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Investigation of land deformation and ground fissuring in Azar oil field using Persistent Scatter Time Series Interferometry (PS-InSAR)

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Abstract

Ground fissuring in Azar Oil Field (AOF) in Ilam Province that almost happening after heavy rainfalls, has been threaten engineering structures like refinery facilities, pipelines, oil well cellars and some access roads. From geological point of view, AOF located on the north limb of Changoleh anticline, composed of the Lahbari section of the Aghajari geological Formation. Sandstone, siltstone and claystone are the main rock units in the studied area. Sandstone and siltstones are very loose material with collapsibility potential. Ground fissures regularly created almost perpendicular to anticline axis. In this article, in order to evaluate ground deformation mechanism and related ground fissuring, engineering geological investigation has been used in a company with Radar interferometry technics. Radar interferometry studies using time series analysis based on PS-InSAR technics on two data sets using Sentinel-1A dataset including 68 images from 2014 to 2020 show that ground deformation in Azar oil field occurs with two different pattern. Linear and permanent deformation in north west of the Changoleh anticline which is in direction with anticline axis and plunging. The other deformation that occurs in south east of Changoleh anticline is a nonlinear and periodic deformation with intervals of 5 to 6 years. This deformation occurs with heavy rainfalls in the region. This research reveals that ground fissures in AOF is a consequence of ground deformation related to enlargement of Changoleh anticline and collapsing of loose sandstones of Aghajari Formation.

Keywords: *Ground fissure, Engineering geology, PS-InSAR, Geotechnical investigation, Lahbary formation, Changoleh anticline*

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Extended Abstract:

1. Introduction

Ground fissuring geo-hazard may cause considerable financial damages to the infrastructures. They have been formed as a result of ground deformation and induced surface tension following the human activities including the abstraction of groundwater and mining, as well as natural forces such as tectonic activity, active faults, earthquake, slope instability and, hydro compaction of collapsible soils. Previous studies indicate that the remote sensing methods especially, Permanent Scattered InSAR (PS-InSAR) technique which could rectify the field observations data with high-resolution tools, extensive coverage in millimeter-scale, continuous all-weather inspection and low operating costs (Ferretti et al., 2001), have successfully been applied in different surface deformation studies. In this study, the ground fissuring mechanism of Azar Oil Field (AOF), located in the western part of Iran, has been evaluated with Ps-InSAR time series analysis. Previous studies illustrated that these fissures occurred extensively during the first heavy rainfall after the experience of a drought period in November 2012. From the geological point of view, the study area consists of claystone, siltstone, and sandstone belonging to Late Miocene-Early Pliocene Lahbari Member of the Aghajari Formation characterizes by badlands with dendritic drainage patterns, on the Simply Folded zone of the Zagros orogeny (Khalesi et al., 2016). A gentle fold is above the Zagros Foredeep Fault (ZFF) in the study area named Changoleh anticline. The single look complex (SLC) images from Sentinel-1A satellite employed in this study, because of their good global coverage, and their quick and free data delivery (Raspini et al., 2018). The results of Ps-InSAR time series analysis in combination with detailed field investigations have been also used for evaluating the surface deformations of AOF.

2. Materials and methods

Over 250 fissures have been surveyed during the field investigations and satellite imagery interpretations. At least two major fissure sets have been identified in parallel cluster division of fissures (strike: N35-55 and N55-90). The persistence of fissures measured from 100m up to 1500m and initial aperture of about 10 cm. Over times their aperture extended up to 1 m and in some cases arranged sinkholes formed along the fissures.

Geotechnical investigations including drilling of 10 exploratory boreholes with depths of 30m have been carried out to clarify the ground profile and evaluate the materials characteristics of the study area. Tests have been designed and performed on the disturbed and undisturbed samples taken from the core drilling boxes. The physical and index properties of the samples have been classified the materials as CH, CL, ML, and SM. The SM and ML materials have low moisture contents, low plasticity index values (6 to 8 %), and low natural unit weight (1.69 KN/m^3). Uniaxial compressive strength test (0.87 to 1.98 KPa), direct shear test (C=0.165 to 0.3 KPa and Ø=25.9° to 27.9°), collapsibility (low collapsible for CH and CL and, moderate collapsible for SM and ML) and dispersion test (ND1 for CH, CL and, SM to ND3 for ML) have been conducted on undisturbed materials. According to the test results, the ground materials in the study area have been classified as hard soils to soft rocks.

In this study, the standard PS-InSAR time series analysis has been employed on tow S-1A ascending datasets consists of 38 SAR acquisitions from 2014 to 2019 and 68 SAR acquisitions from 2014 to 2020 in SARPROZ software (Perissin et al., 2011). An ALOS Global Digital Surface Model "ALOS World 3D-30m" (AW3d30) has been used as an external DEM to remove the main topographic contribution in the interferometric phase. In the following, a mask has been generated for the selection of PSCs based on amplitude stability index (ASI) more than threshold value of 0.75. After estimating the absolute values of PSCs, the contribution of the phase noise, i.e. the spatial and temporal decorrelation factors as well as the atmospheric phase, have been separated based on their spatial and temporal behavior differences. Eventually, the PS points with high terrain correction values have been used to generate the line-of-sight (LOS) displacement map for each dataset. After some trial and error practices, a non-parametric model has been used to enhance the low temporal coherency obtained after APS removal. So, the cumulative displacement has been resulted by the time series analysis.

3. Results

Geotechnical investigation in AOF indicates the presence of loose sandstone and siltstone layers at different depths. From the engineering geological point of view, the rock materials of the Lahbari Section have been classified as weak rocks (less than 2.0 MPa). The strength of such materials decreases under saturation conditions.

The analysis of data between the 2014 and 2019 timeframe shows the displacements have been mostly observed in the western part of Changoleh Anticline. The graphs of these points show that many points have met abrupt displacement in the southeast of Changoleh anticline since late 2019, while they have not had any distinct movement before that time. The maximum LOS deformation value has been reportedly about 28 mm for the 38 images dataset happened over the 4.5 years on the west of Changoleh Anticline. These evidences have been seen in the cumulative map of data between the 2014 and 2020 timeframe, too. shows that the northwestern part of the anticline moves at a relatively constant rate of about 4-5 mm per year in the direction with anticline plunging, e.g., toward NW. In contrary, the southeastern part of the anticline has been deformed at an inconstant rate over time where has experienced a sudden displacement of about 20 mm in late 2019 after 5 years of stability in the area.

4. Conclusion

PS-InSAR time series analysis indicates two different mechanisms for the ground deformation. The northeastern part of the anticline has been moving steadily along the folding axis toward NW. In opposition, the southeast portion of the anticline experienced a nonlinear periodic displacement. Collapsible loose materials of the AOF and reaction of them in saturation (heavy rainfalls) have been responsible for stress release in the area as the form of long parallel fissures.The ground fissures with the N85 strike are the result of this kind of stress field. Therefore, the engineering geological characteristics of the ground materials, tectonic situation, hydrogeology, and morphology of the anticline are the most important factors that affect the formation and development of the ground fissures in the AOF.

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