

## RESEARCH ARTICLE

# Seismic Multiattribute Application for Porosity Distribution at F3 Block, North Sea

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## Abstract

Reservoir characterization is essential in hydrocarbon exploration to understand subsurface properties, with porosity being a key indicator of storage capacity. This study focuses on mapping porosity in the FS8 interval of the F3 Block, North Sea, using a linear multi-attribute seismic approach. Post-stack seismic and well log data from four wells were utilized. A cross-plot of acoustic impedance (AI) and porosity logs shows a strong correlation, suggesting AI can be a useful attribute in the analysis. Acoustic impedance volumes were generated through model-based inversion, and a set of seismic attributes was selected using a stepwise regression method. The selected attributes—acoustic impedance, filtered impedance, amplitude envelope, and integrated absolute amplitude—were used to predict porosity values across the seismic volume. Cross-validation shows high correlation coefficients (training: 0.861; validation: 0.824) and low prediction errors (5.2% and 5.8%, respectively), indicating robust prediction accuracy. The resulting porosity distribution map reveals a spatial trend, with higher porosity in the shallower western area and lower porosity in the deeper eastern area.

**Keywords:** Acoustic Impedance, Seismic Multiattribute, Porosity Distribution

## 1. Introduction

Reservoir characterization is a critical step in hydrocarbon exploration and production, aimed at understanding the geological characteristics and physical properties of reservoirs. One key aspect of reservoir characterization is porosity mapping, which serves as an essential indicator of hydrocarbon. In this study, reservoir characterization is carried out to map and analyzes the distribution of porosity at F3 Block, North Sea, particularly in the FS8 interval, using seismic multiattribute method. Multiattribute analysis involves the use of multiple seismic attributes to identify and characterize subsurface features more comprehensively. The multiattribute method can be used to estimate rock porosity values using seismic attributes in a linear or nonlinear approach. This study uses a multiattribute linear regression method, which assumes that seismic attributes have a linear relationship with porosity. Multiattribute methods provide significant improvements in characterization resolution and reservoir accuracy (Russell et al., 1997).

## 2. Geological Setting

The F3 Block is located in the North Sea, Netherlands. In this block, the Nederlandse Aardolie Maatschappij (NAM) company conducted 3D seismic acquisition for oil and gas exploration in 1971. At a depth greater than 1,200 msec, reflectors from the Miocene to Pleistocene eras are observed. The significant dominance of sigmoidal bedding geometry indicates that the depositional system is fluvio-deltaic on a large scale, with sediment sources originating from the Baltic Sea region.

The stratigraphy of the North Sea is divided into three geological eras: Paleozoic, Mesozoic, and Cenozoic. This research focuses on a rock formation known as the North Sea Group, which formed during the Tertiary and Quaternary periods. The North Sea Group consists of three sub-formations: Lower North Sea (Paleogene), Middle North Sea (Paleogene), and Upper North Sea (Neogene). The interest zone is in the Upper North Sea Group, which is a gas-bearing reservoir, and the formation consists of claystone, fine-to coarse-grained sandstone with gravel, and layers of brown coal. (Sorensen et al., 1997; Overeem et al., 2001).

## 3. Data and Methods

### 3.1 Seismic and Well Data

The data used in this study consists of 3D post-stack seismic data and four wells: F02-1, F03-2, F03-4, and F06-1 (Figure 1). The seismic data cover inline numbers ranging from 100 to 750 and crossline numbers from 300 to 1,250 with the line spacing for both is 25 m. The seismic data has zero phase, normal SEG polarity, and a sample rate of 4 msec. Figure 2 shows the seismic line crossing the locations of four wells. The well data includes top marker information, checkshot surveys, and log measurements. Figure 3 shows the example of well log for F02-1 well. The interest zone is FS8 to FS7 interval in the Upper North Sea Group. Only wells F02-1 and F03-2 have measured density logs. The density log for F03-4 and F06-1 were estimated using the neural network method based on sonic, gamma ray, and available density log from other wells.

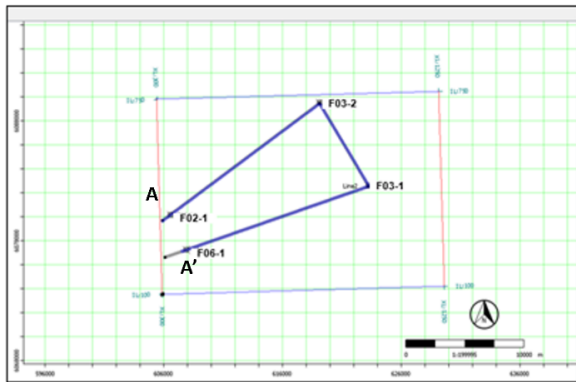


Fig 1. Base map of study area

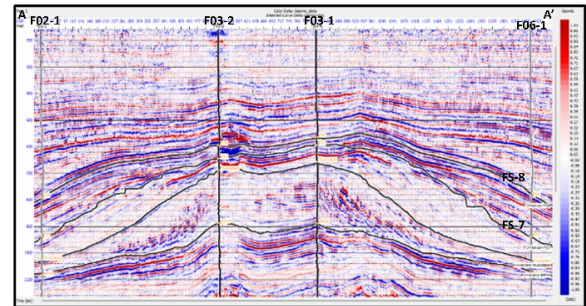


Fig 2. Seismic line at line A-A'

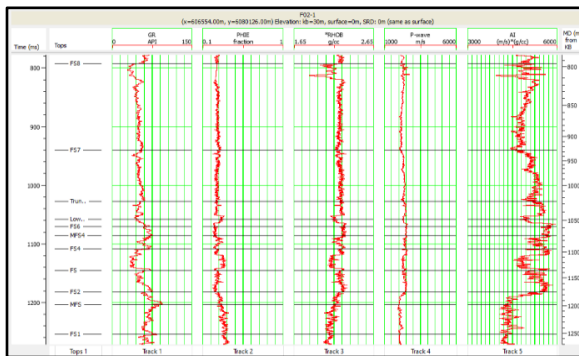


Fig 3. F02-1 Well Log

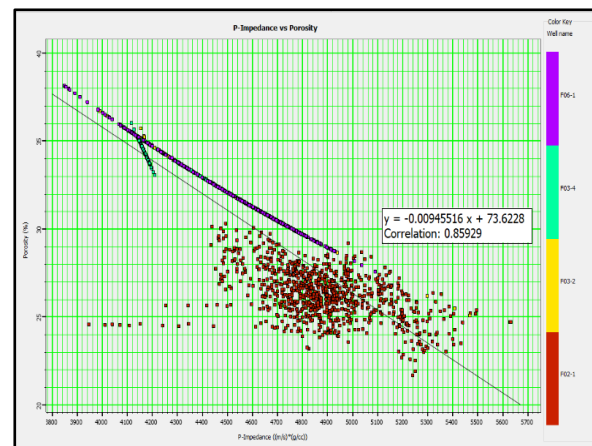


Fig 4. Crossplot between P-Impedance and Porosity

### 3.2 Methods

One of the seismic attributes widely used in reservoir characterization is acoustic impedance, which is obtained through post-stack seismic inversion. In this study, the acoustic impedance volume is generated using a model-based inversion method, based on the Generalized Linear Inversion (GLI) algorithm. The initial step involves creating an initial acoustic impedance model. The next step is to compare the synthetic data generated from the initial model with the seismic data and calculate the error. This process is repeated by modifying the model over a specified number of iterations until the minimum error is achieved (Russell, 1988).

Multi-attribute analysis involves using various seismic attributes to identify and characterize subsurface features more comprehensively. Multi-attribute method can be used to estimate rock porosity values from seismic attributes using both linear and non-linear approaches (Hampson et al., 2001). To evaluate the reliability of the derived multi-attribute transform, cross-validation is performed. In this approach, each well is systematically excluded from the training set, and the transform is recalculated using the remaining wells. The prediction error for the excluded (hidden) well is then computed. The validation error,

defined as the average prediction error across all hidden wells, serves as an estimate of the expected prediction error when the transform is applied to the entire seismic volume. In this study, multi-attribute analysis uses a linear approach, and attribute selection is based on the stepwise regression procedure (Draper and Smith, 1966). Stepwise regression is an iterative procedure for selecting the best combination of attributes by progressively adding one attribute at a time based on the lowest prediction error, assuming that previously selected attributes remain in the set.

### 4. Results

#### 4.1 Log and Crossplot Analysis

Log analysis was performed on all four wells within the FS8 interval. Each well shows low gamma ray values, ranging from 50 to 75 API, porosity values, ranging from 27% to 33%; and low acoustic impedance values, ranging from 3,600 to 5,600 (m/s)\*(gr/cc). The average thickness of the FS8 interval is 66 m.

Crossplot analysis was conducted for the four wells in the FS8 interval, with log impedance on the x-axis and porosity on the y-axis, resulting in a correlation coefficient of 0.859, as shown in Figure 4. In the crossplot, there is a

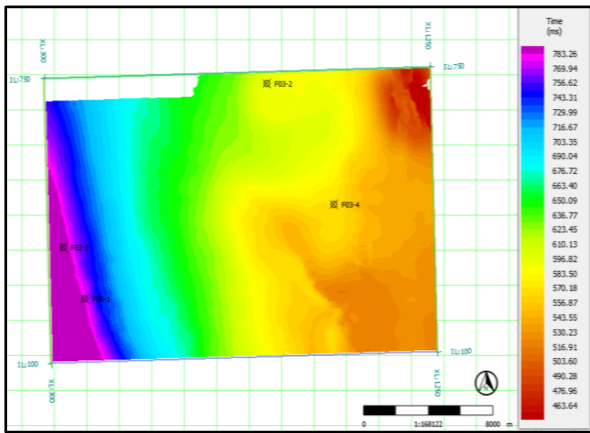


Fig 5. Time Structure Map of FS8

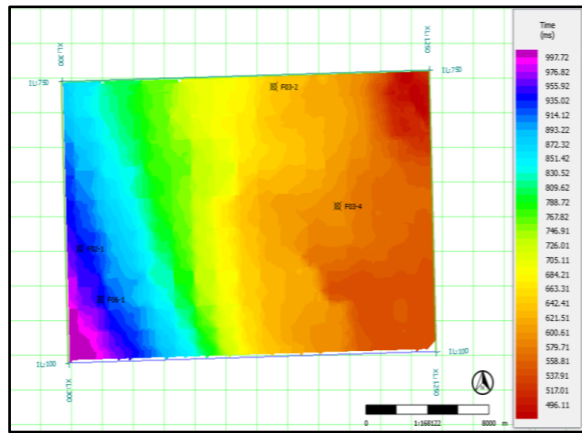


Fig 6. Time Structure Map of FS7

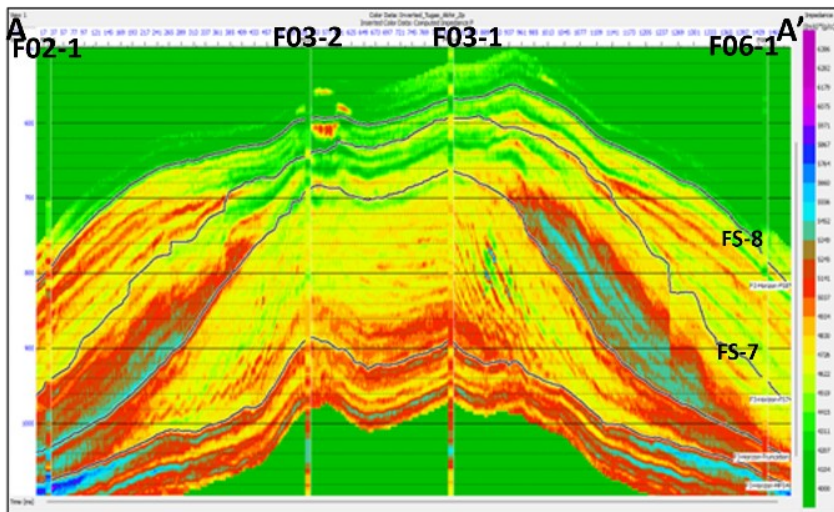


Fig 7. Acoustic Impedance from inversion on Arbitrary Line

linear line which is attributed to the fact that the density logs in wells F03-4 and F06-1 were predicted using the density logs from the other two wells, while the porosity logs were derived from the predicted density logs. Based on this analysis, porosity distribution in this area cannot be reliably estimated using only the impedance-porosity relationship. Therefore, a multiattribute method is employed, as it incorporates additional seismic attributes to improve porosity prediction.

#### 4.2 Time Structure Map

Figure 5 and Figure 6 show the FS8 and FS7 time structure maps. A time structure map represents the subsurface in the time domain. The maps show that wells F03-2 and F03-4 are located in a high structural area, indicated by lower two-way travel times, while wells F02-1 and F06-1 are situated in a low structural area, indicated by higher two-way travel times.

#### 4.3 Model Based Inversion Result

The model-based inversion method aims to obtain an acoustic impedance volume that best matches the measured seismic data with the smallest possible error.

Figure 7 shows the acoustic impedance section along an arbitrary line generated from the model-based inversion. In the FS8-FS7 interval where hydrocarbons are indicated, the impedance values are low, ranging from approximately 4,000 (m/s)\*(gr/cc) to 5,245 (m/s)\*(gr/cc). At a depth of 750 ms, a high impedance is observed, which is also consistent with the log data. The correlation between impedance log and impedance from inversion at well location is 0.86. Therefore, the impedance inversion results most likely represent the actual geological conditions

#### 4.4 Multiattribute Method

This study uses a linear multiattribute method consisting of external and internal seismic attributes. The external attribute is acoustic impedance derived from model-based inversion, while the internal attributes are extracted directly from seismic data. The target property is porosity volume. The selection of the optimal seismic attribute group is based on the prediction error and validation error values.

Table 1. Correlation and Error Seismic Attributes

Target	Attribute	Training Correlation	Training Error	Validation Correlation	Validation Error
Porosity	Acoustic impedance from inversion	0.981	0.019	0.980	0.020
Porosity	Filter from acoustic impedance from inversion	0.983	0.017	0.982	0.018
Porosity	Amplitude Envelope from inversion	0.984	0.016	0.983	0.017
Porosity	Integrated Absolute Amplitude from inversion	0.985	0.015	0.983	0.017

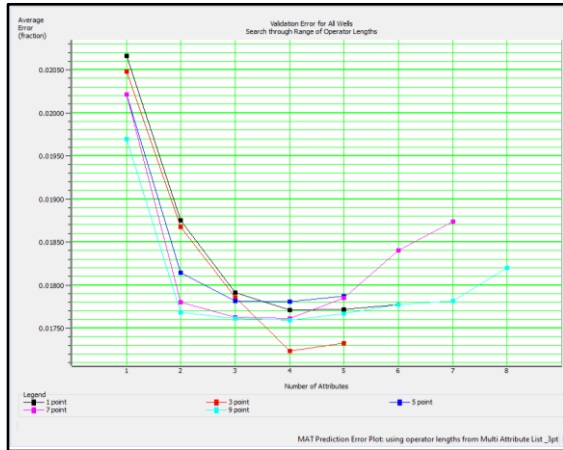


Fig 8. Multiattribute error validation curve

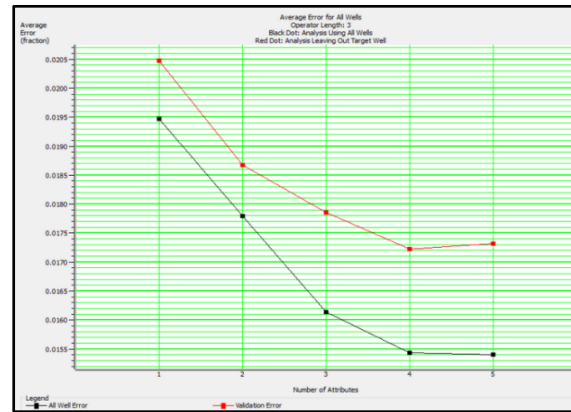


Fig 9. Average error for all wells

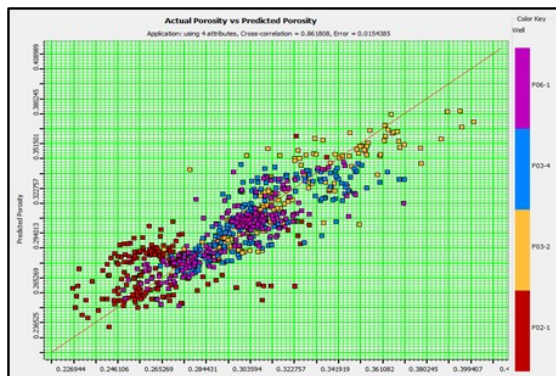


Fig 10. Log Porosity vs Predicted Porosity Crossplot

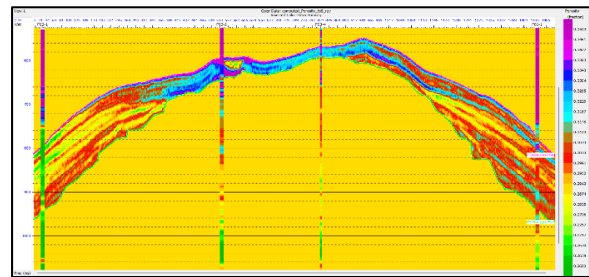


Fig 11. Porosity from Multiattribute

**Figure 8** shows the validation error curves. According to the curve, the minimum error occurs at an operator length of three with four attributes. The average error across all wells for this operator length also indicates that the lowest error is achieved using four attributes, while adding a fifth attribute increases the error (**Figure 9**). The four selected attributes are listed in **Table 1** and all of them is attribute of acoustic impedance from inversion process. They are acoustic impedance, filtered acoustic impedance, amplitude envelope of the acoustic impedance, and integrated absolute amplitude of the acoustic impedance.

**Figure 10** shows a crossplot of the porosity log against the porosity predicted using the multi-attribute method, showing a good correlation coefficient of 0.861. The training result shows correlation of 0.861 and 5.2% error.

Meanwhile validation result shows correlation of 0.824 and 5.8% error. Given the good correlation and low error from the multi-attribute analysis, the generation of the porosity volume using the selected attributes is able to provide accurate results.

The multiattribute results for the four wells are shown in **Figure 11**. The estimated porosity values range from 26% to 35%. In the vicinity of F02-1, porosity values are approximately 29% to 30%; around F03-2, they range from 32% to 35%; near F03-4, from 31% to 35%; and in the area surrounding well F06-1, from 30% to 31%. At a depth of 750 ms, zones of low porosity are observed. Previous analysis that this zone corresponds to high acoustic impedance.

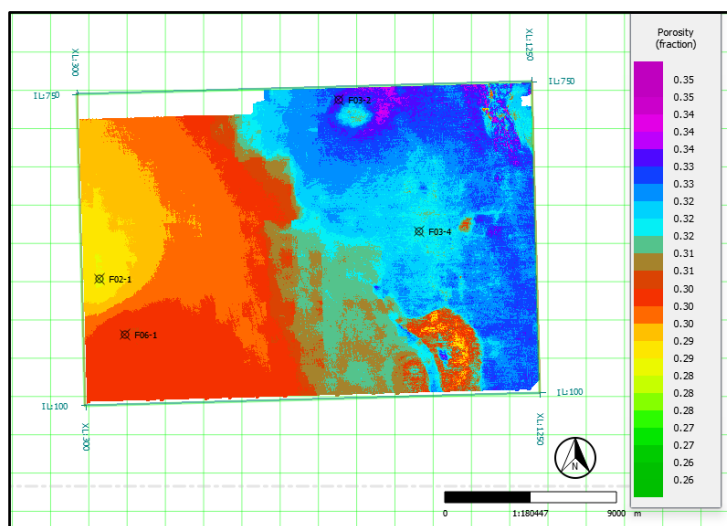


Fig 12. Porosity Distribution Map at FS8 interval

**Figure 12** shows the porosity distribution map derived from the multiattribute results for the FS8 intervals. The map shows that wells F02-1 and F06-1, located in the eastern part of the study area, have low porosity values of around 29% to 31%, while wells F03-2 and F03-4, located in the western part, have higher porosity.

## 5. Conclusion

This study demonstrates the effectiveness of a linear multi-attribute seismic approach for porosity estimation in the FS8 interval of the F3 Block, North Sea. By incorporating acoustic impedance derived from model-based inversion, the multi-attribute method achieved reliable porosity predictions. Cross-validation results show strong correlations (training: 0.861; validation: 0.824) and low prediction errors (5.2% and 5.8%, respectively), indicating that the selected attributes provide an accurate representation of porosity distribution. The resulting porosity volume shows spatial variation, with higher porosity values observed in the western part of the study area (around wells F03-2 and F03-4), and lower values in the eastern part (wells F02-1 and F06-1). This is likely due to the eastern area being at a shallower depth than the western area, resulting in higher porosity.

## Data availability

The data that are used in this study are openly available in OpendTect format on the dGB Open Seismic Repository via TerraNubis portal terranubis.com.

## Acknowledgements

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