TITLE: SOME COMPUTERIZED GRAPHIC TECHNICAL APPLICATIONS FOR FEDERAL MINERAL LEASE MANAGEMENT SUPPORT

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SUBMITTED TO: First Geological Survey Computer Symposium
U. S. Geological Survey, Reston, Virginia

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SOME COMPUTERIZED GRAPHIC TECHNICAL APPLICATIONS FOR FEDERAL MINERAL LEASE MANAGEMENT SUPPORT

ABSTRACT

Management reports related to the regulation and status of Federal mineral leases are excellent applications for computer graphics. The Los Alamos Scientific Laboratory has employed and developed a variety of computerized graphics techniques to display technical products about Federal mineral leases. These analyses use data and models from and for the Geological Survey. Many of these graphic technical products use color to more effectively communicate the results relevant in making technical and management decisions.

Selected, sample color graphic technical products are presented along with a review of the supporting ADP configuration. The technical products include (a) a map showing the status of Federal mineral leases, (b) a color-coded matrix of correlation coefficients, (c) color-coded multi-axis graphs, (d) Fourier series and Chernoff face representations of multi-dimensional data, (e) geographic maps of Federal mineral leases, and (f) a color computer-generated movie which illustrates the simulated behavior of a gas-water reservoir through time. Input for these technical products are the Lease Production and Revenue (LPR) data bases and an assumed reservoir model.

These computer graphics products fulfill some continuing and obvious needs for management reports about Federal mineral leases. There is, however, another application that is perhaps even more important than the production of finished management reports which are concise, effective means of communicating information. The management reports must, if they have credibility, be based on data bases that are complete in quantity and superior in quality of data. Our experience shows that computer graphics techniques can be useful in checking both the quantity and quality of the data in complex data bases.

I. INTRODUCTION

This paper presents and describes some computer graphics products which can be used in the management of Federal mineral leases. The main discussion is divided into three parts. Section II briefly describes the Los Alamos Scientific Laboratory (LASL) computer hardware and software which were used to generate the examples provided in Section III. Section IV indicates some possible applications for the technical products.
Finally, we gratefully acknowledge the scientists who have contributed to the successful development and production of the products.

II. HARDWARE AND SOFTWARE

The Central Computing Facility (CCF) of LASL houses and maintains a variety of both hardware and software to produce computerized graphic output. The worker computers are Control Data Corporation (CDC) 6600, 7600, and Cyber 70 Model 73 machines. After computation, the graphics results can be displayed on Tektronix Series 4000 cathode ray tube (CRT) units, on 12" or 30" Calcomp plotters, or on 105/35/16-mm black and white or color film via the SC4020 or FR80 film recorders. The Tektronix units are used interactively to observe and to refine the graphics output before recording it on film.

The software includes both commercial packages and codes written by LASL staff members. One commercial package, System 2000, is a data base management system developed by MRI Systems Corporation, Austin, Texas. System 2000 is used for the storage and retrieval of data from the Lease Production and Revenue (LPR) data base. The data are recorded under the auspices of the Conservation Division of the U. S. Geological Survey and distributed by the Systems and Programming Branch, General Services Administration, Fort Worth, Texas. The hierarchical organization of the LASL LPR structure can be diagrammed as follows:
This data base currently contains approximately 7,000,000 characters and is operated and maintained by the Energy Systems and Statistics Group (Q-12) of LASL.

Another commercial package available in the LASL CCF is the ADBMS (A Data Base Management System) system obtained from the University of Michigan. A query language for this system is being developed. Unlike System 2000, which has a hierarchical structure, the ADBMS system has a network structure. The ADBMS system is useful in generating lease maps.

A third commercial software package is DISSPLA (Display Integrated Software System and Plotting Language), which is marketed by Integrated Software Systems Corporation, San Diego, California. DISSPLA is used to produce many of the graphic products described in this paper. The options in DISSPLA are extensive and include curve-drawing routines, 3-D plotting and mapping routines, and elaborate character fonts.
One in-house package is an image processing program called IMGPROC. IMGPROC is a command-oriented program to process and display sampled images. We have used a small part of the package to display color-coded matrices of correlation coefficients.

III. SAMPLES OF COMPUTER GRAPHICS OUTPUT

In this section we describe eleven color reproductions of 35-mm computer generated slides. Figure 1 summarizes the offshore lease activity from October 13, 1954 - November 16, 1976. The number of leases, the year(s) of the leasing, the number of acres leased, and the number of production acres (through 1974) are given for individual states and regions as well as totals for all the leases.

Figure 2 is a color-coded correlation matrix which displays the pairwise correlations between selected variables for offshore leases in the August 1976 mid-Atlantic sale (Sale 40). The color scale on the right assigns red tones to positive correlations and blue tones to negative correlations with white indicating high positive correlation and black indicating little or no correlation. The variables used in constructing the matrix are listed in Table 1. As well as summarizing some bidding

<table>
<thead>
<tr>
<th>Notation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>LPSV</td>
<td>Natural logarithm of presale value</td>
</tr>
<tr>
<td>LHBID</td>
<td>Natural logarithm of high (or bonus) bid</td>
</tr>
<tr>
<td>AVGLB</td>
<td>Arithmetic average of the natural logarithm of the bids (ln(bids))</td>
</tr>
<tr>
<td>STDLB*</td>
<td>Standard deviation of ln(bids) (Leases receiving only one bid are assigned a standard deviation of 1.0.)</td>
</tr>
<tr>
<td>LPSVA</td>
<td>Natural logarithm of presale value per acre</td>
</tr>
<tr>
<td>LHIPA</td>
<td>Natural logarithm of high bid per acre</td>
</tr>
<tr>
<td>AVGLP</td>
<td>Arithmetic average of ln(price/acre)</td>
</tr>
<tr>
<td>NBIDS</td>
<td>Number of bids</td>
</tr>
<tr>
<td>NBDRS</td>
<td>Number of bidders</td>
</tr>
<tr>
<td>NWNRS</td>
<td>Number of companies in the winning bid</td>
</tr>
<tr>
<td>NB20</td>
<td>Number of bidders in the top 20 companies</td>
</tr>
<tr>
<td>NW20</td>
<td>Number of winners in the top 20 companies</td>
</tr>
</tbody>
</table>
relationships for a sale, color-coded correlation matrices can also summarize statistics for bidding entities (a group which submits a bid). For comparison of various bidding groups, it is useful to view several matrices simultaneously.

Figures 3 and 4 present multi-axis graphs showing cumulative lease statistics for Shell Oil Company (net amounts for both solo and joint leases) and all (bonus) bids, respectively. Time is represented along the x-axis in years from 1954 through 1975. The magenta axis is millions of acres purchased. The green axis is billions of bonus dollars bid, the blue axis is millions of barrels of liquid produced, and the red axis is trillions of cubic feet of gas produced. As indicated for the color-coded correlation matrices, it is especially useful to view the cumulative graphs for several bidding entities simultaneously.

Figures 5, 6 and 7 illustrate two methods for displaying multivariate data. We have selected the fifteen variables shown in the left-hand column of Table 2 to represent each of ten companies.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Facial Feature</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Includes solo and joint leases)</td>
<td></td>
</tr>
<tr>
<td>1. Total net dollars paid (in billions)</td>
<td>Face width</td>
</tr>
<tr>
<td>2. Average gross dollars paid above 2nd highest bid. (in millions)</td>
<td>Brow length</td>
</tr>
<tr>
<td>3. Total net acres leased (in millions)</td>
<td>Face height</td>
</tr>
<tr>
<td>4. Number of leases won</td>
<td>Eye separation</td>
</tr>
<tr>
<td>5. Average percent of ownership of leases</td>
<td>Pupil position</td>
</tr>
<tr>
<td>6. Percentage of leases, ultimately found to be producing, won by the company</td>
<td>Nose length</td>
</tr>
<tr>
<td>7. Average number of years between sale and first production (production lag)</td>
<td>Nose width</td>
</tr>
<tr>
<td>8. Net gas production (in trillion cubic feet)</td>
<td>Ear diameter</td>
</tr>
<tr>
<td>9. Net liquid production (in millions of barrels)</td>
<td>Ear level</td>
</tr>
<tr>
<td>10. Net royalty paid to government (in millions)</td>
<td>Mouth length</td>
</tr>
<tr>
<td>11. Net royalty/net bonus (in dollars)</td>
<td>Eye slant</td>
</tr>
<tr>
<td>12. Net royalty/number of years of production (in thousands)</td>
<td>Mouth curvature</td>
</tr>
</tbody>
</table>
Table 2 (Continued)

13. Square of correlation coefficient from multiple linear regression of royalty/pro. yr. on bidding data, production lag and years of production (for producing leases only)

14. Royalty/production year/producing acre (in dollars)

15. Percentage of owned leases terminated

In Figures 5 and 6, each company is represented by a particular Fourier Series. This technique, due to Andrews (1972), uses the data for a given company as coefficients in the function:

\[ f(t) = x_1 \sin t + x_2 \cos t + x_3 \sin 2t + x_4 \cos 2t + \ldots \]
\[ \quad + x_{13} \sin 7t + x_{14} \cos 7t + x_{15} \sin 8t \]

for \( t \) in the range \((-\pi, \pi)\). For visual clarity, the resulting functions for ten selected companies are arbitrarily divided into two subsets and plotted in Figures 5 and 6. Figure 7 illustrates a technique due to Chernoff (1973) whereby each variable is arbitrarily associated with a facial characteristic (see Table 2 for the assigned association between "facial feature" and "variable") to produce the so-called "Chernoff faces." Here all ten selected companies are presented on one picture.

Figures 5, 6 and 7 can be used to visually cluster the companies. In Figures 5 and 6, relatively tight bands suggest clusters. Using Chernoff faces, one can cluster the companies by comparing the general overall appearances of the faces. This latter method can be easily applied to a subset of the fifteen variables to investigate possible associations. For example, we could group together those companies having similar mouths, or ears, etc.

Figures 8 and 9 illustrate a capability to generate lease maps in the Gulf of Mexico via computer. Figure 8 portrays a map of all but a few of the leases in Texas and Louisiana which are included in the LASL LPR data base. (Forty-seven deep water leases, which had not produced by 1974, are not included.) Both active and terminated leases are included. The green line is the Gulf Coast, while the white checkerboard pattern represents the
survey lines upon which the leases are based. The area of each lease is colored yellow. Figure 9 portrays the same lease region but highlights (in red) leases which produced some natural gas between 1954 and 1974.

Figures 10 and 11 are prints of two introductory slides which illustrate the contents of a four-minute, 16-mm color movie titled "Three Gas-Water Reservoir Simulations." Both the slides and the movie are computer generated. Figure 10 motivates our selection of the particular simulations in the movie. The three cases, labeled A, B, and C, respectively, correspond to different initial rates of production (Table 3). The production rate function for these simulations is of the form \( r(\theta) = a[P(0)]^2 \), where \( r(\theta) \) is the rate of production at time \( \theta \), \( P(0) \) is the pressure at time \( \theta \) and the constant "\( a \)" is determined from the initial condition where \( a = r(0)/[P(0)]^2 \). The ultimate recovery, \( u \), is the total production or more formally \( u = \int_0^{\theta_c} r(\theta) d\theta \), where \( \theta_c \) is the cutoff time. Since the reservoir is assumed initially to contain one mole of gas, \( u \) can alternatively be viewed as the proportion of gas produced to initial gas in place. Production ceases and the cutoff time, \( \theta_c \), is determined as soon as either the volume of the reservoir gas drops to ten percent of the initial volume (a volume cutoff) or the rate of production drops to ten percent of initial rate (a rate cutoff). For the reservoir considered in these simulations, initial rates below 0.072 implied volume cutoffs whereas initial rates exceeding 0.072 implied rate cutoffs. We chose the three rates for the movie simulations to illustrate the effect of initial rate of production on ultimate recovery. Additional details concerning the numerical computations are contained in McFarland et al (1976).

**Table 3.**

<table>
<thead>
<tr>
<th>Case</th>
<th>Initial Rate (moles/yr.)</th>
<th>Ultimate Recovery</th>
<th>Cutoff Time (years)</th>
<th>Cutoff Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.010</td>
<td>0.859</td>
<td>132</td>
<td>Volume</td>
</tr>
<tr>
<td>B</td>
<td>0.072</td>
<td>0.933</td>
<td>50</td>
<td>Volume, Rate</td>
</tr>
<tr>
<td>C</td>
<td>0.100</td>
<td>0.821</td>
<td>30</td>
<td>Rate</td>
</tr>
</tbody>
</table>
Figure 11 corresponds to a typical frame in the movie for case A. There are three basic components in each frame. The box in the upper left-hand quarter of the frame is a representation of the reservoir. There are two layers in the box. The red top layer represents gas in place which can be recovered. The volume of the red layer is proportional to the volume of this gas. The blue layer portrays the water which invades the reservoir as the gas is removed. As the water floods into the reservoir, some of the gas in place is trapped or dissolved in the water and is essentially lost. The number of arrows on top of the reservoir is proportional to the rate of production. The five arrows which appear in Figure 11 imply that the current rate of production is between 50% and 60% of the initial rate.

A "pressure gauge" appears in the upper right-hand quarter of the frame. As the pressure drops, the arrow on the gauge travels in a counter-clockwise direction. For this frame, the pressure has dropped to 3826 psi from an initial pressure of 5000 psi. The tick marks on the gauge, which are unequally spaced, correspond to pressures at which the rate of production is a multiple of the quantity \(0.1 \times r(0)\). Whenever the pressure gauge passes a tick mark, one arrow on the reservoir lid disappears.

The lower half of the frame is devoted to the plotting of two curves. The green curve is the rate of production vs. time function. This curve is strictly decreasing, since the pressure drops during production. The magenta curve is the cumulative production vs. time function. Thus, the magenta curve is equivalently the area under the green curve (from time zero to the current time). Since these curves are "drawn" as the movie progresses, the current time is the time corresponding to the right-hand edge of the curve. Hence, in Figure 11, the current time is 100 years.

For simulation cases B and C there are two minor differences in the typical frames. The green scale is from 0 to the initial rate. The horizontal time scale is from 0 to the cutoff time.

In viewing the three simulations, we can compare the rate of change with respect to pressure, volume, production and cumulative production. For example, the pressure gauge for cases B and C moves dramatically faster than for case A. The influx of water--the blue layer of the box--is more apparent in cases A and B than in case C. The value of the cumulative
production curve at the cutoff time yields the ultimate recovery. Perhaps the most valuable aspect of the movie is that we can observe the change in numerous variables simultaneously, which in turn leads to considerable understanding of the gas-water reservoir.

IV. APPLICATIONS FOR THE COMPUTER GRAPHICS OUTPUT

The samples of computer graphics described in the preceding section are technical products which contribute to the statistical analysis and communication of lease activity information. The set of potential users for these products spans a wide range of individuals whose interests in Federal mineral leases vary from the lease management responsibilities to the general interest of any public citizen. With that scope of users in mind, we emphasize that the finished products are based on the best available data. Further, we believe the data to be of such quality and quantity that the analyses provide credible results. Of course, in realizing that the technical products can never be better than the data on which they are based, we must continue to strive for the collection, validation, and verification of data for use in subsequent analyses.

We have found that computer graphics techniques are very effective in the necessary "back room" work of checking the correctness of data bases upon which management reports are based. Further, we acknowledge that the technical products displayed here are the result of many cycles of learning experiences which have provided better technical products at each iteration. Perhaps our experiences can assist others in the graphic representation of data analyses and continue to produce improved technical products.

Whether one is working with data bases, models, or both, the applications of computer graphics output in the production of finished management reports is obvious. But, perhaps an even greater application is and will be the use of computer graphics in checking and correcting data bases and models. Computer graphics techniques lead to improved data analysis for use in decision making by management because they have the capability to expose "nonsense" data through visual display.
V. ACKNOWLEDGEMENTS

A multidiscipline team of scientists is responsible for the production of the products discussed in this paper. We gratefully acknowledge their efforts in this section. All of the persons named are potential resource persons in their area of expertise and may be contacted for further information about various products.

The formation of the LASL LPR database and the statistical data analysis tasks have been directed by Lawrence Bruckner of LASL. Myrle Johnson of LASL has played the major role in developing new graphics software and in utilizing DISSPLA and other existing graphic software to produce the finished products. She also worked with Mark Johnson to produce the 16-mm movie. Mark Johnson computed the numerical results described in the movie. Eldon Pequette and John Sibert of LASL produced the offshore lease maps. A portion of a program developed by Katherine Campbell of LASL (Campbell [1974]) was used to produce the color-coded correlation matrices. James McFarland of the University of Houston and a Visiting Staff Member to the LASL has provided resource economics expertise for maximum efficient rate of production studies. Richard Phillips of the University of Michigan and a Visiting Staff Member to the LASL has worked with Pequette and Sibert to install and develop the ADBMS (A Data Base Management System) system in the LASL Central Computing Facility.

It is our pleasure to express our appreciation to these people for their contributions to the success of this project.

VI. SUMMARY

The computer generated graphic products described in this paper represent a variety of techniques for summarizing and analyzing large amounts of data. Included are summary maps, color-coded correlation matrices, multi-axis plots, Fourier series, Chernoff faces, color-coded lease maps, and a color movie of gas-water reservoir model simulations. These methods offer several alternatives for describing, analyzing and inspecting the 7,000,000 characters in the LASL LPR data base.
REFERENCES


8. "System 2000, Data Base Management System," developed by MRI Systems Corporation, P. O. Box 9968, Austin, Texas.

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