Dynamic Digital Map of the Springerville Volcanic Field and the DDM-Template: An example of an open-source tool to distribute maps, data, articles, and multi-media materials

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ABSTRACT

Dynamic Digital Maps (DDMs) are computer programs that manage the display and distribution of high-quality color maps, digital images, movies, analytical data, and explanatory text, including field guides. They do this in a cross-platform format that opens associated files of maps, images, and movies either from a local device (e.g., a hard drive) or from a web source (server). DDMs are intuitive to use, can be easily and quickly searched for sample and image sites and analytical data, and require no additional software such as web browsers or readers to operate. DDMs fill a niche between the extremes in the digital mapping world that range from a simple digital copy of a paper map to the highly linked geographic information system (GIS) product. A DDM enables one to create an integrated study that confines its focus on a specific map, unlike other interfaces. They offer an ideal way to present, for example, premeeting or postmeeting field trips, so they can be pre-run or revisited, enriching the experience. All DDM maps and images can be saved to disk for printing, and data saved to tab-delimited files. DDMs are made using the open-source DDM-Template, written in the cross-platform programming environment Runtime Revolution, as assisted by videos, tutorials, and the DDM-Cookbook. The DDM of the Springerville volcanic field, the example used here to demonstrate these capabilities, was made from this template. The template is highly extensible, and ongoing modifications and updates are available, as are more than 20 other examples of DDMs.

INTRODUCTION

Intent

Geologic maps form one of the major foundations on which geology has been built, providing a framework within which samples are placed and observations and interpretations made. This short paper, and the more extensive computer program that forms the bulk of this report, introduces a version of these maps in the form of the Dynamic Digital Map (DDM) of the Springerville volcanic field. The intent is to illustrate the usefulness of DDMs, the niche they fill in the digital mapping world, and how they can be made, using the open-source DDM-Template program, and its associated tutorials. The future development and links to examples of DDMs conclude this report.

Digital geologic maps run the gamut from raster images and portable document format (pdf) file renditions of simple paper maps and web-browser displays of similar images, to full-blown often highly structured and linked geographic information system (GIS) products. Examples of the raster images have proliferated at websites: the Geological Survey of Canada's Geoscience Data Repository site alone has more than 10,000 map scans; examples of pdf format maps include Evans et al. (2009) and Graymer et al., (2006); see Smith (2009) for a description of the *Digital Geological Map of Great Britain* (British Geological Survey, 2008). The GIS products, while providing tremendous analytical capability, require expensive software and extensive training to be able to access and manipulate the wealth of data associated with them. DDMs fit between the two extremes and provide a flexible format in which to display a map, its explanation, and associated text, and embed with it links to a range of analytical data, images, movies, and animations. Two of the DDMs produced to date (DDM-DRWKnotweed and DDM-Marl) used as their basis maps and data that were parts of ArcGIS projects. They were created to provide the public access to those maps and supply selected links to their associated data in a simplified nonproprietary format. Comparisons to, and the place that DDMs fit between, other end-member types of digital geologic maps are included here as the DDM's characteristics are discussed.

Digital Map: What Form?

The digital age has brought with it the public's dependence on the web as a primary source of information. Geologic map makers and publishers today face the difficult problem of finding the most effective way to publish, archive, and distribute their products, while taking advantage of this new medium. Can we do this in a way that reaches across the divide between the general public and the specialized scientist? If so, what attributes are essential to this effort? One result of the digital revolution is that data that can and should be embedded into geologic maps has become much richer in content. Maps today transcend the simple geometric relationship between shapes and locations and now must integrate within their structure objects such as orientated images (and samples), movies, animations, and scientific visualizations. In addition, maps have become smarter, with built-in measurement tools and search-and-find routines [e.g., see the description of the *University of Wisconsin-Madison: Campus Map* (University of Wisconsin Madison Cartography Lab, 2009); Roth et al. (2009); and the slow but interactive web map application of part of the *Oregon Geologic Data Compilation* (Oregon Department of Geology and Mineral Industries,

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2009) described by Ferns et al. (2009)]. To be viable for use by the general public, maps now need to include embedded internal links to display analytical data and associated descriptive text, and external links to other web sources, to name a few essential attributes, unlike the often beautiful but essentially flat or traditional maps.

ATTRIBUTES OF A DIGITAL MAP

The attributes or characteristics of any interface designed to present these data require careful consideration. Some essential characteristics include that it must be compatible with a variety of computer operating systems (e.g., Windows XP to Windows 7, Mac OS X, Linux) so that it can be widely used. It should have the capability to operate without relying on a particular web browser (or version of one), which often change, making data inaccessible. The product should be able to access data from the Internet, and work equally well at opening files from local sources only (e.g., from CD, DVD, flash memory, hard drives) for when users do not have Internet access. The viewing, use, and access of the maps and content should require no proprietary software, which, for example, in the case of ESRI's ArcGIS, render the use its layers impossible on the Macintosh and Linux platforms, unless a product for ESRI GEO Viewer has been created. The map application should also provide access capability to a site of the mapmaker's choice, where they retain control of the content, and not a company that may change their base images (e.g., as does Google). A single product that displays these maps and their associated media should be designed to reach a range of audiences, from the interested citizen to the specialized scientist. This is especially important because most maps represent a large investment of time, and often of public money, and thus their outreach potential (and their citation index) should be maximized so that it is professionally worthwhile to an investigator to invest that time.

BACKGROUND AND REPORT FORMAT

The publication on CD of the DDM of the Springerville volcanic field (DDM-SVF) (Condit, 1995a) was an early step toward answering the challenges just described. The DDM-SVF (described in Condit, 1995b, 1999) was confined to the Macintosh operating system, and provided no web access, aside from being downloadable from a web page. Subsequent National Science Foundation funding resulted in the building of the more generalized DDM-Template. It is an open-source program designed for modification by anyone wanting to make their own dynamic digital map. The new DDM-SVF, adapted from this template, and introduced here, is an example of one of these maps. Examples of the capabilities of the DDM-SVF are detailed in the following. After that description, the reader is directed to the web page (Fig. 1) where the ~40 MB DDM-SVF application can be downloaded to a computer, started, and the 11 min automated "Guided Tour" taken (which requires a moderately fast Internet connection). In Appendix 1, the reader can choose to examine additional features of the DDM. The DDM meets all the above attributes for a digital map, and is greatly expanded in scope and capability relative to the 1995 DDM, as demonstrated here. A brief introduction to the DDM-Template follows (and see Appendix 2); it is a highly extensible program that can be used to make DDMs. Associated resources, including the DDM-Cookbook, tutorials, and videos, have been designed to facilitate this effort, and are also touched on briefly (e.g., see the example of the English-like scripting code in Appendix 3. For more comprehensive descriptions, see the web pages at the listed URLs.).

DDM: AN OVERVIEW AND ITS NICHE

Managing the process of displaying and distributing high quality color maps, digital images, movies, analytical data, and explanatory text

Welcome to the location with links to download the latest cross-platform, web enabled versions of the Dynamic Digital Map of the Springerville Volcanic Field (DDM-SVF). The Springerville is a late Pliocene to Holocene basaltic volcanic field located in east-central Arizona. It is dominated by over 400 cinder cones and associated lava flows. The DDM displays nine thematic geologic maps of the field, 234 images and QuickTime movies (many aerial and from NASA's World Wind satellite), over 480 major and trace element whole-rock chemical analyses, mineral chemistry for 31 units, paleomagnetic polarity data from >160 sites, ~ 40 K-Ar dates, and Sr, Nd and Pb istopic analyses, all linked to sample sites located on the maps and in some of the photos. The DDM also includes three articles, each with numerous hyperlinks to the maps and images. The first is an introduction to the geology of the field, and to the map and mapping conventions. The other two are field trip guides. The first of the guides is a modified version of the 1989 IAVCEI field trip which concentrates on the petrology of the field; it contains hyperlinks to icons of field trip stops, displayed on the lithlogic map. The second guide concentrates more on the volcanologic and tectonic features of the field.
A Guided Tour button on the lower right side of the *Home Screen* will give you an automated tour of the program, in the form of a nine-minute scripted playback, introducing you to the basics of how to use a DDM.
Go here to see what DDMs are and how you can make them.

These downloads are standalone programs that run without other software. The programs access their data [maps and images (in jpeg format), and movies] from my file server using the web, thus requiring fast internet connections. All DDMs can access data from CDs or Hard Drives, if the data is available in those locations. To see any included movies, both Windows and Mac based computers must have the latest QuickTime Player installed (free from Apple for both platforms, at www.apple.com). Computers with less than 512 MB of free RAM will run these programs very slowly at best. Downloads labeled ***"Opens using Web-Access with Automatic Start to Tour"*** can be reset to open without Autostart to Tour (see the ReadMe file in downloaded folder).

- **ddm-svf-2010-05-28.exe- A Windows version (Win98, 2000, XP, Vista, Windows 7) sent as a Zip archive**
  ddm-svf-win.zip (both this and the tour below ~18 MB compressed, ~37 MB uncompressed)
  ddm-svf-win-web-tour.zip (Opens using Web-Access with Automatic Start to Tour)
- **ddm-svf-2010-05-28.app - A Macintosh OSX Universal Application, sent as an Zip archive**
  ddm-svf-mac.zip (both this and the tour below ~20 MB compressed, ~41 MB uncompressed)
  ddm-svf-mac-web-tour.zip (Opens using Web-Access with Automatic Start to Tour)
- **ddm-svf-2010-05-28- A Linux version, sent as a zipped tar (tgz) file**
  ddm-svf-linux.tgz (both this and the tour below ~19 MB compressed, ~39 MB uncompressed)
  ddm-svf-linux-web-tour.tgz (Opens using Web-Access with Automatic Start to Tour)
- **ddm-svf-2006-07-27L- A Macintosh Classic OS9 version (FAT, will also work on 64K Macs), sent as an sea.hqx (self-extracting archive as binhex) file**
  ddm-svf-Mac-Classic (8.2 MB compressed, 23.2 MB uncompressed)
- **ddm-svf-2010-05-28.rev - The Revolution-Open-Source code sent as a zipped file**
  DDM-SVF-Cross-Platform (~16 MB as sent, ~49 MB when uncompressed)

Figure 1. A typical web page of a Dynamic Digital Map (DDM) (of the Springerville Volcanic Field). From this page (http://ddm.geo.umass.edu/ddm-svf) the viewer can download the DDM that is compatible with their operating system.

(i.e., map collar text and field guides), DDMs are computer programs that integrate multiple components into a map. Maps, cross sections, correlation charts, and photos, all saved as jpeg (Joint Photographic Expert Group) files, and movies are stored outside the program, which acts as an organizational framework, index, and link to present these data. Text documents and analytical data are stored within the program, and can be saved for use outside of the program as tab-delimited files (in the case of data). Once the above, and index-linking information, are combined into a single open source DDM-Template program, three cross-platform royalty-free applications are produced for all Macintosh, Windows, and Linux operating systems. Each application can access its associated images and maps either from the web, if there is access, or from local media if the data are stored there (e.g., on DVD, flash drive, or hard drive). The programs are intuitive to use, relying largely on point-and-click access and numerous hyperlinked map labels, texts, and lists. Sample sites, image numbers, and units can all be easily found on all maps and images by clicking on a menu Find button and entering the item's name, which produces a list of all the places it can be found. A click on a line in the list opens the map or image and centers itself on that object and surrounds it with a blinking red rectangle. All analytical data associated with a unit or sample can likewise be searched for. Keyword searches describing the content are possible on the numerous indexes that list the content of the DDM, and also provide clickable access to it. Unlike many other digital maps created with Adobe, ESRI, or Google, it requires no additional proprietary software to operate.

The DDM has some clear limitations and a specific niche. It enables one to integrate a specific study, focused around a given map, incorporating a variety of media and data. It does so in an open-source format that, because it can be modified, retains flexibility, unlike that required by many GIS schemata. While it links the viewing of analytical and map data in context, it is important to note that DDMs are not substitutes for GIS or database systems, which include many specialized functions and analytical capabilities that go beyond those of the DDM. Because the DDM's map bases, excluding their label symbols, are raster images, their scalability suffers relative to pdf maps or Google's tiled maps. The maximum scalability of jpeg map images in the DDM is ~4× resolution before running into pixelation. The trade off for this limit, when compared to the higher range found in pdf files, is balanced against the fact that jpeg images are almost universally accessible, whereas pdf files require a dedicated viewer. When compared to tiled Google maps (Whitmeyer et al., 2009), the DDM's map bases are much simpler to prepare. In Google, tiled images make very high-resolution displays possible. This makes it easy to exceed the accuracy of the mapping in cases where vector overlays of map unit polygons, contacts, or faults are draped over tiled images (Whitmeyer et al., 2010). While scrollable and scalable, maps in DDMs clearly lack the freedom of three-dimensional (3-D) movement that gives the users of Google and National Aeronautics and Space Administration (NASA) World Wind (http://worldwind.arc.nasa.gov/download.html) the capability to see an area from different perspectives. Carefully focused QuickTime fly-around movies (both real, as flown by me, and cyber generated) from various perspectives are included in many of the DDMs (available at http://ddm.geo.umass.edu/). When compared to a traditional database, analytical data are simpler to handle in a DDM, because they are inserted into the DDM from a simple tab or comma delimited file. The data of the file chosen for input rely on code in the DDM-Template for formatting. Once in the DDM, the data then use the program's built-in code to be displayed or found in searches. A limitation is that DDMs lack the federated (multiple) database accessibility and more sophisticated searches that, for example, the highly useful GeoMapApp (http://www.geomapapp.org/) has, along with its capabilities as a data exploration and visualization tool; however, the GeoMapApp does not include a dedicated geologic map interface, as does the DDM.

DDM-SVF—BRIEF DESCRIPTION OF CONTENTS

The basic maps of the DDM-SVF were derived from those found in U.S. Geological Survey (USGS) Miscellaneous Investigations Maps I-1993 (Condit, 1991) and I-12431 (Condit et al., 1999). The Springerville volcanic field is a late Pliocene to Holocene basaltic volcanic field located in east-central Arizona, USA. The field is dominated by more than 400 cinder cones and associated lava flows, and is on the southern margin of the Colorado Plateau. The DDM displays nine thematic geologic maps of the field, 212 images and 28 QuickTime movies (many aerial, and two from NASA World Wind), descriptions for each of the ~450 units, >480 major and trace element whole-rock chemical analyses, mineral chemistry for 31 units, paleomagnetic polarity data from >160 sites, 40 K-Ar dates, and Sr, Nd, and Pb isotopic analyses, all linked to sample sites located on the maps and in many of the photos. The DDM also includes three articles, each with numerous hyperlinks to the maps and images. The first is an introduction to the geology of the field and to the map and mapping conventions, and is largely derived from the 1999 USGS map. The other two are field trip guides. The first guide is a modified version of the 1989 IAVCEI (International Association of Volcanology and Chemistry of the Earth's Interior) field trip (Condit et al., 1989), and concentrates on the petrology of the field; it contains hyperlinks to icons of field trip stops, displayed on the lithologic map. The second guide concentrates more on the volcanologic and tectonic features of the field (Crumpler et al., 1994). The potential of interactive scientific visualizations is demonstrated by an animated sequence showing the waxing and waning areas of volcanism in the field (from Condit and Connor, 1996), and another visualization in which one can watch the patterns and control the rates of the appearance of sequential eruptions of vents in the field.

A LOOK AT DDM-SVF

The start-up page of the DDM (Fig. 2) gives the user the option to access associated media (the DDM maps, image, and movies) using Local Access data sources (e.g., CD, DVD, or a hard drive) or remote WEB Access sources. The link to Program Status Notes opens a page with text that may be aimed at the programmer or the user, giving plans for ongoing improvements or additions to the DDM program. After the user chooses the data source (web or local disk), the program opens the DDM's Home Screen.

The Home Screen page features an index map that provides links to open detailed maps (Fig. 3) from graphic illustrations outlining the areas of these map segments. Because the maps that a DDM displays are jpeg images, and the size limit for these raster files is 4000 × 4000 pixels, any map larger than those dimensions must be divided into smaller segments. For maps such as these, that have the option to display each of these areas as one of nine different thematic types, selection buttons across the bottom of the screen give that choice (a more generic DDM may include, e.g., a topographic map and an orthophoto map). On the left, beneath the Quit button, a series of buttons open indexes that contain lists of the DDM's content. These index categories include (Fig. 4) images (photos and movies), articles (e.g., map collar text, guide articles), maps, correlation charts, cross sections (not shown for the SVF map), and available analytical data.

Index lists contain hyperlinked text lines, each linking to the data described. These lists can be sorted by index number (leftmost column), or by various column headings (Fig. 4).

Figure 2. Start-up page of the Dynamic Digital Map (DDM) of the Springerville Volcanic Field. In addition to giving the user a choice of accessing the program's data from local or remote sources via the Local Access and WEB Access buttons, the page displays acknowledgments and gives access to the web page where program updates are stored, and to notes describing recent changes made to the program.

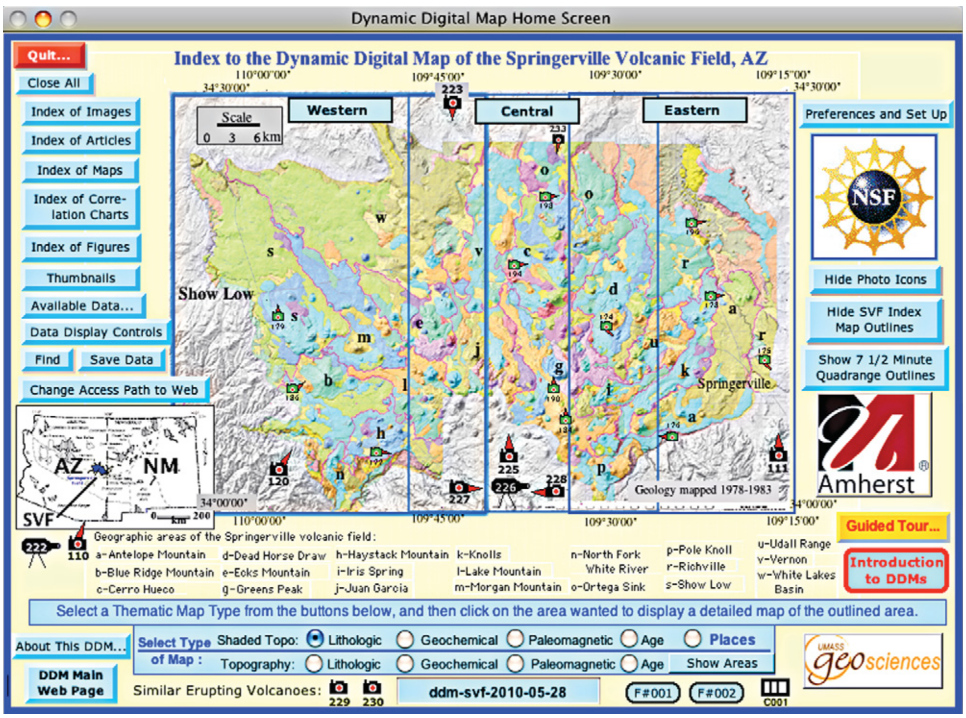

Figure 3. Home Screen of the Dynamic Digital Map (DDM). Access to all components of the DDM (maps, images, articles, correlation charts, and analytical data) can be opened from buttons on this page. Across the bottom, radio buttons allow the selection of thematic map type. A click on the index map opens the detailed map segment, and centers that segment on the location clicked on.

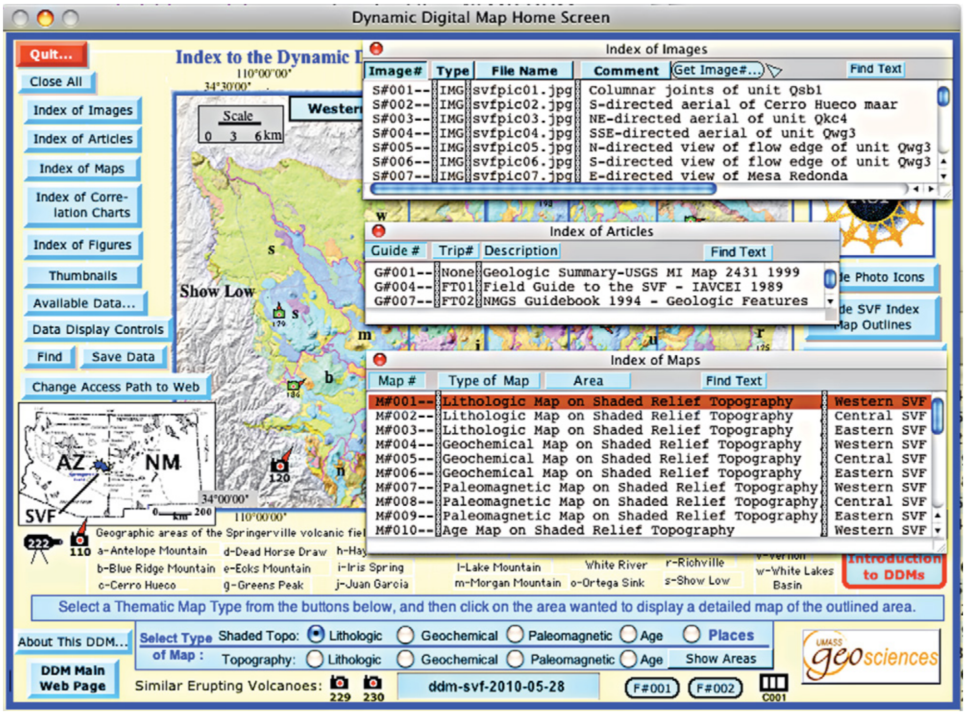

Figure 4. Examples of three types of index lists in the DDM-SVF (Dynamic Digital Map–Springerville Volcanic Field). All lists can be sorted by column by clicking on the column headings. For example, in the Index of Images, column sorts include (from left to right) by Image number (#) by Type (Image, QuickTime movie, QT panoramic movie), by File Name, and alphanumerically by first word in the Comment column. A click on a line in these index lists opens the image, article, or map described by that line of text.

Lists can also be searched by keywords found in the Comment field.

All DDMs have menu selections across the top of the screen, most of which, in the Controls-Access menu list (Fig. 5), mimic the functions of the buttons found on the Home Screen. One notable addition is the first menu selection, which allows the user to Return to Index Map and Close All Windows. The first two map menu items (Map Explanation and Map Features Access) open palettes explaining map unit symbols and colors for a given thematic map, and provide access to features associated with the open map segment (top center and left, respectively, of Fig. 6). In the top right portion of the map view window (Fig. 6), a map explanation for symbols common to all thematic maps is displayed.

On an open map, all map unit symbols and sample site labels shown in bold font can be selected with a mouse click to open a new window (a floating palette) showing information pertaining to that label (the label is stored in the program as a named text vector object, see following). In Figure 6, a lithologic thematic map of the eastern part of the Springerville field, two labels for lava flow units Qkc6 (near the lower center of the map) and Qae2 (near the center right of the map) have been clicked on, to display floating palettes containing unit descriptions (top left of Fig. 6). Sample site labels on these units have also been clicked to display the major element chemistry associated with each site. Additional sample data can be displayed by clicking on the sample identification found in the unit description palette, or by clicking one of the buttons across the top of that palette (as can additional unit description palettes, with similar clicks on map unit symbols).

Figure 7 shows the same area as Figure 6, but instead displays a different thematic map, the paleomagnetic polarity of the lava lows. Sample sites associated with paleomagnetic data replace those associated primarily with chemical and petrologic information on this map, and several sites have been clicked on to display their associated data. In the lower right side of the maps in Figures 6 and 7, note the latitude and longitude read-out in the Map Window Control Palette, which gives the cursor location. Measurements for straight and curved line distances and areas, along with the cursor location, can be made using the Tools button and its associated palette (left side of Fig. 7). The Measurement Collection Palette (upper right) records the data for map measurements, and can be saved as a text file. The drawings of these measurements (M#1 just above the palette showing magnetic polarity data, and M#2 just below the left side of the Measurement Collection Palette) can also be saved as an image, along with the underlying map, using the Save Map button on the right side of the Map Window Control Palette or the File-Save Map menu (Fig. 5).

Camera icons are placed at the location of photos, and where appropriate their arrows denote the direction the camera was aimed. When the user holds the cursor over a camera icon (see the camera icon 089; Fig. 7, right center, above and left of the rollover text "Click to open"), the keywords describing that image, found in the Comments column of the Index of Images palette are shown as a Tool Tip in the rollover. Movie icons (see black icon 136 near the map's center) likewise display keywords, as do field trip stop icons (the green rectangle numbered 1 east of the paleomagnetic data being displayed).

A click on field trip icon 1 (Fig. 7, center) opens a floating palette containing an associated article, in this case a field trip guide (Fig. 8). The program centers the text at the point in the guide

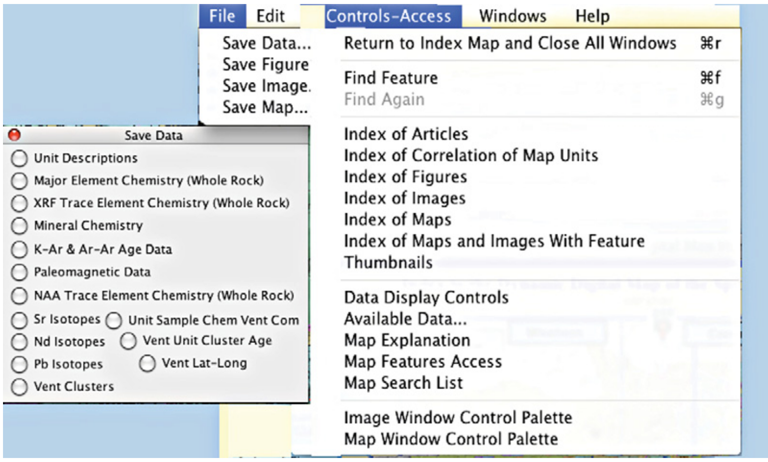

Figure 5. Examples of some of the menu selections available in the DDM-SVF (Dynamic Digital Map–Springerville Volcanic Field). The File menu (left) allows one to save open maps or images to file for printing. Using the File-Save Data menu selection opens the pop-up window that contains options one can use to save data externally as tab or comma delimited text files. On the Controls-Access menu (right) the first four Index menus provide linked Tables of Contents for the DDM. The Index of Maps and Images With Feature menu selection will dynamically search for and compile a list of all maps and images (including the image's captions) that contain the asked-for words. It is opened, as seen on the top left. More than 480 samples of whole-rock major and trace element data are included in this DDM, along with mineral chemistry for 31 units, magnetopolarity for 160 sites, K-Ar data for 40 sites, and Sr, Nd, and Pb isotopic data for 35, 22, and 20 sites, respectively.

that describes that stop. A click on the hyperlinked text in the guide (in bold font and underlined, S#078) would open another digital photo. An "alt-click" on that same text would scroll the map and center it on the camera icon; alternatively, an "alt-click" on the line containing the image number in the Index of Images palette does the same. A click on the turquoise image numbers in the upper left side of an open image locates the camera icon on the map. Additional clicks on other camera icons on the map or other images will open up to nine images; a click on the movie icon 092 in image 089 will open a QuickTime panorama of the lava flow top. Any one of these images or movies may have a figure caption associated with it, displayed by selecting the Caption button on the Image Windows Control Palette (bottom, Fig. 8).

Three different versions of text for each article or image and/or movie caption may be included in the DDM, useful if one wants to explain these at differing levels of sophistication (or in one of three languages). In this way a single DDM can reach audiences ranging from the research scientist to the interested layman or secondary school student, thus maximizing its outreach potential. Changes to the User Level settings can be made in the Preferences and Set Up palette (not shown), along with changes to various other settings (e.g., thematic map type, Tool Tip displays, desk top visibility, and which ancillary palettes to automatically open when a map segment is displayed).

DDMs have the capability to search all the analytical data sets included in them for a sample's (or site's) data or to determine if a geologic unit has been analyzed for a given data type (e.g., are there any trace element data for unit Qab?). The search will either highlight the found sample in a list of each type of data, or both highlight and display the data (Fig. 9). Selecting the Controls-Access and/or Available Data menu (or the Available Data button on the Home Screen) opens a dialog (Fig. 9) that gives the user a choice of search options; a subsequent dialog box provides the user a place to enter the sample, site, or unit for which information is needed. The result (top right, Fig. 9) is a series of lists of all samples for each type of analytical data. In this case the user asked the program to search for sample 717MR. In 7 of the 11 lists, sample 717MR was found, and is highlighted in the second (Chem) and third (Traces) lists but not in the fourth (Min Chem) list. In lists containing the selected sample the background color of the title for that data type changed to green. In those lists where sample 717MR is not found, the background title for that data type is orange. If that sample is found, it is highlighted in the list; clicking on the sample's entry displays the data, whereas an "alt-click" locates the sample on the map.

Searches for the location of objects on maps and images (e.g., samples or map units), initiated from sample lists as described above, or by using the menu selection Control-Access and/or Find Feature recenters the map on the found feature. A red box surrounds the feature and flashes several times. When the feature is not found on the open map, the user is asked if they want to look for it on other maps or images. If so, the DDM searches all maps, images, and image captions, and presents the user with a palette (Fig. 9, lower right) containing two click lists. The upper list displays all maps with that sample; the lower list displays all images (and image captions) containing that sample. A click on the list opens the map or image in the line clicked on, and as above, finds the object.

A Map Search List can be opened from a menu item, or a button in the Map Features Palette (Fig. 8). This function compiles a list of all objects on the open map segment (e.g., unit symbols, sample site designators, cultural feature names, image site icons by image number, and field trip stop icons). Clicking on a line in the Map Search List locates the object on the map, as described above.

Downloading the DDM-SVF and Running the Automated Tour

Folders containing the ~40 MB stand-alone applications of the DDM-SVF can be downloaded from the web page (Fig. 1) at the URL: http://ddm.geo.umass.edu/ddm-svf/index.html. With the exception of the 2002 version for the Mac Classic OS, each of the applications listed access >1 GB of data from a file server at the University of Massachusetts Amherst (movies make up about half of this). The compressed downloads are each <20 MB. The first pair of links will download a DDM-SVF program that works for all versions of Windows computers, the next pair for all Macintosh OSX computers, and a third pair, DDMs for Linux operating systems. The second of each of these three pairs of links (ending in "-web-tour.zip" or "-web-tour .tgz") gives the user the option to download a folder that, in addition to the DDM, contains a "ddm-svf-Settings.txt" file. This settings file will cause the DDM application to immediately start an 11 min automated Guided Tour of the DDM-SVF (note: to pause the tour at any time, hold down the shift key). After the first three steps, the tour can be stopped by moving

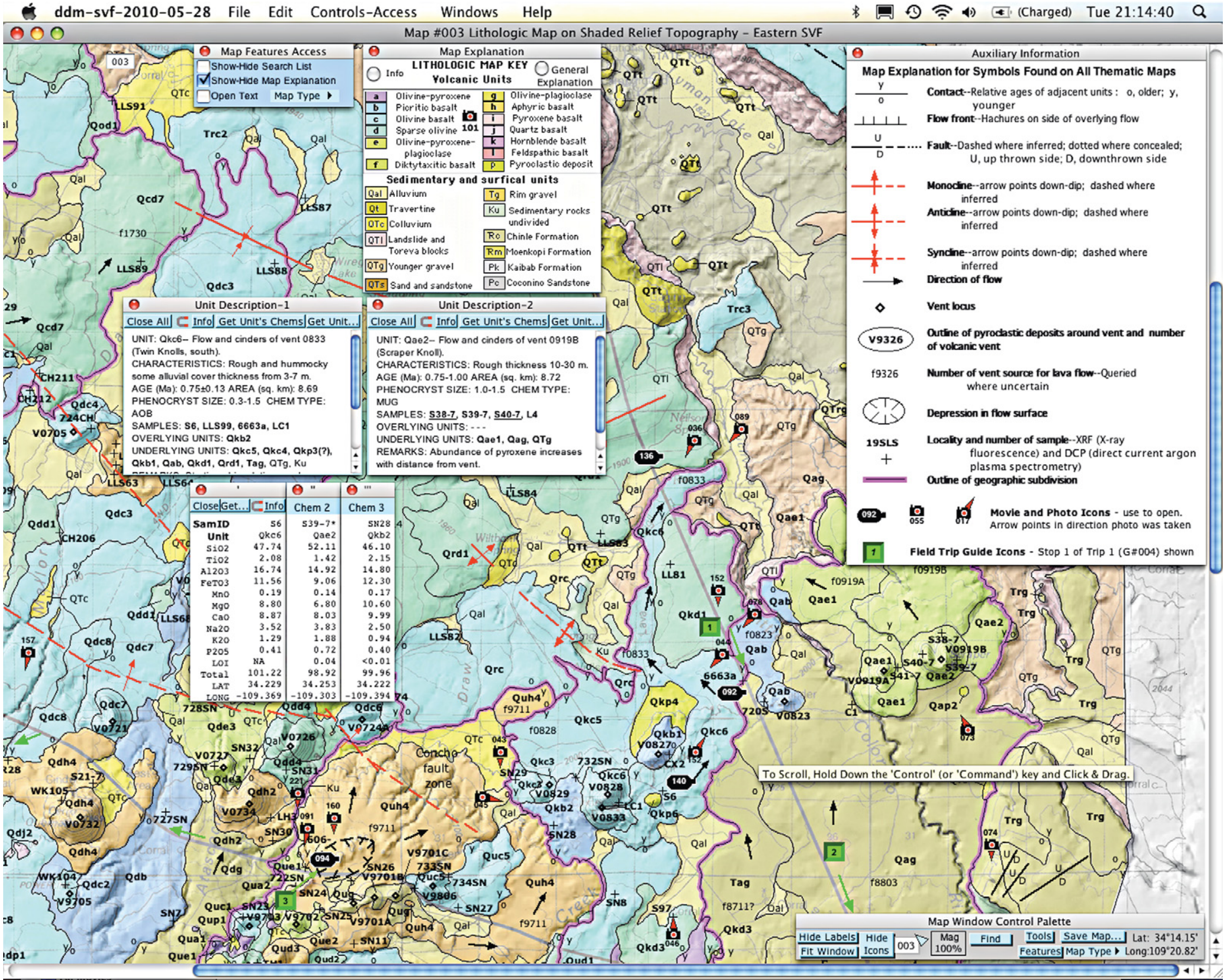

Figure 6. The easternmost of three map segments of the DDM-SVF (Dynamic Digital Map–Springerville Volcanic Field), displaying one of nine thematic types; here the map units reflect the lithologic variations (see map key in upper center) of the lava flows. Compiled on a 1:100,000 scale topographic map base, the geologic map is draped over shaded relief. Several of the bold symbols on the map have been selected by mouse click, causing the data associated with them to be displayed (here we see map unit descriptions and lava flow chemistry). Map scrolling is via scroll wheels on mice, by the window's scroll bars, or by using a click and drag with the control (or command) key depressed (see the popup Tool Tip, near bottom center of map).

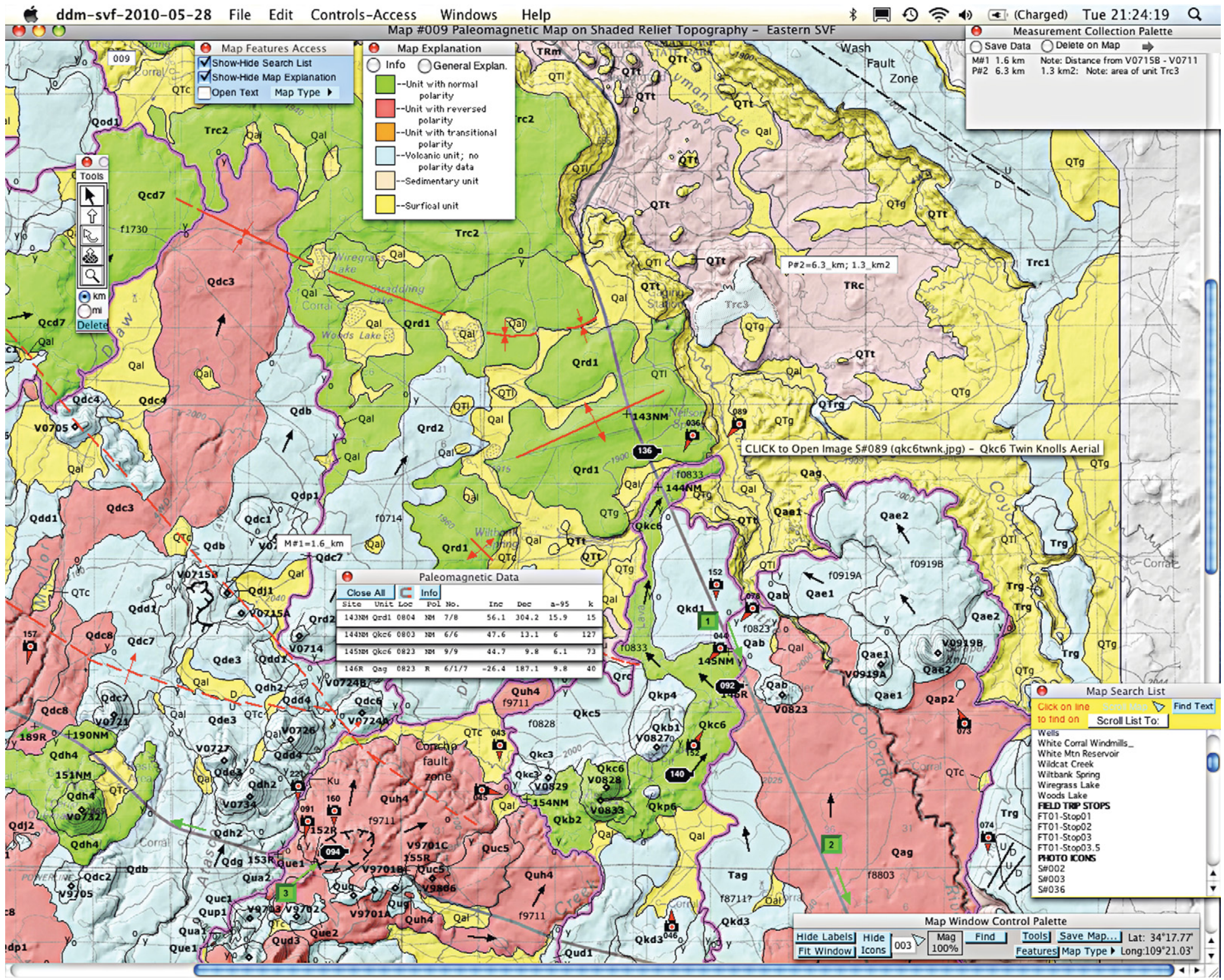

Figure 7. A paleomagnetic thematic map of the same area shown in Figure 6. The sample site symbols selected by a mouse click display the data associated with this new thematic map type, and the units are colored to highlight the magnetic polarity of the lava flows. Note the latitude-longitude read out of the cursor location (the cursor was not captured in this screen-grab image of the map), and the Map Search List palette (lower right).

Figure 8. Example of the hyperlink-accessed image and Field Guide. This image was opened by clicking on camera icon 089 of the lithologic map. When the icon on a map that denotes a field trip location or stop (e.g., the green 1 on this map) is selected with a mouse click, the description of the field trip stop, as reported in the guidebook article, is displayed. The image window takes its title from the keywords associated with the image number in the Index of Images palette. Keywords also are displayed in the Tool Tip for movie image 044, as shown in the center of the figure. Note this window has been scaled to 67% resolution; to show at full resolution the user clicks the yellow button Scale 1:1 in the lower left of the Image Windows Control Palette (see lower left).

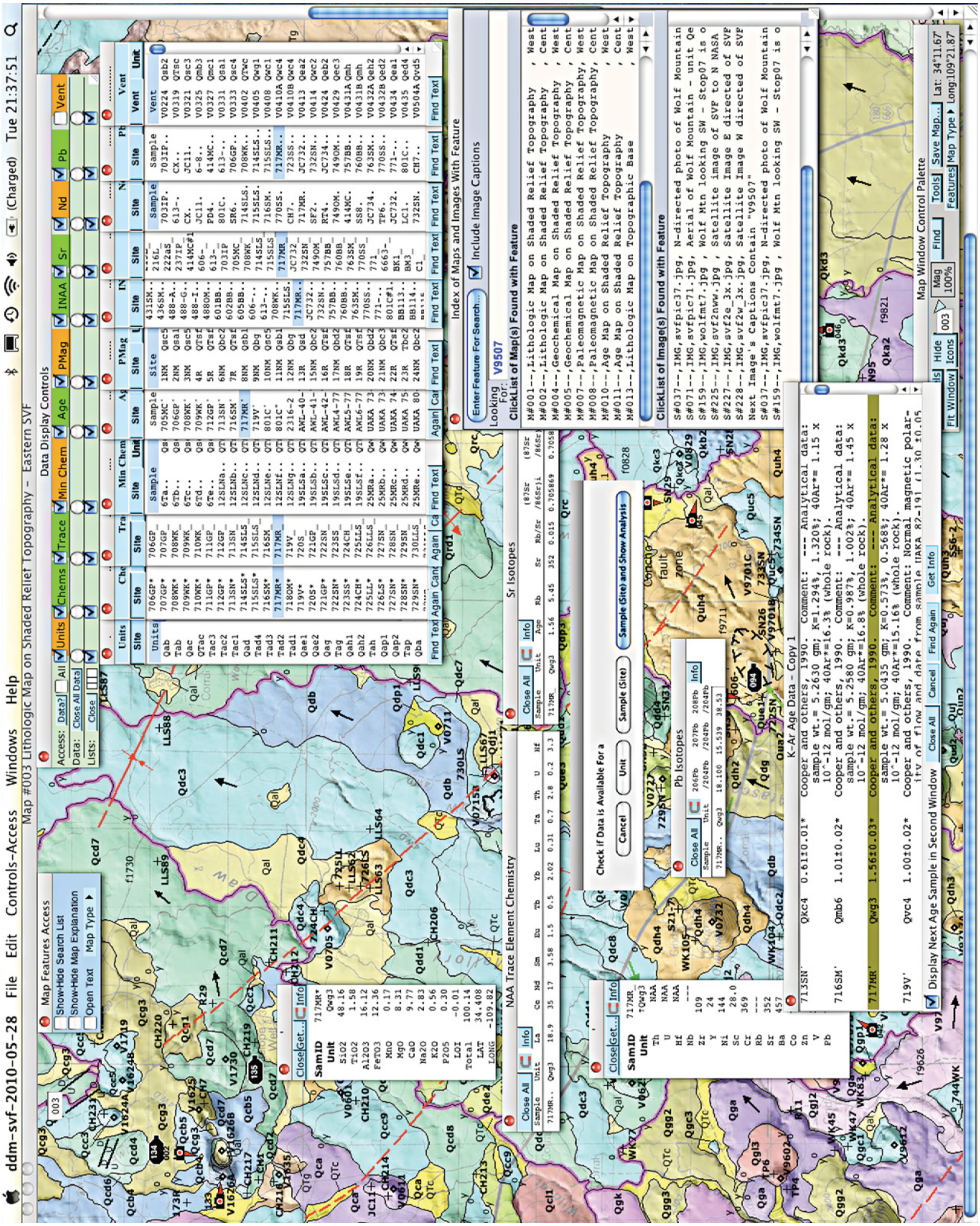

Figure 9. Screen showing the result of searching for analytical data using the DDM-SVF (Dynamic Digital Map–Springerville Volcanic Field). Here, the Available Data search shows any occurrences of a sample (here sample 717MR) in all data sets, and displays those data. In the lower right part of the map window, a palette displays the result of searching for a feature (volcanic vent V9507) that was not found on the displayed map. All maps, images, and captions are searched for the occurrence of the feature, and a list of where it was found (maps, top part of palette; images, bottom part of palette) is presented to the user. A click on a line will display the map or image named in the line, and cause a red rectangle to flash around the feature. It will also center the map or image, if either are larger than the window (and thus contain scroll bars).

the mouse and clicking on the resulting dialog box's Cancel button. At the tour's end the user is shown how use a button in Preferences and Set Up palette to change the "ddm-svf- Settings.txt" file in order to stop the tour from starting automatically when the DDM is opened. Alternatively, one can simply delete the "ddm-svf-Settings.txt" file. To explore additional features of the DDM-SVF, see Appendix 1.

DYNAMIC DIGITAL MAP TEMPLATE

Introduction

An open source program, the DDM-Template into which one can insert their data, and accompanying DDM-Cookbook on how to do this are available at http://ddm.geo.umass.edu/ddm-template. Making a DDM from the template requires the use of the relatively inexpensive, multiplatform programming environment Runtime Revolution (see http://www.runrev.com for the free basic version of the program; the cost is US$350 with an educational discount, and there is an optional free fully functional 30 day trial version). Loosely defined, Runtime Revolution is a high-level object-orientated program with a low learning curve that is designed for rapid application development. Within ~8 h of watching short videos and working through three tutorials (one specifically aimed at making an example DDM) you can begin making your own DDM from the template, if you have maps, images, and text all ready.

Example of Modifying the Template

Because the DDM-Template is created in Runtime Revolution, which is a cross-platform programming environment, map authors, editors, or compilers can work with it on the platform of their preference. The template is best thought of as a shell that is modified by DDM makers, who replace template place holders with their own DDM data. The major structural component of any Runtime Revolution program is the familiar window, each of which can contain any number of pages or cards, on which objects such as text, buttons, images, and graphics are placed. Making a DDM involves modifying these objects, following instructions in the DDM-Cookbook, a 66 page pdf file (http://ddm.geo.umass.edu/DDMCookbook.pdf) that contains numerous screen grabs showing this process.

For example, images are opened by the DDM when a user clicks on a line in the list in the Index of Images palette, as illustrated in the Guided Tour described above. To adapt the template to open their own images, the DDM maker replaces the template's file names with their own names in this list, and make sure the correspondingly named jpeg images are placed in the DDM's folder named "imagprod." The script or code associated with this list in the Index of Images palette automatically finds the corresponding image, stored in that folder, when the line with that file name is clicked on. The DDM then opens an Image window and fills it with the jpeg file. To make the template do this, the DDM maker never needs to get involved at the scripting level, but simply supplies the file names. For more information on modifying the DDM and on image and map overlay groups, see Appendix 2.

Adding Text and Including Text Aimed at Different User Levels

Text files, for example, field trip guides, can be inserted from formatted html files into windows designed for them (e.g., see the Field Guide in Fig. 8). Alternatively, one can simply copy the text from a word processor document and paste it into the wanted Article window's text field. Once inserted, links from text to the DDM's maps, images, figures, or external web sites can be made automatically, by clicking a button in the template's Project Modifier palette, described in the next section (e.g., if any of the following text is included in a document, it will be grouped and set to trigger a link so the program can respond the them appropriately: <u>M#001</u>, <u>S#002</u>, <u>F#003</u>; http://ddm.geo.umass.edu or http://www.geo.umass.edu).

Three different versions of text for each article or image caption may be included in the DDM; this is useful if one wants to explain these at differing levels of sophistication (or in one of three languages). Ideally the DDM maker can use this to reach an audience from, e.g., the junior high school Earth science class (Level 1) to the research colleague (Level 3). Along these lines, the DDM-SVF, in addition to being aimed at professional colleagues by containing all and much more than the content of the USGS map publications, was used as a teaching resource in a junior level petrology class (Boundy and Condit, 2004). It provides a basis for choosing parent-daughter lava flows for geochemical modeling of mass-balance calculations. The DDM provides field criteria (starting with unit descriptions, lithology, age, physical proximity, and an examination of major element chemistry of candidate sample sites) while looking at their field relations on the map.

Developmental Components in the Template

The DDM-Template includes developmental components, used by the DDM creator, that the end user map viewer doesn't see when the DDM is turned into a stand-alone application. A major component of this is a floating palette window known as the Project Modifier. The modifier is organized into four tabs, each of which consists of numerous buttons that facilitate editing and adds to the major components of the DDM. The first Open Windows tab contains buttons that speed up the maker's opening of various windows on which they will place graphics or modify text. The second Editing Text tab facilitates the editing and formatting of text data, including, for example, index lists, guidebook articles, and image and figure captions. The third Modify Overlays tab operates to help modify map, image, figure, correlation chart, and cross-section overlays. The last, the Scale-Lat-Long tab, gives the DDM maker help in registering each map's latitude and longitude, and in setting map scales, so the DDM's measurement tools can be used. Collectively, these tabs allow the creator to make and insert camera icons into the overlay files of maps and images, along with unit labels, sample sites, and graphics, and facilitates adding and editing text, and adding and formatting analytical data, among many capabilities.

Making Stand-Alone Applications and Their Distribution

When modifications to the template are complete, and the program renamed to reflect its new content, the map creator instructs Runtime Revolution to, in a single step, make three royalty-free stand-alone programs (DDMs), one for all Windows, another for all Macintosh OS X, and a third for all Linux operating systems. These DDMs can then be compressed and saved in folders with ReadMe files, as zip, dmg (disk image), or tar files, and made available for download from a web page (e.g., see Fig. 1 or the URL http://ddm.geo.umass.edu/ddm-svf). This manner of distribution requires the computer be linked to a fast web connection, so that associated files can be accessed from that web site, as asked for by the DDM. Alternatively, the DDMs can be distributed on CD, DVD, or flash-memory drives, so that the DDM may be used using local access where there is no web connection, for example in the field. The program executes at optimal speed when using local access, because any delays associated with downloading maps and images over the web are minimal. Users with gigabit Internet speed connections will run a DDM at speeds similar to those using local access. The program, whether accessing data locally or from the Internet, is identical in size, and loads data into its structure in either case from files found outside the program, much as do programs like Photoshop or Word.

EXTENSIBILITY AND THE FUTURE

Although a typical DDM maker will probably not get involved at this level, the DDM-Template is highly extensible both because of the programming environment and because it is an open source program. If a functionality is not included in Runtime Revolution, an external, written in a lower level language (e.g., C++), can be placed in Runtime Revolution's library to add this capability. Modifying the program for a specific DDM or adding capabilities is fairly straightforward. This is in part because Runtime Revolution's debugger allows one to follow the programming progress of any script, line by line (see Appendix 3), and watch the values change, and see any actions taken by the DDM as a result. The script is written in an English-like programming language, and script tends to be parsed or broken down into small groups called "handlers," each containing a limited number of lines of code. For an example of the script associated with the Home Screen button named ShowHidePhotoIcons, see Appendix 3. Further, in the present version of the template, programming and the DDM structure have been kept simple to facilitate its adaptation and modification by other geologists. In keeping with this simplicity philosophy, all analytical data are stored in Runtime Revolution text fields, and are copied from them and pasted into the appropriate pop-up display palettes when links in the program request this. Although no attempt has been made to add database accessibility to DDMs, a large group of Runtime Revolution's programming community relies on it for that purpose, and Runtime Revolution includes a built in Database Library. In addition, each of the DDM overlays for a map or image is a simple group of Runtime Revolution objects (e.g., composed of a combination of Runtime Revolution text fields, images, or vector graphic objects). It should be a straightforward but large task to write the code to add the import of KML (keyhole markup language) files to map overlays, or the export map images and overlays using as a starting point the basics described by Walsh (2009). When a map is being viewed, it can be saved to disk as a jpeg image file (see Fig. 5), either with or without its label overlays. That map file, with its associated geo-referenced coordinates, could certainly be imported into Google maps in a procedure independent of the DDM, as described by Walsh (2009), and thus be viewed in their 3-D interactive interface. Additional capability could be added by writing code to use a USB global positioning system interface so that the cursor tracks a computer's location, when maps are displayed in the field.

As capability is added to DDMs, and the inevitable bugs that creep into the many thousands of lines of program code are squashed, I have created a "ddmUpdater" program, which allows DDM makers to add these to their DDM with a simple mouse click, while not changing the DDM's content. This updater, along with more than 20 DDMs, that range from Andean arc and ocean island basalt volcanoes to the geology of western New England (with 6 field trips), and Japanese Knotweed infestations in New England to watershed habitats in Maine to the family history of a Berkshire Mountain apple farm, among many, can be found at http://ddm.geo.umass.edu.

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APPENDIX 1. EXPLORING ADDITIONAL FEATURES OF THE DDM-SVF

This appendix assumes the reader has completed the tour, and uses the knowledge thus gained to use a DDM, and discusses some of the features in the DDM-SVF not covered in the tour.

The ability to include dense links between content can be seen immediately when examining the Map Explanation palette, which is opened automatically when a lithologic thematic map is displayed, if the default "ddm-svf-Settings" file is used. Open the Lithologic Map of the western part of the field, and use the button in the Map Features Access palette to open the Map Explanation if it isn't already open. A click on the camera icon labeled 101 in the Explanation opens a chart showing the Lithologic Definitions for the lava flows in the field. Associated with each definition are two camera icons. A click on the left-most icon opens a photomicrograph of a rock that typifies lavas of this lithologic class; a click on the right icon opens a hand specimen of it. Including numerous links enriches the value of the initial chart, and as long as they are carefully used, they enhance rather than detract from its main message. Unlike books, which provide linear access, pages of material in which one isn't interested can be ignored: simply don't click on the icon.

Links can also provide a feel for the range of outcrop expression that qualified the mapping of this field, from the subtle to the obvious. Use the Find Feature item of the Controls-Access menu, and type S#224 into the dialog box, and press OK; if the camera icon can't be found on the open map, the DDM will open a list of all maps and images containing this camera icon. A click on the top line of the list opens that map segment, and centers it on the icon, which shows the direction the image was taken. A click on that image icon (224) shows what a subtle flow contact between two of the units looks like. Embedded in image S#224 are camera icons that show what outcrop hand specimens look like at those locations, as explained in the image captions. Two other links in image S#224 put the location of these images in the context of a 1:24,000 scale topographic map (image S#079) with no contacts shown, as if one were starting the mapping process, and in the framework of the completed 1:100,000 scale lithologic map (S#080). Other icons open oblique air photos of the area, providing more context. Shown also on image S#080 (the lithologic map) is the location of an obvious flow contact along this same flow edge, where Arizona Highway 260 displays a cross section of the flow edge. A QuickTime panoramic movie of this relationship can be seen in image S#077. It pans both to the road cut and beyond it, to a natural part of the contact (alternatively, open S#176 for those without QuickTime player). Contrast these flow edges (contacts) of these units with those seen in images S#089 and S#153 and their associated links.

One can gain a much better appreciation for the field by taking advantage of the rich audiovisual possibilities of digital maps, when those resources and links are included in the map. Scroll the map ~8 km north from the road cut of movie S#077, to the movie icon S#132. A click on this will open a 32 MB QuickTime movie that flies ~6.4 km down Carnero Creek from that icon, to vent V9818. Examples of basalt stratigraphy can be seen along the way, where the creek has eroded through at least three flows and into the base of the cinder cone of vent V9818.

APPENDIX 2. MORE ON MODIFYING THE DDM AND ON OVERLAY GROUPS

DDMs contain similar windows for displaying different components of a map, including Maps, Figures, Correlation of Map Units, and Cross Sections, which are accessed using parallel procedures. Maps, for example, are added to the template in a manner similar to images (described previously in Example of Modifying the Template discussion). This is done by including file names and the respective folder name for each as a separate line in a map file name list, which the program then formats into an Index of Maps list. When a line in the Index of Maps is clicked on, the program opens the Map window and fills it with the corresponding jpeg file (e.g., it might open the map file "ne.jpg" that is stored in folder named "mapprod1"). Associated with each of these jpeg images are coregistered overlays or layers containing graphic objects and text such as unit symbols, sample sites (both text fields in Runtime Revolution), or camera icons. The DDM maker can add these to a map or image's overlay while viewing them with the underlying image, and save the edited overlay back into the DDM. The program script may use these overlay objects, for example, to open an image, when a camera icon is clicked on, or to open palettes to display unit descriptions or sample data when text labels for those sites are clicked on. In the case of maps, once the latitude-longitude has been registered in the DDM, sample sites or labels with known location references can be read in from text files and plotted on the map overlay (see Developmental Components discussion in the text).

APPENDIX 3. EXAMPLE OF PROGRAMING SCRIPT (CODE) IN A DDM

This is an example of the English-like programming code (termed script in the programming environment Runtime Revolution) associated with the button named ShowHidePhotoIcons found on the Home Screen window (or stack) named DynamicDigitalMapHomeScreen.

The script is divided into three handlers or groups of code that only execute when the condition set by that handle is meant. Handlers all start with "on" and terminate with "end," and all code within a handler is indented two spaces, as is any code between "if...then" and "end if" structures or "repeat..." and "end repeat" structures, all of which are included in the Runtime Revolution script as bold text for programming clarity. Lines of script that start with, or continue following two dashes -- are explanatory comments, shown in Runtime Revolution script in green, and do not execute. For example, the script to the first handler (on mouseDown) will only be performed if a hardware mouse device is clicked down when its associated cursor is within the perimeter of the button ShowHidePhotoIcons. In that case, the script will create a shadow around the button, and then move it two pixels to the right and down. The script to the second handler will only execute if a mouse button is clicked up when its cursor is within the perimeter of the button, in which case the script will remove any shadow around the button and move it two pixels left and to the right. It will then check automatically to see if any groups, which are camera icons exist and if so, check the first of these and see if they need to be made visible or invisible.

```
local thisGroupsName
--declares a variable to hold the name of a photo icon, which is a
--group of objects that includes a text field, and three vector shapes
--this is a local variable that is recognized within all handlers
--that belong to this button only

on mouseDown
  put "none" into thisGroupsName
  --this script looks at all groups of objects on this card
  --and checks to see if the group's name starts with characters "S#"
  --if it does, the group is a camera icon and we change the content of
  --the variable thisGroupsName (none) with that group's name
  --e.g. (S#110) and then we exit the repeat loop

  repeat with x = 1 to the number of groups
    if character 1 to 2 of the short name of group x = "S#" then
      put the short name of group x into thisGroupsName
      exit repeat
    end if
  end repeat
  set the shadow of me to 0
  --me refers to the button to which this script belongs
  move me relative 2,2
end mouseDown

on mouseUp
  --me refers to the button to which this script belongs
  set the shadow of me to 2
  move me relative -2,-2
  play click

  if thisGroupsName = "none" then
    answer "There were no PhotoIcons found on the 'Home Screen'"
    exit mouseUp
  end if

  --if we get to the next line of code then we know there
  --is at least one photo icon group, so next we check the
  --group's visibility state to see if it is visible or
  --invisible, and change it & all others to the opposite state

  if the visible of group thisGroupsName = "true" then
    set the label of me to "Show Photo Icons" -- me = this button
    repeat with x = 1 to the number of groups
      if character 1 to 2 of the short name of group x = "S#" then
        set the visible of group x to false
      end if
    end repeat

  else --if we get here it means the first camera icon's visibility was
    --false so we want to change it to make it visible
    set the label of me to "Hide Photo Icons" -- me = this button
    repeat with x = 1 to the number of groups
      if character 1 to 2 of the short name of group x = "S#" then
        set the visible of group x to true
      end if
    end repeat
  end if

end mouseUp

on mouseLeave
 if the shadow of me is 0 then --me refers to this button
   move me relative -2,-2 -- without this the button may "wander"
   set the shadow of me to 2
 end if
end mouseLeave
```

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