Interferometric Synthetic Aperture Radar (InSAR) applications for mapping of terrain displacement in mineral deposits

InSAR приложения за картиране на теренни деформации на минерални находища

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Abstract. The Interferometric Synthetic Aperture Radar (InSAR) applications for mapping of terrain displacement have been tested on the Vlaykov Vruh and Tsar Assen porphyry-copper deposits to test terrain displacements and possible fault movements. Time series for each area have been prepared to display the evolution of displacement over time, for a given point for both Cu-porphyry outcrops.

Keywords: Interferometric Synthetic Aperture Radar (InSAR), Cu-porphyry deposits, terrain deformation, Sentinel-1.

Introduction

Interferometric Synthetic Aperture Radar (InSAR) consists of the combination of the phase information of two SAR images of the same illuminated scenario, acquired at different times. If a ground deformation occurs during the acquisition period, the phase of the interferogram contains the flat earth, the topographic, and the deformation components, among others. The first two components can be estimated and compensated. If the atmospheric and noise phase contributions are not considered, the result of subtracting the flat-earth component and topography from the interferogram is known as a differential interferogram, and the resulting phase can be directly related to ground deformation. One full cycle in the interferometric fringes represents a displacement equivalent to half the wavelength of the electromagnetic wave employed by the SAR sensor. The result is known as interferogram, whose phase $\Delta \phi$ is sensitive to the scene topography and deformation phenomena. InSAR mapping is widely used for open pit mine slope stability monitoring in addition to land-sliding events and possibly for fault movements observations.

Methods

The analysis presented in the recent study have been performed during the period 02/04/2021–05/10/2021 using Synthetic Aperture Radar (SAR) images from the European Space Agency (ESA) Sentinel-1 constellation in descending orbit. Displacements have been calculated according to the Line Of Sight (LOS) direction from the ground target to the satellite using the Coherent Pixel Technique (CPT). This Persistent Scatter Interferometry (PSI) technique was firstly developed in 2002 by the Remote Sensing Laboratory (RSLab) of the Universitat Politècnica de Catalunya (Lanari et al., 2004; Mora et al. 2002), and it is constantly updated by the team of engineers of Dares Technology. CPT allows the estimation of the linear and non-linear components of displacement, the topo-
graphic error, as well as the atmospheric artefacts. In case of ground deformation during the acquisition period, the interferogram consists of both topographic and deformation components. Therefore, in the last date (05/10/2021) we can find the total accumulated displacement within the analyzed period (Fig. 1).

**InSAR tests results and discussion**

InSAR study was performed in the southern part of the Panagyurishte ore district in Bulgaria with focus on the Vlaykov Vruh and Tsar Assen porphyry-copper deposits (PCD) to test terrain displacements and possible fault movements (Fig. 1). SAR images

![InSAR displacement map for the Vlaykov Vruh PCD](image)

![InSAR displacement map for the Tsar Assen PCD](image)

*Fig. 1. A, InSAR displacement map for the Vlaykov Vruh PCD; B, InSAR displacement map for the Tsar Assen PCD. Fault structure is based on data by Popov et al (2012).*
from the ESA Sentinel-1 satellite constellation were used. The type of SAR images is Single Look
Complex (SLC), and the acquisition mode is Inter-
ferometric Wide Swath (IW). The images used for
this analysis are in descending orbit, with a revisit-
ing period of 6 days, and a resolution of 5×20 m.
Regarding the magnitude (area) of the detected dis-
placement, in the Vlaykov Vruh PCD it ranges from
500 to 4000 m² (Fig. 1A). For the Tsar Assen PCD
(Fig. 1B), it ranges from 500 to 2500 m² (Fig. 1B).
For A1, the first time series denotes a displacement of
3.5 cm, and the second time series shows a displace-
ment of about 3.0 cm. Regarding A2, the time series
shows a displacement of about 4.0 cm. All these dis-
placements are moving away from the satellite in the
LOS direction from the ground target to the satellite.

Several spots with displacement have been de-
tected in both Vlaykov Vruh (Fig. 1A) and Tsar As-
sen (Fig. 1B) areas, where specific zooms have been
prepared for each one. No displacements have been
detected outside of these two areas. Time series for
each area have been prepared to display the evolu-
tion of displacement over time, for a given point for
both Cu-porphyry outcrops.

Conclusions

Our preliminary results from InSAR tests give, in
both case studies, terrain displacements of about
4cm. Considering the geometry and location of
the detected displacements, as well as its small
size, compared to the faults, we assume that they
are the result of slope instabilities occurred in the
waste pile area of Vlaykov Vruh, and possibly a
landslide along fault structure for the Tsar Assen
PCD.

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