Intelligent prediction of stable isotope geochemistry of coalbed gas for its origin

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Abstract

Stable isotope analysis gives the criteria to define the characteristics of the coalbed gas. In this paper machine learning approach was applied for this purpose. There are two fundamental origins of coalbed gas, i.e., thermogenic and biogenic gas. Stable isotope analysis is the primary method to evaluate the origin of coalbed gas.Samples were collected from the previous literatures and artificial neural network (ANN) was developed for calculating stable isotopes of CH_4, CO_2 and H_2. First model was trained with around 300 samples and then cross validated with 40 samples. Hydrocarbon, CO_2-CH_4 (CDMI), Dryness index, Depth and vitrinite reflectance (R_o) have been used as input parameters and stable isotope of three gases were determined. Feed forward back-propagation was extensively used as the optimum network for the effective results. Before feeding into the network, data was scaled down between 0 to 1 using linear normalization. The learning process used 80% of the data, 10% were used for validation and 10 % for testing. for all the process was above 0.9 and overall, it was observed that R^2=0.97762. The stable isotope of coalbed gas was achieved through this method, viz. , and . Based on the stable isotope of coalbed gas, the coalbed gas was characterized and different results were obtained. The Bernard and CD diagrams were also plotted for the coalbed gas characterization. The validation of predicted values by actual values was also shown in the paper. The current research has vast application on coalbed methane fields as well as conventional and other unconventional gas resources. This is the first kind of research which provides the stable isotopes of coalbed gas using machine learning. As stable isotope of coalbed is necessary to recognize the types of coalbed gas. Stable isotope geochemistry of coalbed gas also gives the primary knowledge to management to assess the secondary recovery of methane. This study provides the thorough knowledge on stable isotope geochemistry of coalbed gas for judging the sweet spot for the secondary recovery of coalbed methane.

Intelligent gas origin prediction using stable isotope geochemistry of coalbed gas

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INTRODUCTION

Stable isotope analysis provides the criteria to define the characteristics of the coalbed gas. In this paper machine learning approach was applied for this purpose. There are two fundamental formation mechanisms of coalbed gas, i.e., thermogenic and biogenic formation. Stable isotope analysis is the primary method to evaluate the origin of gas. Once the gas origin is identified, one can better design the methodology for the secondary recovery of coalbed gas. Sample data points were first collected from the literatures and artificial neural network (ANN) was then developed for calculating stable isotopes of CH_4, CO_2 and H_2.

The stable isotopes ($\delta^{13}C_{CH_4}$, $\delta^{13}C_{CO_2}$ and δD_{CH_4}) of coalbed gas were evaluated using the ANN model, based on which the coalbed gas was characterized. Different diagrams were also made for the coalbed gas characterization. The comparison of the predicted and actual values was also shown in the paper.

DATASET AND METHODS

Stable isotope gas data of coalbed gas components has been collected from the literatures and six samples were collected from Huabei coalfield, China (Li et al., 2015). The hydrocarbon index (HI), dryness index (DI), and CO_2-CH_4 (CDMI) index were computed using the following formulas:

$$HI = \frac{C_1}{C_2 + C_3} \quad ; \quad DI = \frac{C_1}{C_1 + C_2 + C_3 + C_4 + C_5}$$

$$CDMI = \frac{CO_2}{CO_2 + CH_4} \times 100\%$$

Together with the depth h, vitrinite reflectance R_o and N_2 data, the stable isotope of coalbed gas was predicted using ANN models. The structure

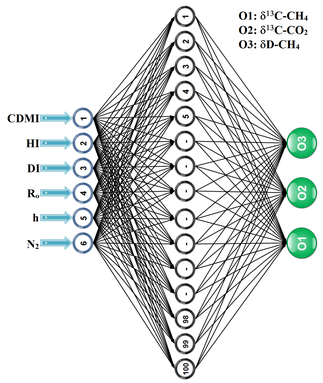


Fig. 1. Structure of ANN model

DATASET AND METHODS

Table 1. Input data for the ANN model

S.N.	CDMI	HI	DI	R_o	h	N_2
1	0.84	14725	0.999864	1.38	551	40.2
2	12.24	789.87	0.998624	0.96	317	28.8
3	5.92	4017.65	0.999751	1.5	379	27.4
4	0.35	3014.29	0.999657	1.15	554	15.3
5	10.8	3360	0.999702	1.78	722	43.5
6	0.32	9490	0.999884	2.54	722	4.8

The feed forward back-propagation ANN model was trained with 300 samples. Six parameters have been used as inputs and stable isotope of gases were determined. Before feeding the data into the network, it was scaled down between 0 and 1 using linear normalization. 80% of the data were used for learning, 10% were used for validation, and 10 % was used for the testing process. Coefficients of determination calculated for the all the processes are more than 0.9 and overall, it is R^2=0.97762. The developed model was cross validated with 40 coalbed gas samples. The trial-and-error method was utilized for selecting the number of hidden layers and the number of neurons in the hidden layer during the formulation of ANN models (Wang et al., 2020).

RESULTS AND DISCUSSIONS

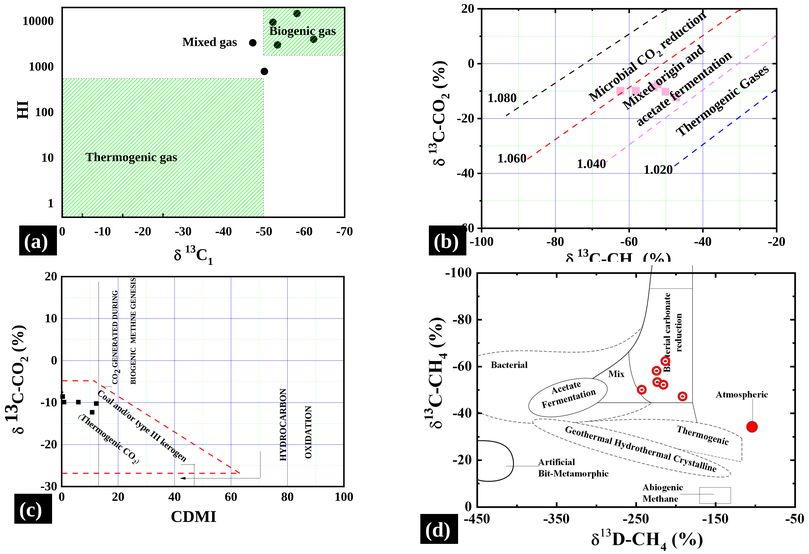
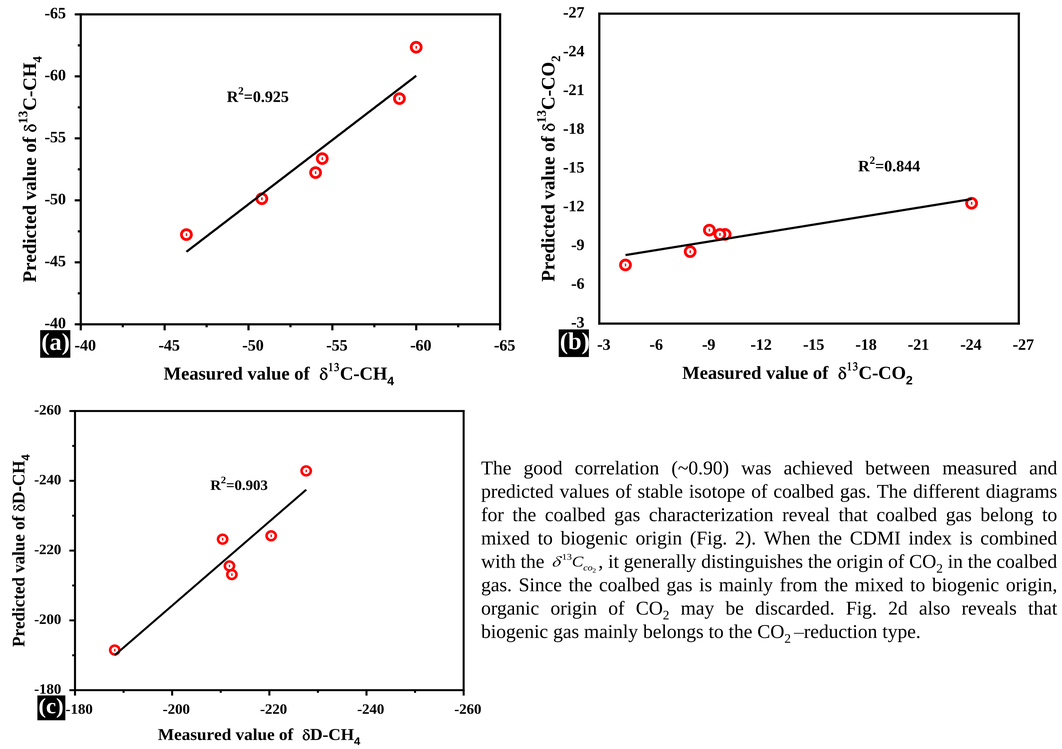


Fig. 2. Diagrams for coalbed gas characterization (Li et al., 2015)



The good correlation (~0.90) was achieved between measured and predicted values of stable isotope of coalbed gas. The different diagrams for the coalbed gas characterization reveal that coalbed gas belong to mixed to biogenic origin (Fig. 2). When the CDMI index is combined with the $\delta^{13}C_{co_2}$, it generally distinguishes the origin of CO_2 in the coalbed gas. Since the coalbed gas is mainly from the mixed to biogenic origin, organic origin of CO_2 may be discarded. Fig. 2d also reveals that biogenic gas mainly belongs to the CO_2 –reduction type.

Fig. 3. Measured and Predicted values of stable isotopes : (a) $\delta^{13}C_{CH_4}$ (b) $\delta^{13}C_{co_2}$ (c) δD_{CH_4}

CONCLUSION

The intelligent prediction method developed and tested in this paper can be applied for analysing the gas origin of coalbed methane as well as other conventional and unconventional gas resources. This is the first kind of research which analyzed the stable isotopes of coalbed gases using Machine Learning models. Stable isotopes analysis of coalbed gases is necessary to identify the types of coalbed gas, which further provides the knowledge for assessing secondary recovery techniques for coalbed methane.

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