Stabilisation of open pit wall movements detected by InSAR using horizontal drains

Presented by: Priyanka Narshai on behalf of the authors: Pooja Ramakrishnan[1], Jacques du Toit[2], Jennifer Scoular[1], Pieter Bas Leezenberg[1] and Jason Pretorius[1]

Affiliations: SkyGeo Netherlands[1], First Quantum Minerals Zambia [2]

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1. Abstract

At the Kansanshi copper mine in Zambia, displacement was detected on the M15 west slope of the Main Pit using TerraSAR-X-based InSAR monitoring. This early warning prompted the implementation of a dewatering intervention using horizontal drains to stabilise the slope. While ground-based systems such as radars and total stations showed no signs of movement, InSAR revealed accelerating subsidence on multiple benches. After the installation of drains, the movement rate decreased from 101 mm/year to 40.3 mm/year. This case study highlights the importance of remote sensing in identifying potential failures early and enabling timely, effective responses.

2. Introduction and Background

Slope stability is a critical concern in open-pit mining operations, where failure can cause interruptions, equipment damage, and safety risks. The Kansanshi Mine, Africa's largest open-pit copper operation, has experienced periodic instability due to challenging geology, legacy weathering, and seasonal rainfall (Figure 1). This study focuses on the M15 west wall, an actively mined slope with a known history of elevated pore water pressure, a fault running through and structural weaknesses (Figure 2).

Figure 1 : Challenging geology with legacy weathering and erosion.

3. Monitoring Approach

To manage risk, Kansanshi employs a suite of monitoring tools including Ground-Based Radars (GBR), Robotic Total Stations (RTS), prisms, Vibrating Wire Piezometers, visual inspections, and satellite-based InSAR (Figure 3). InSAR monitoring began quarterly in 2021. The frequency of reporting was increased to 11 day updates when an alert was issued for the M15 wall InSAR detected displacement patterns not picked up by ground instruments.

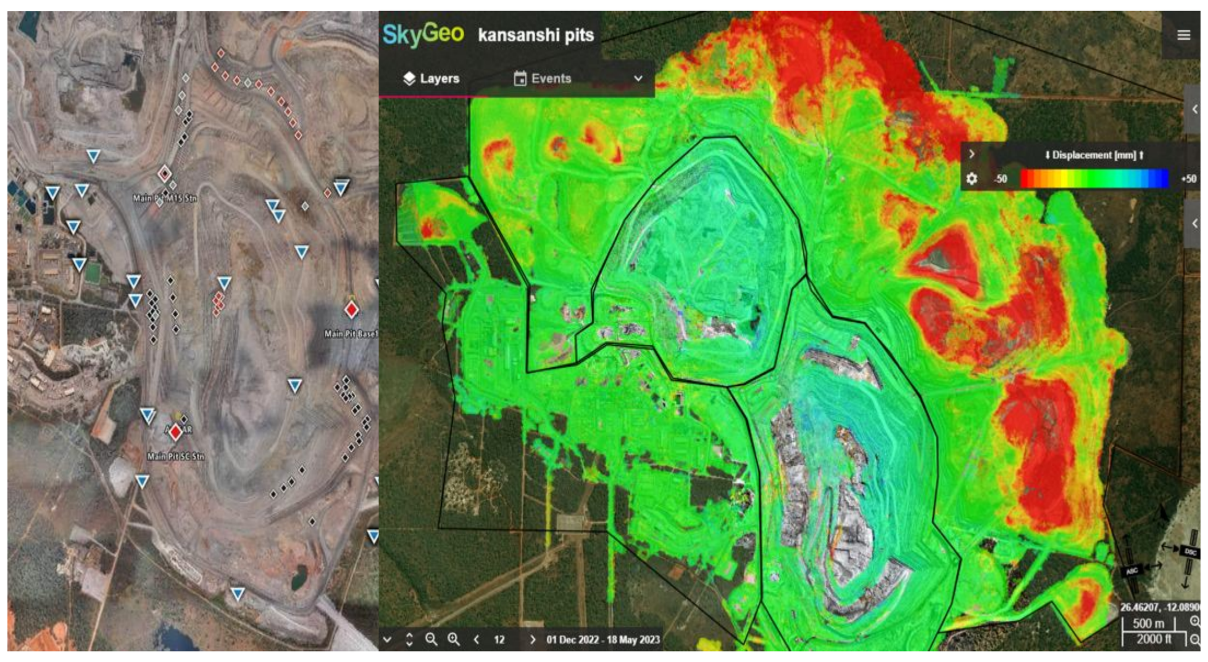

Figure 3 : The location and distribution of Robotic total station (large red diamonds), Prisms (black diamonds), Inactive prisms (small red diamonds) and VWP's (inverted blue triangles)

4. Displacement Observations

InSAR data showed clear signs of surface displacement beginning at the base of the slope and expanding upward in a circular subsidence pattern (Figure 4). This spatial pattern and presence of groundwater daylighting led to the hypothesis that pore pressure was a key factor in triggering the instability. These insights led to immediate action by the mine's rock engineering team.

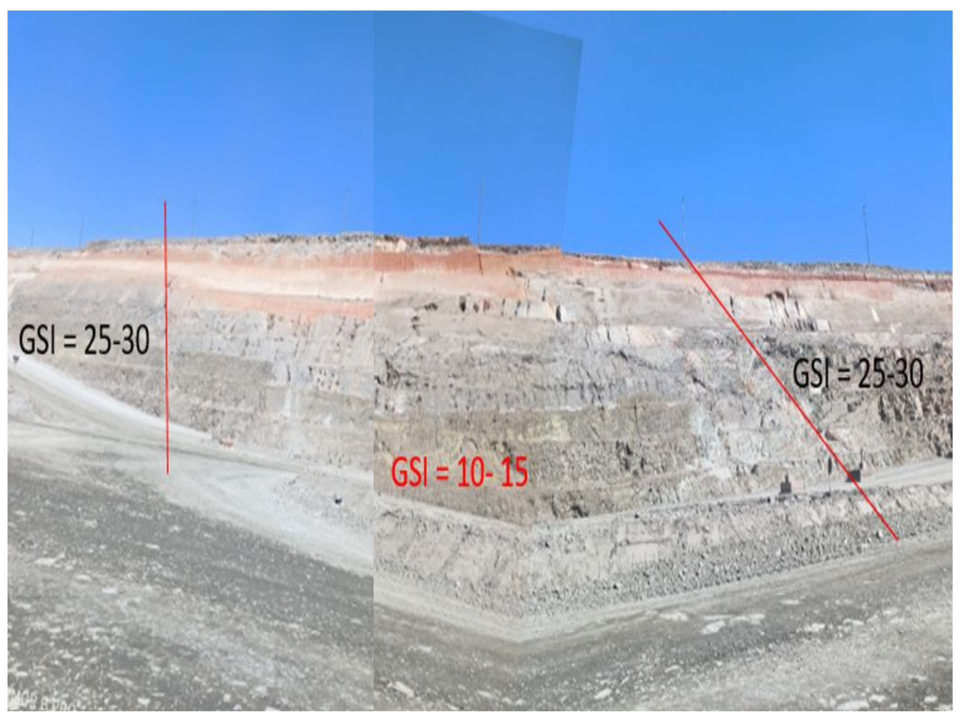

Figure 2 : Main 15 ramp intersection showing the difference in material quality

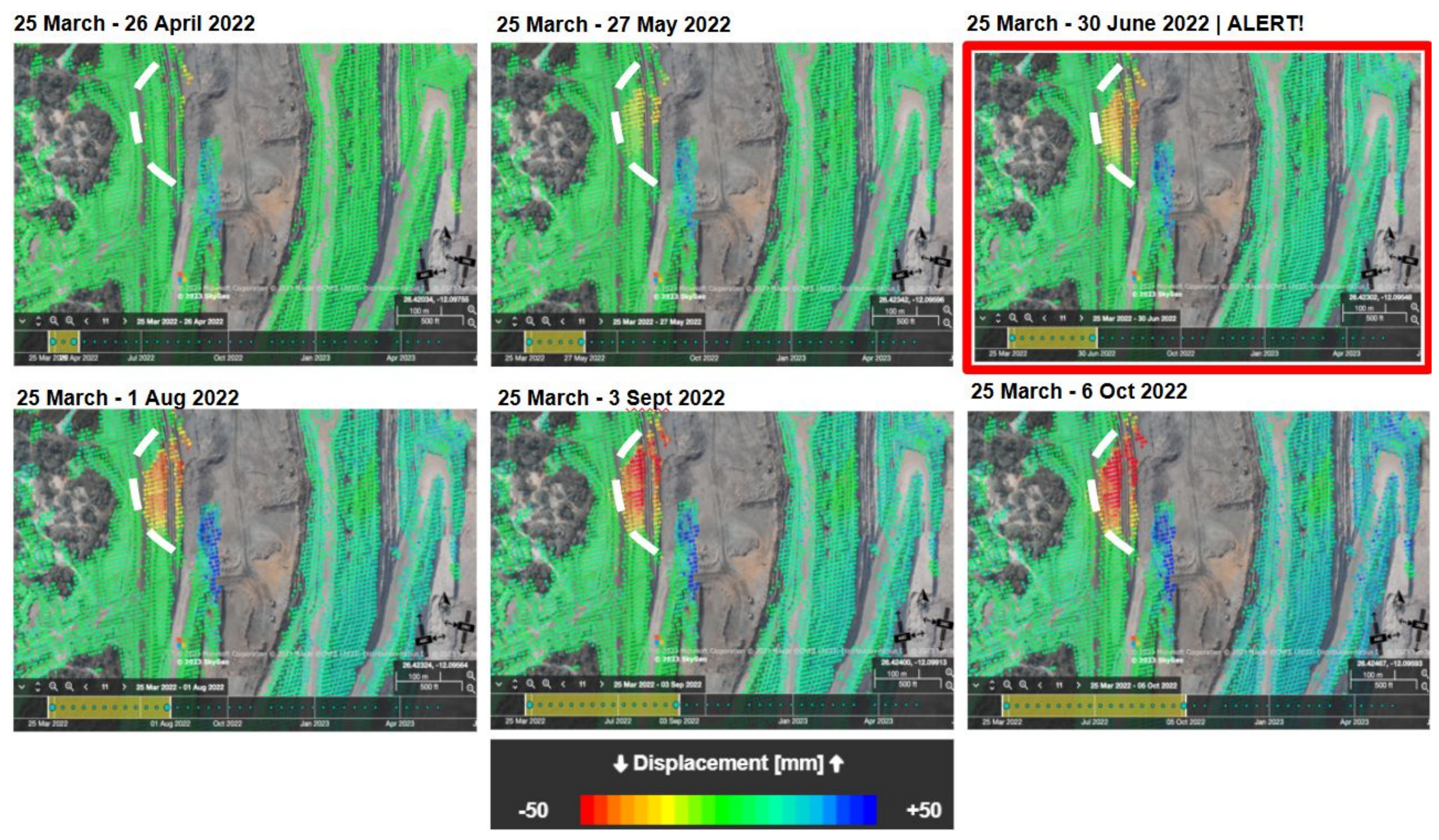

Figure 4 : TSX ascending data showing displacement rate and spatial extent on the M15 wall between March and October 2022 (a to e). Circular subsidence pattern indicated by the black dashed line.

5. Remediation and Results

A dewatering plan was launched in November 2022 with the installation of horizontal drains. The effect of the intervention was quickly observed in the InSAR data, with displacement rates decreasing from over 100 mm/year to around 53 mm/year by the end of the year. The depressurisation slowed the movement, but it was reactivated again in the 2022/23 wet season (Figure 5). This post intervention monitoring gave Kansanshi Mine the ability to plan and implement unloading of the crest before the 2023/2024 rain season.

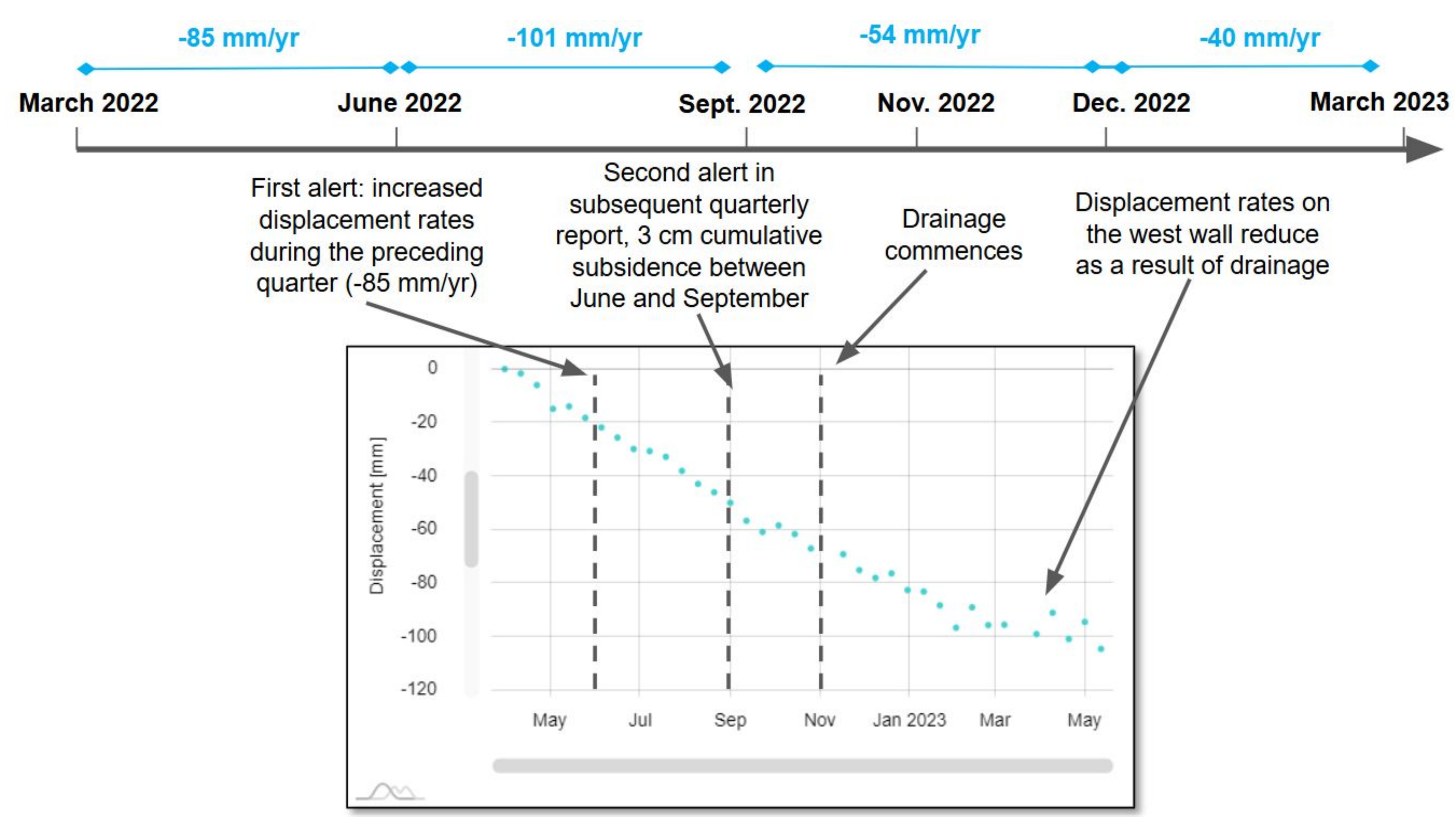

Figure 5 :Timeline of events and displacement rates over the M15 west pit wall.

6. Conclusion

InSAR monitoring provided an invaluable and timely early warning of slope movement that was not captured by ground-based systems. The early detection enabled a successful geotechnical intervention (dewatering) that slowed the displacement and stabilized the pit wall. This proactive approach prevented a potential failure, ensuring the safety of the mine, maintaining operational efficiency, and avoiding significant financial losses.

7. References

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