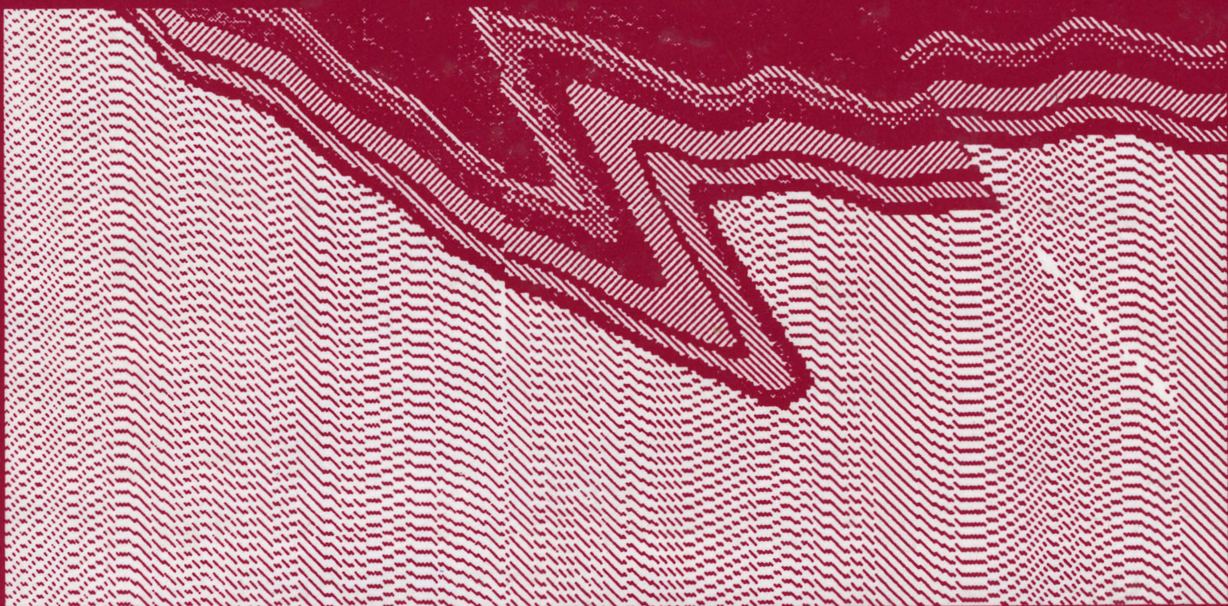
COMPUTER APPLICATIONS IN THE EARTH SCIENCES

Use of Microcomputers in Geology



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ZONEOGRAPHY OF MINERAL RESOURCES

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ABSTRACT

In facing the problem of the exploitation of heterogeneous mineral resources (ore or oil), the question of defining continuous zones exhibiting similar characteristics may arise. A method to approach this question using factorial and geostatistical techniques was developed. It contains three main steps:

(1) Taking as an input the data matrix (samples x variables), a factorial technique (principal components analysis or correspondence analysis) is applied, giving rise to groups of samples of similar characteristics.

(2) The problem of contiguity within samples of the same group and the number of groups to be retained is solved by expert advice of the geological/exploitation team, based on graphical representation of zones.

(3) Once decided which samples belong to each final group, the boundaries from zone to zone are estimated, using a transitive kriging technique, relying on the geometric variogram.

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Two case studies are presented to illustrate the method: The first one discusses a polymetallic sulfide orebody located in the South of Portugal, which is to be split into zones feeding different mineral-processing units. In the second, a Middle East petroleum reservoir is divided into homogeneous zones in order to improve the secondary oil-recovery planning.

The method presented here, combining factorial analysis and geostatistics, is a useful tool for the purpose of delineating zones in heterogeneous deposits of mineral resources. It provides estimates of boundaries between zones based on their geometric structure and gives a reliable basis for further exploitation planning.

INTRODUCTION

When planning the development of large mineral resources, the problem of defining continuous zones with similar characteristics may arise.

When the information available on each sample includes a great variety of attributes of different types, a data reduction procedure based on multivariate statistics is helpful for establishing the zonation guidelines. But the groups of samples provided by the classification procedure must exhibit spatial contiguity in order to meet the requirements of the exploitation method. Furthermore, it usually is necessary to estimate the morphology of each zone by the group of samples with similar properties, which constitutes a technological unit.

By combining factorial analysis, graphical representation of groups, and expert geological advice and morphological geostatistics, a methodology to cope with zonation problems was developed. It contains three main steps:

(1) Taking as an input the data matrix (samples x variables), a factorial technique (principal components analysis or correspondence analysis) is applied, giving rise to groups of samples of similar characteristics.

(2) The problem of contiguity within samples of the same group and the number of groups to be retained is solved by expert advice of the geological/exploitation team, based on graphical representation of zones.

(3) Once decided which samples belong to each final group, the boundaries from zone to zone are estimated, using a transitive kriging technique, relying on the geometric variogram.

Two case studies are presented to illustrate the proposed methodology: the first one regards a polymetallic sulphide orebody located in the south of Portugal, which is to be divided into zones feeding different mineral processing units. In the second, a Middle East petroleum reservoir is divided into homogeneous zones, in order to improve secondary oil-recovery planning.

A MASSIVE POLYMETALLIC SULPHIDE OREBODY

The available data were obtained from several deep drillholes, assayed on 1 m sections for 11 elements - Cu, Pb, Zn, S, Fe, Ag, Hg, Sn, As, Sb, and Bi. The element grades were arranged in matrix form. The corresponding rows represent the 780 samples.

In a first step, the data matrix of 780 samples with 11 variables was submitted to an algorithm performing the principal components analysis (PCA) of standardized data (Lebart, Morineau, and Warwick, 1984). The output gives projections of the samples and variables onto the main factorial axes.

Results of this procedure are shown in Figure 1, where projections of variables onto Axis 1 and 2 are displayed, as well as the initial limits defining 3 groups of samples in the plane of the two principal axes.

Limits on Figure 1 then were changed interactively, according to geological context, until a final morphological definition of zones is reached. The spatial continuity of each zone is visualized through the representation of experimental data, and its final shape is estimated via morphological kriging (Soares, 1990), as displayed for the pyritic ore type in Figure 2.

MIDDLE EAST OIL FIELD

Data on an extensively explored oil reservoir were taken from 172 wells. Their locations are given in Figure 3.

The set of variables available on each well was divided into two categories: the first includes the elevation of the oil-bearing formation and water saturation, whereas the second contains porosity, permeability, and facies. For the purpose of correspondence analysis application

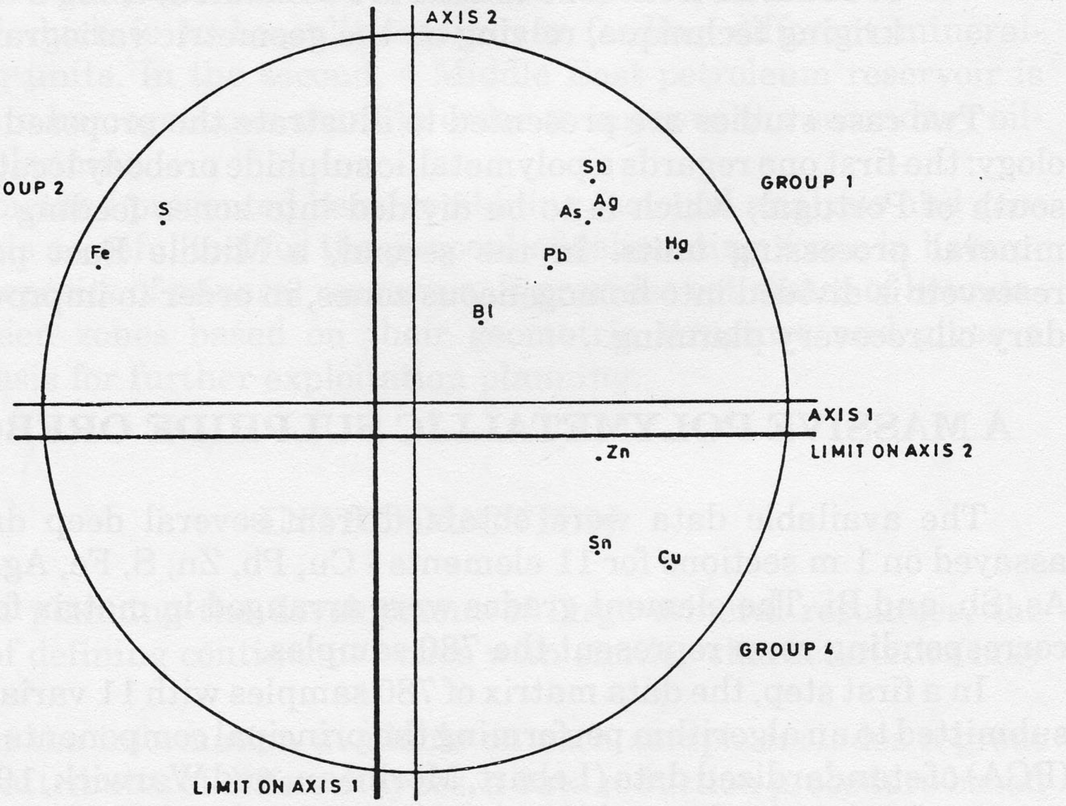

Figure 1. Results of PCA of standardized data and splitting procedure

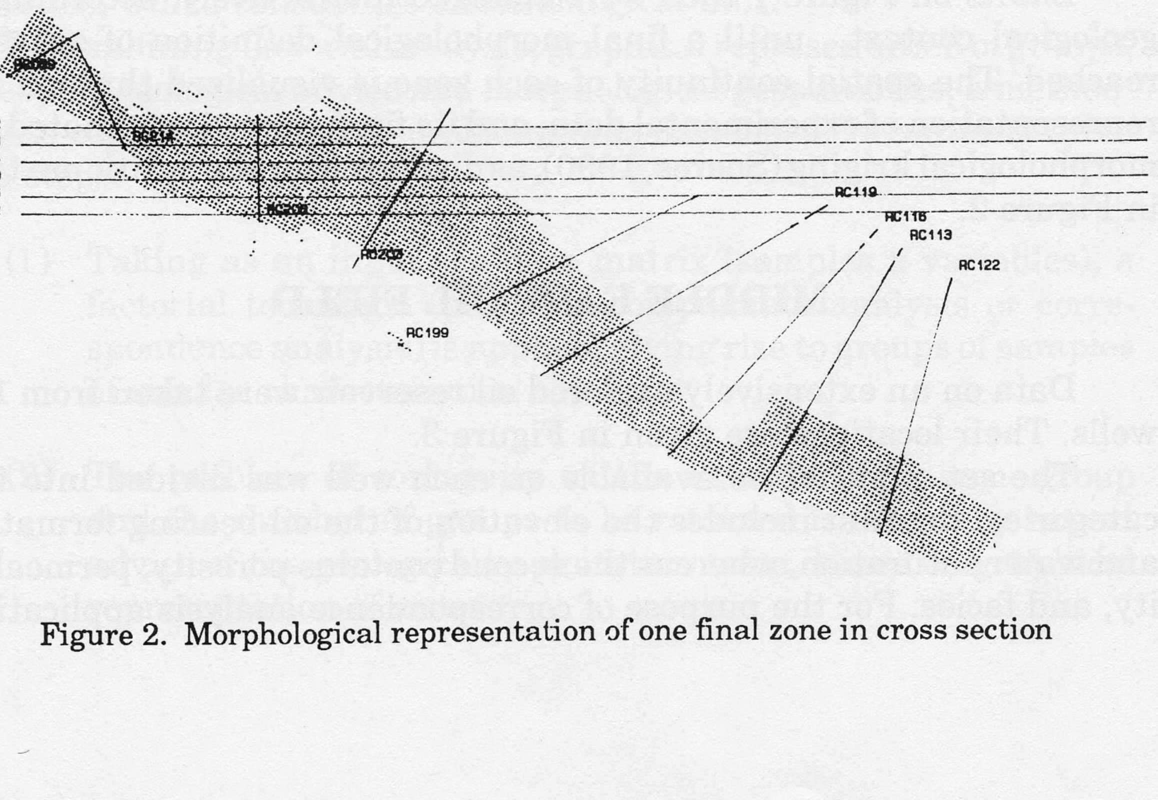

Figure 2. Morphological representation of one final zone in cross section

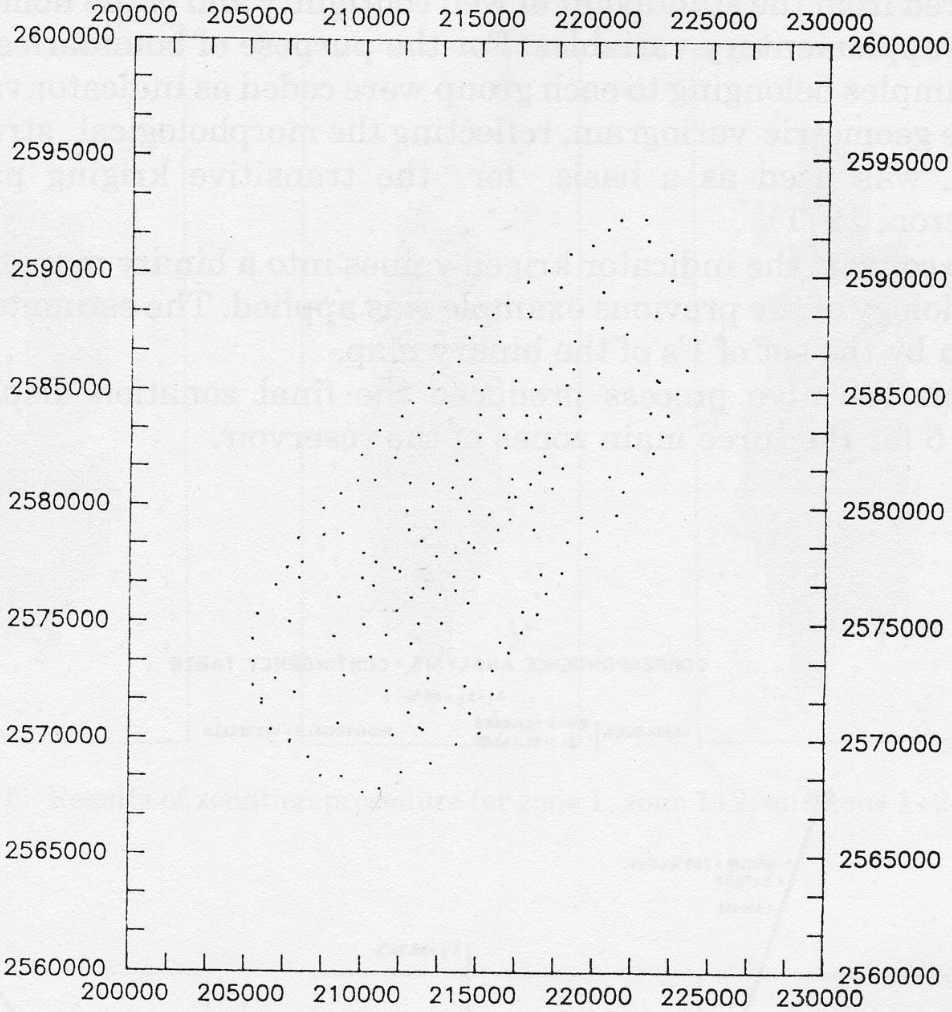

Figure 3. Well location map

(Greenacre,1984), the first subset is denoted "principal", controlling the reservoir quality zones, and the second, denoted "supplementary", provides the basis for a validation criterion construction. The degree of homogeneity of the supplementary variables within each zone is expected to be maximum.

Several contingency tables, which cross-tabulate the two principal variables for different class limits, were used as input into the correspondence analysis program. The results of this procedure for one input table are given in Figure 4.

Based on sample projections onto Axis 1, the splitting procedure was carried out on the output provided by applying correspondence analysis to each of the contingency tables to be tested. The resulting groups were compared from the standpoint of well contiguity and of the homogeneity of the supplementary variables. For the purpose of boundaries estimation, samples belonging to each group were coded as indicator variables, and the geometric variogram, reflecting the morphological structure of groups, was used as a basis for the transitive kriging procedure (Matheron, 1971).

To convert the indicator kriged values into a binary map, the same methodology of the previous example was applied. The estimated shape is given by the set of 1's of the binary map.

This iterative process produced the final zonation displayed in Figure 5 for the three main zones of the reservoir.

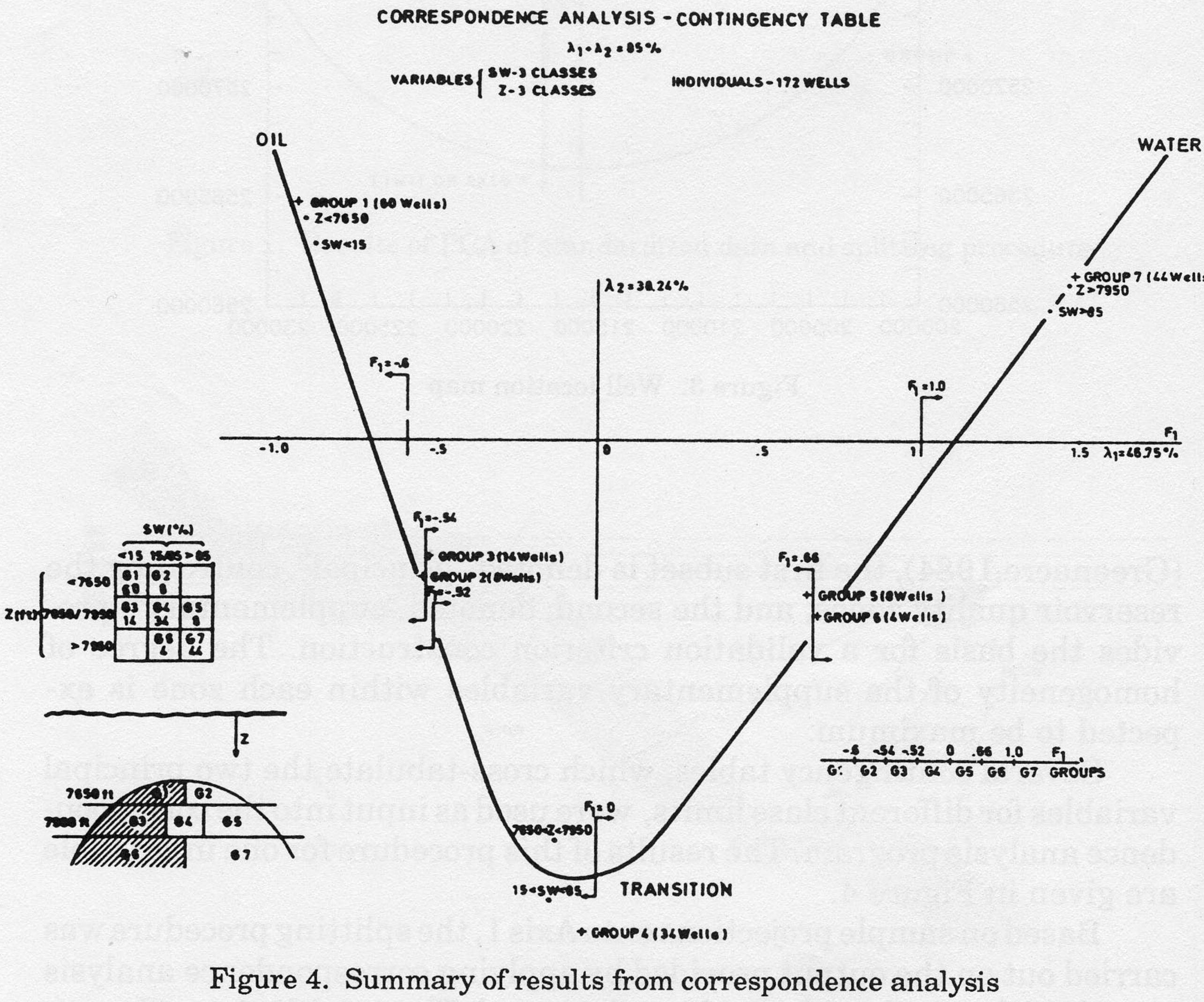

Figure 4. Summary of results from correspondence analysis

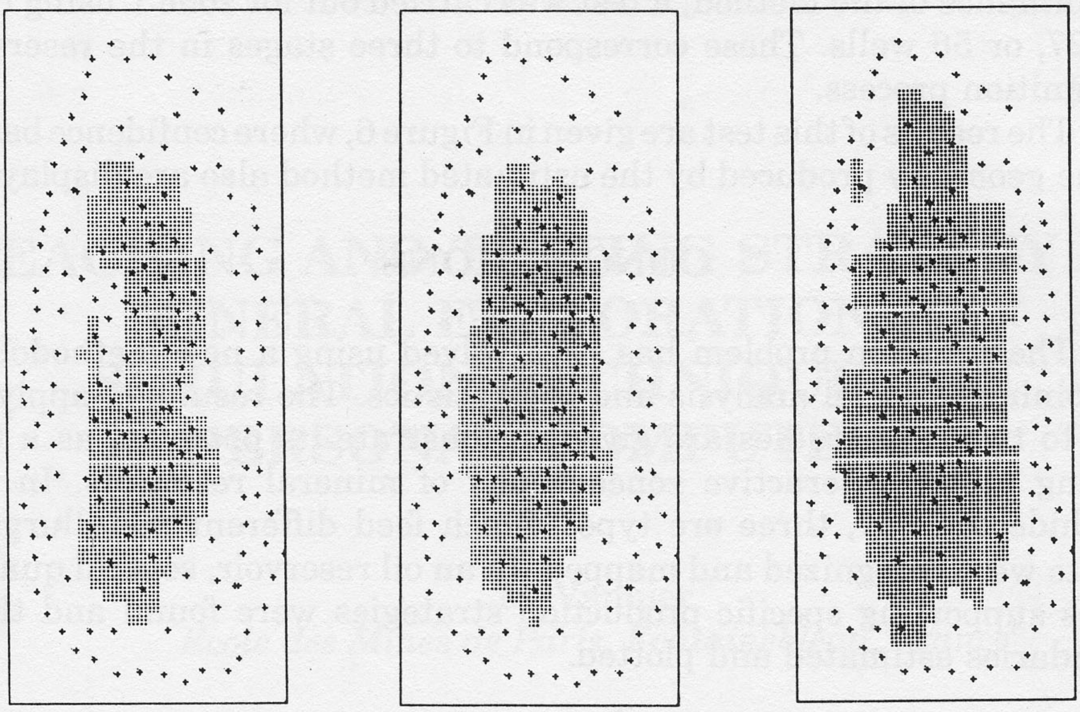

Figure 5. Results of zonation procedure for zone 1, zone 1+2, and zone 1+2+3

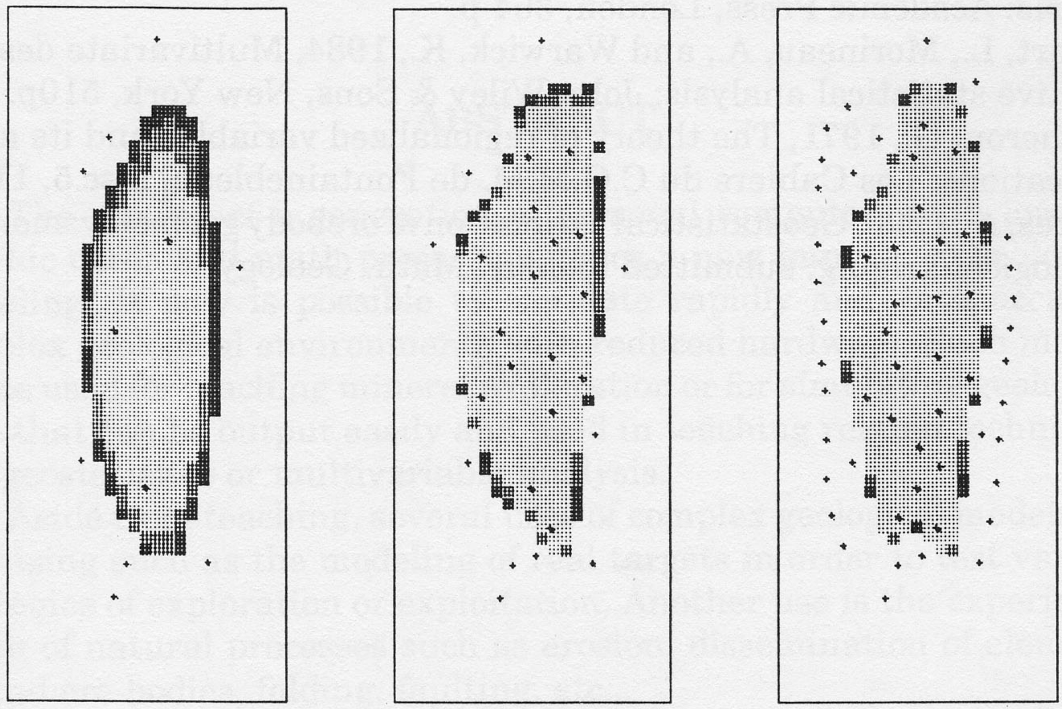

Figure 6. Boundaries estimation

In order to assess the influence of the information level on the performance of the method, a test was carried out for zone 1 using only 11, 27, or 56 wells. These correspond to three stages in the reservoir recognition process.

The results of this test are given in Figure 6, where confidence bands of the geometry produced by the estimated method also are displayed.

CONCLUSIONS

The zonation problem has been solved using a new methodology combining factorial analysis and geostatistics. The results of applying this to two case studies are given to illustrate its potential as a tool aiming at the interactive zoneography of mineral resources. In the sulphide orebody, three ore types which feed different metallurgical plants were recognized and mapped. In an oil reservoir, several quality zones supporting specific production strategies were found and their boundaries estimated and plotted.

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