Technical Note #9

TEEC

Fracture Delineation in the Area of a Gas Storage using the CohTEEC Technology

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1. The CohTEEC Technology

This article demonstrates the impact of the detailed knowledge on the fracture system in understanding the reservoir behaviour. The study objects are the Triassic sandstone reservoirs of the aquifer gas storage at Stenlille near Copenhagen. The reservoirs are located at a depth of 1500 m. The storage is an important part of the Danish natural gas transmission system, owned and operated by DONG Naturgas A/S, and has an inventory of the order of about 1 bcm. A 3D-seismic survey of the Stenlille structure has been acquired in order to provide a reliable data basis for possible extensions of the storage. This includes an estimate of the volumetric storage potential of the structure, and an evaluation of the efficiency of the gas-water displacement in the aquifer reservoirs presently exploited. For this purpose it was decided to conduct a thorough coherence analysis by application of the CohTEEC technique, using higher order statistics and feature extraction from seismic data to improve our understanding of such reservoir type.

The CohTEEC approach consists of a number of methods and algorithms suitable for mapping lithology changes, gas (oil) - water contacts and fracture delineation (patents are pending). Multi-trace filters and other techniques are means to detect and map faults and fracture zones. These filters calculate higher order statistics of the seismic data. Simple statistics are possible but in most cases advanced measures are necessary that take neighbourhood relations into account. In the case of fractures all kind of correlation measures are of interest. This includes seismic coherency which has gained some popularity lately but many other methods exist to characterise seismic data. Pattern recognition and feature extraction are further methods to generate seismic attributes and to cope with the amount of data contained in 3D seismic surveys. Such filters are widely known from material science and medical image processing. Through such methods the orientation and length distribution of fault and fracture systems can be determined and used in building a reservoir model. All calculations can be carried out taking local dip and azimuth of the seismic events into account.

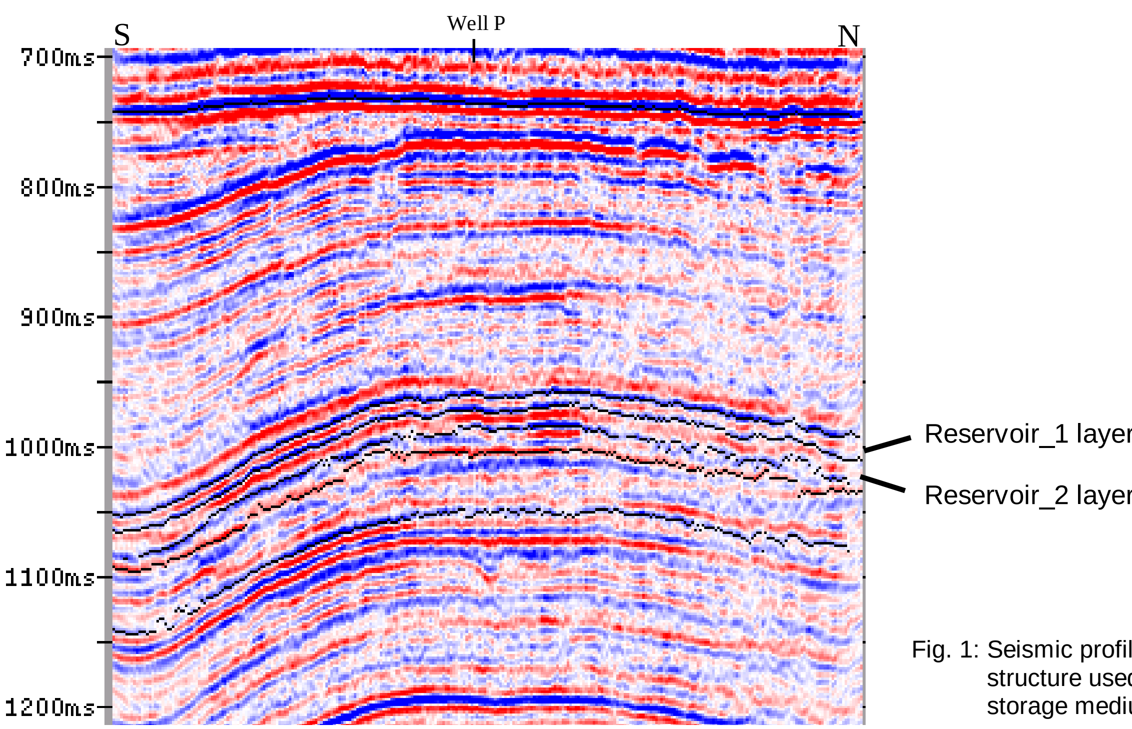


Fig. 1: Seismic profile across the structure used as a gas storage medium.

The seismic attributes are not limited to 3D post-stack data but can be applied successfully to 2D seismic data or pre-stack data. The generated attributes have to be thoroughly examined for their physical and geologic meaning to avoid misinterpretation. Well control, geologic information and production data are ways to calibrate the seismic attributes to rock properties.

2. Fracture Delineation in the Area of a Gas Storage

Fig. 1 shows a seismic random line obtained from a 3D survey recorded across a gas storage. The structural setting is mainly controlled by an anticlinal and only small indications of faulting at reservoir depth level are observed. The amplitude map of the Reservoir_1 layer is presented in Fig. 2. Note the strong amplitude anomaly in the area of the well cluster which represents the top of the structure. This anomaly is associated with the distribution of the injected gas, as has been shown by the combined investigation of AVO and inversion techniques.

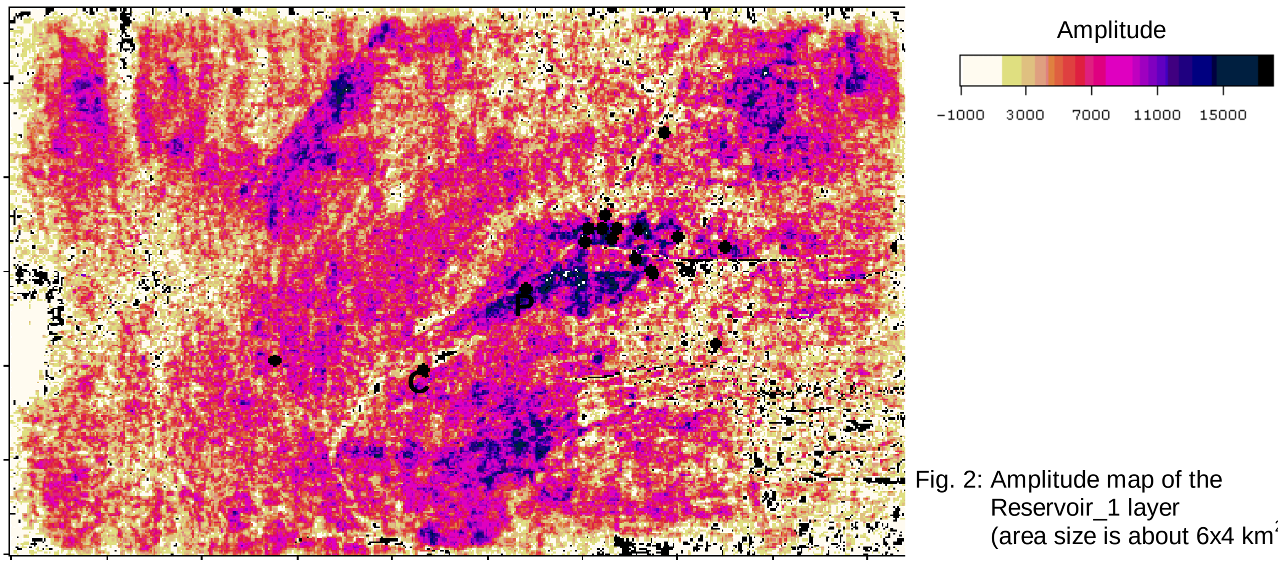


Fig. 2: Amplitude map of the Reservoir_1 layer (area size is about 6x4 km^2).

The coherence map of the Reservoir_1 layer obtained from the CohTEEC approach (Fig. 3) shows lighted regions, which are characterised by high coherence values. A high coherence means a high conformity of seismic neighbourhood traces. On the other hand low agreement is represented by the darker colours. This first attempt enables the interpreter to map a fracture pattern, which is hardly visible on conventional seismic displays. Note the SW-NE striking lineaments, especially the ones near the wells P and C. Further improvements can be achieved by taking into account local dip and azimuth information of the seismic coherence. This information has been used to create an even more detailed map of the Reservoir_1 layer (Fig. 4). While on this map the colour reflects the azimuth of the best seismic coherence, the saturation of the individual colours indicates the dip of the seismic event.

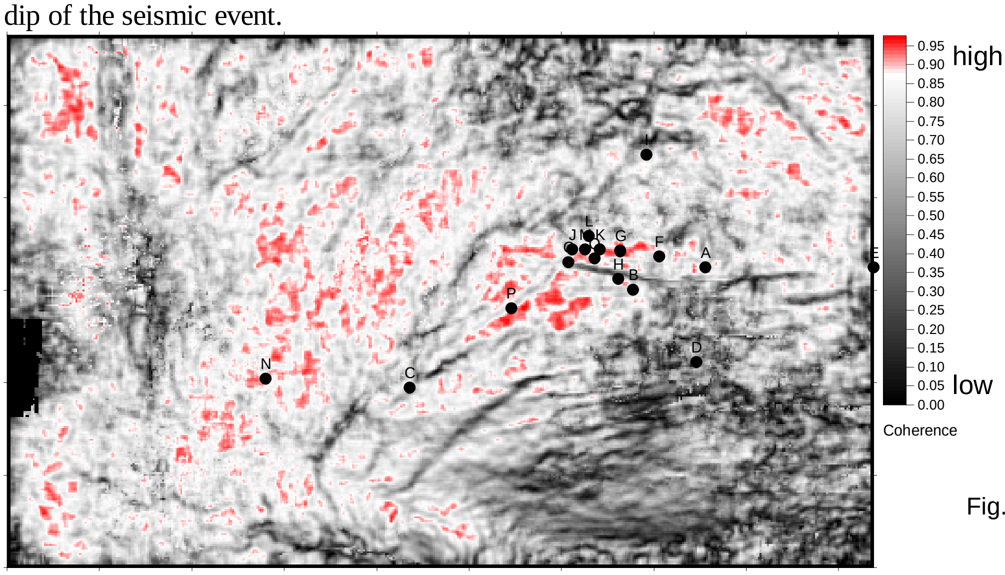
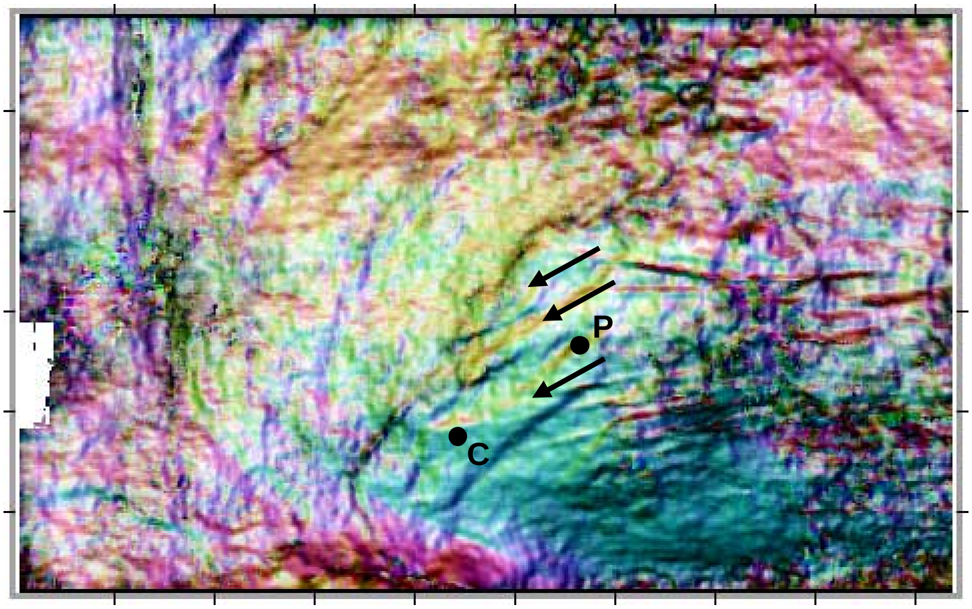


Fig. 3: Coherence map of the Reservoir_1 layer.



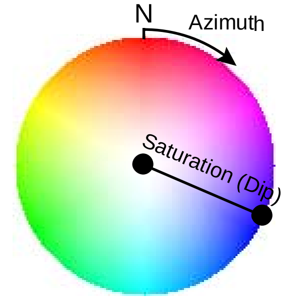
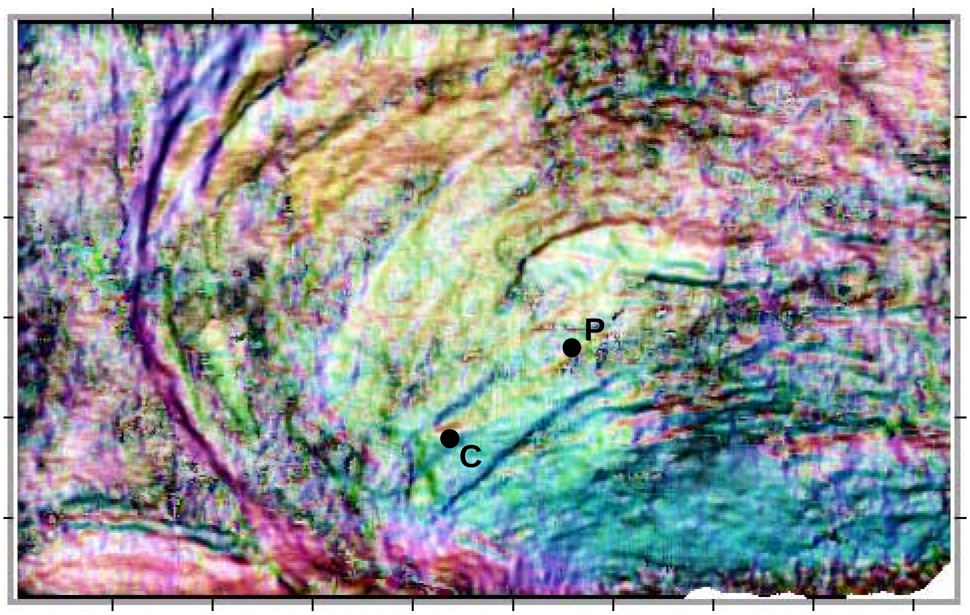


Fig. 4: Coherence map of the Reservoir_1 layer by taking into account local dip and azimuth information, arrows show the resulted pathways of the injected gas.

The analysis described above is carried out for the whole seismic volume of interest. From this volume any horizon slice or arbitrary time slice can be extracted for further analysis. Fig. 5 shows the result of the Reservoir_2 layer by taking into account coherence and local dip and azimuth. Again a subtle fracture pattern at the depth level of the reservoir becomes visible.



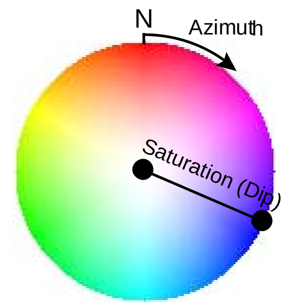
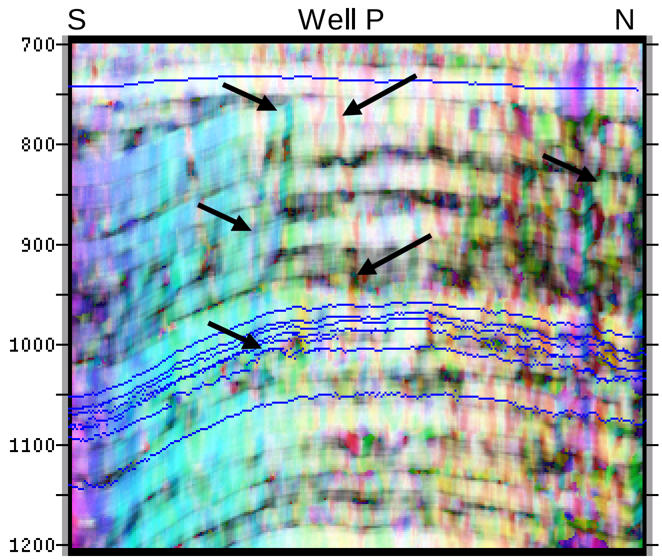


Fig. 5: Coherence map of the Reservoir_2 layer by taking into account local dip and azimuth information.

Further details of the fracture system can by extracted by vertical profiles of the 3D dataset. Fig. 6 shows the profile presented in Fig. 1 but with the CohTEEC technology being applied. On this profile the fracture system can clearly be observed. Note the fracture element near the location of well P which can be followed along the whole structure (Fig. 3-5).



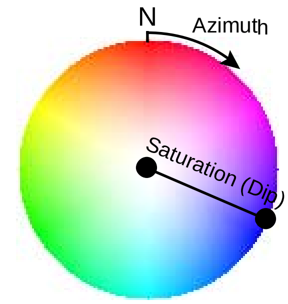
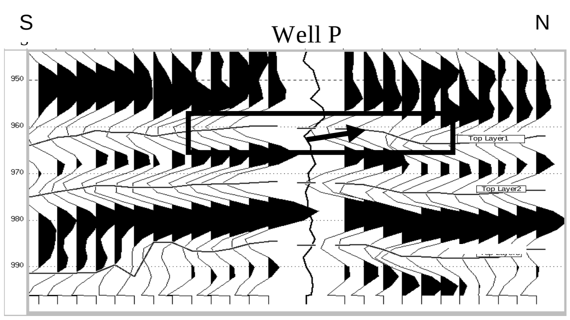


Fig. 6: Coherence profile across the structure after application of the CohTEEC technology.

3. Interpretation and Conclusion

The lineaments to be seen in the coherence maps are interpreted as fractures having a throw of typically 3-6 m (1-2 seismic samples, Fig. 7). Because this throw is in the order of the reservoir thickness a sealing effect of these lineaments has to be considered. The sealing capacity of these faults depends on the local throw of the fault in relationship to the thickness of the individual reservoir zones. In other words the fractures might act as trapping mechanism of the injected gas until the gas column reached a certain spill point (Fig. 7 bottom). In this case the injected gas is able to move into the adjacent block.

The demonstration of seismic lineaments by the CohTEEC technique, in conjunction with attributes of the inverted seismic, has provided decisive contributions to establishing the efficiency of the displacement of water by the storage gas outside of the well area. With this information DONG has been able to obtain a high reliability of the evaluation of the storage volume potential, and expects that the findings will lead to improved exploitation of the storage reservoirs already in the short term.



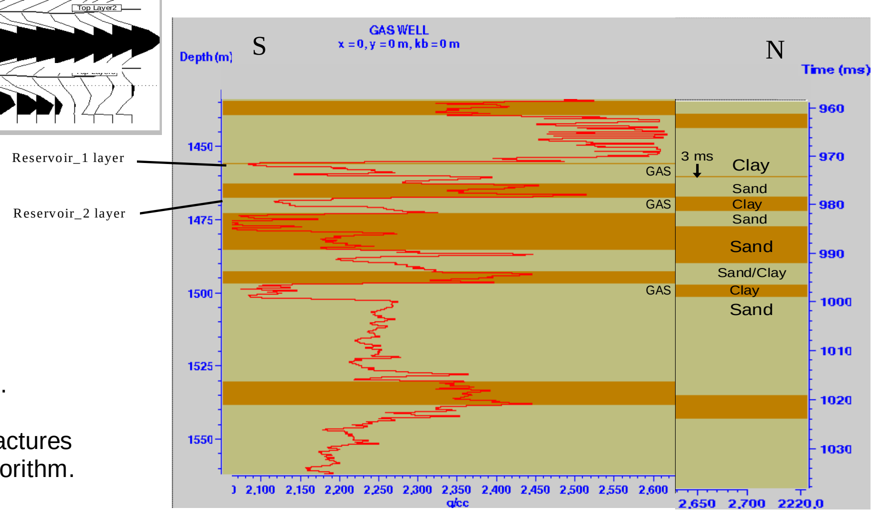


Fig. 7: top: Zoom of the seismic line presented in Fig.1 near well P.

bottom: Concept of sealing fractures detected by the CohTEEC algorithm.

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