Detection of natural gas leakage from deep-seated reservoir using multi attribute analysis through artificial neural network in Poseidon basin, North-West shelf Australia

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Keywords

Gas Chimney, Multi attributes, Artificial neural network and Chimney cube.

Summary

Hydrocarbon seepage has common occurrence in passive continental basins, mainly gas leakage. Accurate delineation of seepage can accentuate the hydrocarbon migration path and can alleviate drilling hazards. Hence, proper identification of gas leakage has huge implication in understanding the petroleum system and its prospectivity. Many authors have reported events of gas leakage in the present study area, it has never been investigated in detail to confirm the origin of this gas leakage as well as to understand the associated petroleum system. In this study, an attempt has been made to delineate detail configuration of such system from full stacked 3D seismic data using multi-attribute analyses together with state-of-the-art artificial neural networks. The study concluded that the deep reservoir of Jurassic age (i.e., Plover formation) is acting as the source of gas which is migrating through the available fault network of this area.

Introduction

In passive continental marginal basins, hydrocarbon leakage is a recognized phenomenon key examples include Orange basin, Gippsland basin, Yampi shelf, Poseidon basin, Colorado basin etc. (*e.g.* Anka et al., 2014). The seepage of hydrocarbon (especially gas) is either by biogenic gas saturation (Judd et al., 1998) or by thermogenic hydrocarbon generation from deep-seated source rocks (Anak et al., 2014). Assessing the hydrocarbon seepage/migration gives concreate idea of seal quality, indication of possible charging of reservoirs or hydrocarbon charge type, Indication of possible spillage from these reservoirs and detection of geohazards. Hence, the knowledge of natural hydrocarbon seepage has proven to be a high-end tool in the realm of petroleum prospectivity, evaluation and exploration.

Subsurface features like gas chimney, isolated carbonate builds, polygonal faults, and bright spots or sea surface features such as mud volcanoes, pockmarks present in post-stack seismic data have been deciphered as an indicator of gas leakage from the deep-seated reservoir rocks (e.g. Anak et al., 2014; Singh et al., 2016). To delineate the features related to gas chimney and fault network, multi attributes analysis through Neural network have been used, as they have revolutionized the domain of 3D seismic interpretation and are recognized as an excellent and efficient imaging tool for enhancing different subsurface features like faults, gas chimney, salt dome etc. (Meldahl et al., 2001; Singh et al., 2016; Mandal & Srivastava, 2018; Kumar et al., 2019a; Kumar et al., 2019b).

Australia's North-West Shelf has witnessed cases of gas seepage for example; in Yampi Shelf it was detected using Geochemistry and Remote sensing techniques (O'Brian et al., 2002) and similarly in Poseidon basin it was detected through carbonate platforms (Howarth & Tiago, 2016). However, gas seepage detection using multi attribute analysis through Neural network has not been applied in Poseidon area. This study aims to assess the path of hydrocarbon migration from the deeper reservoir to the seabed from the identification of gas chimney using multi attribute analysis.

Study area

The Browse basin is a passive continental margin basin having NE-SW trending which was developed from the late Jurassic to the Cenozoic, and the depocentre located entirely in the offshore Timor sea region and there are two major depocenters, Caswell and Barcoo Sub-basins. It has areal extant of approximately 140,000km^2 and consisting sediments thickness of 15Km. and these sediments have been recording all tectonic activities from Palaeozoic to Cainozoic era (ConocoPhillips report, 2012). (please refer figure 1).

The history of basin development can be divided into six main phases (Struckmeyer et al., 1998). These phases include extension, thermal subsidence and inversion and they occurred twice during the basin development (please refer table 1).

Table 1: Tectonic activities corresponds to Periods

Period	Activity
Late Carboniferous to Early Permian	Extension
Late Permian to Triassic	Thermal subsidence
Late Triassic to Early Jurassic	Inversion
Early to Middle Jurassic	Extension
Late Jurassic to Cenozoic	Thermal subsidence
Middle to late Miocene	Inversion

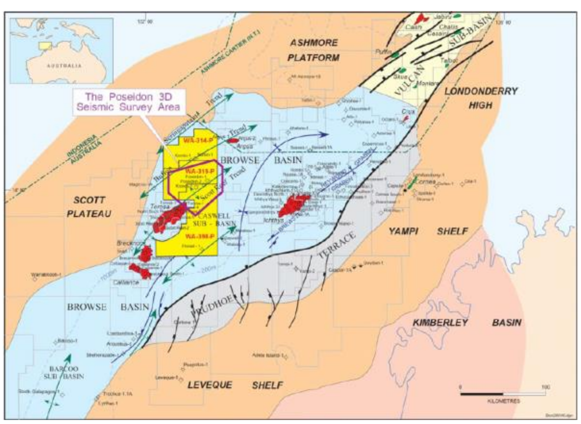

Figure 1: Regional structral map of Browse basin (source: ConocoPhillips report, 2012)

Theory and Methodology

Chimney produce the chaotic features in the seismic data, where the reflectors are discontinuing, and amplitude signatures are week. Keeping these characteristics in mind, we have used attributes that can highlight them clearly. So, in this study attributes have been used. For combining these extracted attributes Neural Network (NN) has been used wherein supervised classification/training was applied for training the NN to generate a gas chimney probability cube (please refer figure 2).

In order to achieve mentioned gas chimney probability cube, the workflow has been segmented into three steps (please refer figure 2). 1) Data conditioning, 2) Attributes calculation, and 3) Applying NN to seismic volume

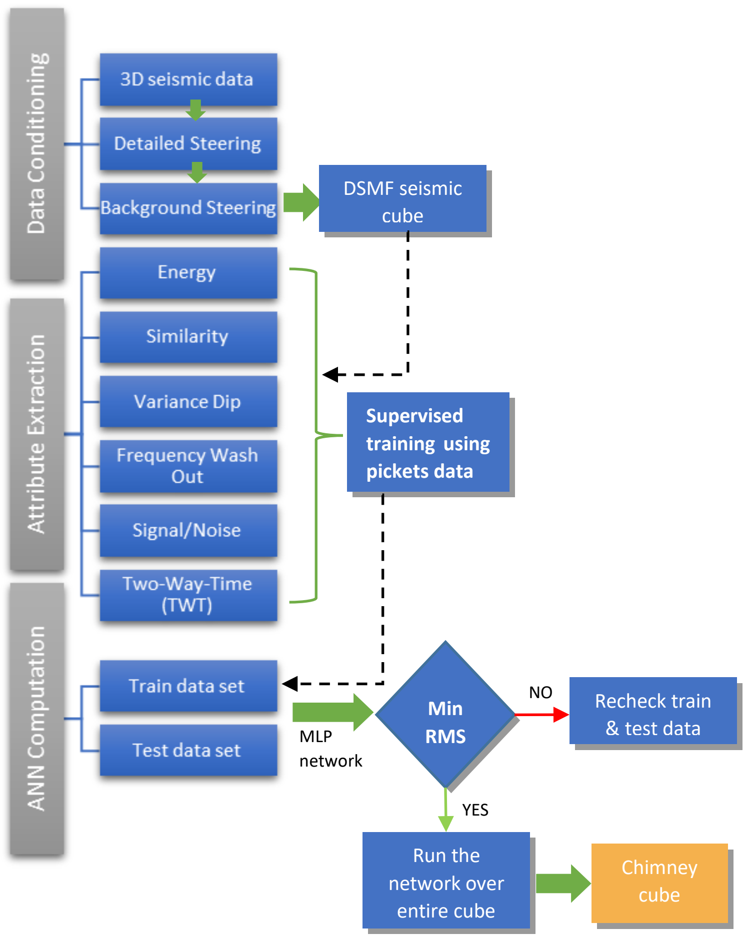

Figure 2: Workflow adopted in this study

1) Data Conditioning

To remove the acquisition footprints, artefacts and noise, which were not removed at the time of processing. Hence data smoothing has performed to get the clear and noise free data for further processing (Mandal & Srivastava, 2018). This data conditioning has following steps;

a) Dip & Azimuth calculation
b) Structural filtering

2)Attributes Computation

Seismic attributes are mathematically derived parameters from the seismic data, which act as a value addition to the qualitative seismic interpretation like enhancing subsurface structural features or identifying active petroleum system (Chopra and Marfurt, 2007). In this study to enhance the features related to gas chimney following attributes has been used (please refer figure 3);

Table 2: Signature of attributes in the gas zones

Attribute	Property	Signature
Energy	Square of amplitude	Low energy
Similarity	Shows coherency between traces	Low similarity
Variance dip	Change in dip direction	Highly variable dip
Frequency wash out	Ratio of low and high frequency	High frequency wash out
Signal/Noise (S/N)	Signal to noise ratio	Low S/N value
TWT	Twice of travel time	More TWT

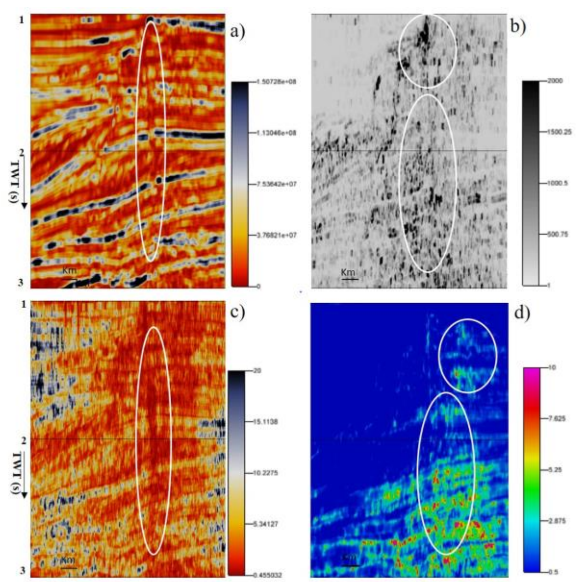

Figure 3: Signature of attributes highlighting gas leakage zones a) Energy – vertical low energy zone, b) Dip variance – high dip variance zones, c) Signal/noise – low vertical zones & d) Frequency wash out – patches of high wash outs

3)Applying NN to seismic volume

For applying NN to complete seismic volume, first dataset needs to be trained by manually picking points of Chimney and non-chimney zones then NN train itself through the data and try to establish the relation between extracted attributes (input) and Chimney yes and no points (output) (please refer figure 4). As it's an iterative process where weights of attributes keep changing and we have to train NN till the time we get minimum RMS error between expected and observed output. For quality check the output of NN can be seen in a section and after getting satisfactory result it can be applied to whole seismic volume.

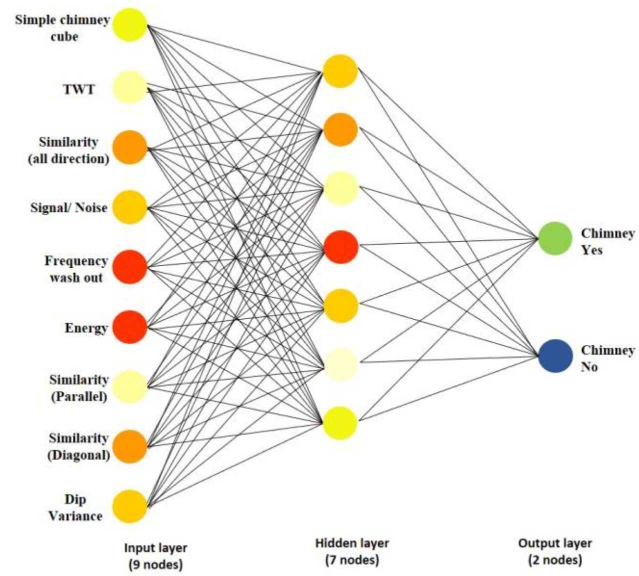

Figure 4: MLP network

Table 3: weights of the extracted attributes

Attributes	Weights
Simple chimney cube	42.0
TWT	16.7
Similarity (all direction)	80.0
Signal/ Noise	53.9
Frequency wash out	85.7
Energy	55.1
Similarity (parallel)	58.9
Similarity (diagonal)	68.9
Dip variance	76.6

Results & Discussion

The created chimney cube clearly indicate that the source of leaked gas is from the deep reservoir (i.e. top plover formation of Jurassic age) and because of seal beach it continued its path through Jamieson formation (i.e. cap rock, Cretaceous age), Johnson formation (Tertiary age) till the seabed (please refer figure 5). In a Johnson horizon we can analyze the close relation between low similarity, which caused due to fault structures and structural deformation and high probability of chimney i.e. gas patches (please refer figure 7).

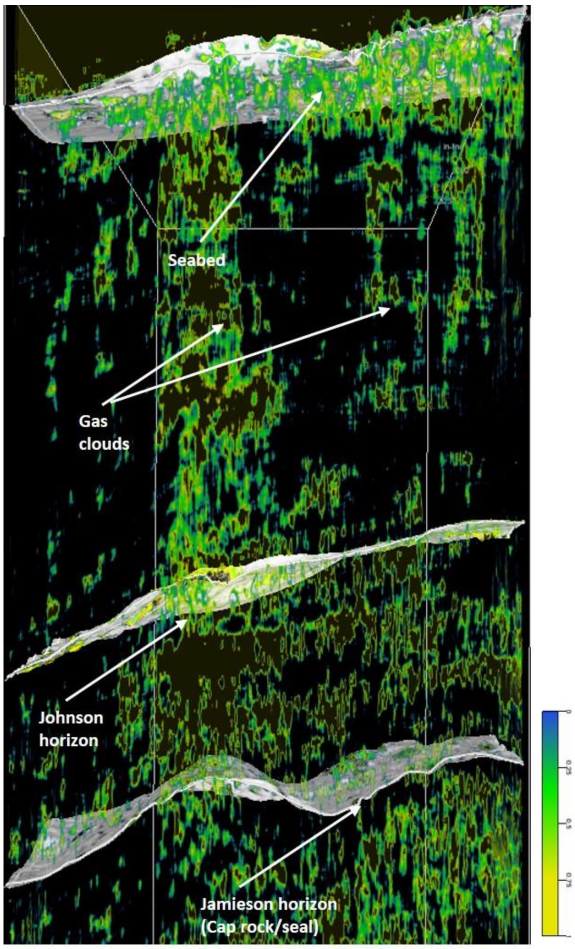

Figure 5: 3D chimney cube

The gas chimney cube can be validated by following parameters;

1) Presence of geological features

In this study area features like DHI, gas pipes and pockmarks are present, which shows that this is a plausible zone for hydrocarbon leakage and the presence of pockmarks clearly indicates that seepage of hydrocarbons are able to come up on the surface (please refer figure 6).

2) Carbonate growth pattern/ Isolated carbonate buildups

Many authors have reported the fluid flow features in North-West shelf Australia (Tuyl et al., 2018) and the occurrence of these fluid flow features in specific areas of the late Oligocene-Miocene and their association with the Pre-Miocene faults could be possible but when it was analyzed with deeper petroleum system of browse basin, it showed remarkable semblance (Serié et al., 2012). Even hydrocarbon leakage from deeper reservoir has been reported in the near area Timor Sea (Gartrell et al., 2003), and Australian Basin (Logan et al., 2010)

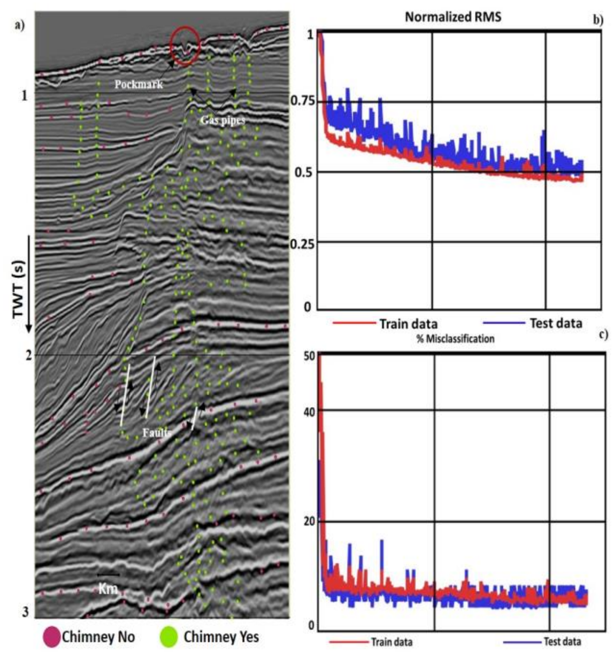

Figure 6: a) section (Inline: 2370)showing selected points for training the NN and graphs showing b) RMS error and c) misclassification

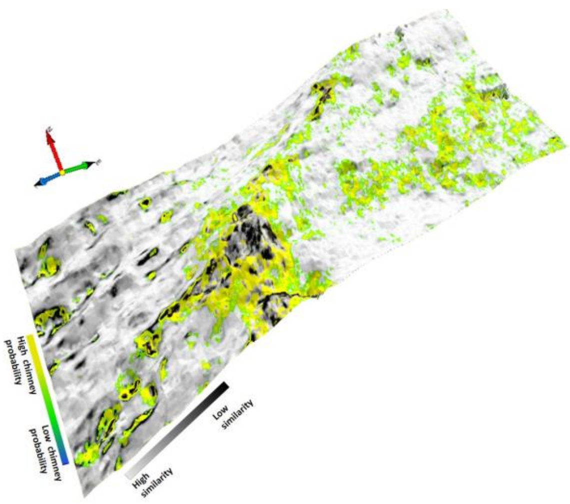

Figure 7: Chimney and similarity attributes are in conjuction at horizon slice of Johanson formation.

Conclusions

This study evidently shows that the main source of gas leakage in Poseidon area, Browse basin is from the deeper petroleum system (Breach in seal) and continued through Jamesion horizon, Johnsons horizon till the seabed. The used technique is robust and reliable for enhancing the subsurface features. The breach in seal can be attributed due to the reactivation of Jurassic faults and regional tectonic inversion that happened after the onset of subduction in the Timor Trough which resulted in highly variable style of deformation in the entire Browse basin .

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