AUTOMATED ELECTROFACIES DETERMINATION USING MULTIVARIATE STATISTICAL ANALYSIS

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ABSTRACT

A systematic methodology is developed for the electrofacies determination from wireline log data using multivariate statistical analysis.

To consider corresponding contribution of each log and reduce the computational dimension, multivariate logs are transformed into a single variable through principal components analysis. Resultant principal components logs are segmented using the statistical zonation method to enhance the efficiency and quality of the interpreted results. Hierarchical cluster analysis is then used to group the segments into electrofacies. Optimal number of groups is determined on the basis of the ratio of within-group variance to total variance and core data.

This technique is applied to the wells in the Korea Continental Shelf. The results of field application demonstrate that the prediction of lithology based on the electrofacies classification matches well to the core and the cutting data with high reliability. This methodology for electrofacies classification can be used to define the reservoir characteristics which are helpful to the reservoir management.

1. INTRODUCTION

Wireline logging data have the advantage of providing a continuous record of various petrophysical properties over the entire well section and can be obtained in conditions where coring is impossible. The integration of core and well log data is thought to give a good formation description. An electrofacies [1] is defined as "the set of log responses that characterizes a bed and permits it to be distinguished from the others." The electrofacies derived by selecting, weighting, and combing well log data can be used as an indicator of lithology. Once reasonable correlation between electrofacies and core analysis is established on a local basis, significant geological information can be extracted from well logs alone. In this study, a systematic technique has been developed for the electrofacies determination from well logs using multivariate statistical analysis and applied to the wells in the Korea Continental Shelf.

2. ELECTROFACIES CLASSIFICATION

Wolff et al. [2] and Moline et al. [3] developed the multivariate statistical procedures to determine the electrofacies. In this study, to enhance the efficiency and quality of the interpreted results, the zonation of principal components logs is constructed prior to clustering and the segmented principal logs instead of the original logs are used for cluster analysis. The electrofacies classification procedure used in this study is summarized by the flow chart in Figure 1.

2.1. descriptive statistical analysis

Data can be revealed their features when they are adequately organized. The univariate tools can be used to describe the distribution of individual variable. In addition, the relationships and dependencies among variables are important features of data when we analyze a multivariate data set like well logs. The correlation coefficient quantifies a relationship between two well logs which are closely related to each other.

2.2. principal components analysis

To consider the contribution of each log and reduce the computational dimension, multivariate logs are combined into a single variable through principal components analysis [2][4]. In order to avoid artificial and undue weighting by any of the logs, the original data should be standard-normalized by subtracting the mean and dividing by the standard deviation. Because principal components logs are ordered, the latter parts of principal components logs usually contain little information and may be dropped for the further analysis without any significant effect. This can reduce the complexity of cluster analysis.

2.3. zonation of well log

Well log data are so vast that the data compression is strongly required before the analysis and interpretation of these data. A number of methods have been developed to condense the well logs data into zones. In this study, the concept of analysis of variance (ANOVA) [5] is applied for the zonation of well log data. An optimal subdivision is attained if zones are established such that the within-zone variance is minimized and the between-zone variance is maximized.

2.4. cluster analysis

Cluster analysis is to group similar objects and to distinguish them from other dissimilar objects on the basis of their measured characteristics. The most common class of clustering methods used in geology is that of hierarchical analysis [3][4]. The basic steps are shown in Figure 2 as an illustration of the clustering of hypothetical zones based on their log responses.

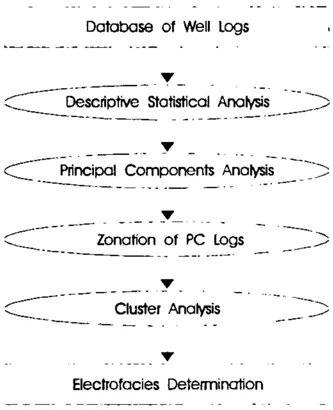

Fig. 1. Flow chart of electrofacies determination.

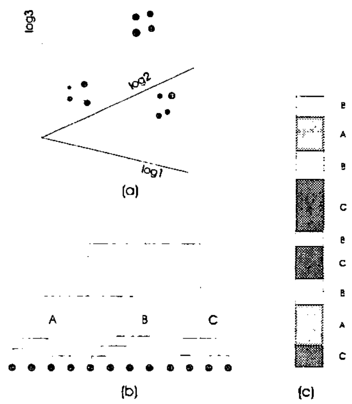

Fig. 2. Stages of cluster analysis of log data

3. APPLICATIONS

For field application, the techniques developed in this study have been applied to the wells in the Korea Continental Shelf. The logs selected for the electrofacies determination were gamma-ray log (GR), sonic log (DT), density log (RHOB), and neutron log (NPHI). These logs were chosen based on the descriptive statistical results and the quality of well log data. The principal components were computed from the correlation matrix of log measurements. The first two principal components accounted for 80% of the total variability. The zonation of principal components logs were constructed prior to clustering. The zone boundaries were determined such that the variance of the within zones was minimized and the variance of the between zones maximized. The segmented first principal component log is shown in Figure 3.

Hierarchical clustering was used to group the segmented principal components logs instead of the original logs with similarity based on their multivariate means. The resulting clustered hierarchy is shown in the dendrogram on Figure 4. Each terminal branch represented an individual log segment. The five groups of electrofacies were determined on the basis of the ratio of the within-group variance to the total variance and core standard. The lithologic description from electrofacies classification matched well with the mud log description (Fig. 5).

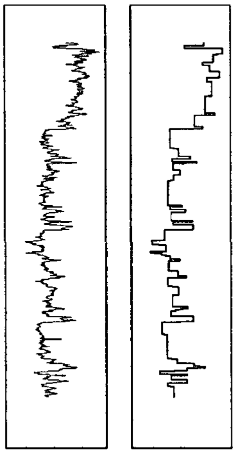

Fig. 3. The segmented first principal component log by statistical zonation method.

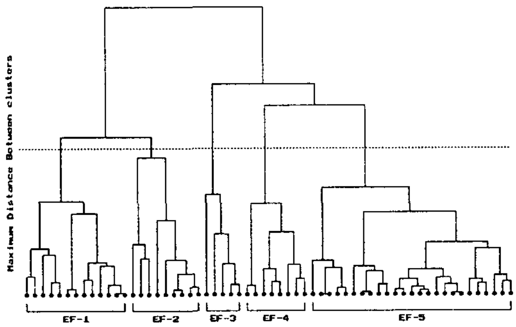

Fig. 4. The dendrogram of zones by cluster analysis for ekectrofacies classification.

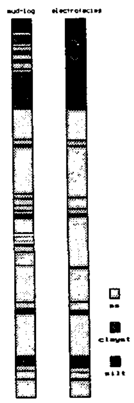

Fig. 5. Comparison of the lithofacies description from electrofacies with a mud-log description.

4. CONCLUSIONS

The systematic technique has been developed for electrofacies classification from wireline log data using multivariate statistical analysis and applied to the wells in the Korea Continental Shelf. The results of field application demonstrate that the lithology predicted based on the electrofacies classification matches well with the core and cutting data. This technique can enhance the efficiency and quality of the electrofacies classification and be used to define the reservoir characteristics that are valuable for reservoir management.

5. REFERENCES

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