Fracture Properties from 3D GPR Diffractions

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Project Objectives

- Assemble and analyze typical diffraction signatures from 3D GPR surveys in fractured carbonates.
- Propose simple geometrical models for scattering mechanisms causing diffractions related to fractures.
- Verify diffraction signatures with synthetic modeling.
- Investigate sensitivity of diffraction responses to fracture properties.

Rationale

Recent advances in high-resolution 3D GPR imaging show how complex fracture networks, including millimeter thin sub-vertical joints, can be delineated with the help of diffractions previously considered as noise (Grasmueck et al. 2010). For the visualization of the fractures, the 3D GPR data have to be migrated to focus the diffractions. The fracture planes appear as alignments between focused diffractions events.

Figure 1: Intersection of sub-vertical and horizontal fractures, a possible cause of fracture related diffractions.

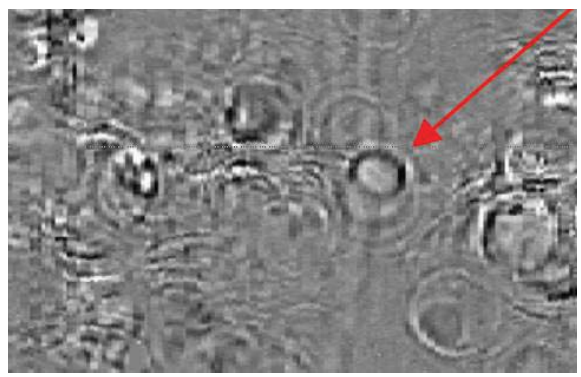

Figure 2: Examples of asymmetric diffractions on a GPR time slice.

This project addresses the origin of individual diffractions caused by fractures. To move from pure delineation of fractures to quantification of fracture properties, a detailed understanding of diffraction mechanisms is necessary. Diffractions originate from sub-wavelength point- and linear-scatterers and, therefore extend the resolution of wave based geophysical methods like GPR and reflection seismic. Such diffraction imaging is also known under the term of super-resolution imaging (Moser and Howard, 2008). Our working hypothesis for the origin of fracture diffractions is the intersection of horizontal and vertical fractures causing sharp edges along fracture planes (Figure 1). This hypothesis needs to be thoroughly tested because inspection of 3D GPR data leaves several open questions, such as: 1) Why is the majority of diffractions circular and not linear as expected from the intersection of 2 planes, and 2) What is the cause of asymmetry in most diffractions (Figure 2)? To date, no model can reproduce these observations of field data. Resolving such questions and advancing the understanding of the nature of diffractions in fractured carbonates is the first step towards quantification of fracture properties, such as dip, azimuth, aperture, and fill from high-resolution geophysical data.

Scope of Work

A detailed analysis of fracture related diffractions has already started in collaboration with Michael Pelissier and Tijmen Jan Moser. High-resolution 3D GPR data examples are used for testing of concepts and techniques. The project involves three main activities:

1. Detailed analysis of diffraction signatures in un-migrated 3D GPR data, with superposition of fracture interpretation obtained from 3D migrated data. The goal is to find the origins and asymmetric patterns related to fracture network and stratigraphy.
5. Develop basic geometric models of scattering points that could cause the observed diffraction patterns. Test if synthetic GPR or seismic data can reproduce the observations.
6. Investigate sensitivity of diffractions to fracture orientation, dip, fill, and aperture by variation of the model parameters.

With the availability of several high-resolution 3D data sets from fractured carbonates in close proximity to outcrops, GPR data are an ideal base to develop a basic understanding of fracture related diffractions. Comparisons with seismic data containing diffraction signatures are used to transfer findings to reservoir depth.

References

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