Visualizing anisotropy in seismic facies using stratigraphically constrained, multi-directional texture attribute analysis

AAPG Hedberg Research Conference
JUNE 1-5, 2014, HOUSTON, TEXAS, USA

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Outline

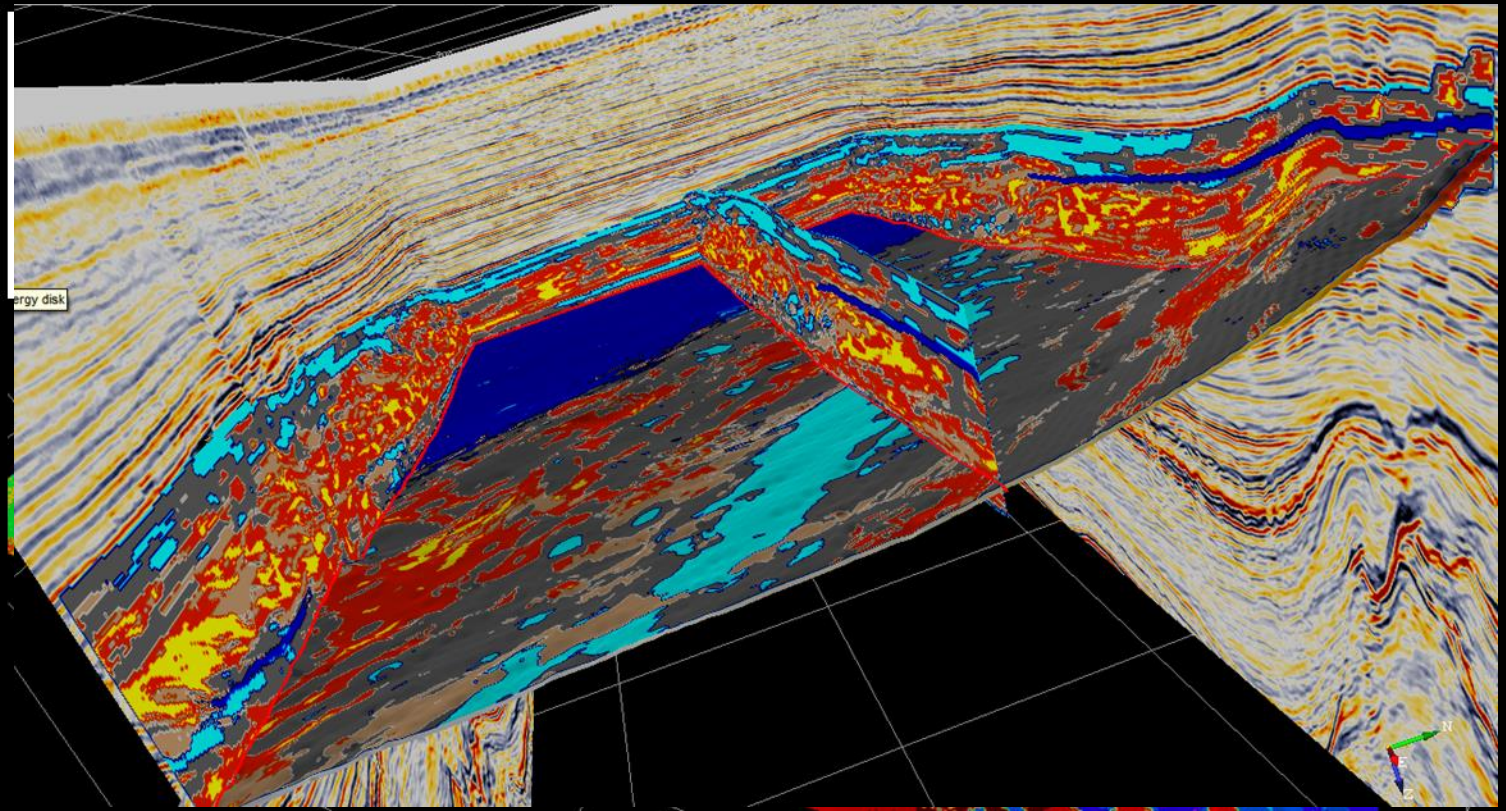
- Introduction
- What's New in this Work
- Examples
- Conclusions & Further Work

Texture Attributes

- Orginate from image processing (Haralick et al., 1973)
- Aim to describe the roughness or smoothness of an image
- Based on the **G**rey **L**evel **C**o-occurence **M**atrix (**GLCM**)
- Used in seismic facies interpretation and to highlight geo-morphological features

Example: Seismic Facies Interpretation

3D unsupervised neural network based waveform segmentation is a popular technique to visualize seismic facies. Components and **Texture Attributes** Waveforms are not suited in 3D mode.



Grey Level Co-occurrence Matrix*

Definition: The GLCM is a tabulation of how often different combinations of pixel brightness values (grey levels) occur in an image

0	0	1	1
0	0	1	1
0	2	2	2
2	2	3	3

Image

Reference pixel value

Neighbouring pixel value

	0	1	2	3
0	4	2	1	0
1	1	2	0	1
2	2	1	0	2
3	0	0	1	2

Count No of Occurrences

Nr. of Occurrences

Reference pixel value

Neighbouring pixel value

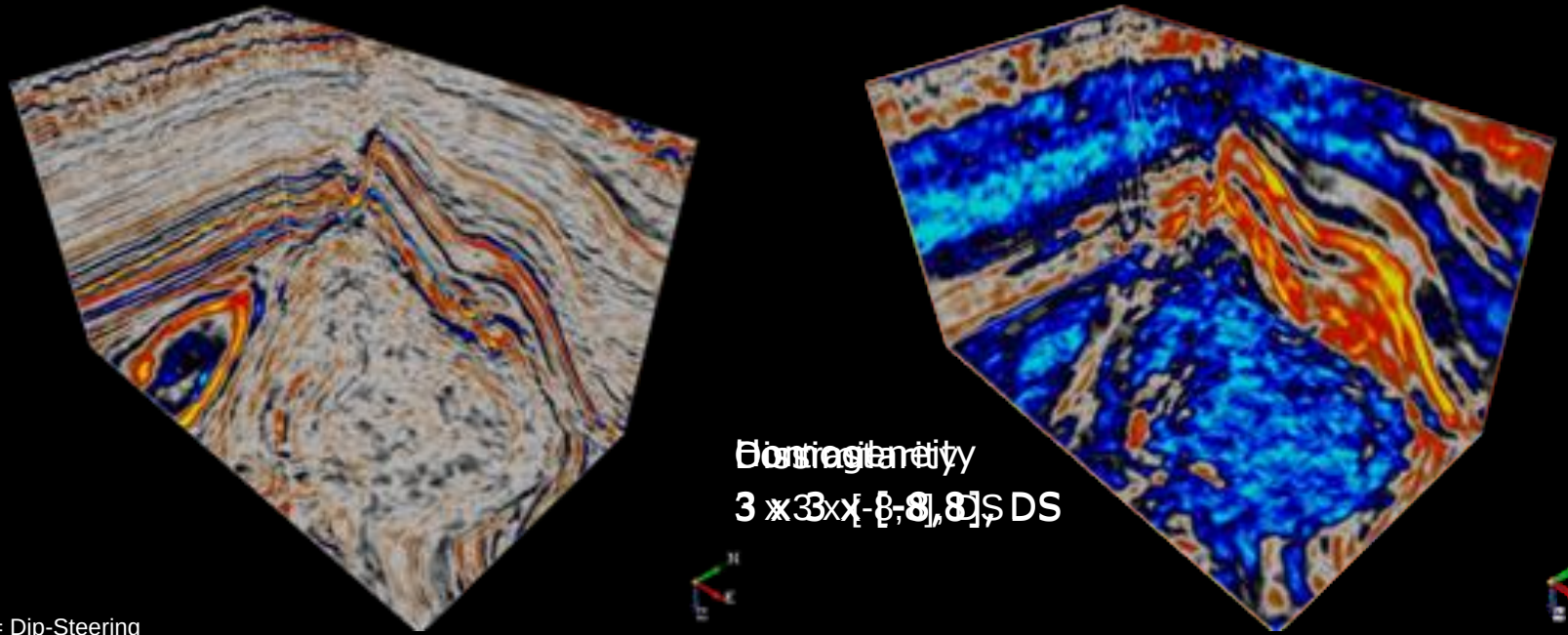
	0	1	2	3
0	0,167	0,083	0,041	0,000
1	0,083	0,167	0,000	0,000
2	0,041	0,000	0,250	0,041
3	0,000	0,000	0,041	0,083

Normalize to “probabilities”

*Adapted from Mryka Hall-Beyer's web pages: http://www.fp.ucalgary.ca/mhallbey/tutorial.htm

GLCM Texture Attributes

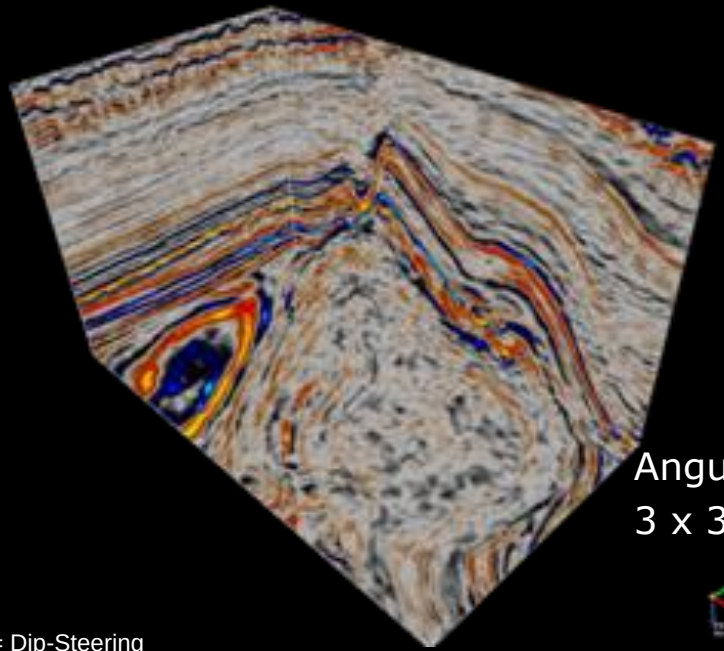
- Contrast Group
  - Measurements based on the distance from the GLCM diagonal



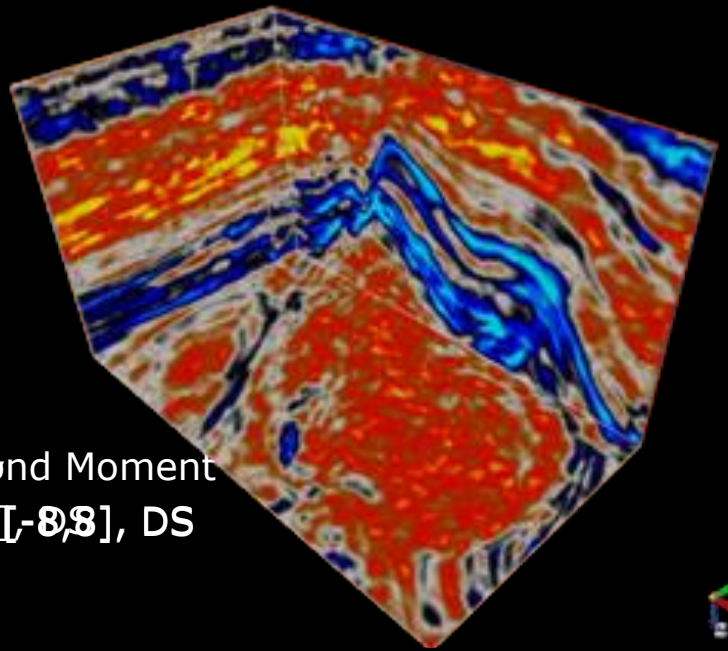
DS = Dip-Steering

GLCM Texture Attributes

- Orderliness Group
  - Measurements of how organized the GLCM is



Angular Second Moment
3 x 3 x [-8,8], DS

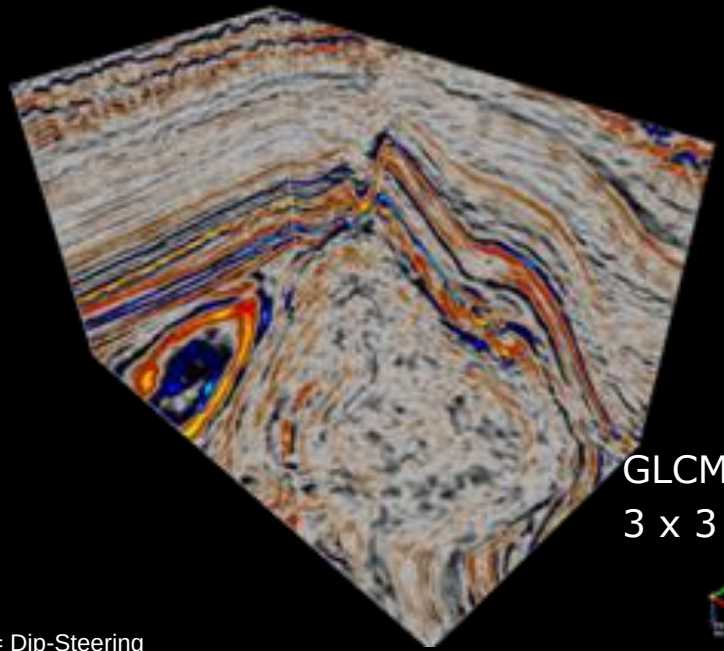


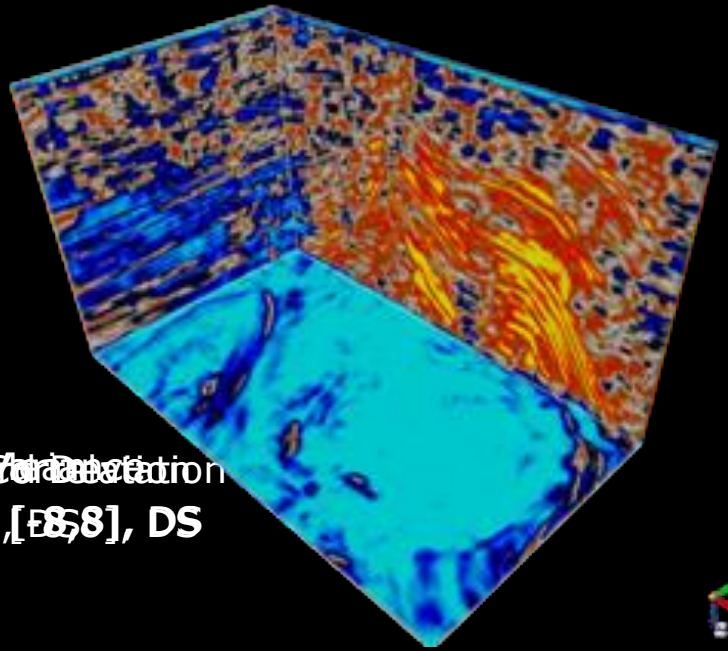
Entropy
3 x 3 x [-8,8], DS

DS = Dip-Steering

GLCM Texture Attributes

- GLCM Statistics Group
  - Standard statistical parameters computed from the GLCM





GLCM Standard Deviation
3 x 3 x 3 [8], DS

GLCM Variance
3 x 3 x 3 [8], DS

DS = Dip-Steering

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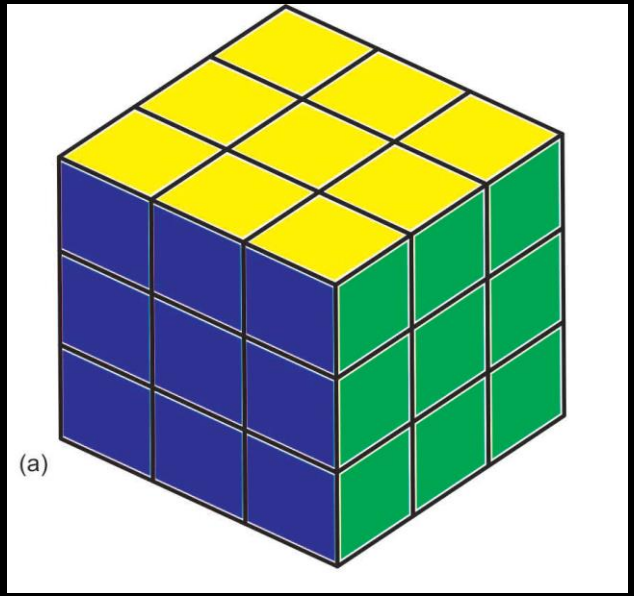
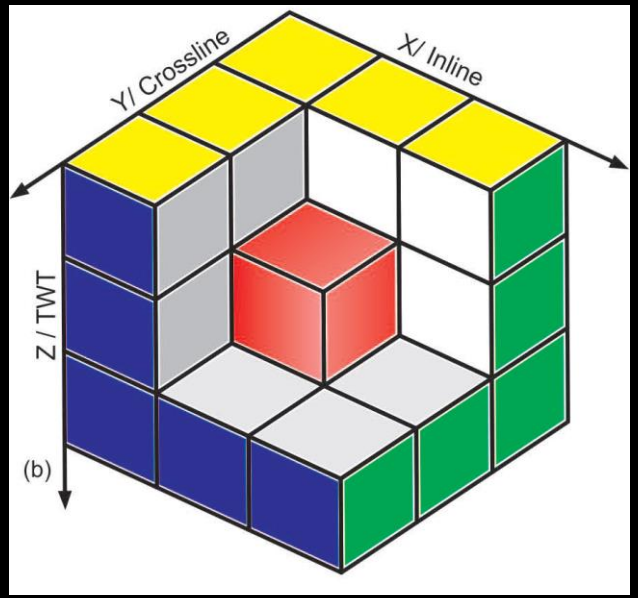
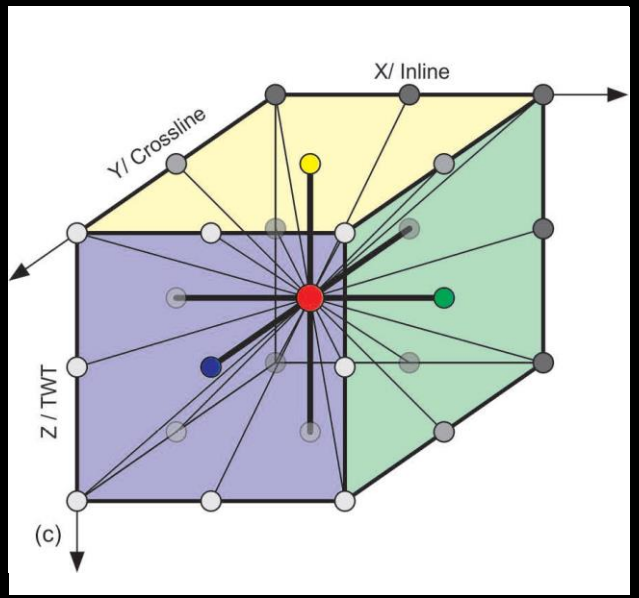
Directional Analysis

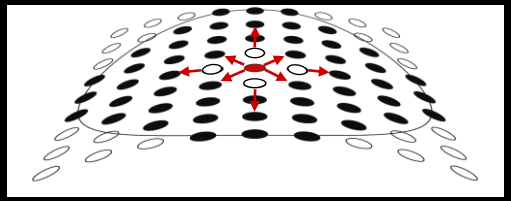
Each seismic cell has 26 neighbours allowing for 13 directions to analyze



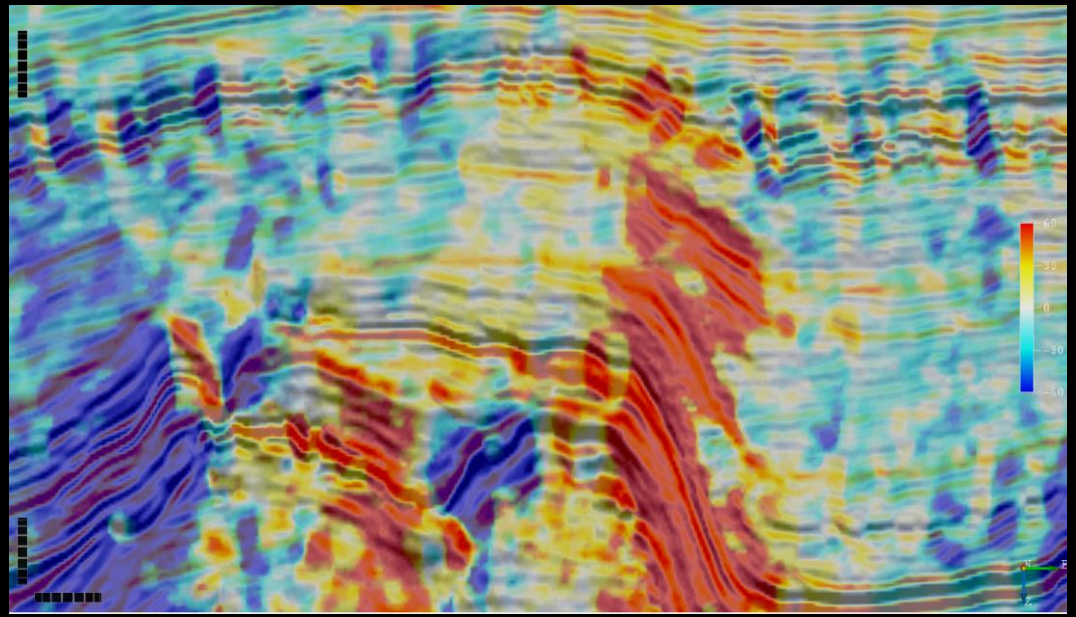




Dip-steered Analysis



Concept of dip-steering: the seismic inputs for the GLCM are extracted along a three-dimensional stratigrahic slice by following the pre-calculated dip field.



(dip-steered cube

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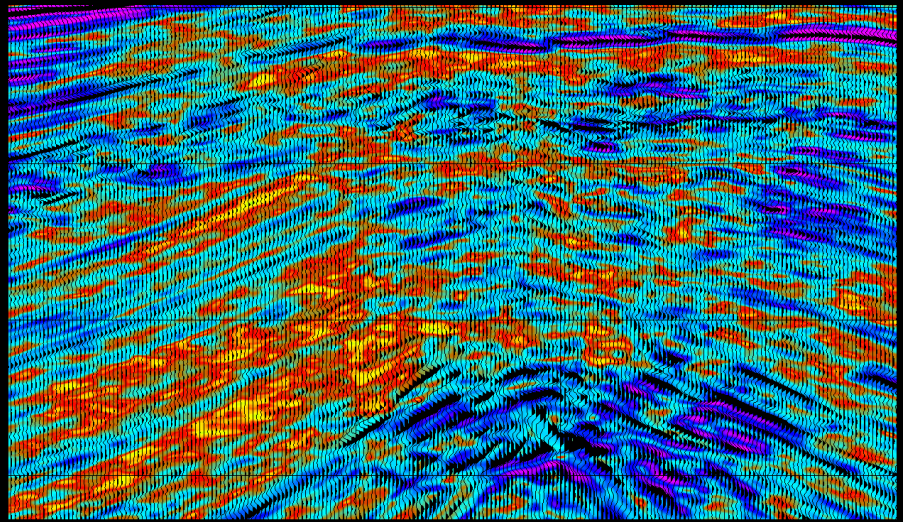
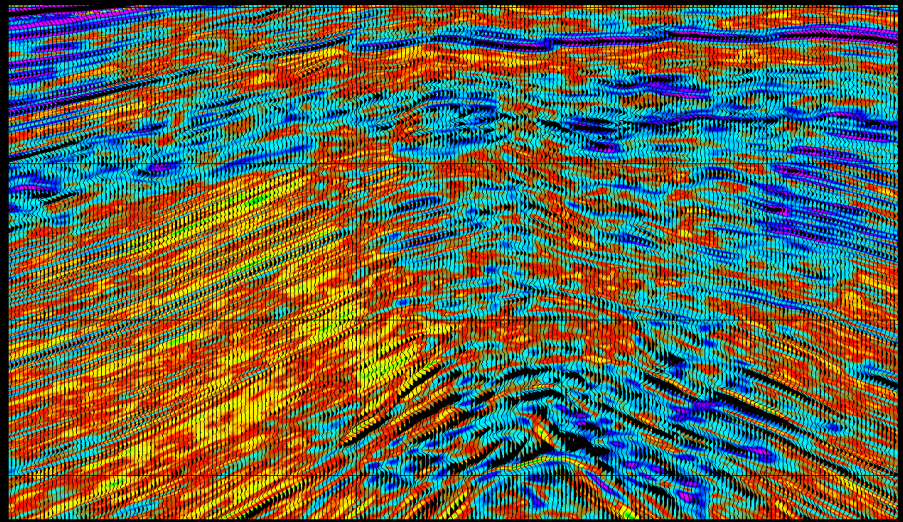
The Effect of Dip-Steering

GLCM Correlation



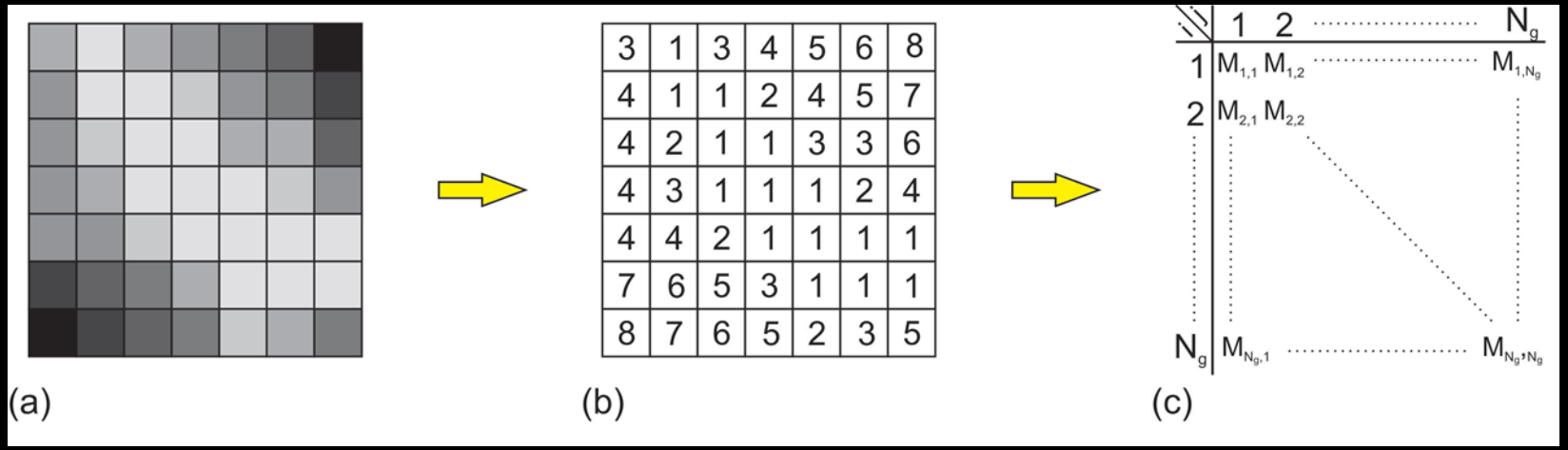
Non Dip-Steered



Dip-Steered

The Effect of Directional Analysis

Synthetic example



Grey-scale image

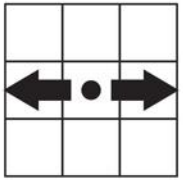
Grey-scale values

GLCM

The Effect of Directional Analysis

Synthetic example

(d)



0°

	1	2	3	4	5	6	7	8
1	18	4	4	0	0	0	0	0
2	4	0	2	4	0	0	0	0
3	6	0	2	2	2	2	0	0
4	2	4	2	2	0	0	0	0
5	0	2	2	0	0	2	2	0
6	0	0	0	0	4	0	0	2
7	0	0	0	0	0	4	0	0
8	0	0	0	0	0	0	2	0

Σ=84

	1	2	3	4	5	6	7	8
1	0.21	0.05	0.05	0.00	0.00	0.00	0.00	0.00
2	0.05	0.00	0.02	0.05	0.00	0.00	0.00	0.00
3	0.07	0.00	0.02	0.02	0.02	0.02	0.00	0.00
4	0.02	0.05	0.02	0.02	0.05	0.00	0.00	0.00
5	0.00	0.02	0.02	0.00	0.00	0.02	0.02	0.00
6	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.02
7	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00

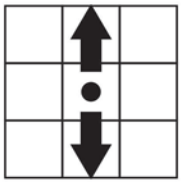
Energy:	0.077
Contrast:	1.609
Homogeneity:	0.825
Entropy:	1.270
Cluster Tend.	40.558

Horizontal Occurrences GLCM Attributes

The Effect of Directional Analysis

Synthetic example

(e)



	1	2	3	4	5	6	7	8
1	18	6	4	0	2	0	0	0
2	4	0	2	0	2	0	0	0
3	4	2	0	4	2	0	0	0
4	2	2	2	6	0	2	2	0
5	0	0	2	2	0	2	0	0
6	0	0	0	2	2	0	2	0
7	0	0	0	0	0	2	0	2
8	0	0	0	0	0	0	2	0

Σ=84

	1	2	3	4	5	6	7	8
1	0.21	0.07	0.05	0.00	0.02	0.00	0.00	0.00
2	0.05	0.00	0.02	0.00	0.02	0.00	0.00	0.00
3	0.05	0.02	0.00	0.05	0.02	0.00	0.00	0.00
4	0.02	0.02	0.02	0.07	0.00	0.02	0.02	0.00
5	0.00	0.00	0.02	0.02	0.00	0.02	0.00	0.00
6	0.00	0.00	0.00	0.02	0.02	0.00	0.02	0.00
7	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.02
8	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00

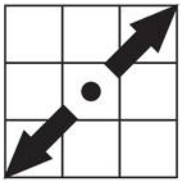
Energy:	0.076
Contrast:	2.128
Homogeneity:	0.806
Entropy:	1.293
Cluster Tend.	42.982

Vertical Occurrences GLCM Attributes

The Effect of Directional Analysis

Synthetic example

(f)



	1	2	3	4	5	6	7	8
1	8	4	6	6	0	0	0	0
2	6	0	0	0	2	2	0	0
3	6	0	0	0	2	0	2	0
4	6	2	2	0	0	2	0	0
5	4	0	0	0	0	0	0	2
6	0	2	2	0	0	0	0	0
7	0	0	0	2	2	0	0	0
8	0	0	0	0	0	2	0	0

Σ=72

	1	2	3	4	5	6	7	8
1	0.11	0.06	0.08	0.08	0.00	0.00	0.00	0.00
2	0.08	0.00	0.00	0.00	0.03	0.03	0.00	0.00
3	0.08	0.00	0.00	0.00	0.03	0.00	0.03	0.00
4	0.08	0.03	0.03	0.00	0.00	0.03	0.00	0.00
5	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.03
6	0.00	0.03	0.03	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.03	0.03	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00

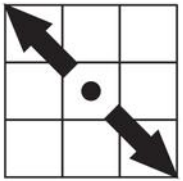
Energy:	0.063
Contrast:	4.627
Homogeneity:	0.601
Entropy:	1.257
Cluster Tend.	38.173

Diagonal 45 Occurrences GLCM Attributes

The Effect of Directional Analysis

Synthetic example

(g)



135°

	1	2	3	4	5	6	7	8
1	22	0	2	0	2	0	0	0
2	4	0	4	0	0	0	0	0
3	2	8	0	2	0	0	0	0
4	0	2	4	4	2	2	0	0
5	0	0	0	0	4	2	0	0
6	0	0	0	0	0	2	2	0
7	0	0	0	0	0	0	2	0
8	0	0	0	0	0	0	0	0

Σ=72

	1	2	3	4	5	6	7	8
1	0.31	0.00	0.03	0.00	0.03	0.00	0.00	0.00
2	0.06	0.00	0.06	0.00	0.00	0.00	0.00	0.00
3	0.03	0.11	0.00	0.03	0.00	0.00	0.00	0.00
4	0.00	0.03	0.06	0.06	0.03	0.03	0.00	0.00
5	0.00	0.00	0.00	0.00	0.06	0.03	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.03	0.03	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Energy:	0.130
Contrast:	1.390
Homogeneity:	0.887
Entropy:	1.088
Cluster Tend.	34.019

Diagonal 135 Occurrences

GLCM

Attributes

The Effect of Directional Analysis

Synthetic example

(h)

All Directions

	1	2	3	4	5	6	7	8
1	66	14	16	6	4	0	0	0
2	18	0	8	4	4	2	0	0
3	18	10	2	8	6	2	2	0
4	10	10	10	12	6	6	2	0
5	4	2	4	2	4	6	2	2
6	0	2	2	2	6	2	4	2
7	0	0	0	2	2	6	2	2
8	0	0	0	0	0	2	4	0

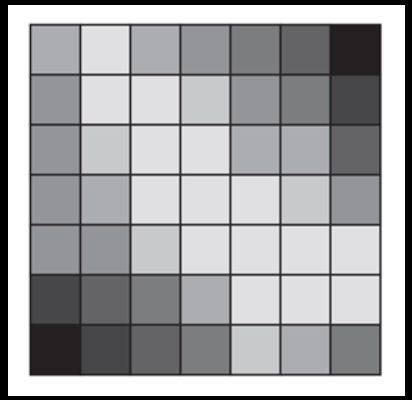
Σ=312

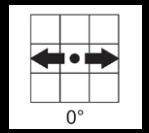
	1	2	3	4	5	6	7	8
1	0.21	0.04	0.05	0.02	0.01	0.00	0.00	0.00
2	0.06	0.00	0.03	0.01	0.01	0.01	0.00	0.00
3	0.06	0.03	0.01	0.03	0.02	0.01	0.01	0.00
4	0.03	0.03	0.03	0.04	0.02	0.02	0.01	0.00
5	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01
6	0.00	0.01	0.01	0.01	0.02	0.01	0.01	0.01
7	0.00	0.00	0.00	0.01	0.01	0.02	0.01	0.01
8	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00

Energy:	0.068
Contrast:	2.492
Homogeneity:	0.784
Entropy:	1.432
Cluster Tend.	39.077

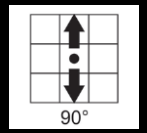
All Directions Occurrences GLCM Attributes

Lessons Learned

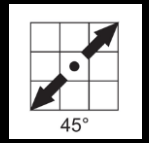




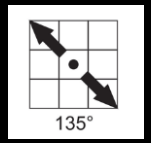
Average values for all texture attributes



Highest Cluster Tendency



Highest Contrast; Lowest Homogeneity

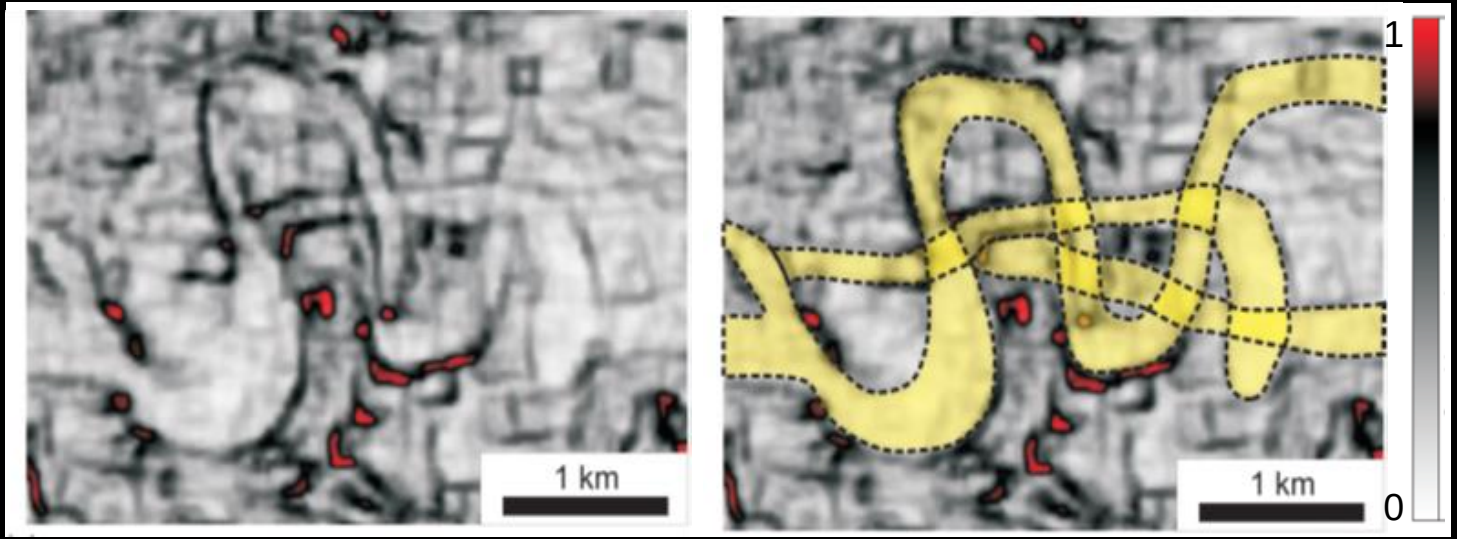


Lowest Energy; Lowest Cluster Tendency

Highest Entropy

2D Example

Channels Vienna Basin



Coherency-based Semblance

Interpretation

Energy

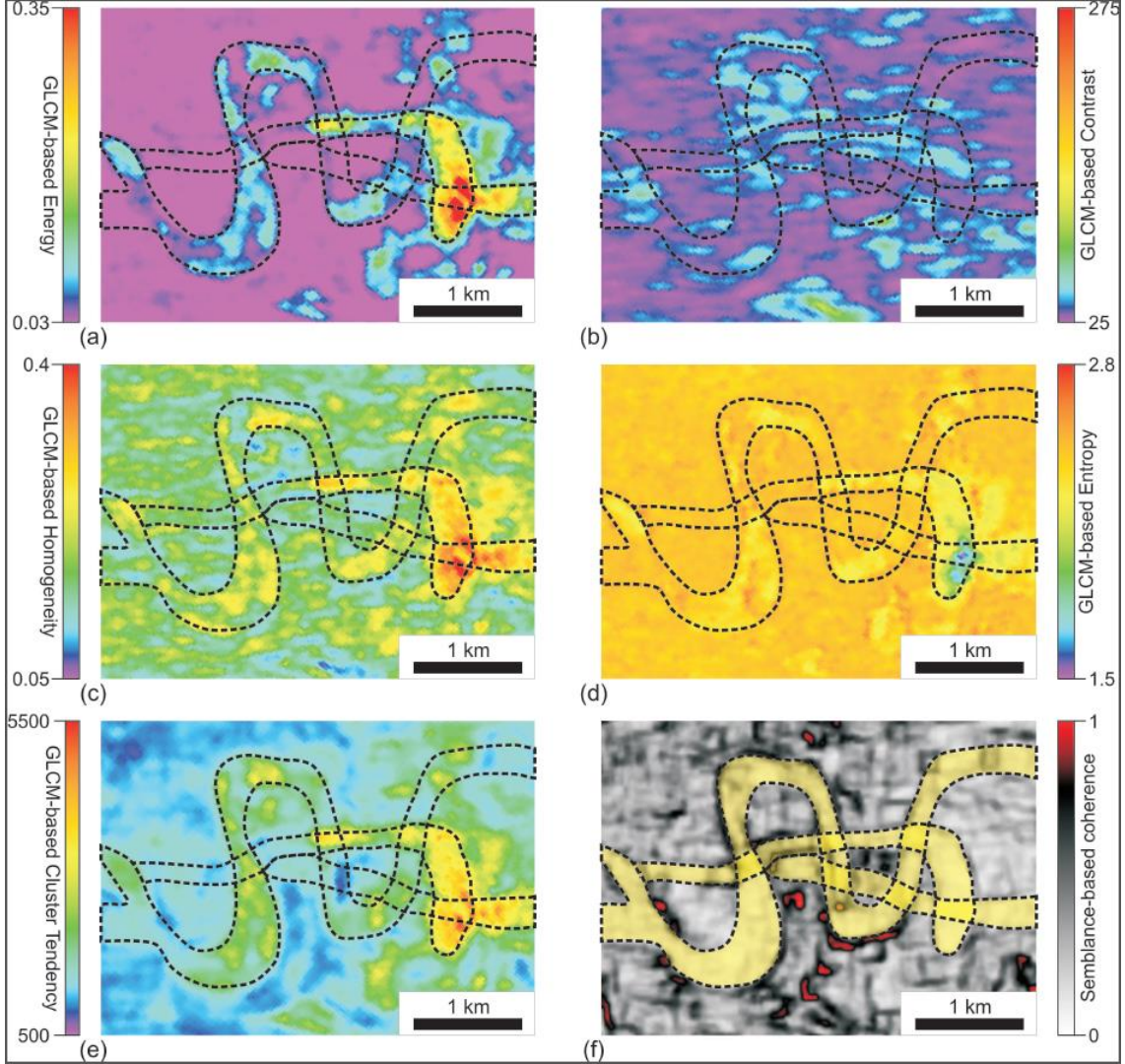
Contrast

Homogeneity

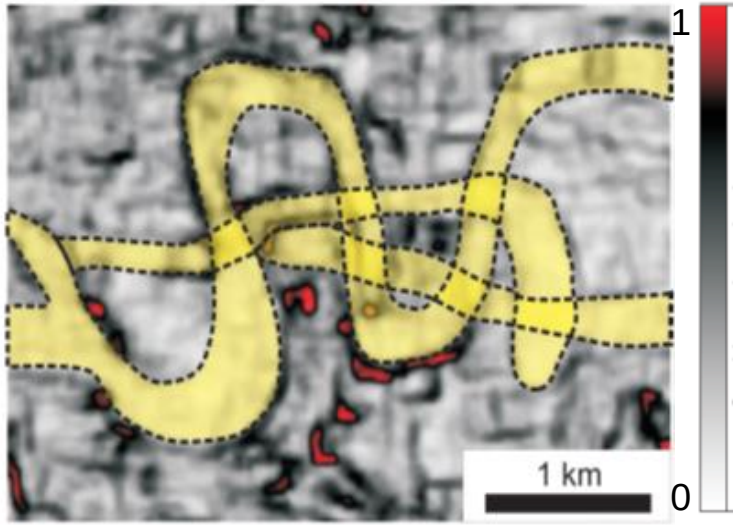
Entropy

Cluster Tendency

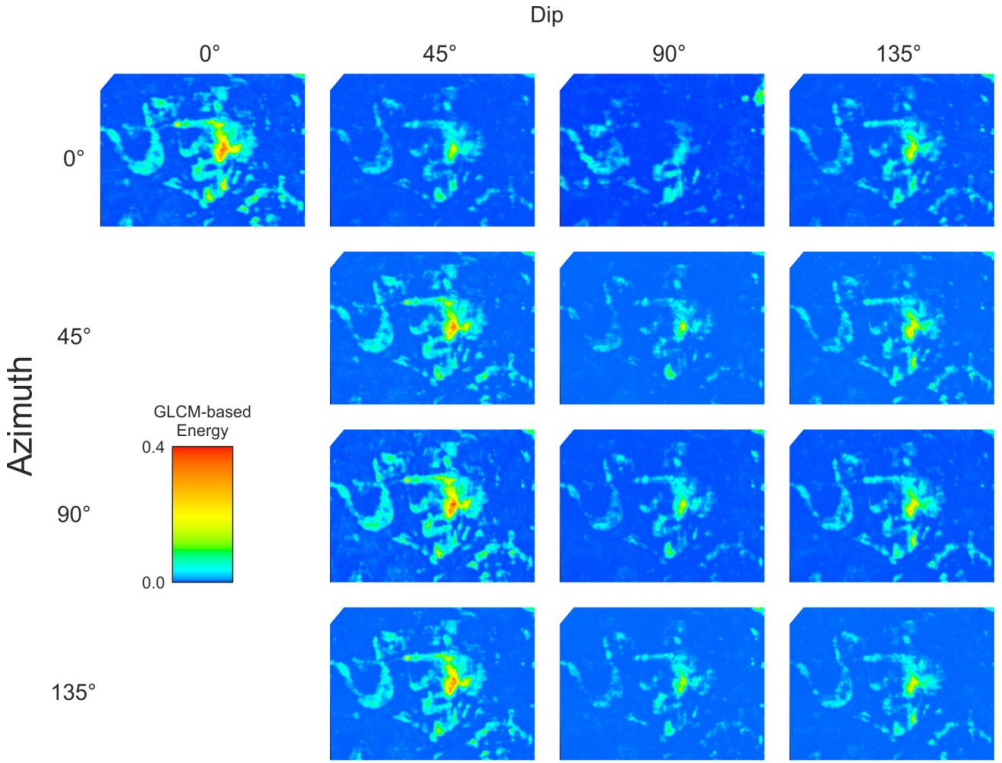
Semblance + Interpretation



Directional Energy



Semblance + Interpretation



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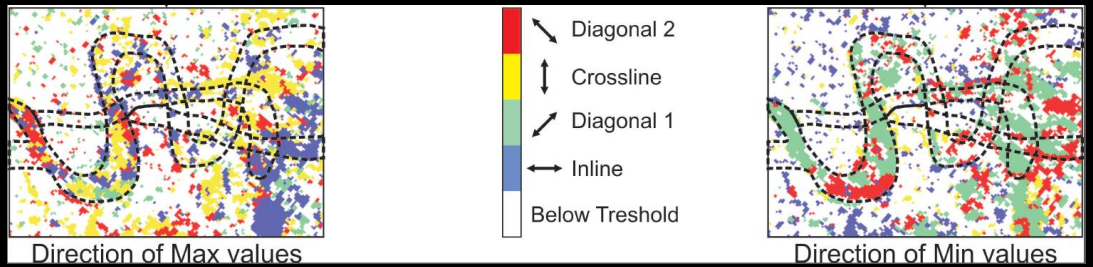
Conclusions

- Texture Attributes are making a **comeback** in seismic interpretation
- Original applications are **seismic facies** analysis and visualization of **geomorphological** features
- **Dip-Steering** constrains the analysis to **stratigraphic layering** and generates higher signal-to-noise responses for texture attributes
- **Directional** analysis reveals **anisotropy** in the **image**
- Dip-Steered, Directional Texture Attributes have potential for analyzing **anisotropy in rock properties** and thus be used in the analysis of fracture density, stress fields, fluid flow paths, ...

Further Work

- Joanneum Institute has developed a **workflow** to help interpret variations in directional response
- Visualization of **anomalous responses** in various directions
- This workflow will be extended from **2D** to **3D**



Acknowledgment

The texture attributes shown in this paper were developed independently by Joanneum Research and dGB Earth Sciences as plugins to OpendTect, the open source seismic interpretation system. OMV is acknowledged for funding Joanneum's research project and for giving permission to publish these results.

OMV, Joanneum and dGB recently agreed that Joanneum's texture attribute plugin will in future replace dGB's plugin and that the software will be released as an open source (free) plugin to OpendTect.