[GC]Seismic Meta-Attributes as a Practical Exploration Tool: Gas Chimney and Fault Volumes*

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Introduction

Gas chimney and fault volumes extracted from 3-D seismic data are rapidly becoming valuable tools for exploration and field development. Various seismic anomalies such as chimneys, faults, fractures, salt and sand bodies can be highlighted using a new technique that analyzes data with combinations of seismic attributes.

This article focuses on the mapping of gas chimneys and faults.

New Type of Seismic Volumes

Chimney cubes (Figure 1) and fault cubes (Figure 2) are used to map areas where the seismic detects anomalous patterns of amplitude and similarity in combination with other attributes like dip variance and curvature. They help determine where hydrocarbons originated, how they migrated into a prospect and where they leaked, creating shallow gas (and sometimes mud volcanoes, or pockmarks) at the sea floor.

Current applications of chimney and fault cubes include:

- Unraveling a basin’s migration history.
- Distinguishing between charged and non-charged prospects.
- Distinguishing between sealing versus non-sealing faults.
- Determining vertical migration of gas.
- Identifying potential for overpressure.
- Detecting shallow hazards.
- Predicting hydrocarbon phase and charge efficiency, especially in multiphase petroleum systems.

Computers can be trained to search through data volumes looking for seismic objects, using carefully designed criteria “meta-attributes,” which are an aggregation of a number of seismic attributes where the interpreter's insight is combined with the power of a trained neural network to detect a particular seismic anomaly.

As shown in Figure 3, a multitude of attributes from known or suspected chimneys (or faults) are used as input to a neural network. Training of the neural network using interpreter's insight renders the "meta-attribute" suitable for detection of a given seismic body, like gas chimneys or fault patterns.

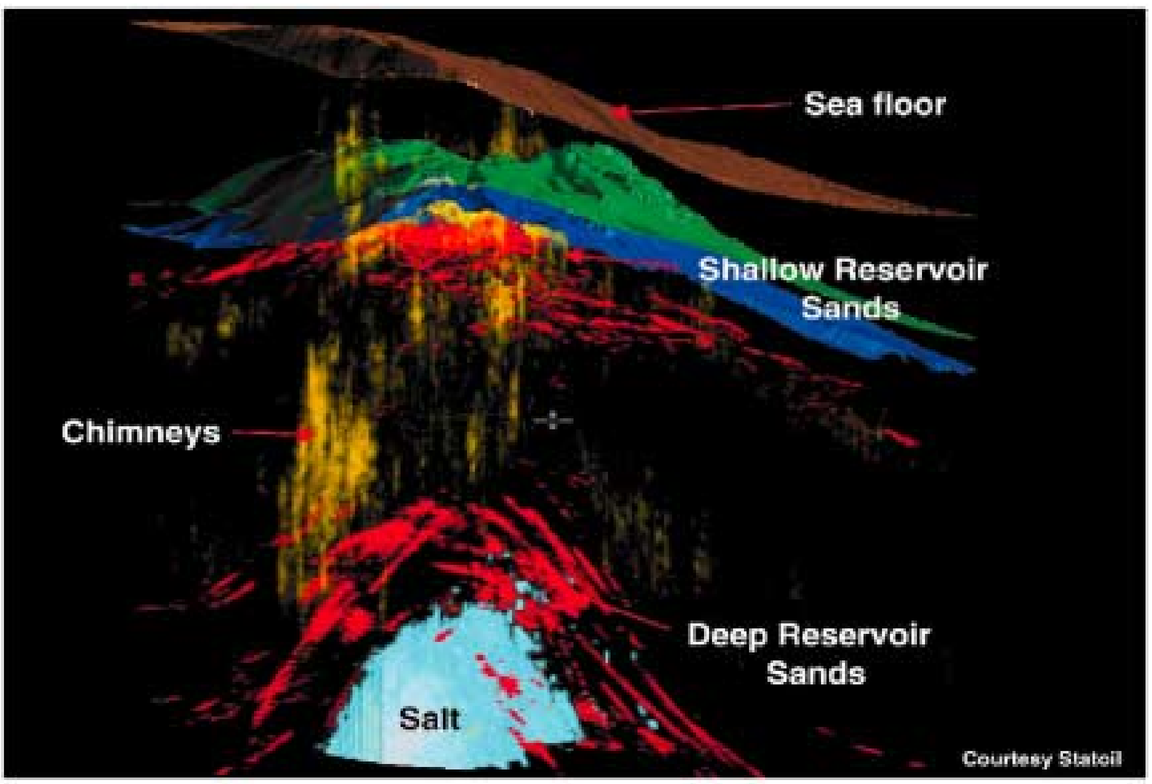

Figure 1. Gas chimney (in yellow) overlaid on reservoir structure.

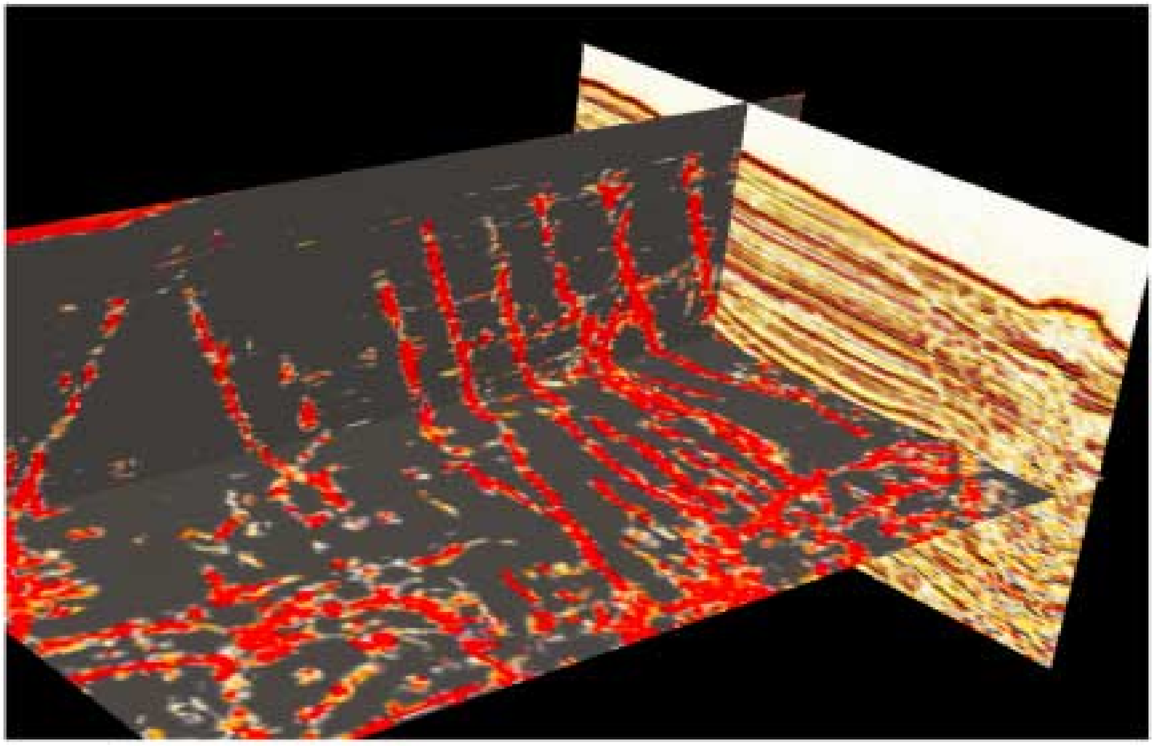

Figure 2. An example of a fault cube with the horizontal and vertical slices tied to an original seismic section.

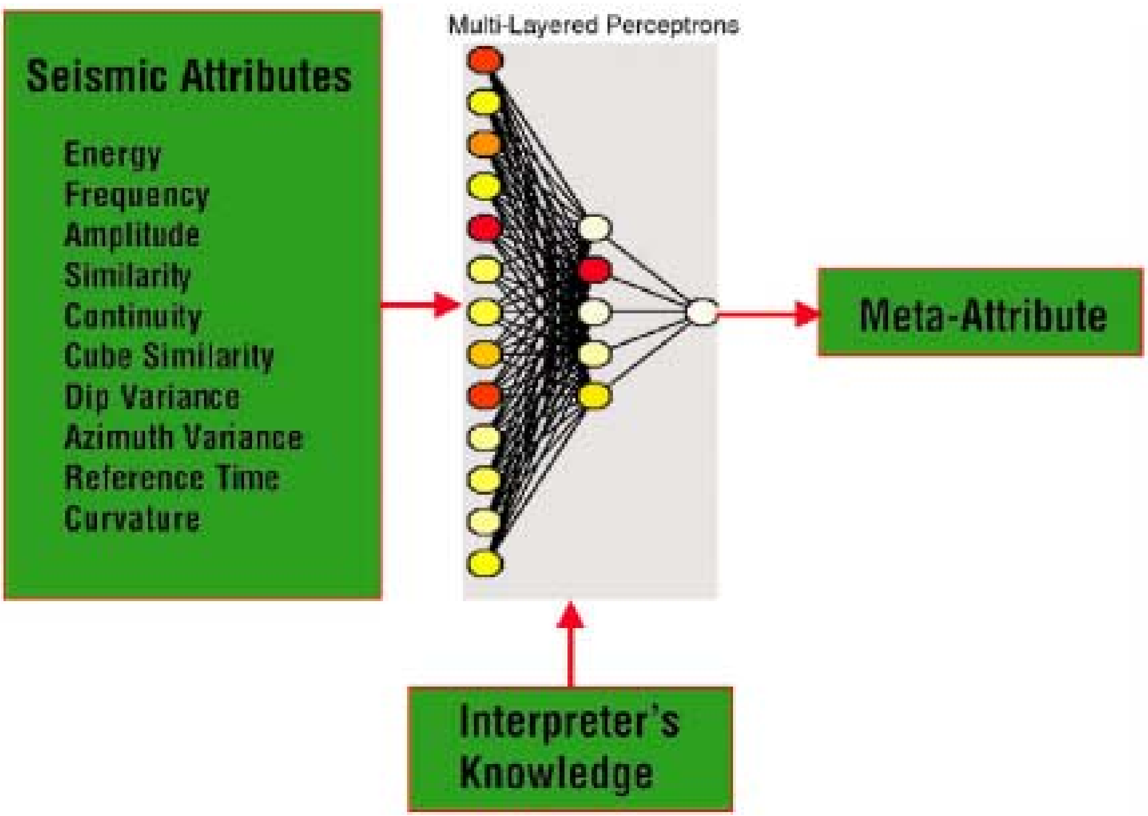

Figure 3. Creation of a meta-attribute.

Gas Chimney

Figure 1 shows a typical gas chimney in yellow overlaid on a deep salt structure with deep and shallow reservoir units. It highlights the migration pathway of hydrocarbon from deep structures into shallower reservoirs and into near surface gas pockets.

Gas clouds and gas chimneys have often been considered as a source of seismic noise that degrades the quality of seismic reflection events. Much effort has been devoted to filter out the impact of gas clouds and provide interpretable sections by imaging through them. Our main focus, however, is to highlight such events and establish a link between chimney characteristics (occurrence, type and extent) and geologic concepts critical for successful exploration. For example, mapping the location and origination/termination points of gas chimneys helps the:

- Understanding of deep petroleum migration processes.
- Distinguishing between charged and non-charged fault segments.
- Detecting sealing versus leaking faults.
- Distinguishing oil-prone versus gas-prone prospects.

Sometimes it is difficult to pinpoint deep migration pathways on a conventional seismic line – but chimney cubes can highlight subtle features like vertical gas migration in the geopressured sections of the Gulf of Mexico. This helps substantiate predictions of geochemists and geologists that vertical migration is an important process in charging Tertiary reservoirs in the Gulf of Mexico and in other similar basins around the world. Chimney and fault volumes improve the understanding of the petroleum system and identify the role faults play in the migration of hydrocarbons into the reservoir.

Distinguishing Charged Fault Segments

In Figure 4 we have overlaid the chimney halo (in orange) on top of the seismic section. Note that the two structures on opposite sides of the fault have similar seismic response but very different charge probability. The structure on the right side of the fault has no chimney halo associated with it, and thus is less likely to be charged. In general, structures with some associated strain possess preferential charging potential. Of course, we have to keep in mind that excessive strain would be a major leak risk, so chimney analysis should be used in conjunction with other tools which predict stress/strain regimes.

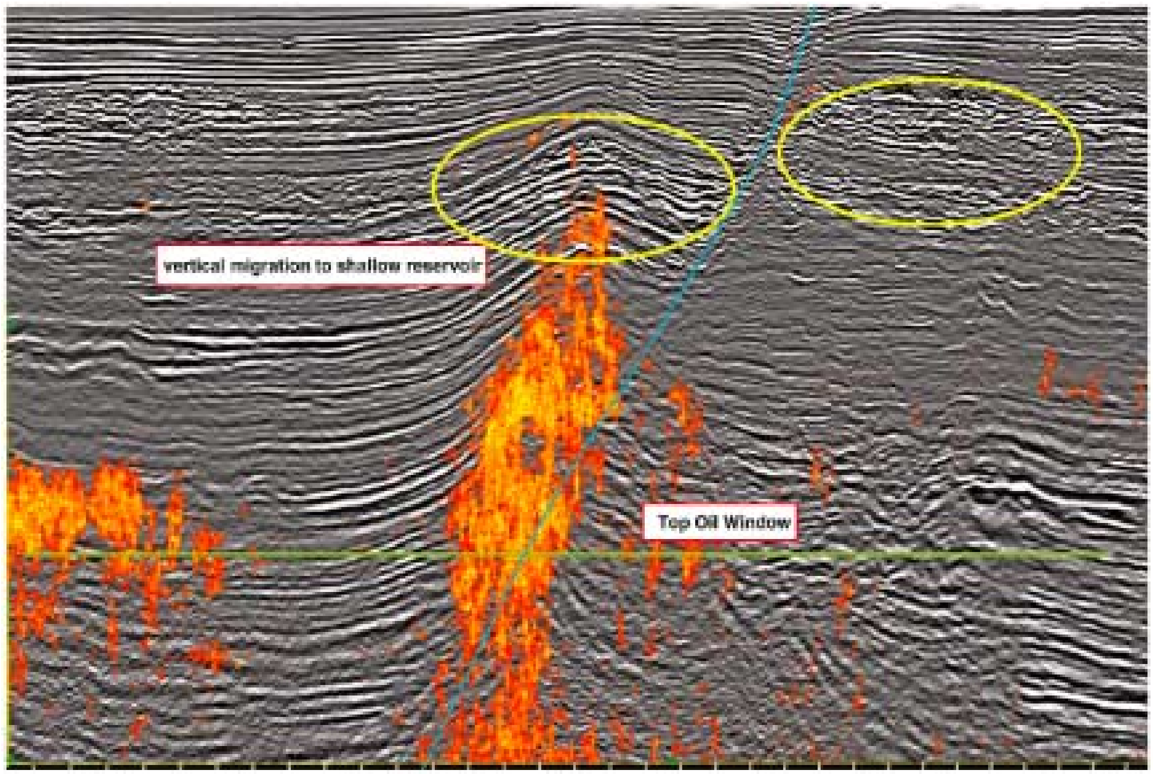

Figure 4. Distinguishing gas-charged versus non-charged fault segments.

Sealing vs. Leaking Faults

Combining fault and gas chimney data can be a powerful tool in detecting hydrocarbon migration pathways. Figure 5 shows their use in determining sealing versus leaking faults. While all the mapped faults are highlighted in Figure 5b, the subset of the faults that are likely to be leaking show up in the chimney volume of Figure 5a. This information can then be integrated with other regional information to assess probability for hydrocarbon charge and seal.

Many fields in the Gulf of Mexico and other basins demonstrate that the fault systems associated with gas chimneys have been major charging pathways for the reservoirs. Figure 6 shows active chimneys (in yellow), both large (e.g., one at the intersection of the two lines) and small (along selected fault blocks) that are considered to be leaking. Presence of chimney-like behavior along faults can indicate evidence of vertical hydrocarbon movement.

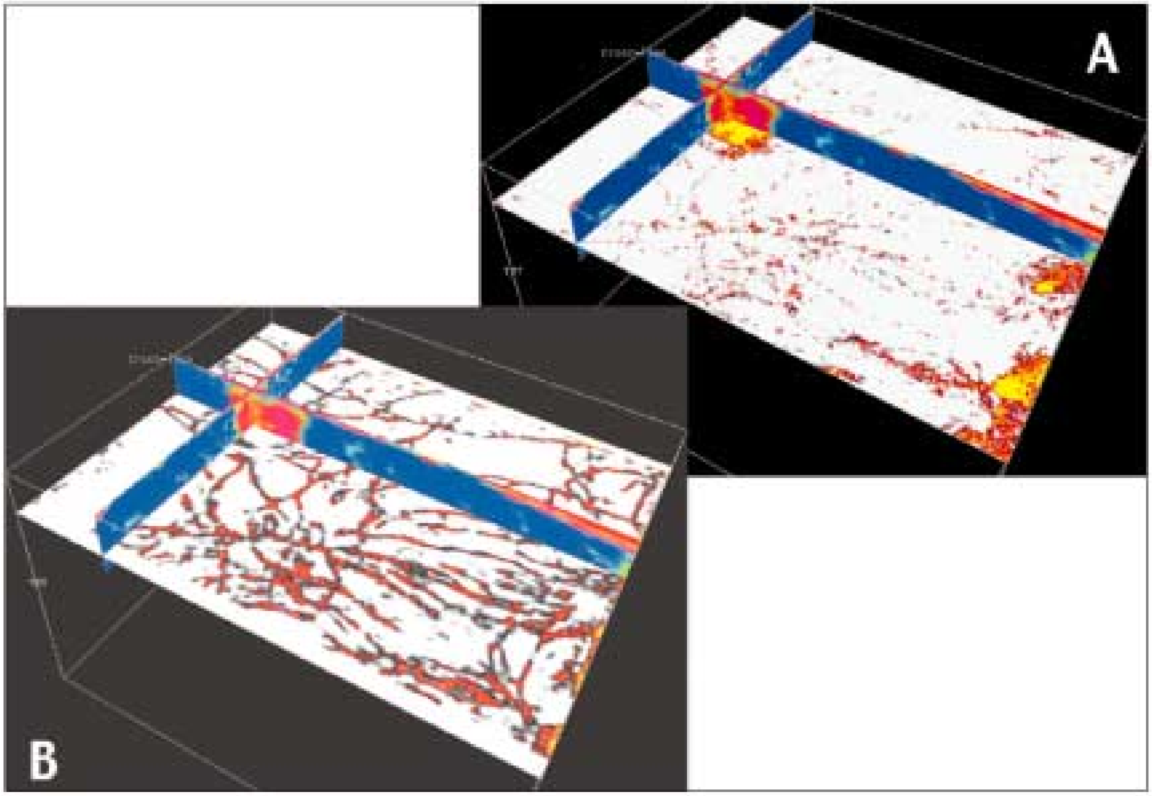

Figure 5. Comparison of a horizontal slice of a chimney cube (A) and fault cube (B).

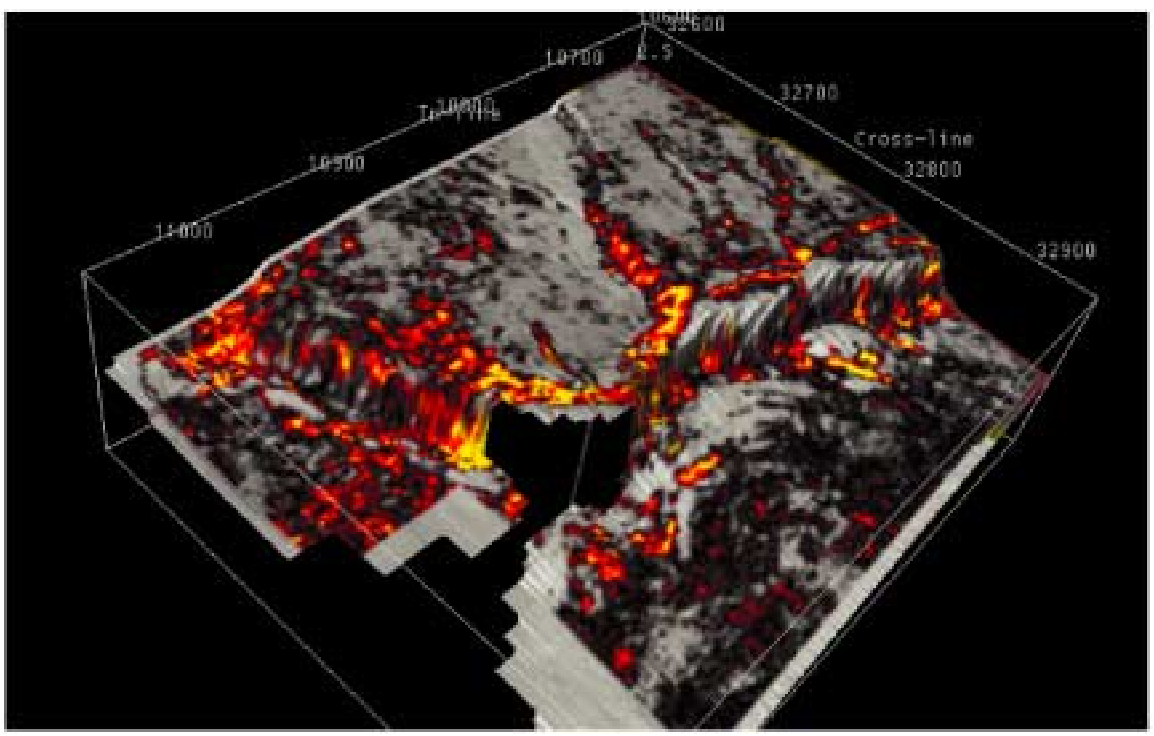

Figure 6. Active chimneys (in yellow) along faults that form the trapping mechanism of the gas reservoir.

Oil-Prone vs. Gas-Prone Prospects

In multi-phase petroleum systems, where both oil and gas are migrating into a trap, the structures that vent the gas (either through faulting or fractures) will be more oil-prone. Processing can detect the weak signal associated with venting. This approach has been used to successfully predict hydrocarbon phase in a number of basins in West Africa, the North Sea, GOM and the Far East.

Based on worldwide case histories from gas prone basins, chimney and fault cube analysis is a proven tool to make geologic predictions. This includes:

- Relating surface seeps to subsurface structures and reservoirs.
- Understanding the hydrocarbon history model.
- Ranking prospects.
- Detecting reservoir leakage and spill points.
- Assisting in identifying potential over-pressured zones and shallow gas drilling hazards.
- Assessing the sea floor stability for platform design and drilling.