DDM-SVF: A Prototype Dynamic Digital Map of the Springerville Volcanic Field, Arizona

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ABSTRACT

Dynamic Digital Map–Springerville Volcanic Field (DDM-SVF) is a stand-alone "presentation-manager" program that contains and displays four thematic geologic maps of the Springerville volcanic field, Arizona, on the Macintosh computer. It is essentially a complete "geologic map on disk" (CD-ROM). Because of its digital format, the program contains far more data than even the most complete analog maps. This digital map offers several advantages over hard-copy maps in that it simplifies finding samples (or units), makes information on map features and associated digital photos instantly available, and allows sequential changes in thematic map type. The maps can be printed out in color on desktop printers, or saved as separate files, and all data can be saved from the program to tab-delimited ASCII format, making the data easily accessible and accurately transferable to other workers. Maps of this type offer a venue for producing high-quality color maps and associated data quickly and efficiently, and can be distributed electronically (for example, by Internet) or on disk (by either diskettes or CD-ROMs).

INTRODUCTION

Desktop computers today offer a new medium for presenting geologic maps, brought on by the development of "hypermedia" programming languages (or "environments"). One such program is SuperCard, which has been used to produce DDM-SVF, a prototype geologic map on disk soon to be available (see p. 88) on CD-ROM from the Geological Society of America (Condit, 1995). Hypermedia environments provide an efficient way to write software to link maps, data, or digital photos into an interactive framework, providing the geologist immediate access to both the map and its associated information. An example of such a link: a geologist looks at a map on the screen, sees a symbol for a chemical analysis or a map unit and, using a mouse, clicks on the symbol, immediately bringing up a window containing the chemical analysis or unit description. Maps and data can be easily inserted into such a program; an example is SuperMap 7/23/92 (Condit and Neutra, 1992), which is included on a CD-ROM. In essence, these programs present a geologic map in a digital format that stresses ease of use and accessibility.

This article describes DDM-SVF, a prototype dynamic digital map I developed for use on the Macintosh computer (a Windows "player" should be available from Allegiant, which publishes SuperCard, early in 1995 for use
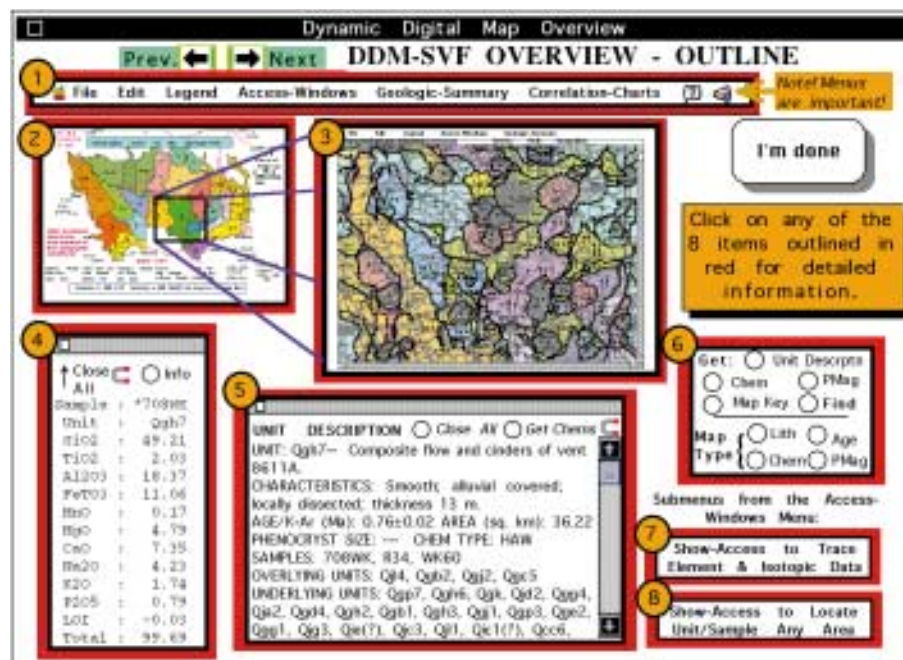

Figure 1. Page 1 of Dynamic Digital Map overview. Items numbered 2–6 show the major types of windows in the program. Item 2 is the index map; selecting (clicking on) the green area in this window displays the corresponding map segment (item 3). A click on a chemical sample site or on a unit symbol on that map segment displays the floating palette windows shown in items 4 and 5, respectively. The window of item 6 provides alternative means to display this information (see text), to search for and find units and samples on maps, and to transform a map from one thematic map type to another.

on DOS computers). DDM-SVF displays four thematic geologic maps of the Springerville volcanic field, a late Miocene to Pleistocene volcanic field in east-central Arizona; a hard-copy version of these maps will soon be published as a U.S. Geological Survey Miscellaneous Investigation Series map (Condit et al., 1995). DDM-SVF is a major expansion of both SuperMap 7/23/92, which included only a small part of the field, and of the four hard-copy thematic maps, because it includes a large petrologic data base and digital photographs. I hope this article points the way toward what is possible in the development of digital maps and inspires others to produce such maps; DDM-SVF barely scratches the surface.

A demonstration version of DDM-SVFDemo-v.xx.xx.94 can be obtained through the Internet by anonymous FTP from eclogite.geo.umass.edu (IP address 128.119.45.20), in the directory "ccondit." The hardware needed to run

DDM-SVF is a Macintosh with 8 megabytes of random access memory, an eight-bit (256) color 13 inch monitor, a hard disk, and/or a CD-ROM reader. If a color printer is available, most figures and all maps can be printed in color.

ATTRIBUTES OF DDM-SVF

What DDM-SVF Is and Is Not

Several attributes differentiate DDM-SVF from map-making systems on desktop computers (for example, the Macintosh-based MiniCad maps developed by the Geological Survey of Canada (Peterson and Hanmer, 1992) and DOS-based systems, including GSMAP (Selner and Taylor, 1991) and those of Ambroziak and Cook (1993). First, it is a stand-alone application—that is, one needing no other software to run. Second, it was designed by a geologist with the intent of making the map and data as intuitively and easily accessible as possible; all maps, images, text, and data can be viewed, saved, or accessed by simple click or click-and-drag commands with the mouse. Third, this is not a map-making system. It is a map "presentation-manager"—that is, a program designed to take already completed digital maps and, with a minimum of reformatting, put them in a package that maximizes their accessibility to the user.

DDM-SVF Program vs. the Data in the Program

A clear distinction between the program that contains and presents the map (written using a hypermedia programming language) and the map and data within the program may

Figure 2. The Map window of DDM-SVF, showing a lithologic map of the northern part of the Greens Peak map segment. Pop-up windows (floating palettes) display information on units and samples within this map segment (see text for details). All palettes can be moved to see the map beneath them. On the right side, the page icons represent some of the files that can be saved from this program for use outside it. These include Pict-format files of the map segment and of a digital photo, and tab-delimited ASCII files of five different types of data that can be opened directly in spread-sheet programs or with word processors. The hand symbol below the magenta circle numbered 41 is the mouse cursor; a click on this circle brings up the digital photo shown in Figure 3.
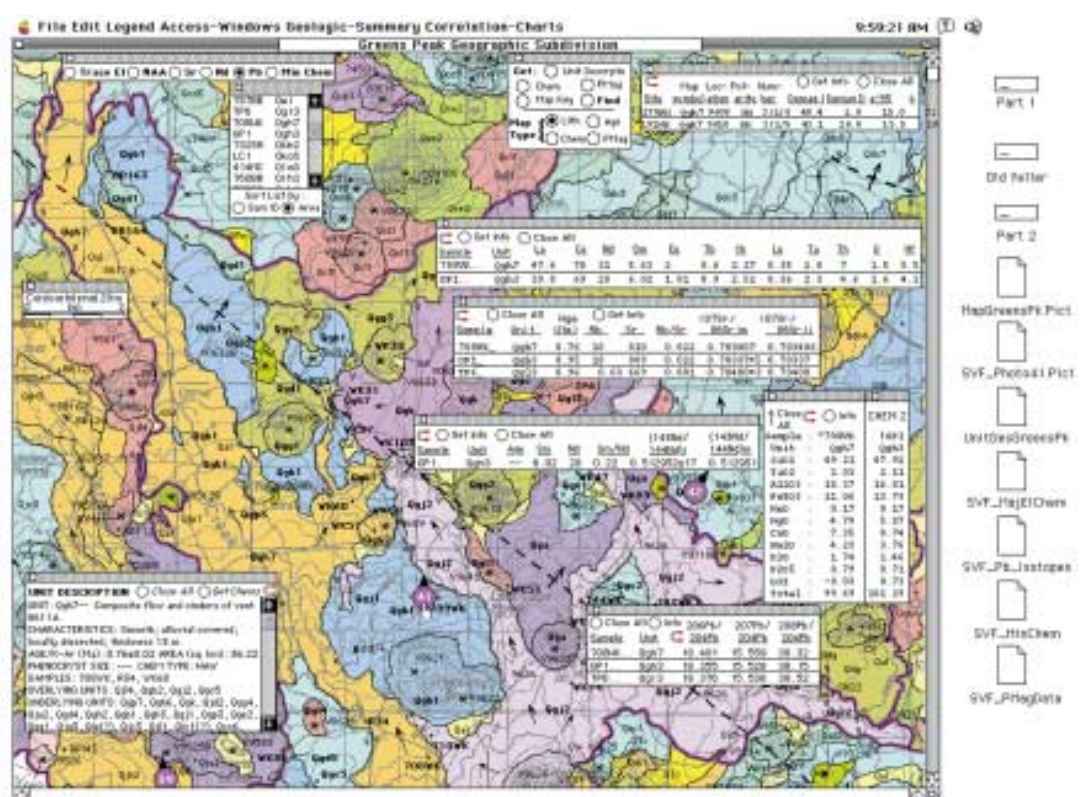
perhaps best be made by analogy. A casual reference to the hard-copy (read "paper") map on which DDM-SVF is based (USGS map I-2431) probably refers to all four map sheets, including the maps, text, and data found on the paper within the brown envelop into which the whole map is inserted. To be a purist, the actual map is the colored "cartoon," complete with contacts and, unit and sample labels, that is overlaid on the topographic base. The rest is accompanying figures, tables, and text. In this analogy, the program, created with SuperCard, is the "paper background" on which the digital map is "printed." For example, the programmer may create a card within a window into which she decides to put a map. In this case, the map has been created outside the SuperCard program using a computer-aided drafting program (for example, Canvas). The programmer then pastes this map into the appropriate card in the SuperCard program. Likewise, the programmer may create another card and window into which he decides to insert a figure or another card into which he inserts the map's introductory text. From here the distinction between the program and what is inserted into the program blurs, because the SuperCard program, instead of being a "dumb" white piece of paper on which the map pieces simply sit inert, can provide these pieces with an interactive link to other parts of the digital map. The programmer, anticipating that the geologist might want to know what the map symbol Qbb2 stands for, gives that symbol a script that says, in effect, "when clicked on, go find your unit description (stored elsewhere in the program) and display it on the screen." Similar "hypermedia" links are provided

throughout the program to map labels, text and tables after they are inserted into the SuperCard framework; many are also programmed into the framework (that is, the windows and cards of the program). Because scripts for a type of map label (for example, map unit symbols) can be identical and are easily assigned to each label, building such links is efficient once each label has been assigned an identity (that for the map unit above is simply assigned the name "Qbb2").

Windows Within DDM-SVF

DDM-SVF is a presentation-manager program that provides a series of windows, each containing some component of the map. The program allows the geologist to navigate between and within these windows. The first window (Fig. 1) is the hub, which is always displayed by default on the screen; it contains an index map. To see a part of the detailed map, the user points and clicks at the appropriate place on the Index Map, which closes the index map window, and opens another window (the map window) containing the designated segment of the map (Fig. 2). The user can scroll around the map within the window, a feature common to all windows in the program in which the information in the window might exceed the window's size. When done, the user closes the Map window by clicking a Close box on the window, causing the index map to reappear. The Map window actually contains 24 cards, each containing one map segment, but displays only one card at a time. The reason for dividing the original map into overlapping segments is to accommodate computers with only 8 megabytes of random-access memory, because loading a map segment that is too

Figure 3. Photograph window of DDM-SVF, showing one of the 74 photos in the program. This oblique aerial photo shows the north-central part of the Springerville field in late afternoon light. A click on the Show/Hide Labels button in the upper left hides all labels. A click on the left or right arrow (upper right) displays the previous or next photo in the program; the Get button lets the user type in the next photo she wishes to view. The photo can be saved as a Pict-format file by clicking on the Save as Pict … button.

large would cause "out-of-memory" problems.

Menus and the Introductory Text Window

The program has menus that enable the user to access additional windows not directly associated with the map proper. For example, the menu titled Correlation of Map Units presents the user with a list that opens a window containing any one of the map's 23 Correlation of Map Units charts. Another menu, Geologic-Summary, also provides the user with a list of selections. The selection Intro-

ductory Text opens a window containing the equivalent of a hard-copy map's summary text. Figures and tables can be called up by clicking on bold-faced words in the text (e.g., "table.1"). The Introductory Text window, as in any word-processor program, has search and find capabilities, and its text can be saved to an ASCII disk file. As the preceding description suggests, DDM-SVF contains all information normally associated with a hard-copy color map, including the explanation of map symbols, correlation diagrams, summary

Figure 4. A: The Map window of DDM-SVF, showing the lithologic map of the northern part of the Greens Peak map segment. The key to the thematic colors of the map is at the lower left. The cursor, represented by the hand (in the palette at the upper left), is poised to click on the "Chem" button to transform the map to a chemical thematic map, shown in Figure 4B. The user can scroll around the map using the "slider" controls on the right and bottom sides of the map window. B: The Map window of DDM-SVF, showing a geochemical map of the northern part of the Greens Peak map segment. The key to the thematic colors of the map is at the lower left. The cursor, represented by the hand (in the palette at the upper left), is poised to click on the "Age" button to transform the map to an age thematic map, shown in Figure 4C. C: The Map window of DDM-SVF, showing an age map of the northern part of the Greens Peak map segment. The key to the thematic colors of the map is shown at the lower left. A pop-up palette with K-Ar age data for a sample floats

above the map. The cursor, represented by the hand (in the palette at the upper left), is poised to click on the PMag button to transform the map to a magnetopolarity thematic map, shown in Figure 4D. D: The Map window of DDM-SVF, showing a magnetopolarity map of the northern part of the Greens Peak map segment. The key to the thematic colors of the map is shown at the lower left. The cursor, represented by the hand, has just clicked on paleomagnetic site 184R; the pop-up palette that resulted is displayed on the right.
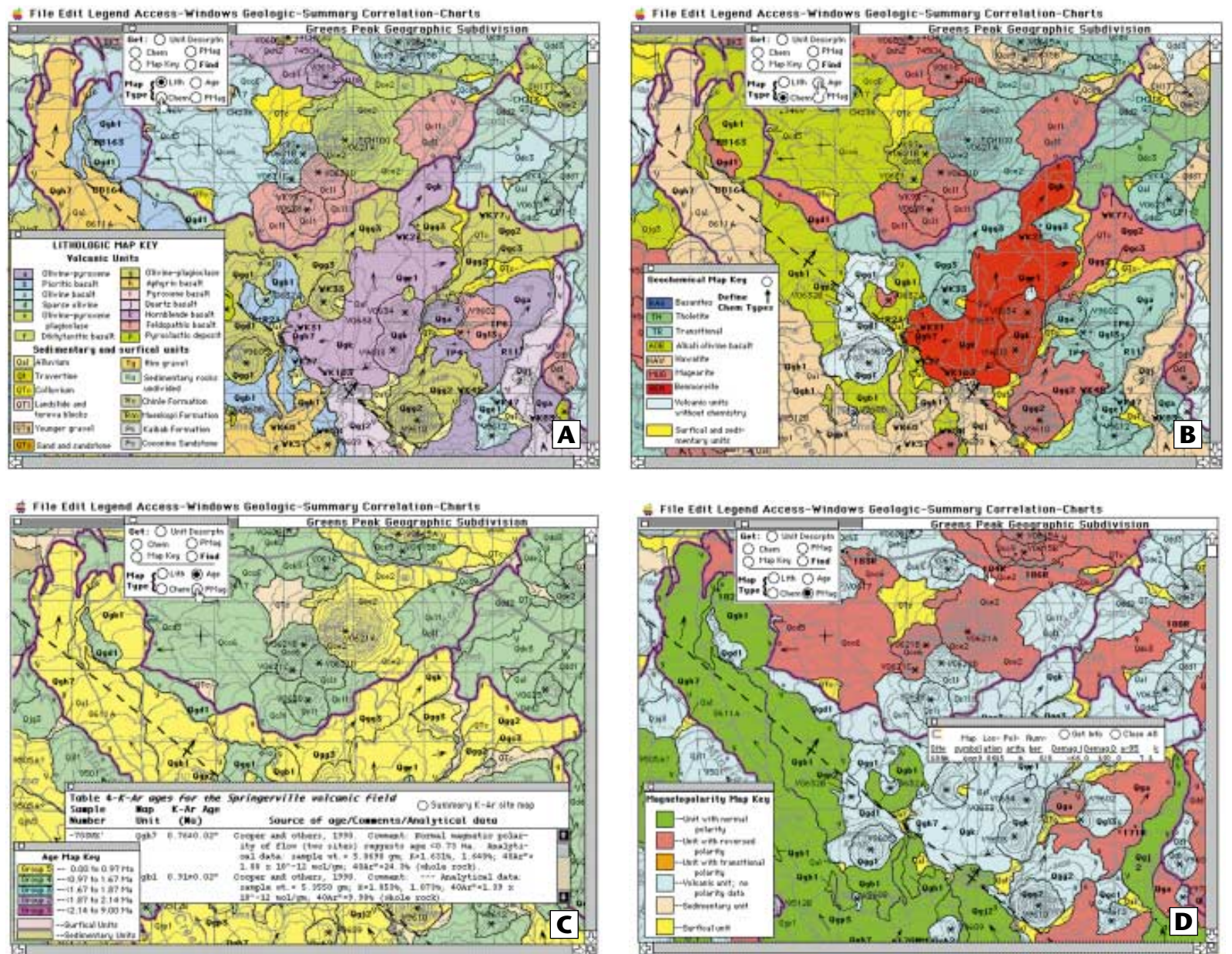
text (including associated figures and tables), unit descriptions, and more.

Map Window

The hypermedia programming built into the maps of the Map window simplifies finding samples (or units), makes information on a map feature instantly available, and allows sequential changes in thematic map type.

Finding Sample Locations and Map Units. There are two methods for locating a map label denoting a sample location or map unit (equivalent to search and find in a word processor program). Using the first method, the user clicks on a Find button displayed on a floating palette window, and types in the desired label (Fig. 2). The program then centers the map segment on that label; a circle surrounds the feature, and the label blinks. The second method for finding labels is provided from the Access-Windows menu, using the Show Access to Units/Samples All Areas selection. This activates a pop-up window with buttons that display a list of labels (sample lists include major-element chemistry, paleomagnetic data, and K-Ar data). A click on the desired label in this "click list" causes the program to locate the feature on the map. The order of samples on a list can be changed "on the fly" by clicking a Sort button to sort the list alphanumerically either by sample number or by associated map unit. Similar click lists are available for displaying less comprehensive data sets, such as isotope, trace-element, or mineral chemistry.

Displaying Unit Descriptions and Analytical Data. When a map segment is displayed, all map labels shown in bold print serve as buttons. Clicking on any of them extracts the associated data from a hidden data field and displays it in a small pop-up window. A click on a unit symbol immediately displays a description of that unit; likewise, a click on a sample label shows its major-element chemical analysis. These windows can be dragged around the screen to better see the map. This type of information can also be called to the screen by clicking on a Get button, superposed on the map in a floating palette window, and typing the wanted label into the resulting pop-up window. Additional links allow the display of major-element chemistry; clicking on the sample identification listed in the unit description's pop-up window (also a floating palette) or clicking on the Get Chem button in that same unit window displays all chemistry for a given unit.

Displaying Digital Photographs. Additional buttons on map segments provide access to digital photographs of geologic features of interest (Fig. 2). These buttons are small purple circles with the photo number and an arrow showing the direction of view (for example, 41 and 42 in Fig. 2), which can be displayed or hidden by a control

from the Access-Windows menu. A click on one of these buttons closes the map window and opens a Photograph window with the photo (Fig. 3). Photos include a caption and labels, which can be hidden to allow viewing of the photo without clutter. A button on the photos allows each to be saved to disk. Where several photos exist for a given feature (e.g., oblique aerial and ground-based photos), a button embedded in each photo calls up the associated photo (after closing the previous one), and buttons on that photo allow return to the original photo. A Digital Photograph Index Map, accompanied by a click list describing all photos, can be called up from the Geologic-Summary menu to provide alternative access to the photos. Photomicrographs of each lithologic classification (and four xenoliths) can be accessed through the click list associated with the Digital Photograph Index Map, from figures describing the lithologic types, or from any map segment where a round gray button similar to those for photos indicates a photomicrograph exists for a sample.

Changing Thematic Map Types. One of the most useful features of DDM-SVF is its ability to depict thematic attributes while viewing a map segment by simply clicking a button in a floating palette. The Springerville thematic maps consist of four types (Fig. 4): a lithologic map, wherein all 409 volcanic units are assigned (and color coded) to one of 13 lithologies, based on mineral type and abundance; a geochemical map, wherein units are assigned to one of nine geochemical classes; an age map, in which volcanic units are assigned to one of five age groups; and a magnetopolarity map, wherein volcanic units are assigned to one of three polarity groups. Appropriate thematic map keys can be displayed for each map type. When changing map type, an additional change takes place: samples appropriate to the new thematic map type are made visible, and samples that were relevant to the previous map type are hidden. For example, when changing from a lithologic or chemical map (where chemical sites are plotted) to a paleomagnetic map (where paleomagnetic sample sites are plotted), the chemical sites disappear, and the paleomagnetic sample sites appear.

Saving Data From DDM-SVF to ASCII Files

One of the most important facets of this program is that all data can be made accessible outside the program itself for further use. A wealth of data exists in this program, all of which can be saved to disk file: unit descriptions for 409 units; more than 600 major-element analyses; 215 X-ray fluorescence and direct current plasma trace-element analyses; 103 neutron activation analyses; 57 Sr, 21 Nd, and 33 Pb isotopic analyses; 41 K-Ar analyses; and data for more than 180 paleomagnetic sites. All chemical and

paleomagnetic data are saved in tab-delimited ASCII files, which can be directly imported into spread-sheet or word-processing programs for modeling and further use. All map segments and correlation charts for each segment can be saved as Pict format files, which can be opened by most CAD programs. Because these Pict files preserve all vector and raster file formats, and most CAD programs can convert them to DXF files, they also can be imported into geographic information systems (GIS) such as Arc/Info. In addition, all map segments can be printed in color; this capability has been tested with HP Deskwriter C and HP Paintjet XL300 printers.

DDM-SVF Overview— A Built-in Tutorial

Although care has been taken to lay out the program in a logical format, equal importance has been attached to familiarizing the user with the program. This encapsulated look at the program can be found in the DDM overview window, accessed through the Apple menu using the DDM overview selection. This overview gives step-by-step instructions to the user about how the eight different major window types are activated (Fig. 1 is the first page of this window) and delineates what is available in each. A click on any of the eight parts of this first page brings up an associated page with more detailed information on that topic.

PROGRAM VERSIONS

The CD-ROM contains three different versions of DDM-SVF, to meet different users' needs; all are stand-alone applications, needing no other software to run. The first is the full-blown 35 megabyte program; this includes all the features described above. The second version includes no digital photos; its size is 12 megabytes. The last version is a demonstration program of 7 megabytes size; it contains all features the other programs do, but includes only three of the 24 map segments (and their associated unit descriptions, chemical data, and correlation charts) and seven photos. The demo program can be archived and stored on three 1.4 megabyte diskettes.

CONCLUSIONS

Dynamic digital maps can include a far broader range of material than can hard-copy maps, thus enhancing their scientific usefulness. Because of the ease of access such hypermedia programs afford, a wide range of audiences can be reached in one package. For example, a hard-core petrologic modeler or Petrology 320 class may want to examine and extract the isotopic and trace-element data only and may have no interest whatever in the aerial photos. An interested nongeologist, beginning geology student or geomorphologist, on the other hand, might find the aerial photos very interesting. Each person can pick what to look at—with CD-ROM disk space, program size is no object (yet)—and programs can be structured to make wading through unwanted information avoidable.

Those interested in creating their own DDM should examine the digital map making section in the DDM-SVF program—the bottom line is that with a little knowledge of SuperCard, most people should be able to make such a program. An examination of the script in these programs should help; because SuperCard runs in an interpreted mode, all code and parts of any stand-alone program can be loaded into the SuperCard editor and examined, and the process can be stepped through

and modified. It is hoped that making maps of this type will be of special interest to graduate students who have produced high-quality, data-intensive, map-based research that they find difficult to distribute, and to workers in multidiscipline research projects who need to make their data available to their colleagues.

This type of program should not be viewed as a substitute for map-making systems, GIS, or hard-copy maps, each of which has its own valuable place in geologic research. The maps and data in this presentation-manager program can, however, be printed out on desktop printers, and all data can be saved from the program to tab-delimited ASCII format for other use. Future maps of this type offer a venue for workers who find it difficult to publish high-quality color maps and associated data quickly and efficiently. They also can be distributed electronically (for example by Internet), or on disk (either diskettes or CD-ROMs). Because of the digital format, one can include a large quantity of data with the map, something difficult to do with even the most complete analog maps. Further, because of the ability to save data from programs of this type into ASCII format files, these data need never be typed into digital form again, making the data easily accessible and accurately transferable to other workers.

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CD-ROM Map Available Soon

The CD-ROM map publication described here by Christopher D. Condit will be released soon by GSA, for use on Macintosh computers only. It describes the geology of the Springerville volcanic field, and includes 24 digital maps, 75 digital color photos, 23 correlation charts, and more than 1200 chemical and geophysical analyses, as well as text, figures, and tables. It also contains about 10 additional geologic HyperCard stacks on such subjects as tsunamis, earthquakes, fossils, and the Northridge earthquake, all by Tau Rho Alpha. The GSA product identification is DPM001M, *Dynamic Digital Map: The Springerville Volcanic Field,* Macintosh version. Prepublication list price is $24, and the GSA member discount applies. Contact Publication Sales, phone (800) 472-1988 or (303) 447-2020, extension 152. A Windows version may be available later, depending on the release of the Windows version of the SuperCard technology that Condit used.