STUDY ON THE EVOLUTION OF THE DISPLACEMENT AND DEFORMATION OF THE SURFACE PRODUCED BY THE EXPLOITATION OF IRON DEPOSITS IN THE MINING PERIMETER OF GHELARI, HUNEDOARA COUNTY, ROMANIA

Ioan VOINA, Dr. Eng., „1 Decembrie 1918" University of Alba Iulia , Voina I. Ioan Expert Tehnic Judiciar Topografie, Cadastru şi Geodezie, Bocşa, Caraş-Severin, Romania, nutu_rc@yahoo.com
George Emanuel VOICU, Lect. Dr. Eng., „1 Decembrie 1918" University of Alba Iulia, Romania, emanuelgeorge81@yahoo.com
Florina VOICU, Assist. Dr. Eng., „1 Decembrie 1918" University of Alba Iulia, Romania, florina.voicu@uab.ro

***Abstract**: The mining activities for the exploitation of the iron deposits often lead to massive deformation and displacement of rocks, with major consequences on the civil and industrial buildings on the surface, sometimes even including the loss of human lives.*

The mining activity in the research area have had in time a series of negative effects on the soil and human settlements. The first manifestations of the deformation were the appearance of cracks in the monumental building of the Orthodox Church of Ghelari, as well as to some houses in the influence area of the mining exploitation.

The great degradation in the perimeter of Ghelari is well-known. In time, a series of submergence of the land due to the mining activities was signalled. The present paper intends to present a study on the character and the amplitude of the phenomenon of mining subsidence as a result of the anthropic activity mentioned above.

***Keywords:** monitoring, parameters, subsidence, topography.*

1. Introduction

The monitorisation of the phenomenon of mining subsidence is an important operation in the mining areas for observing in advance the possible displacement of the surface in the mining influence area.

It is known that the mining subsidence refers to the vertical and horizontal displacement of the surface, caused by the exploitation of any type of deposit (coal, salt, minerals, etc.), excluding the displacement caused by earthquakes, landslide, erosion or other external factors.

The bigger are the cavities created by the exploitation of the mineral deposits, the more the surface above the exploitation is affected, through submergence, displacement, deformation and even cracks.

The displacement of the surface is produced as a result of the redistribution of the tensions in the rocks, under the influence of the underground excavations created during the mining activities or as effect of the drainage of the aquifer formations.

The qualitative and quantitative evaluation of the displacement of the rocks as result of the underground exploitation is performed by monitoring the parameters of the displacement of the surface above the exploitation, necessary for the design of the safety pillars or the establishment of the safety measures for the constructions in the area.

The area in our research is historically attested (213-215 B.C.) as an iron mining area.

Constantin Daicoviciu affirms in his scientific works that the old Latin inscription ”natus ibi ubi ferrum nascitur” (born where the iron is born), from *Corpus Inscriptiorum Latinorum*, refers to the locality of Ghelari.

Ghelari is geographically situated at 45°42' north latitude and 22°47' east longitude, in the eastern part of the Mountains Poiana Ruscă, Hunedoara County, Romania.

Topographically, the former iron mining exploitation Ghelari is placed, according to the general urban plan both in the intravillan and the outside of the locality of Ghelari. Figure 1 shows the location of the research area.

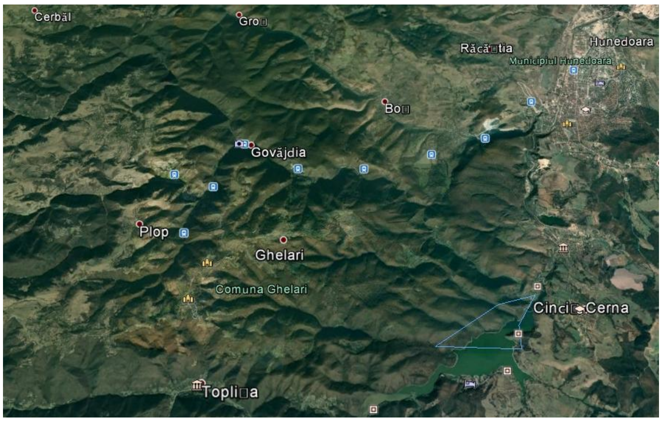

Figure 1: The location of the locality of Ghelari

The mining exploitation Ghelari negatively influenced in time the soil and the human settlements. The first manifestations of the subsidence were the appearance of cracks in the monumental building of the Orthodox Church of Ghelari and in other houses from the exploitation area.

The degradation of the soil surface and the appearance of the subsidence areas in the perimeter of the locality was produced by the submergence of the land due to the underground procedures for the extraction of minerals in all the mining perimeters of Ghelari Central, Ghelari East, and Ghelari West.

Figure 2 presents a significant example for the negative effect produced by the phenomenon of subsidence.


Figure 2: The negative effect of the phenomenon of mining subsidence

In time, in the area, a series of studies and research were performed in order to monitor, forecast and model the phenomenon of deformation and submergence of the surface in the influence area, depending on the strategy for the exploitation of the new deposits.

Due to the special importance of this area for the monitoring of the mining subsidence, we aimed to contribute to this aspect with the results of our study.

2. Materials and methods

To perform the study on the mining perimeter of Ghelari, we designed a network of alignments for the observance of the researched phenomenon, using a micro-triangulation network created with the help of the GNSS technology, through the static method. Next we performed the topogeodesic measurements, with the help of the total station, for the determination of the planimetric values of the tracking marks placed above the influence area of the diving bed, using the method of radiation. The altimetric values were established with the help of the level and its accessories, for a superior precision of the observations, using the method of middle geometric levelling.

As a result of the topogeodesic measurements, we analysed and evaluated the precision in the determination of the planimetric and altimetric values. The elimination of the measuring errors was possible through the compensation of the topographic measurements using a specialised soft for the automatic processing of the topographic measurements, finally obtaining the results presented in figure 3.

Current measurements				Initial measurement			
Nr.	Easting(Y)	Northing(X)	Z	Nr.	Easting(Y)	Northing(X)	Z
1	327628,560	470183,910	731,2400	1	327628,640	470183,822	731,280
2	327652,910	470195,093	733,170	2	327655,973	470197,921	733,228
3	327668,982	470222,254	732,2928	3	327668,919	470222,203	732,342
4	327691,690	470257,640	732,0063	4	327691,596	470257,602	732,059
5	327715,430	470282,690	733,0910	5	327710,660	470279,332	733,156
6	327746,070	470300,330	735,0221	6	327746,150	470300,394	735,079
7	327775,970	470308,220	736,8359	7	327775,960	470308,368	736,850
8	327796,200	470324,610	737,7026	8	327796,096	470324,735	737,769
9	327823,780	470338,270	738,4445	9	327823,796	470338,432	738,4923
10	327852,670	470353,920	738,8675	10	327852,736	470354,556	738,995
11	327899,380	470379,540	738,9341	11	327880,116	470369,415	739,130
12	327908,120	470384,540	738,5944	12	327908,093	470384,838	738,846
13	327936,600	470401,150	738,4352	13	327936,543	470401,460	738,664
14	327965,020	470417,270	738,2572	14	327964,945	470417,594	738,500
15	328000,640	470431,100	737,7838	15	328000,501	470431,451	738,038
16	328021,370	470445,500	737,0920	16	328021,179	470445,843	737,345
17	328077,790	470494,230	735,2789	17	328077,793	470494,234	735,536
18	328077,721	470462,548	735,001	18	328077,724	470462,551	735,140
19	328104,490	470518,620	734,7742	19	328104,242	470519,024	734,932
20	328117,701	470530,242	733,899	20	328117,705	470530,246	734,258
21	328133,260	470556,920	734,620	21	328141,800	470572,416	734,800
22	328152,839	470585,670	734,480	22	328152,827	470585,674	734,760
23	328152,740	470585,330	734,5106	23	328152,746	470585,335	734,844
24	328199,390	470628,049	733,4651	24	328199,394	470628,042	734,153
25	328209,320	470636,880	733,920	25	328209,621	470637,085	734,180

Figure 3: Extract from the centralising table resulted after the topographic measurements

After obtaining the planimetric and altimetric values and the data processing by applying the compensation of the errors, we calculated the parameters defining the diving bed.

The processing of the topographic measures necessary to the calculation of the parameters defining the diving bed was performed using a calculation system where we introduced all the planimetric and altimetric data resulted after the topographic measurements in the field, especially the value of the level differences and of the distances reduced to the horizon, used to determine the values of the parameters specific to the phenomenon of subsidence (submergence, inclination, curvature, radius of curvature, specific horizontal displacement, and horizontal displacement).

Figure 4 shows an extract from the calculation centraliser for the determination of the final values of the parameters specific to the diving bed of the mining area of Ghelari.

								Parameters characteristic of the diving bed					
Current measurements				Initial measurement				SUBMERGENCE $S_i = H_i^0 - H_i^K$ [mm]	INCLINATION $I_{i,i+1} = (S_{i+1} - S_i)/D_{i,i+1}$ [mm/m]	CURVATURE $K_{i,i+2} = (I_{i+1} - I_i)/(D_{i,i+2}/2)$ [mm/m²]	RADIUS OF CURVATURE $R_i = 1/K_{i,i+2}$ [m²/mm] sau [km]	HORIZONTAL DISPLACEMENT $D_{i,i+1}^* = \Sigma (D_{i,i+1}^k - D_{i,i+1}^0)$ [mm]	SPECIFIC HORIZONTAL DEFORMATION $\varepsilon_{i,i+1} = (D_{i,i+1}^K - D_{i,i+1}^0)/D_{i,i+1}^0$
Nr.	Easting(Y)	Northing(X)	Z	Nr.	Easting(Y)	Northing(X)	Z	S	I	K	R	D*	ε
1	327628,560	470183,910	731,2400	1	327628,640	470183,822	731,280	40	-	-			
2	327652,910	470195,093	733,170	2	327655,973	470197,921	733,228	58	0,67176	-		-3.959,890	-128,756
3	327668,982	470222,254	732,2928	3	327668,919	470222,203	732,342	49	-0,27971	-0,03415	-29,279	4.042,399	146,903
4	327691,690	470257,640	732,0063	4	327691,596	470257,602	732,059	53	0,08390	0,00988	101,200	5,789	0,138
5	327715,430	470282,690	733,0910	5	327710,660	470279,332	733,156	65	0,35669	0,00716	139,711	5.604,925	193,893
6	327746,070	470300,330	735,0221	6	327746,150	470300,394	735,079	57	-0,22995	-0,01697	-58,925	-5.914,168	-143,307
7	327775,970	470308,220	736,8359	7	327775,960	470308,368	736,850	14	-1,38341	-0,03511	-28,481	65,413	2,120
8	327796,200	470324,610	737,7026	8	327796,096	470324,735	737,769	66	2,00807	0,12178	8,212	87,483	3,371
9	327823,780	470338,270	738,4445	9	327823,796	470338,432	738,4923	48	-0,60474	-0,09254	-10,806	-123,962	-4,012
10	327852,670	470353,920	738,8675	10	327852,736	470354,556	738,995	128	2,42722	0,09531	10,492	-272,067	-8,212
11	327899,380	470379,540	738,9341	11	327880,116	470369,415	739,130	196	1,28391	-0,02655	-37,668	22.122,724	710,152
12	327908,120	470384,540	738,5944	12	327908,093	470384,838	738,846	252	5,53026	0,13408	7,458	-21.877,400	-684,813
13	327936,600	470401,150	738,4352	13	327936,543	470401,460	738,664	229	-0,69154	-0,28913	-3,459	19,859	0,603
14	327965,020	470417,270	738,2572	14	327964,945	470417,594	738,500	243	0,42879	0,03413	29,296	8,743	0,268
15	328000,640	470431,100	737,7838	15	328000,501	470431,451	738,038	254	0,29808	-0,00370	-270,447	49,858	1,307
16	328021,370	470445,500	737,0920	16	328021,179	470445,843	737,345	253	-0,04833	-0,01099	-90,968	47,261	1,876
17	328077,790	470494,230	735,2789	17	328077,793	470494,234	735,536	257	0,05479	0,00207	483,311	73,781	0,991
18	328077,721	470462,548	735,001	18	328077,724	470462,551	735,140	139	-3,72671	-0,12846	-7,784	-1,000	-0,032
19	328104,490	470518,620	734,7742	19	328104,242	470519,024	734,932	158	0,30293	0,22286	4,487	-255,017	-4,088
20	328117,701	470530,242	733,899	20	328117,705	470530,246	734,258	359	11,43347	0,28315	3,532	68,781	3,924

Figure 4: Extract from the calculation centralisation for the parameters of the transversal alignment – Ghelari mining parameters

3. Results

After the calculation of the specific parameters, for a general observation and presentation of the results, we graphically represented the parameters, as depicted in the images below:

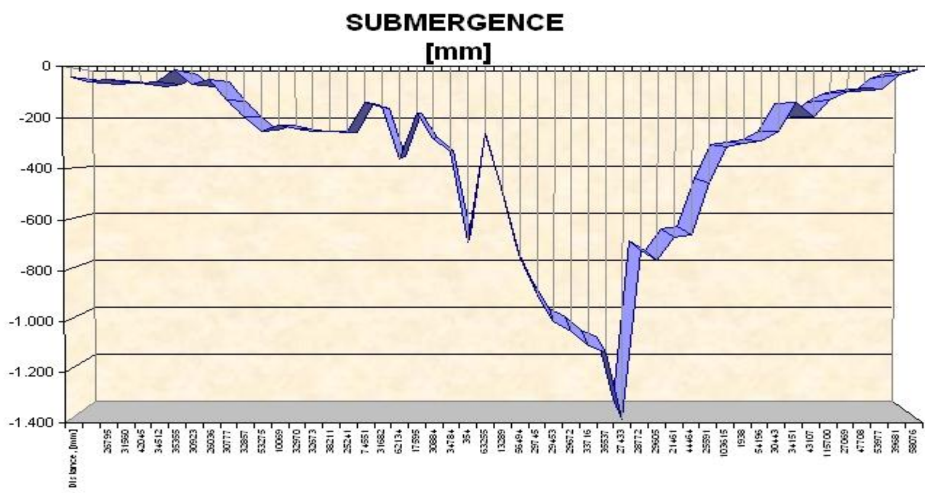

Figure 5: The representation of the submergence

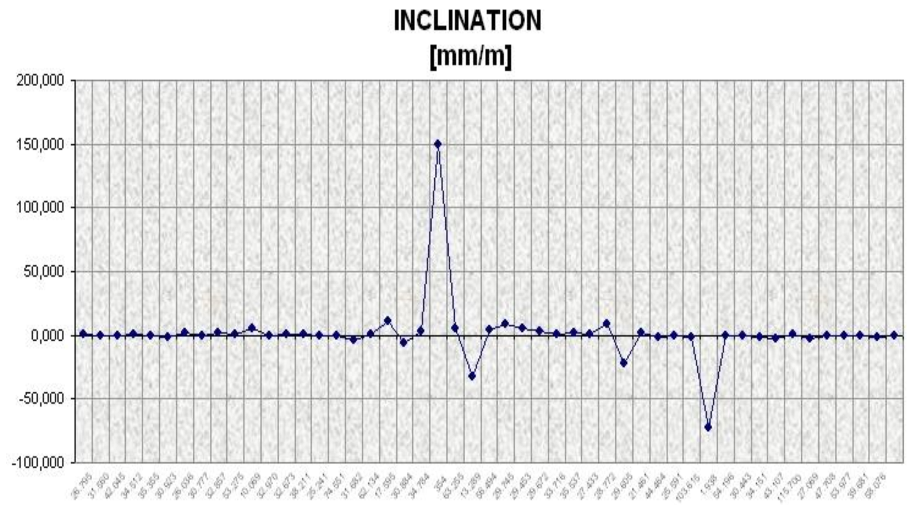

Figure 6: The representation of the inclination

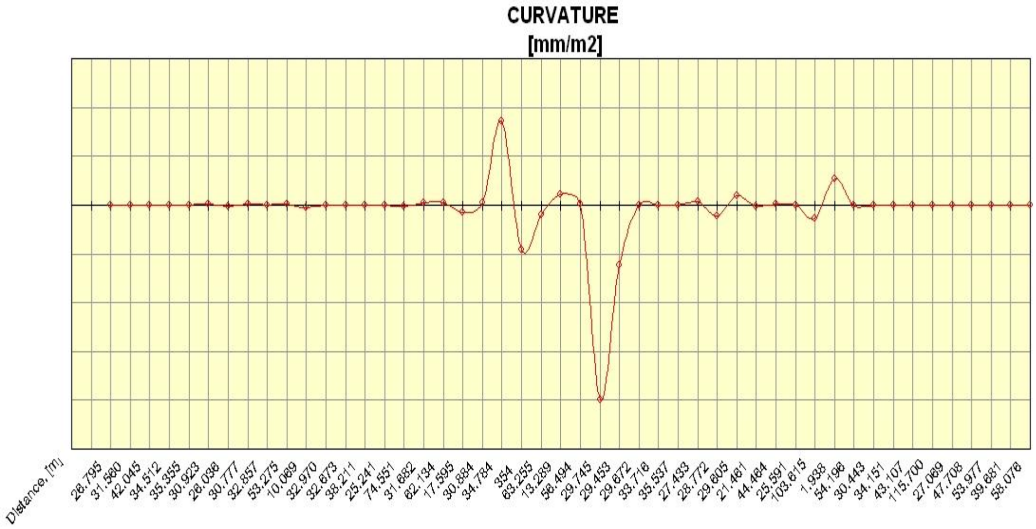

Figure 7: The representation of the curvature

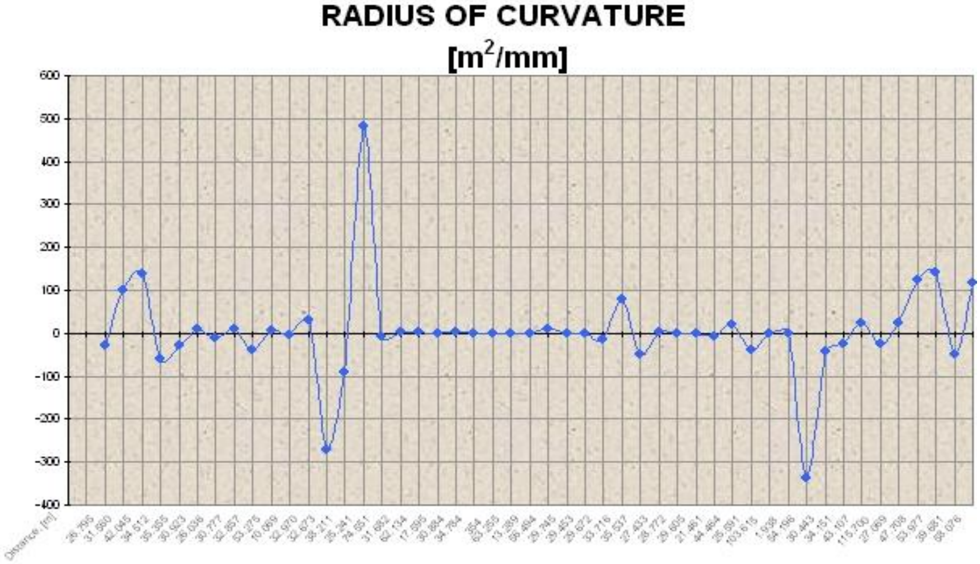

Figure 8: The representation of the radius of curvature

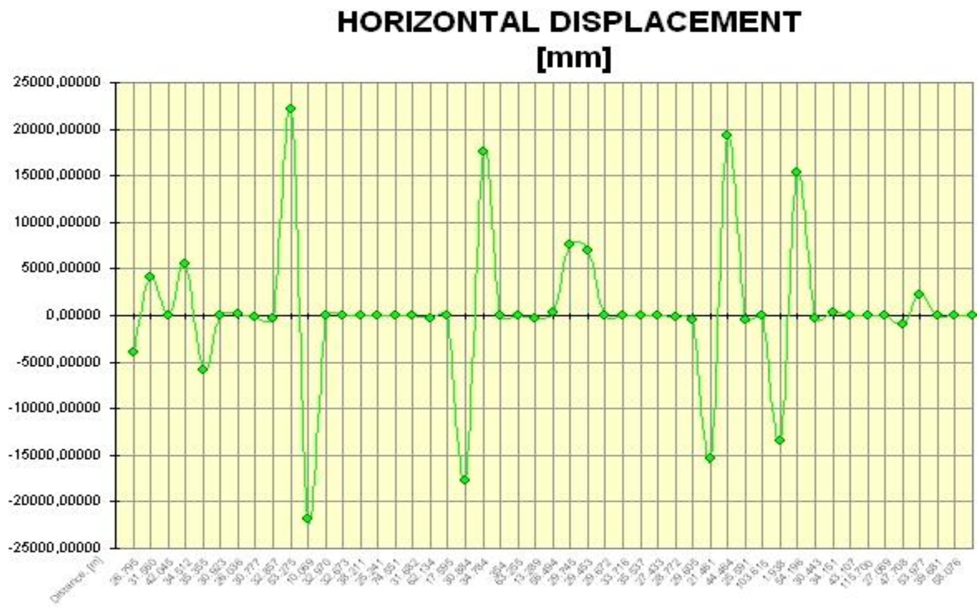

Figure 9: The representation of the horizontal displacement

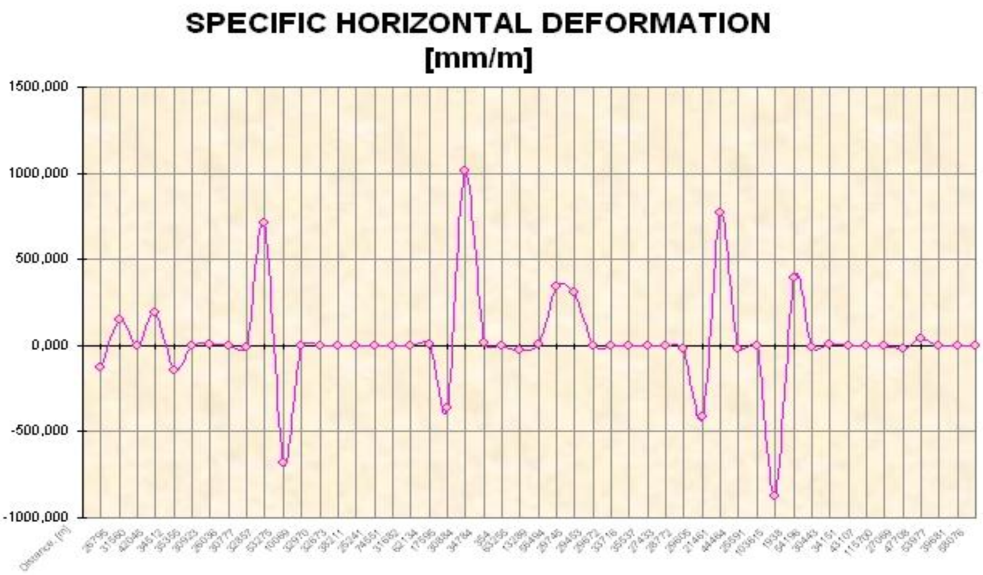

Figure10: The representation of the specific horizontal deformation

4. Conclusions

The studies and research have shown that, by analysing the movement of the tracking marks situated in the influence area of the diving bed, after the displacement and deformation end, the tracks placed in the surface will change their initial position, neither vertically, nor horizontally.

Starting from this aspect, we can appreciate that the elements helping for the characterisation and the quantitative and qualitative evaluation of surface movement – the parameters of the diving bed – are used to establish the dimension of the safety pillars and the safety measures for the constructions on the surface or in the underground.

To understand the modification of the surface as effect of the underground mining is necessary to study in detail the displacement of the entire package of rocks in the exploitation level toward the surface and to precisely determine the parameters specific to the diving bed influencing the entire process of displacement and deformation of the surface.

The evolution of the displacement and deformation of the land depends on the parameters specific to the deposit, the types of rocks met during the excavation, which are factors revealing a unique behaviour for each type of mining exploitation.

The study of the influence of the underground exploitation is necessary to highlight the movement and to establish the safety measures for the constructions at the surface and for the surface itself.

5. References

1. Beldea M., Palamariu M., Voina I. - ,,Topographic research upon the subsidence in the east of the mining basin of Petroşani'' , The 14th International Symposium U.S.A.M.V. Cluj-Napoca 2015, Cluj-Napoca, Romania.

2. Brauner, G., ,,Subsidence due to Underground Mining. 1.Theory and practices in predicting surface deformaiton'', Bureau of Mines Information Circular, S.U.A., 1973 .

3. Marian D.P. ,,Urmărirea topografică şi analiza deformării suprafeţei terenului afectat de exploatarea subterană'', Editura Universitas, Petroşani, 2012, România.

4. Neamțu M., Onose D., Neuner J. (1988). „Măsurarea topografică a deplasărilor şi deformaţiilor construcţiilor", Bucharest Construction Institute, Romania.

5. Onicioiu G., ,,Asupra unor probleme a scufundării – tasării suprafeţei terenurilor sub influenţa exploatării subterane'', Revista minelor, nr. 3 , 1997

6. Ortelecan M., Pop N., ,,Metode topografice de urmărire a comportării construcţiilor şi terenurilor înconjurătoare'', Editura ACADEMICPRES, Cluj-Napoca, 2005, România.

7. Palamariu M., Ungur A.R., Balaneanu F.A, ,, Topografie subterană – Îndrumător de lucrări aplicative", ISBN: 978-973-53-0245-0, Editura Risoprint, Cluj-Napoca, 2009, România.

8. Stefan N. ,, Studiul deformării terenurilor aflate sub influenţa exploatarii subterane a stratelor de carbune din bazinul minier Valea Jiului'' Teză de doctorat, Universitatea din Petroşani, Petroşani, 2015, România.

9.Voina I., Palamariu M, Neuner I., Beldea M, ,,Overview on the use of the profile functions method in forecasting the subsidence phenomenon in the Jiu Valley mining basin", RevCad Jurnal of Geodesy and Cadastre, Universitatea ,,1 Decembrie 1918" Alba Iulia, Alba Iulia, 2016, Romania, pp179-186.

10. Voina, I., Palamariu, M, Neuner, I., ,,Considerations on the ways of determining the movement of the earth's surface due to the phenomenon of subsidenece " The International Conference of the University of Agronomic Sciences and Veterinary Medicine of Bucharest , Bucureşti, 2016, Romania, pp109-114.

11. Voina I., Palamariu M, Neuner I., ,,Topographic determinations used in the analysis of subsidence" , 16th International Multidisciplinary Scientific GeoConference SGEM 2016,www.sgem.org, SGEM2016 Conference Proceedings, ISBN 978-619-7105-59-9 / ISSN 1314-2704, June 28 - July 6, 2016, Book2 Vol. 2, pp 663-672

12.Voina I., ,,Cercetări privind analiza fenomenului de subsidenţă datorat exploatării zăcămintelor stratiforme", Teza de doctorat, Universitatea Tehnică de Construcţii din Bucureşti, Bucureşti, 2018, România.

13. Voina, I., Dragomir. L, - ,, Digital modelling of the land as a result of the phenomenon of mining subsidence", RevCad Jurnal of Geodesy and Cadastre, Universitatea ,,1 Decembrie 1918" Alba Iulia, Alba Iulia, 2019, Romania, pp65-70.
14. Voina,I, Dragomir.L, Lasconi, A., Monitoring the minier subsidence phenomenon in Valley Arsului Area – Vulcan mining exploitation, RevCad Jurnal of Geodesy and Cadastre, Universitatea ,,1 Decembrie 1918" Alba Iulia, Alba Iulia, 2019, Romania, pp71-76.
*15*** Colectivul condus de Rancea. G. - I.C.P.M.C. Petroşani, ,,Instrucţiuni privind regimul obiectivelor amplasate la suprafaţa zonelor purtătoare de rezerve de cărbune şi dimensionarea pilierilor de protecţie", 1979, Petroşani, România.*