Supplementary Appendix SA

Sedimentary deformation relating to episodic seepage in the last 1.2 million years: a multi-scale seismic study from the Vestnesa Ridge, eastern Fram Strait

Frances Cooke\*, Andreia Plaza-Faverola, Stefan Bünz, Nabil Sultan, Hariharan Ramachandran, Heather Bedle, Henry Patton, Sunny Singhroha and Jochen Knies

**\* Correspondence:** Corresponding Author: frances.a.cooke@uit.no

**SA1** **Seismic discontinuity attributes**

*Coherence*

# Coherence is a measure of similarity between adjacent waveforms or traces. It is commonly referred to as a discontinuity attribute, one that can aid in edge detection and varies between 0 and 1 (Bahorich and Farmer, 1995), where a value of 1 would signify a high degree of similarly or coherence between the nearby waveforms. In this study we use variance which is the inverse of coherence and estimates trace-to-trace variance. High variance can suggest faults or high fracture intensity. It is amplitude invariant, therefore provides the same response in both low and high amplitude regions.

# *Curvature*

Curvature is an effective tool to detect small-scale faults and fractures, or local morphologies with low displacement that would otherwise not be possible to identify with other fault attributes such as coherency (Chopra and Marfurt, 2007). Curvature is the second derivative of the structure, therefore mathematically, it measures changes and highlights upwards or downwards concavity, ideal for this investigation. The K1 computation enhances lower frequency (long wavelength) less noisy components of the seismic data (Al-Dossary and Marfurt, 2006). The input is the inline and crossline components of dip, and the outputs are the magnitude and orientation (eigenvalue and eigenvector) of K1 (parameters in Table 1).

# SA2 Fracture density workflow

Noise removal in seismic data processing is performed primarily in the prestack domain, however coherent noise may still exist in the stacked seismic data, which overprints geological information. We condition the data (a technique also referred to as poststack processing) prior to attribute computation (i.e., M-GS destriping, and dip steered median filter) and use the conditioned seismic volume as input to the advanced attribute workflow (i.e., fracture density). Without data conditioning the quality of the attribute processing and interpretation is compromised. Here we provide more information on the geostatistical filtering (M-GS destriping), the fracture density advanced attribute workflow, variance, and K1 attributes.

The M-GS (Moving Geostatistics) destriping algorithm is based on a factorial kriging technique and is used to remove the seismic acquisition footprint. The algorithm uses as few parameters as possible and relies on an underlying variogram model composed of two structures: a signal and a noise structure in the form of stripes. The parameters required in the M-GS destriping program are footprint width (distance between acquisition footprint divided by 2), orientation and footprint type (parameters in Table 1). The output cube from the M-GS destriping is then used as input to the Principal Component Analysis (PCA) steering cube. PCA uses an eigen value decomposition to extract the direction (as a 3-component vector) of maximum amplitude changes, as the largest eigen value of the decomposition. The PCA steering cube is also median filtered (parameters in Table 1). The steering data calculated using the destriped cube is used as an input in the curvature attribute, which calculates most positive curvature. The most positive curvature cube is used as input discontinuity data in the fracture attribute program calculating a circular radius of 20 m for the fracture density. The final fracture density output cube is flattened to the seafloor after the attribute calculation. To test the validity of the fracture density attribute we compare the result with two other discontinuity attributes: variance and K1.

**Table 1.** Summary of parameters for each attribute process used in the volume calculations.

|  |  |
| --- | --- |
| **Process** | **Parameters** |
| M-GS destriping | 50 m footprint width along the inline using the structural footprint type |
| Principal component Analysis (PCA) Median Filter (MF) | 1 x 1 x 1 stepout 2 x 2 x 5 stepout |
| Most positive curvature | Dip Steered Median Filter (PCA + MF) calculated on destriped volume  Inl/Crl stepout 2, and constant velocity of 2500 m/s (default), with full steering |
| Fracture density | Calculated on most positive curvature volume |
| Variance | Plain variance (horizontal direction only), calculated on destriped volume  Inl/Crl/vertical smoothing stepout: 3 x 3 x 15 |
| Structural most positive principal curvature (K1) | Maximum operator radius: 125m (equivalent to 20x distance between two adjacent traces) Bandpass filter type: long wavelet Lambda 1 = 1881.55m Lambda 2 = 70.733m Lambda 3 = 35.3665m Lambda 4  = 17.6833m Weight 1 = 1.0 Weight 2 = 0.666 Weight 3 = 0.333 Weight 4 = 0.0 |