Possibilities of Using the Kinematic Structural Monitoring Methods in the Time Behavior of Constructions and Terrains Located above the Mines in Conservation

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Key words: static conditions, sensors, kinematic structural monitoring methods

SUMMARY

Based on a real case land deformation scenario (i.e. the terrain displacements above and in the area of vicinity of Iara mine, Romania), the North University of Baia Mare and University of Petrosani, has been monitoring its evolution using conventional surveying and GPS techniques since March, 2009. The severity and magnitude of the physical phenomenon has eventually resulted in the collapse of a large (27.10.2009/1413 m^2) area that evolved to a deep (27.08.2010/6676 m^2) cone shaped pit. This incidence took place several years after the mine activities have been stopped and had serious effects on people's activities living in the greater area of the scenario. This paper presents the details of observation campaigns and data analysis undertaken so far, and proposes an alternative strategy for carrying out similar studies based on modern processing methodologies, geodetic instrumentation as well as data transfer and manipulation techniques.

REZUMAT

Bazat pe un caz real de deformare a terenurilor (deplasările de teren din zona de vecinătate a minei Iara, România), Universitatea de Nord din Baia Mare şi Universitatea din Petrosani, a monitorizat evoluţia acestui fenomen folosind tehnici topografice convenţionale şi tehnici GPS începând din Martie, 2009. Gravitatea şi amploarea fenomenului fizic a dus, în cele din urmă, la prăbuşirea unei suprafeţe mari de teren evoluând de la (27.10.2009/1413 m^2) la (27.08.2010/6676 m^2) formându-se practic o groapă în formă de con. Această incidenţă a avut loc la câţiva ani după ce activităţile miniere au fost oprite şi a avut efecte grave asupra activităţilor oamenilor care locuiesc în zona, cu mult mai mare decât scenariul iniţial prevăzut pentru exploatarea minieră. Această lucrare prezintă detaliile unor campanii de observare şi analiză a datelor, întreprinse până în prezent, şi propune o strategie alternativa pentru realizarea unor studii similare pe bază de metodologii de prelucrare şi instrumente geodezice moderne precum şi transferul de date şi tehnicile de manipulare adaptate unor cazuri similare.

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1. GENERAL CONSIDERATIONS

After extracting a volume of useful minerals from a deposit, the void resulted from the exploitation makes the state of strain and deformity from the massif exploited to modify, resulting in the destruction of stability of surrounding rocks, their movement being able to reach the land surface daily, leading to its degradation and thus the destruction of buildings situated on the surface. The size of surface degradation and the character of the rock movement are influenced, mainly, by the following factors: Size of the void created by mining; The location depth of the exploitation; Thickness and inclination of the deposit; Exploitation method and technology; Pressure control module; Geo-mechanical characteristics of rocks; Deposit tectonics; Duration of the exploitation, etc.

The sinking of the land surface may be continuous or discontinuous. Discontinuous sinking, representing phenomena of local breaking of rocks, are characterized by significant displacements of the surface over the area of the exploited surface, and by the formation of discontinuities in the surface profile of the day, which can develop suddenly or gradually, and which may manifest at different scales. Sinking funnels are characterized by gradual subsidence of the deformation caused by unsupported mining excavations, through covering rocks, to the surface. The sinking surface may be similar to the one of the underground excavation. Subsidence funnels can be formed from the exploitation of deposits found in weak rocks, in rocks that have already collapsed or in regularly cracked rocks. The formation of the subsidence funnels occurs most often abruptly (seldom progressively), the phenomenon being known as dynamic sinking. We can identify three mechanisms through which the subsidence funnels are produced, associated with different geological formations:

- First mechanism occurs in the case of altered or poor rocks, or in the case of rocks that have already collapsed. It is a progressive mechanism that is triggered by breaking the direct roof, after inclined surfaces,
- The second mechanism is also progressive, but occurs as a result of discontinuity of rock mass,
- The last mechanism differs from the other two in that it is controlled by one or more main geo-mechanical characteristics of rocks, which causes the appearance of some areas with a low resistance to shearing, on which some rock banks may slip gravitationally, as a rigid body. In this case a vertical movement will arise, that will be transmitted to the surface having the same size as the void underground.

2. MONITORING THE MASCA CONE-SHAPED LANDFALL, CLUJ COUNTY

2.1 Location of the exploitation perimeter

Băişoara - Cacova exploitation perimeter is located in Cluj County, on the territory of Băişoara, Masca and Cacova-Ierii localities, 8 km N - NW from the commune Iara. Exploitation perimeter Băişoara - Cacova consists of **Cacova-Ierii** deposit - which may be regarded as a continuation of the **Masca-Băişoara** deposit, which is only open and under investigation. While the **Cacova- Ierii** deposit is an important iron ore deposit in the country, capitalizing it raises special problems, because much of the deposit is located under the inhabited area, at a relatively low depth. Thus, the exploitation of the deposit could lead, by moving the formations around the openings created - by exploitation, to the damaging of the terrain surface, which is partially inhabited area. This is what happened in 2000 as the debut, peaking in the spring of 2009, which led to the start of monitoring operations, presented in the case study conducted in static regimen.

2.2 Geological situation in the region in which the deposit is located

The Iara - Băişoara - Cacova Ierii region is composed of eruptive, sedimentary, metamorphic rocks and contact formations. Iron ore deposits and polymetallic sulphide deposits in the region Iara - Băişoara - Cacova Ierii are located on the eastern crystalline frame of the Gilău In the region, the dominant rocks are metamorphic rocks assigned to the Gilău – Muntele Mare crystalline, eruptive formations belonging to the Iaramic (banatitic) subsequent magmatism, together with the products of thermal metamorphism, generated from it, and sedimentary formations. Stratigraphically, the region's foundation belongs to the Gilău – Muntele Mare crystalline, metamorphic rocks that are separated according to the intensity of the metamorphism and the time of formation in several series.

2.3 Analysis of the opening and of the deposit exploitation. Brief History

In the period 1955-1957, a first step of geological exploration was carried out, which was repeated in the second stage in the 1970s and continued until 1990. Starting from this year, geological research work was virtually interrupted. In the period of the geological investigations, iron ore deposits have been discovered near villages: *Masca-Băişoara - Cacova Ierii*. The Băişoara Mining Sector was established in 1972, by acquiring prospected and researched geological reserves from the south-east sector pit P-I, by the former *Cluj Mining Plant* (now *S.C. COMINEX S.A.*), as a sector of the *Căpuş Mining Exploitation*. The sector began preparatory work in order to place the deposit into exploitation. In 1981, the operation is performed at all three pits, production increased gradually and the exploitation area was expanded and the organizational form of mining exploitation was achieved (ME Iara). During 1990-1994, work regarding iron ore mining and preparation had great fluctuations, decreasing the annual production from 1990 to 1994 in an accelerated rhythm, leading to the termination of the underground work.

3. PRESENTATION OF THE MONITORING ACTIVITY CARRIED OUT BETWEEN OCTOBER 2009-SEPTEMBER 2010

3.1 Overview of monitoring activities carried out within the Masca perimeter

After identifying the affected area, following the consultation of the teaching staff from University of Petrosani and Baia Mare and then of the specialized institutions, namely Mindvest, Cepromin, Conversmin, I attended a measurements session and I recorded the data for the first two tracking cycles, then executing another three cycles, in March, June and August, for the last two cycles making measurements using GPS equipment, so that the data can be compared, verified, certified and ultimately deemed relevant.

We established a network of support points, creating the tracking network, consisting of six points, each point having visibility to all other points, the area being hilly and totally open. We could not connect the network to the national system, because the points from the national network were located over ten miles away from the area, calling from cycle four, the second cycle performed by me in June 2010, at the GPS positioning. We repeated GPS measurements in the last cycle, cycle 5, executed at the end of August 2010. Points in the network have resulted in Feno-GPS type bench marks.

The perimeter survey for the subsidence cone was made for cycles 1 and 2 by classical manner with a total station, cycle 3 also, with a reliable station type TOPCON 7002, and for cycles 4 and 5 mixed, with both total station and GPS technology. Previous to the topographic operations, the outline of the affected area was pegged out in order to take the same points (with the station, GPS rover respectively).

3.2 Presentation of the establishment and verification measurements for the lift-tracking network.

The following boards and tables establish the general guidelines of the monitoring process unfolded over a span of six months, March-September 2010, the network part, as follows:

1. The bordering of the preserved mining perimeter, related to the position of the cone-shaped landfall traced. One can notice that the position of the cone-shaped landfall is close to the monitoring area's centroid(Figure 1),

2. Proportion between the geodesic points of the national network and the GPS points materialized in the field for the establishment of the tracking network, through GPS technology Because the distances between the state network points and the centre of the traced cone were very large, the establishment of an individual GPS network seemed, from all perspectives, as being the most convenient,

3-5. Session 1 of the GPS-May 8th 2010 measurements, the ETRS89 geographical coordinates of the points in the established network, before post-processing, quality control; before post-processing and the 1970 stereographic coordinates of the points in the established network, before post-processing,

6-7. Session 2 of the GPS-August 28th 2010 measurements, the ETRS89 geographical coordinates of the points in the established network, before post-processing, quality control and the 1970 stereographic coordinates of the points in the established network,

8. Capture screen, the points of the national GPS network, for post-processing,

9-10. Session 1 of the GPS-May 8th 2010 measurements, the ETRS89 geographical coordinates of the points in the established network, post-processing, quality control and the 1970 stereographic coordinates of the points in the established network, after post-processing, 11-14. Session 2 of the GPS- August 28th 2010 measurements, the ETRS89 geographical coordinates of the points in the established network, after post-processing and without and with the compensation of the GNSS network and the 1970 stereographic coordinates of the points in the established network, after post-processing and without the compensation of the GNSS network and with the compensation of the GNSS network

Presentation of the verification measurements for the lift-tracking network with the complete topographic station. All six points in the network have been stationed and sights for the other points have been given. A TOPCON GTP 3102, 2′′equipment has been used. The table shows the coordinates established in the two measuring cycles, with the complete measuring station compared to the ones established through GPS technology, the static 60′ method. The differences between the coordinates are also presented, both between the GPS measuring cycles and the station ones. The maximum differences measured are -82mm on the X coordinate, -62mm on the Y, respectively 56mm on the Z. The next board presents the sketch of the sights, and next the tables regarding the side orientation of the formed intersections, for all 6 stations (the field data are in the added C addendum and the post-processing data in the added E addendum).

1. Comparison between the 1970 stereographical coordinates for the points in the established network, set through GPS technology, after processing and with the compensation of the GNSS network, cycle 1 and 2, with the ones set through the complete station(Table 1) ;
2. Differences between coordinates (mm), maximum differences(Table 2) ;

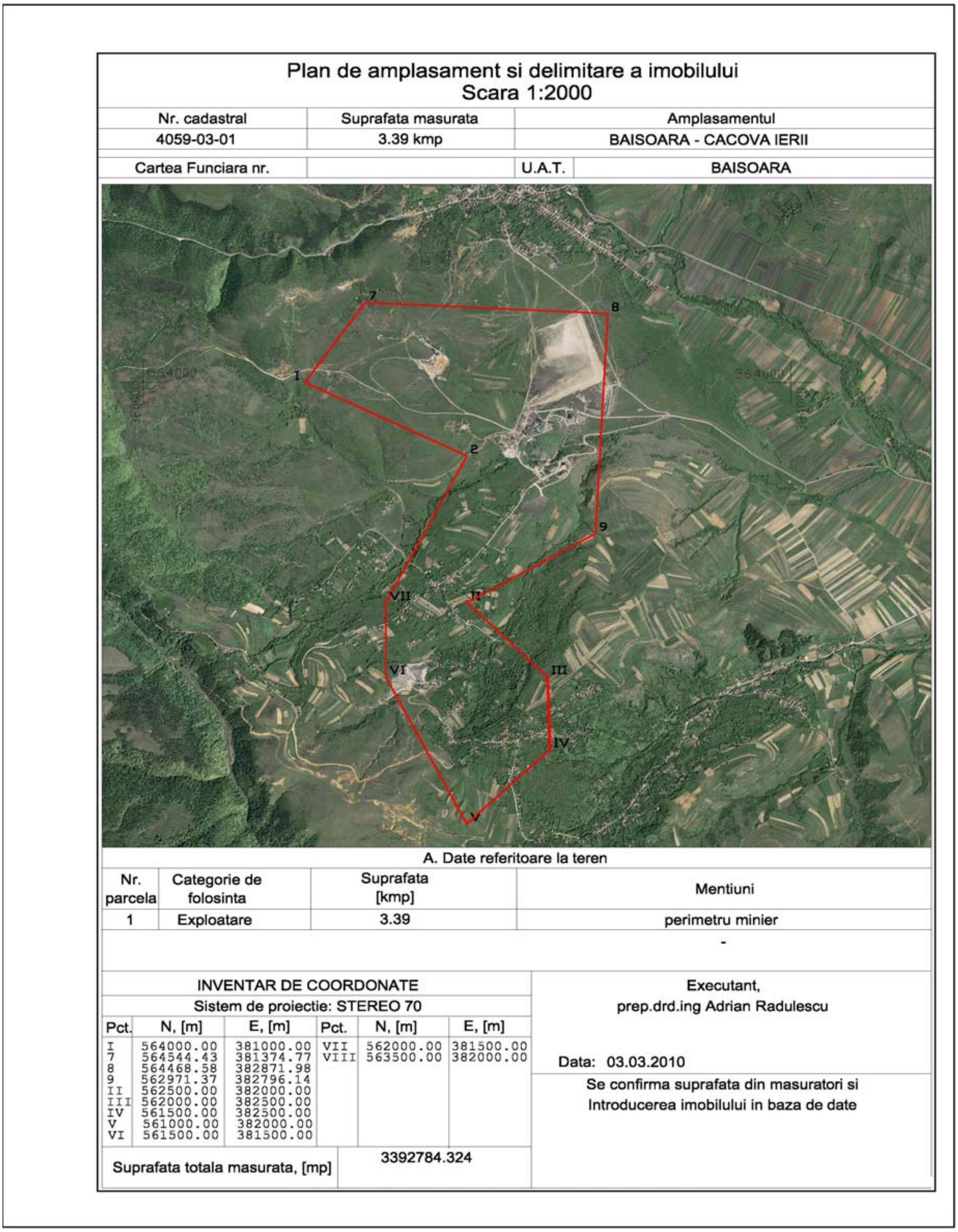
3.3 Monitoring measurements for the Maşca cone-shaped landfall

For each monitoring cycle of the cone-shaped landfall the following steps were taken:

- The outline and marking of the cone was made at the time of the measurements, each cycle having different marking colors, yellow for cycle 3, orange for cycle 4 and pink for cycle 5. Also, the evolution of the cone through the expansion of the set area is so fast that at cycle 5 we noticed that all the stakes placed at cycle 3 were already inside the cone and also a great number of the ones from the previous cycle.
- The outline of the cone was lifted from two stations, in points from the lift-tracking network, performed with the complete topographic station, and so the coordinates can be calculated both through intersections and polar coordinates.
- The outline of the cone was lifted through GPS stationing, in the same points that were marked and measured before.

The following elements of the two monitoring cycles for the evolution of the Masca cone-shaped landfall are presented (the field GPS data is found in the external E addendum):

1. Session 1 of GPS-08 measurements, May 2010, the ETRS89 geographical coordinates for the points on the cone-shape landfall, cycle 4, quality control;
2. The evolution of the cone-shaped landfall for the five measuring cycles(Figure 2);
3. Longitudinal and sectional profiles through the cone, cycle 3(Figure 3);
4. The diagram for the cone bottom settlement related to the terrain line(Figure 4);.



Plan de amplasament si delimitare a imobilului
Scara 1:2000

Nr. cadastral	Suprafata masurata	Amplasamentul
4059-03-01	3.39 kmp	BAISOARA - CACOVA IERII

Cartea Funciara nr.		U.A.T.	BAISOARA

A. Date referitoare la teren

Nr. parcela	Categorie de folosinta	Suprafata [kmp]	Mentiuni
1	Exploatare	3.39	perimetru minier
			-

INVENTAR DE COORDONATE
Sistem de proiectie: STEREO 70

Pct.	N, [m]	E, [m]	Pct.	N, [m]	E, [m]
I	564000.00	381000.00	VII	562000.00	381500.00
7	564544.43	381374.77	VIII	563500.00	382000.00
8	564468.58	382871.98			
9	562971.37	382796.14			
II	562500.00	382000.00			
III	562000.00	382500.00			
IV	561500.00	382500.00			
V	561000.00	382000.00			
VI	561500.00	381500.00			

Suprafata totala masurata, [mp]	3392784.324

Executant,
prep.drd.ing Adrian Radulescu

Data: 03.03.2010

Se confirma suprafata din masuratori si
Introducerea imobilului in baza de date

Figure 1. The bordering of the preserved mining perimeter, related to the position of the cone-shaped landfall traced

Table 1. Comparison between the 1970 stereographical coordinates for the points in the established network, set through GPS technology, after processing and with the compensation of the GNSS network, cycle 1 and 2, with the ones set through the complete station

POINT	X			
	CYCLE 1 GPS	CYCLE 2GPS	STATION 1	STATION 2
	08.05.2010	28.08.2010	08.05.2010	28.08.2010
RGR1	563362.320	563362.358	563362.322	563362.331
RGR2	563309.679	563309.625	563309.614	563309.618
RGR3	563173.396	563173.382	563173.333	563173.314
RGR4	563580.267	563580.265	563580.243	563580.255
RGR5	563569.556	563569.509	563569.582	563569.573
RGR6	563461.620	563461.621	563461.611	563461.613
POINT	Y			
	CYCLE 1 GPS	CYCLE 2GPS	STATION 1	STATION 2
	08.05.2010	28.08.2010	08.05.2010	28.08.2010
RGR1	382410.189	382410.189	382410.189	382410.189
RGR2	382314.083	382314.083	382314.083	382314.083
RGR3	382021.918	382021.918	382021.918	382021.918
RGR4	382328.649	382328.649	382328.649	382328.649
RGR5	382162.879	382162.879	382162.879	382162.879
RGR6	382004.819	382004.819	382004.819	382004.819
POINT	Z			
	CYCLE 1 GPS	CYCLE 2GPS	STATION 1	STATION 2
	08.05.2010	28.08.2010	08.05.2010	28.08.2010
RGR1	575.278	575.278	575.278	575.278
RGR2	579.453	579.453	579.453	579.453
RGR3	587.668	587.668	587.668	587.668
RGR4	569.194	569.194	569.194	569.194
RGR5	575.994	575.994	575.994	575.994
RGR6	575.888	575.888	575.888	575.888

Table 2. Differences between coordinates (mm), maximum differences

POINT	X			
	CYCLE 2 GPS- CYCLE 1 GPS	STATION 1- CYCLE 1 GPS	STATION 2- CYCLE 1 GPS	DIF MAXIMMUM
RGR1	38	2	11	38
RGR2	-54	-65	-61	-65
RGR3	-14	-63	-82	-82
RGR4	-2	-24	-12	-24
RGR5	-46	26	17	-46
RGR6	1	-9	13	13
POINIT	Y			
	CYCLE 2 GPS- CYCLE 1 GPS	STATION 1- CYCLE 1 GPS	STATION 2- CYCLE 1 GPS	DIF MAXIMMUM
RGR1	8	24	19	24
RGR2	-62	-40	-51	-62
RGR3	-20	-4	-7	-20
RGR4	-21	17	29	29

RGR5	**-13**	**8**	**-17**	**-17**
RGR6	**-2**	**13**	**37**	**37**
POINIT	**Z**			
	CYCLE 2 GPS-CYCLE 1 GPS	**STATION 1-CYCLE 1 GPS**	**STATION 2-CYCLE 1 GPS**	**DIF MAXIMMUM**
RGR1	**-4**	**-9**	**-2**	**-9**
RGR2	**11**	**44**	**11**	**44**
RGR3	**-44**	**34**	**-13**	**-44**
RGR4	**22**	**4**	**-28**	**-28**
RGR5	**20**	**-1**	**-13**	**20**
RGR6	**-19**	**26**	**56**	**56**

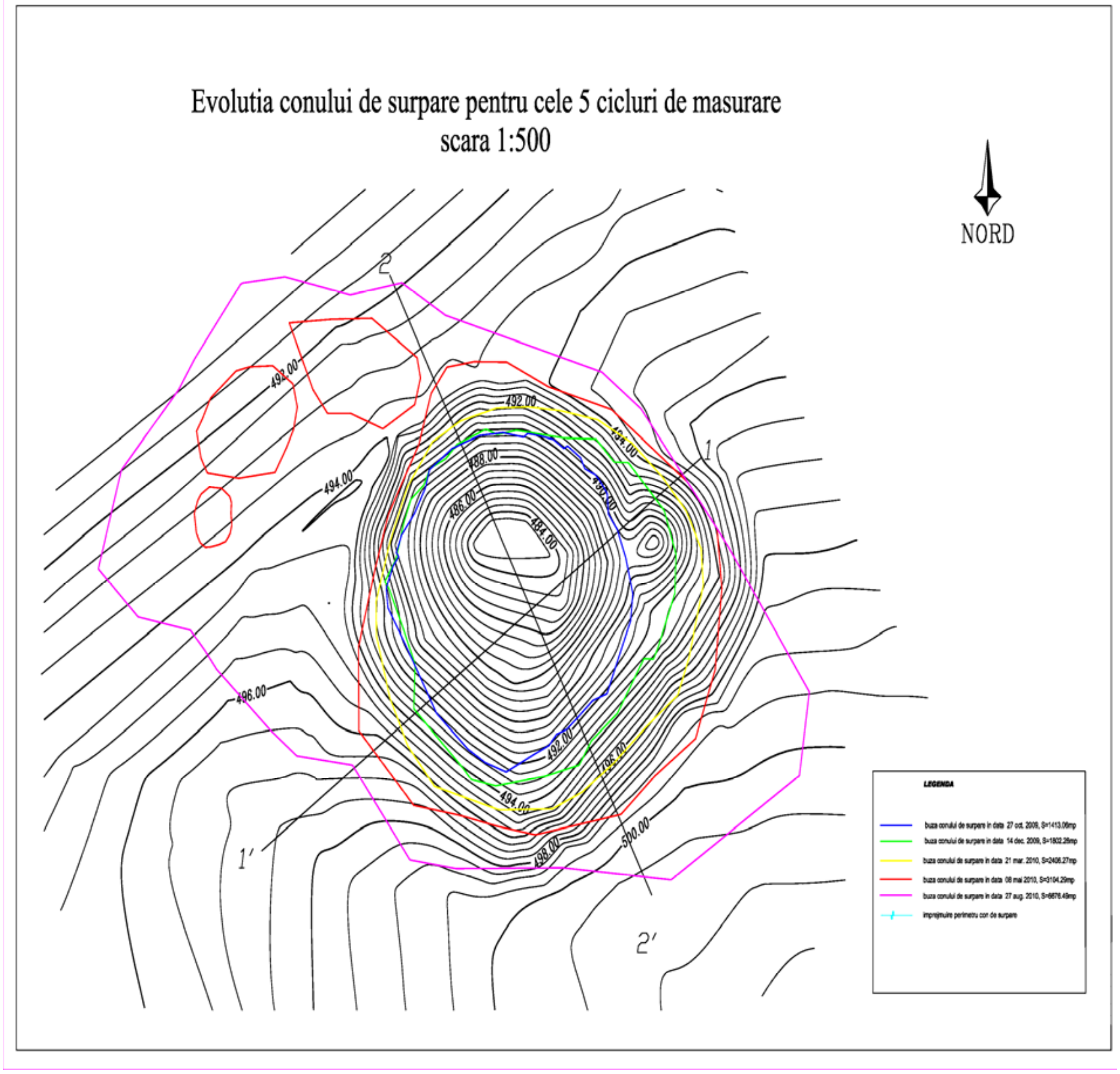


Figure 2.The evolution of the cone-shaped landfall for the five measuring cycles

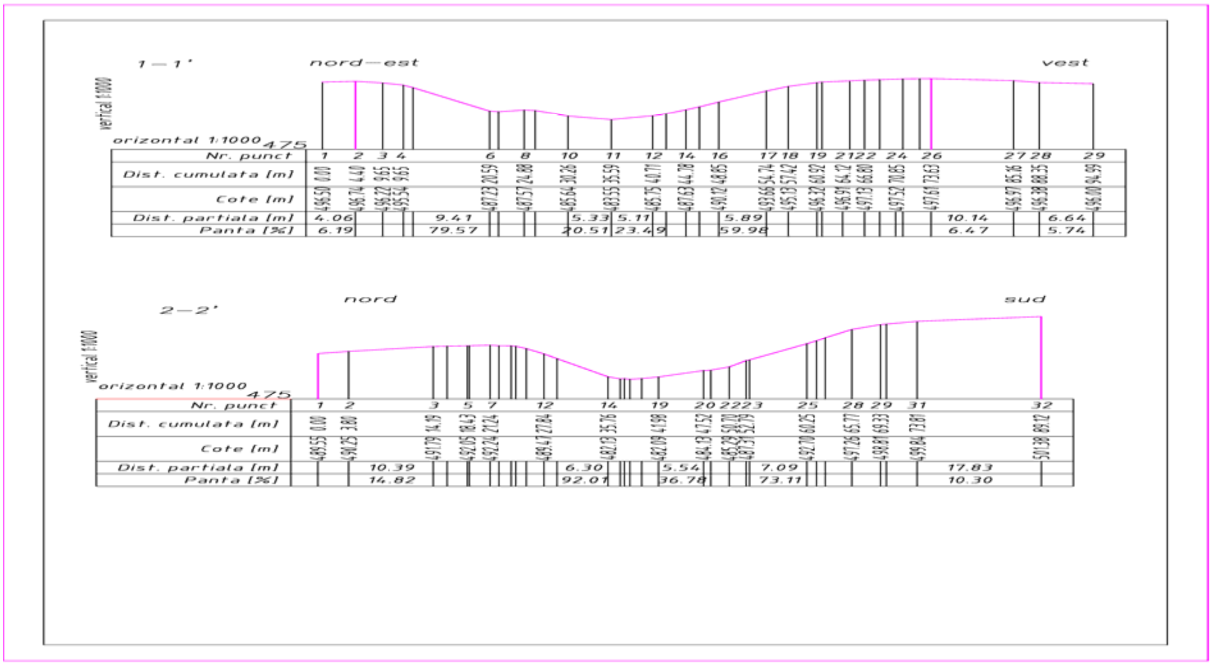
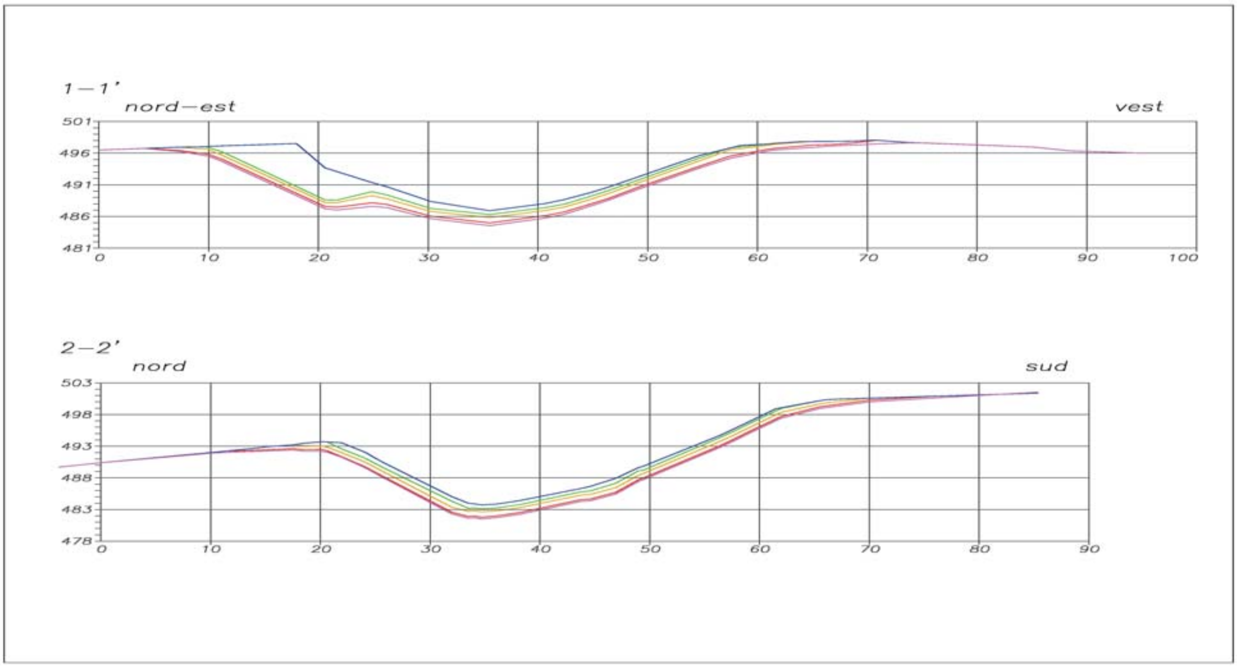


Figure 3. Longitudinal and sectional profiles through the cone, cycle 3; 27.08.10



-- 27 octombrer 2009
-- 14 decembre 2009
-- 21 march 2010
-- 08 may 2010
-- 27 august 2010

Figure 4. The diagram for the cone bottom settlement related to the natural line of the terrain

Figure 5. Evolution subsidence cone mask throughout the monitoring period a.04.10.2009, b. 27.10.2009, c. 12.11.2009, d. 14.12.2009, e. 17.02.2010 alarm situation, f. 15.03.2010, g. 08.05.2010, h. 28.08.2010

4. THE POTENTIAL OF MODERN DEFORMATION MONITORING TECHNOLOGIES IN SERVICE OF THE IARA MINE CASE STUDY

It is clear that from now on the physical phenomenon is unpredictable as it still evolves in time – however, its side effects are evident and easy to predict. Thereby, the collapse of land, produced in the shape of a cone, will stop only after a full volume balance between the surface-underground is realized. In this phase, the phenomenon cannot be stopped or reduced, its effects are predictable and the only hope is that the area in the immediate vicinity only a few properties there exist that need to be evacuated in the immediate.

In this context, the design of new processes and the adaption of modern technologies that would be capable to study the phenomenon in a continuous and quasi-dynamic / dynamic regimen refer only to applications in similar cases. Unfortunately, in recent years, such cases are becoming more common, not only in Romania but also worldwide. Depending on the individual characteristics that constitute a physical phenomenon (e.g. landslide, subsidence) a number of observation techniques, processing methods and instrumentation is currently available to monitor and assess the dynamic behavior of a scenario. This section provides only a brief overview of the various methods used to study similar phenomena with emphasis given in modern technologies.

1. Sensors (1-16) Figure 6, data transmission through optic fibers (OF) at the A data acquisition station, wireless data transmission, through system B, in environment C, at the collection, processing and interpretation base F of data,

2. Sensors (k), placed in 2-4 rounds of gradual monitoring, Figure 7, wireless data transmission, through system A, in environment B, data acquisition station C, wireless data transmission, through system D, in environment B, at the collection, processing and interpretation base F of data,

3. Total Topographic Station (3DEMON Robotic Laser Robovec system for 3D multiple milimeter monitoring of strains, based on laser technology) A, Figure 8, with the regular registration of the prisms 1-16 position, monitored in environment B, by a monitoring program C, with a return on the prism at an interval t, data transmission to base F.

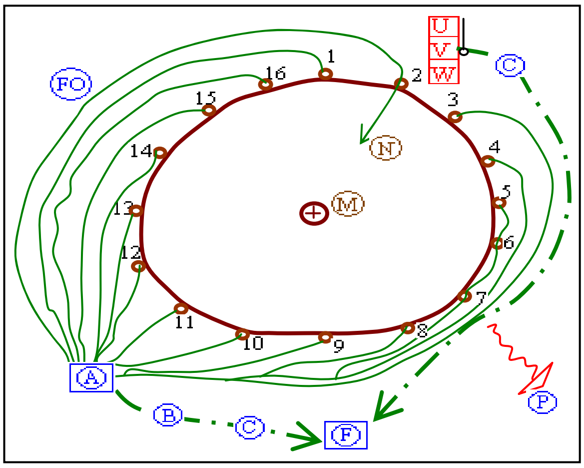


Figure 6 Sensors technology, data transmission through optic fibers

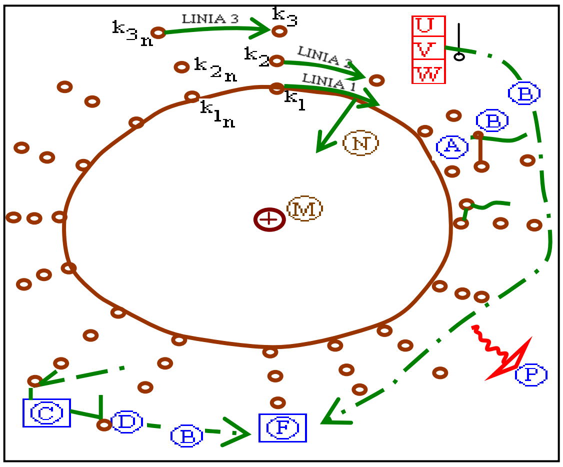


Figure 7 Sensors technology, wireless transmission data

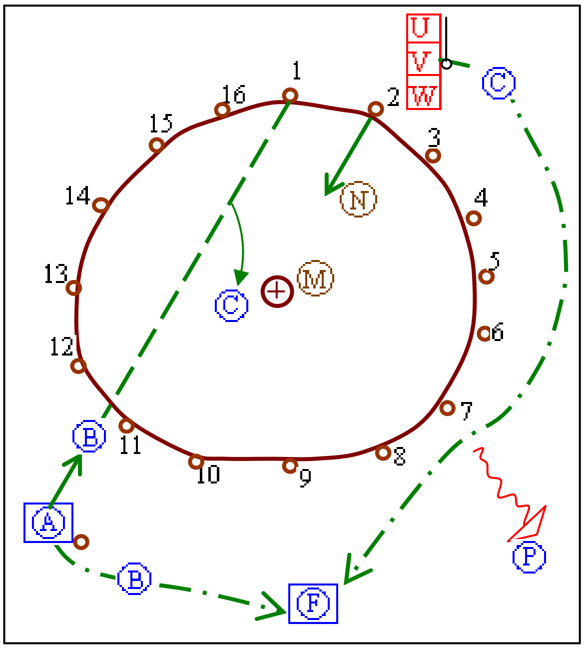


Figure 8 Total Topographic Station

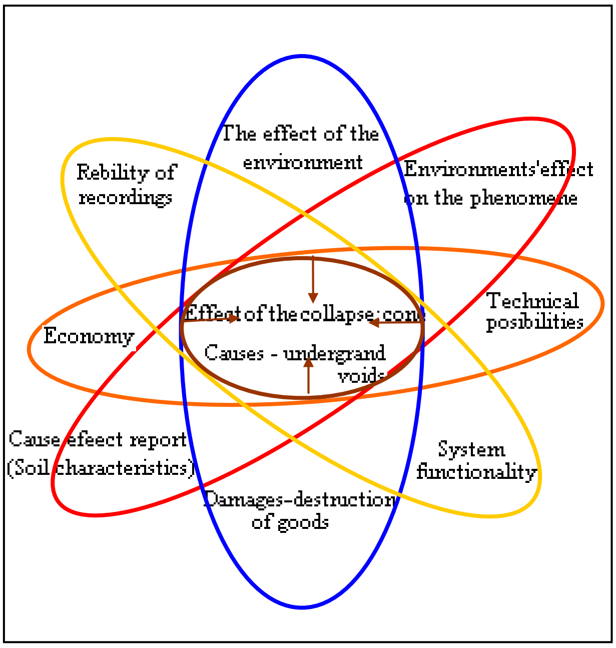


Figure 9 The Complexity of the Subsidance

4. Terrestrial laser scanning (TLS) enables the measurement and location of a very large quantity of 3D points (known as "point cloud") in an automated manner and a very short time. Such systems use the reflection of a focused laser beam from objects to compute their location and intensity values. Until recently, TLS systems were used mostly for the topographic surveying of plants, civil engineering structures as well as in cultural heritage documentation and in reverse engineering problems. However, the increased accuracy in distance measurement that modern systems can offer and the potential of processing software to produce detailed 3D models render TLS a viable method for use in many (structural) deformation monitoring projects.

More specifically, in case studies such as in the Iara mine the use of TLS technology is expected to provide valuable results due to the high displacement rates an its ability to provide a complete modeling representation of the scenario. Besides, TLS does not presupposes the use of targets, and thus surveying engineering operations are executed remotely.

5. Over the last twenty years the **Synthetic Aperture Radar (SAR)** principle has been successfully employed to compute the near vertical terrain deformation rates caused due to tectonic activity. The same principle has been recently used in Ground Based SAR (GB-SAR) systems to compute the static or dynamic displacements of structures and physical processes such as landslides. Such systems use interferometry to consent the displacement of an object by comparing the phase information of the electromagnetic waves reflected by the object in different instants of times. The key advantages of GB-SAR systems with respect to existing monitoring systems (such as GPS, extensometers, and strain gauges) are centred upon their ability to perform remote monitoring with high displacement accuracies (< mm), to produce a continuous displacement map of the area of interest (up to several km^2) as well as to operate during day and night and in all whether conditions. However, the applicability of such systems depends largely on the characteristics of the physical phenomenon – in particular, its pattern of kinematics, its geometry and relative geometry between the sensor and the scenario. Besides, the cost of the sensor and processing software can be a limitation to the use of such systems.

6. The traditional **videometrics technique** is usually adopted to measure the relative position and pose between the intervisible objects, and is invalid for measuring the three-dimensional position, pose and deformation of the non-intervisible target. An innovative broken-ray videometrics method is proposed(9) to resolve the non-intervisible measurement problem. "The research on broken-ray videometrics can not only solve the problem of measuring three-dimensional position, pose and deformation between non-intervisible objects, but also promote the progress of the videometric technique and expand its application fields. The broken-ray videometrics method proposed are very promising and will play an important role in the crucial science and technology fields such as deformation measurement, stress analysis, and structural monitoring"(9).

It is realized that the methods / systems outlined in this section can under certain circumstances contribute in monitoring the phenomenon at Iara mine. However, a thorough study is required that would balance the evolution characteristics of the phenomenon to available systems and funds. In all cases presented it is proposed that there would be U temperature sensors in the field, V wind speed, W air humidity, capable to transmit wireless data to station F. It is also recommended to execute regular photographs, daily if possible, of the contour area of the cone. The need to obtain a systematic picture file is evident as at previous cycles it is noticeable that new subsidence cones may occur or through a joining of several cones outside the subsidence area it can have atypical shapes. Programmable cameras with wireless data transmission can be installed in the boxes located in areas from which the cone is visible.

By all methods considered classic, which operate under static regimen, as well as the dynamic 1-2, quasi-dynamic 3 methods, data cannot be retrieved from the inner cone, M cone bottom respectively, and the active area N. Methods 4-6 can potentially capture the entire phenomenon in view, meaning that they could monitor the surface spreading of the movement of volumes involved in the phenomenon.

5. DISCUSSION AND CONCLUDING REMARKS

The deformation monitoring of constructions and terrains located above underground voids presents a series of issues that concern with result interpretation, cause-effect relation establishment, specifically to the mining activity.

This paper demonstrates that a great number of today's methods used in similar actions, applied for other categories of constructions and terrains can also be used in this case. Obviously, in specific situations certain adjustments and adaptations are needed, so that the cause proportion is appreciated as correctly as possible.

The static, quasi-static and dynamic monitoring activity of constructions and terrains, in any category or made in any location conditions, is a specifically topographic activity and must be kept like this, and the paper represents only a modest argument.

Cinematic topography, presented inside the paper as being a new branch of topography, is the chapter which studies the methods, instruments and data processing possibilities in the design, execution and tracking of the behavior over time of constructions under the effect of certain dynamic action forces, the most important being:

1. Wind action,
2. Earthquake action,
3. Volcanic activity action
4. The action of underground voids, of underground mining activities in general,
5. The action of landslides in critical stages,
6. Torrent action, in a similar stage,
7. Actions specific to road and railway traffic
8. The operation of large volume machines,
9. human induced settlements,
10. Accidents, explosions and in general other exceptional situations.

In the circle of quasi-static-quasi-dynamic actions I would include:

1. The action of uneven sun spreading on structures,
2. The action of underground voids, in pre-critical stages,
3. The action of human traffic and living regarding the usage of the monitored spaces,
4. Similarly, the action over time on machine operation,
5. The aging effects of construction materials,
6. The effects of variation, due to rainfall, of the underground water level,
7. The effects, in the active but not acute circle, of landslides,
8. The effects of certain design errors,
9. The effects of certain errors which occurred during construction,
10. The continuous monitoring of volcanic activity.

All the actions mentioned previously, in the two chapters about the monitoring activity, also produce effects in time, with a continuous dynamics, but with a necessary monthly or annual sequential research, already specific to the known and regulated activity regarding tracking over time, which in the new context will have to receive another label: “static regimen”.

In the principle of cumulative information, the proportion between the behavioural provisions and today’s real recorded results will serve for perfectioning the exploitation method we will use tomorrow. The paper also refers to topography’s contribution in the exploitation phase because it entails, now when it is possible and accessible, that the surface monitoring (constructions and terrains) be made a continuous activity and not a sequential one, as it has been until now.

I consider this to be the first and most important conclusion of the paper:

1. The surface movement process (constructions and terrains) located above or in the vicinity of an underground mining exploitation is a continuous process that in certain cases is visually noticeable or detectable through classic means. As a result, the deformation monitoring activity must become continuous, according to the evolution of sinking-sliding phenomena, in *order to validate, in extreme cases, the dynamic analysis methods for the already mentioned phenomena.*

The usage of the previous information, in the sense of the evolution and existence of topographic methods and instruments, allows the statement of the second conclusion resulted from the paper's context:

2. Given that the effect-phenomena manifested on the land surface by the existence and evolution of the underground voids have a continuous character, the monitoring process should be divided into three classes, resulted from the relation between cause-effect over time: that is to say static, quasi-static and dynamic regimen recordings.

The results obtained through dynamic modern means allow the presentation of data in all three means, static, quasi-static and dynamic and also the answer to the question: once the previously mentioned condition is fulfilled, are other categories of measurements still necessary?

This allows the statement of the third conclusion:

3. The dynamic methods are expensive and their use cannot be applied in all cases - especially if long deformation monitoring times are required

The following conclusion-statement derives from the previous declaration:

4. One will resort to the dynamic methods only in the case of aggressive phenomena, whose evolution must be continuously monitored, either for the presentation of data in a static, quasi-static regimen, either for the presentation of the continuous evolution of volume movement phenomena studied.

Another conclusion-statement, which I can make as a result of the research carried out is:

5. All the monitoring methods of constructions and terrains over time are ordinary and there are very few particularities regarding, generally, the environment in which the tracked structures are located and even fewer regarding their nature.

Regarding the use of classic methods, in which the studied phenomena are secquentially put into evidence, the following conclusions can be stated after the studies made:

6. The classic recording methods show disadvantages by limiting the information flow. Thus, being gathered through different means, in different ages, the compatibility of the information received drops, making it hard to establish data banks.

7. The lack of continuity would cut out a sequential character in monitoring data. The cost is still high, the difficulties which appear are great and the results obtained are modest.

8. Weather conditions can have an impact not only on the structure but also on the equipment used for recording the deviations – the data being transferred from the functional to the viewable, if the recordings taken in different cycles are made in diverse climate conditions.

9. The information acquired based on recordings of phenomena of similar characteristics can be extremely useful – however, unfortunately the results of the measurements are rarely communicated and therefore it is arduous to build a data bank in this field.

10. Knowing the general, particular and special behavior model of construction A, with the structural parameters B, located in the C area, characterized by D environment factors, makes the calculation of the worst case possibilities of combining the influence factors of the monitored construction's behavior possible and the taking-up, within the maximum resistance limits provisioned, of the optimum solution for designing a similar future project,.

REFERENCES

1. **BARLA G. , ANTOLINI F. , BARLA M. , MENSI E. , PIOVANO G.** (2010) *"Monitoring of the Beauregard landslide (Aosta Valley, Italy) using advanced and conventional techniques"* Enginering Geology, 116 pp.218-235
2. **CHRZANOWSKI, A., and WILKINS R.,** (2005) *Continuous monitoring of deformations in open pit mines-problems and solutions*, Proceedings of 6 Geokinematischer Tag (ed. A. Sroka, R. Wittenburg), Freiberg, May 12-13, published in Schriftenreihe des Institutes für Markscheidewesen, T.U. of Mining, Freiberg, Heft 2005-1, pp. 17-3
3. **DIMA N., HERBEI O., VERES I.** (2005), *New possibilitels for monitoring of land subsidens,* Simpozionul SESAM, INSEMEX, PETROSANI,
4. **DIMA N., HERBEI O., BENDEA H., VERES I.** (2002), , *Possibilities of making prognosis for the displacements of the terrestrial area influenced by the underground mining exploitation,* 6-th Conference on Environment and Mineral Processing Part II, 27-29 june 2002 Czech Republic.
5. **GIKAS, V., SAKELLARIOU, M.** (2008) "Settlement Analysis of Mornos Earth Dam (Greece): Evidence from Numerical Modeling and Geodetic Monitoring", Engineering Structures, Vol. 30, pp 3074–3081
6. **KARAMITSOS S., KOTSIS J., GIKAS V., ALEVIZATOS A.** (2006) *"Surface Deformation Monitoring in Tunnel S2 of the Egnatia Highway",* 12th FIG Symposium on Deformation Measurement and 3rd IAG Symposium for Geotechnical and Structural Engineering, Baden, Austria, May 22-24
7. **KOTSIS, I., KARAMITSOS, S., GIKAS V.,** (2005) *"3D Terrestrial Scanning for Tunnel Surveying: Hints and Tips and Comparison with Conventional Methods",* International Symposium on Modern Technologies, Education and Professional Practice in Geodesy and Related Fields, Sofia, Nov. 3-5
8. **LICHUN SUIA, XUE WANGA, DAN ZHAOA, JIA QUA** (2008) *"Application of 3D laser scanner for monitoring of landslide hazards", The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences. Vol. XXXVII. Part B1. Beijing 2008*
9. **QIFENG YU , GUANGWEN JIANG , SIHUA FU , YANG SHANG , YONGHUI LIANG , LICHUN LI,** (2008) *Broken-ray videometric method and system for measuring the three-dimensional position and pose of the non-intervisible object,* The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences. Vol. XXXVII. Part B5. Beijing 2008
10. **RĂDULESCU GH.M.T., RĂDULESCU ADRIAN T.G.** (2006),„ *Dynamic Surveying As Means To Assure A Special Structure Safety,* Paper CIBW99-0074-06, Theme: Measurement and quantitative analysis, Preceedings of CIB W99 2006, International Conference on Global Unity of Safety and Health in Construction. Beijing, China / June 22-30 /2006
11. **RĂDULESCU ADRIAN T.G., RĂDULESCU GH.M.T.** (2010),„ *Geometric Structural Monitoring in Cinematic Regime- dynamic Surveying as Means to Assure a Structure Safety*, PAPER (3945), FIG Congress 2010 - Facing the Challenges – Building the Capacity, Sydney, Australia, 11-16 April 2010
12. **GHEORGHE M.T. RADULESCU, ADRIAN TRAIAN G. RADULESCU,VIRGIL MIHAI G. RADULESCU, OVIDIU STEFAN AND CORINA M.E.E. RADULESCU** (2010)„ *Technology developments in mining structural health monitoring, on interdisciplinary research,* Mine Planning and Equipment Selection (MPES) Conference 2010, 1 – 3 December 2010, Fremantle, Western Australia, Paper Number 9
13. **ROBERTS G.W. and col.** (1999),„ *Real – time Deformation Monitoring of Structures Using GPS-Accelerometers,* Univesity of Nottingham,
14. **STEFOULI M., APOSTOLIDIS E., GIKAS V., RIPIS K., ANTONATOU O., ZANOU D., PEPPES E., OIKONOMOU S.** (2006) *"Landslide Risk Assessment Using Remote Sensing and Geodetic Data Integrated on a WEB-GIS Platform"* 11th International Symposium on Natural and Human Induced Hazards and 2nd Workshop on Earthquake Prediction, Patras, Greece, June 22-25
15. **TIMOTHY NUTTENS, ALAIN DE WULF, LANDER BRAL, BART DE WIT, LEEN CARLIER, MARIJKE DE RYCK, DENIS CONSTALES, HANS DE BACKER** (2010) *"High resolution terrestrial laser scanning for tunnel deformation measurements",* FIG Congress 2010, Sydney, Australia

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