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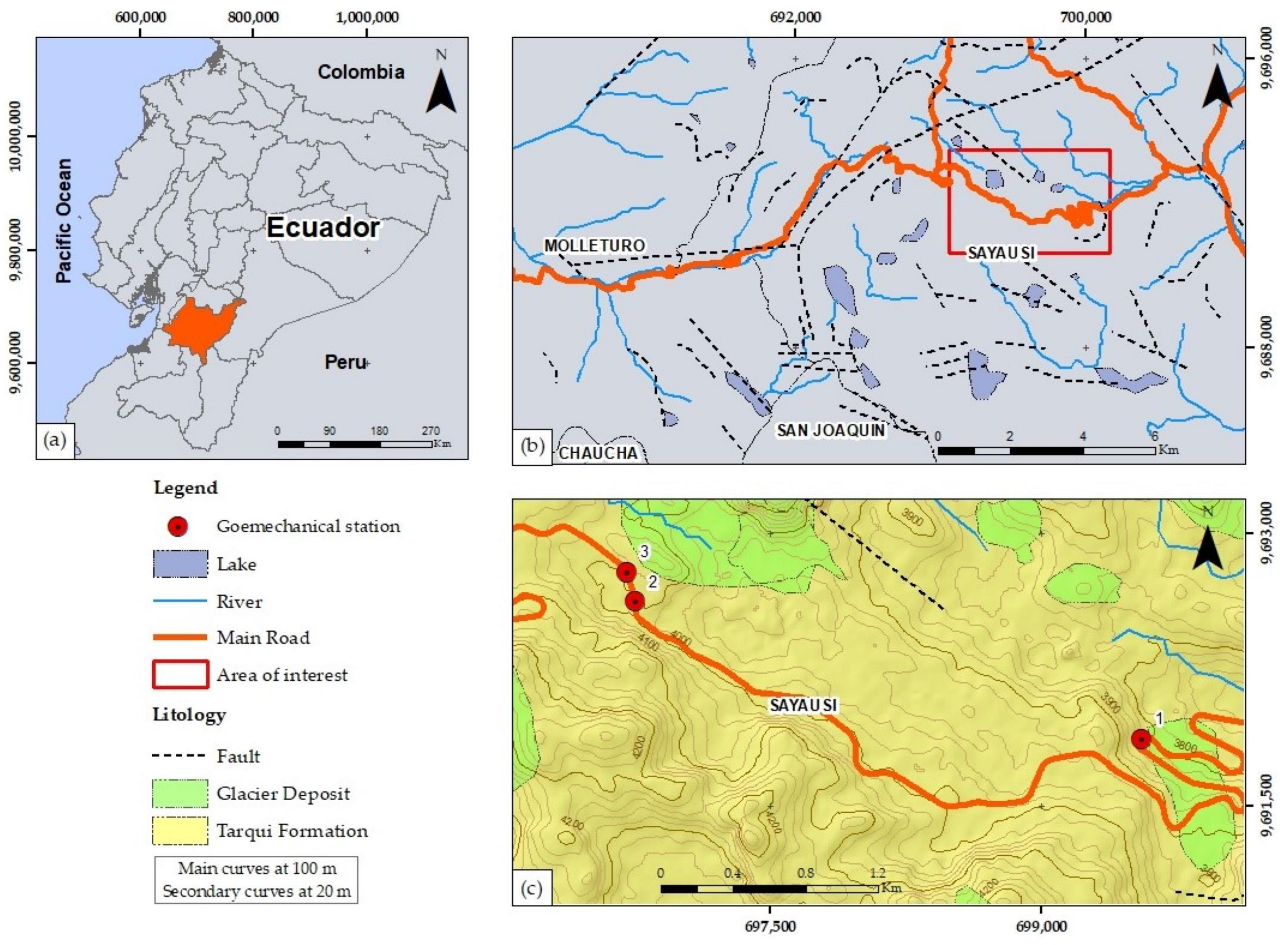
ROCK SLOPE STABILITY ANALYSIS USING TERRESTRIAL PHOTOGRAMMETRY AND VIRTUAL REALITY ON IGNIMBRITIC DEPOSITS

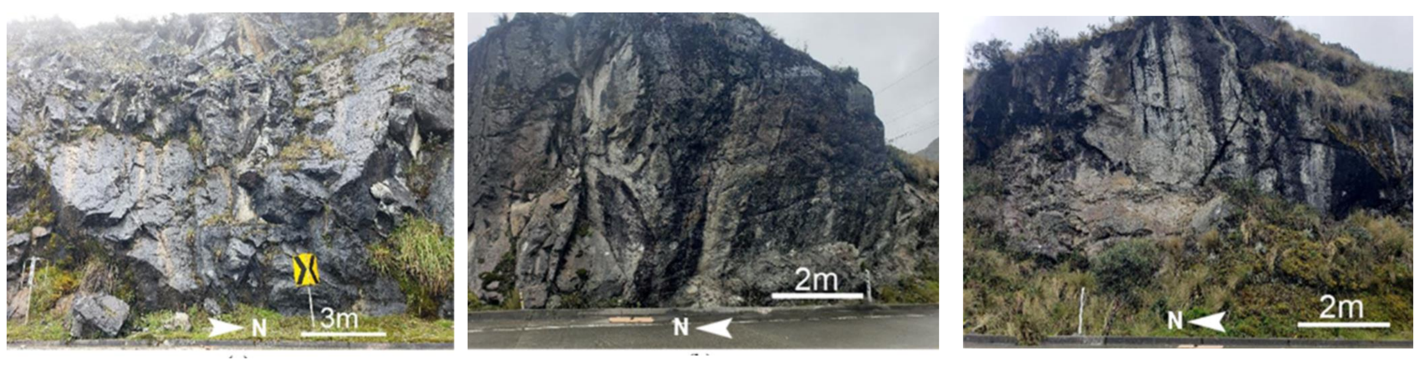
PROBLEM

Puerto de Cajas is a crucial high-altitude pass in Ecuador, linking the coastal region to the city of Cuenca. The stability of its rocky massif is carefully maintained through assessing blocks and discontinuities, ensuring safe passage. Studying slope stability requires meticulous evaluation to comprehend potential instability. Direct data collection is vital for kinematic analysis, while terrestrial photogrammetry helps discern geometric features at high elevations. The objective is to integrate field observations with kinematic analysis to determine the stability of these rocky formations



MAIN GOAL

The primary objective of this study is to assess rock mass stability through mapping and processing techniques, highlighting the benefits of each applied methodology (SMR, Q-slope, and kinematic).



METHODOLOGY

Analyzing the stability of rock slopes within jointed rock masses at shallow depths requires a systematic approach to evaluate the orientation and strength of discontinuities such as joints, strata, and faults, which directly influence their stability.

In this study, advanced techniques are employed to obtain data from areas that are inaccessible for the application of the methodologies (SMR, Q-slope, and kinematic).

Information Collected in the Field

Field survey
- Roughness
- Persistence
- Slope geometry
- Orientation

Data processing
- Photogrammetry
- Structure from movement
- Point cloud evaluation
- 3D Reconstruction

Types of Analysis

Empirical Analysis

Slope Mass Rating (SMR)

SMR = RMR + (F1 X F2 X F3) + F4

Q-slope classification

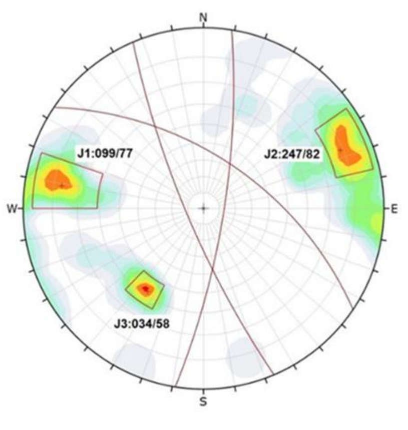
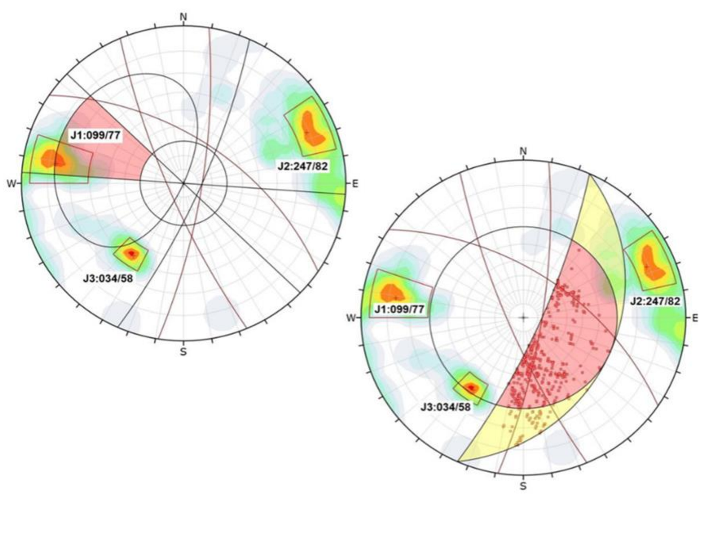
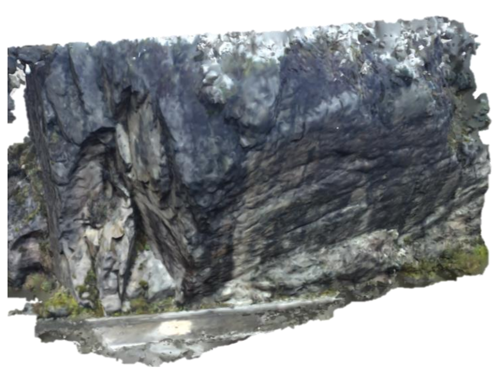
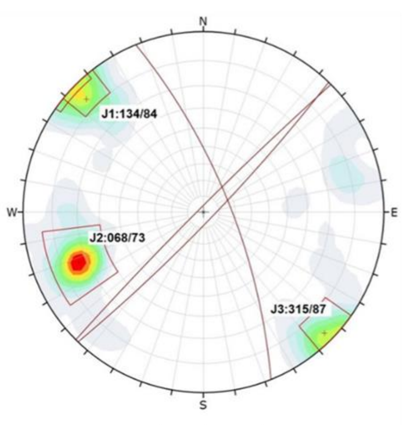
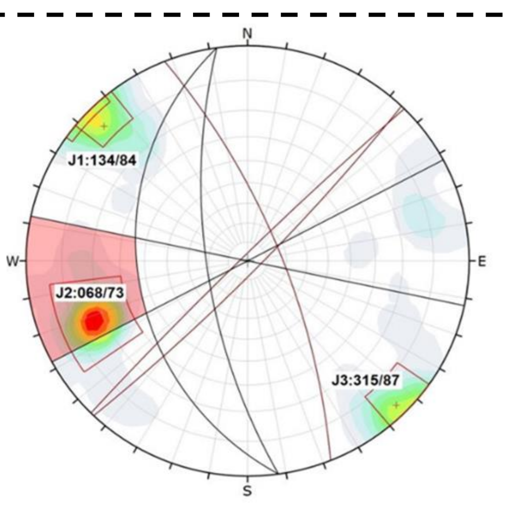
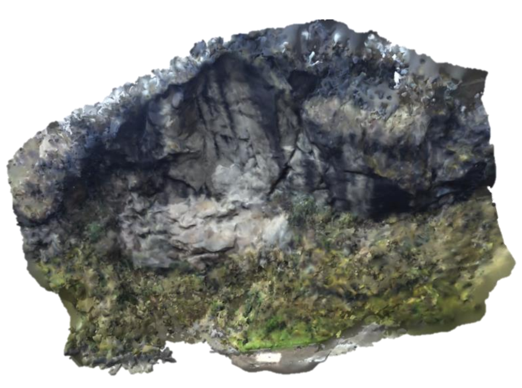
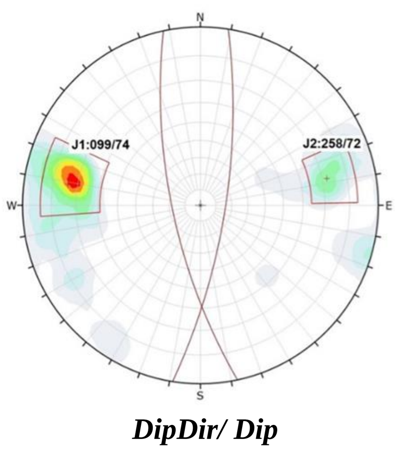
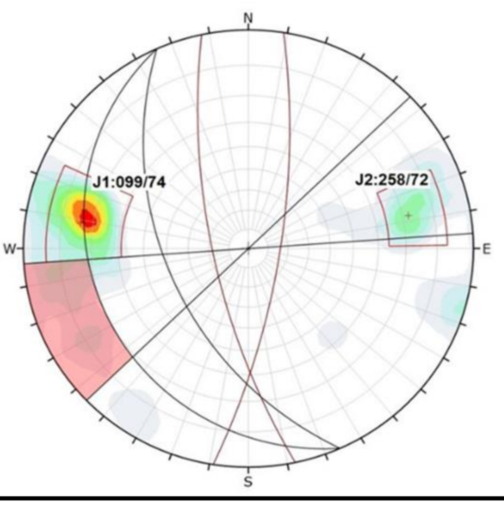
$$Q_{slope} = \frac{RQD}{J_n n} x \left(\frac{j_r}{j_a}\right)_o x \frac{j_{wice}}{SRFslope}$$

Kinematic Analysis

Discontinuities – represented in a stereogram

φb | MPa | Ω | JRC

RESULTS

3D Model	Stereogram (Joint sets)	SMR	Q-Slope	Kinematic
Slope 1 	 **DipDir/ Dip** 099/77 | 247/82 | 034/58	***RQD:*** 90 – 100 ***UCS (Mpa):*** 50 ***RMR:*** 53 ***Type of failure:*** (4 Joint sets identified) Planar (J1), Wedge (J1- J3), Toppling (J1), Toopling (J2), Planar (J2) ***SMR***: 26 - 51.8 – 57 – 57 - 39 ***Stability:*** Unstable (Planar: J1, J2), Partially Stable (Toppling: J1,J2 ; Wedge: J1-J3)	***RQD:*** 91 ***Jn, Jr, Ja:*** 12 - 4 - 1 ***Q-Factor:*** 0.75 ***Jwice:*** 0.5 ***SRF:*** 15 ***Q-Slope:*** 0.76 ***β°:*** 63 ***Stability:*** Stable	
Slope 2 	 **DipDir/ Dip** 134/84 | 068/73 | 315/87	***RQD:*** 70 - 80 ***UCS (Mpa):*** 40 ***RMR:*** 33 ***Type of failure:*** (4 Joint sets identified) Wedge (J1- J3), Toppling (J1), Planar (J1), Planar (J2) ***SMR:*** 40.5 – 37 – 38 - 10 ***Stability:*** Partially Stable (Wedge: J1- J3), Unstable (Toppling: J1 ;Planar: J1), Completely unstable Planar: J2)	***RQD:*** 77 ***Jn, Jr, Ja:*** 12 - 4 - 4 ***Q-Factor:*** 0.75 ***Jwice:*** 0.5 ***SRF:*** 15 ***Q-Slope:*** 0.16 ***β°:*** 49 ***Stability:*** Transition	
Slope 3 	 **DipDir/ Dip** 099/74 | 258/72	***RQD:*** 90 - 100 ***UCS (Mpa):*** 50 ***RMR:*** 37 ***Type of failure:*** Wedge (J1- J2) ***SMR:*** 41 ***Stability:*** Partially Stable	***RQD:*** 91 ***Jn, Jr, Ja:*** 6 - 7 - 7 ***Q-Factor:*** 1 ***Jwice:*** 0.6 ***SRF:*** 5 ***Q-Slope:*** 0.39 ***β°:*** 57 ***Stability:*** Stable	

CONCLUSIONS

This study integrates various methods for rock mass data collection and stability analysis. While smartphone apps efficiently measure slope characteristics, traditional compass methods remain indispensable. Terrestrial photogrammetry enhances safety and reduces costs in remote areas like Cajas.

Results varied using the Q-slope method, particularly for Slope 2, indicating the need for combined methodologies. All slopes demonstrated susceptibility to different types of failures, underscoring the importance of integrated analysis for understanding slope stability

Slope N°	*SMR*	*Q-Slope*	*Kinematic*	*Visual*
1	Unstable	Stable	Unstable	Unstable
2	Unstable	Transition	Unstable	Unstable
3	Unstable	Stable	Unstable	Unstable