Constraining Late Pleistocene to Holocene seismic fault activity in NE Iberia: The value of integrating complementary techniques in a low-strain region

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1. INTRODUCTION

The Northeastern region of the Iberian Peninsula, from the Vallès-Penedès Graben to the Valencia Depression, constitutes the emerged part of the **Valencia Trough**, a passive margin that shows multiple NNE-SSW-oriented Neogene normal faults (Fig. 1). Previous studies have demonstrated that some of these faults, such as the *El Camp fault*, are active, with slip rates as low as **0.02 m/kyr** for Late Pleistocene. [1]
Recently, the analysis of high-resolution Digital Elevation Models (DEMs) revealed several additional **morphological scarps in Quaternary alluvial fans** in the region, from the *Sant Jordi* Plain to the *La Salzadella* Basin. These scarps share the same orientation as the Neogene fault system, suggesting a comparable tectonic origin.

The scarps detected are located in different generations of Quaternary alluvial fans with ages ranging between 735 Kya and recent days [1]. These alluvial fans are the result of the erosion of both the Catalan Coastal Ranges and the Iberian Massif, as the area is located where these two mountain ranges merge.

As the basement of the area is mainly composed by Jurassic and Cretaceous rocks (Fig. 2), the alluvial fans are rich in carbonates gravels, which have led to the development of **significant caliches**.

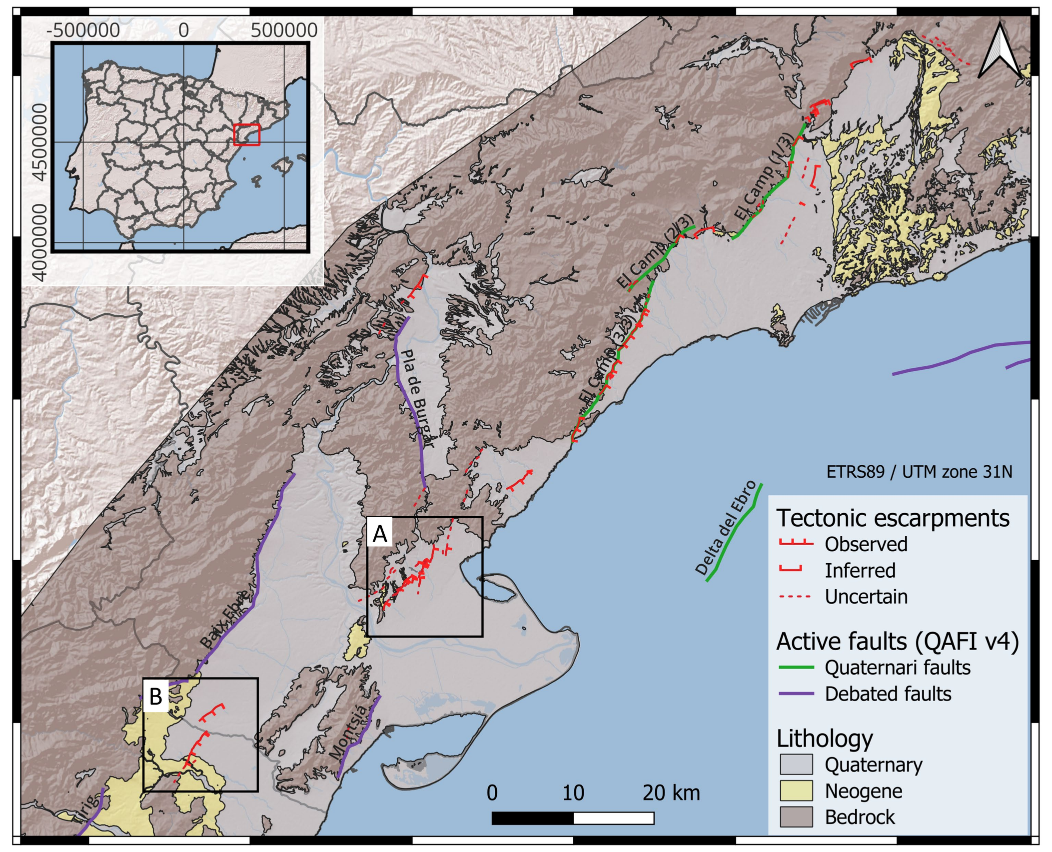

Fig. 1: Location of the recently discovered scarps along the western margin of the Valencia Trough. There are shown the active faults of the area [2]. A. Camarles Plain; B. La Sénia Plain

2. GEOMORPHOLOGY

The scarps are discontinuous, arranged following a **right-stepped pattern** (Fig. 2), and show a remarkable **vertical offset of up to 8 metres** in some places. (Fig. 3)

A detailed geomorphological analysis identified several geomorphic features that insinuate **recent tectonic activity**. Some of these indicators include aligned fractures in the fans near the scarps, or entrenched channels on the upthrown block that fade out after crossing the scarps. (Fig. 4)

Additionally, three **cosmonuclide depth-profiles** were sampled to date displaced geomorphic surfaces, and hence estimating the long-term slip rates of the faults.

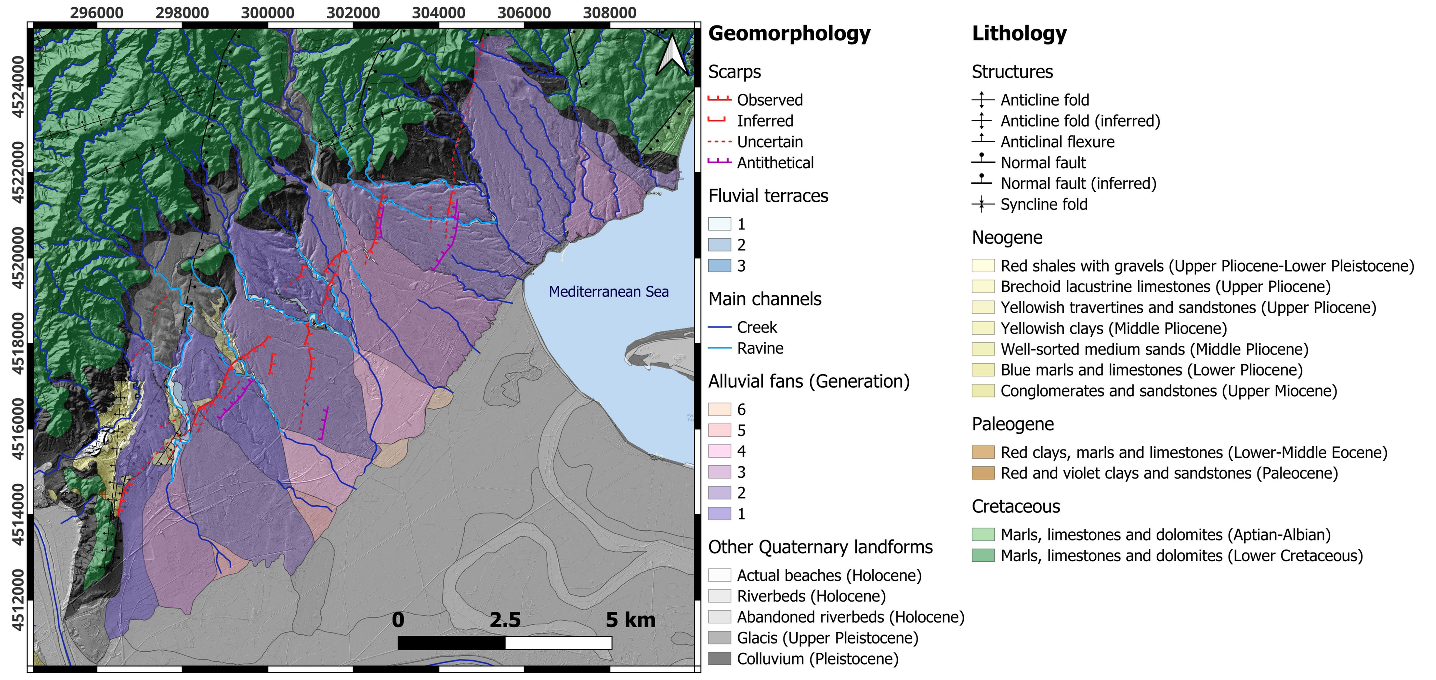

Fig. 2: Geomorphological map of the Camarles Plain, where six distinct generations of Quaternary alluvial fans have been identified, some of which exhibit varying degrees of tectonic offset.

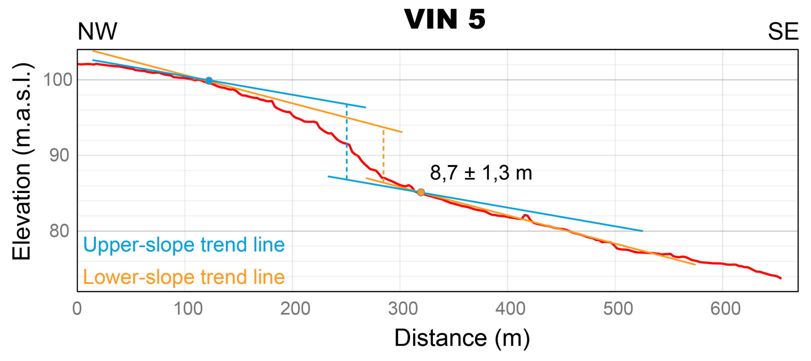

Fig. 3: Topographic profile across the Vinaixarop escarpment, showing the offset measurement obtained following the methodology of Canari et al. (2025) [3]. The vertical scale is exaggerated. Location is indicated in Fig. 4A.

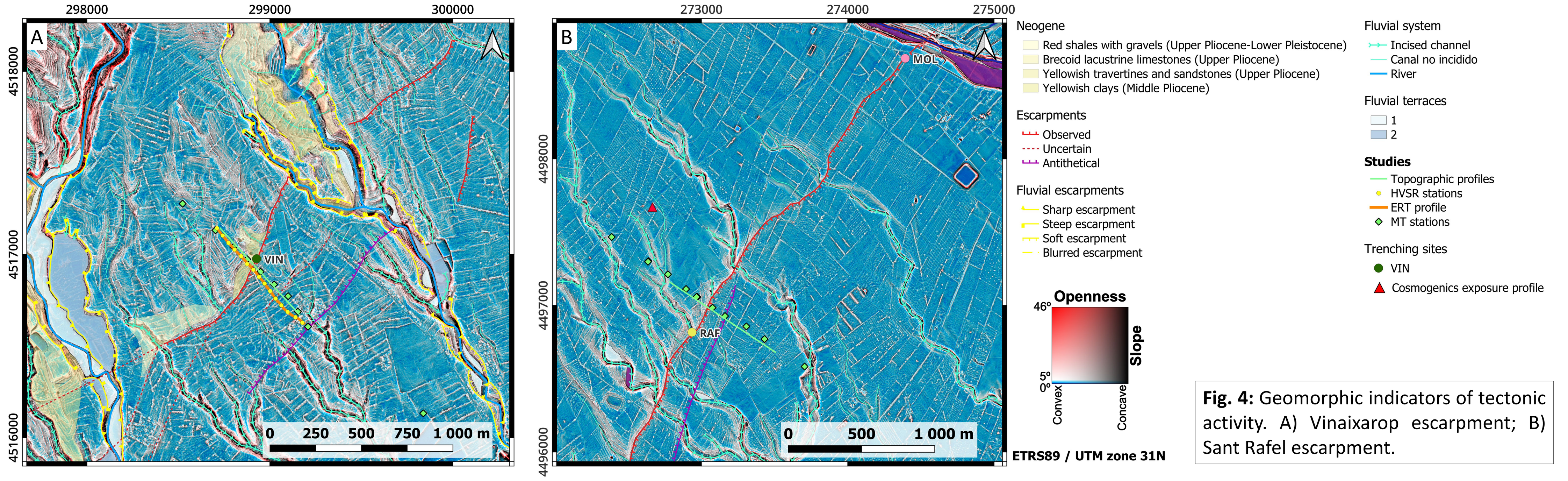

Fig. 4: Geomorphic indicators of tectonic activity. A) Vinaixarop escarpment; B) Sant Rafel escarpment.

3. GEOPHYSICS

Geophysical surveys (including Ground Penetrating Radar, **GPR**; Electrical Resistivity Tomography, **ERT**; Seismic Refraction Tomography, **SRT**; Horizontal-to-Vertical Spectral Ratio, **HVSR**; and Magnetotellurics, **MT**), confirm the presence of faults beneath each of the analysed escarpment systems. At the Vinaixarop escarpment, for example, ERT profiles (Fig. 5) reveal a steeply dipping discontinuity plane with an estimated vertical offset of approximately 40 m affecting Upper Pliocene sediments. A combination of methods has been employed to improve the characterization of subsurface structures (e.g., **ERT integrated with SRT**), whereas other techniques have been applied to investigate fault geometry at different depths. In particular, **GPR has been used to identify near-surface open fissures**, while **HVSR and MT data provide constraints on the offset of the base of Quaternary deposits**.

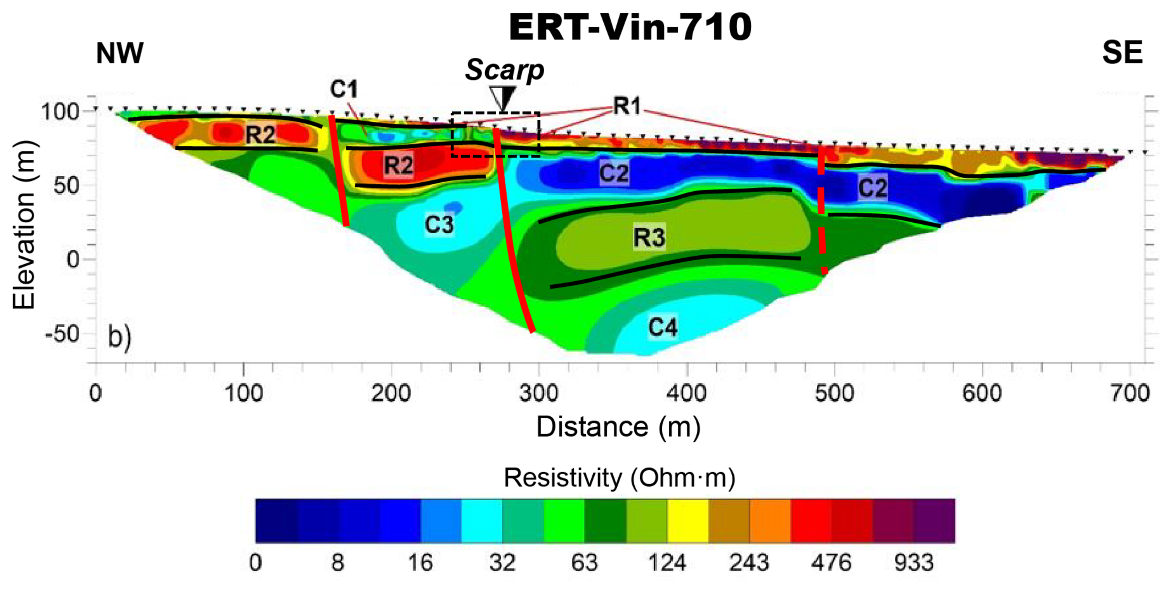

Fig. 5: ERT profile at the Vinaixarop scarp. 72 electrodes deployed along a 710 meters profile. The model was derived from inversion of dipole-dipole data with a relative error <10%. Location shown in Fig. 4A. It is displayed the approximate position of trench VIN.

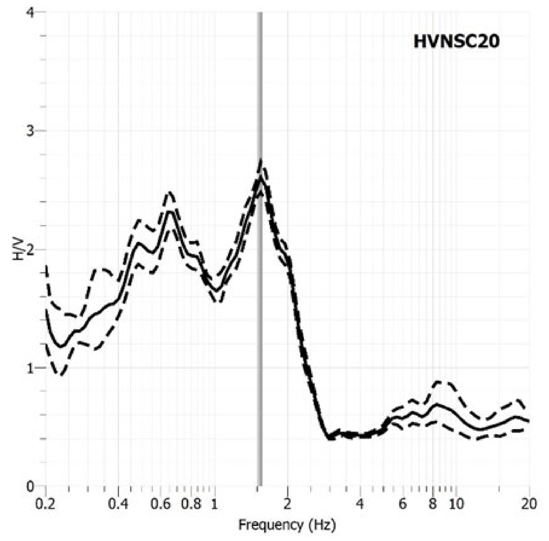

Fig. 6: HVSR profiles, where main peaks indicate subsurface discontinuities, expressed in frequency domain (Hz). Location shown in Fig. 4A.

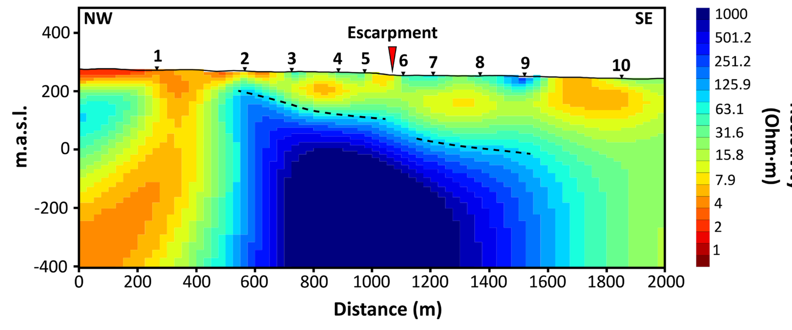

Fig. 7: Preliminary MT results. Data were collected from 10 stations (shown), measuring at three different frequencies (128, 512, and 4096 Hz). A 2D resistivity model was obtained from the inversion of data acquired along an N110°-oriented profile. The interpreted Mesozoic surface is displayed. The location is shown in Fig. 4B.

4. TRENCHING AND DATING

Optically Stimulated Luminescence (OSL) is commonly used in paleoseismology. However, the lack of quartz in most trenches has limited its application to only certain cases (dating in course).

Nevertheless, the low slip rates of the faults, combined with the extensive development of pedogenic calcretes, led to the formation of open fractures within the petrocalcic horizon that were subsequently infilled with crystalline calcite. Both the calcretes and the infill of these fractures have been dated using **U/Th series**, yielding Holocene ages in some cases.

In trenches where suitable material was available, **radiocarbon** samples have also been collected.

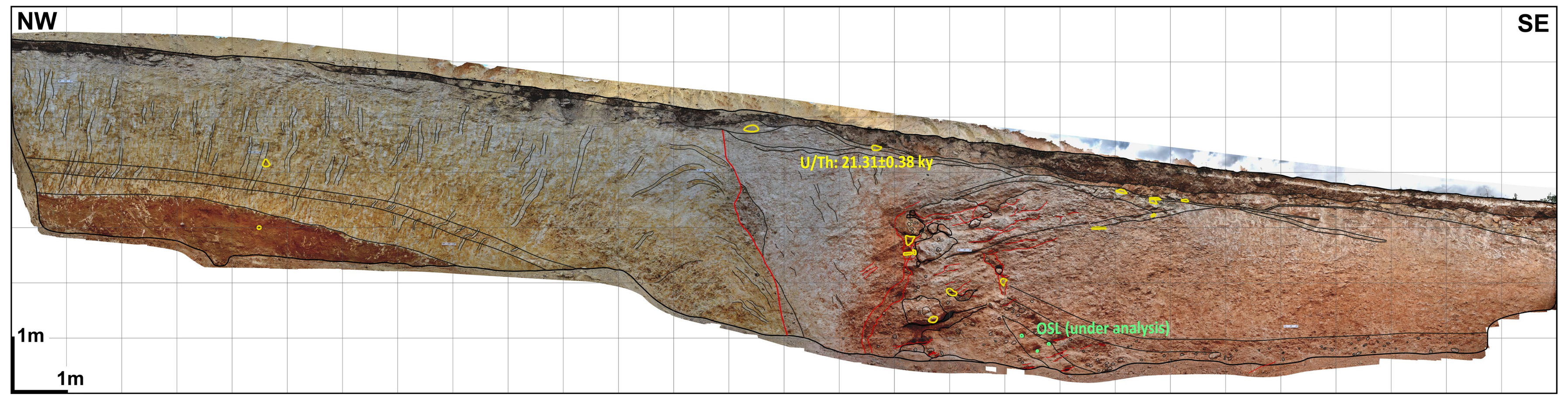

Fig. 8: Northern wall of paleoseismic trench VIN. Trench location is shown in Fig. 4A.

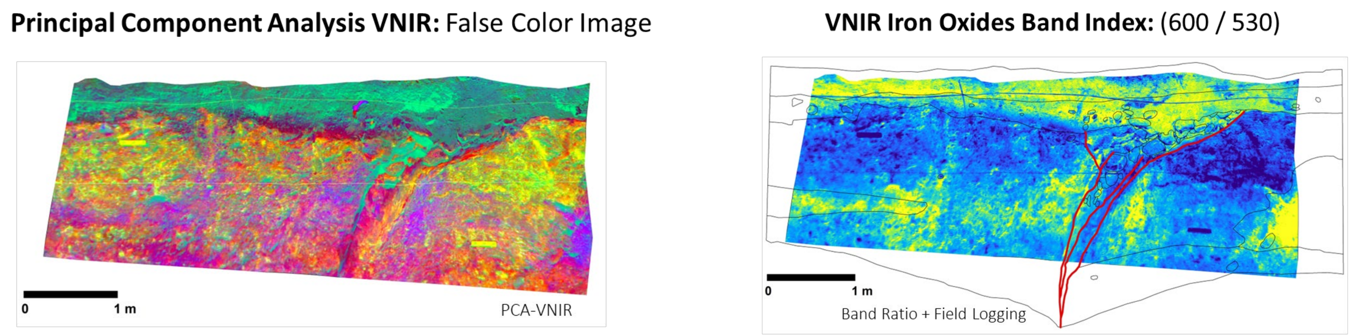

Fig. 9: Hyperspectral imaging of NE wall of trench RAF. Trench location is shown in Fig. 4B. Scan the QR for more details about this technique.

5. CONCLUSIONS

Based on our results, Electrical Resistivity Tomography (ERT) is highly recommended as a first step towards identifying active faults due to its ease of deployment, the robustness of its results, and its relatively low susceptibility to interference and other operational limitations. However, the proper characterization of faults requires the integration of multiple methodologies. This combined approach becomes particularly important when investigating low slip-rate faults, where the limitations of individual methods can be compensated by others.

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