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Investigation on The Displacement of A Mining Induced Landslide with Time Series SAR Offset Tracking

Northeastern University 东北大学

F Wang[1], M. Ao[1] ,L. Wei[1], C. Tolomei[2], C. Bignami[2], Y. Mao[1], S.Liu[1]

1 Northeastern University, Shenyang, China：2395wangfang@163.com(F. Wang);aomeng@mail.neu.edu.cn(M.Ao) ; weilianhuan@mail.neu.edu.cn(L. Wei); liushanjun@mail.neu.edu.cn(S.Liu)
2 Istituto Nazionale di Geofisica e Vulcanologia, Rome, Italy; cristiano.tolomei@ingv.it(C. Tolomei); christian.bignami@ingv.it(C. Bignami)

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Abstract

In recent years, as the mining scale of open-pit mines continues to expand, a large number of high and steep slopes are formed, leading to increasingly serious slope instability disasters. Landslide disasters are complex, concealed and hazardous, and it is difficult to grasp the accurate deformation development law[1]. Therefore, it is very important to carry out large-scale, long time series and high-precision dynamic monitoring of the slopes of open pit mines to ensure the safe production of mines.

Traditional deformation monitoring technology has the disadvantages of low efficiency, small monitoring range, high labor cost, and inability to obtain a wide range of monitoring data. Therefore, based on the demand for efficient, accurate and near real-time landslide disasters monitoring technology, the interferometric synthetic aperture radar (InSAR) is widely used in the field of landslide monitoring for its advantages of short revisit period, high measurement accuracy, low weather influence and large monitoring range[2]. For large complex landslides with fast sliding, the interferometry technique based on phase information is plagued by the phase unwrapping and is only applicable to slowly deforming landslides with small deformation gradients[3]. However, the Pixel Offset-Tracking (POT) technique based on SAR amplitude information is not affected by the phase unwrapping and space-time de-coherence problems, and can overcome the limitation that InSAR can only acquire one-dimensional deformation and measure two-dimensional deformation in azimuth and line of sight (LOS) simultaneously. Under the high-resolution data condition, the deformation solution accuracy of POT technology can reach the decimeter level[4].

In this paper, a total of 34 scenes of Cosmo-SkyMed SAR data from June 4, 2014 to December 18, 2016 were acquired to monitor the landslide of Fushun West Open Pit Mine using the time-series SAR offset tracking technique, analyze the development pattern of the open pit slope deformation and study its deformation evolution mechanism. In addition, this paper analyzes the degree of influence of three influencing factors, namely, search window, oversampling factor and step size, on reliable pixel point extraction by setting up several groups of comparison experiments, and then selects the most suitable parameters for the analysis of temporal offset slippage deformation by considering the running time and experimental effect. Finally, the obtained monitoring results were verified with GPS observation data, and the comparison results existed high consistency, which further verified the high feasibility and applicability of the pixel offset tracking method in the application of large complex multi-gradient landslide monitoring, and the research results have important reference significance for the slope stability monitoring of Fushun West Open Pit Mine.

Data processing and Results

Study area

Fushun West Open Pit Coal Mine, located in the southwest of Fushun City, Liaoning Province, which started open pit mining in 1914, has since formed the largest open pit in Asia with an east-west length of 6.6km, a north-south width of 2.2km, a depth of 418m and an area of about 10.86km². The Fushun West Open Pit is located in the Hun River Fracture Zone, which is a complex tectonic area with many longitudinal and transverse faults, including the east-west F1A and F1 faults and several secondary faults distributed near the north slope of the coal mine, as shown by the red solid lines in the Fig. 1. The geological structure of a profile passing through the pit (E400) is in Fig. 2. On the south slope of the coal mine, there is a typical cascade landslide named Qiantai Shan, with gneiss, basalt, tuff, etc., and a small amount of thin coal seams interspersed from bottom to top. The Qiantai Shan landslide is the largest landslide among the more than 90 landslide events happened to Fushun pit mine, which experienced fast moving period during 2014 to 2016.

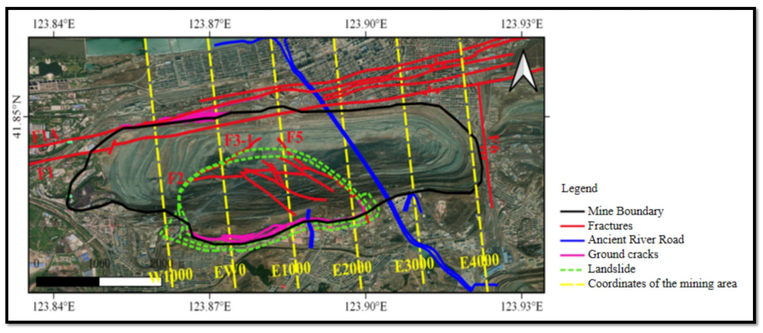

Fig.1 Study Area

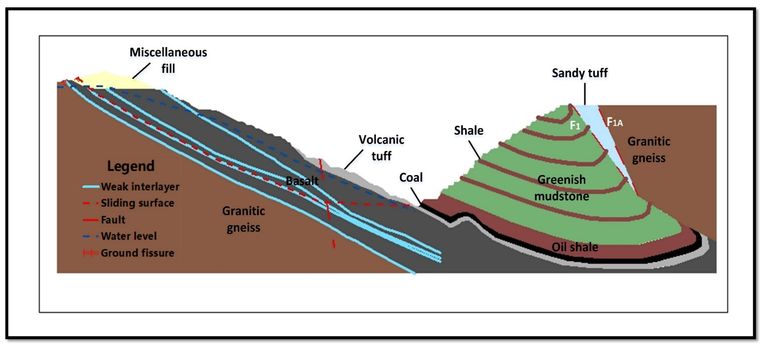

Fig.2 Geological setting of profile E400

Dataset

Table1 Parameters of the SAR images

Sensor Name	Band	Images number	Temporal span	Orbit type	Heading angle	Incidence angle
COSMO-SkyMed	X-band （3.1cm）	34	20140604-20161218	Descending	-165°	23.1°

Results

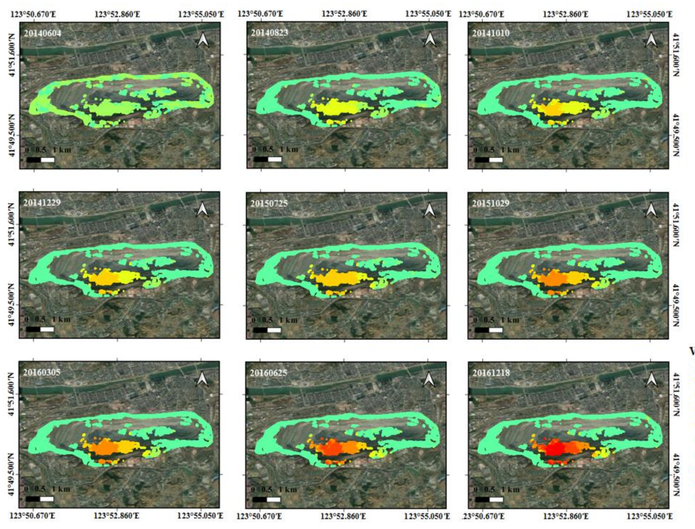

Fig.3 POT monitoring time series result(Azimuth direction).

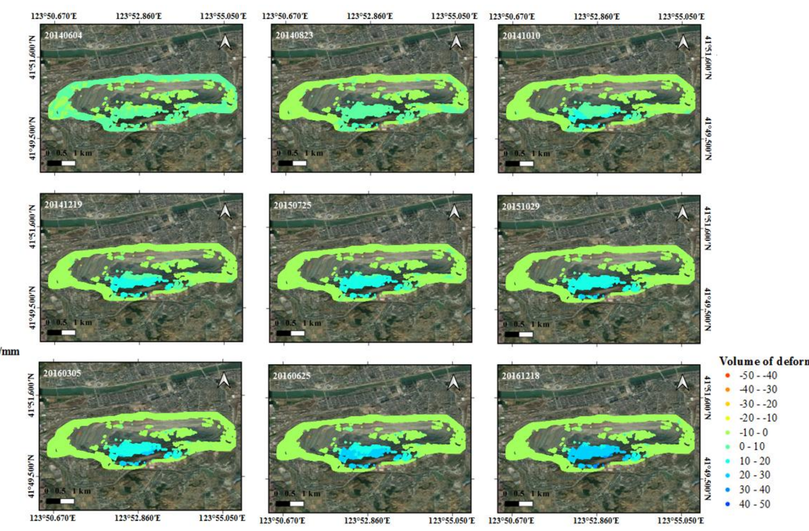

Fig.4 POT monitoring time series result(Range direction).

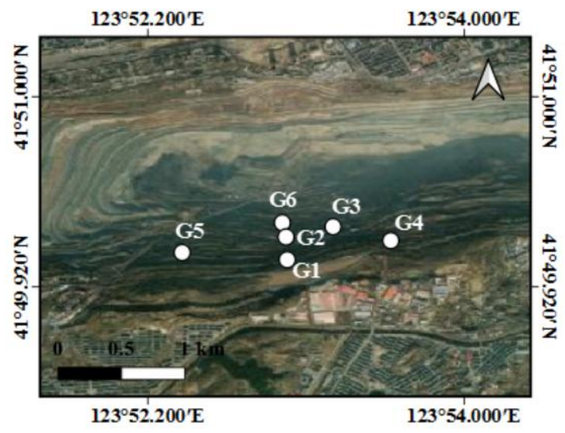

Fig.5 GPS observation station location map

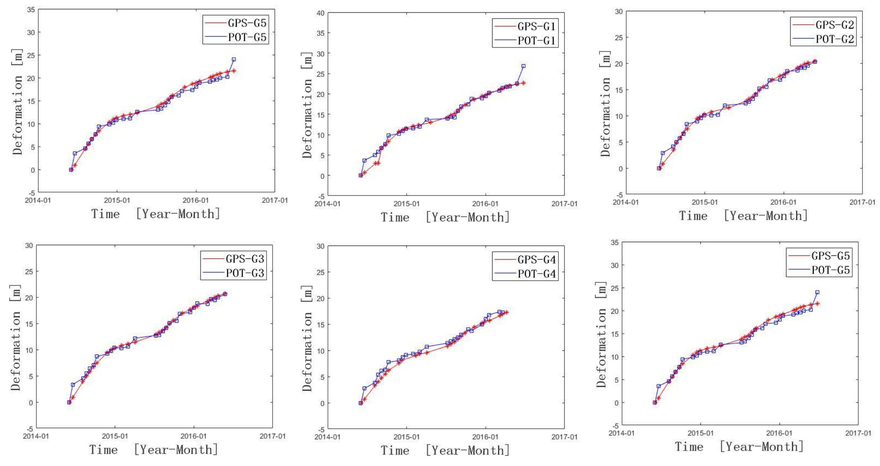

Fig.6 Comparison of GPS observation point and PS-POT results (LOS direction).

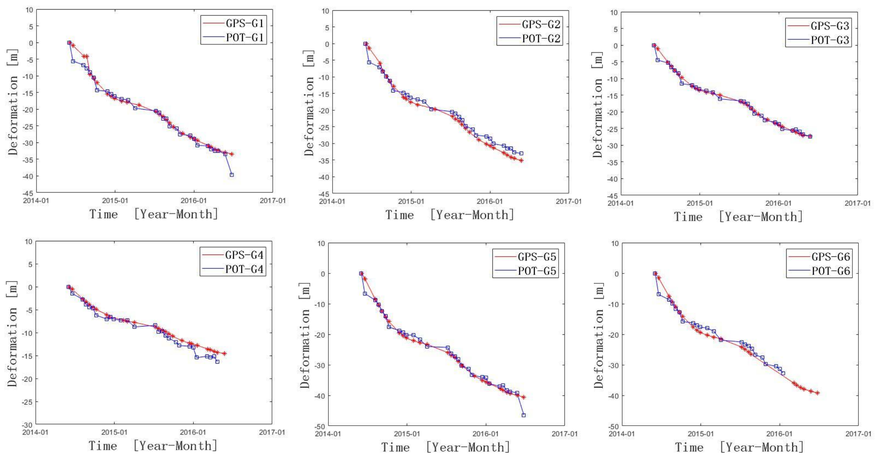

Fig.7 Comparison of GPS observation point and PS-POT results (Azimuth direction).

In this paper, based on 34 Cosmo SkyMed SAR image collected from 20140604 to 20161218, displacement of the Qiantai Shan landslide in Fushun West Open Pit Mine is investigated using time series Pixel Offset-Tracking technique, in both azimuth and range direction, as shown in Fig.3 and Fig.4.

In order to evaluate the accuracy of the estimated displacements, the estimated time series displacements are compared with GPS measurements (distribution of the GPS stations is shown in Fig.5). For comparison, according to the viewing geometry of the SAR dataset and slope angles of the landslide, the 3D GPS measurements are converted to azimuthal and line-of-sight(LOS) direction. As a result, the displacement time series estimated from POT have shown very good consistency with the GPS measurements, as depicted in Fig. 6 and Fig.7.

Conclusion

In this paper, the large-scale displacement of Qiantai Shan landslide in Fushun West Open Pit Mine is investigated using SAR pixel offset time series tracking technique. The results are compared with on-site GPS measurements for accuracy assessment, and they present very good consistency with each other. The outcome of this paper has further verified the high feasibility and applicability of the pixel offset tracking method in the application of large complex landslide monitoring, and the research results have important reference significance for the slope stability monitoring of Fushun West Open Pit Mine.

Major references

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