SEISMIC AND GEOLOGICAL CONDITIONS AT THE BOHUNICE NPP SITE

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ABSTRACT

The paper brings basic information on geological and seismic characteristics of the site of NPP Jaslovské Bohunice, Slovakia. Western Carpathians and Trnava bay geological properties are briefly introduced. The most important macroseismic data and data obtained from field measurements are analysed. Main features of the expected strong seismic motion are discussed. The attention is devoted to local soil characteristics just under the site of NPP.

1. INTRODUCTION

The NPP V1, V2, EBO is located in north-west part of Danubian basin - so called Trnava bay, that is nearly 10 km in south-east direction from the mountains of Small Carpathians and in west direction from the Váh river valley. The Trnava bay territory belongs to the best geologically investigated parts of Slovakia. Many deep boreholes were realised here, together with all supporting seismological investigations. This is connected with prospector works and also with construction of important structures as dams, plants, factories. etc. The mentioned territory of EBO was the subject of intensive geological and seismological investigations during the last decade. The complex synthesising work of all those investigations was done in the closing document of Institute of the Earth Physics AS in Moscow and C-S Institutes [4]. Due to recommendations of [4] the measurements of the seismic activity of near field of NPP were realised by the help of the very sensitive seismic station network. Thanks to obtained data we have nowadays new useful information about the site behaviour and in this way we can do the additional analyses of the safety degree and the measure of upgrading of NPP structures and technologies.

2. GEOLOGICAL BASIC CHARACTERISTICS

The NPP EBO is situated in the north part of Danubian lowland near to west part of Carpathians massif. The Carpathian massif forms 1500 km long and 150-200 km wide arc, which is open to the south. The Western Carpathians are characterised by fold and overlying sheets of north ergental composition.

In Trnava bay the position of EBO is in its central part. (Fig. 1). On the west side the Trnava bay is limited by Small Carpathians, that are the south-west far part of inner Western Carpathians. They close from the west side all Danubian basin along the edge faults of NE-SW direction. The mountains are disturbed by many transverse depressions of NW-ES direction. The core of mountains is Pezinok Carpathians, that are created from the south by crystallinic core and by tatric cover from the west side. On the north we can follow the trias limestones. Brezová Carpathians consist prevailingly from trias limestones and dolomites, they are lower (Klenová - 585 m). The north part of Small Carpathians - Čachtice Carpathians are also built from trias limestones, they create narrow tectonic relief on the north-east side of mountains and separate the Trnava hills from Myjava hills.

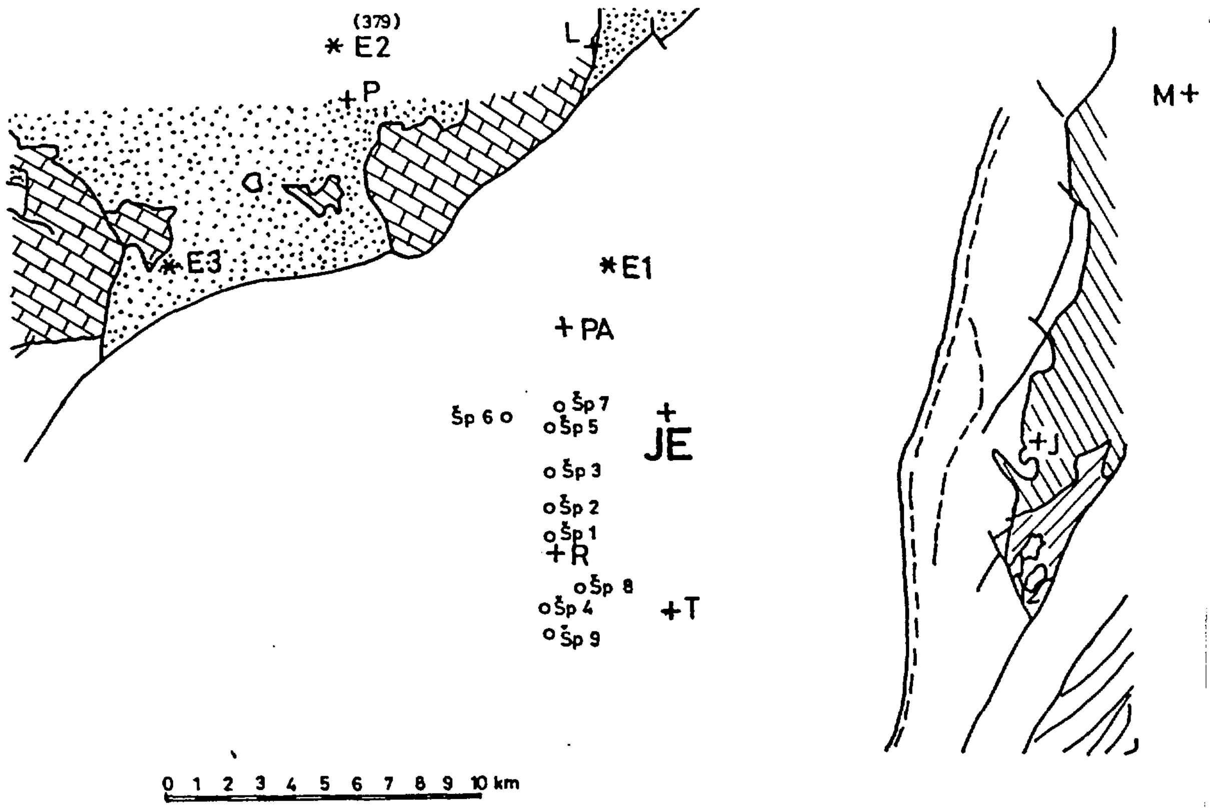


Fig. 1. Position of NPP EBO in Trnava bay.

Považský Inovec separates on the east Piešťany and Topoľčany bays of Danubian basin. This mountain also is limited by faults of N-S and NE-SW direction.

From geotectonic view the EBO site is in Danubian tectonic block, that in deep composition behaves as individual comparatively homogeneous unit, with high values of gravity. It is tectonically limited by deep faults. On the south-east side it is Čertovice fault, west side is limited by Peripieninal lineament that lies at the west edge of Small Carpathians and continues to Trenčín. On the north-east side is deep Skýcov fault. Parallel to it there are Danubian, Pezinok, Kolárovo and Hurbanovo faults. The last is also called Dobrá Voda deep fault, it can be classified as important one.

Trnava bay belongs to northern parts of Danubian basin. Its deepest central part is called Trnava-Blatné depression. Tectonic mesh is formed by young Carpats tectonics in NE-SW direction, older transverse tectonics in NW-SE direction is less important.

Many deep boreholes were realised in and near site of NPP EBO. The list of them is in Table 1, position of series Špačince deep boreholes can be seen in Fig. 1. The thickness of neogen sediments in Trnava bay reaches 4000 m. Prevailing ground formation consists from calcareous clays, sandstones and conglomerates.

Table 1. List of deep boreholes near the site of NPP EBO

Name	Height o. s. l. (m)	Depth (m)	Name	Height o. s. l. (m)	Depth (m)
Borovce 1	186.96	1455.00	Sereď 7	171.59	1400.00
Bučany 1	152.53	2661.00	Sereď 9	171.17	1400.00
Bučany 2	157.74	2800.00	Suchá 1	169.73	2903.00
Dobrá Voda 1	293.80	1141.00	Suchá 2	174.24	2500.00
Dubová 1	207.70	2945.00	Suchá 3	167.56	3121.00
Dubová 2	197.38	3000.00	Špačince 1	165.08	2823.00
Krupá 1	218.08	1091.00	Špačince 2	170.11	2283.00
Krupá 2	221.02	1202.00	Špačince 3	174.16	3472.00
Krupá 3	215.37	1135.00	Špačince 4	161.56	3356.00
Krupá 4	223.08	510.00	Špačince 5	179.44	3305.00
Krupá 5	226.08	805.00	Špačince 6	179.60	2401.00
Krupá 6	248.24	536.00	Špačince 7	163.50	2555.00
Krupá 7	248.42	503.00	Špačince 8	163.80	2700.00
Madunice 1	148.39	1486.00	Špačince 9	158.69	2351.00
Madunice 2	149.63	1566.00	Trakovice 1	141.39	2200.00
Madunice 3	146.79	1463.00	Trakovice 2	140.69	1468.00
Madunice 4	149.79	1938.00	Trakovice 3	139.84	1475.00
Madunice 5	145.50	1310.00	Trakovice 4	139.34	1688.00
Madunice 6	148.35	1510.00	Trakovice 5	139.11	1675.00
Madunice 7	146.64	650.00	Trakovice 6	156.73	1584.00
Nižná 1	175.09	1895.00	Trakovice 7	161.48	1220.00
Nižná 2	185.99	2121.00	Trakovice 8	140.84	1200.00
Nižná 3	185.96	2100.00	Trakovice 9	141.46	1272.00
Nižná 4	189.34	2400.00	Trakovice 10	138.77	1105.00
Nižná 5	179.40	2200.00	Trakovice 11	142.53	1000.00
Nižná 6	175.62	2367.00	Trakovice 12	140.99	1000.00
Nižná 7	186.66	1319.00	Veľké Kostoľany	148.63	2250.00
Ratnovce 1	145.33	2016.00			

Site of NPP EBO is characterised by Pliocene (Levant) upper composition. These layers are characterised by loam, clays and sandy gravels. Below these layers we can follow Pont layers with loam, sand and gravel regions. The deepest are layers of Sarmat and Terten. In the upper

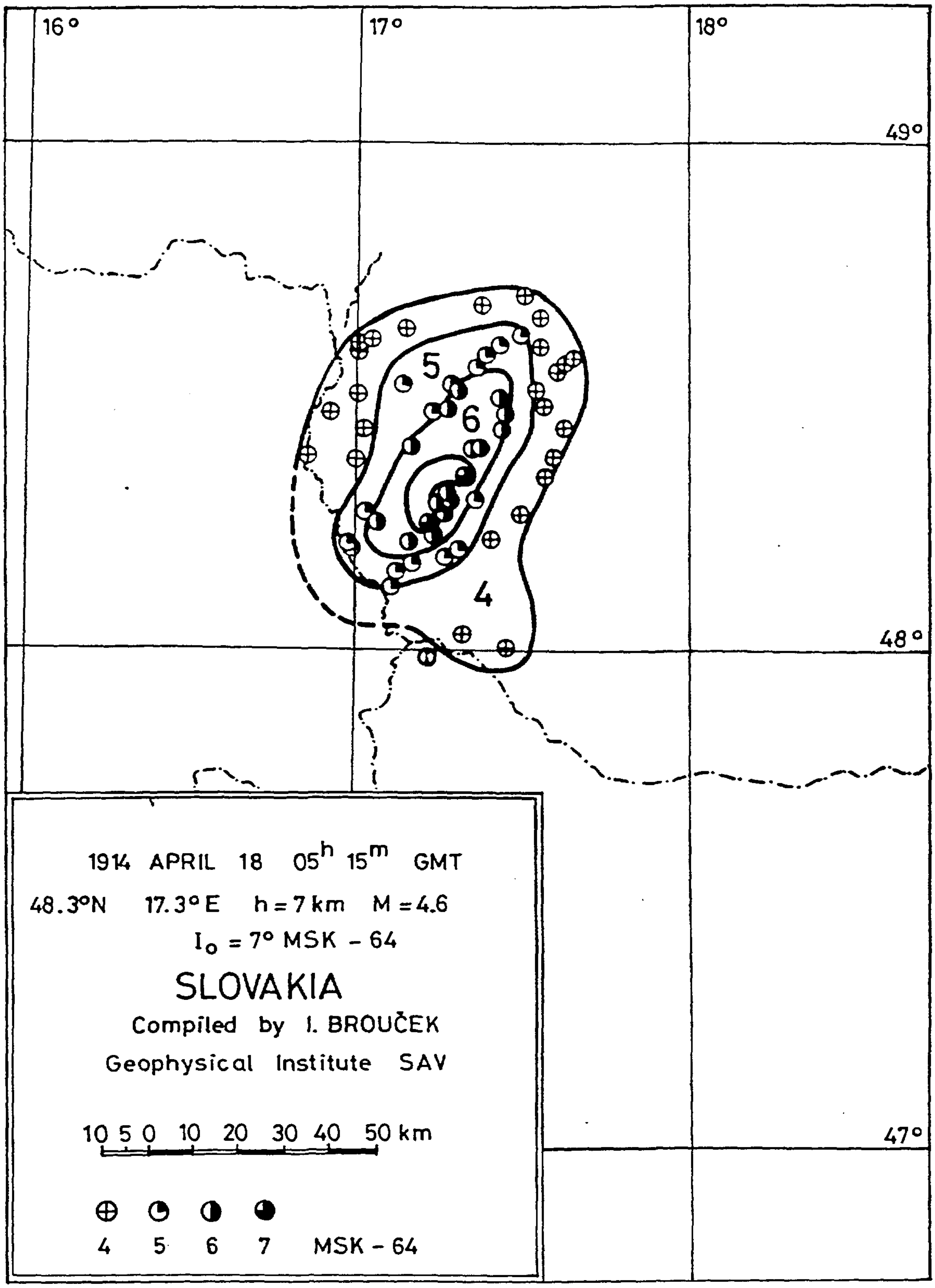


Fig. 2. Isoseismal map of 1914 earthquake.

part up to 9 m is hard loess, then follow the layers of sandy loam, and deeper are 7-8 m thick comparatively uniform sandy gravel layers. Below them is again sandy loam.

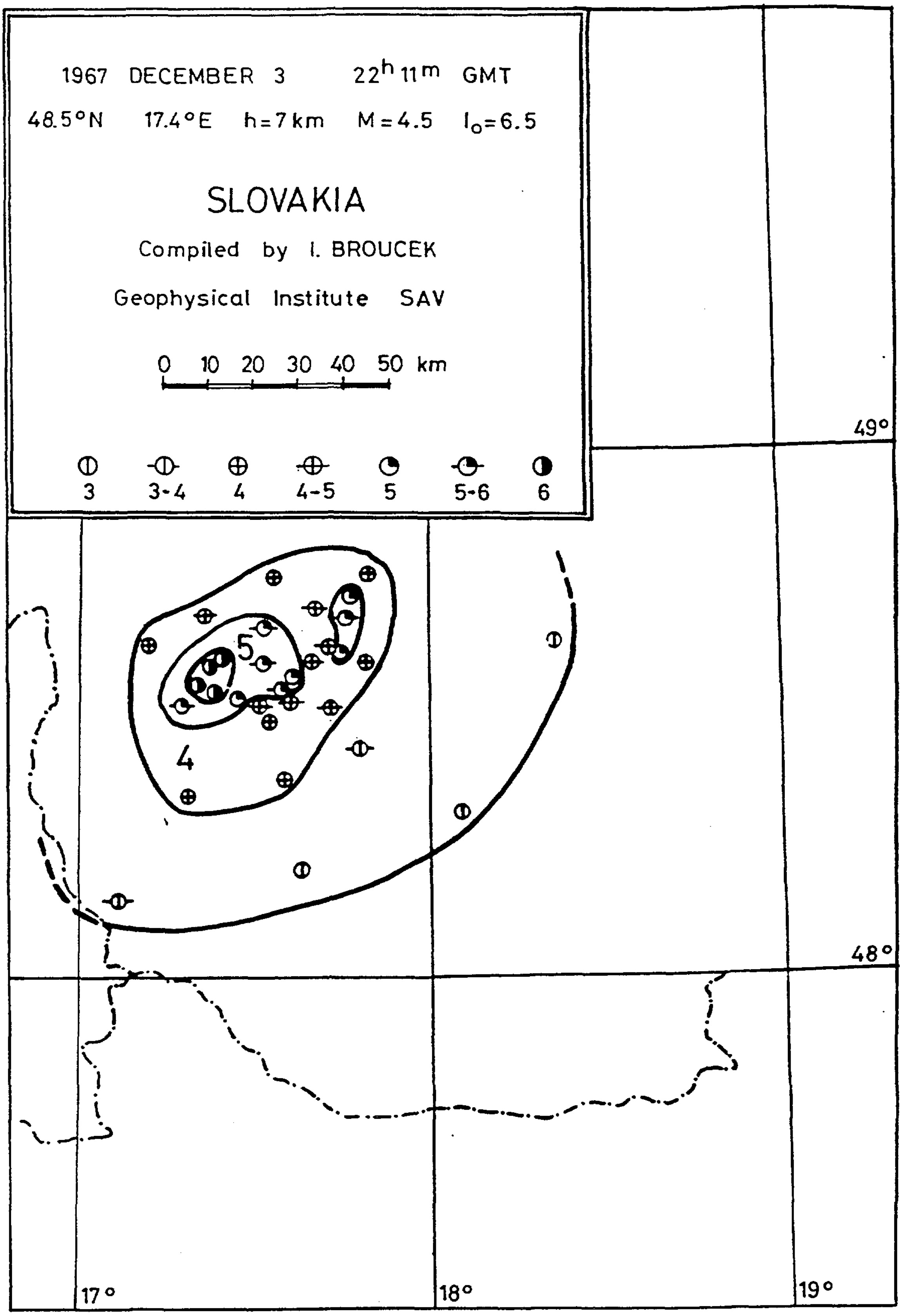


Fig. 3. Isoseismal map of 1967 earthquake.

3. SEISMIC ACTIVITY

NPP EBO site is in the distance of 17 km from the epicentre of 1906 Dobrá Voda earthquake. Dobrá Voda is village in west-north part of Small Carpathians. It belongs to Peripieninal first category region. Its fault composition creates the boundary between two basic geotectonic units - Czech Massif and Carpathian system. The epicentral intensity of Dobrá Voda 1906 earthquake was $I_0 = 8°$ MSK-64, M = 5.7, h = 9 km.

Second category region is Ráb region with 1763 Komárno earthquake, that was of epicentral intensity $I_0 = 8\text{-}9°$ MSK-64, M = 5.6, h = 6-9 km. Then continue Central Slovakia regions with earthquakes near Žilina and Banská Štiavnica.

Third category earthquakes and fourth category earthquakes are less important.

Nowadays it is considered to expect large possible earthquake (with 10000 years return period) from Small Carpathians source of magnitude $M_{max} = 6$, $I_0 = 8°$ MSK, and small earthquake defined by near seismic source with M = 5, that can appear anywhere and randomly.

Basic criteria were stated as follows

for large earthquake:

epicentre intensity $I_0 = 8°$ MSK,
epicentral distance ≤ 20 km,
depth of focus ≤ 20 km,
magnitude 5.5 - 6.5,
maximum intensity of NPP site $I_0 = 7°$ MSK,

for small local earthquake with focus under the site

depth of focus 5 - 10 km
magnitude 4.5 - 5.5,
maximum intensity of NPP site $I_0 = 7°$ MSK.

When analysing the information from macroseismic observations, we have available the catalogue collection of historical earthquakes [1] with isoseismical maps. We have chosen two examples of Carpathians earthquakes (1914 and 1967). In Figs. 2, 3 we can see that besides of usual falling down of intensity with increasing distance there are some regions with lower degree of intensity. This phenomenon was not fully explained, however, there exist few hypotheses. Just directly in the Jaslovské Bohunice village was no evidence of earthquake with macroseismic effects. It is supposed that this is influenced either by seismic block positive influence or that of soil layers composition.

Nevertheless, in order to reach high level of security and safety, the appropriate program of seismic upgrading, seismic instrumentation and measurement has started, together with the evaluation of any new results about weak or medium seismic motion records.

4. EXAMPLES FROM LAST OBSERVATIONS

The dense network of seismic stations, that was in action on different sites, with different time of operation, has recorded few seismic events. They belong to the category of weak earthquakes.

Weak earthquake is defined by magnitude less than 3. Besides of usual determination of the earthquake magnitude, epicentre co-ordinates and depth, the records could be used to clarify the time history of seismic motion, the expected seismic response and the falling down of amplitude either of that of free field motion or that expected through the seismic response quantities. The basic information about recorded 3 events are in Table 2.

Table 2. Weak earthquakes recently recorded

Name	Date	Magnitude	Time	X (km)	Y (km)	Z (km)
(051)-E1	10.2.1991	2.02	12:14:14.80	241.4 ± 0.4	530.2 ± 0.8	11.5 ± 1.2
(379)-E2	21.10.1991	2.40	2:2:3.24	234 ± 0.4	538.9 ± 0.2	9.3 ± 1.1
(743)-E3	14.7.1992	2.50	21:36:47.82	241 ± 0.4	544 ± 0.6	12.8 ± 1.1

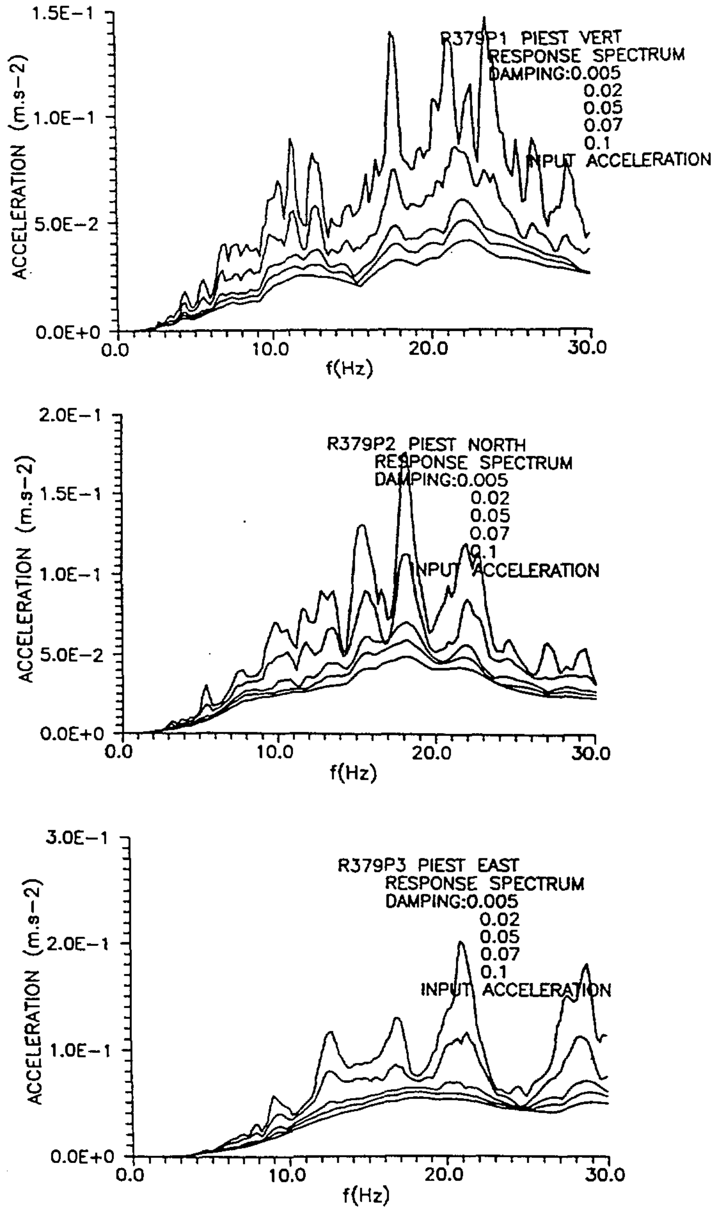


Fig. 4. Response spectrum for Piešť record.

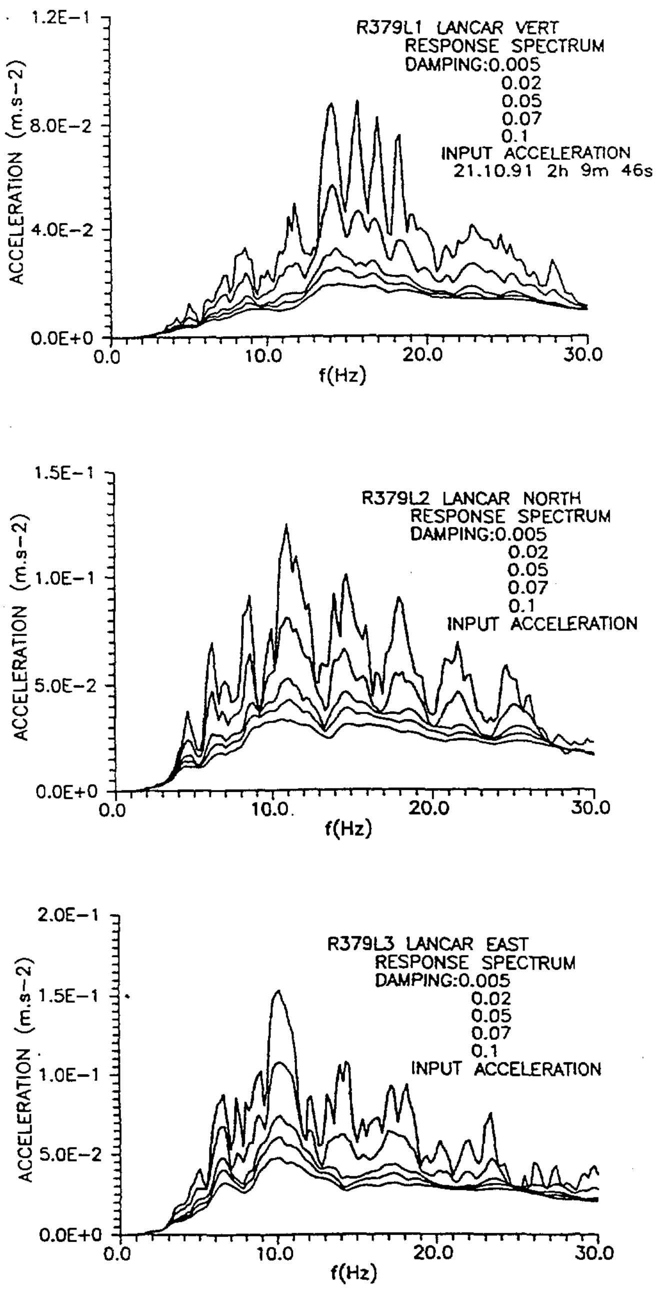
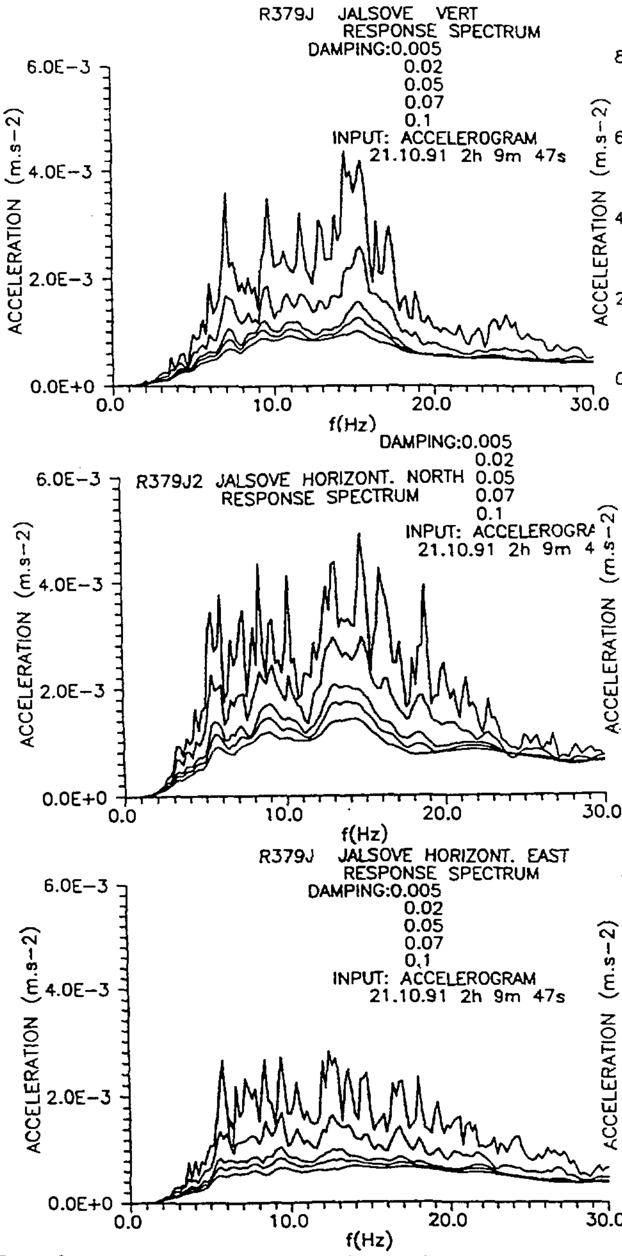


Fig. 5. Response spectrum for Lančár Record.

Using records for deeper engineering analysis, we can evaluate the seismic response spectra either from acceleration time history, or from deflection time history. We can also use the deflection and velocity combination, as is explained in [2]. The seismic response spectra were calculated for usual range 0.005 up to 0.1 value of damping ratio.

The response spectra, calculated for E2 earthquake, are in Figs. 4, 5, 6, 7, 8, 9. The stations Piešť, Lančár, Jalšové, Moravany were on base rock, stations Paderovce, Rybničky and Trakovice were on sediments [3]. In Fig. 10 we can follow the amplitude of maximum acceleration in three basic directions. Falling down of amplitudes with a distance is shown in



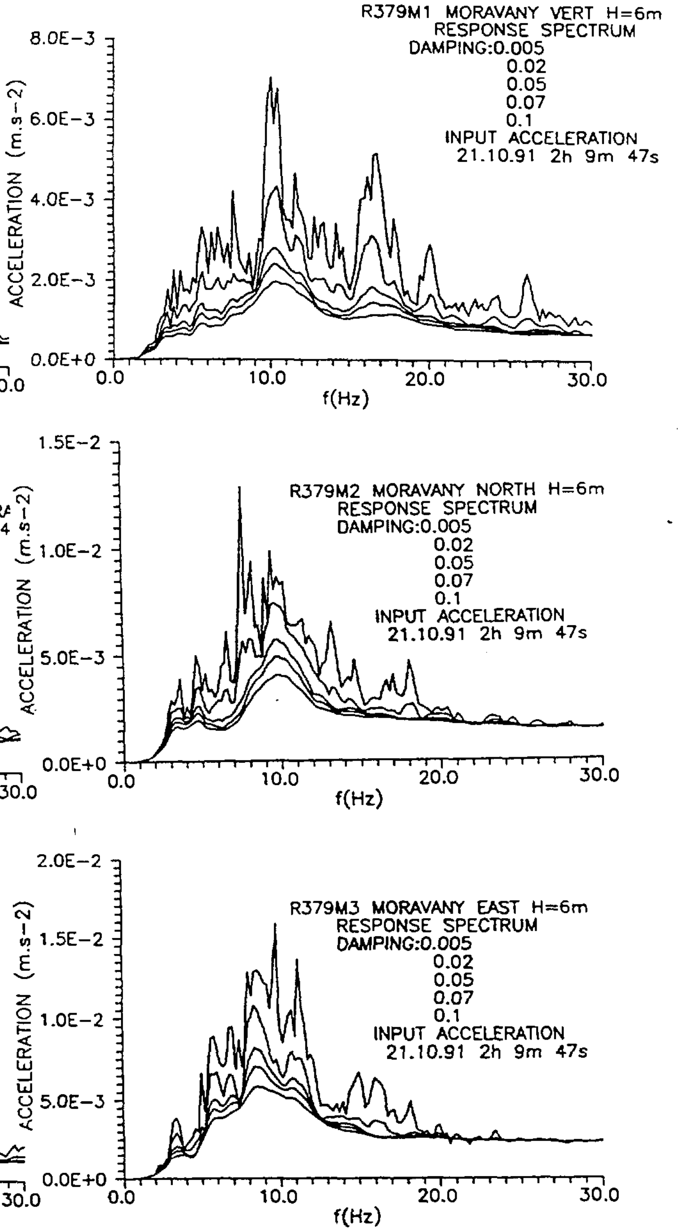


Fig. 6. Response spectrum for Jalšové record. Fig. 7. Response spectrum for Moravany record.

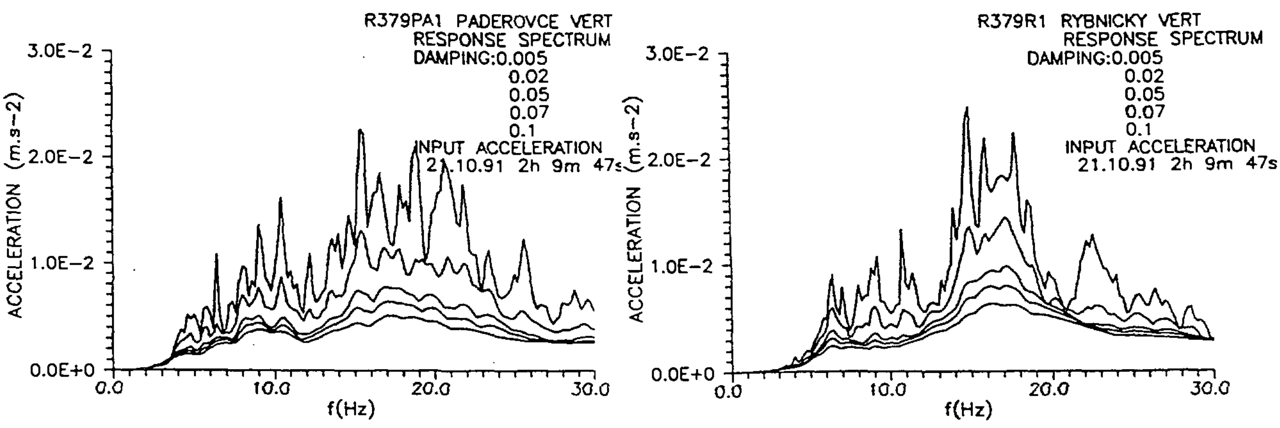


Fig. 8. Response spectra of records obtained on sediments in Paderovce and Rybníčky.

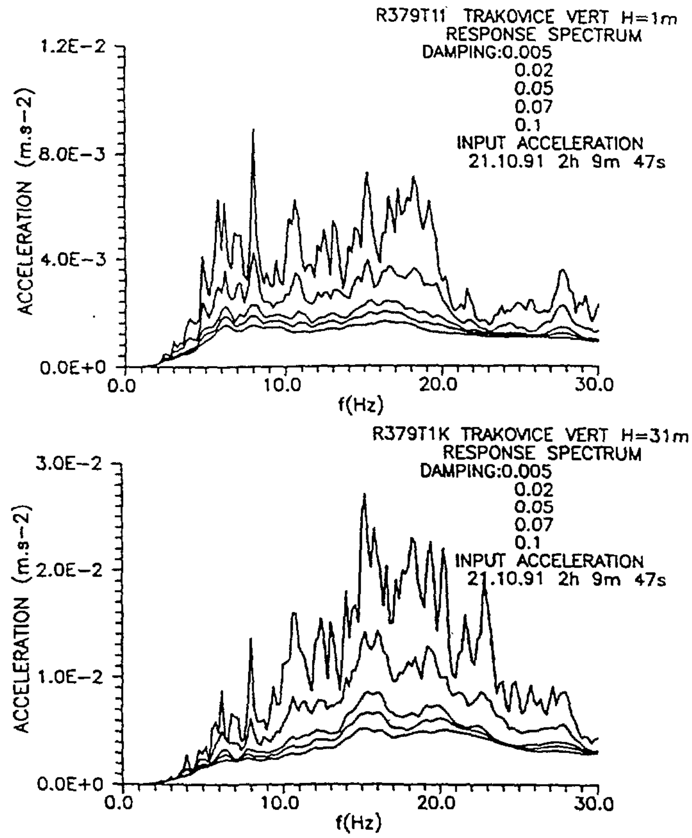


Fig. 9. Response spectrum for Trakovice records in depth H = 1 m and H = 31 m.

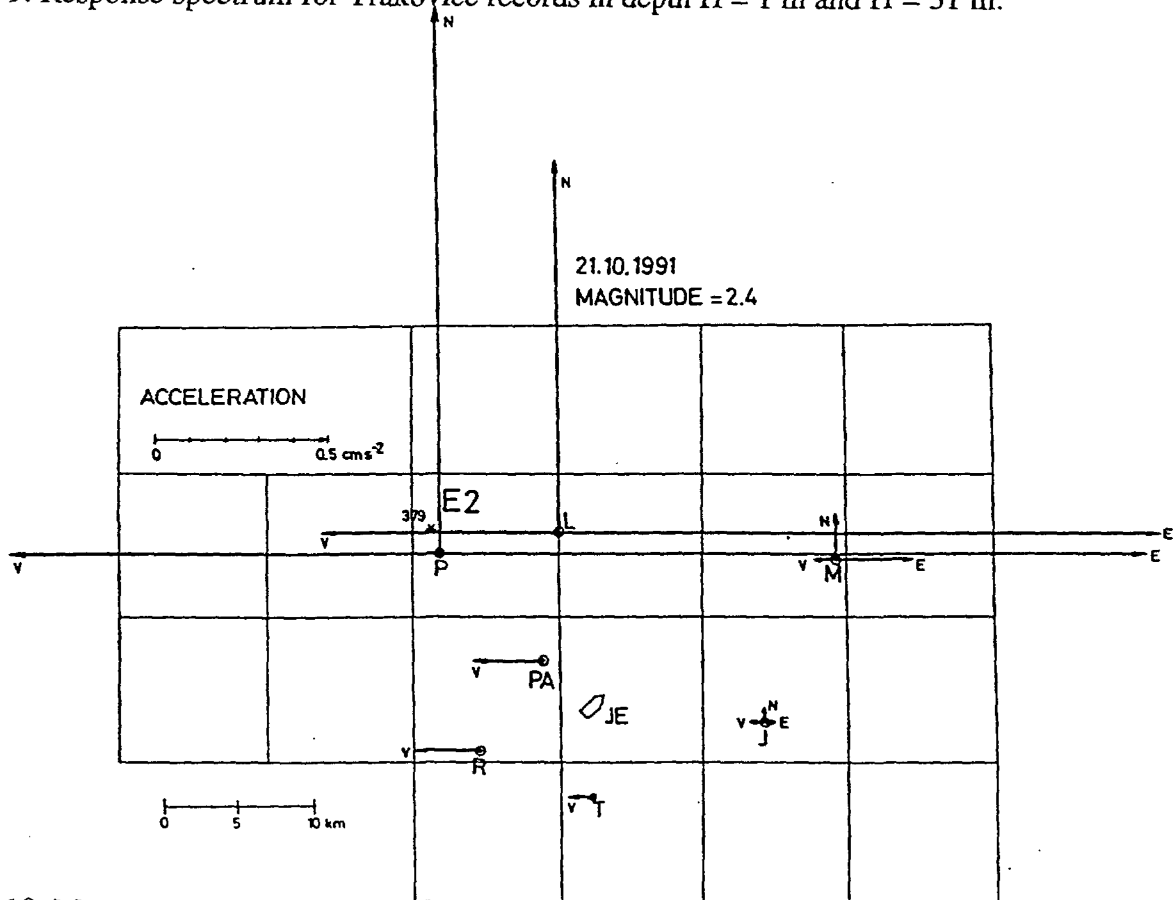


Fig. 10. Maximum acceleration amplitude components registered at different stations.

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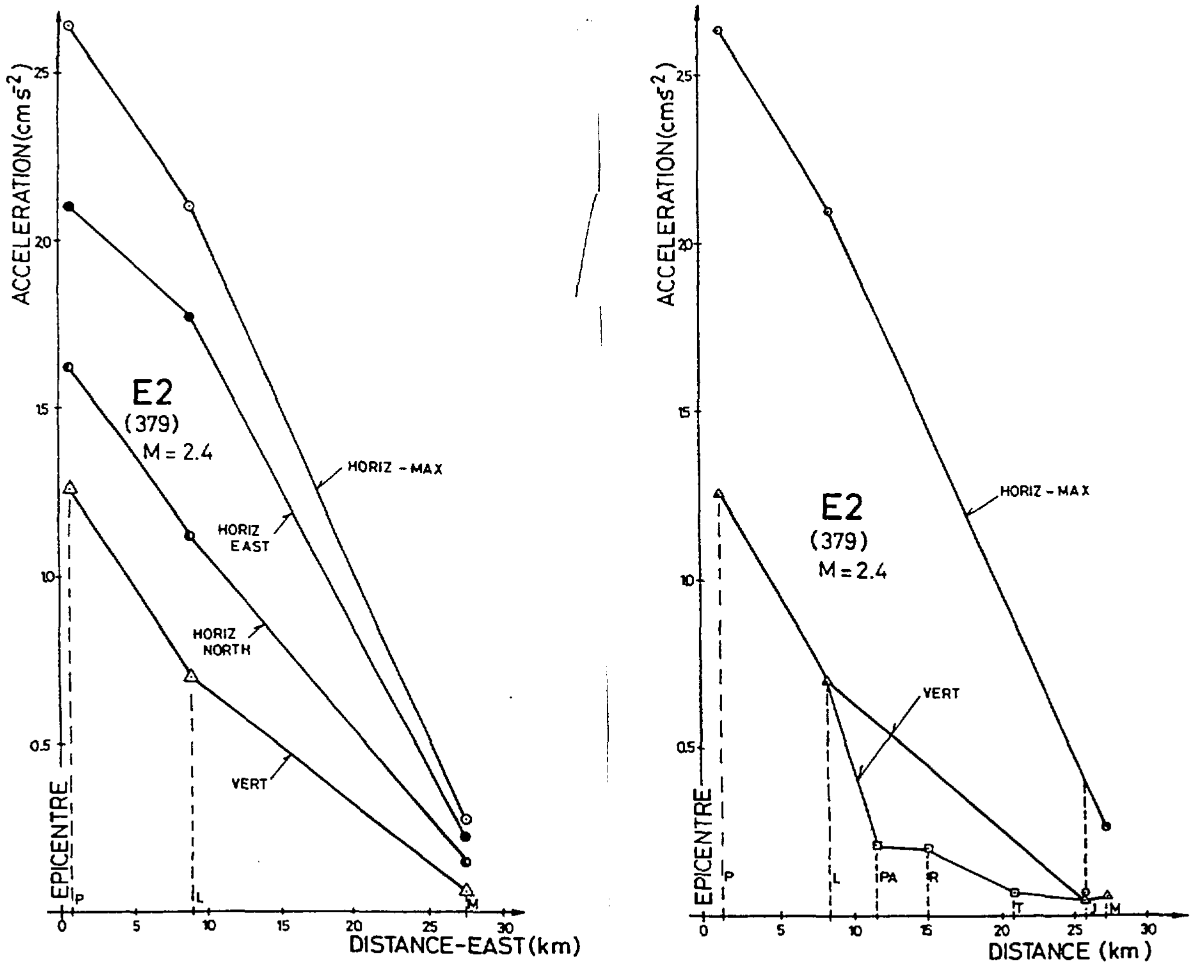

Fig. 11. Changes of maximum acceleration amplitude components with epicentral distance.

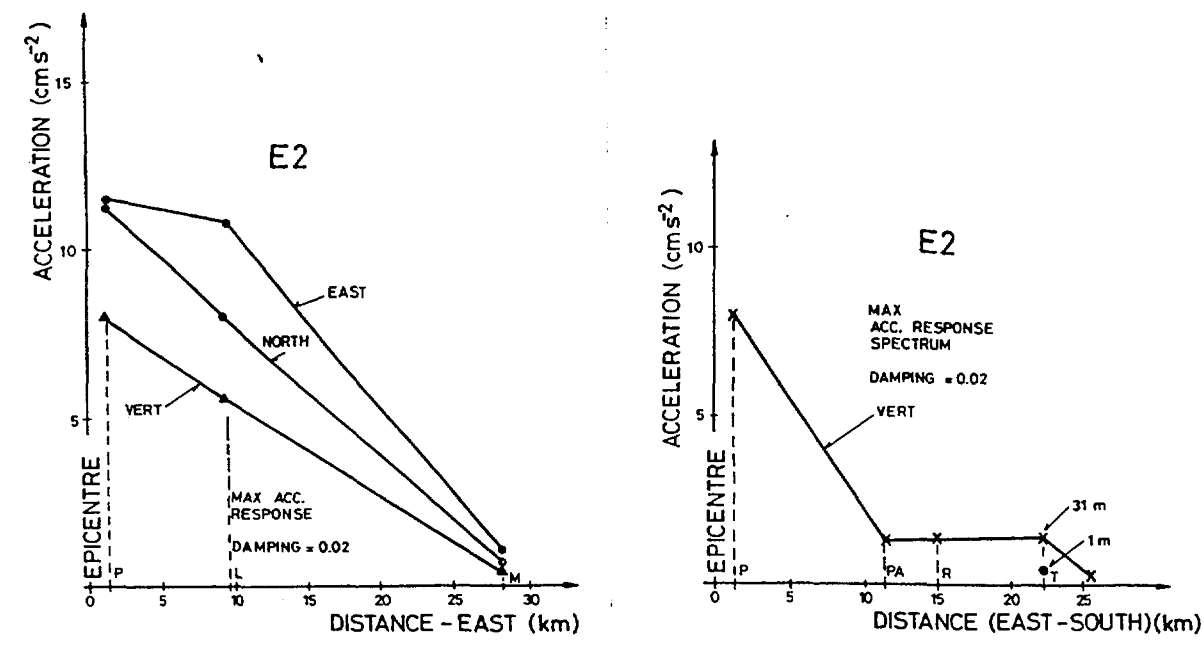

Fig. 12. Changes of maximum acceleration seismic response with epicentral distance for damping ratio 0.02.

Fig. 11. Similarly we can analyse the decreasing of seismic response maximum. For low damping ratio 0.02, such amplitudes are much more near to macroseismic effects than the pure free field maximum acceleration amplitude. These changes are shown in Fig. 12.

What is interesting in these results is that actually in sediments the maximum amplitude is rather to the side from that recorded on the rock stations. Next full three-component measurements promise to identify in larger measure the mechanism and actual seismic behaviour.

5. CONCLUSIONS

The knowledge of geological and seismic conditions at NPP site is important part of seismic security and seismic upgrading of NPP plants of Slovakia. For that purpose it is necessary to utilise the new information from science, techniques, and also any experiences own and that from over the world. Implementation of new results into existing approaches helps to more realistic solution of structure and technology seismic response and finally to reduce the degree of natural seismic risk of NPP.

6. REFERENCES

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