

Eliminating the influence of caprock thickness on anomaly intensities in geochemical surface survey in the south slope of the Dongying Depression in east China

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Summary

In geochemical surface surveys, anomalies are used to predict oil/gas fields. However, it was revealed that caprock thickness strongly influences anomaly intensities where caprock thickness varies intensely. In this paper, we established a method to eliminate this influence by using wavelet analysis. In the south slope of the Dongying Depression in east China, there are no anomalies over several oil fields (undeveloped) all the same, even if surface interference was eliminated. After we processed the data with this method, the corrected anomalies coincide with oil fields (wells), traps and sand-bodies. This study illustrates that the influence of caprock thickness on anomaly intensities may result in unreliable prediction where caprock thickness varies intensely but it can be eliminated by using wavelet analysis.

Introduction

Surface geochemical exploration for hydrocarbons dates back to 1929 when the first survey of this kind was carried out. Since then, this technique has been greatly modified and improved (Klusman 1993; Davidson 1994; Tedesco 1995). However, it is still considered as an unconventional tool and has not frequently been used in present-day hydrocarbon exploration.

Research work in the theory and application of surface geochemical survey identified problems in surface interference and anomaly recognition of multi-type anomalies. In the past twenty years, we focused on these problems and established a series of methods by using statistics, fractal geometry, wavelet analysis and artificial neural networks (Zhang et al., 1998, 2002, 2003, 2006). These methods were successfully used in more than ten areas in China. However, the influence of caprock thickness on anomaly intensities has not been addressed. Where caprock thickness varies intensely, this influence can largely change anomaly intensities so that some anomalies cannot be recognized due to their very low intensities. This could be one of the many reasons why geochemical hydrocarbon exploration still remains an unconventional approach in the petroleum industry. To solve this problem, we established a method to correct anomaly intensities by using wavelet analysis. The application of this method eliminated the influence of caprock thickness in the south slope of the Dongying Depression. In the results, the corrected anomalies coincide with oil fields (wells), traps and sand-bodies.

Method

Although anomaly intensities can be directly corrected by using caprock thickness data, the datum quantity is usually not enough. Furthermore, these data cannot be obtained before extensive drilling where geochemical survey might have been conducted. Therefore, we have to establish a method to extract information of caprock thickness variation from data of geochemical surface survey.

Variation of caprock thickness provides low frequency information in geochemical data. But this information only affects anomalies that exist in high frequency information. Therefore, we broadened the frequency (width) of peaks (possible anomalies) in the data after surface interference elimination and decomposed the data with the broadened frequency by using the Mallat wavelet which is also used in surface interference elimination, to obtain the information of caprock thickness information. The correction factor can be taken from the continuous sequence (low frequency parts) at the same scale of wavelet analysis as surface interference elimination. The distribution of the correction factor are compared with caprock thickness map. If they have similar distribution features, the extracted correction factor can be considered to be proper. As the caprock thickness only affect anomalies, the data after interference elimination are decomposed again by using the same wavelet, the detailed sequence (high frequency parts) is multiplied by the correction factor and the inverse transformation of wavelet analysis was conducted to obtain the data containing corrected anomalies. Anomalies are recognized by using the methods in Zhang et al. (1998, 2002, 2006).

Example

The study area is located in the south slope of the Dongying Depression. In this area, more than 40 wells were drilled but only 6 wells can produce commercial oil. For prospective evaluation, a geochemical surface survey was conducted. Unexpectedly, even though surface interference was eliminated, there are no anomalies all the same in the northwest part of this area where there are most oil wells (as shown Fig. 1). In Fig. 2, the caprocks become thickest in the NW part. The anomaly intensities may be largely reduced by thick caprocks so that the anomalies cannot be directly recognized, compared with relative thin caprocks. Therefore, our method was used. As shown in Fig. 3, the anomalies, corrected with this method, appear in the NW part. Finally, we recognized multi-variate (including methane, ethane, propane, butane and pentane) anomalies that show three petroleum accumulation belts distributed at the NEE direction and coincide with sand-bodies, traps and oil wells. The methods for multi-variate anomaly recognition are documented in Zhang et al. (1998, 2002, 2006). The corrected anomalies with other geological data were used to predict oilfields in the area.

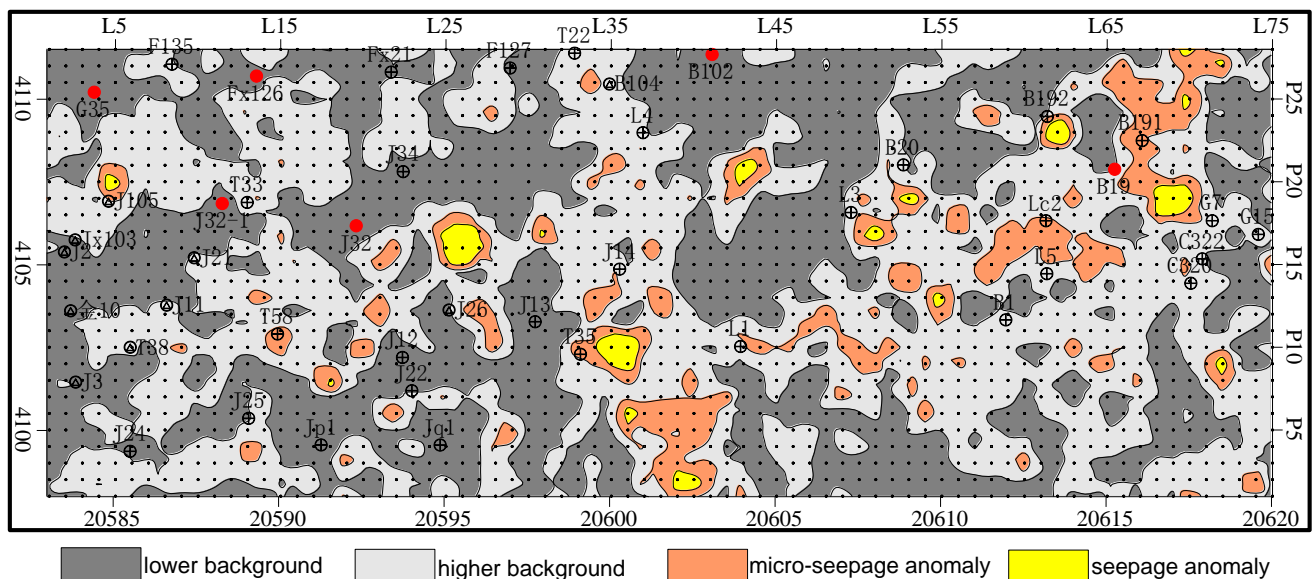


Fig. 1 Anomalies of acid-extractable ethane after the elimination of surface interference in the South slope of the Dongying Depression.

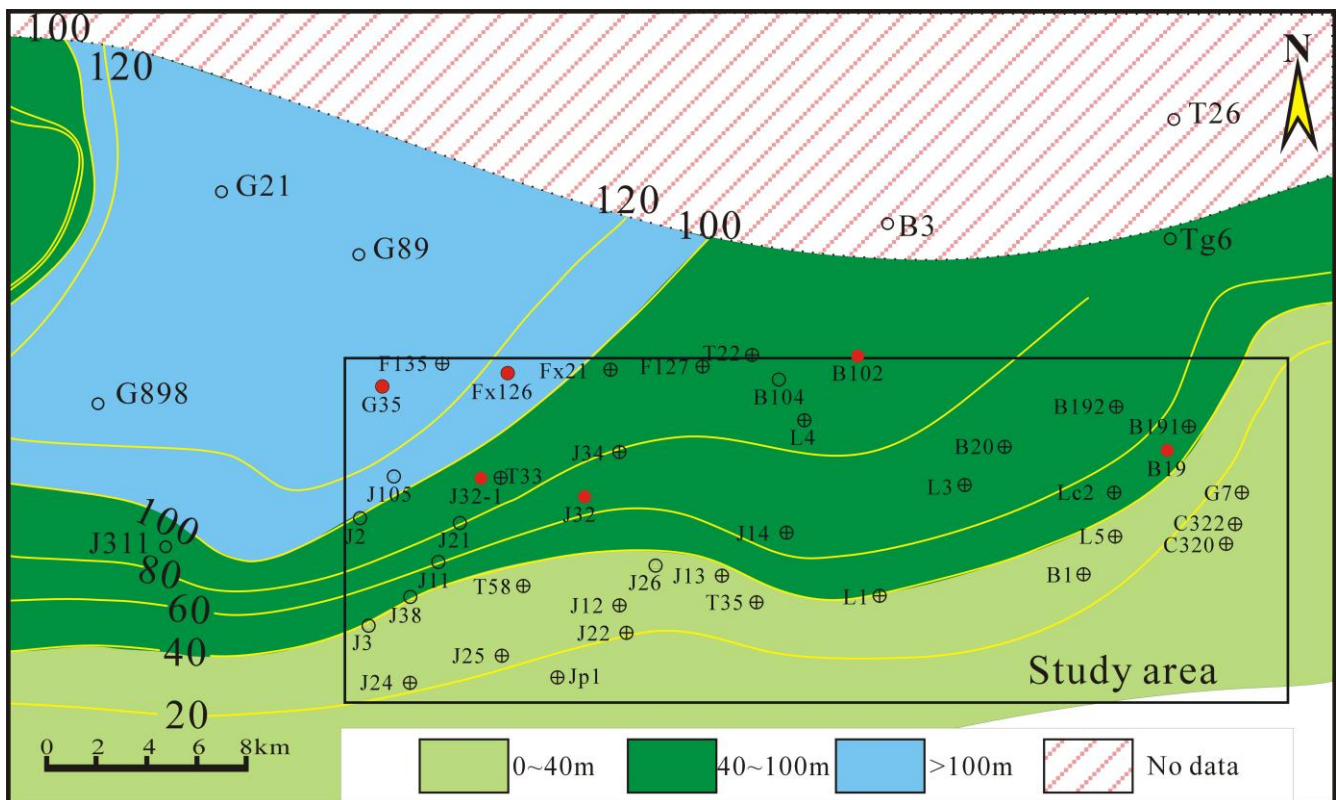


Fig. 2 Caprock thickness in the Guantao formation in the South slope of the Dongying Depression.

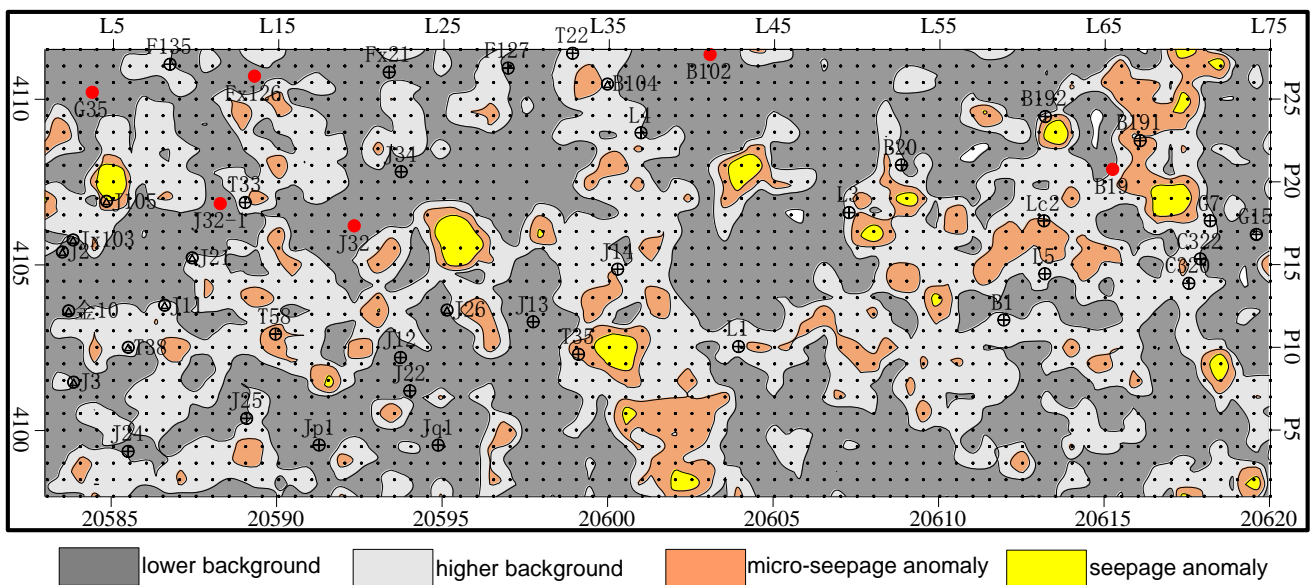


Fig. 3 Anomalies of acid-extractable ethane after the elimination of both surface interference and caprock thickness influence in the South slope of the Dongying Depression.

Conclusions

Commonly, the influence of caprock thickness on anomaly intensities is not considered to be important and has been ignored in many geochemical surveys. However, this influence can result in unreliable prediction where caprock thickness varies intensely. In this case, therefore, it must be eliminated for geochemical prospecting.

The variation of caprock thickness provides low frequency information in geochemical data. Therefore, it can be eliminated via wavelet analysis. The method designed in paper was demonstrated by actual data in the south slope of the Dongying Depression. We believe that this method can be useful for geochemical surveys in the other areas.

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