GAS CHIMNEY IDENTIFICATION USING THE INTEGRATION OF SEISMIC ATTRIBUTES

M.R. BAKHTIARI[1] and M.A. RIAHI[2]

[1] *NIOC Exploration Directorate, P.O. Box 19395-6669, Tehran, Iran.*
RBakhtiari@niocexp.org
[2] *Institute of Geophysics, University of Tehran, P.O. Box 14155-6466, Tehran, Iran.*

(Received September 30, 2007; revised version accepted September 1, 2008)

ABSTRACT

Bakhtiari, M.R. and Riahi, M.A., 2009. Gas chimney identification using the integration of seismic attributes. *Journal of Seismic Exploration*, 18: 43-56.

Open and fluid conductive fractures in some reservoir rocks cause gas accumulation in upper horizons leading to a gas column resembling a chimney and thus known as a gas chimney. There are two different methods for identification of gas chimney locations; the first one is the direct viewing of signal amplitude variations and in the second method, single seismic attributes like dip variance, energy and similarity, etc. are used.

In this paper we introduce a new method based on the direct viewing of amplitude variations and the integration of several attributes in an Artificial Neural Network (ANN). A comparison of the results obtained by the presented approach with those given by the common approach using only amplitude viewing method or single seismic attribute shows a considerable improvement in the identification of gas chimney location.

KEY WORDS: gas chimney, seismic attributes, artificial neural network, amplitude, dip variance, energy, similarity.

INTRODUCTION

Many interpreters try to identify gas chimneys (Tingdahl et al., 2001; Tingdahl, 1999; Heggland et al., 1999; Heggland, 1997) either by viewing the amplitude variations on the seismic sections or by using single attributes, but these methods do not give reliable results for the identification of gas chimneys.

0963-0651/09/$5.00

As is known, the identification of such objects is very important because if their exact location is recognized, then it will be possible to explore a gas reservoir. In spite of the fact that the identification of these events on the seismic sections is extremely difficult as they may often be caused by fractured zones.

Some of the industry interpretation software has introduced new attributes to improve gas chimney identification. In this article a combination set of attributes was input to an Artificial Neural Network (ANN) by using OpendTect software. Based on our approach, at first, a preliminary interpretation of the gas chimneys was done on the seismic section. In the next step all the single attributes on the seismic section were derived. In the third step, the results from the first and the second steps were combined and considered as a target dataset for the ANN system.

By inputting our datasets to the ANN system, two different results were generated. The first output dataset indicated a cube showing a gas chimney and the second dataset provided a cube that does not contain a gas chimney.

GEOLOGY OF THE STUDIED AREA

This study was done in the southern Caspian Sea near the Iranian shoreline. According to the geology of this area, the basement of the Caspian Sea is divided into three major parts. The northern part of the Caspian Sea belongs to the Precambrian stage and the average depth of the Caspian Sea in this area is about 8 meters; the middle part, which is the continuation of the Caucasus Mountains, belongs to the Hercinian stage; and the southern part of the Caspian Sea belongs to the Mesozoic and Pliocene stages. The maximum depth of the sea in the southern part is nearly 1000 meters and the average depth in the southern part is 200 meters and for this reason, drilling in the southern part of the Caspian Sea is very difficult. Therefore, the exploration activity in the southern part has been focused close to the seashore only, and no serious exploration activities have been done in the southern part of the Caspian Sea. Most of the geologists believe that in the southern part of the Caspian Sea the oceanic crust consists of basaltic basement.

This area is well-known for the existence of numerous gas chimneys, but the system of these types of gas chimneys has not been exactly indicated. Identification of the gas chimneys in the southern part of the Caspian Sea is of great importance for making new and successful explorations of gas reservoirs. However, gas chimneys can occur over oil fields in the Caspian basin (Heggland, 2005). In order to identify the location of gas chimneys by the direct investigation of the amplitude variations, the seismic section of Inline 1100 was selected (Fig. 1) and a preliminary interpretation of the section was conducted.

As is shown in Fig. 1, the red circles indicate the region containing the gas chimneys and blue circles indicate the non-chimney area, but the exact locations of the chimney are not constrained.

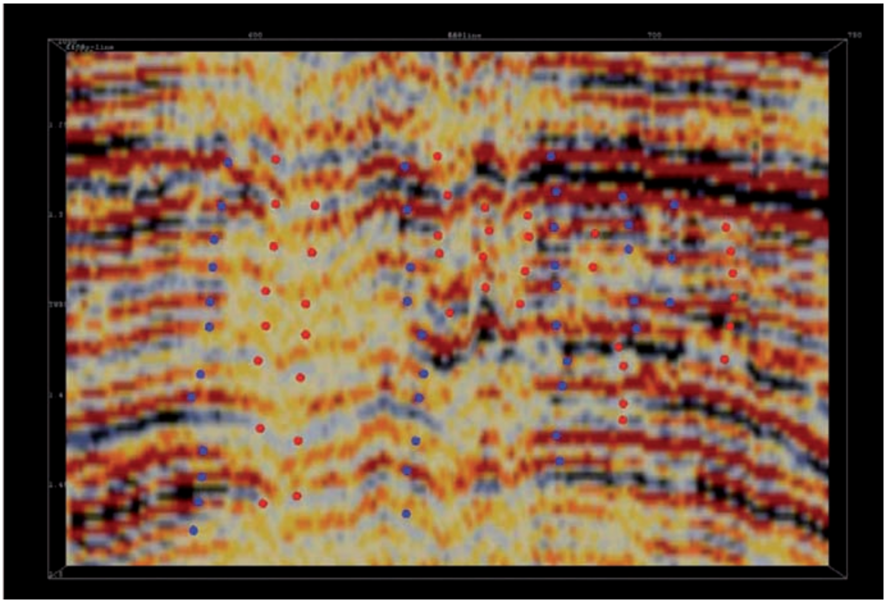


Fig. 1. The seismic section of Inline 1100 showing the picked areas, the blue circles indicate the non chimney area and the red circles indicate the chimney area.

APPLIED ATTRIBUTES

To better identify the location of gas chimney, attributes such as: dip variance, similarity and energy were also studied. The results derived from each single attribute were investigated separately and then the integration of these attributes was performed on the same seismic section. The next sections give the relations for the above mentioned attributes which were applied on the seismic section by different specifications.

DIP VARIANCE

Dip variance is one of the best attributes that can detect the variation of the dip layers. It is defined by the following relation:

$$\mathrm{var}\,p(x) = [1/(n-1)] \sum_{\beta=-x_s}^{x_s} \sum_{\alpha=-y_s}^{y_s} \sum_{\tau=-a}^{b} [p_x(x+\alpha,y+\beta,t+\tau) - \bar{p}_x]^2 \quad . \quad (1)$$

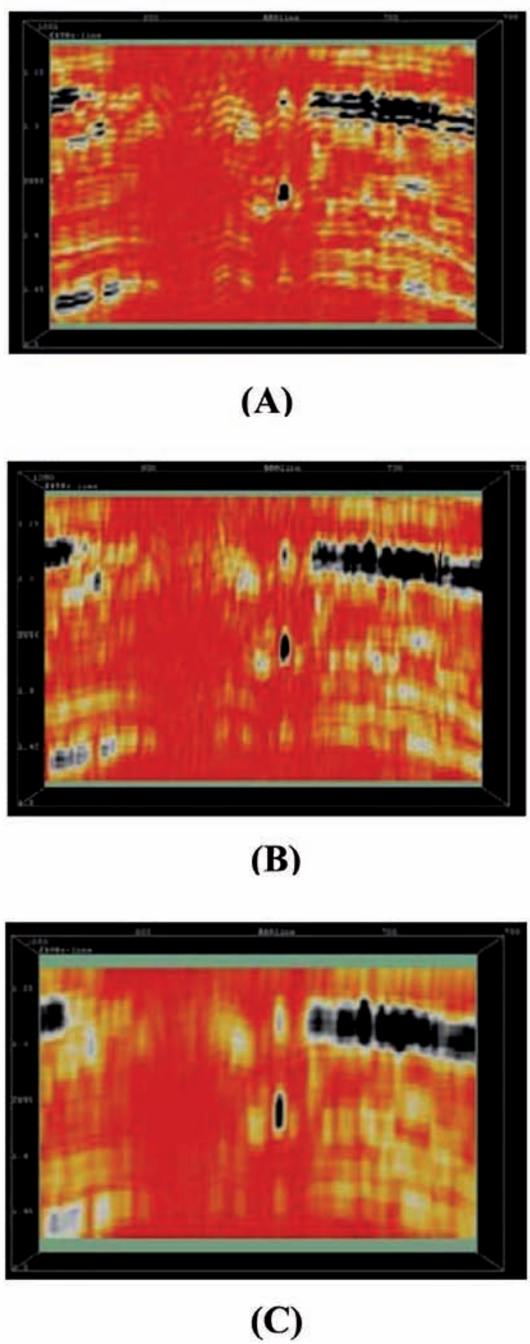


Fig. 2. Dip variance attribute with different time gates.

Part	Time gate	Lateral position
A	(−5, 5)	Step-out 1
B	(−10, 10)	Step-out 1
C	(−15, 15)	Step-out 1

Parameter n is the total number of terms in the triple summation; x_s and y_s are maximum trace steps-out; a and b are the upper and lower limits of the cube respectively; and p is the dip value which is defined by the following formula:

$$\bar{p}_x = (1/n) \sum_{\beta=-x_s}^{x_s} \sum_{\alpha=-y_s}^{y_s} \sum_{\tau=-a}^{b} p_x(x+\alpha, y+\beta, t+\tau) \ . \qquad (2)$$

Fig. 2 shows the result of the dip variance attribute on the seismic section with different time gates.

SIMILARITY

Similarity is a form of coherency attribute that shows how much two traces look alike. The maximum similarity is one which means that two traces are identical. The minimum similarity is zero which is used when the two traces are totally different. It is defined by the following relations:

$$S = 1 - |v - u|/(|v| + |u|) \ , \qquad (3)$$

where

$$v = \begin{bmatrix} f(t_1, x_v, y_v) \\ f(t_1+dt, x_v, y_v) \\ \vdots \\ f(t_2-dt, x_v, y_v) \\ f(t_2, x_v, y_v) \end{bmatrix} \ ,$$

and

$$u = \begin{bmatrix} f(t_1, x_u, y_u) \\ f(t_1+dt, x_u, y_u) \\ \vdots \\ f(t_2-dt, x_u, y_u) \\ f(t_2, x_u, y_u) \end{bmatrix} \ ,$$

Parameter dt is the sampling interval; t_1 and t_2 are the limits of the time gate, x_v, y_v and x_u, y_u are the trace positions; and f(t,x,y) is the amplitude value in the cube.

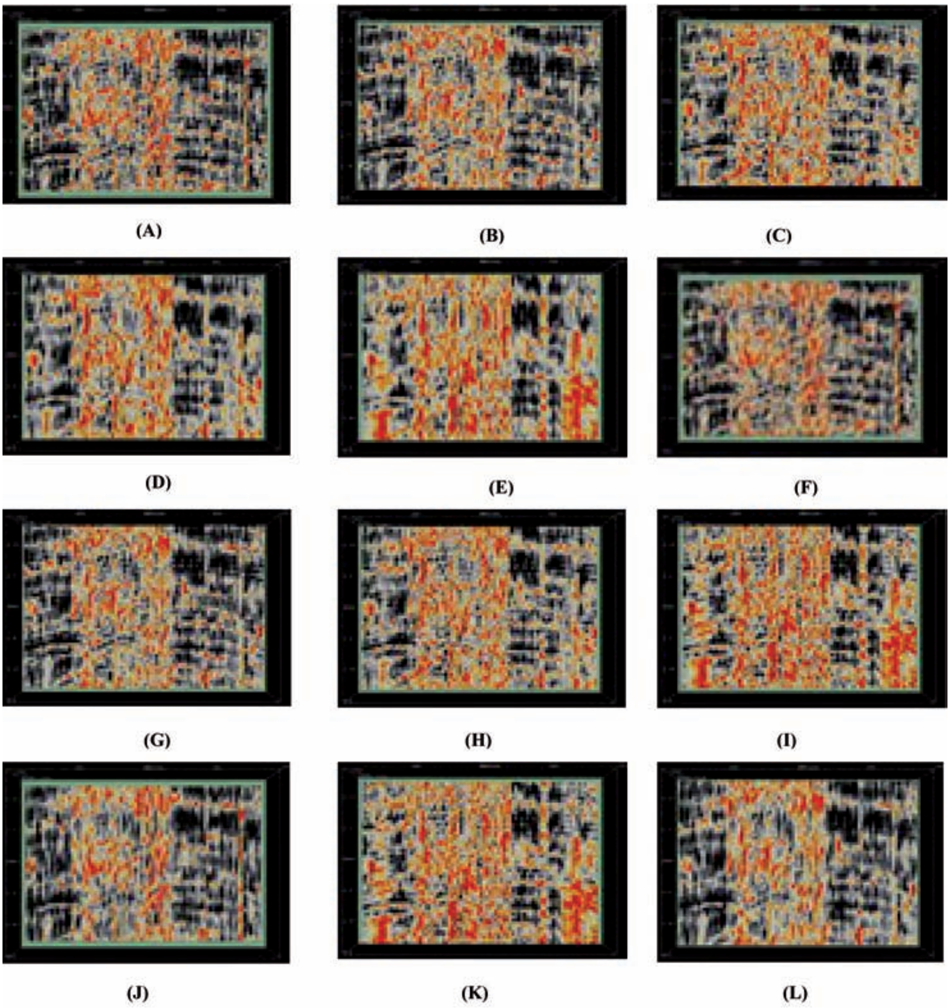


Fig. 3. Similarity attributes resulted from the different specifications given by Table 1.

Table 1 shows the similarity specifications that we used for ANN calculations. Full steering indicates that the similarity attribute follows the dip of the seismic event. This is critical in steeply dipping stratigraphy. The full steering cube contains the local dip and azimuth of the seismic events at every sample position but in the no-steering similarity we consider only the amplitude of seismic events regardless of the locations of the events. In this study, to improve the final result we have considered a combination of the full steering and no-steering similarity attributes. Fig. 3 shows the results from the application of similarity attributes based on the specifications tabulated in Table 1.

Table 1. Similarity attributes specifications used for ANN calculations.

Part	Time gate	Lateral position	Other settings
A	(−10,−5)	(−1,−1)(1,1)	Full steering
B	(−10,−5)	(−2,0)(2,0)	No steering
C	(−10,−5)	(−3,1)(3,−1)	No steering
D	(−10,−5)	(−4,3)(4,−3)	No steering
E	(−5,5)	(−1,−1)(1,1)	Full steering
F	(−5,5)	(−2,0)(2,0)	No steering
G	(−5,5)	(−3,1)(3,−1)	No steering
H	(−5,5)	(−4,3)(4,−3)	No steering
I	(5,10)	(−1,−1)(1,1)	Full steering
J	(5,10)	(−2,0)(2,0)	No steering
K	(5,10)	(−3,1)(3,−1)	No steering
L	(5,10)	(−4,3)(4,−3)	No steering

ENERGY

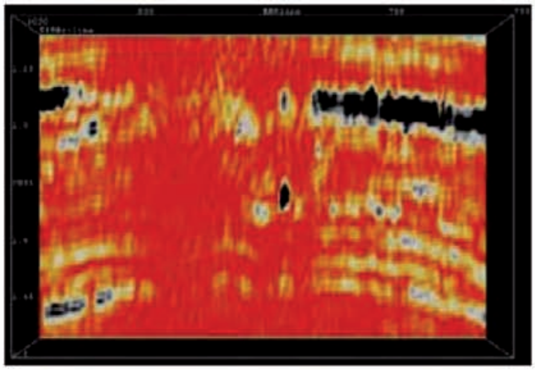
It is known that energy is the square of the signal amplitude which can be computed as in the relation below:

$$E = [\sum_{i=1}^{n} A_i^2]/n \quad , \tag{4}$$

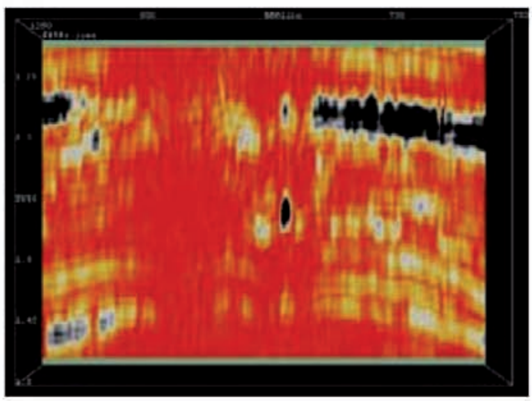
where n is the number of the samples of signal amplitude and A is the time gate. In this study, the energy attribute has been calculated within 3 different time gates: (−5,5), (−10,10) and (−15,15).

Fig. 4 shows the energy attributes computed from the selected time gates on the seismic section Inline 1100.

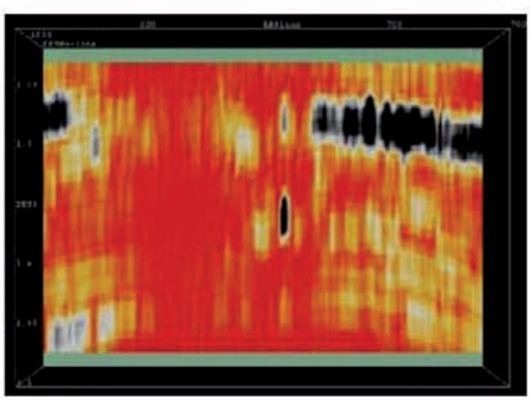
The comparison of the presented results of figures A, B and C shows that the proper location of the gas chimney is not clear. Therefore an attempt was made to combine these three attributes in an ANN system which was applied to the seismic cube.



(A)



(B)



(C)

Fig. 4. Energy attributes of different time gates: a) (−5,5), b) (−10,10), and c) (−15,15).

ARTIFICIAL NEURAL NETWORK (ANN)

After calculating all single attributes on Inline 1100, an ANN system with 3 layers, like the one shown in Fig. 5 was designed.

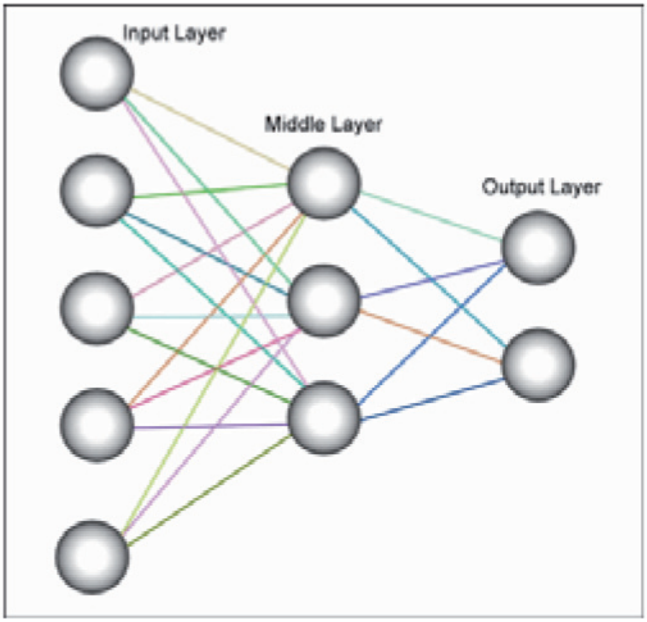


Fig. 5. A schematic diagram of an artificial neural network and its layers.

In an ANN system, data are fed to the system through the input layer. In this study two datasets were input to the system. The results of the first dataset are shown in Figs. 2, 3 and 4. The second dataset was derived from our preliminary interpretations of gas chimney locations (Fig. 1). Then calculations were made through the hidden layer and in the output layer we obtained two resulting datasets or output cubes at the nodes. The output from the first node is related to the chimney cube and the output from the second node belongs to the non-chimney cube. Table 2 shows the list of attributes and their specifications that were input to the ANN system.

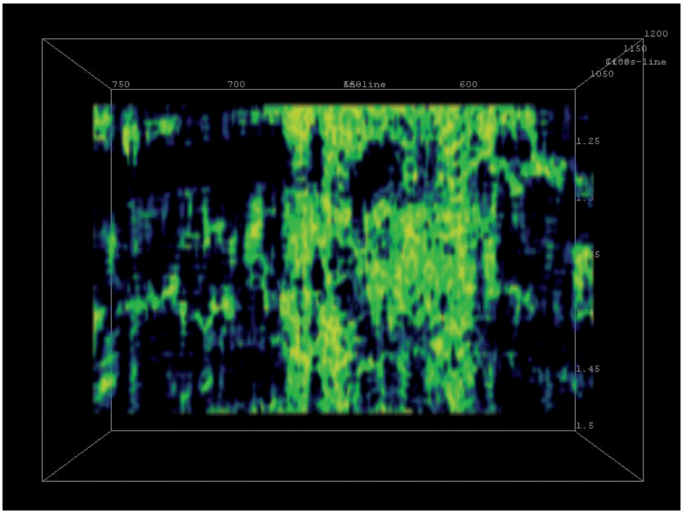
Table 2. The attributes and their specifications that were used in the ANN system.

Attribute	Time Gate	Lateral Positioning	Other Settings
Dip Variance	(−5,5)	Stepout 1	No Steering
Similarity	(−10,10)	(−2,0)(2,0)	Full Steering
Similarity	(−10,−5)	(−1,−1)(1,1)	Full Steering
Similarity	(−10,−5)	(−2,0)(2,0)	No Steering
Similarity	(−10,−5)	(−3,1)(3,−1)	No Steering
Similarity	(−10,−5)	(−4,3)(4,−3)	No Steering
Energy	(−10,10)	....	....
Dip Variance	(−10,10)	Stepout 1	No Steering
Similarity	(−15,15)	(−2,0)(2,0)	Full Steering
Similarity	(−5,5)	(−1,−1)(1,1)	Full Steering
Similarity	(−5,5)	(−2,0)(2,0)	No Steering
Similarity	(−5,5)	(−3,1)(3,−1)	No Steering
Similarity	(−5,5)	(−4,3)(4,−3)	No Steering
Energy	(−15,15)	....	....
Dip Variance	(−15,15)	Stepout 1	No Steering
Similarity	(−5,5)	(−2,0)(2,0)	Full Steering
Similarity	(5,10)	(−1,−1)(1,1)	Full Steering
Similarity	(5,10)	(−2,0)(2,0)	No Steering
Similarity	(5,10)	(−3,1)(3,−1)	No Steering
Similarity	(5,10)	(−4,3)(4,−3)	No Steering
Energy	(−5,5)	....	....
Energy	(−10,10)	....	....
Energy	(−15,15)	....	....

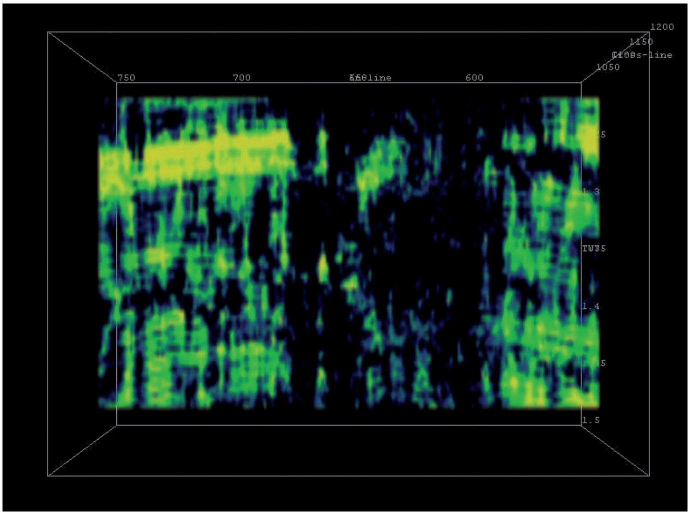
ANN RESULTS

In order to have better visualization of the ANN results, the generated gas chimney cube and non gas chimney cube are presented in Fig. 6. In Fig. 6A, the black color indicates the most probable locations of gas chimneys which are consistent with the locations obtained by the amplitude viewing method (Fig. 1). A comparison of the obtained results from the amplitude viewing method (Fig. 1) and those from the seismic attribute methods (Figs. 2, 3 and 4) with Fig. 6(A) shows that the presented approach in this paper, which is based on the integration of seismic attributes and the amplitude viewing method into the ANN system, can constrain the location of gas chimneys better than what each method individually can. Therefore, the presented approach may enable the interpreter to more confidently locate and identify the gas chimneys.

In order to better illustrate the ANN output, Fig. 7 has been generated based on time slice at 1348 ms from both gas chimney and non-gas chimney cubes. In this figure the gas chimney area and non-gas chimney area have been separated clearly. As shown in Figs. 7(A) and 7(B), the gas chimney location can be easily identified by tracking colors.

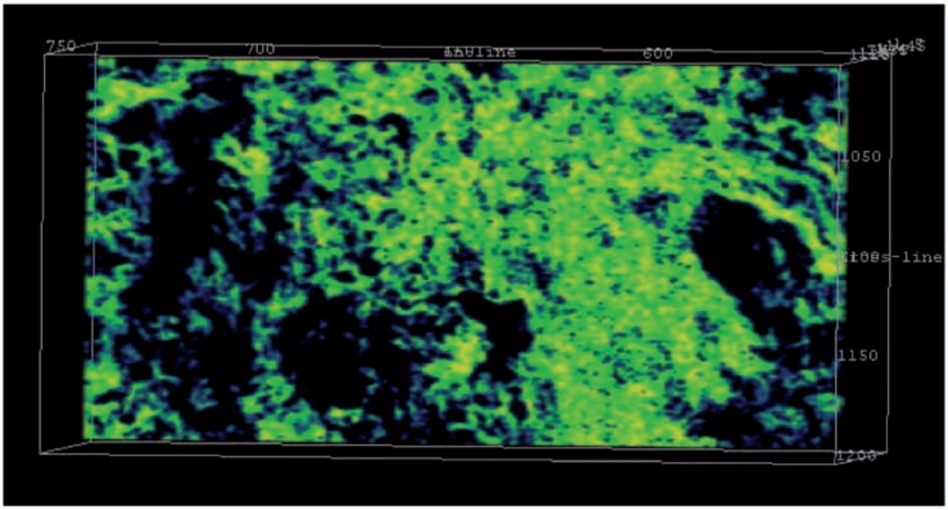


(A)

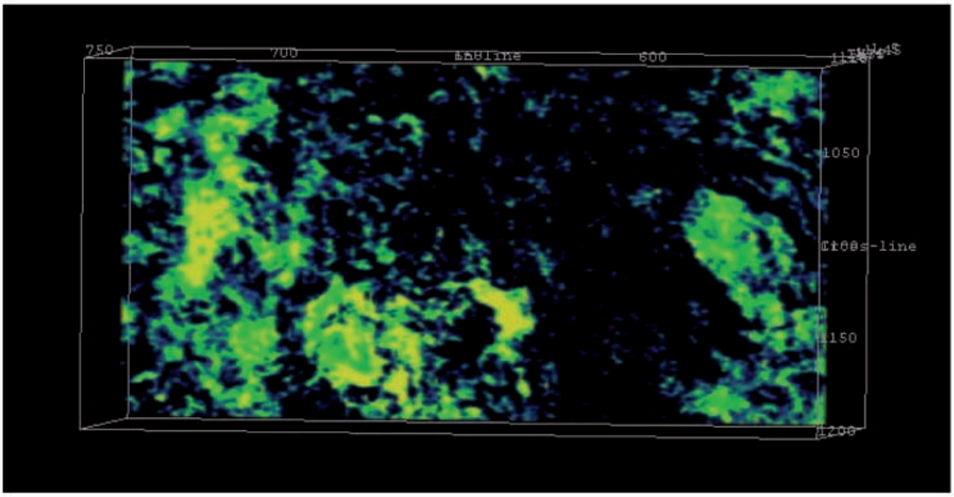


(B)

Fig. 6. The gas chimney cube (A) and the non-gas chimney cube (B) resulted from an ANN system used for seismic section Inline 1100. In section (A), the green color indicates the high possibility of gas chimney area and the black color indicates the high possibility of non-gas chimney area. In section (B), the black color shows the high possibility of gas chimney area and the green color indicates the high possibility of non-gas chimney area.



(A)



(B)

Fig. 7. Time slices of gas chimney cube (panel A) and non-gas chimney cube (Panel B) at 1348 ms. In panel A, the green color indicates the high possibility of gas chimney area and the black color indicates the high possibility of non-gas chimney area. In panel B, the green color indicates non- gas chimney areas and the black color indicates gas chimney areas.

CONCLUSION

To determine gas chimney locations, the conventional approaches like the amplitude variation viewing method as well as the dip variance, similarity and energy attributes were applied to the seismic section Inline 1100, respectively.

The results obtained from the amplitude variation viewing method and those from each single attribute were investigated and verified in terms of their ability to determine the gas chimneys location. Their poor presentation in the determination of the gas chimney location using either the amplitude viewing variation method or a single attribute leads the authors to present a new approach. For this purpose, the results of all these methods were input to a three layer ANN system, in an integration approach. This approach provided two cubes of datasets as outputs from the ANN system. One dataset was related to the gas chimney cube and the other to the non-gas chimney cube. The gas chimney cube or dataset showed the clear location of the gas chimney areas. Therefore, the integration of different results provided a better possibility of properly recognizing and constraining gas chimneys rather than applying either method separately. Accordingly, it is concluded that the presented approach is a powerful method for the interpreter to more confidently identify gas chimney locations.

ACKNOWLEDGMENTS

The authors greatly appreciate the support of the Institute of Geophysics and the Research Council of the University of Tehran, which enabled us to do this research. The authors are grateful to Mr. S.M. Mohaddess, director of the Exploration Directorate of the National Iranian Oil Company (NIOC), who collaborated with the authors and gave them every possible assistance in preparing real data for this study. We also thank Mr. M.M. Khorasani, the head of the Geophysics Department of the NIOC Exploration Directorate for his generous help. We are grateful to David L. Connolly, Chief Geologist dGB-USA for his helpful comments. We would like to acknowledge the dGB Software and Service and Professor Paul de Groot for providing us with an academic license of OpendTect for this research.

REFERENCES

Heggland, R., 2005. Using gas chimneys in seal integrity analysis: A discussion based on case histories. In: Boult, P. and Kaldi, J. (Eds.), Evaluating Fault and Cap Rock Seals. AAPG Hedberg Series, 2: 237-245.

Heggland, R., 1997. Detection of gas migration from a deep source by the use of exploration 3D seismic data. Mar. Geol., 137: 41-47.

Heggland, R., Meldahl, P., Bril, A.H. and de Groot, P.F., 1999. The chimney cube, an example of semi automated detection of seismic objects by directive attributes and neural networks. Part II: Interpretation. Expanded Abstr., 69th Ann. Internat. SEG Mtg., Houston.

Tingdahl, K.M., 1999. Improving Seismic Detectability Using Intrinsic Directionality. Earth Sciences Center, Goteborg University, Goteborg, Sweden.

Tingdahl, K.M., Bril, A.H. and de Groot, P.F., 2001. Improving seismic chimney detection using directional attributes. J. Petrol. Sc. and Engin., 29: 205-211.