Eliminating the Influence of Caprock Thickness on Anomaly Intensities in Geochemical Surface Survey in the South Slope of the Dongying Depression in East China*

Liuping Zhang[1], Zhenli Wang[2], and Yingquan Zhao[2]

Search and Discovery Article #41304 (2014)
Posted March 31, 2014

*Adapted from extended abstract prepared in conjunction with presentation at CSPG/CSEG/CWLS GeoConvention 2012, (Vision) Calgary TELUS Convention Centre & ERCB Core Research Centre, Calgary, AB, Canada, 14-18 May 2012, AAPG/CSPG©2014

[1]Key Laboratory of Petroleum Resource, Institute of Geology and Geophysics, Chinese Academy of Science, Beijing, China (lpzhang@mail.iggcas.ac.cn)
[2]Key Laboratory of Petroleum Resource, Institute of Geology and Geophysics, Chinese Academy of Science, Beijing, China

Abstract

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 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 the most oil wells (as shown Figure 1). In Figure 2, the caprocks become thickest in the northwest 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 Figure 3, the anomalies, corrected with this method, appear in the northwest 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.

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 this 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.

Acknowledgements

We would like to express our gratitude to Messieurs Zhongxiang Cao, Kebin Zhao, Yongjin Gao, and Changqing Sun of the Sinopec Corp. for their generous contribution of geological and geochemical data for our work.

References Cited

Davidson, M.J., 1994, On the acceptance and rejection of surface geochemical exploration: Oil & Gas Journal, v. 94/23, p. 70–76.

Klusman, R.W., 1993, Soil Gas and Related Methods for Natural Resource Exploration: Wiley, New York, p. 1–112.

Tedesco, S.A., 1995, Surface Geochemistry in Petroleum Exploration: Chapman & Hall, New York, p. 1–125.

Zhang, L., and G. Bai, 2002, Application of the artificial neural network to multivariate anomaly recognition in geochemical exploration for hydrocarbons: Geochemistry: Exploration, Environment, Analysis, v. 2, p. 75–82.

Zhang, L., and Z. Liao, 1998, A study of the method for the recognition of anomalies in geochemical hydrocarbon exploration: J. China Uni. Geo-sciences, v. 9, p. 72–80.

Zhang, L., G. Bai, and Y. Xu, 2003, A wavelet-analysis-based new approach for interference elimination in geochemical hydrocarbon exploration: Mathematical Geology, v. 35/8, p. 939–952.

Zhang, L., G. Bai, K. Zhao, and C. Sun, 2006, Restudy of acid-extractable hydrocarbon data from surface geochemical survey in the Yimeng Uplift of the Ordos Basin, China: Improvement of geochemical prospecting for hydrocarbons: Marine and Petroleum Geology, v. 23, p. 529–542.

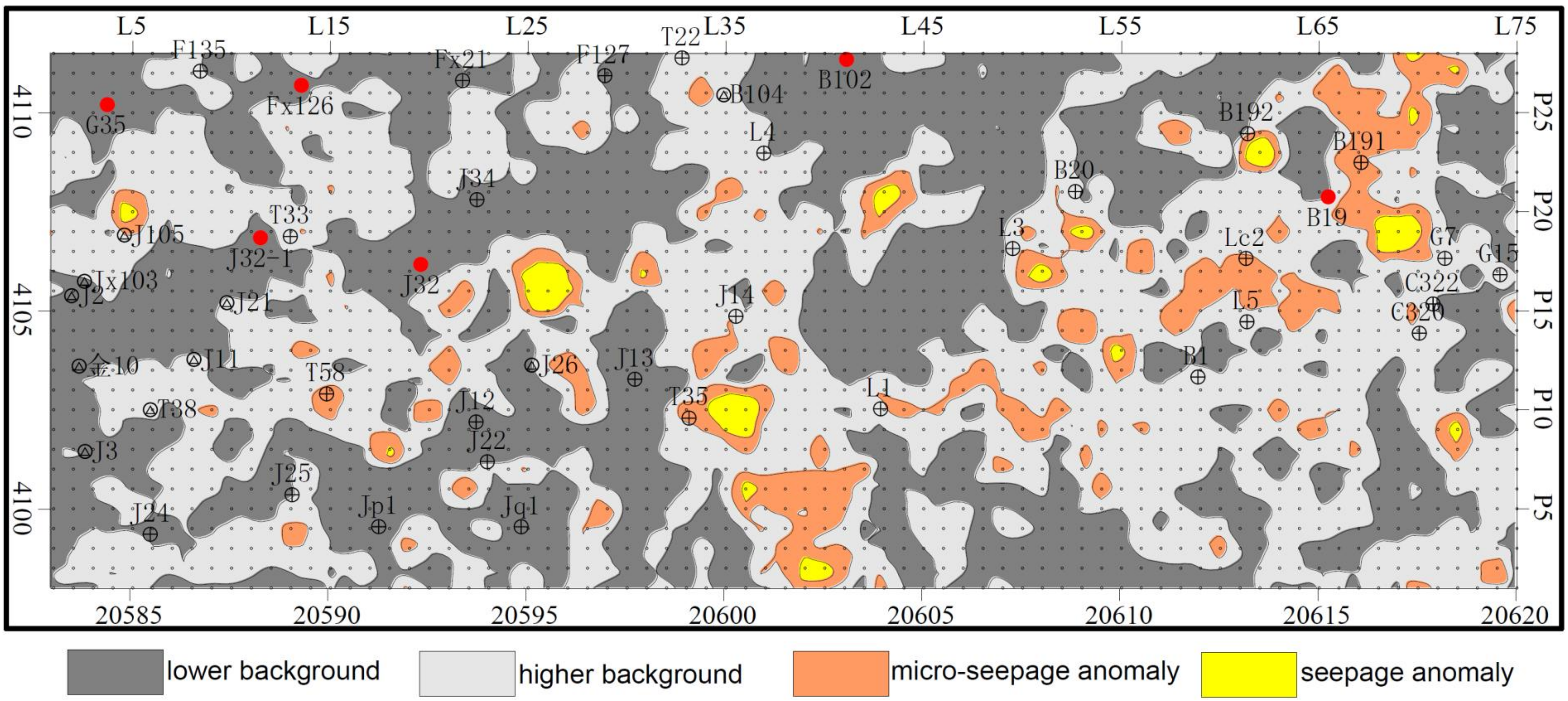

Figure 1. Anomalies of acid-extractable ethane after the elimination of surface interference in the south slope of the Dongying Depression.

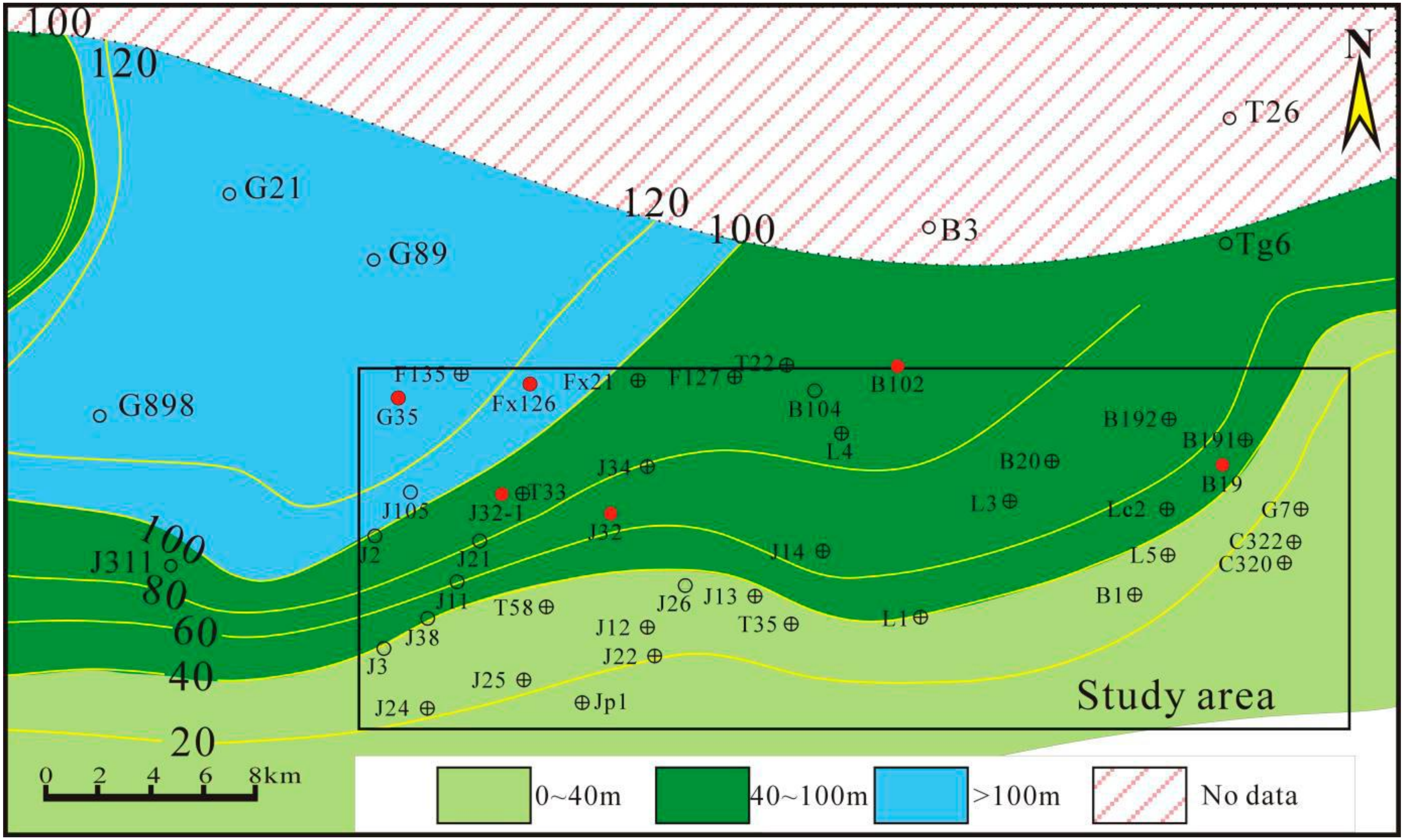

Figure 2. Caprock thickness in the Guantao Formation in the south slope of the Dongying Depression.

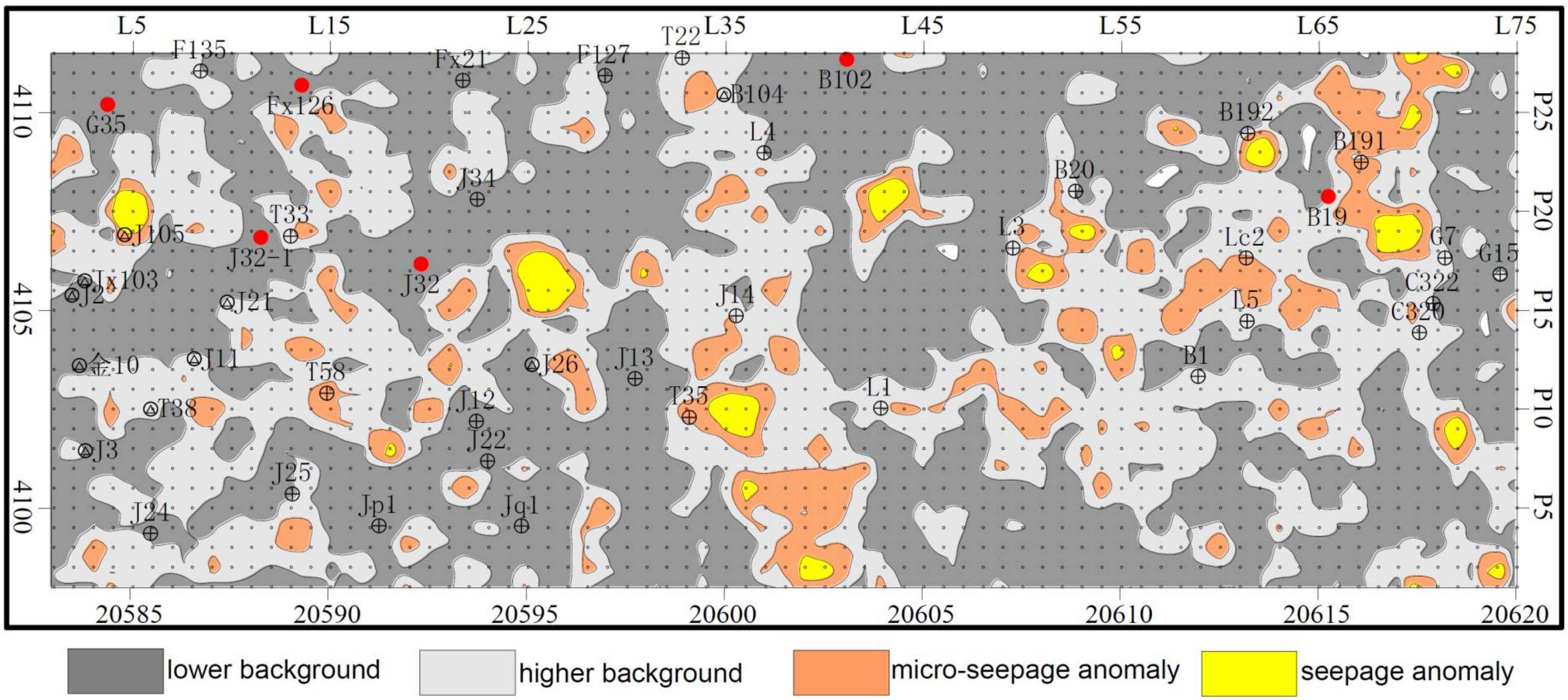

Figure 3. Anomalies of acid-extractable ethane after the elimination of both surface interference and caprock thickness influence in the south slope of the Dongying Depression.