Surface deformation determination and monitoring in deep mining areas with InSAR technology

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***Abstract*—In this study the applicability of the InSAR technology will be examined in the Márkushegy Mining Facility as test site during the period of 2014-2019. In this period the Facility undergone the final mining then the re-cultivation process. In the paper we present the surface deformation trends during these phases by using Sentinel-1A and 1B radar images.**

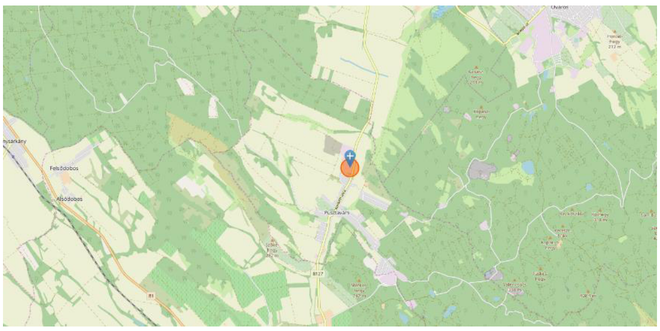
I. Introduction

In our previous papers, the focus of the research was on the large-scale deformation monitoring, like the vertical motion effects of earthquakes and volcanic eruptions. Since Hungary is rarely affected by these phenomena the need to find an application area where significant deformations could occur and also the validating measurements possibility is given. Our choice was for the application field of deep mining, since the deformations occurred by it can affect relatively large surface area, and the deformations itself can reach the range of tens of centimeters.

Until the recent days to determine the exact value of surface deformations only traditional geodesic techniques (precise leveling) could be used. These methods are costly since they require many on-the-field measuring hours for at least 3 people so in this paper we examine the possibility of a substitute method of an InSAR based technology [1][2].

II. The Test Site

The test area we examined is the Márkushegy Mining Facility (c.f. figure 2.) located in Oroszlány coal-basin (c.f. figure 1.) where the main mined mineral was not



1. Figure Pusztavám area

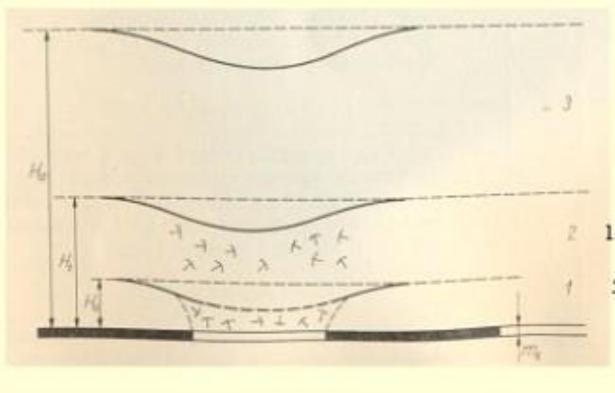
surprisingly coal. When we use “was”, it is intentional, since the mine closed in 2015 January, and the re-cultivation finished by mid-2016. So, we have the unique opportunity to process data from the last part of a mine’s life cycle, when the water-pumps are stopped, then the mine-shafts refilled.

The underground areas of the mine reaches 4-500 meters in depth and the total length of underground trench system is more than 50 kilometers. To the mine area belonged a surface excavation site called Doba-depo which we excluded from this research, since we focus now on the effects of underground mining.

2. Figure Area of mining facility within Pusztavám

In areas where deep cultivation has been carried out, there is a continuous investigation of surface movement caused by mining. These movements are triggered by mining extraction processes and recultivation. Underground movements start from mining passages and other cavities and sometimes reach the surface. As a result of the abandonment technique, no matter how careful the reloading motions are occurring because of the results from the material and composition of the charger and the environment.

Movements underground after the passages have ceased, under certain parameters (height of the exposed cavity, thickness of the covering rocks), different ranges of movement are formed in the underground layers. These can cause various deformations on the ground.



3. Figure Cross section of the under mined earth layers

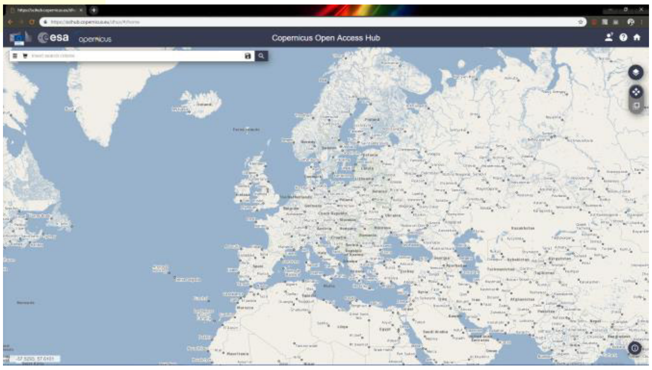
- In Zone 1 (overlap zone), the layers loosen but do not break, causing a ditch on the surface.
- In Zone 2 (cracked zone) the rock layers break but remain in one.
- In Zone 3 (crumbling zone), the overlying layer is highly fragmented. The rocks will loosen and may collapse.

The movements resulting from mining extend beyond the size of the open spaces. Artificial and natural features on the surface, in the dune, can be damaged by the movement, causing them to lose their stability, limit or even eliminate their use.

There are basically two purposes to measuring movements, which are to regularly survey the surface and artificial features of the mined area, and to provide data for the examination of rock pressures.

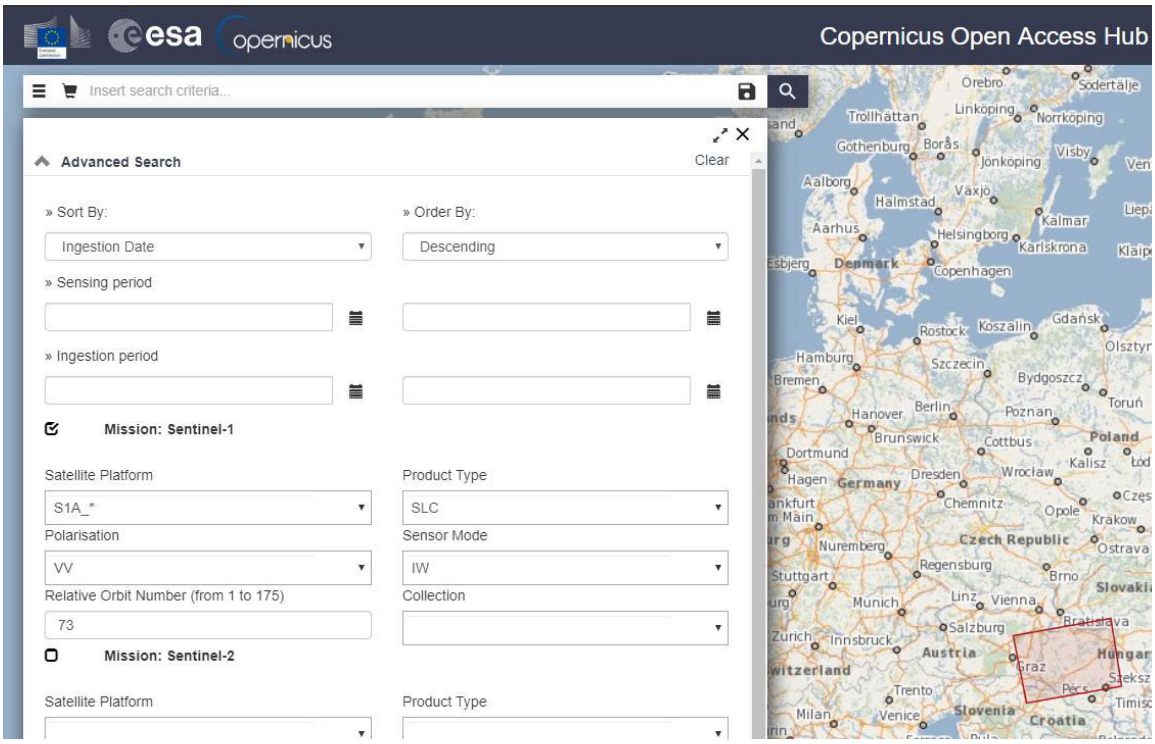
III. Data Processing

The whole process started with data mining. In the case of conventional measurement, this would be the step to design and perform field measurements. In our case, the Sentinel-1 satellites have already done this. The recordings were made available from an online, completely accessible site. This is www.scihub.copernicus.eu (Copernicus Open Access Hub) (c.f. figure 5.). [7] [8]



5. Figure Copernicus Open Access Hub

The search criteria can be used to accurately specify the area, type of recording, and time that is used to evaluate the time frame analysis at the same time intervals for the same seasons, in order to eliminate differences and their effects from such differences (c.f. figure 4.).



4. Figure Parameters and geographical location of the data search

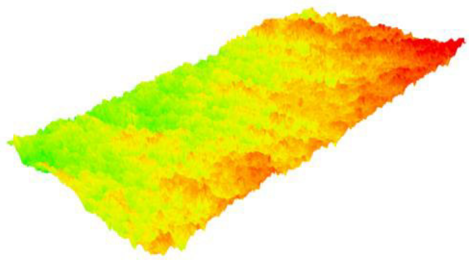
The studied time interval was the period 2014-2019, since the recordings are available from 2014, so we could process the effects of the last year of mining, the re-cultivation and the following period. In terms of dates, we chose March, which, as it turned out, wasn't the luckiest choice.

Compared to our previous research, the present looks a bit further back in the past, so downloading the recordings was done in a different way than before. After the search, we had to specify which images we would like to use, which became available for download only after 24 hours, the time it took from the archive to upload to active storage, and the images were only available for 3 days before returning to archive status. A user can only request two recordings at a time, so downloading took longer than usual and required more careful planning.

The processing work was routinely carried out in the manner presented in our previous publications, using Sentinel 1A satellites for the present study as shown in the table below (c.f. figure 6.).

6. Figure Steps of processing [6] [8]

The final evaluation of the results required a visual representation using ArcGIS. From the processed images, the areas affected by the mine cultivation and their vicinity were cut out and the displacement ranges were set to the same value. Spatially, this meant the village of Pusztavám and its two-kilometer zone, as the mining activities were carried out beyond the boundaries of the village. The next step was to separate the mining site and its immediate surroundings for better evaluation of the results. Finally, the results were evaluated in a three-dimensional manner (c.f. figure 7.).



7. Figure Results represented in 3D

IV. Problems douring processing

The task was not very easy due to the many minor obstacles due to the technique and the fact that SNAP software was originally developed to run within less limited hardware capabilities. Among other things, I have often encountered freezes, sudden shutdowns, and similar problems of the programs I use. As a suggestion, I would suggest that the computer or laptop on which we are processing should be equipped with a minimum 8 core processor to reduce unwanted program stoppages. This is the level where hardware imperfections can be handled with proper parameterization.

There were also obstacles to obtaining the recordings. One year back, we can download almost all at once, but older ones need to be downloaded after they are selected, which is usually done after a day. This is because only the 'fresh' recordings are on the central server, the old ones are stored on the secondary server and then accessed from there.

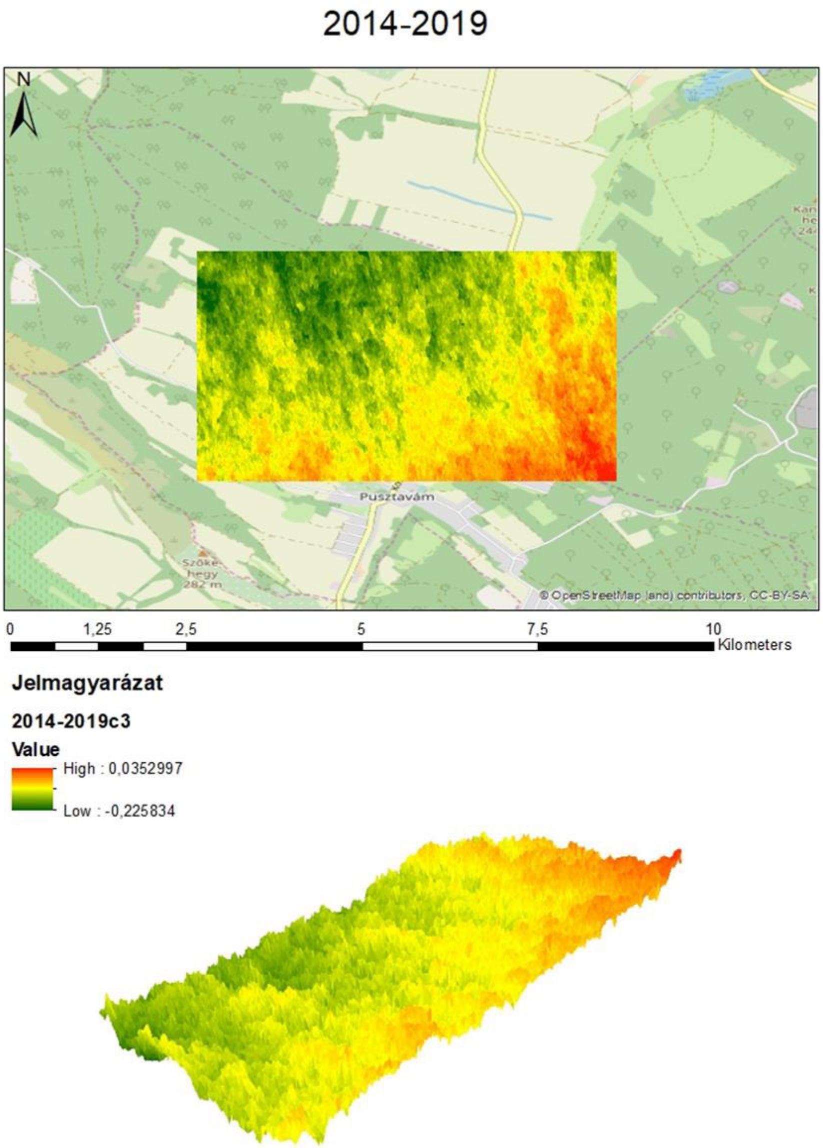
V. Conclusions

In my dissertation I presented the steps of the theoretical solution of InSAR based evaluation. The following figure summarizes the differences between the two dates. Of course, these values cannot be considered true motions in the present state of processing. The figures also contain clear regular errors in the evaluation. Further investigations are warranted to determine the reasons for this. In the future, I would like to limit my investigations to specific areas where actual surface movement due to mining is expected. Of these areas, I would like to investigate the surface not covered by outlying vegetation. To determine the actual, high-precision surface motion, a PS InSAR technology, which is not discussed in the dissertation, could be a more appropriate method, which would provide a motion detection solution for specific points.

In order to evaluate the results, validation measurements using the traditional method would be necessary, but this would be much more than the work of such a thesis. It is in the process of being discovered that during the period under review, these accurate leveling measurements were made in the field, the results of which could possibly be used for comparison.

In addition, an accurate mining map would be a useful component of such an investigation to know which areas are affected by mining.

It can also be seen from the above that this is only the first step of a larger series of research, which I hope will be completed in a deeper study.



8. Figure Final results on map and in 3D

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