THE IMPACT OF A STRONG MINING TREMOR ON THE SUBSIDENCE OF THE AREA SURFACE IN THE LEGNICA-GLOGOW COPPER AREA

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Abstract

One of existing negative influences of the mining on the deposit on large depth are strong tremors reaching the parameters close to the ones occurring in small earthquakes. In the conditions of the Legnica-Glogow Cooper Basin tremors have the energy up to 10^{10} J and accelerations exceeding 1000 mm/s^2. Geodetic measurements run on the surface of the area register translations and deformations caused by deposit exploitation. Leveling measurements made directly before a strong tremor of the energy 2.5 x 10^9 J and after the tremor allowed a quantitative determination of extra subsidence on four observation lines. The interpretation of the results of measurements allowed to determine the location of tremor epicentre and its comparison with the one determined by seismic grid. Maximum value of the growth of subsidence after the tremor was also estimated and equaled about 150 mm. The necessity of carrying out large surface measurements of the deformations of area surface in mining areas, with the use of geodetic methods was emphasized.

1. Introduction

The deposit of copper ores in the Legnica-Głogów Copper Area (Legnicko-Głogowski Okręg Miedziowy - LGOM) is situated on the depth of about 600 m to above 1100 m and its thickness varies from 1.0 m to over 15.0 m. The deposit is exploited in pillar-chamber systems adjusted to high rock mass pressure and changeable mining conditions.

In the first period of mining exploitation in LGOM two-stages pillar-chamber systems were applied. In the first stage of the realization of such a system a selected field is paneled with chambers, while supportive pillars of an approximate size 25 x 35 m are left between them. In the second stage those pillars are divided into technological pillars that are clinched and then go into a post-destruction stage. During this process elastic energy collected in the rock mass can be released, which results in a para-seismological tremor or crump. When there is a danger of crumps – one-stage systems turned out to be safer. They are based on selecting (in one phase) technological pillars of smaller size, which directly after being cut down, go into a post-destruction stage. Since 1993 breaking down exploitation systems with a (small scale) roof deflection and subsidence on the remains of the technological pillars left has been introduced. Applied and constantly modified systems of the exploitation of the copper ores deposit do not eliminate, however, the threat of crumps or para-seismological tremors.

In this article the surface the impact of one of the biggest tremors registered in the LGOM area is analyzed. This tremor occurred on April 11, 2000 at 1.24 p.m. in G-6 section of the mine „Lubin". Tremor energy was 2,5 x 10^9 J. Subsidence and surface deformations were registered on a dense network of geodesic points, in the periods from 3 to 12 months. The tremor occurred directly after a series of geodesic measurements was made, these measurements are regularly made on a dense network of observation points. This fact inspired conducting extra two measurement series in the following two days after the tremor had occurred. The result of the analysis of those observations makes the main content of this publication.

2. Geologic and Mining Conditions in the Area of G-6 Section

The deposit of copper ore occurs in dolomites, shales and sandstones on the level 750 ÷ 800 m. Mean thickness of deposit is 6.6 m. Over the deposit series compact limestone dolomites of about 3.0 m thickness are situated. Total thickness of carbonate series of lower Zechstein is 63 m. Massive limestone dolomites occur in the immediate roof, then they go into micro-crystal limestone of mean clinch resistance 124.1 Mpa. Over a carbonate complex packs of upper Zechstein sulfate formations about 180 m thick, 170 m thick mottled sandstone formations and Tertiary and Quaternary formations of total thickness of about 400 m occur.
The deposit subsides regularly with an angle 3 ÷ 4^{o}. Rock mass is poorly differentiated tectonically. In the area of G-6 section there are 4 faults, mainly of northwest – southeast direction and the amplitude from 0.2 to 1.0 m. Microtectonic phenomena i.e. cracks and breaks filled with silt or gypsum material are predominant.
In G-6 section located in the area of west shafts in the mine „Lubin", a deposit of 4.2 m to 8.0 m (on average 6.6 m) was exploited by a chamber-pillar system with roof deflection and subsidence. At the moment of the tremor the second stage of paneling resistance pillar was made in two directions i.e. westwards – on the length of about 1000 m and southwards – on the length of about 150 m (Fig. 1). Paneling meant cutting down the pillars of a size 8 ÷ 11 x 15 ÷ 31 m, with chambers and packs 6 ÷ 7 m wide. The roof of workings was built up with expansion-shell bolts 1.8 m long in a bolting net 1.5 x 1.5 m.

3. Characteristic of the Causes and Results of the April 11, 2000 Tremor

The analyzed area of G-6 section, because of its specific character, i.e. the neighborhood of mine old workings and a considerable thickness of an exploited deposit is under a potentially big threat of high-energy tremors. In the period 1998 ÷ 2000 total amount of energy emitted in this field was:

1998 - $\Sigma E = 1.21 * 10^8$ J
1999 - $\Sigma E = 3.76 * 10^8$ J
2000 - $\Sigma E = 2.53 * 10^9$ J

while the tremors of energy $E > 10^6$ J occurred in the following years: in 1998 - 3 times, in 1999 – twice, and till April 11, 2000 r. – twice.
The tremor of energy 2.5×10^9 J that occurred on April 11, 2000 in underground workings caused the slide of the sides of supportive pillars (in some areas making impossible to enter the working) and sides of works, throwing rocks into workings as well as a local upheaval and crack of the gallery floor.
The causes of the tremor were the following:

- large surface of old workings in the neighborhood of the paneled resistance pillar,
- carrying out paneling of pillars characterized with different-size and changeable geometry,
- the presence of compact and strong dolomite rocks in the roof,
- natural promptness of the rocks to bumps.

The epicentre of the tremor, registered by the Mine Seismological Station, was under the settling pond „Gilów" (Fig. 2). On the measurement lines L-16, L-17, L-18 and L-19, established on the head of the pond dike and its forefield, geodesic measurements are made to register the influence of mining exploitation run in the area of the protective pillar of the dike. Measurement point no. 33 of the observation line no. 16 was in a distance about 350 m south-westwards from the tremor epicentre (Fig.2).

4. The Analysis of the Results of Geodesic Measurements

On April 11, 2000, before the tremor, a leveling measurement was made on lines L-17 (points no. 604 ÷ 609), line L-18 (points no.599 ÷ 603 and 34D) and line L-19 (points no. 595 ÷ 598 and

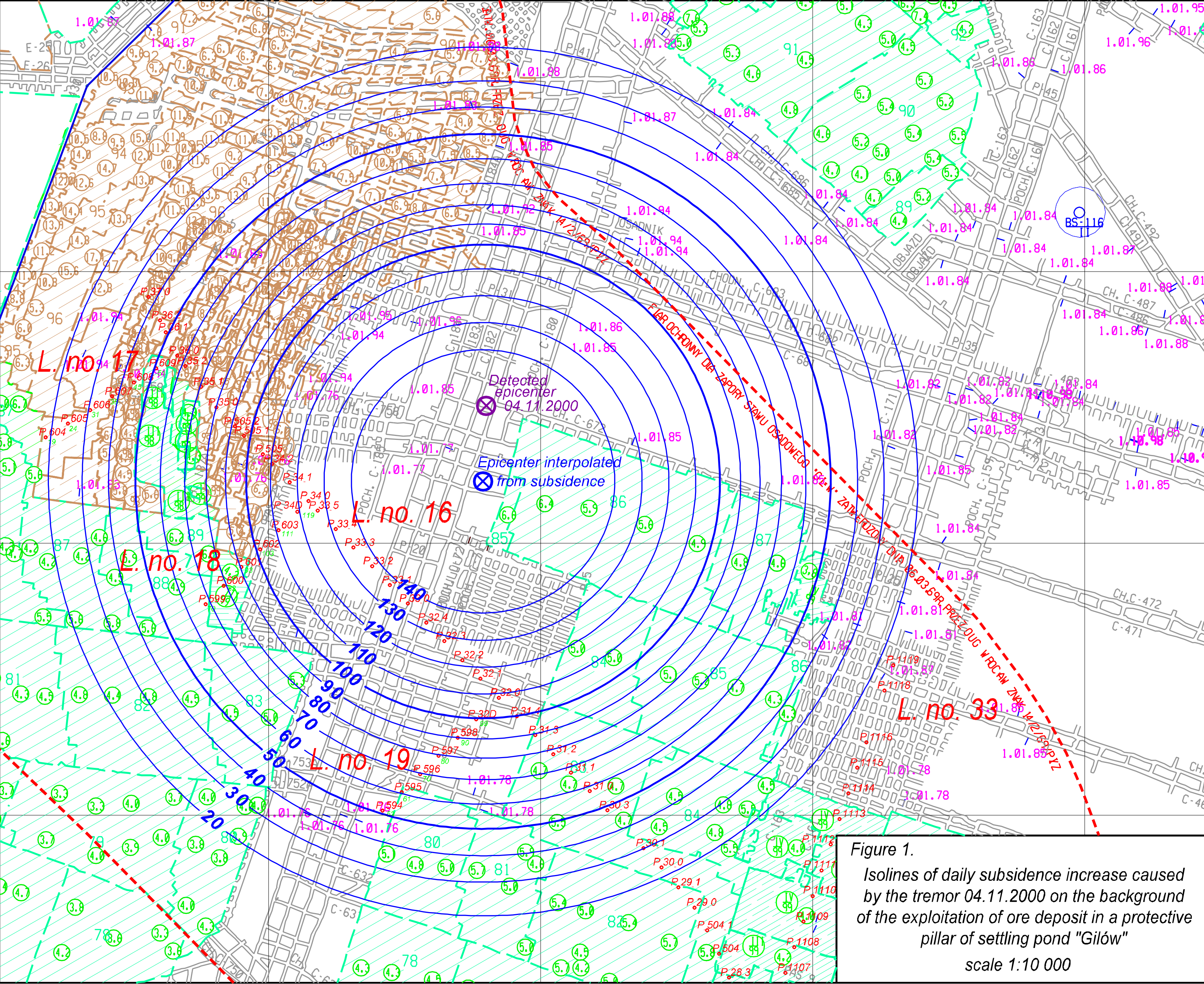

Figure 1.

Isolines of daily subsidence increase caused by the tremor 04.11.2000 on the background of the exploitation of ore deposit in a protective pillar of settling pond "Gilów"

scale 1:10 000

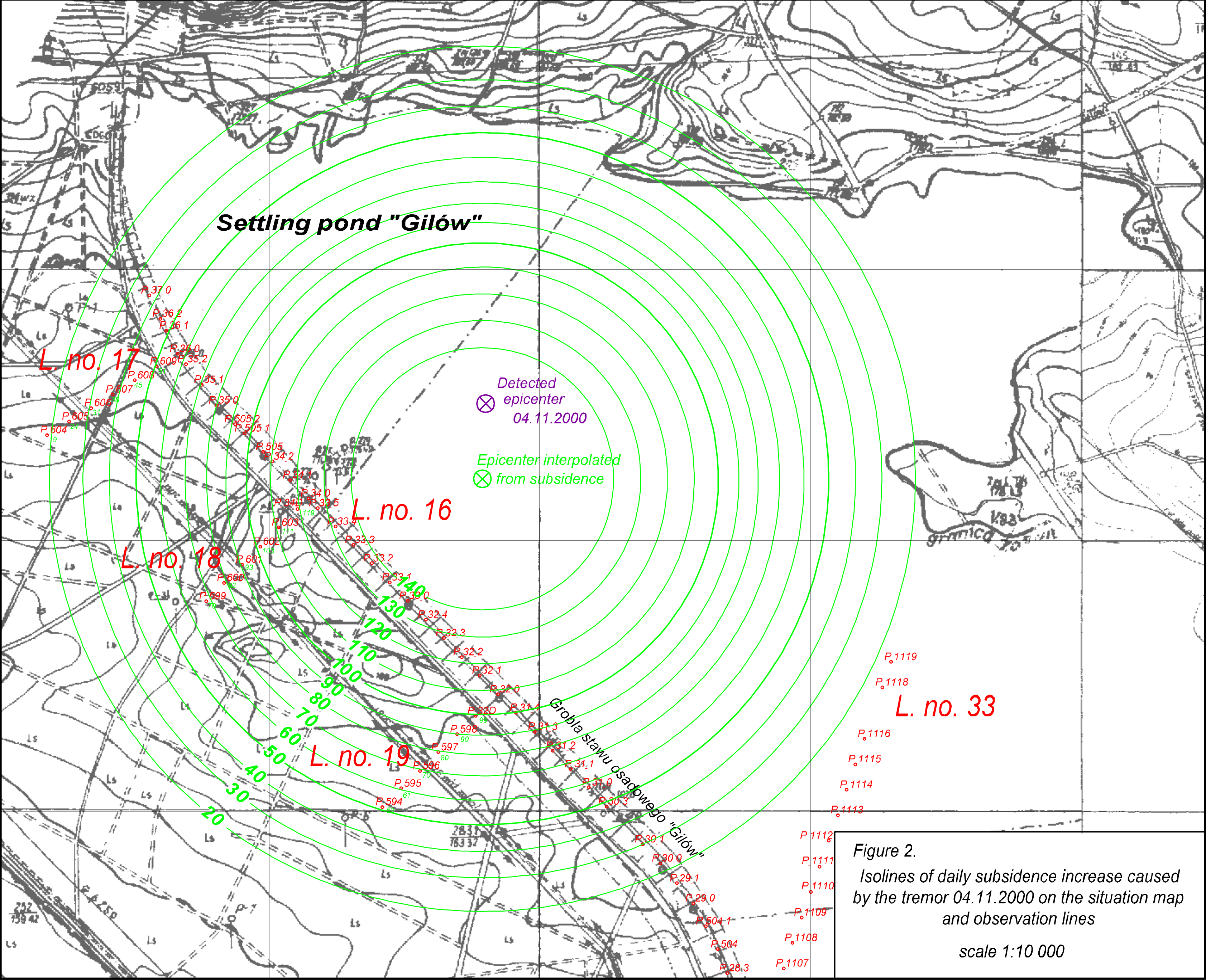

Figure 2.
Isolines of daily subsidence increase caused by the tremor 04.11.2000 on the situation map and observation lines
scale 1:10 000

32D). The measurement was also made after the tremor – on April 12 and 13, 2000. The results of measurements are presented in Table 1.

Table 1.
Subsidence of bench marks on lines L-17, L-18 and L-19 on April 11, 12 and 13, 2000

Line no.	Point no.	Subsidence 04/11/2000	Subsidence 04/12/2000	Subsidence 04/13/2000	Subsidence increase 04.11÷12.	Subsidence increase 04.12÷13.
17	604	-2609	-2628	-2631	-19	-3
	605	-2651	-2675	-2678	-24	-3
	606	-2671	-2702	-2705	-31	-3
	607	-2671	-2808	-2711	-37	-3
	608	-2638	-2683	-2686	-45	-3
	609	-2588	-2639	-2642	-51	-3
18	599	-2076	-2145	-2149	-69	-4
	600	-1921	-2003	-2006	-82	-3
	601	-1801	-1895	-1898	-94	-3
	602	-1626	-1729	-1732	-103	-3
	603	-1501	-1612	-1615	-111	-3
	34D	-1403	-1522	-1525	-119	-3
19	595	-1092	-1143	-1147	-51	-4
	595	-1120	-1181	-1183	-61	-2
	596	-1145	-1215	-1218	-70	-3
	597	-1172	-11252	-1255	-80	-3
	598	-1227	-1317	-1320	-90	-3
	32D	-1314	-1413	-1417	-99	-4
	Subsidence in table is given in millimeters					

The measurement on L-16 line was made only on April 13, 2000 r., after the tremor (Table 2.).

Table 2.
Subsidence of bench marks on dikes and the forefield of the decanting point „Gilów" (line no.16) on April 13, 2000 r.

Subsidence	Observation point no.								
	30	31	32	33	34	34D	35	36	609
[mm]	-3045	-2754	-1586	-1204	-1561	-1525	-2511	-2681	-2642

Based on daily increase of subsidence measured on lines L-17, L-18 and L-19 and based on the interpretation of the results of observations made on line L-16, isolines of daily subsidence from 04.11. to 04.12.2000 were drawn (Fig.2). It can be stated from the interpolation that maximal subsidence of the head of the dike could be 140 mm, and the range of the surface subsidence caused by the tremor was about 900 m around its epicenter. Comparing the location of the epicentre determined according to the data from Mine Seismological Station with the location of this epicentre determined based on the distribution of the isolines of daily subsidence increase and the results of the tremor in mine workings, it should be stated that the localization based on subsidence is very likely. For the comparison, in Table 3. monthly increases of subsidence on line L-16 are presented.

Monthly subsidence increase in the periods 04.1999 ÷ 11.1999 and 11.1999 ÷ 12.04.2000 on points no. 31, 32 and 32 D results from the influence of exploitation run in the resistance pillar of a set of planes C-160. This exploitation was carried out in 3rd and 4th quarter of 1999. Similarly, in point no.33 the impact of exploitation was detected in 1999 in G-6 section.

Table 3.

Monthly subsidence increase of the points on observation line L-16

Point no.	Mean monthly subsidence increase [mm]					
	11.97÷04.98	04.98÷11.98	11.98÷04.99	04.97÷11.99	11.99÷04.00	04.11.00 ÷04.12.00
31	-9.0	-8.8	-4.4	-13.6	-22.8	
32	-3.2	-4.3	-3.0	-11.9	-34.8	
32D	-2.2	-3.6	-3.0	-10.8	-12.0*	-99.0
33	-3.4	-6.3	-8.4	-13.2	-40.8	
34	-10.0	-19.6	-27.4	-23.9	-40.8	
34D	-10.0	-19.5	-30.0	-24.0	-16.0*	-119.0
35	-28.6	-43.5	-36.8	-33.3	-31.6	
36	-28.8	-40.0	-30.0	-28.6	-24.6	
609	-28.0	-37.0	-27.8	-25.8	-11.8*	-51.0
	* subsidence increase registered 11.99 ÷ 04.11.2000					

Points no. 34 and 34D subsided as the result of approaching exploitation front of G-6 section to the border of the protective pillar. Points no. 35 and 36 are situated over the exploitation carried out earlier, thus the speed of subsidence increase slowed down.

From the comparison of the differences in subsidence of the points on measurement lines L-17, L-18 and L-19 (Table 1.) it can be concluded that in the period from April 11, 1999 (before the tremor) to April 12, 1999 (after the tremor), daily subsidence increase varied from 19 mm (in point no. 604) to 119 mm (in point no. 34D). Mean value of daily subsidence increase in the area of the dike of decanting pond was 69 mm. Comparing this value with mean values of monthly subsidence increase (Table 3.) one should state that the tremor caused a subsidence exceeding 2 ÷ 3 times the increase of subsidence directly caused by mine exploitation.

After the tremor buildings and gas installation in zones of V^o and VI^o intensity of vibrations in MSK-64 scale were audited. No damage to the construction or gas facilities was detected. There were only slight scars in the buildings situated 600 m from the epicenter. In the situated 2,3 km from the epicenter industrial objects of shafts L-IV and L-V in „Lubin" mine no damage was detected. The measurements of the subsidence of bench marks stabilized in shafts L-IV and L-V did not show any changes.

4. Conclusions

Presented in this publication results of the registration of area subsidence, carried out directly before and after a strong mining tremor allow to state the following conclusions:

1) After the rock mass tremor of energy 2.5 x 10^9J, connected to underground mining exploitation, on geodesic points, the increase of subsidence of the area surface (maximal 0.119 m) was registered. Surface distribution of subsidence indicated that - as a result of the tremor - maximal area subsidence over the epicenter could be 0.140 m.
2) The distribution of subsidence increase indicates a concentric system of isolines. The cente eof this system approximately overlaps with the localization of the epicentre determined from the registration of seismologic stations.
3) The dispersion of increased subsidence is not big and it can preliminary be estimated as about 900 m around the tremor epicentre.
4) Despite high energy of tremor and significant increase of subsidence no damage to the buildings on the area surface or mining shafts in this area was detected.