Squeezing image information for reservoir understanding

Automated Borehole Image Interpretation using Computer Vision Techniques and Machine Learning

CAYROS group

1. Introduction to CVT - What is a CVT Analysis?

A CVT analysis comprises the use of diverse ***Computer Vision Techniques*** (CVT) to capture different features from any kind of images as WL and UV **core photos**, Bore Hole Images (***BHI***) or **Thin Sections**.

The results of a CVT analysis consist of a new set of images with their own log or measurement.

Additionally, all this image-derived logs can be used to classify facies or rock types using Machine learning.

CVT Approach:

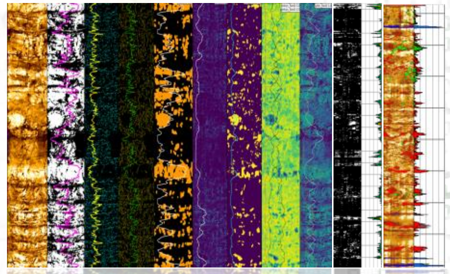
- Since image data is highly reliable, CVT extract **quantitative logs from pixels**.
- New generated logs can be integrated seamlessly with existing quantitative data.
- Core image data can be extended to the reservoir.
- The set of CVT logs contributes to the inference of rock characteristics such as rock type and facies.

The use of new technologies such as computer vision complemented with machine learning allows to take image analysis to a higher level.

Input data (any kind of images formats jpg, png, pdf, dlis, etc)

data processing

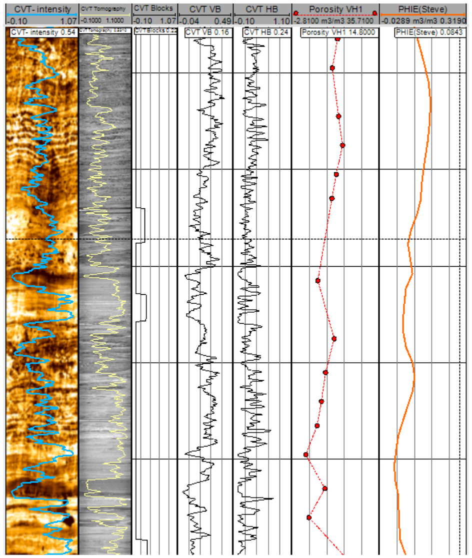
Output data



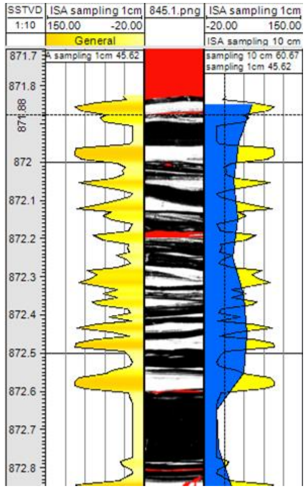
CVT-Morphologic
CVT-Texture
CVT-Component detection
CVT- E-D Cycles

Introduction to CVT - ***CVT logs are useful for:***

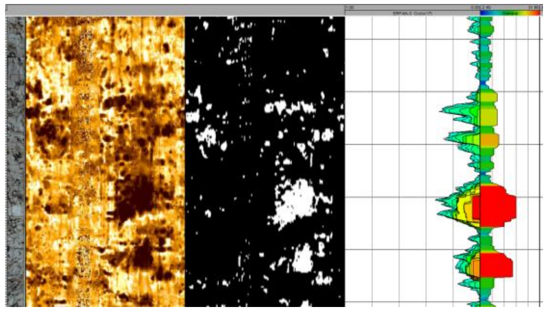
1. Core depth matching



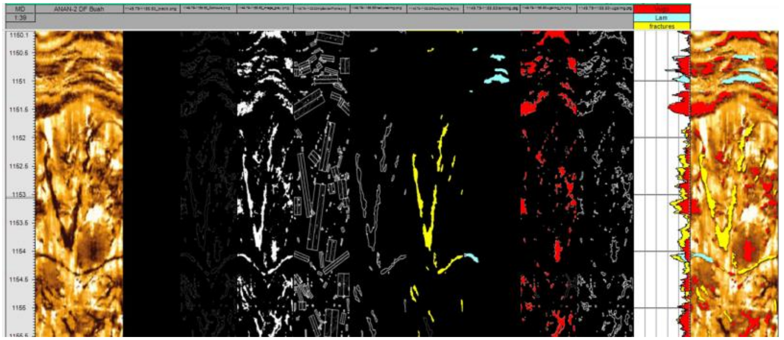
2. Net to gross in heterolithic deposits



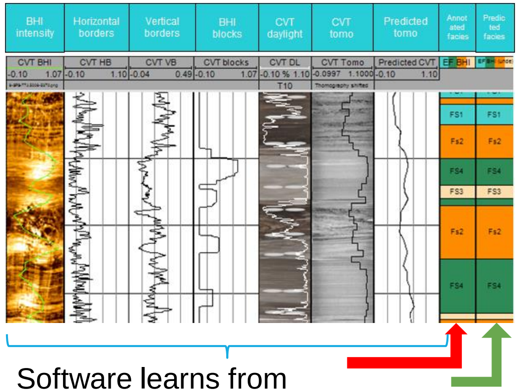
3. E-D Cycles



4. CVT-Component detection

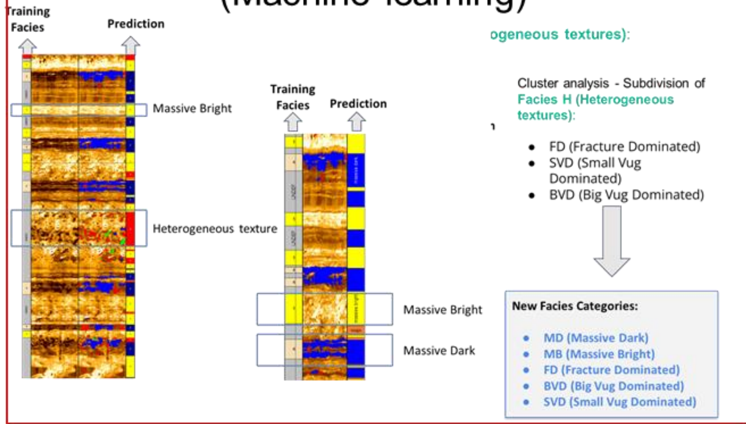


5. Facies prediction (Machine learning)

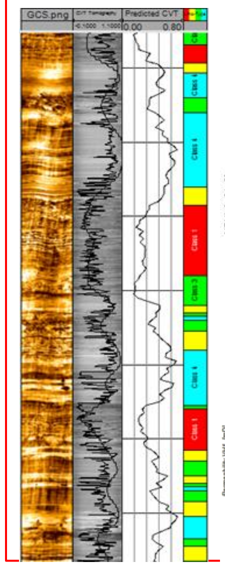


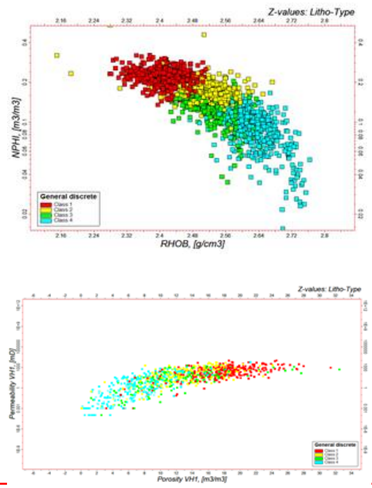
Software learns from these logs to see this

6. Textural detection (Machine learning)

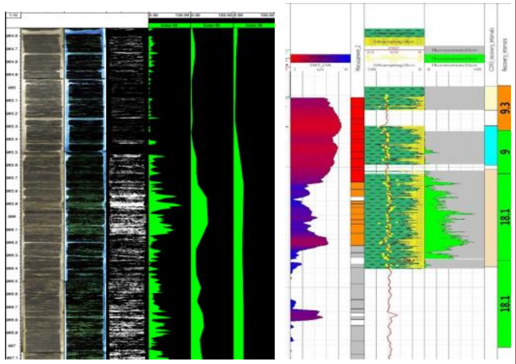


7. Rock types



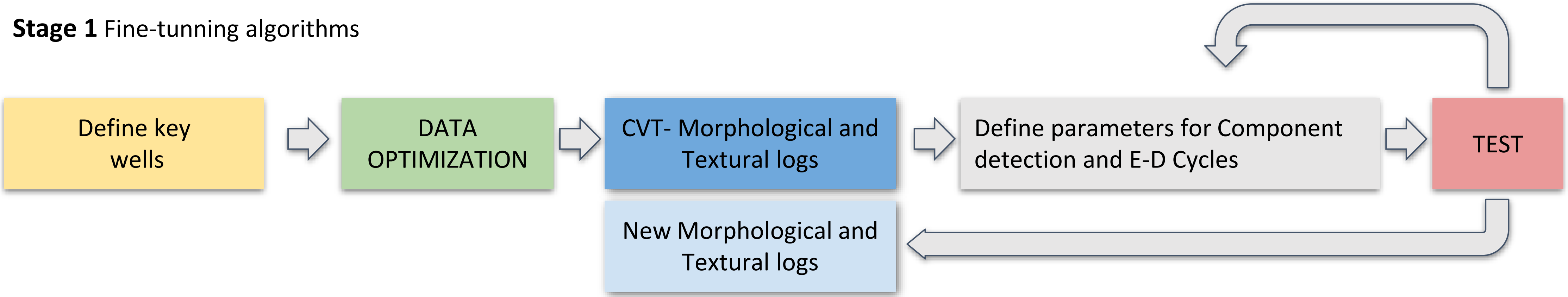


8. Fluorescence analysis (contacts definition)

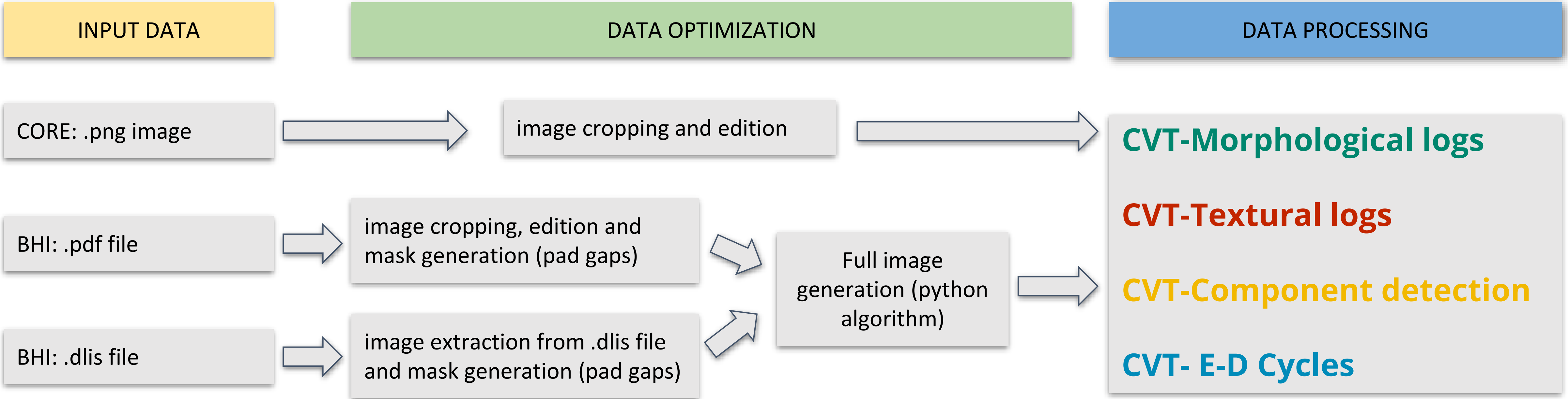


Introduction to CVT - ***CVT WORKFLOW***

Stage 1 Fine-tunning algorithms

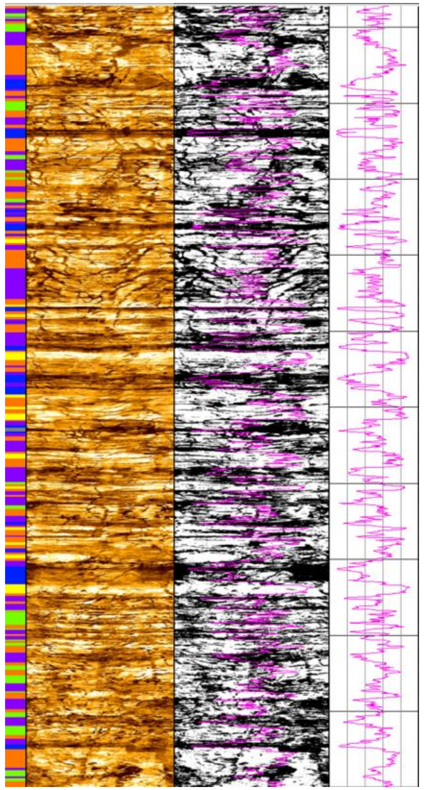


Stage 2 Running the algorithms



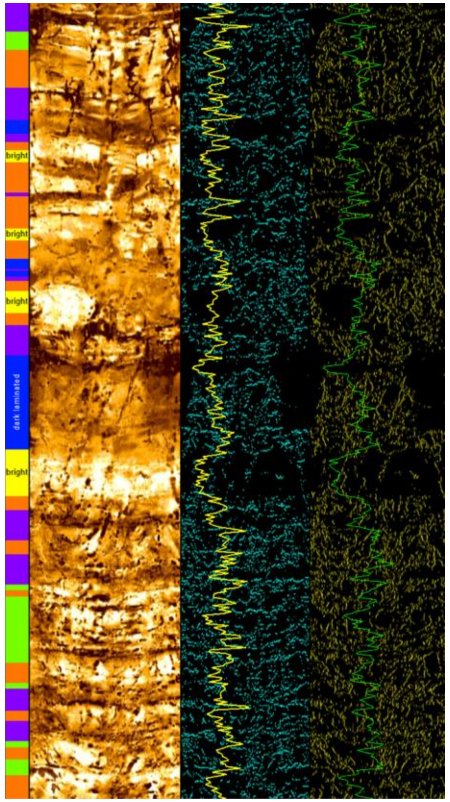
2. CVT- Data Acquisition

CVT-Morphologic Logs



CVT Intensity

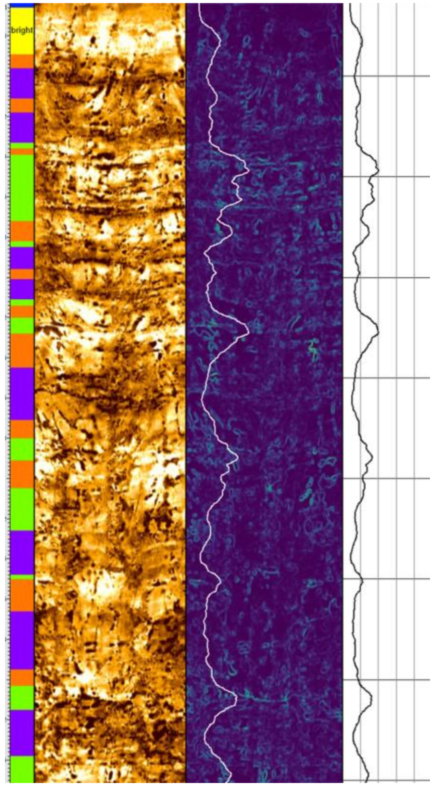
It measures pixel intensity directly related to resistivity. Higher values represent higher resistivities.



CVT Horizontal and Vertical Borders

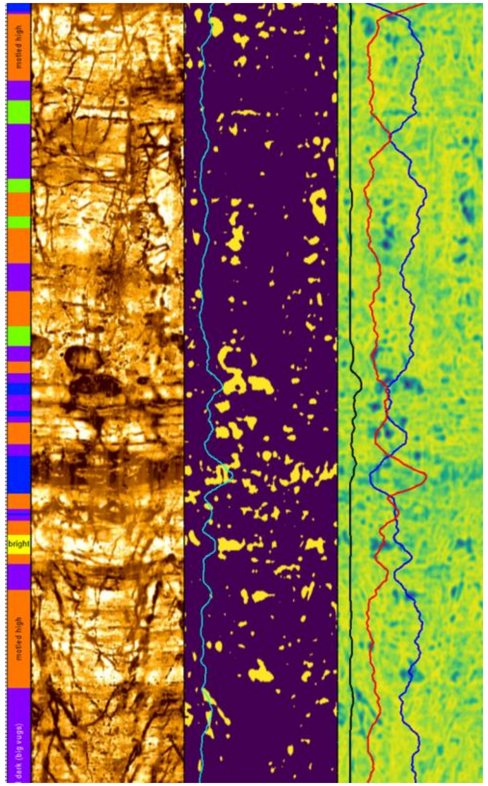
It measures pixels affinity or continuity in horizontal or vertical direction

CVT-Texture Logs



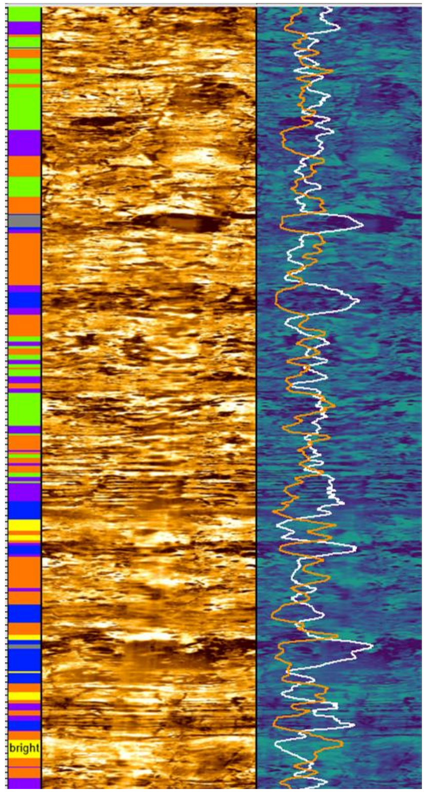
Variance

A multidimensional uniform filter



CVT Entropy and Entropy Threshold

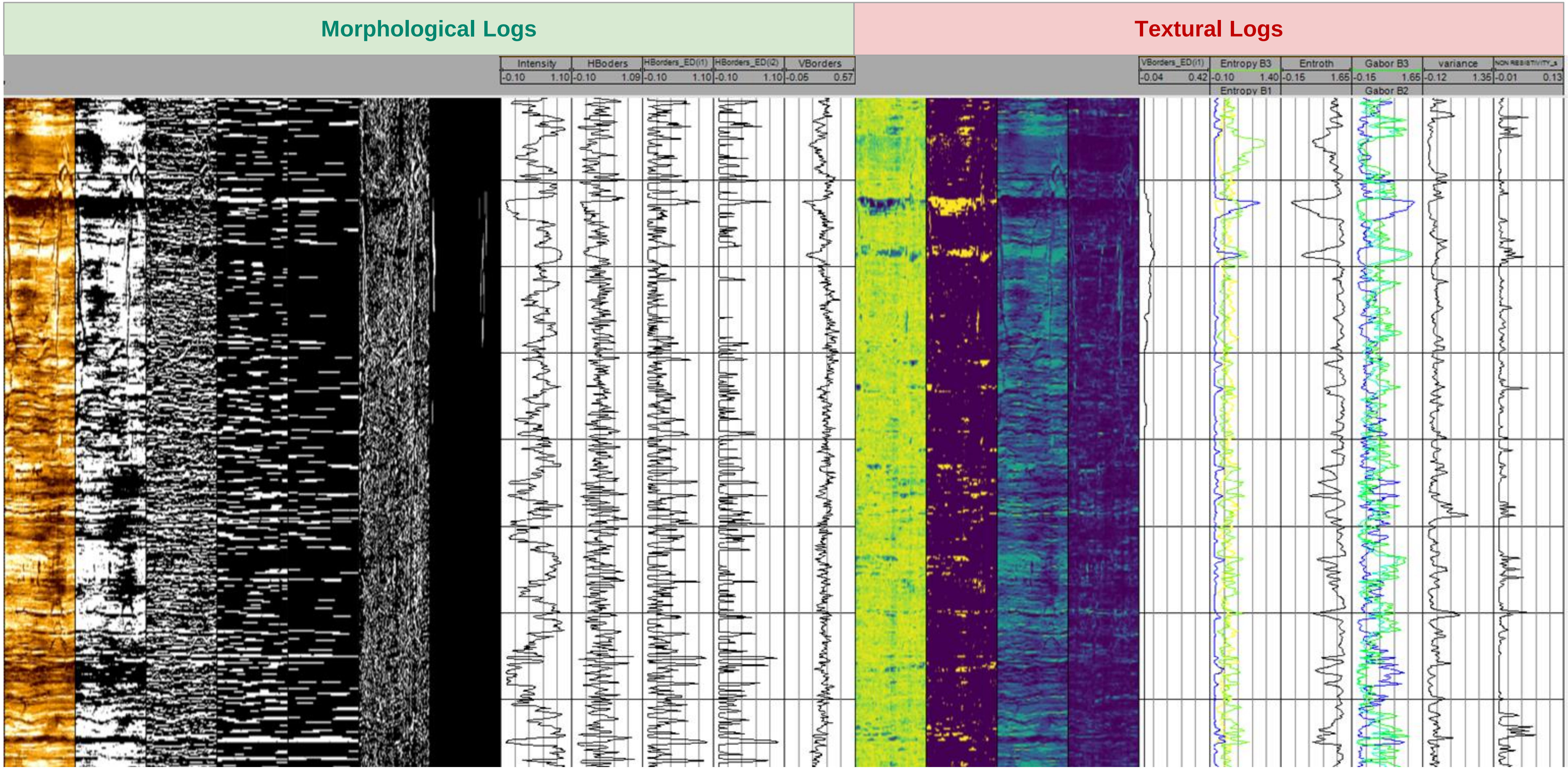
Entropy quantifies the disorder. Entropy values in near homogeneous areas will be lower respect to that in laminated, or heterogeneous areas



CVT Gabor filter

A great filter for mapping textures. Good choice for recognizing features for machine learning process

2.1 CVT-Texture and CVT-Morphologic comparison

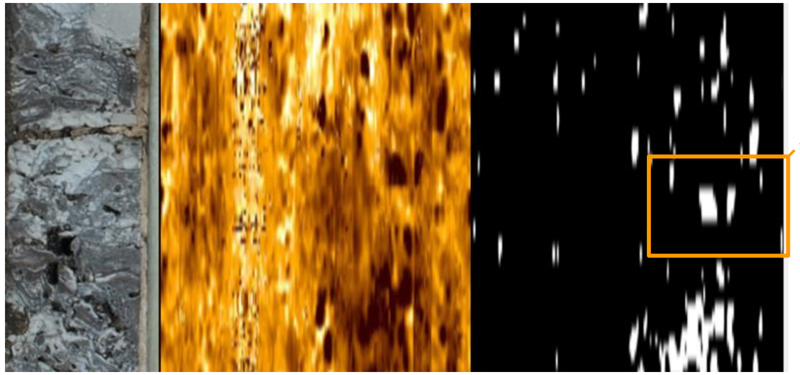


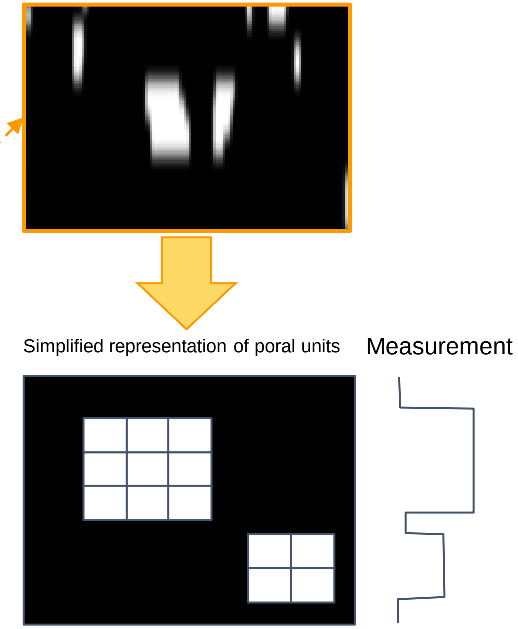
2.2. CVT- E-D Cycles

- Pore size analysis using Erosion - Dilation cycles.
- Allow to quantify pore families.

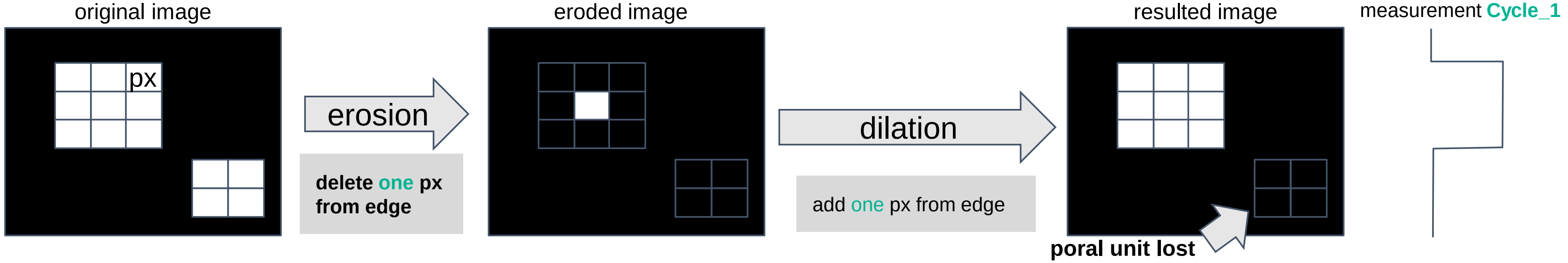
The CVT-E-D Cycles could be used to recognize and measure the elements (clasts and lamination) identifying permeability barriers.

Image Binarization of resistivity zones

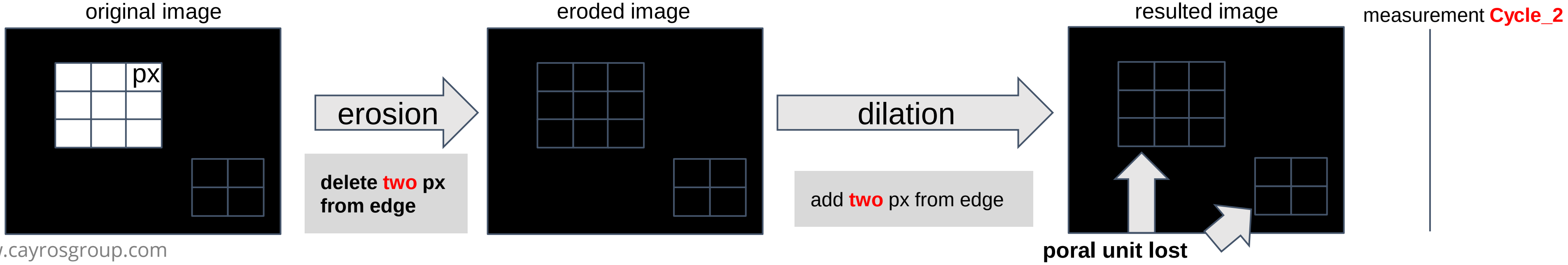




1st cycle of erosion - dilation

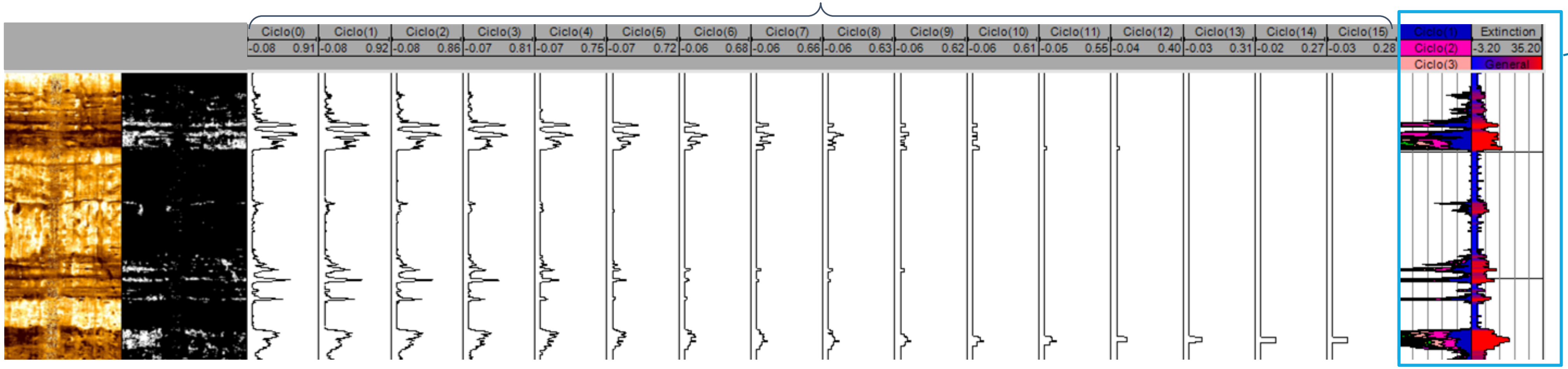


2nd cycle of erosion - dilation



2.2. CVT- E-D Cycles

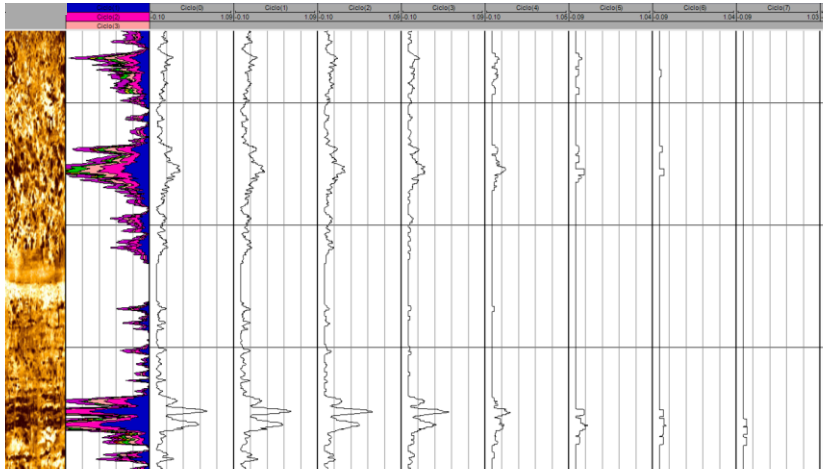
Erosion - Dilation cycles



Additional logs:

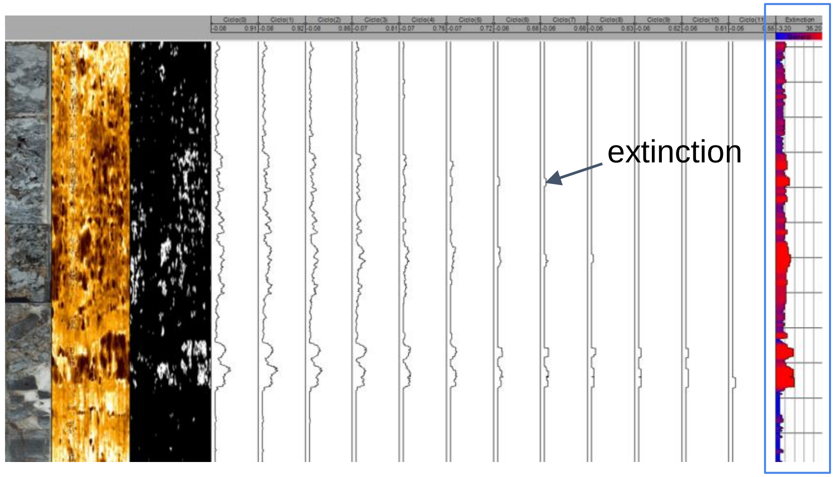
- Roughness log
- Extinction log
- Residual log

Roughness log



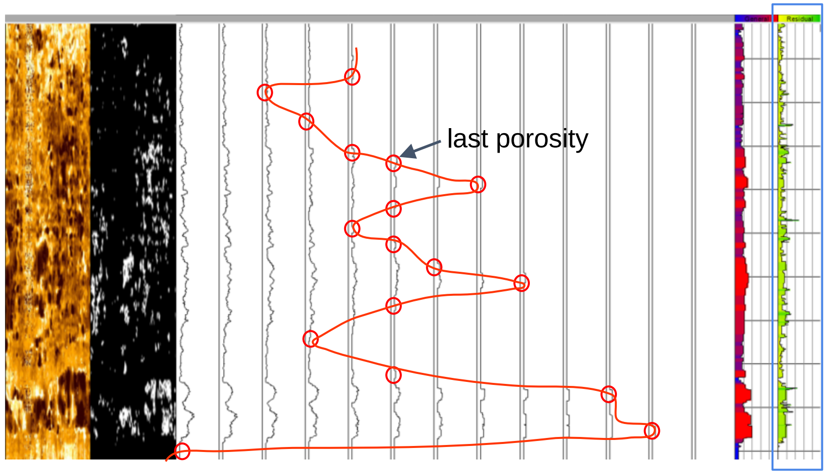
The roughness logs are calculated for each cycle (n Cycles, n Roughness logs) and represent the amount of pore units extinct in a cycle.

Extinction log



"E-D cycles to disappear". This log represent the maximum ED cycles needed to eliminate all poral units.

Residual log



Quantification of residual pore units before extinction. This log represent the residual size and means the effective sphere of the pore unit.

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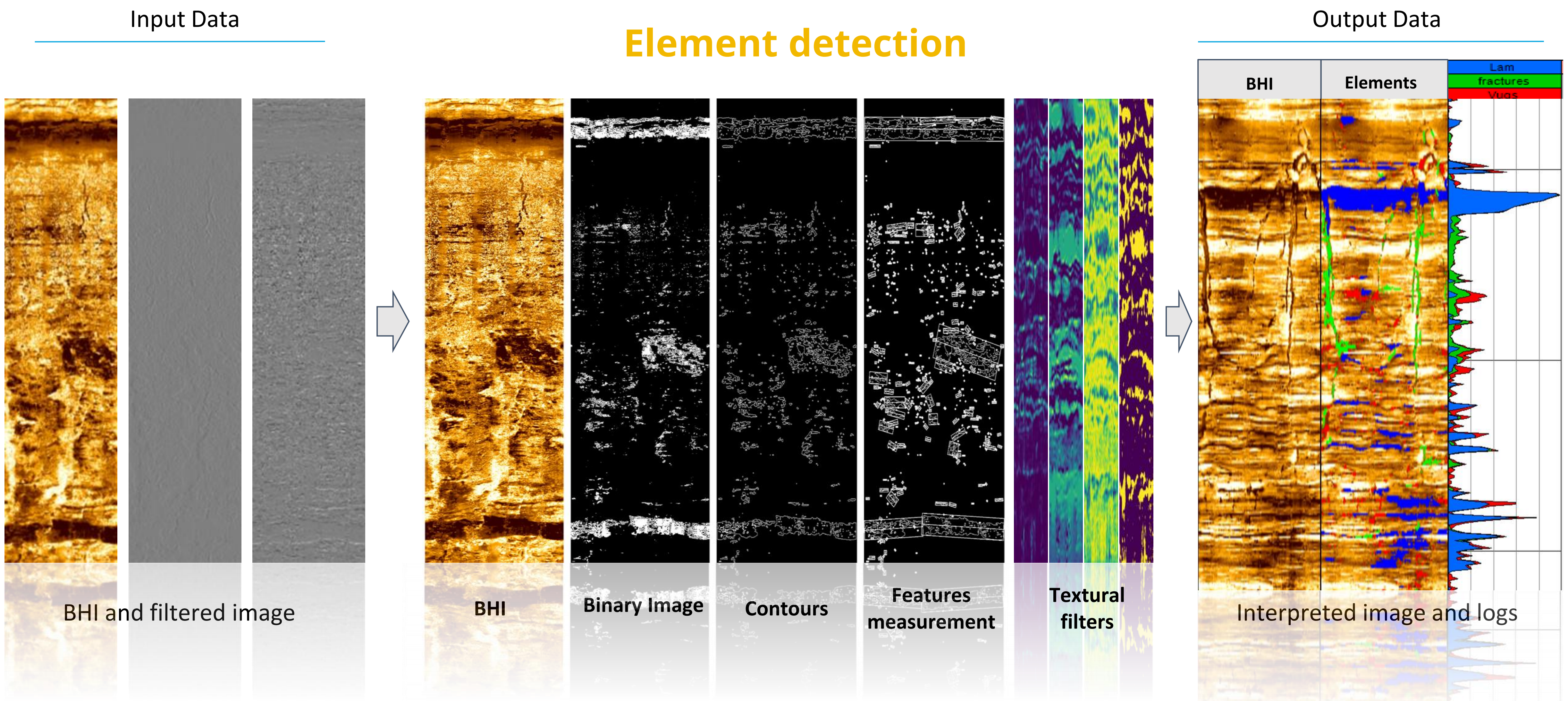
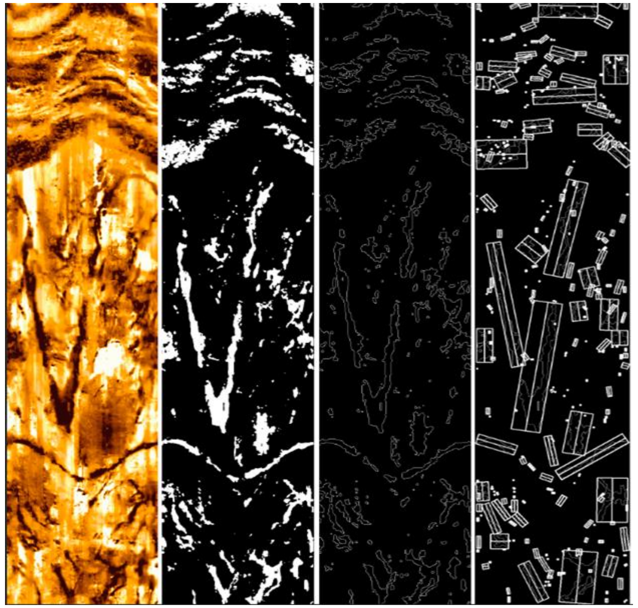
2.3. CVT-Element detection



2.3. CVT-Element detection

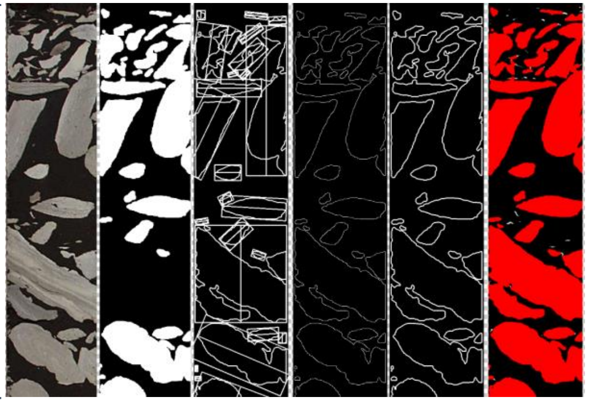
Component detection

example in carbonate reservoir

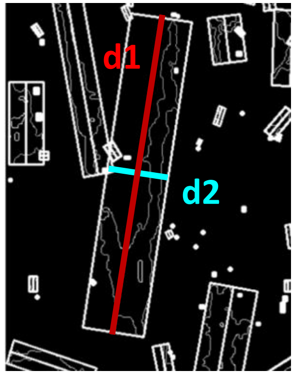


BHI | Binary Image | Contours | Features measurement

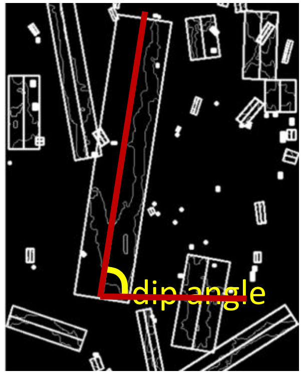
example in clastic reservoir



Features measurement

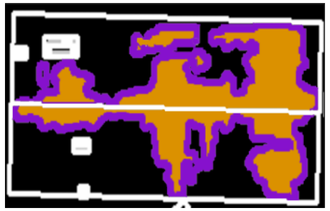


Aspect ratio
Greater distance(d1)/Lower distance(d2)

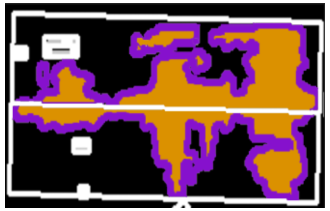


Dip angle

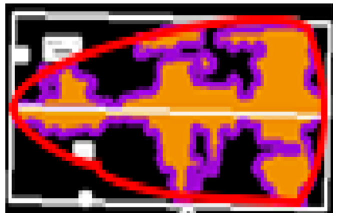
Component size / area
Greater distance(d1), Component area



Area ratio
Component area(orange)/Rectangle area



Perimeter ratio
Area (orange)/Perimeter (violet)

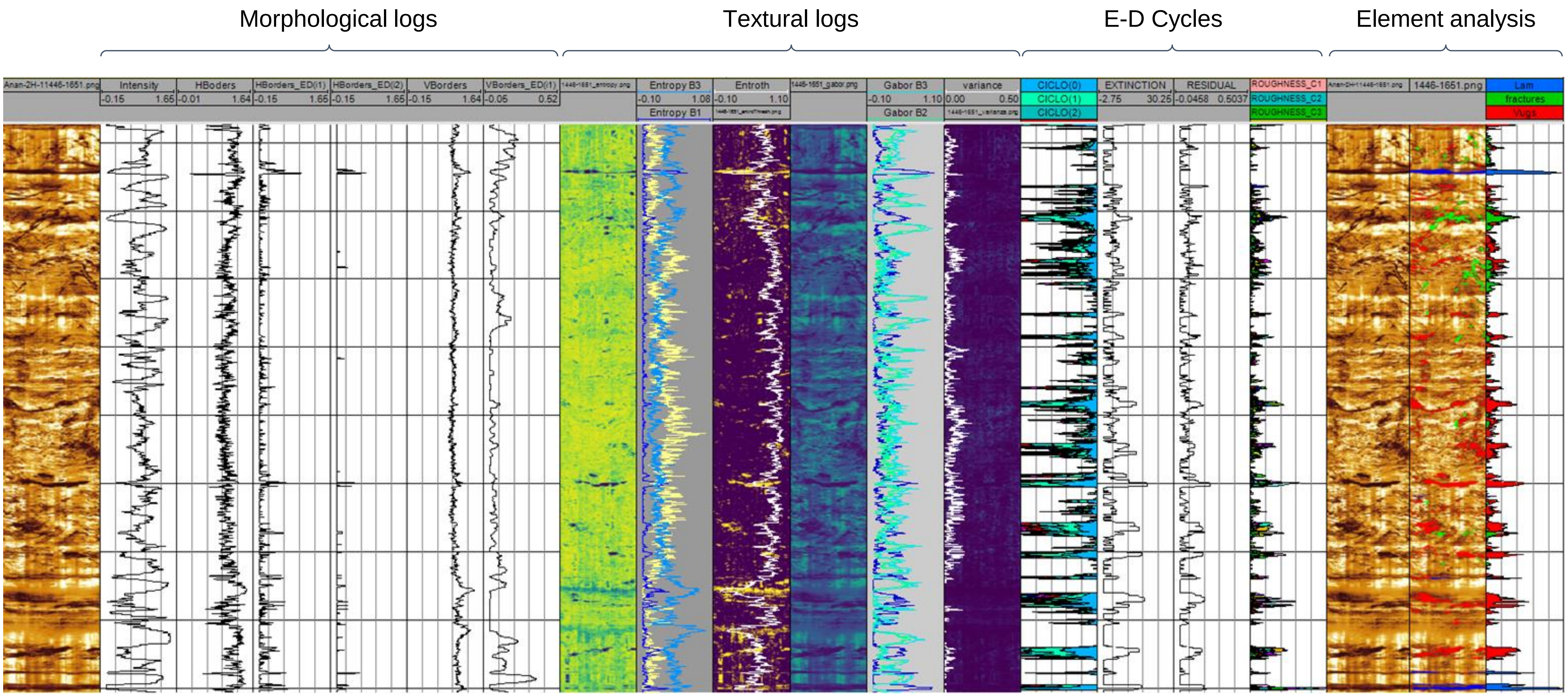


ConvexHull ratio
Component área (orange)/ConvexHull area (red)

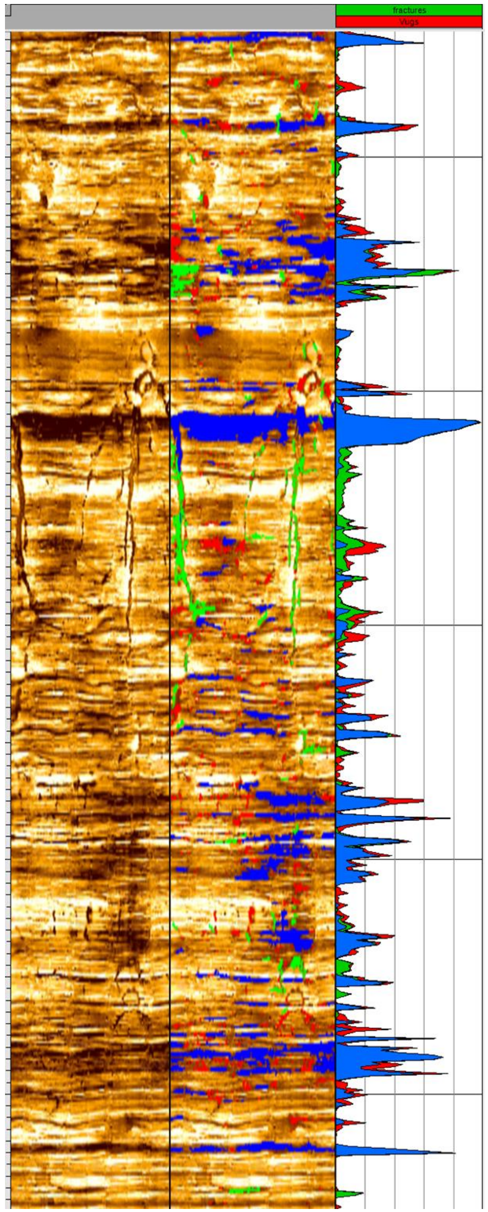
Features can be stored. Allows statistical analysis to improve clasts and clay layers segmentation.

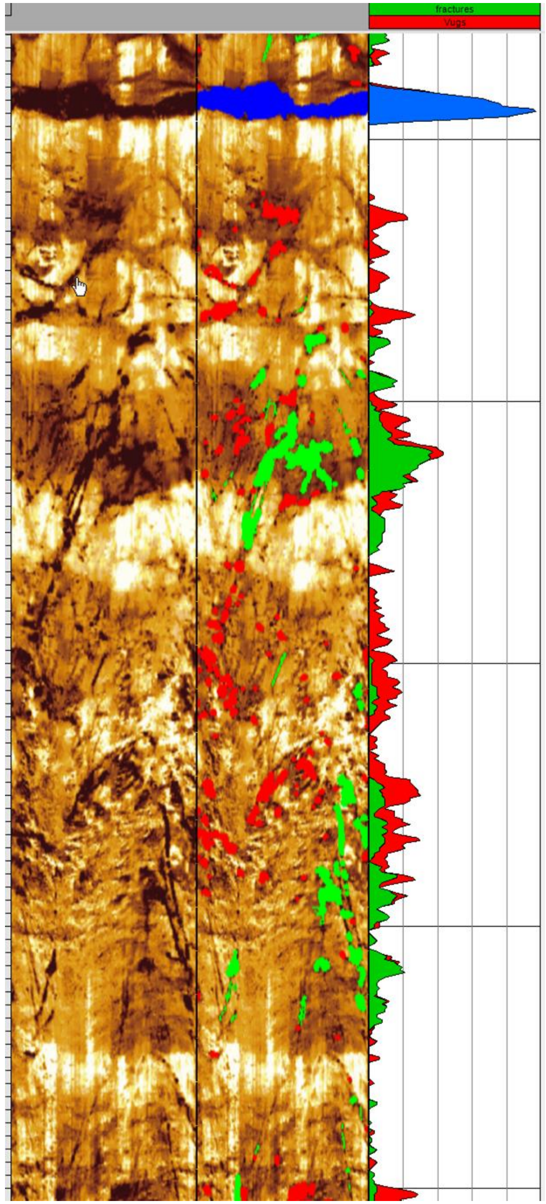
Element	d1	d2	dip_angle	d1/d2	Area	Area ratio	Texture Segmentation
0	12.00	9.00	57.30	1.33	74.00	0.69	Vugs
1	4.00	4.00	0.00	1.00	11.00	0.69	Vugs
2	43.05	9.06	57.23	4.75	247.50	0.63	Fracture
3	6.00	3.00	57.30	2.00	15.00	0.83	Vugs
4	2.83	2.83	40.51	1.00	6.00	0.75	Vugs

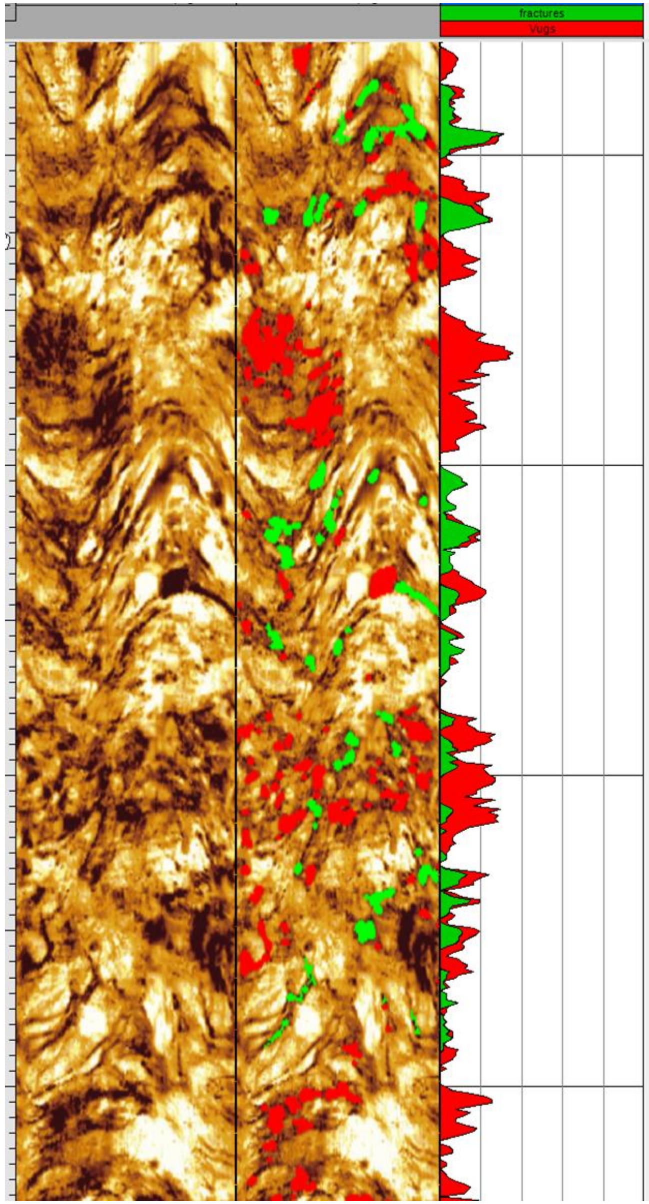
Summary of CVT logs

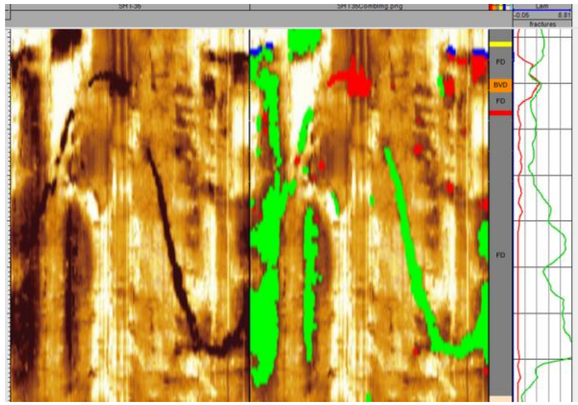


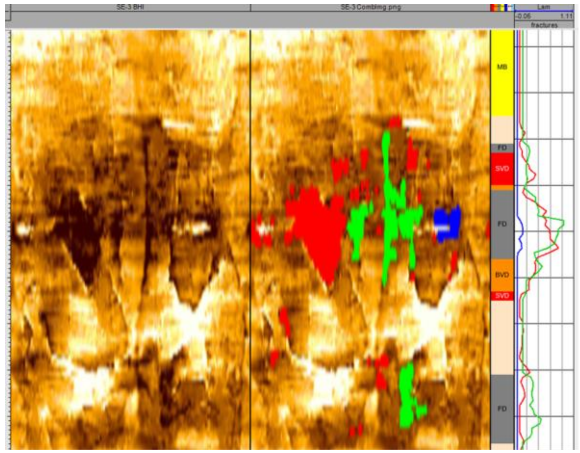
Some examples of element detection











Lam
fractures
Vugs

Conclusions

- **Data Integration:** The use of CVT allows for the extraction of valuable information from both core and well images, enabling digital integration with other reservoir data. This significantly enriches the dataset available for analysis.

- **Variety of Collected Data:** The software collects a wide range of data, including textural and morphological curves, as well as information on different elements such as fractures, vugs, laminations, and massive intervals. This provides a diverse set of details about the reservoir.
- **Characterization of Elements:** Various elements in the images can be characterized by aspects like size, orientation, or the type of contour, such as contour roughness. This variety of features offers numerous options for the analysis and quantification of facies.
- **Precision in Core Matching:** CVT has proven to be accurate in matching core data, which is essential for data validation.
- **Effectiveness in Heterolithic Reservoirs:** In heterogeneous reservoirs, CVT proved to be an effective tool for determining net to gross, a crucial parameter in hydrocarbon exploration. Additionally, its application in fluorescent images aided in determining the location of water table and oil-gas contact.
- **Machine Learning for Facies:** The integration of CVT with machine learning techniques yielded outstanding results in identifying facies in wells with minimal human intervention. This reduced subjective user errors and opened up the possibility of analyzing a large number of wells in significantly shorter timeframes compared to manual analysis.

In summary, CVT software has emerged as a powerful and versatile tool for analyzing core and well images in the oil and gas industry. Its ability to integrate data, characterize elements, and apply machine learning has proven to be especially valuable in reservoir exploration and evaluation, making it a highly efficient tool for decision-making

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