

# Fracture and Fault Imaging From VSP Data.

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### Summary

This paper presents two case studies in which multi-offset VSP data sets are utilised to assist in the understanding of fractured reservoirs. It is considered that the VSP methodology is generally under utilised and the wealth of additional information within a VSP data set is generally unexploited. Traditionally VSP data sets are acquired to determine time-depth relationships and produce sections and images. Walk-away data sets are generally acquired to provide information on anisotropy and structural information; whilst walk-around data are often used to provide information on fracture directions. These data and offset data sets contain an abundance of additional information, particularly on fracturing, that is rarely exploited but can be extracted through additional advanced processing.

It is generally considered that fracture information cannot be reliably determined from zero offset data sets, however, results of fracture imaging using such data sets are discussed. Examples of imaging and further analysis e.g. shear wave splitting; will also be discussed which demonstrate that these methods can be effective in; granitic basement prospects and fractured carbonates. The advanced processing methods can be applied to any VSP data set, from those acquired in a traditional reservoir to unconventional reservoirs and have applications in fractured reservoir characterization, e.g. fractured carbonates, fractured basement plays, shale, tight sands, coal bed methane and also oil sands. These case studies illustrate that additional understanding of the subsurface can be obtained when VSP data are fully processed.

### Introduction

Fractured reservoirs have porosity and permeability associated with naturally occurring fractures. They are found in sedimentary, igneous and metamorphic rocks and can be associated with both structural and stratigraphic traps. Fractured reservoirs represent a globally significant play type and are found in most petroleum basins, with estimates suggesting that approximately sixty percent of the reservoirs around the world are affected by fractures (Aguilera, 1995; Nelson, 2001). From this it is clear that understanding the nature of faulting and fracturing within a fractured reservoir, or even in the seal above the reservoir, would be of considerable interest. In this paper it will be demonstrated that with complete processing of the recorded VSP data additional information on the subsurface faulting and fracturing can be extracted and visualized.

### Case Study 1

The interpretation of 3D seismic data over a basement structure on the UKCS produced a top basement structure map with the location of the major faults being identified. Initially, only unambiguous faults were interpreted in order to produce a map, at top basement level, that represented a minimum number of faults present. The mapped fault network was used to locate a well and find suitable reservoir targets. The first basement well, drilled in 2009, successfully targeted two fault zones within the Lewisian Basement. On reaching TD, the basement interval was comprehensively logged with wireline tools and a multi-offset VSP data set was acquired, with the resulting data being integrated with the interpretation of the 3D seismic data.

The wireline data showed that the fault zones could be clearly identified on both the image logs and conventional logs with the exception of fault zone 1 which behaved slightly differently on the wireline logs. The presence of the fault zones 1, 2 and 4 were identified from the seismic interpretation whilst fault zone 3 was of sub-seismic resolution. The VSP data set enabled the fault plane associated with fault zone 1 to be imaged, as shown in the orbital VSP image in Figure 1.

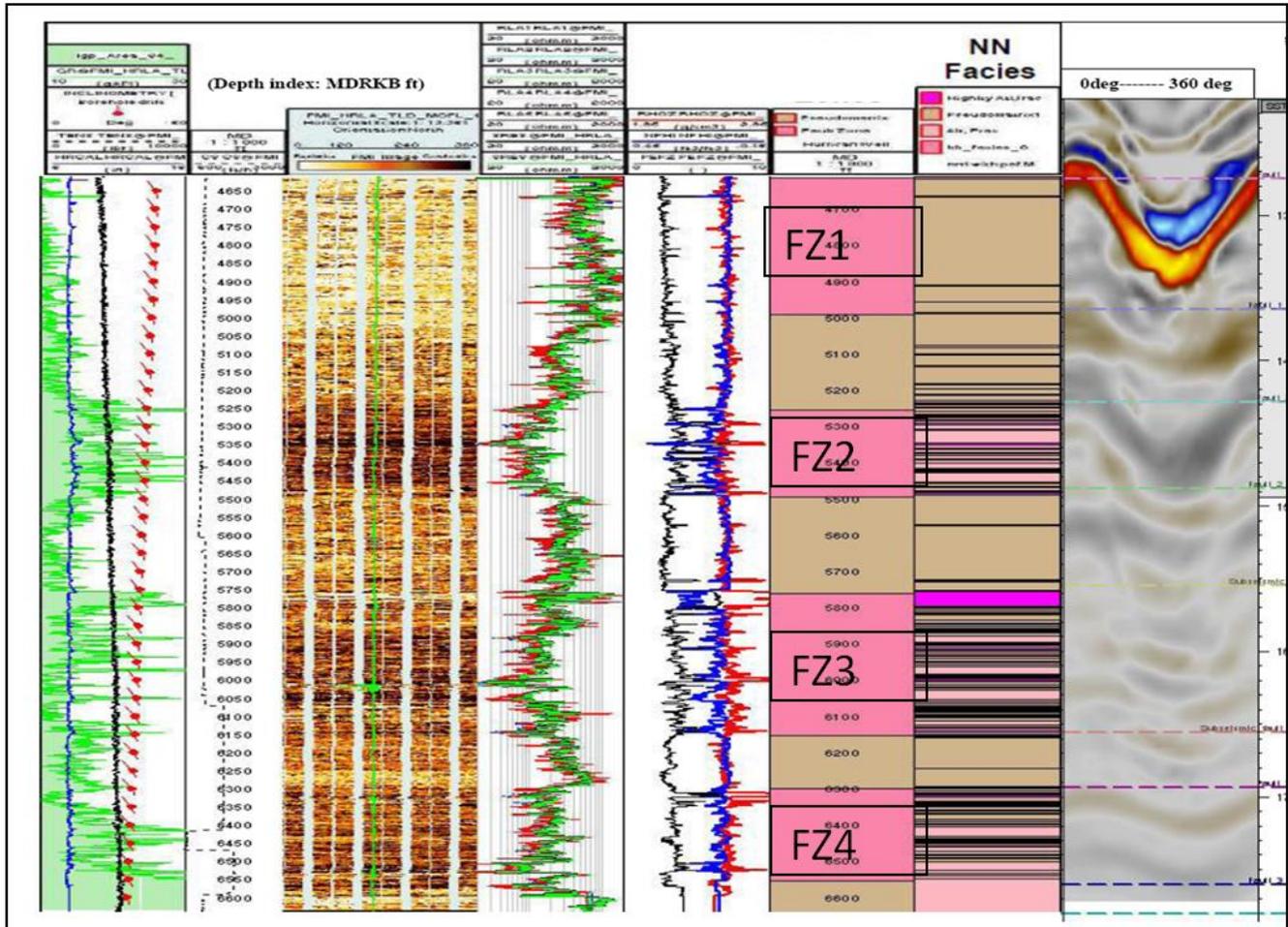


Figure 1: Wireline data acquired over the upper 4 fault zones along with the VSP image illustrating the top of the faults plane (reproduced from wireline processing and interpretation report performed by Schlumberger).

The VSP data were further processed using shear wave splitting analysis and complex imaging using the General Interferometric Migration (GIM) approach. The shear wave splitting analysis allowed fracture orientations to be determined with depth, in the basement. The main fracture directions identified through this analysis correlated with the strike direction of Fault Zone 1 and Fault Zone 2. The fracture orientation information obtained by this analysis may be interpreted in terms of the internal architecture of the fault zone (Figure 2) which may have significance in terms of flow properties within the fault zones.

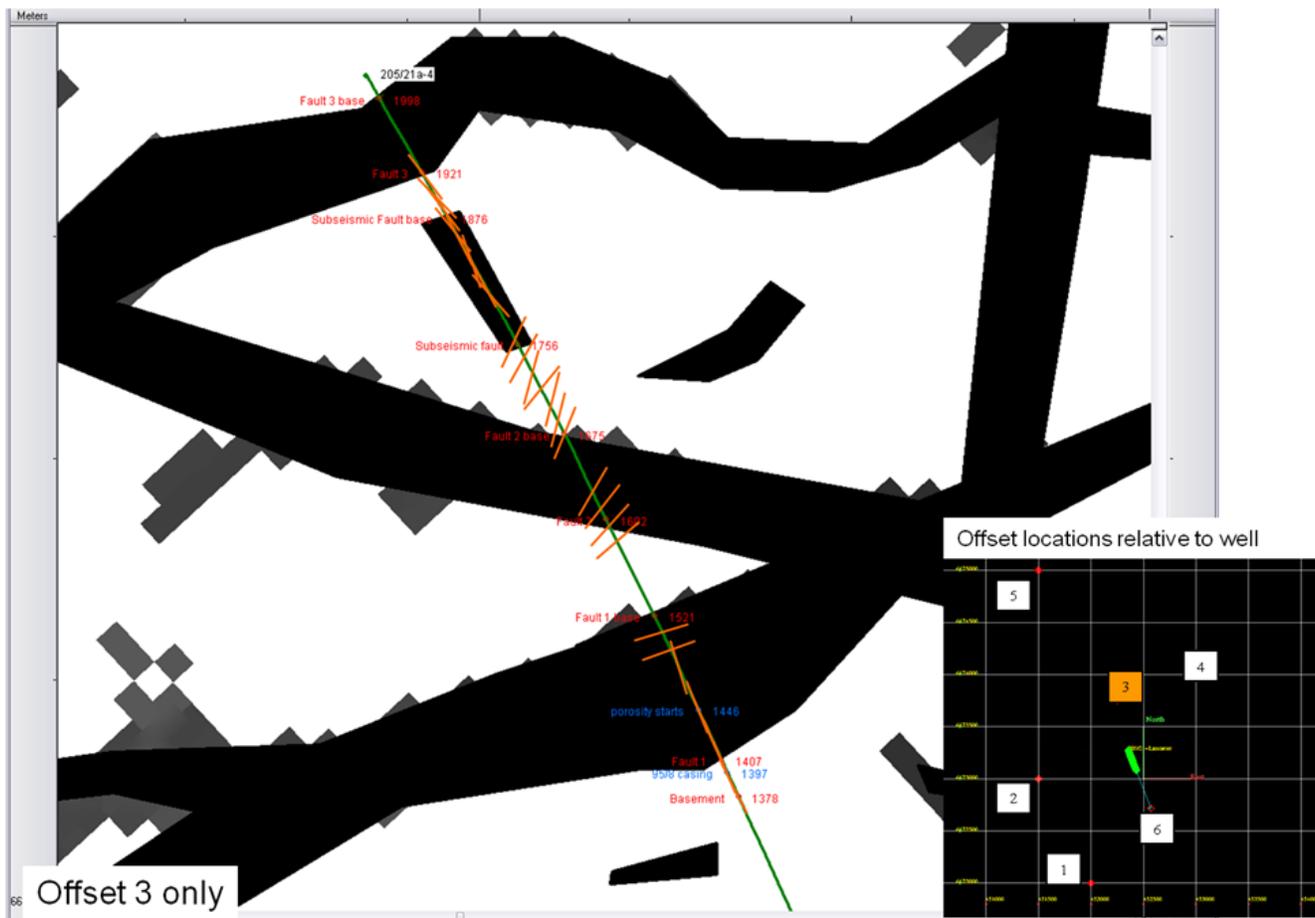


Figure 2: Integration of VSP imaged fractures, shown overlying the wellbore trace (green) with interpreted faults.

Additionally, the data were processed using advanced imaging methodologies, GIM, which allowed additional faults to be identified in the basement which had not been interpreted from the 3D seismic data. This processing allowed for fault polygons to be mapped in 3D space, with the spatial coordinates being calculated, along with the dip and dip directions.

### Case Study 2

In areas of complex geology such as fractured carbonates, which are being explored and exploited in areas such as Northern Iraq where significant topographic variations exist, the use of VSP imaging can be of considerable assistance in defining fault structures and assisting in the interpretation of the seismic data sets.

The high topographic relief of these areas can cause problems for seismic surveys with the resulting in poorer imaging and there are also areas in the seismic data that appear to have low signal to noise ratios. In this case it was unclear whether these were due to the acquisition or the presence of fracturing. The acquisition of VSP data sets allowed for the imaging of faults and fracture systems. In this example the data set consisted of a zero offset and three offset source locations. These data sets were fully processed using complex 3D imaging methodologies which allowed a number of faults and fracture systems to be identified (Figure 3) some of these features mapped into the zones of low signal

to noise ratio indicating the presence of fracturing was the cause of the poor imaging in this particular case.

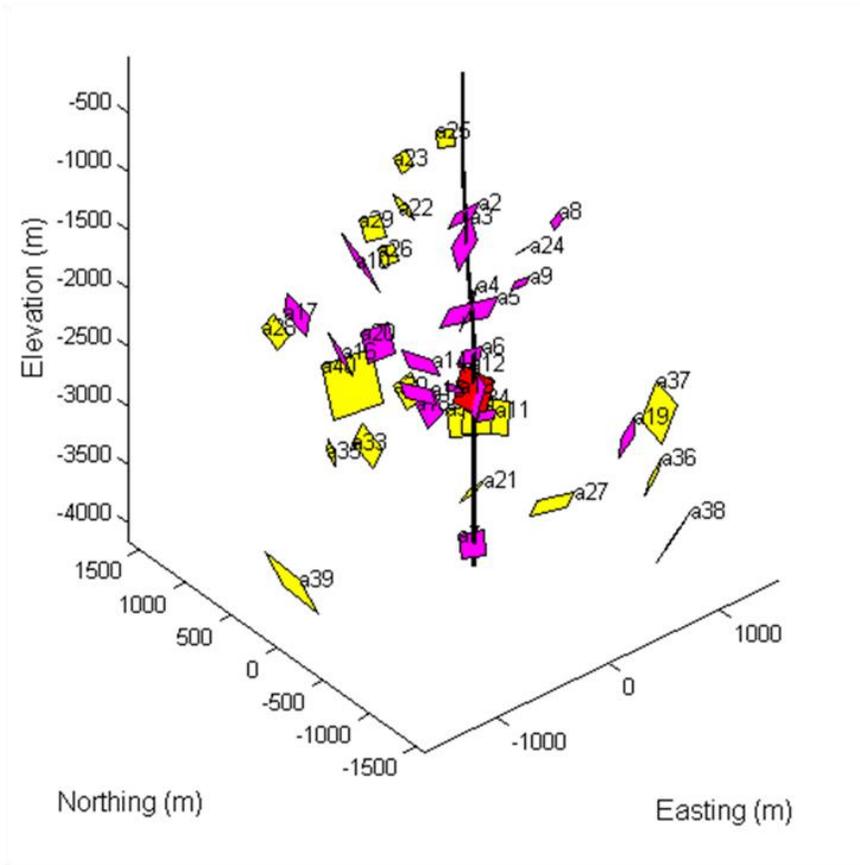


Figure 3: Reflectors imaged, using complex VSP imaging methodologies, from the zero offset data set.

These data have been loaded as fault polygons into the new 3D seismic volume and this has given confidence in the interpretation of the seismic data and have also aided in the interpretation of areas of poorer quality seismic data.

## Conclusions

The two case studies presented illustrate that a considerable amount of additional information can be determined from VSP data than is routinely obtained. In both case this has led to enhanced understanding of the subsurface and can also potentially assist in understanding flow geometries within the fault zones.

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## References

- Aguilera, R., 1995. Naturally fractured reservoirs: Tulsa, Pennwell Publishing Company, 521.
- Nelson, R. A., 2001. Geologic analysis of naturally fractured reservoirs: Boston, Gulf Publishing Company.

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