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PARES & NONES® Un break científico

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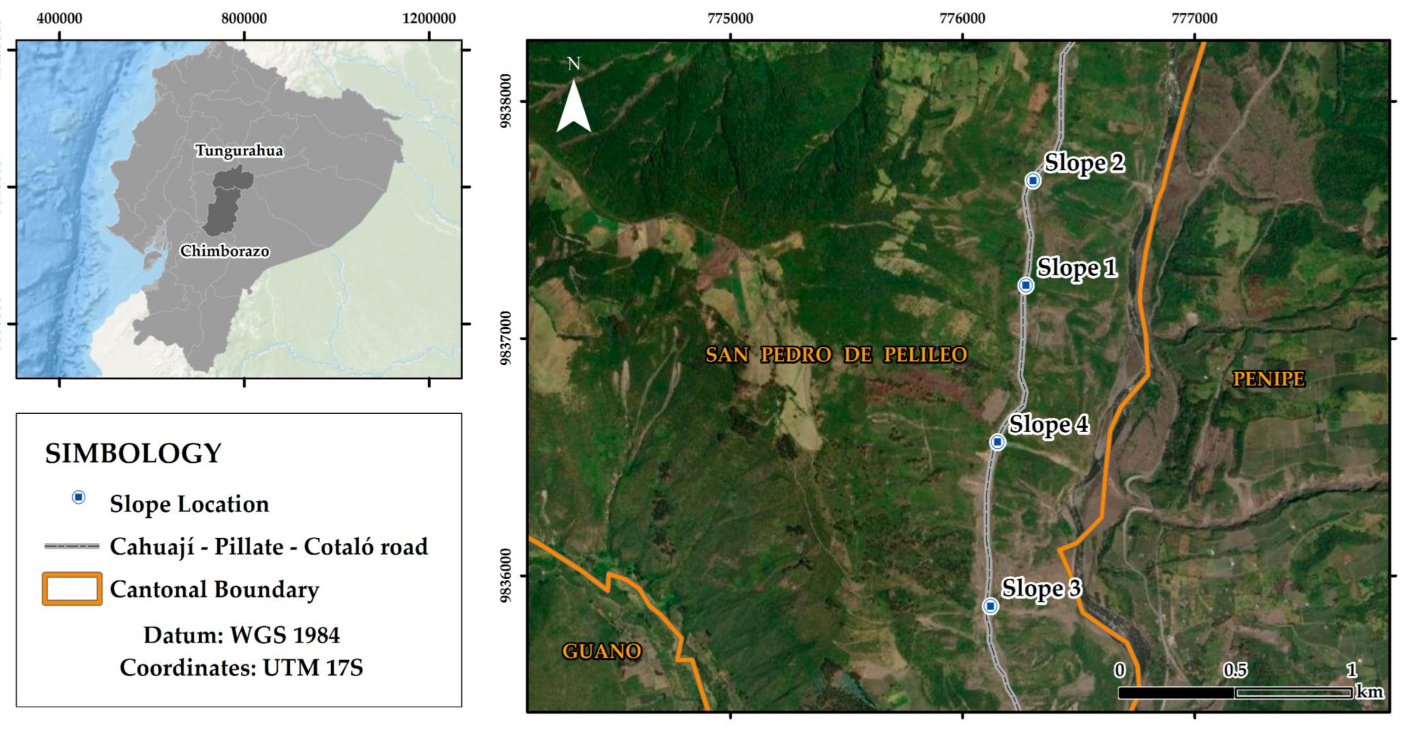
AN ANALYSIS OF SLOPE STABILITY IN THE PENIPE–BAÑOS ROAD BY APPLYING EMPIRICAL METHODS, KINEMATIC ANALYSIS AND REMOTE PHOTOGRAMMETRY TECHNIQUES

PROBLEM

Since 1999, the Penipe-Baños road has been affected by multiple eruptions of the Tungurahua volcano. The old road crosses more than seven ravines, and due to the high risk in the area, the SGR has declared a state of emergency on several occasions. This road connects the agricultural and tourist municipalities of Baños and Penipe, which belong to the provinces of Tungurahua and Chimborazo, respectively.



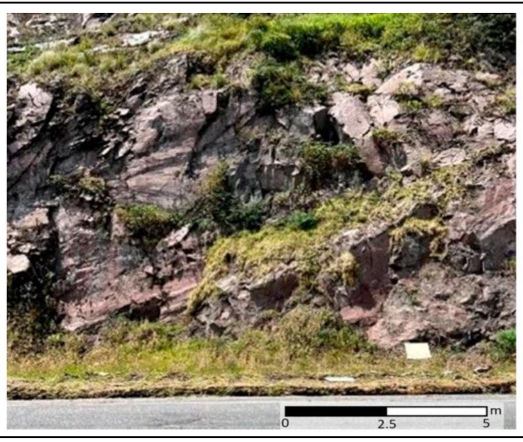
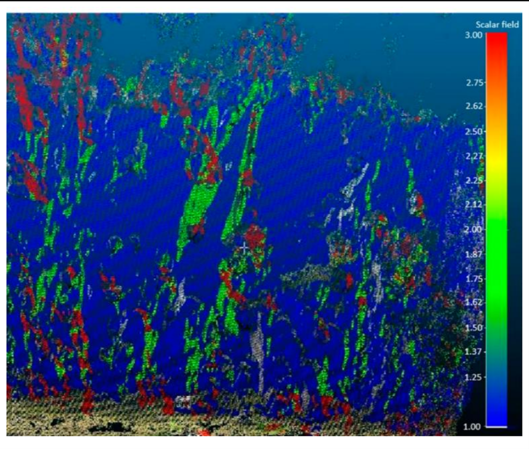
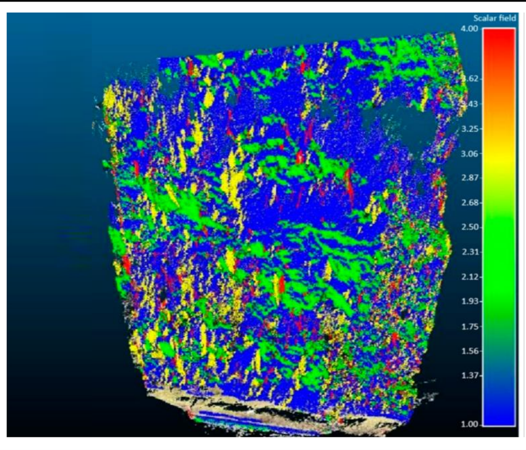
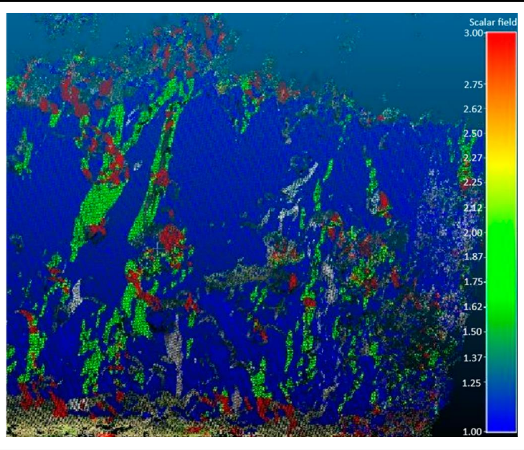
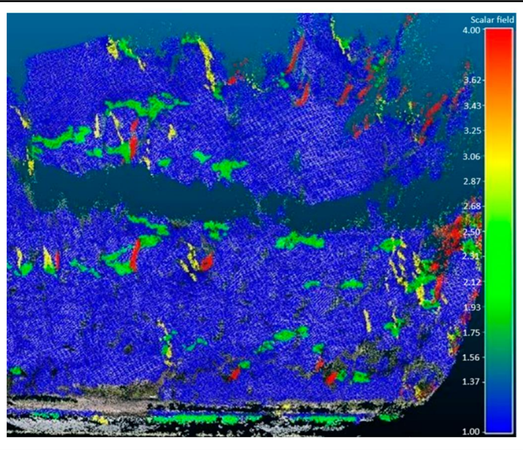
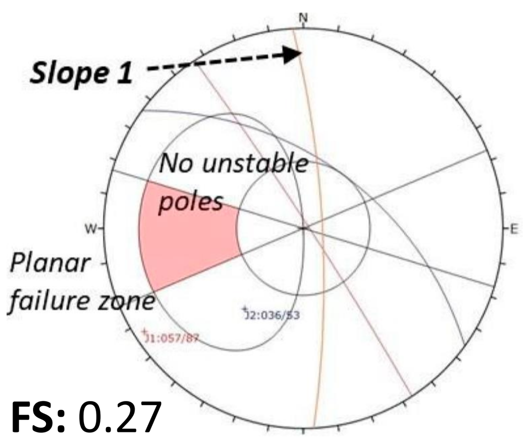
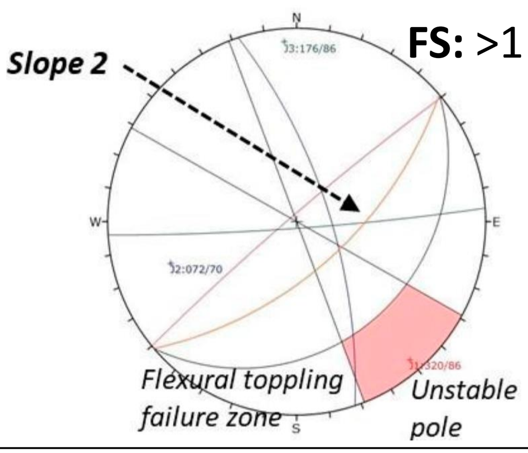
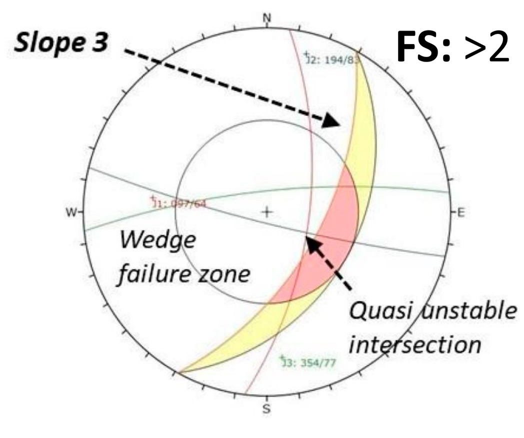
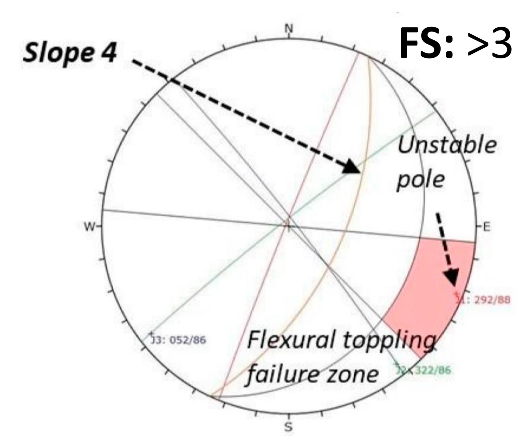
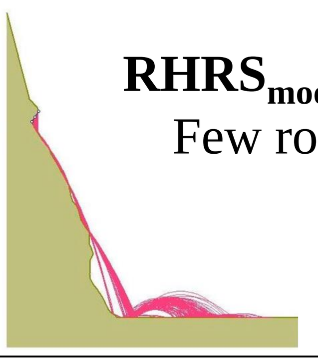
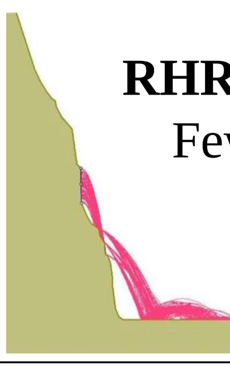
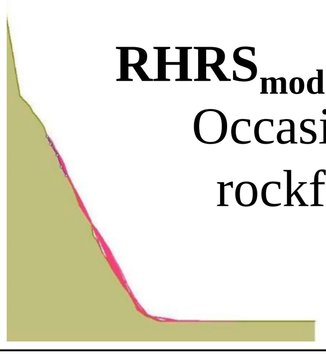
MAIN GOAL

To **analyze the stability of four slopes** located on the Cahuají–Pillate–Cotaló road, an alternative route to the Penipe–Los Pájaros (Baños) road, **applying different approaches** including SfM photogrammetry and empirical methods (Q-slope, RMR, SMR, DIPS, and RHRS).

METHODOLOGY

The methodology used for the analysis began with data collection using geomechanical stations and remote techniques such as SfM photogrammetry, which allows for better characterization of inaccessible parts of the slopes. The data obtained were used for applying empirical methods such as SMR, Q-slope, and the Rockfall Hazard Rating System (RHRS). These methods were evaluated using Rocfall3 software to analyze the trajectory of rockfall blocks.

RESULTS

METHODS	SLOPE 1		SLOPE 2		SLOPE 3		SLOPE 4	
Geomechanical station/ SfM photogrammetry		Stable		Partially stable		Stable		Stable
Discontinuity Set Extractor (DSE)								
Join Sets DipDir/Dip	**J1**: 057/87 **J2**: 036/53		**J1**: 320/86 **J2**: 072/70 **J3**: 176/86		**J1**: 097/64 **J2**: 194/83 **J3**: 354/77		**J1**: 292/88 **J2**: 322/86 **J3**: 052/86	
Kinematic analysis		Stable		Stable		Stable		Stable
Slope Mass Rating (SMR)	**Lithology: Ignimbrite** **UCS:** 45.08 MPa **RQD:** 93.00 % ***RMR:*** *67.30 %* ***SMR:*** *58.30 %*	Partially stable	**Lithology: Ignimbrite** **UCS:** 33.32 MPa **RQD:** 94.00% ***RMR:*** *68.00 %* ***SMR:*** *43.00 %*	Partially stable	**Lithology: Ignimbrite** **UCS:** 35.28 MPa **RQD:** 97.00 % ***RMR:*** *68.00 %* ***SMR:*** *64.25 %*	Stable	**Lithology: Ignimbrite** **UCS:** 42.14 MPa **RQD:** 85.00 % ***RMR:*** *57.00 %* ***SMR:*** *32.00 %*	Unstable
Q-Slope	**Slope height:** 10.80 m ***β:*** *69.80°* ***θslope:*** *79°* **Q-Slope:** 1.74	Unstable	**Slope height:** 23.70 m ***β:*** *62.30°* ***θslope:*** *61°* **Q-Slope:** 0.73	Stable	**Slope height:** 8.00 m ***β:*** *72.70°* ***θslope:*** *57°* **Q-Slope:** 2.43	Stable	**Slope height:** 11.15 m ***β:*** *61.40°* ***θslope:*** *57°* **Q-Slope:** 0.66	Stable
Rockfall Hazard Rating System (RHRSmod)	 **$RHRS_{mod}$:** *242.80* Few rockfalls	Medium risk	 **$RHRS_{mod}$:** *208.90* Few rockfalls	Low risk	 **$RHRS_{mod}$:** *205.40* Few rockfalls	Low risk	 **$RHRS_{mod}$:** *249.20* Occasional rockfalls	Medium risk

CONCLUSIONS

The methodologies employed demonstrate the feasibility of assessing slopes quickly and cost-effectively using remote techniques such as photogrammetry with control points (SfM). These analyses are crucial for accident prevention and minimizing disruptions on roadways. Comparing methods highlights the importance of combining results for accurate interpretation.

Methods like Q-slope have limitations as they omit discontinuity orientation, whereas kinematic approaches and SMR enhance reliability by integrating these variables with visual field observations.

Ultimately, the RHRS method provides a rapid and economical solution by using field data and site maps to comprehensively assess road risk, identifying critical areas prone to potential slope failures.