Chapter 17: Computerization of Map Analysis

COMPUTER LITERACY certainly is helpful in any modern profession, and this applies particularly to the earth sciences. Visual images - including geological maps and cross-sections - are an important part of our profession. The display and manipulation of geological graphics can be greatly facilitated by digital image processing. Limited computer capacity and excessive cost have previously constrained wide-scale application of digital image processing. But, technological innovations are continually optimizing computing capacity. Professional systems, although still expensive, are becoming more affordable and, consequently, are more widely available. Not surprisingly, software programs for geological applications are rapidly improving and diversifying. These applications include map display, sectioning operations, and reservoir modeling. This chapter discusses some of the options currently available. Additional resources, including geological software and data processing services, are listed on page 367 and onward.

Contents: The digital future of map representations is discussed in section 17-1. Hardware and software items are summarized in sections 17-2 and 17-3. Geographical Information Systems are introduced in section 17-4. The promising development of dynamic digital maps is highlighted in section 17-5. Some hints for on-line resources of maps are given in section 17-6. The role of interfacing platforms in industrial applications is explained in section 17-7.

17-1 Digital geoscience

A clever practitioner of map interpretation will use any technique which adds to the quality and validity of the result. The role of computerized map analysis can be important in this process. Computer applications are coming of age, and full-fledged automated data manipulation is particularly advanced in geological applications since it involves huge amounts of old and newly acquired field data. In modern geological surveys, nation-wide geological observations are increasingly being stored digitally and mapped using computer databases. Similarly, mining and

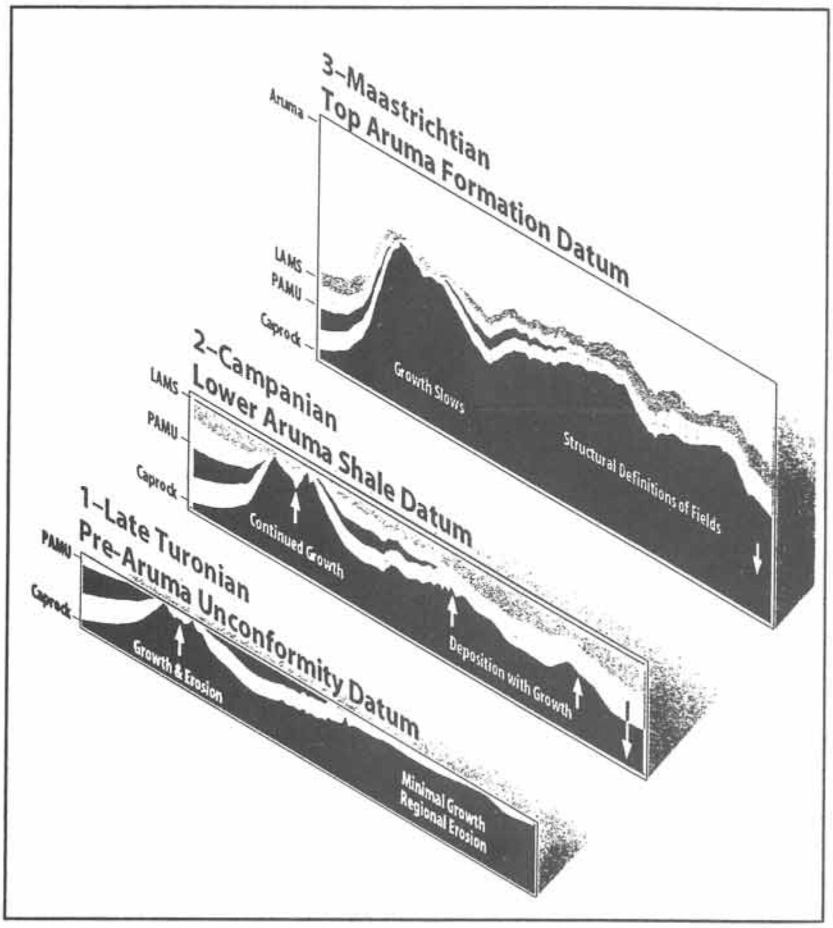


Figure 17-1: *Growth history of oilfield below caprock, depicted in cross-sections at three stages of development, Arabian Gulf region.*

oil companies are faced with the task of storing and managing enormous sets of data related to prospect areas. These operations are becoming dependent on advanced application programs, which allow the full integration of directly accessible digital data sets.

For example, well-log data are presently recorded digitally at the well-head and can be displayed together with seismic sections and maps, using powerful software packages. These data are part of bigger, compatible databases that are continually expanding and improving. Three-dimensional recording of seismic data enables the graphic display of subsurface structures from any angle of view. All these operations help to optimize well locationing, reservoir management, and strategic planning. The information processed by current workstations typically are of the order of five hundred Megabytes or more. Team efforts can be compiled on so-called video-walls, which allow the comparison of a dozen images, each routed there from its own workstation. This allows the development of integrated geological models, using 3-D seismic information and structural and stratigraphic data. Reservoir management and mining can be optimized, using this new approach (Fig. 17-1).

Digital image processing not only requires a good grasp of the basic techniques of map interpretation, but also an understanding of the hardware and software that can help to complete the task more effectively. Newly developed software is sometimes clumsy and difficult to use. This can be a nuisance to users who are preoccupied with a multitude of other tasks. Computer programs, if not used on a regular or routine basis, consume considerable time to reaquaint the infrequent user. Most geologists, concentrating on the actual mapping of rock units and the associated structures in the field, have too little time to maintain a skill-level required for digital image processing of complex geological maps. Such data manipulation is best done in a team operation, where experts can combine their different knowledge and skills to achieve professional results. This still means that geologists need to understand, at least, some basic principles of digital map systems in order to communicate effectively with the operator of such systems. However, the operator, performing the map analysis, may well be a weathered geologist, who has later concentrated on data-processing and computer skills.

The preceding chapters were aimed at developing a thorough grasp of the basic principles of map interpretation. This was achieved by practicing manual excercises of analog construction techniques. However, the future of map interpretation is in digital image processing, and geologists need to understand, at least, the basic principles of the available technology. One way to achieve this is to increase your computer literacy at every opportunity.

17-2 Hardware

Advanced digital image processing involves considerable investment in hardware (the machine) and software (the interactive instruction program). Detailed knowledge of the technical capacity of hardware is essential for a smooth and professional performance. The hardware required for digital map analysis involves the computer, its monitor, and accessories. Before making any choices, it is essential to check carefully which software is compatible with your computer system. The kind of hardware accessible to you determines your possibilities. Digital image processing involves a large number of data or bits, so that a reasonable processing speed is required. The development of the technical standards in this area is much faster than the time required for this book to be printed. It is, therefore, beyond the scope of this book to survey the available hardware in any depth, and only some guidelines are provided here. This section concentrates on PC platforms for instruction purposes. However, to perform the mapping, cross-sectioning and other modeling functions, most oil companies now use local networks with SUN or SGI UNIX workstations connected to mainframe computers (e.g., IBM, Cray, Amdahl, DEC, or Hewlett Packard).

The processing speed of your computer is to a large degree dependent on the type of microprocessor (or microchip) used to build the central processing unit inside the computer. Use modern software on a modern computer. The main memory, residing in a section of the central processor unit, includes both a ROM-unit (read only memory) and a RAM-unit (random access memory). Additional mass storage memory is provided by various types of resident memory (hard disk) and by removable disks. Sufficient RAM-capacity is particularly important. Some user programs cannot be implemented on computers with a small RAM-size. For example, *AutoCAD* - a powerful graphics utility program with many geological applications - presently requires a minimum of four megabytes RAM. It, also, requires your machine to include a rather costly math coprocessor - a booster for the central processing unit - to enable rapid data manipulation. The latest microchips have math coprocessors built in.

The chip-speed is not the only factor controlling the processing speed, because the amount and speed of the main memory and caches, also, play a role. Nonetheless, Intel's microchips are most widely used, and the present generation is characterized by the *5xx*-series (including the Pentium Pro), which supersedes the *xx486*-digit series. Older generations of microprocessor units bear labels coded 80386, 80286, 8086, 8088, 8085, 6800, 6502, and Z80. New generations of chips are likely to enter the market by the time this book reaches you. In order to allow your computer to display graphics, you may need to purchase an optional graphics card for the vacant slots inside your machine. A high resolution (minimum 640 by 480 pixels, VGA) color monitor with a large format screen is, also, desirable for any kind of professional image processing. Sophisticated image manipulation further requires special equipment to transfer the image from the monitor to a hardcopy medium. This may include large format color printers and inkjet plotters, the quality of which is rapidly improving.

You, also, need accessories that allow the feeding of raw data into the machine. Map data can be drawn entirely from scratch onto the computer screen, but this is uncommon. Digital maps may be based on topographic maps, existing geological maps, aerial photographs, or satellite images. Base maps need to be fed digitally into the computer. There are several ways to achieve this: a) Reading of existing digital base maps, commercially available on CD-ROM. b) Accessing existing digital map files via Internet (see section 17-6). c) Digitizing your own hardcopy maps with the help of a digitizing tablet and supporting software to create the data file. d) Scanning your own hardcopy map with the help of a scanner unit and supporting software to create the data file. The methods referred to above require the following hardware: (a) CD-ROM drive, (b) Internet modem, (c) digitizing tablet, and (d) scanning unit. This equipment must be connected to, and correctly communicate or interface with, your computer. Special software is required for creating the digitized or scanned data files (see below).

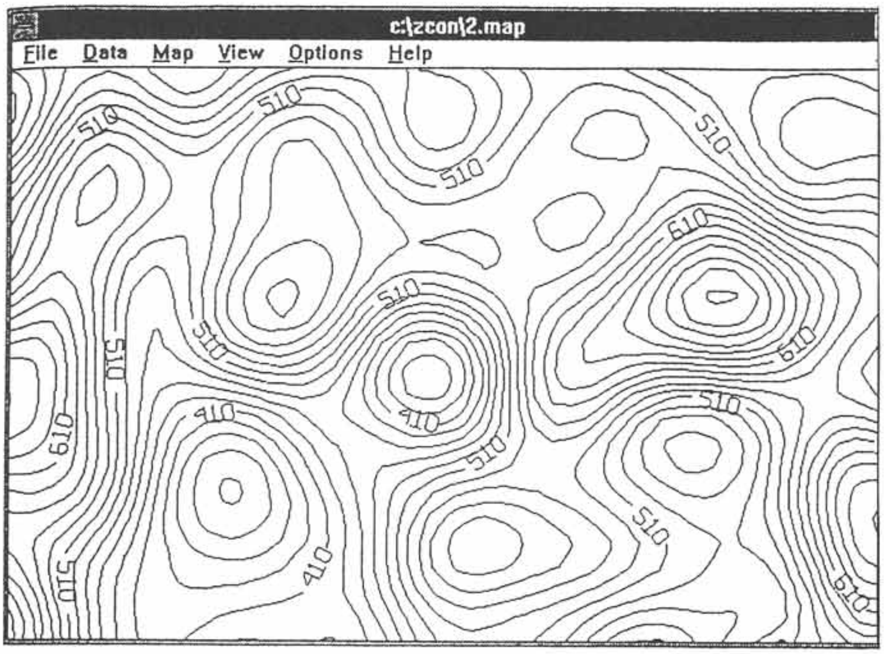


Figure 17-2: Contour map, generated by Z/CON from spaced elevation points.

One thing that seems certain is that it is hard to keep abreast of advances in hardware development. Larger companies, government agencies, and academic institutions all have special staff to assist you in this task. Smaller institutions have little or no support and typically tend to outsource technological expertise and to lease rather than buy their computer equipment. Ultimately, you may find yourself developing into a computer nerd, by pure necessity.

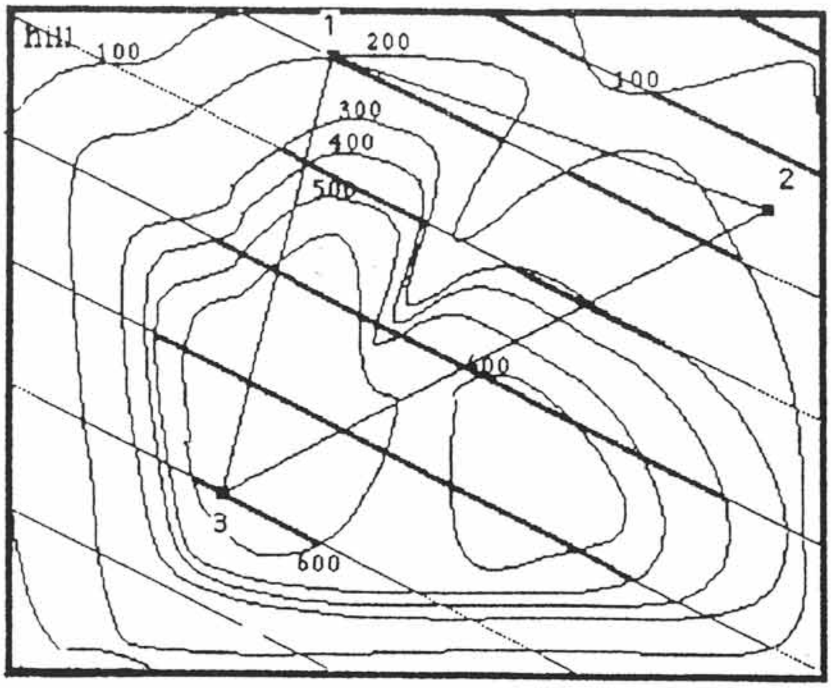


Figure 17-3: Structure contours, drawn interactively by SL-Macintosh on a topographic base map, generated by CNTR.

17-3 Elementary software

When you actually want to try a digital map analysis, the communication between you and the machine is maintained by an interactive user program. The initial choice of software to be used is a very important one, because data presentations in one program often cannot be readily transferred to or read by another program. Presently, software packages are divided into several groups, based on operating systems: i.e., DOS, UNIX, Windows, or Macintosh. Some very useful programs may be available only for one of the operating systems. Another limitation on your application may result from the processor speed and the various types of memory in your computer.

In order to get started with digital map analysis select a program that performs the particular type of geological map analysis required and then make it work on your computer system. The type of software you need depends on what you want the computer to do for you. There are simple and inexpensive software packages for small tasks, such as producing contour maps from elevation data, or a single type of block diagram. More sophisticated (and costly) packages have many subprograms, which allow contouring, cross-sectioning, and perspective drawing for arbitrary angles of view. This section concentrates on software for use on PC's and Macintosh computers. For comparison, some main UNIX software company offerings include *Zmap*, *Stratamodel* and *Stratworks* by *Landmark*, and *CPS-3* and *Stratlog-2* by *Schlumberger*.

Although some examples of commercially available software are outlined below, much more is available from a variety of sources. No attempt has been made to asses the quality of any products. Prospective users are advised to critically evaluate the performance and functionality of individual products. Suppliers of geological software and services are included in the final section, *Additional Resources* (p. 367 and onward).

DIGITIZE-Macintosh & PC: This is a digitizing program, which creates an ASCII data file from analog drawings. You need an electronic digitizing tablet plugged into a serial port of your computer. An electronic pointer is used to trace the analog coordinates of the graphical elements from a map taped to the digitizing tablet. The data files thus created can be read with more advanced software for further manipulation and display of the digital drawings. Digitizing tablets are supplied by a range of manufacturers but not that not all digitizing software runs on all tablets. Check what software is suitable for your brand of tablet. Details on *DIGITIZE* can be obtained from *RockWare*.

Figure 17-4: *Perspective landscape of Mount St. Helens, processed from elevation-data files (DEM), using GRIDZO.*

Z/CON-PC: This is a contouring program to generate smoothed and labeled contour maps from *ASCII*-files with the raw data points (Fig. 17-2). This program is compatible with IBM-PC's equipped with the Windows-interface. Details on *Z/CON* can be obtained from *RockWare*.

CNTR and SL-Macintosh: Contour filemaker *(CNTR)* can be used to digitize points from simple maps after scanning them into your PC. Points on each contour are captured by clicking the mouse to create a digital file of your contour map for further processing. *Structure Lab (SL)* reads the *CNTR*-file and solves three-point and structure contour problems (Fig. 17-3). Sample

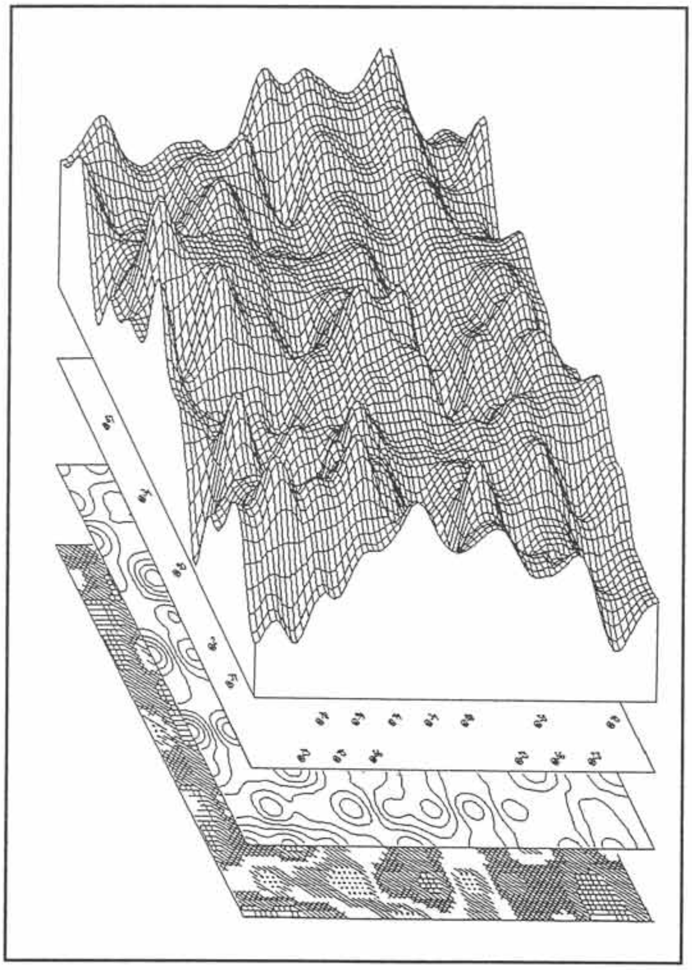


***Figure 17-5:** Contour maps and fishnet block diagram, drawn by GRIDZO.*

maps and a manual for student exercises are included. Details on *CNTR* and *SL* can be obtained from *Earth'n Ware*.

DEM-Macintosh & PC: Digital elevation models (*DEM*) are elevation data files from the *United States National Geophysical Data Center*'s data base, compiled from satellite surveys. Each *DEM* covers a 7.5 by 7.5 minute block of any part of the United States. These data files can be read with more advanced software for further manipulation and display, e.g., *GRIDZO* or *3D* discussed below (Fig. 17-4). Details on *DEM* can be obtained from *RockWare*.

3D-PC: This software is designed to transform *DEM*-files into isometric block diagrams of the surface topography. The surface shape can be visualized by colored and raised relief contours or as a shaded relief for different light sources. The block diagram can be viewed from any angle and from different heights above the horizon (Fig. 17-4). Details on *3D* can be obtained from *RockWare.*

GRIDZO-Macintosh & PC: This is a mapping package for producing contour maps and block diagrams with raised contours or fishnet mesh grids (Fig. 17-5). The package includes comprehensive manuals and tutorials. Details on *GRIDZO* can be obtained from *RockWare.*

VistaPro-PC: This is a state-of-the-art landscape simulator, which uses real-world-data from the *United States Geological Survey* and *NASA* to draw relief scenes. Landscapes included are Mount St. Helens of Washington, Crater Lake of Oregon, Olympus Mons of Mars, and El Capitan of Yosemite National Park, California. Synthetic landscapes can be generated with the built-in fractal expressions. Colors and physiographic features, such as trees, snow, lakes, and rivers, can, also, be

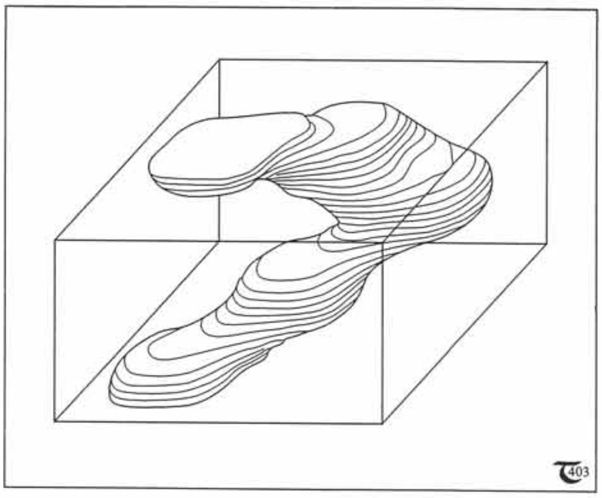


***Figure 17-6:** Elevated structure contours, outlining the shape of an ore body, drawn by Rocksolid.*

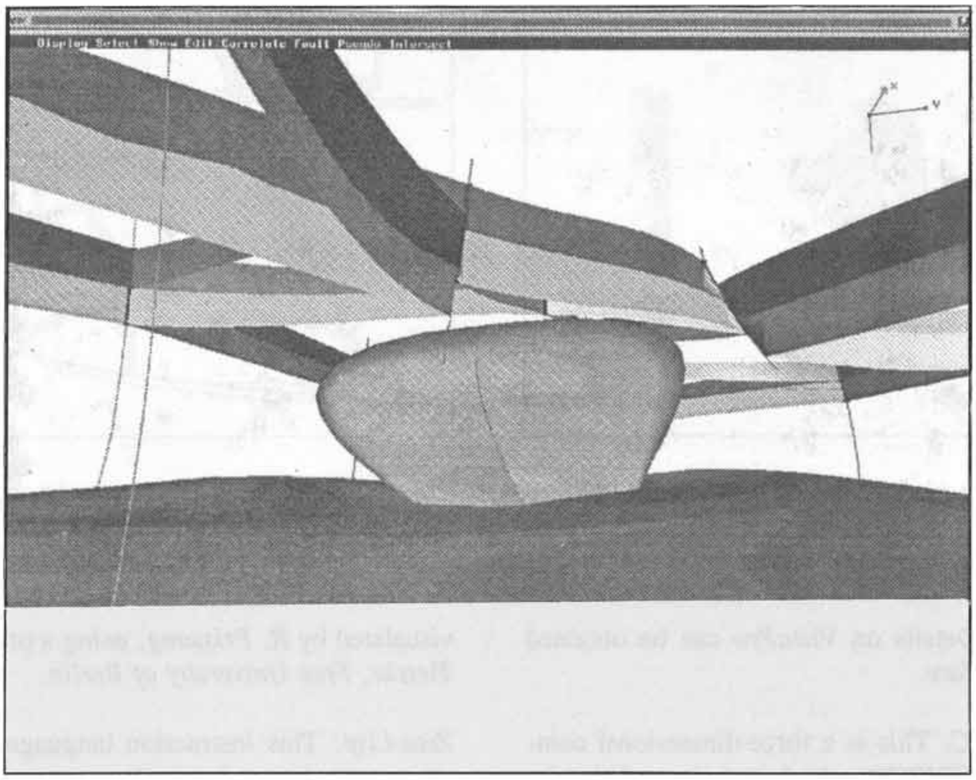


Figure 17-7: *Perspective view of salt dome and fence diagram of surrounding beds faulted by the buoyant salt, generated with IREX.*

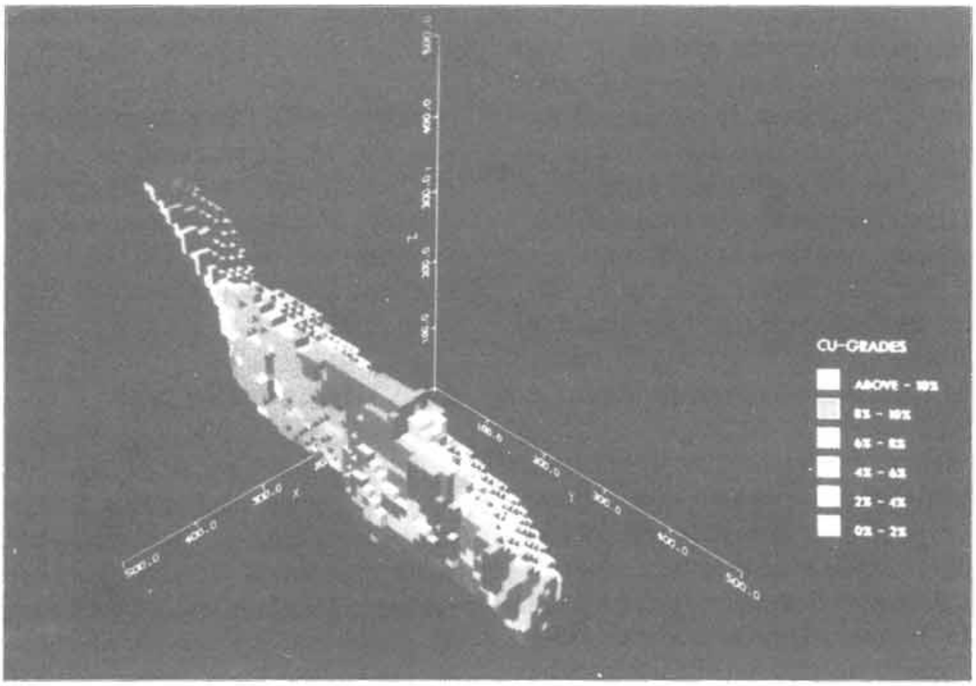


Figure 17-8: *Shape and copper-grade of the Cayeli ore body, Turkey, drawn with Ca-Disspla.*

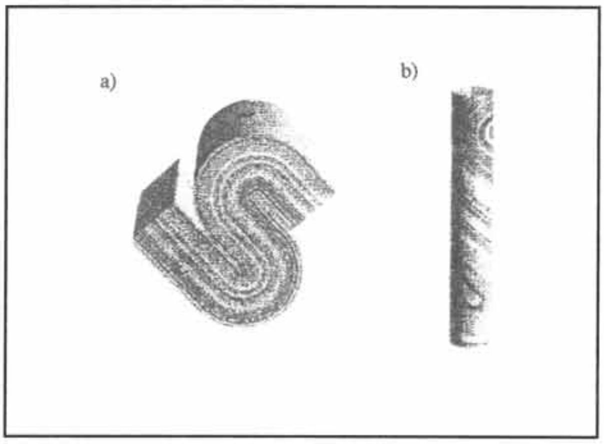


***Figure 17-9:** a) & b) Overturned isoclinal parallel fold and its appearance in a vertical drill core in perspective views, simulated by Zeta-Lisp.*

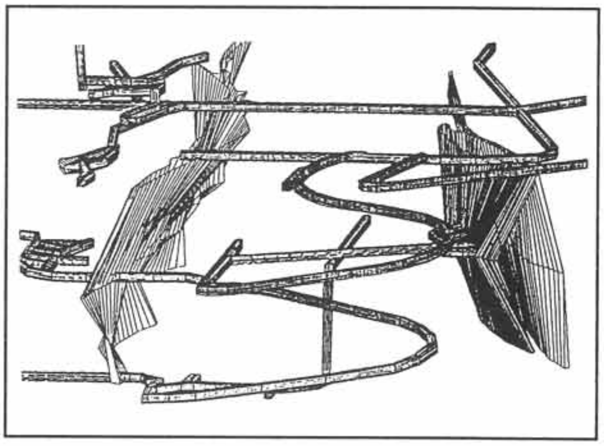


***Figure 17-10:** Tunnel system and position of steep fault surfaces, generated by AutoMiner.*

simulated. Details on *VistaPro* can be obtained from *RockWare.*

Rocksolid-PC: This is a three-dimensional complement to *GRIDZO*, which includes utilities for structure-contouring of 3-D orebodies (Fig. 17-6). Details on Rocksolid can be obtained from *RockWare.*

IREX: This advanced software package, developed by an industry consortium, runs on Silicon Graphics series of computers. It is designed for high-performance 3-D graphics of reservoir models. Figure 17-7 is an *IREX*-generated perspective view of a salt dome, surrounded by fence sections of the sedimentary host rocks. The faults are marked, and the 3-D display can be swiftly modified when additional data become available from new seismic survey lines and drill cores. Details on *IREX* are available from *TechLogic.*

Ca-Disspla: This is a powerful graphics library, which can be utilized to write your own customized graphics program. For example, object rendering utilities can be used to write a program that enables a display of both the shape and grade of ore bodies in the subsurface. Figure 17-8 illustrates the spatial distribution of Cu-grades by color coded cubes for the Cayeli Cu-Zn-Pb deposit, eastern Turkey. This application was visualized by *R. Prissang*, using a program by *J. Tietske, Free University of Berlin.*

Zeta-Lisp: This instruction language, like many others, can be used to write geometric modeling programs. The appearance of deformed layers on the surface of cylindrical drillcores (Fig. 17-9) has been modeled by *Stefan Luthi*, using a graphics program, written by *Kurt Fleischer and Andy Whitkin of Schlumberger Research.*

AutoMiner-PC: This software provides a subroutine for, or enhancement of, *AutoCAD*. It is particularly useful for mining applications and the planning of ramps and tunnels (Fig. 17-10). Ore volumes and weight can be calculated from sections. Details on *AutoMiner* can be obtained from *RockWare.*

17-4 Digital GIS maps

Geographic information systems (GIS) form the basis for many applications in modern digital mapping, including geoscience functions. The basic idea behind GIS-databases is to store data related to locations on the surface and subsurface as geographic entities. A number of different databases can be superimposed in data planes and a selection of the relevant data can be combined in a customized map. Examples of data sets suitable for manipulation in GIS are electro-magnetic radiation patterns, such as seen in Landsat or Spot images, gravity anomalies, aeromagnetic field strength, terrain models, well locations, infrastructure, geophysical survey lines, spatial variations in geochemical data, etc. Each GIS is adapted for integrating many different kinds of geoscientific data in what is sometimes termed a synergistic analysis. The final database contains a variety of information, all referenced to a common geographic datum.

Before the arrival of computer-based GIS analyses, geologists had to compare maps of a variety of scales, flipping them back and forth while forming a mental model of the integrated data. Interpreting such data becomes much more effective if all the information systems are combined in a geographically-referenced system. Most GIS software packages can import a range of formats from data sets that are obtained in digital format from a variety of sources. For example, digital elevation data are available through some government agencies in North America. Such files include DEM's (digital elevation models), DTM's (digital terrain models) of the USGS, and TIGER's (topologically integrated geographic encoding and referencing), which contain infrastructure data from the US Census Bureau. Other examples are satellite images of Landsat's thematic mapper and seismic epicenter locations which are recorded in digital format from the outset.

The incorporation of geological and geophysical information into digital GIS format was greatly simplified by the advent of global positioning system (GPS) technology. It is now easy to obtain digital latitude and longitude readings from hand-held GPS devices. In 1978, the first global positioning satellites were launched by the *United States Air Force* to keep track of the geographical positions of ground vehicles, aircraft, and personnel. The average design-life of the satellites is 7.5 years, and a total of 40 have been built. At present, a constellation of 24 GPS-satellites orbit 1,200 miles above Earth. The satellites receive information on their ground positions from ground stations that control the system. The satellite positions are known and the distances to them are determined by highly accurate timing signals.

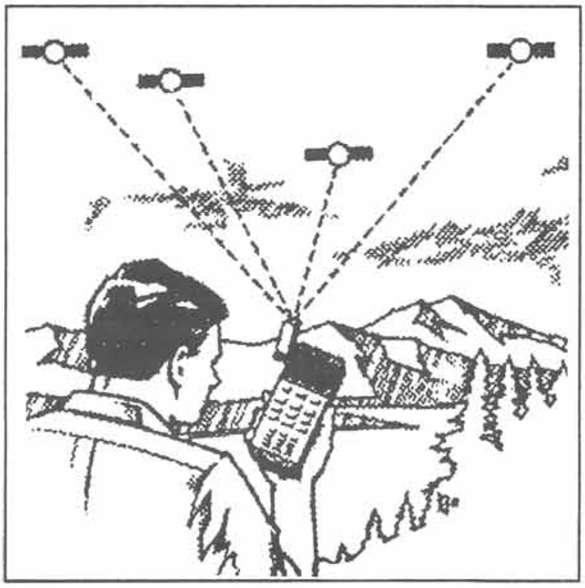


Figure 17-11: *GPS satellite receiver uses signals from US Air Force satellites to triangulate ground positions.*

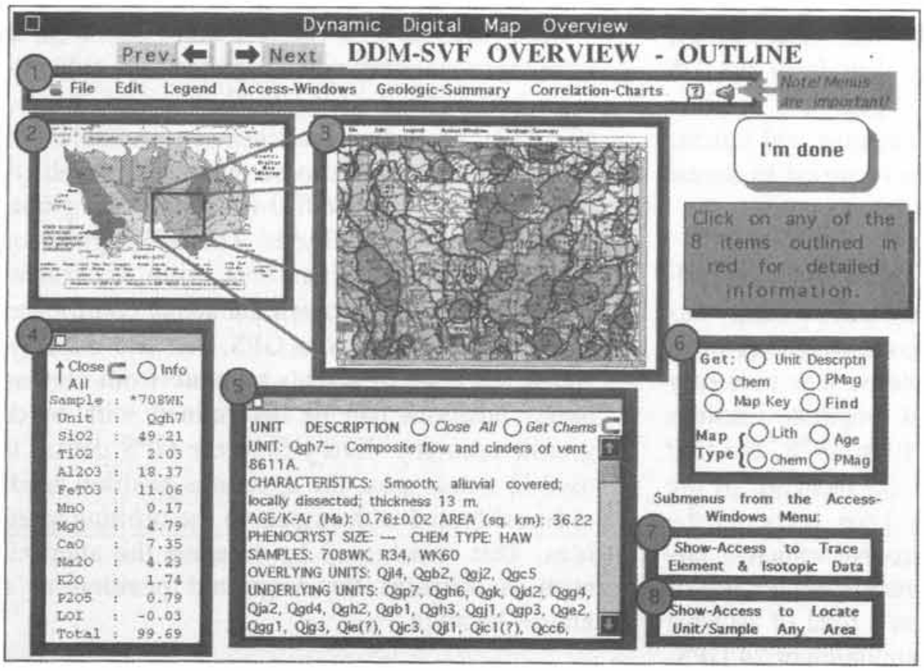
Each personal GPS-receiver takes data from at least three satellites to triangulate and calibrate the actual position of the receiver on the ground (Fig. 17-11). If four satellites are available, the altitude of a position can be obtained, as well. A ground position is specified in terms of the global geographic grid coordinates. The GPS-signals for civilian receivers commonly give accuracies within 100 meters between the actual coordinates and those received from GPS. For the military, which use a set of signals separate from civilian users, positions can be determined with much greater accuracy. Every time the GPS device is used in a new area, the apparatus position needs to be calibrated with respect to the orbiting satellites. This is achieved by entering the approximate coordinates for a ground position at a known location.

All data recorded with GPS coordinates can be downloaded into a GIS database using the geographical coordinates to locate data properly on the map. Distortions inherent in properly locating most field mapping data are reduced. Computerized image processing is now, also, possible in the field, using portable computers. Although these units add both weight and vulnerability to any outdoor trip in rough terrain, they reduce the data processing time back in the office. However, it is unwise to abandon the manual interpretation of geological maps altogether. Keep practicing manual methods, so that you can operate without digital support if such situations arise.

Geological data of conventional (non-digital) maps are best entered by optical scanning, adjusting for scale and distortions related to map projection. However, it is both costly and time-consuming to convert existing geological maps into digital format, if separation of various data sets in different data planes is required. This is due to the large volume of complex data commonly contained in professional geological maps. Ultimately, the precision of any final map accuracy is dependent on the spatial resolution of the input data, the scale of the final map, the way in which incomplete geological boundaries have been interpreted, and the resolution of the printing hardware used to produce the hardcopy map. GIS software has tools to manipulate raster data and vector data, but the complexity of coding schemes obviously requires specialist knowledge to achieve good results.

17-5 Dynamic digital maps

The concept of the dynamic digital map utilizes the new possibilities offered by modern computer hardware by incorporating customized, pull-down menus, that allow interactive display of selected data. Dynamic digital maps contain a series of windows, each containing some component of the map. The windows include index maps, field images, zoom facilities, and scrolling options. The power of this approach can best be appreciated by studying the dynamic map of the Springerville Volcanic Field, Arizona, prepared by *Christopher Condit* and available on CD-ROM from the *Geological Society of America*. Pop-up windows display information on lithological units and locate specific samples within the map segment studied (Fig. 17-12). All palettes can be moved to see the map beneath them. The software is based on Supercard, a hypermedia programming language. This environment has been used to write a presentation manager, a program designed to reformat digital maps into a package that maximizes user accessibility.



Click on any of the 8 items outlined in red for detailed information.

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Sample : *708WK
 Unit  :   Qgh7
 SiO2  :  49.21
 TiO2  :   2.03
 Al2O3 :  18.37
 FeTO3 :  11.06
 MnO   :   0.17
 MgO   :   4.79
 CaO   :   7.35
 Na2O  :   4.23
 K2O   :   1.74
 P2O5  :   0.79
 LOI   :  -0.03
 Total :  99.69
```

UNIT DESCRIPTION
UNIT: Qgh7-- Composite flow and cinders of vent 8611A.
CHARACTERISTICS: Smooth; alluvial covered; locally dissected; thickness 13 m.
AGE/K-Ar (Ma): 0.76±0.02 AREA (sq. km): 36.22
PHENOCRYST SIZE: --- CHEM TYPE: HAW
SAMPLES: 708WK, R34, WK60
OVERLYING UNITS: Qjl4, Qgb2, Qgj2, Qgc5
UNDERLYING UNITS: Qgp7, Qgh6, Qgk, Qjd2, Qgg4, Qja2, Qgd4, Qgh2, Qgb1, Qgh3, Qgj1, Qgp3, Qge2, Qgg1, Qjg3, Qie(?), Qjc3, Qjl1, Qic1(?), Qcc6,

Submenus from the Access-Windows Menu:

Show-Access to Trace Element & Isotopic Data

Show-Access to Locate Unit/Sample Any Area

Figure 17-12: Major windows displayed in dynamic digital map of the Springerville Volcanic Field, Arizona.

Dynamic digital maps may be based on GIS systems, but they, also, include multimedia accessories. For example, the dynamic map of Springerville includes photograph windows with oblique aerial views and outcrop close-ups. Other windows display introductory text. The hypermedia-aspect allows interactive linking of data within various parts of the map. For example, when the unit Qgh7 is highlighted, its spatial distribution, description, locations of rock samples, and chemical analysis can be quickly assessed. The dynamic geological map is programmed to provide menus that enable the user to have quick access to a variety of data. These data may include tables, videofilm, spoken text, and other attributes now available for multimedia presentations. Consequently, dynamic geoscience maps include a far broader range of material than the traditional hard-copy maps. The formatted CD-ROM is inexpensive to reproduce, with nominal cost between one and two US dollars for multiple copies. Digital maps can employ high-quality colors without the cost concern that sometimes impedes the production of hardcopy maps in color. Dynamic maps can be rapidly distributed electronically, using Internet facilities or local library networks, and enhance scientific productivity by reducing search time.

17-6 On-line resources for maps

Ordering CD-ROM, magnetic tapes, and other physical storage formats of digital map files is one way to acquire digital map data. But you can, also, try to surf cyberspace to access digital map files from a variety of sources. One of the primary functions of the Internet is file transfer. One way to transfer files is through server programs, such as Gopher, WAIS, or the World Wide Web, which provide interfaces to Internet's multiple resources. These servers are used to send and retrieve information across the Net. Others methods include e-mail, telnet, and other gateways. The simplest form of file transfer is through FTP (file transfer protocol).

In order to get the files, some versatility in cyberspace surfing is essential. Once you start, you may like it, and, after the initial novelty wears off, you may use it even for professional purposes. An excellent on-line document by *Bill Thoen* on resources for Earth Scientists via Internet is available (when this book went to press) via FTP from URL: *ftp://ftp.csn.org/COGS/ ores.txt*. This list has been superceded by an HTML version on *Bill Thoen*'s and *Ted Smith*'s Web site at URL: *http://www.sni.net/~bthoen*. URL (universal resource locator) is a convention to represent each file address in a standard way. More information on URL's can be found in an article by *Tim Berner-Lee* at URL: *http://www.w3.org/pub/WWW/Addressing/URL/Overview.html* or by searching for *Berner-Lee*, using Gopher.

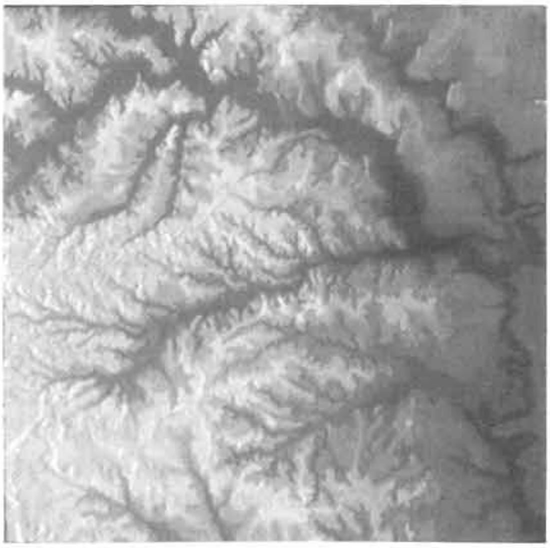

Figure 17-13: *Landscape simulation, using USGS digital elevation data.*

The *United States Geological Survey* has extensive on-line databases (Fig. 17-13). For example, ARC/INFO™ export files of US counties, derived from Census TIGER-files, can be accessed on-line (see information in URL: *ftp://ftp.csn.org/COGS/ores.txt*). The data in these files are derived from USGS 1:100,000 digital line graphs (DLG), complemented with older DIME data in metro areas. ARC/INFO™ itself is a GIS generating program written by the *Environmental Systems Research Institute*. More information is found at: URL: *http://www.esri.com/*

Information on Geographic Information Systems is available at URL: *http://ogis.org*. This

Web site is maintained by the *Open GIS Consortium*, which overall aim is to formulate compatible data formats for applications of GIS, Earth imaging, and other geo-processing technologies. *GISnet BBS* is an electronic bulletin board system that provides on-line resources for everyone interested in GIS, digital cartography, remote sensing, desktop mapping, and other earth science fields. Information on map data sets and other shareware is availabe at URL: *http://www.gisnet.com/gis/mapinfo/index.html*. On-line information on over 25,000 images of Earth from space and over 100 radar images from the Mission to Planet Earth can be found at URL: *http://www.csn.net/malls/rmdp*. Remote sensing imagery is, also, found at: URL: *http://www.coresw.com/*. Declassified CIA maps of the world are found at URL: *ftp://GIS.queensu.ca/pub/gis/cia/*. Other public domain maps, including DLG, DEM, DTM, and TIGER files are at URL: *ftp://spectrum.xerox.com/pub/map/*. Although addresses may have changed by the time this book reaches you, be assured there is plenty of browsing material out there.

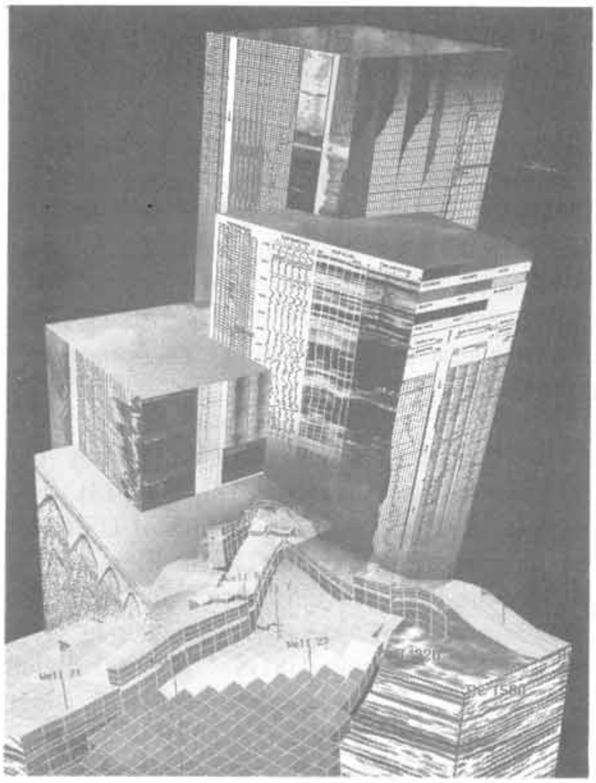

Figure 17-14: *Artistic visualization of reservoir conditions by data integration on advanced imaging systems. Data visualization supports communication between geological experts.*

17-7 Interfacing platforms

Geoscientists in many industries, government agencies, and academia have experienced problems in getting data to and from their existing applications. The need for integration of databases is particularly pressing in the petroleum industry. For example, in order to monitor exploration developments, well-log data, residing in Geoshare files of *Schlumberger*, may need to be integrated with GIS maps of seismic lines, stored in ARC/INFO™. If additional information on production data is required, files with statistics on local and global industry data may need to be accessed. The simultaneous display of all these data can be achieved only through an interfacing platform. Such platforms aim to create a consistent environment for accessing and managing geoscience data.

Obviously, visualization technology plays a key role in developing integrated models of subsurface data. Visualizations of sophisticated reservoir models are used to enhance understanding and improve communication among the various specialists involved in reservoir analysis (Fig. 17-14). Comprehensive reservoir models must account for 3-D seismic and well-log stratigraphy, petrophysical properties, pore geometries, borehole images, permeability, saturation with natural and injected fluids, gravity, magnetics, radar, and other electromagnetic imagery. The models can include the kinematics of the system by showing temporal and spatial hydrocarbon migration paths (4-D models). The uncertainty of all these models varies and decreases with the spacing of the input data. Geostatistics can play an important role in the modeling effort by extrapolating various characteristics through reservoir volumes, away from well control points. Finally, all data must be integrated in one common format. This integration process makes building reservoir models can be very time-consuming. To be successful, visualization technology and the integration of databases must be user-friendly, accurate, but still cost-effective.

In the early 1990's, the need to integrate databases, residing in different geoscience application programs, became widely apparent. In 1993, SAS/GEO™ of the *SAS Institute Incorporated*, Houston, was conceived. SAS/GEO™ is an example of a data and application integrator, specifically tailored to the needs of many geoscience applications. File translators give users the ability to read data from files that do not conform to the SAS™ standard. Some major third-party vendor application programs facilitate file transfers, because they include so-called API's (application programming interfaces), designed to facilitate the transfer of data between applications of different vendor programs. SAS/GEO™ includes pull-down menus and scrollable workarea, containing the user's choice of icons, which act as graphical interface between the user and SAS/GEO™. This platform works primarily as a data integrator. The product is designed to manage data with direct links to third-party vendor applications that use the same data. This allows users to work with the industry data model of their choice (POSC, PPDM, or a proprietary model specific to the company).

Started in 1991, many major companies with an interest in exploration and production, oil companies and software vendors alike, are sponsoring POSC (*Petrotechnical Open Software Corporation*, Houston). POSC aims to encourage the industry to adopt standards for API's, to define formats for an open data management model, formats for exchanging data between companies and software platforms. Advancing computer technology continually introduces new problems for the industry with the integration of digital databases on old and new applications. This is very costly, and POSC is a neutral industry group that is attempting to provide a common data model. Among its members are major exploration and production companies, such as *Mobil, Texaco, Arco, Chevron, Conoco, Norsk Hydro, Elf Aquitaine, Statoil, Shell, British Petroleum, Halliburton, Schlumberger,* and others. It, also, has major computing industry members in *IBM, Landmark Graphics, Oracle, Petrosystems, Digital Equipment, Sun Microsystems, UniSQL,* and many others.

Public Petroleum Data Model (PPDM) is another, non-profit organization dedicated to the development of standard data models for petroleum exploration and production needs. The obvious idea behind POSC and PPDM is that improving data management practices by establishing standards will increase effectiveness. Most petroleum companies are dealing with proprietary databases that required them to write their own programs, previously without industry-wide standards. The establishment of common standards will enable the petroleum industry to share data, if so required. A common standard will, also, allow them to buy, rather than develop, their own applications, in contrast to earlier trends. The petroleum industry can then focus on data access, as driven by business requirements, and will be less limited by computing standards.