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POTENTIAL OF MINING GROUND DEFORMATIONS STUDIES BASED ON OPEN DATA?


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INTRODUCTION

Motivation: (1) underground mining affects the surrounding area, one of the effects is ground deformation, (2) mining ground deformations need to be continuously monitored and pre-calculated to secure safety of mining operation and to control potential damage to the ground Surface (Kratzsch, 1983), (3) in case of temporal and spatial limitations in ground deformation monitoring data nowadays open data published by public services can be a cost-effective alternative for initial assessment of deformations, (4) underground extraction of minerals in complex and complicated geological and mining settings calls for alternative to traditional empirical and influence function methods for pre-calculation of ground deformations.

Objective: (1) to assess availability and applicability of geodata from public open services for mining ground deformation monitoring and modelling (pre-calculation) with exploratory data analysis (EDA), (2) to review data driven method approaches for prediction (modelling) of mining ground deformation.

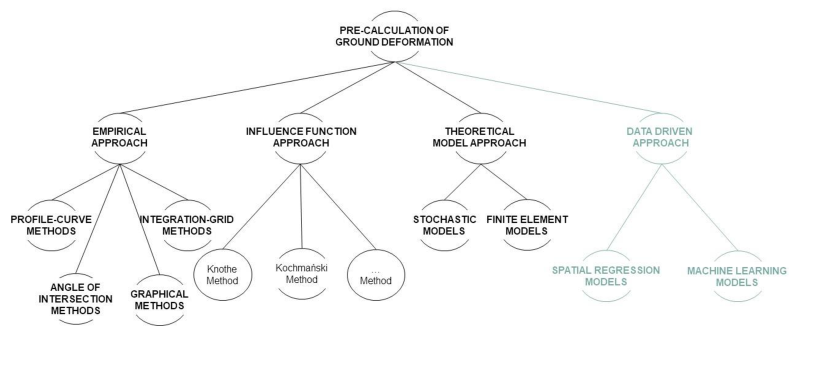

Fig. 1. Classification of approaches used for pre-calculation of mining related ground deformation (based on Kratzsch, 1983; Kwiatek, 1997; modified)

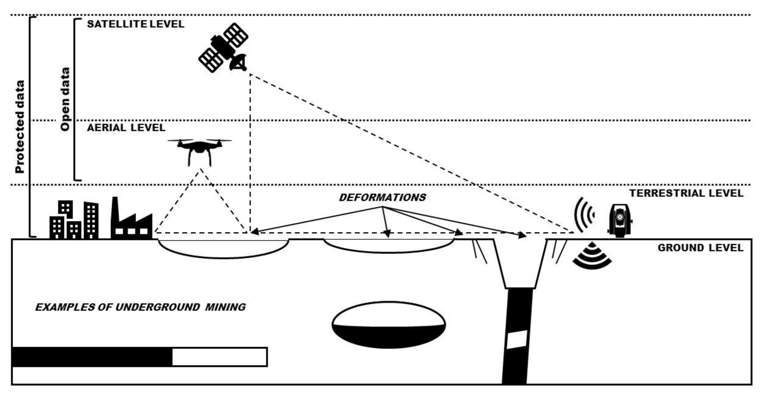

Fig. 2. Multiresolution and multisource approach to monitoring mining related ground deformation (Blachowski and Ellefmo, 2022)

RESEARCH AREA

- Underground iron ore mine extracting mineral with sub-level caving method (Fig. 3),
- Ground deformation in three distinct zones: caved area, discontinuous (fracture) area and continuous deformation area parallel to the extent of the mined deposit,
- Complex geological and mining settings,
- Complex topographical settings (hillslope, open-pits from prior open cast mining operations),
- Difficult climate and weather conditions (long snow cover period),
- Limited scope of ground deformation observations taken by the mine (i.e. sporadic UAV surveys only),
- Five production levels (315 to 123 m a.s.l. – Fig. 4) with another one at 93 m a.s.l. planned by the mine,
- Visual ground deformations observed on the hanging-wall side (AOI in this study)
- Predicted extent of fracture zone for level 123 approx. 300 m away from the edge of the caved zone on the hanging wall side (Blachowski and Ellefmo, 2012).

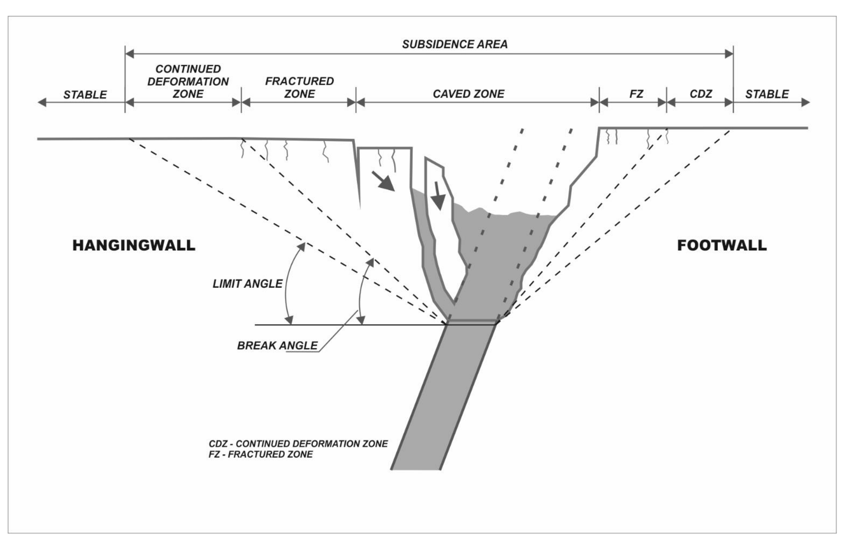

Fig. 3. Rock mass deformation in the sublevel caving (SLC) mining system (Blachowski & Ellefmo, 2012)

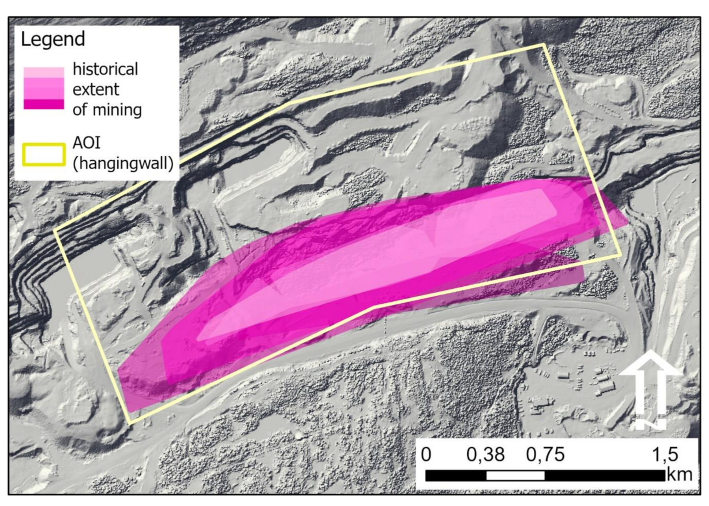

Fig. 4. Historical underground mining, area of interest (AOI) – hangingwall – against the background of hillshade model

MATERIALS AND METHODS

MATERIALS (public data)

- InSAR Norway: PSInSAR Line of Sight (LOS) data for 4 tracks (A102, A175, D066, D168) available for 2016-2021, max. 5 x 20 m spatial resolution, data update annually (source: https://insar.ngu.no) (Fig. 5)
- European Ground Motion Service (EGMS): ortho (horizontal and vertical components) 100m grid and GNSS calibrated LOS data (source: https://egms.land.copernicus.eu/),
- GeoNorge: DEM with 1-10 m resolution, available for 1966, 2011, 2019 (source https://kart.geonorge.no/),
- Norwegian National Seismic Network: Register of seismic events (magnitude, type of event, coordinates) (source Norwegian National Seismic Network).

MATERIALS (mine historical data)

- Geometry of the iron ore deposit, Fig. 5. (Bottom)
- Mining operation plans and schedules,
- UAV photogrammetry derived DEMs of the mining area,
- Blasting data.

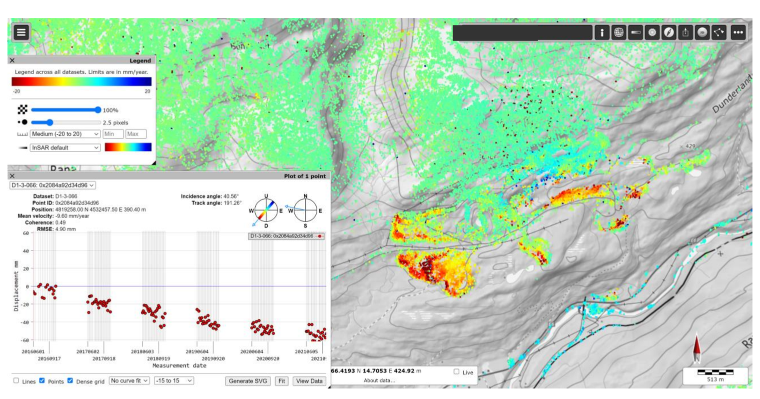

Fig. 5. InSAR Norway Map Viewer (https://insar.ngu.no/)

EXPLORATORY DATA ANALYSIS

DATA VERIFICATION AND PRE-PROCESSING ⇒ GEODATABASE DEVELOPMENT (e.g. feature class conversion) ⇒ EXPLORATORY DATA ANALYSIS (e.g. histogram, spatial distribution) ⇒ OPEN DATA INTERPRETATION AND ASSESSMENT

Fig. 5. Workflow for stage one of the research

RESULTS

PSInSAR Line of Sight (LOS) displacements EDA for hanging-wall area

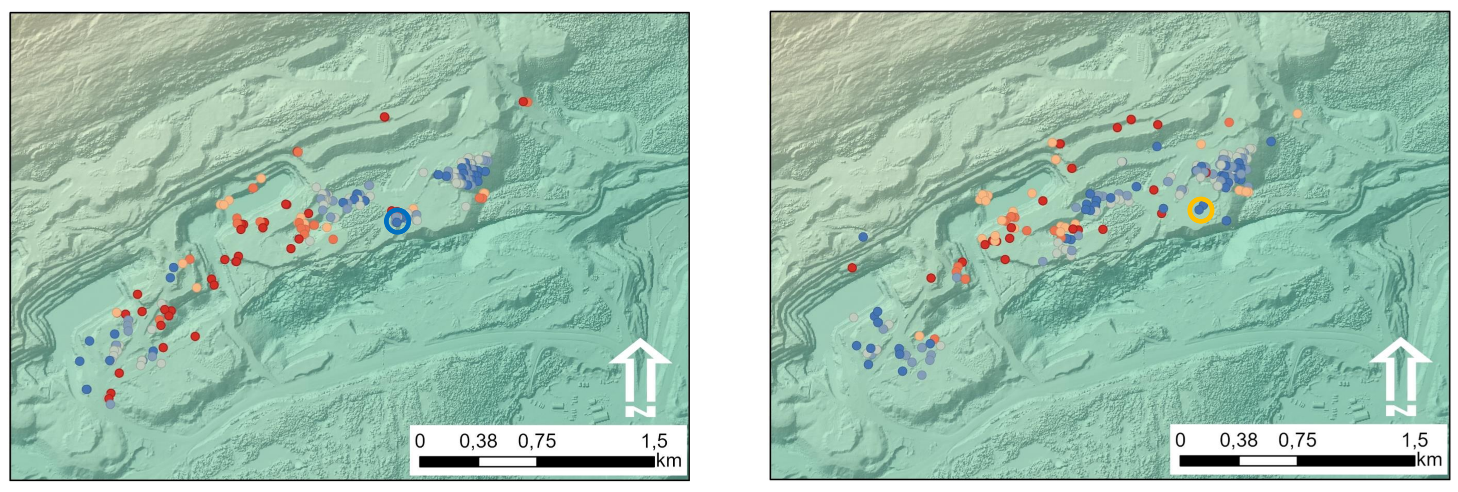

Fig. 6. Spatial distribution of statistically significant areas of ground surface LOS displacement (2016-2021), Left: Track D168, Right: Track 066

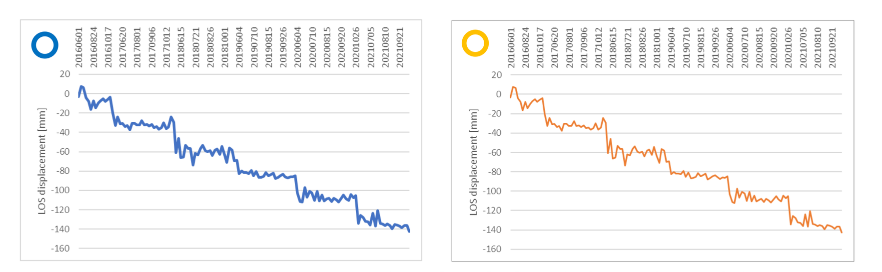

Fig. 7. LOS displacements timeseries for selected identified significant deformation sites

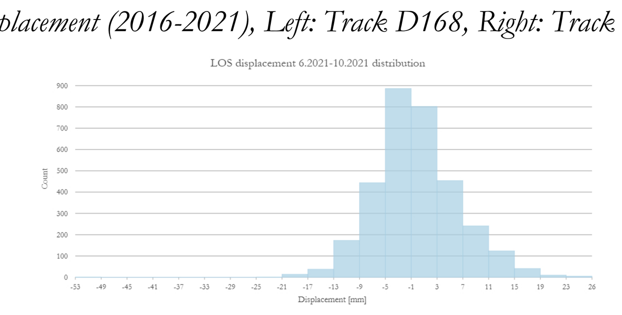

Fig. 8. Distribution of LOS displacements for selected track (D068) 6-10.2021

EDA of seisimc events registered by the NNSN in the mine area

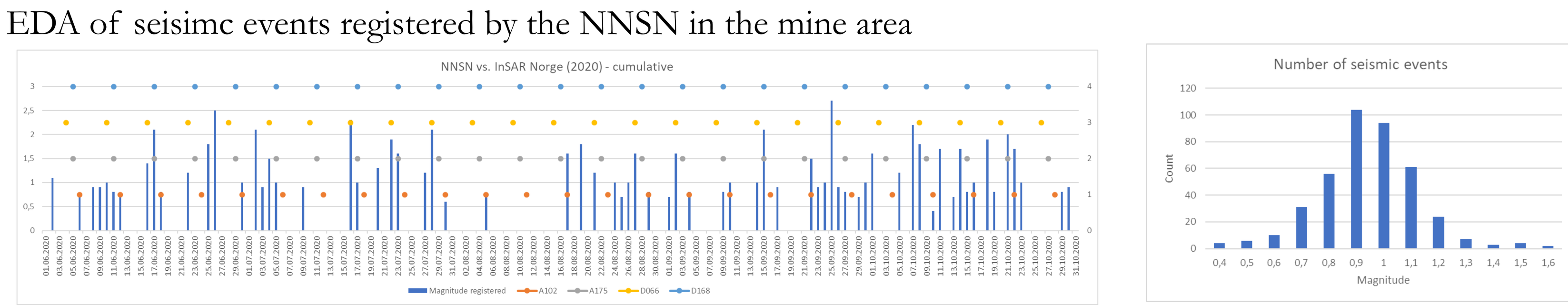

Fig. 7. (Right) Calendar of seismic events registered by the NNSN and InSAR data acquisitions (2021 example), (Left) Histogram sesimc events

DEM processing for the mine area

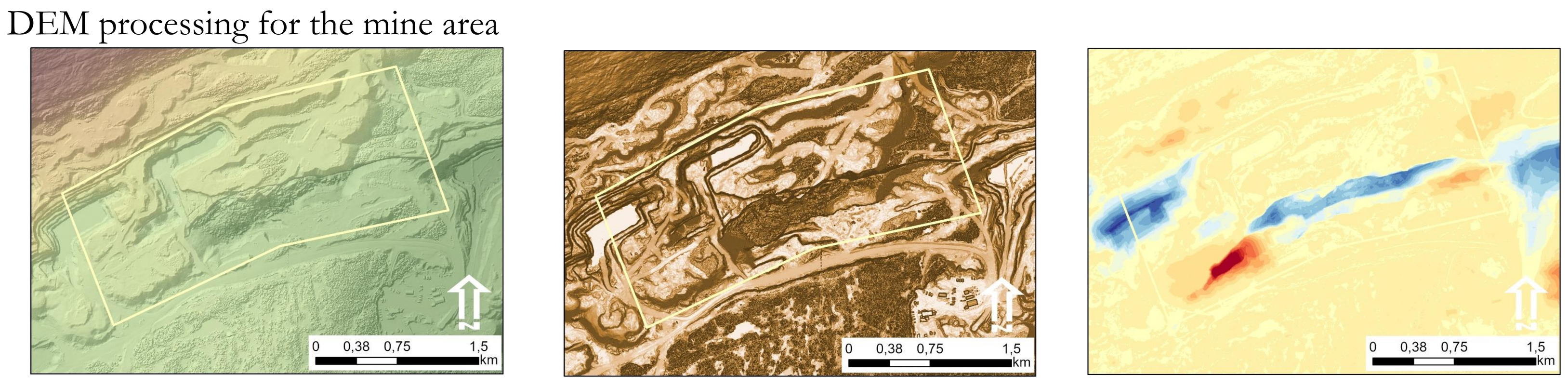

Fig. 8. Left to right. 1m DEM (2019), slope (1st derivative), DoD (2011-2019)

DISCUSSION AND CONCLUSIONS

Opportunities:

- Numerous (4) Sentinel 1 tracks are availabe in national service,
- National service provides relative and local deformation, will provide GNSS calibrated
- Historical data are available (2016-2021),
- Frequency of data acquisition in the snow-free season (12 days),
- Topography of the mine area suitable for observations of the hanging-wall,

Challenges

- Fast (non-linear) moving areas (>100mm/yr) filtered out (https://www.ngu.no/emne/dataegenskaper-og-begrensninger),
- Geometry of satellite observations (incidence angle) does not allow to observe caved area and/or excavations,
- Data available for snow free season only (June-October).

Further steps

- Correlation analysis (time and magnitude of seismic events vs registered LOS displacements,
- Multivariate spatial regression analysis of registered LOS displacements and potential driving factors (mining, geology, topography).

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