Best Practice for Acquisition, Processing, and Interpretation of 3D GPR Data for Visualization of Deformation Bands, Fractures, and Karst in Carbonates

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Project Objectives

- Develop guidelines for optimal acquisition parameters of full-resolution Ground Penetrating Radar (GPR) data in fractured carbonates.
- Optimize processing for extracting fractures and karst from 3D GPR volumes.
- Propose a workflow for interpretation of GPR volumes with fractures for enhaced visualization of structural features and karst.

Rationale

Using a newly developed GPR system with the capability of efficiently acquiring high-resolution data at centimeter precision (Grasmueck and Viggiano, 2007)), we have imaged fractures, deformation bands, and karst features in porous and tight Cretaceous carbonates. The partitioning of the rock by fractures and karst at and below the GPR wavelength, thin vertical fractures and irregular karst features and a faint stratigraphy present a challenging task for GPR imaging. A crucial aspect of fracture imaging is to design surveys with the optimal grid density, frequency and antenna polarization to collect non-aliased data with high-information content (Fig. 1).

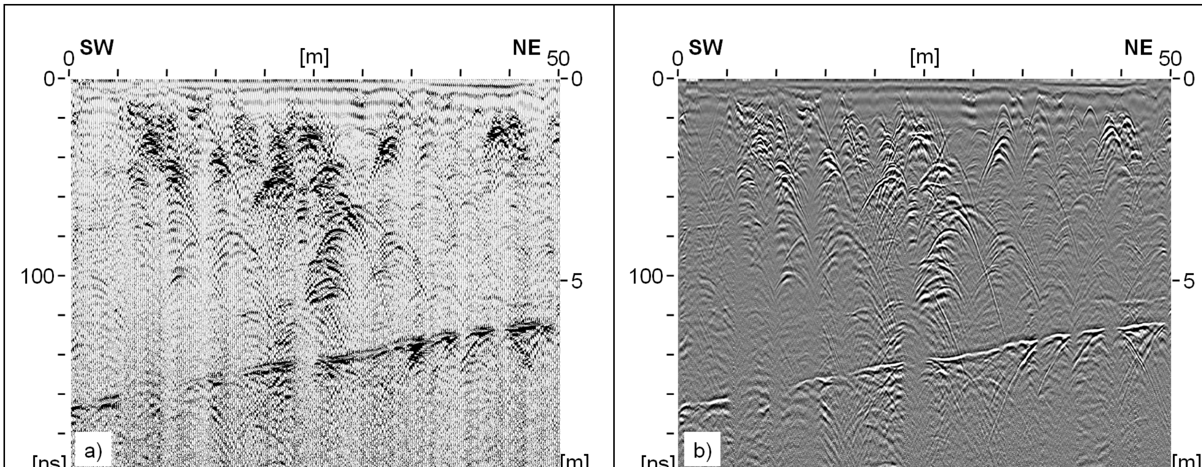

Figure 1. Vertical fractures and irregular karst features produce diffractions apearing as chaotic crisscross patterns or clear hyperbolids depending on the trace spacing. 200 MHz GPR profile acquired with a) half-wavelength trace spacing of 20cm and b) eighth-wavelength trace spacing of 5 cm. Depth scale is based on 9.75cm/ns.

Equally important is to apply an appropriate processing suite, including 3D migration that aligns the diffraction apices in vertical fracture planes and cluster of karstic dissolution features (Fig. 2). Final fracture visualization relies on using the best attribute in the interpretation packages. The aim of this project is to use different survey designs, processing and interpretation suites to develop a much-needed guideline for optimal imaging of fractures and karst in three dimensions.

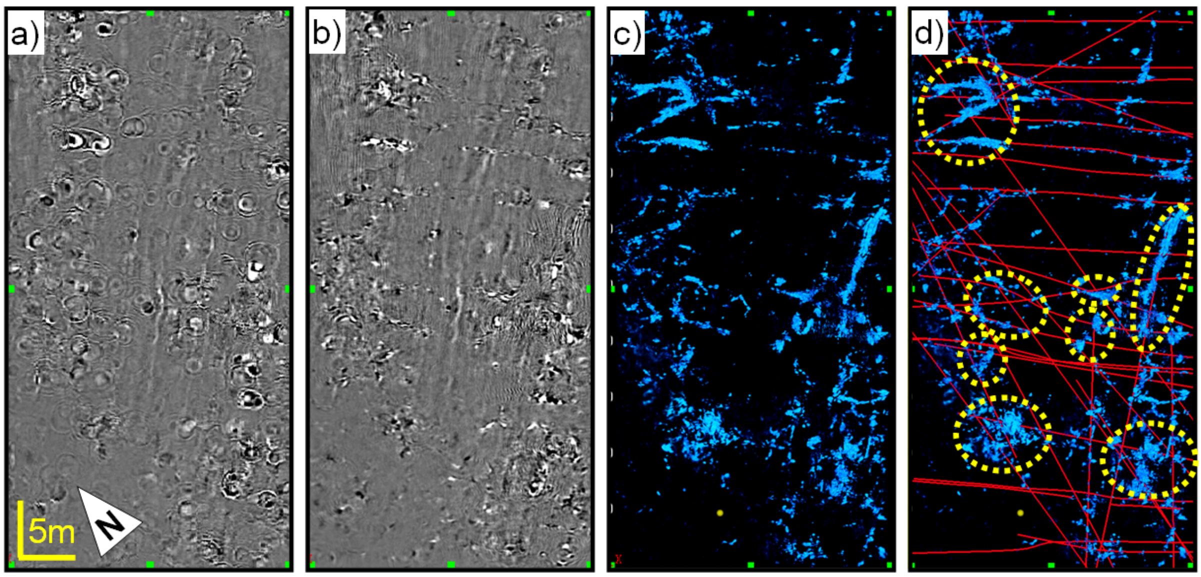

Figure 2. Topview of horizontal slice through 3D GPR cube extracted at 1.95 m depth in the Solvay quarry near Cassis, France. (A) Unmigrated data with abundant diffraction circles. (B) 3D migrated (C) Volume rendering of part of 3D migrated cube ranging from 0 to 2.50 m depth. Low amplitudes are set transparent and the higher amplitude anomalies show in shades of blue. (D) Interpretation overlay shows how focused diffractions are aligned in vertical fracture planes. High amplitude clusters are interpreted as karst features.

Scope of Work

To decide on the optimal acquisition parameters we will analyze several survey designs in which the trace spacing, the frequency, and the antenna polarization were changed. We will discuss the advantages and disadvantages for each design. Processing of the different cubes will provide additional information for the best survey design. Different processing suites will evaluated to optimize the resolution of the fracture imaging. A crucial step is the visualization in interpretation software. Initial results indicate that choosing the appropriate attribute(s) depends on the fracture type and improves the visualization of the fracture and karst network and, thus, the accuracy of the structural analysis.

References

Grasmueck, M. and D. A. Viggiano, 2007, Integration of Ground-Penetrating Radar and Laser Positioning Sensors for Real-Time 3-D Data Fusion. IEEE Transactions on Geoscience and Remote Sensing, vol. 45, n. 1, January 2007.