Analytics Explorer

A new approach to seismic facies analysis using Artificial Intelligence and self-organizing maps

S&P Global
Commodity Insights

An enhanced workflow for geoscientists in Exploration & Production

Overview:

Section One

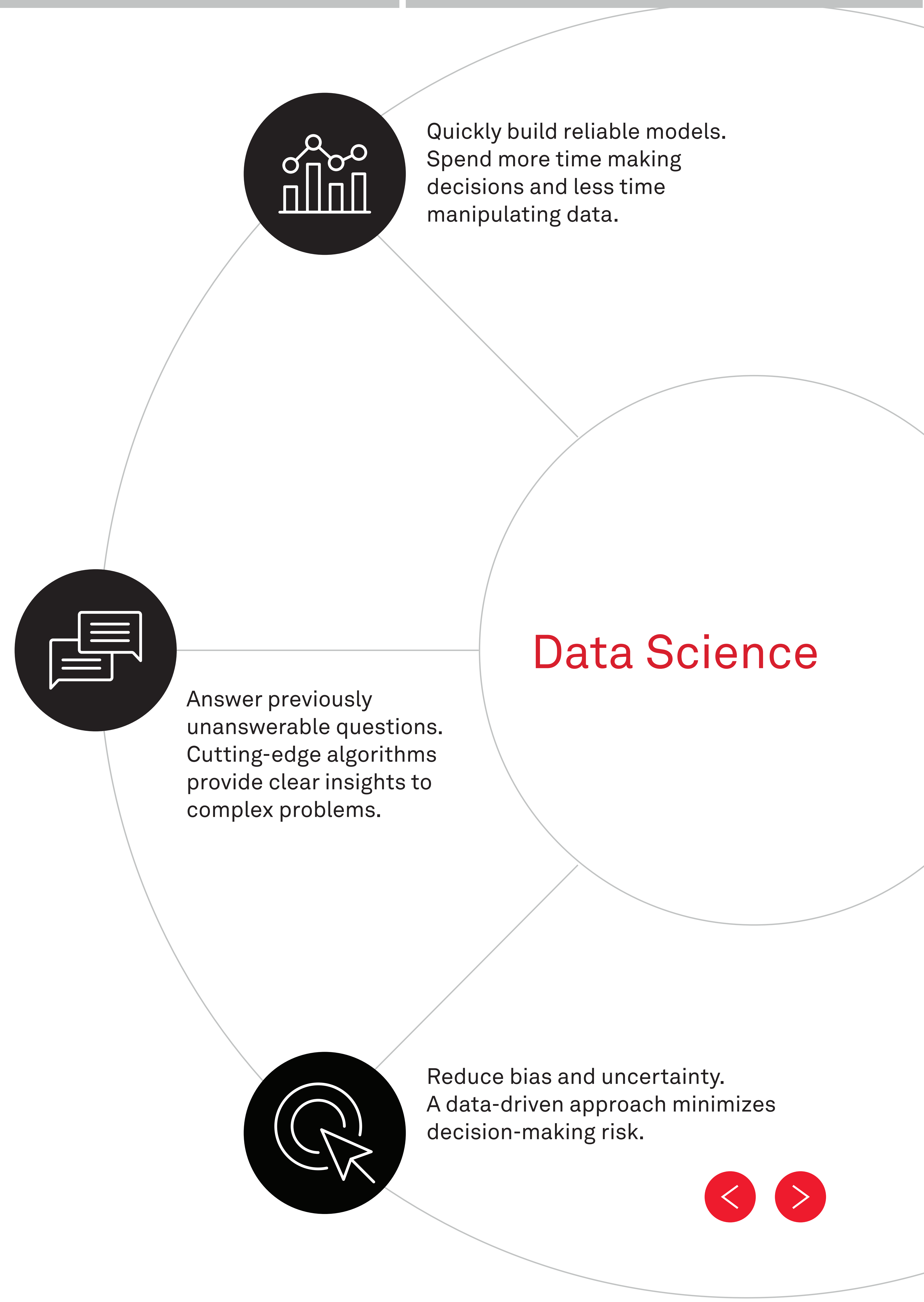
Data Science

Data Science Made Accessible

Today's oil and gas industry is different.

In the wake of countless oil and gas market disruptions, exploration and production (E&P) companies continue to endure and do more with less. Geoscientists working in E&P are challenged with maintaining productivity levels and delivering projects on time; still, they must also deal with tedious and time-consuming workflows, handling big data, and trying to identify the next well location and sweet spots accurately.

This e-book introduces a data-driven workflow utilizing Analytics Explorer by S&P Global Commodity Insights, an advanced data science and Machine Learning (ML) platform for E&P. Geoscientists can use this workflow to efficiently integrate and analyze multiple seismic datasets to understand the subsurface better and identify key producing facies.



Data Science in Analytics Explorer

Good data is the foundation of good data science.

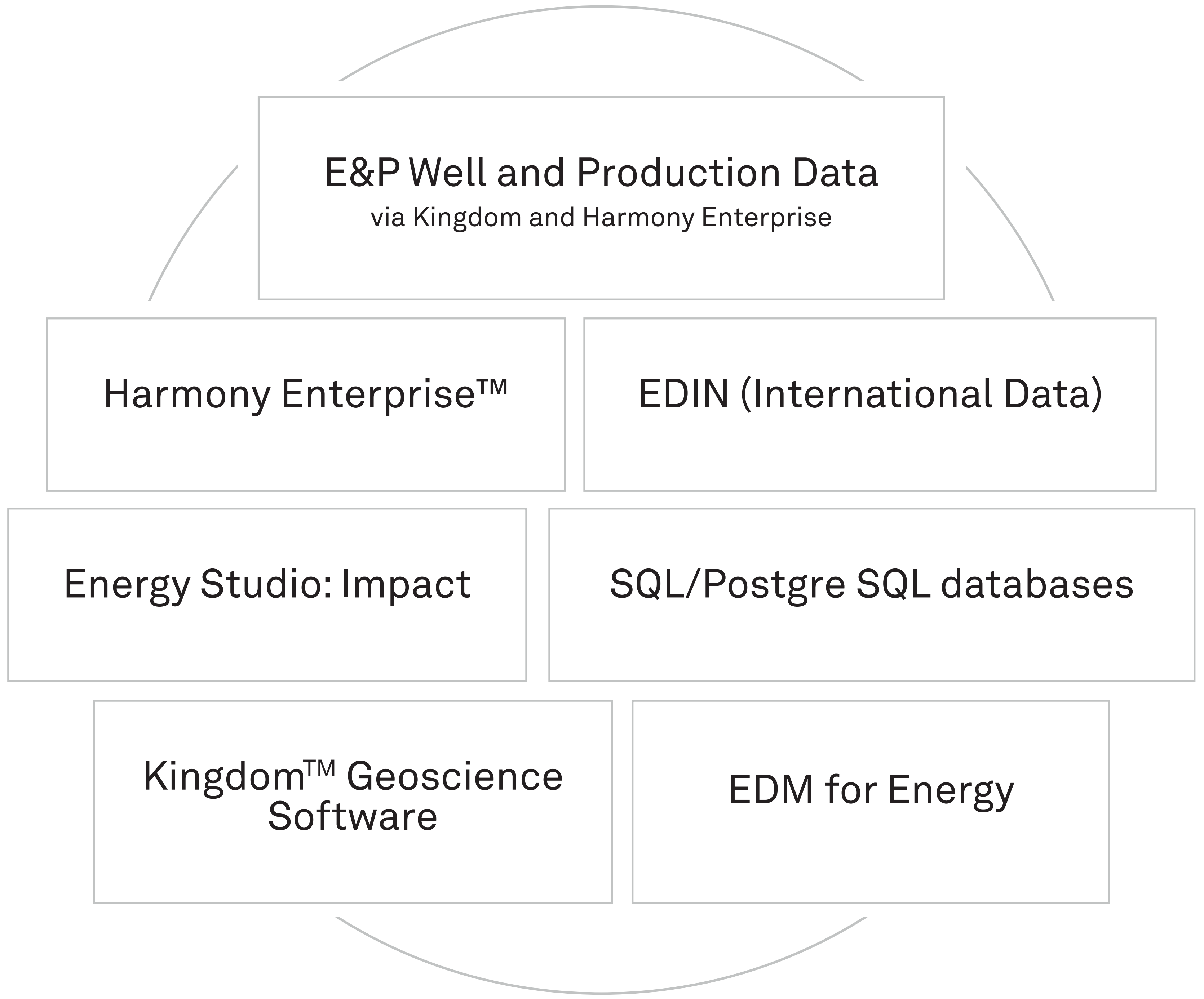
Analytics Explorer was built by a network of data scientists and domain experts utilizing developed robust and sound ML algorithms and the extensive S&P Global Commodity Insights data library. In one such case, our well property estimations and log imputations were calibrated using 10 million wells and 350,000 digital logs from multiple basins.

These algorithms have been rigorously tested and fine-tuned to address known E&P challenges so we can bring our clients out-of-the-box workflows for reliable modeling.

Featured workflows include:

- Multi-attribute geological and geophysical facies analysis
- Data mining, data imputation and QC
- Automated well spacing calculations
- Production performance predictive maps

Analytics Explorer has built-in connections with the following S&P Global Commodity Insights products/solutions, services, and databases:



Section Two

Combined Analytics Workflows

Interpretation Driven by Data Science

A new approach to seismic facies analysis.

Analytics Explorer leverages the capabilities of Principal Component Analysis (PCA) and Self-Organizing Maps (SOM) to blend and analyze multiple seismic attributes. The resulting integrated seismic attributes enable a better understanding of facies distribution across large areas.

Data from the North Sea, offshore UK (Figure 1.) was used for the workflow. The area is 1,200 square miles and contains over 1.2 million data points and 39 seismic attributes extracted onto the target horizon.

The workflow covers the following key steps from data analysis to decision-making:

- Multi-attribute analytics
- PCA
- SOM
- Facies identification
- Correlation with production

This workflow is uniquely possible with the unsupervised machine learning capabilities of Analytics Explorer and coupled with EDIN data, help to enhance the seismic attributes in integrated databases like Kingdom.

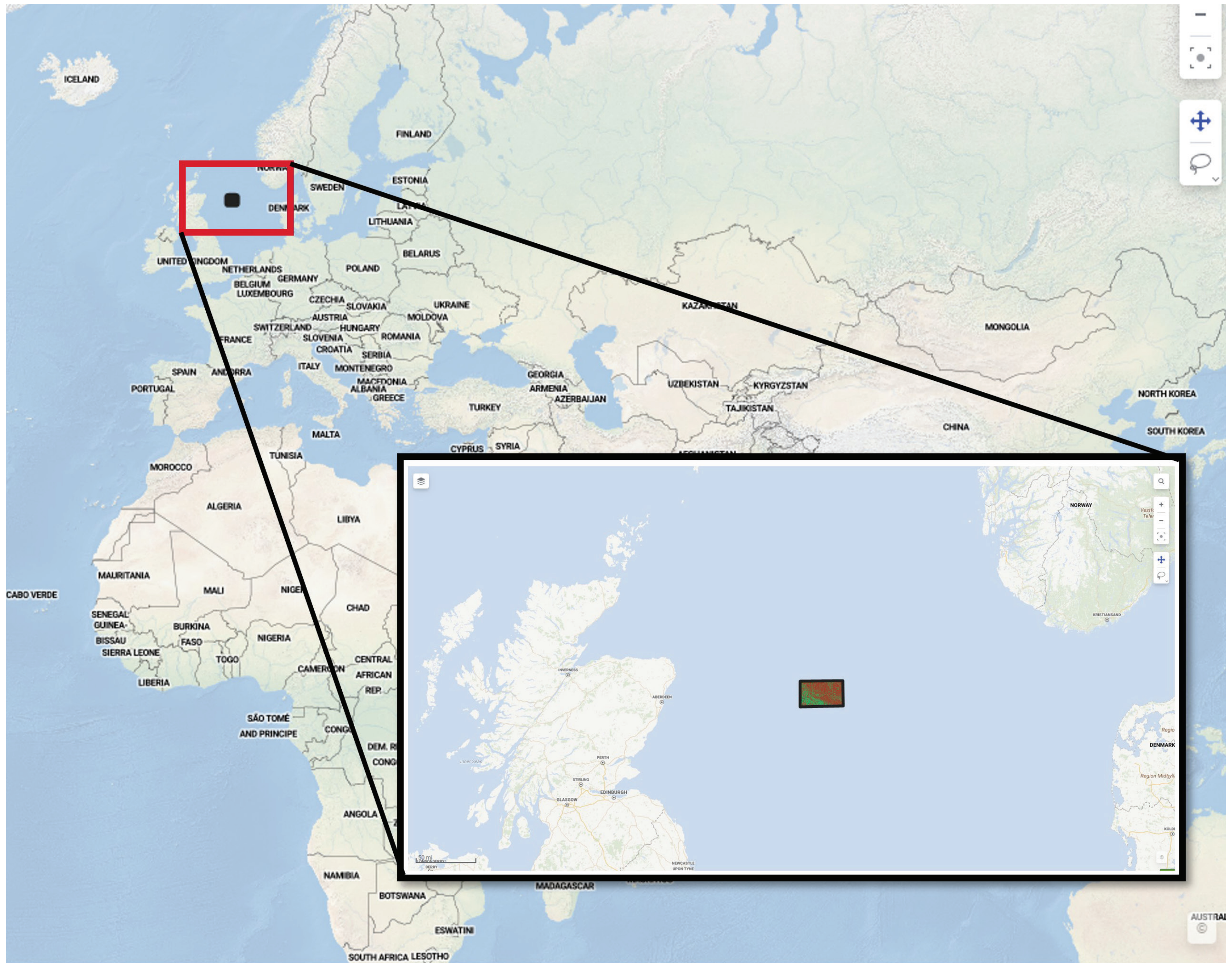


Figure 1:Project location map view of the North Sea.

Multi-Attribute Seismic Analysis

Enhanced geological workflows.

More than 50 seismic attributes can be used to interpret structure, stratigraphy, and rock properties. Traditionally, each attribute is viewed individually (Figure 2).

A typical approach to understanding distributions of seismic data in a region is to create multiple maps and display them side-by-side to interpret the convergence of certain features in a single location. Common attributes used by geoscientists to map stratigraphic changes in the subsurface along a geologic interval of interest include:

- **Amplitude Response** and **Instantaneous Frequency** describe the shape of the seismic wavelet and its response to changes in geologic layers.
- **Fault Scan** helps with geometric identification (looking for boundaries and pinch-outs).
- **Thin Bed** identifies the thickening and thinning of the seismic response.

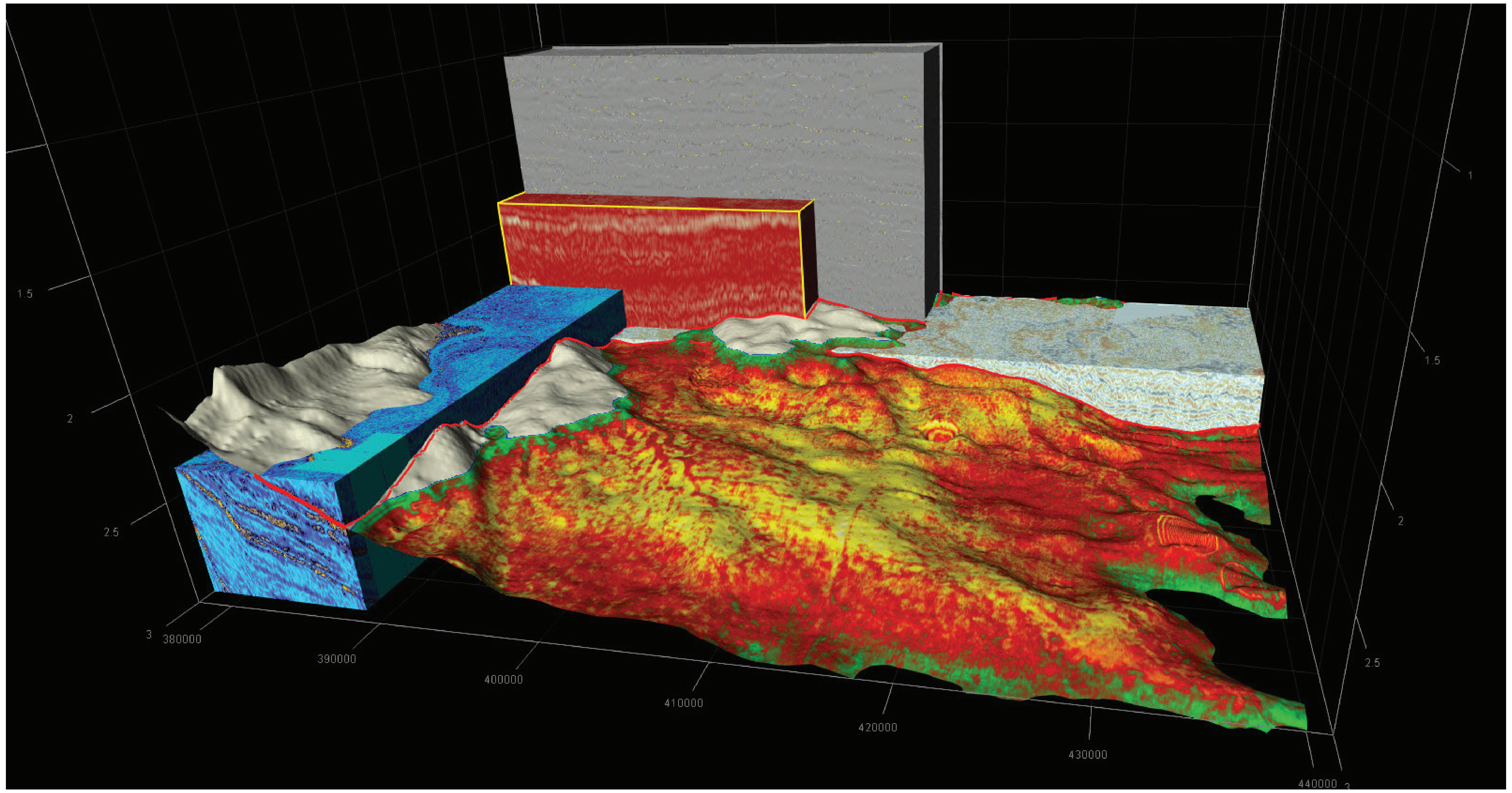


Figure 2: Kingdom 3D view of multiple seismic attributes extracted from a volume located in the UK North Sea. A time-consuming workflow, it is a single-view approach to understanding numerous attribute distributions.

Multi-Attribute Seismic Analysis

Enhanced geological workflows.

This multi-map approach can be seen below in Figure 3. While still a valid workflow, machine learning takes this approach even further by allowing the interpreter to blend the attributes into a single map and empowering the geoscientist to realize trends in the data they might have previously missed.

Viewing a combination of seismic attributes together in Analytics Explorer gives interpreters a full picture of the seismic data and see trends to aid in facies identification and potential sweet spots.

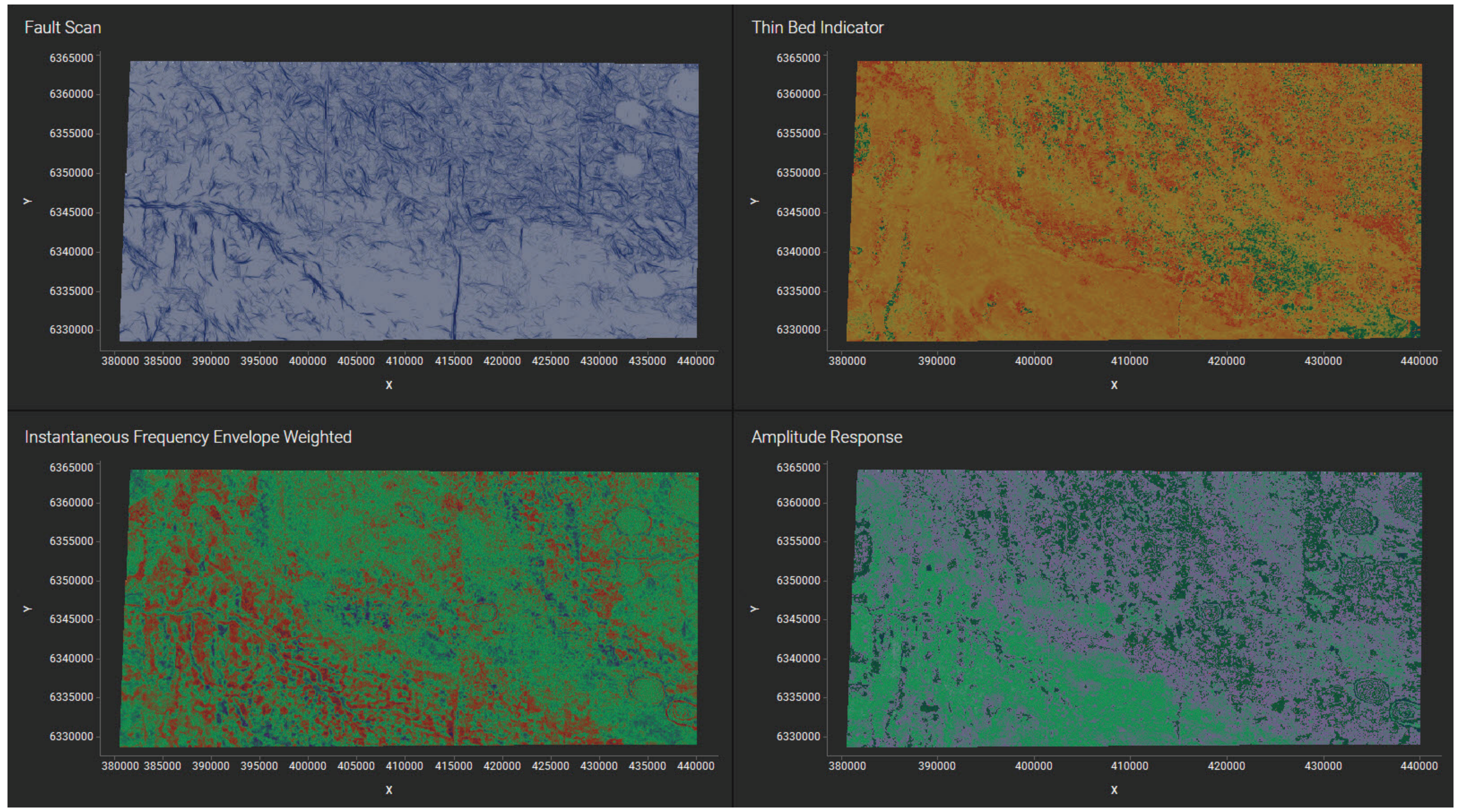


Figure 3: Analytics Explorer dashboard showing how you can simultaneously examine multiple seismic attributes to evaluate geometry and thickness—a simpler way of analyzing sequence stratigraphy.

SWEETNESS is a composite seismic attribute used to highlight thick, clean reservoirs, along with hydrocarbons contained within. Sweetness is calculated by dividing the instantaneous amplitude (amplitude envelope) by the square root of the instantaneous frequency.

ABSOLUTE IMPEDANCE highlights changes in velocity x density. Sometimes low impedance represents porosity. Sometimes it can mean hydrocarbon presence, but it is one of the most important seismic attributes because both velocity and density can characterize reservoir quality or type.

RELATIVE IMPEDANCE is like absolute impedance without the low-frequency component. So, where an absolute impedance data range might be 8,000-12,000 relative impedance would be -200 to 200.

ENVELOPE TIME is an attribute that describes the wavelet shape and if the wavelet shape defines seismic stratigraphic features this will be a good classifier.

THIN BED INDICATOR tries to describe potential interferences between reflections of different layers and relates to closely spaced seismic events.

INSTANTANEOUS FREQUENCY ENVELOPE WEIGHTED is another attribute that describes the seismic wavelet and if the wavelet shape defines seismic stratigraphic features this will be a good classifier.

Principal Component Analysis

Reduce Interpretation Bias.

Before applying machine learning to a dataset, interpreters must select the input features they want to use in the model. PCA helps them identify which variables are more representative of the entire dataset.

It does this by:

1. Removing statistically irrelevant input features from the dataset, so only the most critical remain. – Remaining features can be used to generate combined maps of the seismic attributes showing only the most important features. See Figure 4.

2. Identifying and ranking the eigenvectors that account for the majority of the data relationships (covariance). – The principal component lines represent a group or cluster of the original data on each axis, depending on how related the attributes are to each other. Hence, each principal component line is a potential combination of multiple attributes from the original seismic attribute horizon. See Figure 5.

KEY ANALYSIS IN PCA:

- Reduce the number of attributes to the most relevant
- Transform PCA results to the AOI and generate Principal Component maps

Figure 4: Analytics Explorer table results of PCA, indicating which input features are most represented at each principal component line. Interpreters can use this table to determine which input features are the most relevant and use those features in advanced clustering workflows. The attributes shaded in red are the top two most important attributes in a given principal component line.

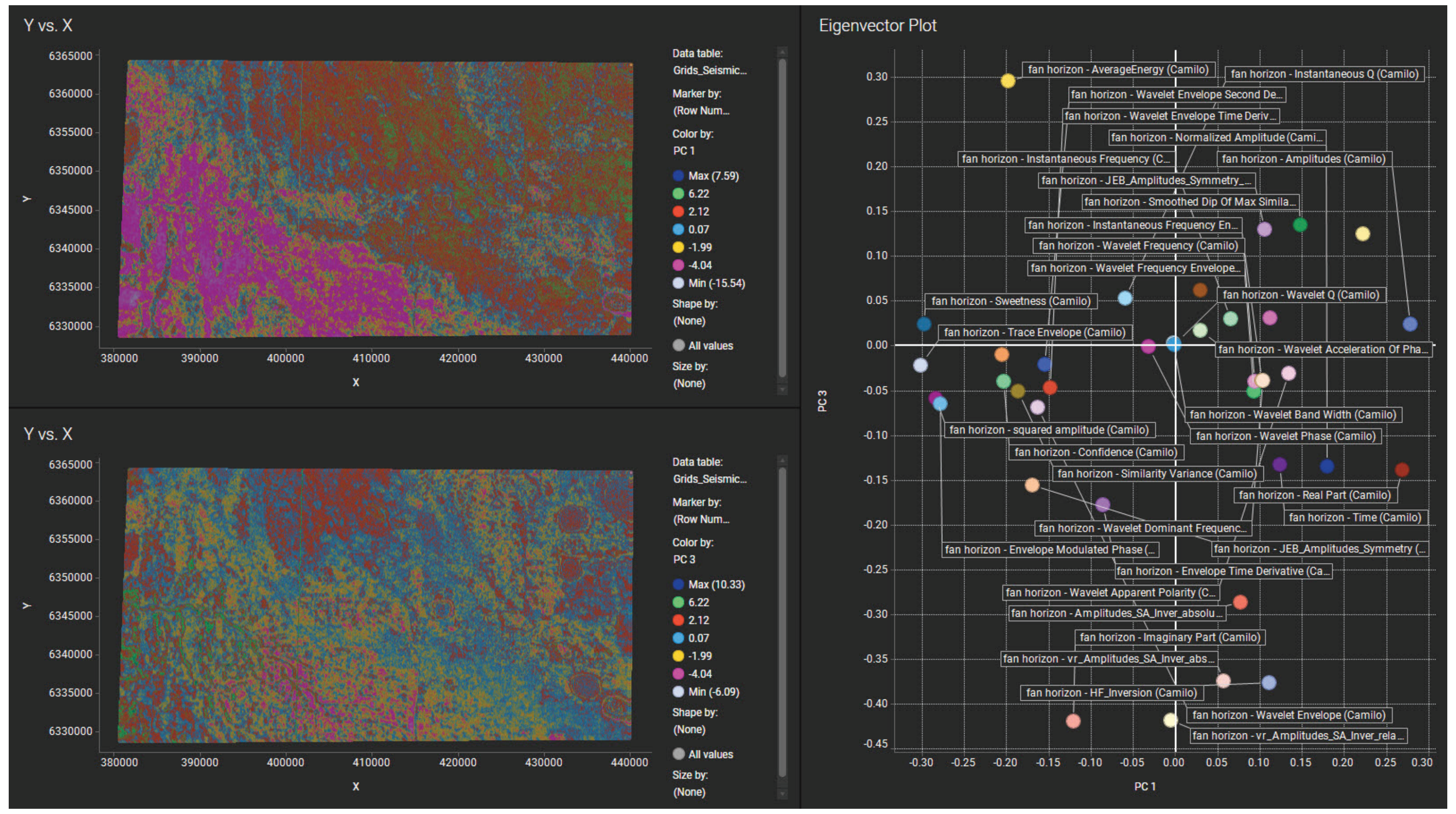


Figure 5: Analytics Explorer dashboard with an eigenvector plot, right, of multiple seismic attributes, grouped along principal component lines. The x-axis shows principal component 1 and the y-axis shows principal component 3.

Section Three

See Inside the Seismic

Unsupervised SOM Algorithm

Machine learning's next step.

Running the SOM algorithm is the next step in machine learning after completing PCA. Developed by Teuvo Kohonen in the early 1980s, the SOM algorithm is an Artificial Neural Network (ANN) that follows an unsupervised learning approach and trains its network through competitive learning. It is often used in clustering and mapping techniques to represent multidimensional data onto lower-dimensional space, enabling easier interpretation of complex problems.

In this step, a 10x10 SOM neuron map was used for the dataset to interpret the facies distributions using the six most important attributes from the PCA analysis. The automatically generated visual from Analytics Explorer allows interpreters to interrogate the SOM results quickly and easily. The resulting map (Figure 6) clearly shows channel features located at the bottom section of the map area.

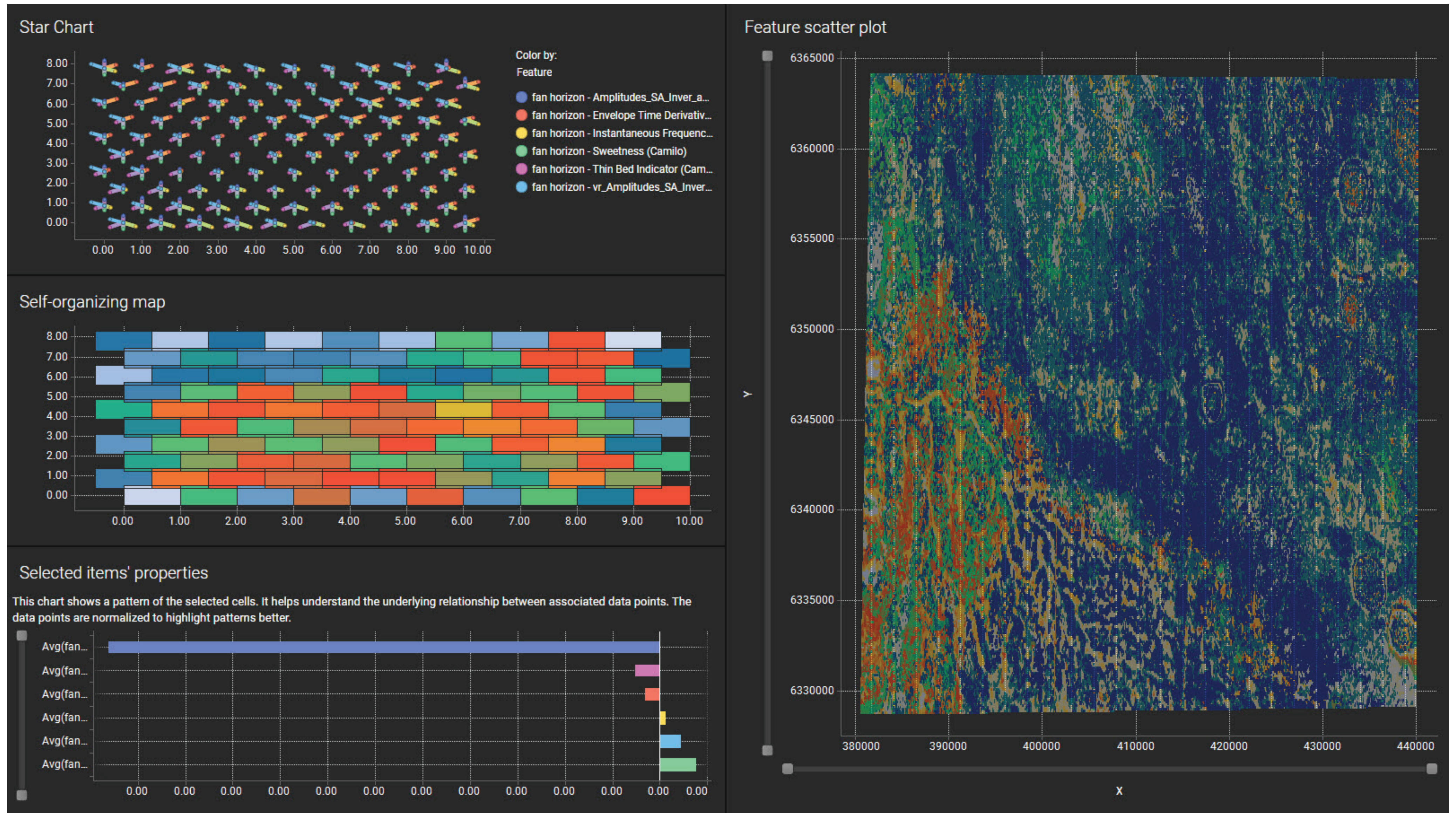


Figure 6: Analytics Explorer dashboard with SOM results using the top six most important attributes based on PCA computations.

Based on PCA results, the following six attributes have the greatest impact:

1. Absolute inversion
2. Thin bed indicator
3. Envelope time derivative
4. Instantaneous frequency
5. Relative inversion
6. Sweetness

A deeper look at the SOM results reveals a fan feature in the dataset with two distinguishable facies (Figure 7). This is shown by selecting two of the SOM cells and analyzing where those SOM groups are found in the interpreted horizon's XY space. The property bar chart details which properties are being described for each facies.

The two distinct facies can be seen within the fan feature in the seismic SOM results (Figure 8). The first facies is characterized as having high values of Absolute Inversion and Instantaneous Frequency, combined with a small response from Sweetness. The second facies is characterized by high values of Relative Inversion and Sweetness but a low response from Instantaneous Frequency.

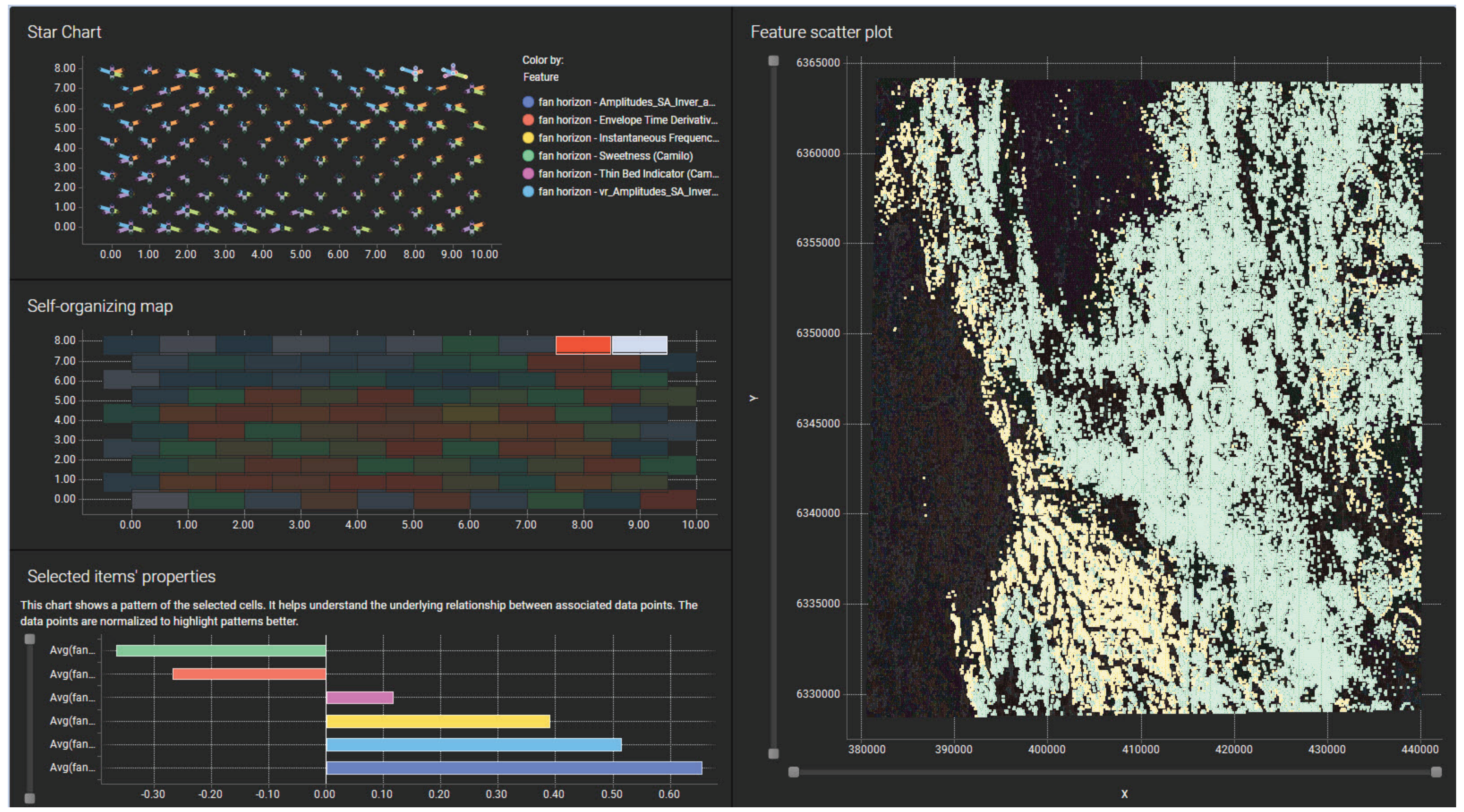


Figure 7: Analytics Explorer dashboard view of EDIN field and well data. Layering this information onto a map, we can review wells in the area and whether they produced or were dry. Each of the two fields shown in this map, the Shaw and Arkwright fields located in the UK North Sea, have oil production data. The Shaw Field has two wells that have been completed and produced oil.

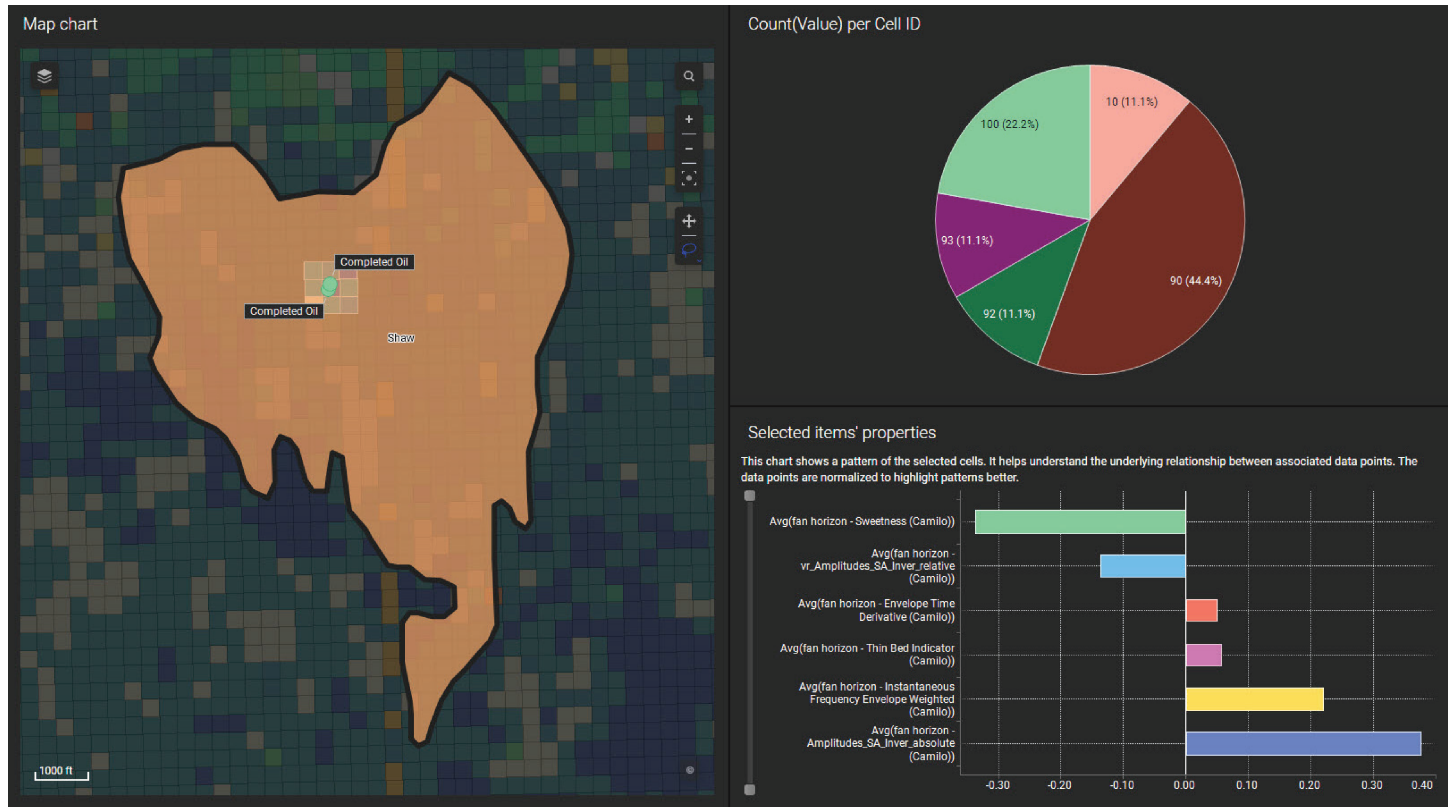


Figure 8: A zoomed-in view of the Shaw Field. Selecting the SOM results in the vicinity of the two oil-producing wells shows what geological facies these wells encountered, e.g., large values from Absolute Inversion and Instantaneous Frequency Envelope Weighted, and small values from Sweetness.

Improving Exploration Results

Results: Before & after Analytics Explorer

With Analytics Explorer, you can easily and seamlessly sync your subsurface interpretations from Kingdom. You can then enhance this data by applying state-of-the-art data science and machine learning algorithms. This deeper dive into your data can help reveal complex patterns to identify the best productive facies more accurately and faster than before.

For geoscientists, the Analytics Explorer seismic facies workflow helps them:

- Fast-track the analyses and interpretation of subsurface data by using guided and automated workflows.
- Save hours to days determining the most relevant attributes by using PCA to reduce the number of attributes.
- Increase reservoir understanding by using SOM to blend seismic attributes together to create facies.

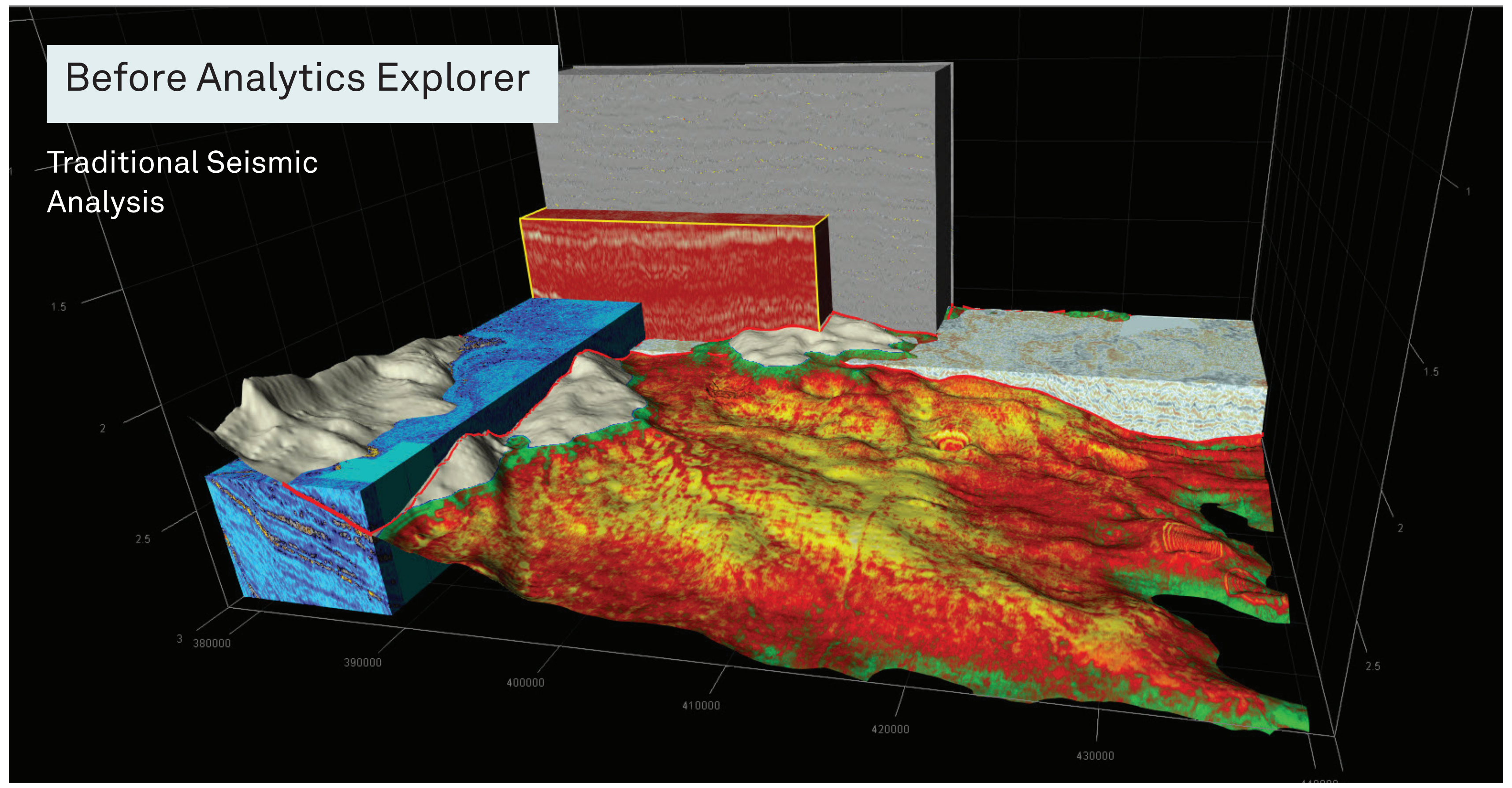


Figure 9: Kingdom 3D view of multiple seismic attributes extracted from a volume—the traditional, single-view approach to understanding multiple attribute distributions. You can only view one attribute at a time mapped across the horizon. One would need to switch between several attributes to view them all.

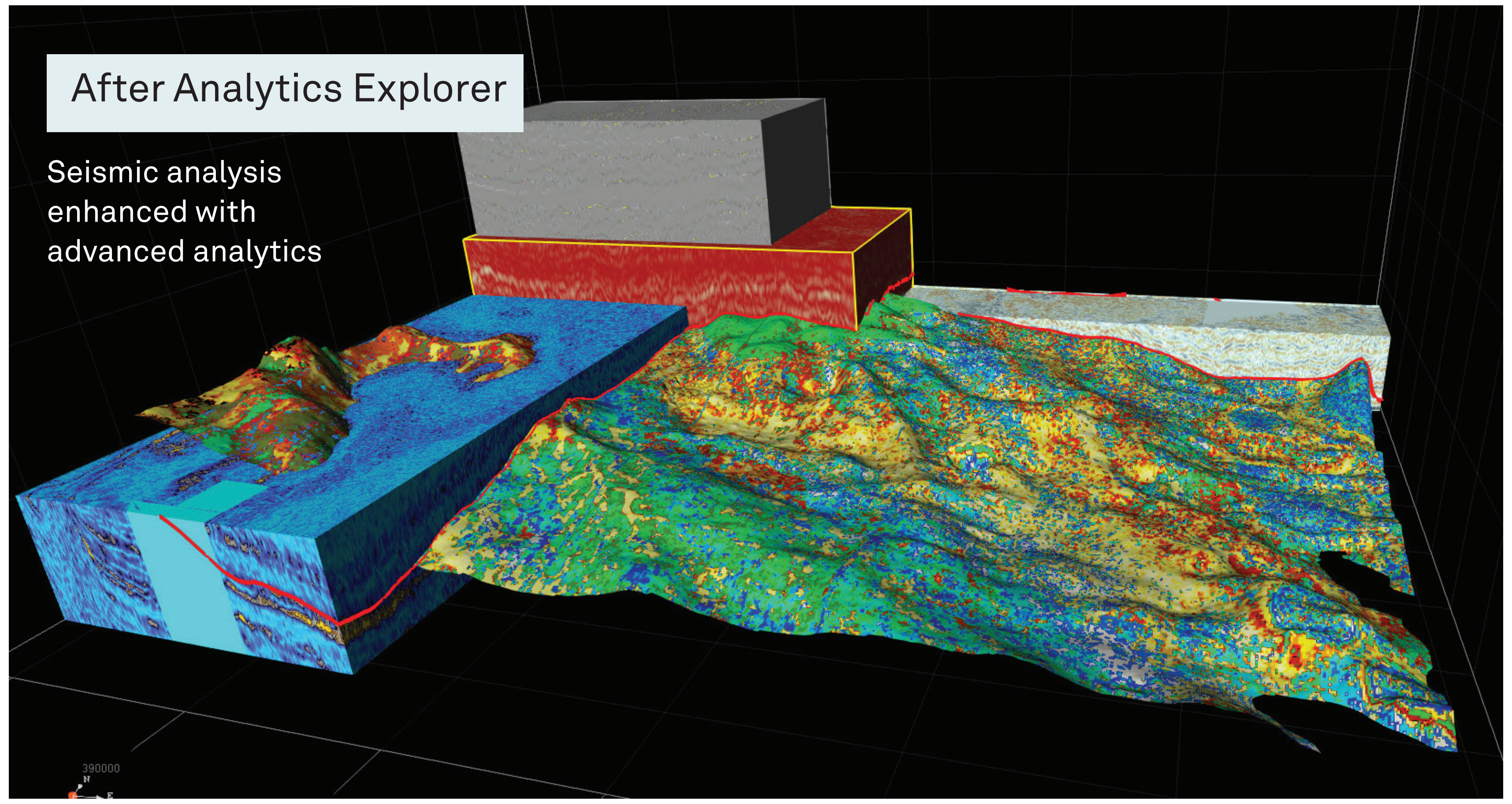


Figure 10: Kingdom 3D view of self-organizing map results—enhanced using Analytics Explorer. With a blend of 6 attributes, understanding of the subsurface becomes clearer. You can then use this and superimpose production wells on the map and tie the dominant seismic facies to the producing wells and anywhere else you see the same characteristics in the area (well performance/well producing).

Section Four

Applications

How will you use Analytics Explorer?

Accelerate the analysis and interpretation of your subsurface data to reveal complex patterns and make better decisions.

Geophysicists

Scan seismic interpretations for outlier identification.

Blend attributes together to create seismic facies.

Explore seismic trends by cross-plotting horizon extractions together

Geologists

QC formation top interpretations.

Calculate well spacing and identify Parent/Child relationships.

Combine geological interpretations with engineering metrics to identify what is impacting well performance.

Petrophysicists

Analyze which wells have log coverage for specific target formations.

Complete missing log data using machine learning.

Identify outlier points quickly in your data.

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