Unpublished Geologic Evidence and Other Databases of the Kentucky Digital Mapping Program

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INTRODUCTION

Between 1996 and 2005 the Kentucky Digital Mapping Program digitized 707 USGS Geologic Quadrangle maps produced by the joint USGS-KGS geologic mapping program that took place from 1960 to 1978. One of the products of this effort is a seamless 1:24,000-scale spatial database of geologic information. The database includes map features and all the explanatory information found on the collar of the printed USGS maps. Since 2001, the Kentucky Geological Survey has been developing Web services to integrate the digital geologic maps with other geoscience databases (Weisenfluh, and others, 2005).

The seamless, 1:24,000-scale database is essentially complete and available as an ESRI ArcIMS map service at the Kentucky Geologic Map Information site (http://kgsmap.uky.edu/website/KGSGeology/viewer.asp). Some supporting data are still being added to the site. Here, we discuss database design elements that were found to be particularly useful for implementing the Web project and current KGS database activities that will extend the usefulness of the Internet mapping site.

MAP EXTENT DATABASE

The first database that was built to support the geologic map system was a catalog of KGS and USGS reports and maps. Map coordinate extents were assigned to publications to facilitate geographic searches for information of this kind, where a single coordinate value does not adequately represent the area to which the information applies. At the onset, most publications were associated with quadrangles or counties, but subsequently, additional area types such as state parks and drainage basins were added. A database of map extents was constructed that contains a geographic area type and name along with the minimum and maximum coordinates for the enclosing rectangular area.

At about the same time, Internet map developers in other Kentucky state government agencies were creating new Internet map services for a variety of information. Among the early drawbacks to these maps were the slow redraw speeds and the difficulty of finding a specific area on a statewide map. Most users utilized repeated zoom and pan methods to find an area, and so finding an area of interest was taxing for both the user and the computer servers. KGS used the map extents database to develop a search and zoom function that could be used by any Kentucky Internet map developer to simplify this process. This service, called the KGSGeoPortal, functions much like the Geographic Names Information System with the added ability to link to most Kentucky-based Internet maps from a single base map. Moreover, the initial view provided by the GeoPortal is typically closer to the user's area of interest because the database stores the full extent of the feature, not just its central value. The GeoPortal is found at <http://kgsmap.uky.edu/website/KGSGeoPortal/KGSGeoPortal.asp>.

The database was enhanced to help resolve similar geographic names. For example, many stream names are duplicated in different parts of the state. Additional attributes were assigned to identify the beginning and ending county name, the drainage basin name, and the name of the stream of the next higher order so that users could identify the correct stream.

All of the initial map extents for this database were for standard geographic features that were readily available in GIS format. The extents were calculated using a simple Avenue function in ArcView or with AML programs in Arc for more complex requirements. More recently, the need to store informally-defined areas has increased, but it was more difficult to calculate these areas. For example, many reports are published for study areas that do not conform to a standard quadrangle or other named geographic features. KGS undertook a project to help the Kentucky Transportation Cabinet catalog

over 5,000 of its geotechnical reports for roadways and structures. Because each of these projects pertains to a small and unique area, an Internet base map service was developed with a function to create a custom map extent by dragging a rectangle across the area as viewed on a topographic map or aerial photograph (Figure 1). Most recent Transportation Cabinet project areas can be defined by the drillholes taken at the site, and therefore, another function was provided to upload the drillhole coordinates and plot them on the map. Users can then draw the project extent on the map or use the minimum and maximum hole coordinates to define the rectangle programmatically.

An unanticipated benefit of this work was discovered late in the project. The Transportation Cabinet has tens of thousands of historical drillholes, but only a few are referenced in a geographic coordinate system. Transportation engineers typically use a local survey system of route alignment station footages and offsets. Locating these holes on a map normally would be time prohibitive. Because the holes are associated with a project report and the reports have been assigned a map extent that, in most cases, is only hundreds of feet square, most of these data can now be placed in a geographic context that is suitable for comparison to geologic maps.

MAP DESIGN DATABASE

The KGS Geologic Map Information site was designed so that users could create a highly customized geologic map of a project area overlain with other related site information, such as oil and gas wells or sinkholes. Over 40 themes are available for geology, derivative classifications of map units, well and sample sites, economic features, hazards, and various base maps. Geologic maps can be customized by selecting individual layers or by choosing one of five predesigned layouts (Figure 2). The service also has a bookmark function that allows users to save a browser "favorite" for the current view that includes the map extent and the map layout. With a bookmark, users can return to the map exactly as designed or send it to a colleague. Bookmarks are stored as URL text strings, and saving in that string the necessary information about the visibility of 40 layers is not practical due to length considerations. Therefore, a database of map layouts (the "IMSLayers" database) was created so that a custom configuration could be stored in the URL as a simple variable number.

Columns in the IMSLayers database (Figure 3) designate the visibility of individual layers, while each

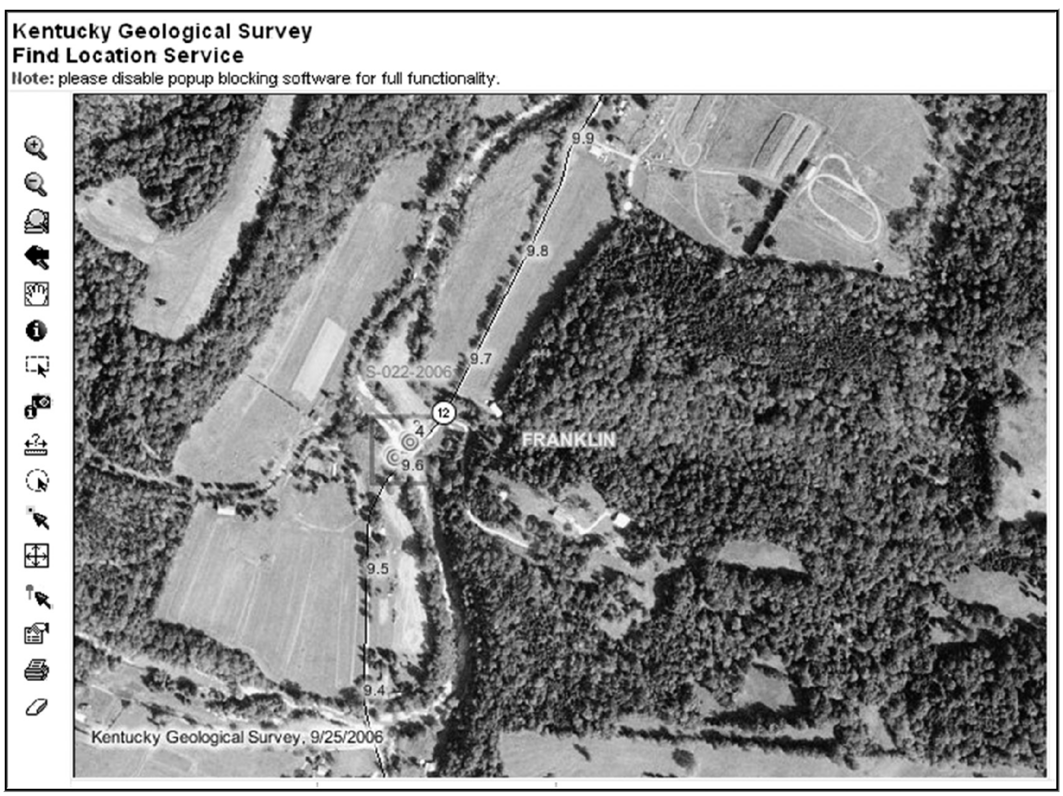

Figure 1. Creating non-standard map extents by interactively drawing a rectangle around plotted drill hole locations on an ArcIMS map service. The holes are plotted by means of a coordinate upload function.

row represents a unique combination of visible layers. To simplify map development, database column names for layers are equivalent to layer names used in the ArcIMS AXL file used for map rendering. Additional columns in the database record the layout ID number (an internal ID), a layout name for standard maps (this field is blank for map layouts defined by users), a counter for the number of users who have used that layout, and the name of the help file that is available for the layout on the map. For simplicity, the geologic map service has only one link to a help file for explanatory information. Because the content of the map can change significantly, the database can specify a different help file dynamically according to which layers are visible. For example, a karst help file is activated when the karst potential theme is turned on.

When a user requests a bookmark, the system compares the current state of visible layers to the database. If the same layout exists, its ID number is appended to the URL along with the coordinate bounds of the view, and its count is incremented. If the layout does not exist, a record is appended to the table, and the new ID number is returned. When an Internet browser receives a URL with an embedded layout ID for this map site, the process is reversed. The ID number is used to obtain visible layers from the database, and the application draws the map in this initial state.

The IMSLayers database provides an easy method of storing customized map layouts that are useful to a diverse user base. Tabulation of layout counts provides information about frequency of use that can be used to identify “favorite” designs so that these can be provided as quick links.

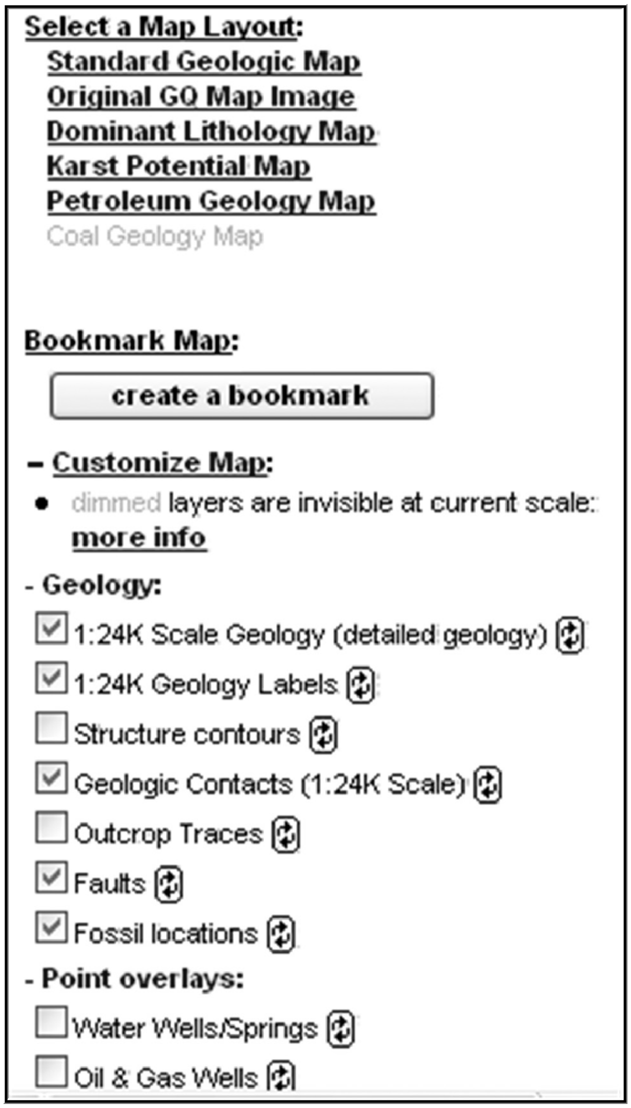

Figure 2. Pre-designed and customized map layouts on the KGS geologic map service.

DERIVATIVE GEOLOGIC MAPS

One of the objectives of the KGS Digital Mapping Project was to make geologic maps accessible to a wider user audience. In Kentucky, this includes many people without formal geologic training. One way to do this is to make derivative classifications of the geology that are conveyed in simpler terms appropriate to the target audience. Derivative maps were made using a variety of methods and are available on the map service as predefined layouts.

An oil and gas map was created by simple layer manipulation. This layout excludes most of the geologic themes, except faults and near-surface structure contours, then overlays oil and gas wells and fields. A dominant lithology map was created by reviewing lithology descriptions for each map unit, then assigning an appropriate

LayoutId	LayoutName	LayoutCount	HTMLFile	Ggeopoly	Gfault	Glabel	Gcontact	Gscontour	Gsmeasure	Gbed	Gfossil	Gxsect	Gcrop	Pwater	Poil
1	Standard Geologic Map	881	default_help.htm	-1	-1	-1	-1	0	0	-1	-1	0	0	0	0
2	Petroleum Map	372	default_help.htm	0	-1	0	0	-1	0	0	0	0	0	0	-1
42	Original GQ Map	273	default_help.htm	0	0	0	0	0	0	0	0	0	0	0	0
31	Karst Potential	277	karst_help.htm	0	-1	0	-1	0	0	0	0	0	0	0	0
3	Dominant Litho	192	litho_help.htm	0	-1	0	-1	0	0	0	0	0	0	0	0
33		0	default_help.htm	0	-1	0	0	-1	0	0	0	0	0	0	-1
34		2	default_help.htm	0	-1	0	0	-1	0	0	0	0	0	0	-1

Figure 3. Design of the IMSLayers database table. Layers assigned the value “-1” will be made visible.

term in a stratigraphic database. Combined units were treated similarly to heterogeneous stratigraphic units. Lithology terms were reduced to seven unconsolidated types and 23 rock terms, all of which were derived from the original geologic map legends. A karst potential map was developed using a multivariate analysis of factors that affect the dissolution of limestone units. This classification, developed by KGS geologists, is intended to show the likelihood that a unit may develop karst features. The four factors considered were percentage $CaCO_3$ in the carbonate portion of the unit, carbonate grain size, bedding thickness, and percent insoluble material. Each factor was ranked for all geologic units, and a combined score was tabulated. From this ranking, a five-level classification was devised, and adjustments were made based on the experience of KGS geologists. Examples of these map types are shown in Figure 4.

Two additional map classifications are in progress. The first is a map that depicts shale behavior by grouping units according to the amount of shale present and properties such as slake durability, expandable clays, and sulfide content. The second is an endangered species potential map that will highlight units that are associated with occurrences of endangered plant and animal species.

IMAGE LIBRARY

One of the most useful ways of communicating the character of geologic units is with photographic evidence. In fact, most geologists’ offices are filled with hundreds, if not thousands, of photographs of outcrops, scenes, and specimens that have been accumulated during their careers. The challenge of making these images available to a general audience always relates to the time needed to catalog them—few working geologists have sufficient time. Recognizing this, KGS developed a digital image application for its staff that simplifies some of the tasks related to the processing and cataloging of photos. The application has Web-based data entry and search functions to provide ease of user access and efficient programming maintenance. The search function < http://kgsweb.uky.edu/geology/image_search.asp > is currently available for public access.

The initial step in cataloging a photograph is to upload the image to the Web server and, optionally, overprint credit text on the picture. No limits to resolution are imposed. Images are stored in their original resolution, and a thumbnail version of 100-pixel width is created. Those who wish to include a credit on the image can type

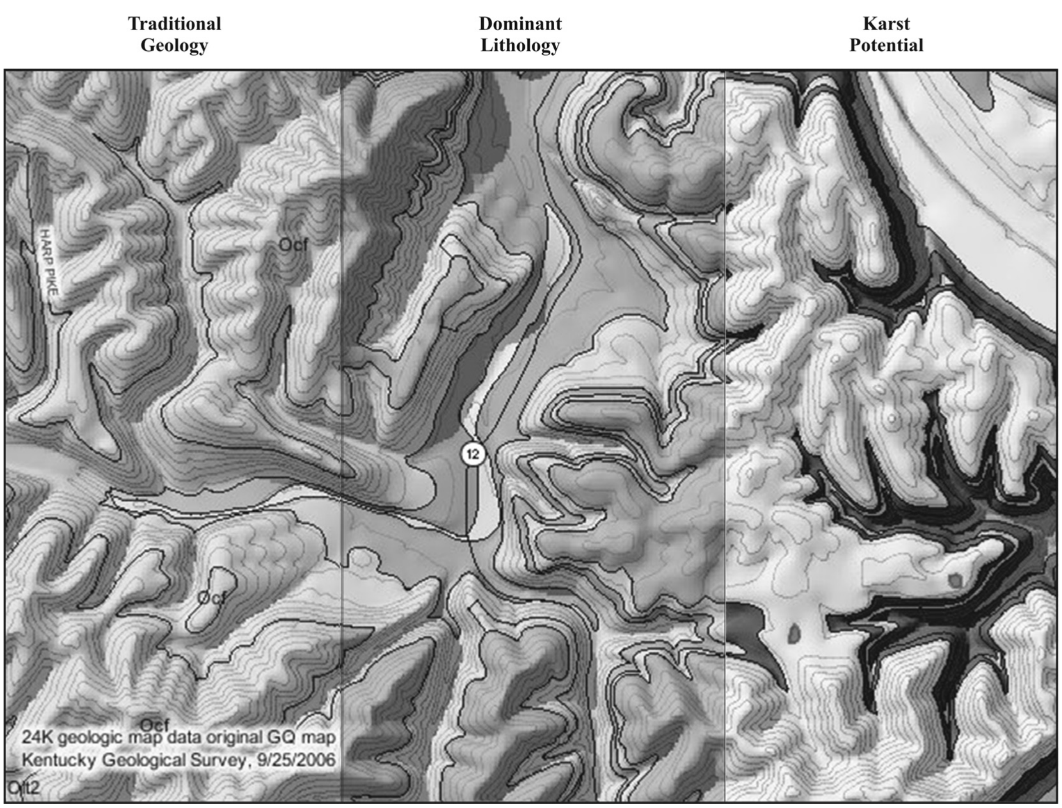

Figure 4. Examples of derivative classifications provided for Kentucky geologic maps.

the text, then specify the font size, color, and position (upper or lower left corner). A preview function is provided to verify that the selected options work well for the given image. Once the user is satisfied, the image is uploaded using the program AspUpload (Persits Software Inc., http://www.aspupload.com/index.html), and the credit text is appended during the operation. Some properties, such as pixel resolution and file size, are harvested from the image file, and a unique file name is assigned at the time of upload.

After the upload is complete, a form is presented for the geologist to describe the image. One of the most important characteristics to record is the location of the photograph. Locations can be specified with a variety of methods and levels of precision, ranging from “in a quadrangle” to a GPS coordinate value. Only images with a coordinate location can be posted on an Internet map; however, those with general locations can be searched from a map using the same methodology that is applied to publications (i.e., by assigning a mapextent value as described above).

The remainder of the cataloging process allows users to supply information about stratigraphic context, authorship, and image properties. It also allows users to provide brief and long descriptions of the photo, and assign keywords. Standard keywords are provided as checkboxes to simplify data entry and maximize the efficiency of the search function. Another keyword function is supplied to assign fossil names from a hierarchical taxonomic list.

The image search function (Figure 5) permits users to search by combinations of all the criteria discussed above. The initial results screen (Figure 6) contains a list of matching photos with a brief description, a thumbnail image, and links to a full description and a geologic map view of the location. Images can be downloaded in their original resolution. Users of the geologic map service can view photo locations on the map, and these symbols are linked to the detail description (download) page.

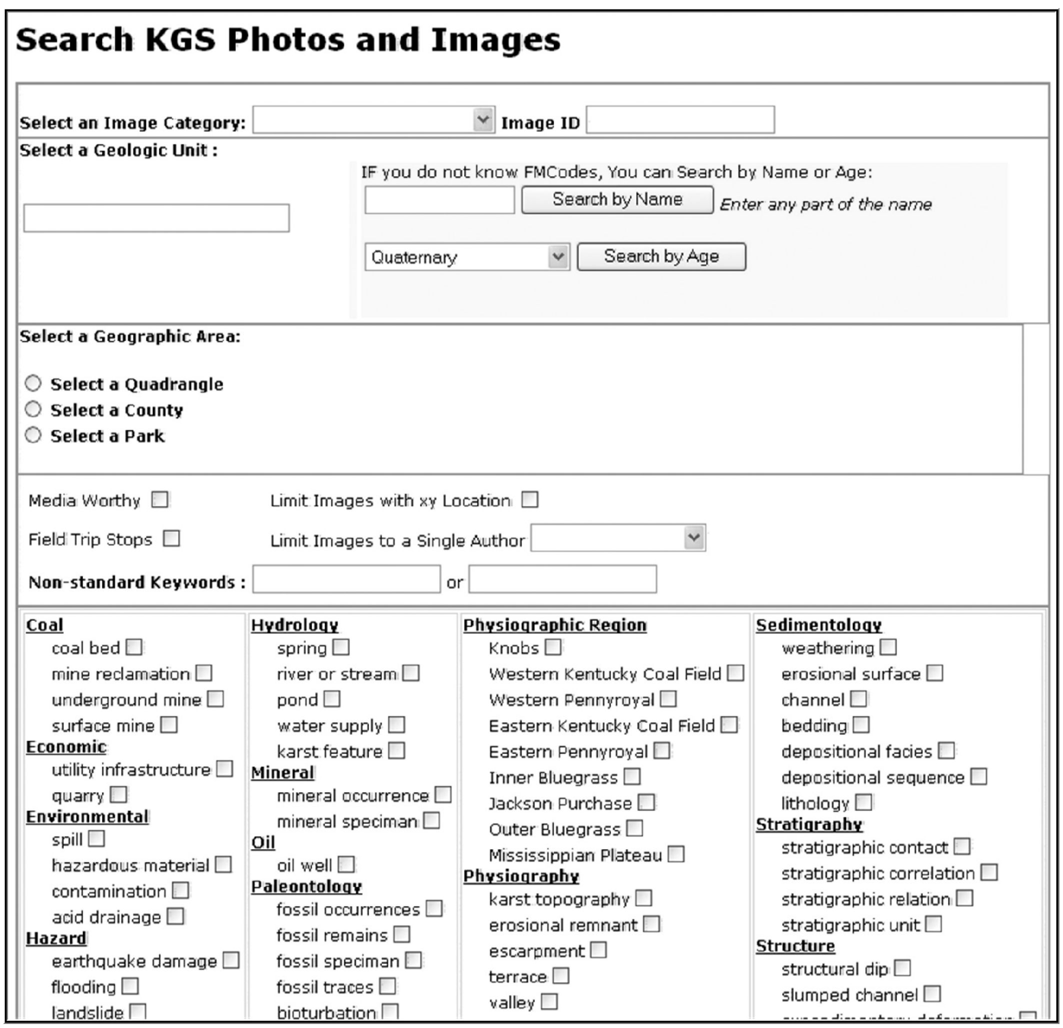

Figure 5. Part of the KGS photo search Web site.

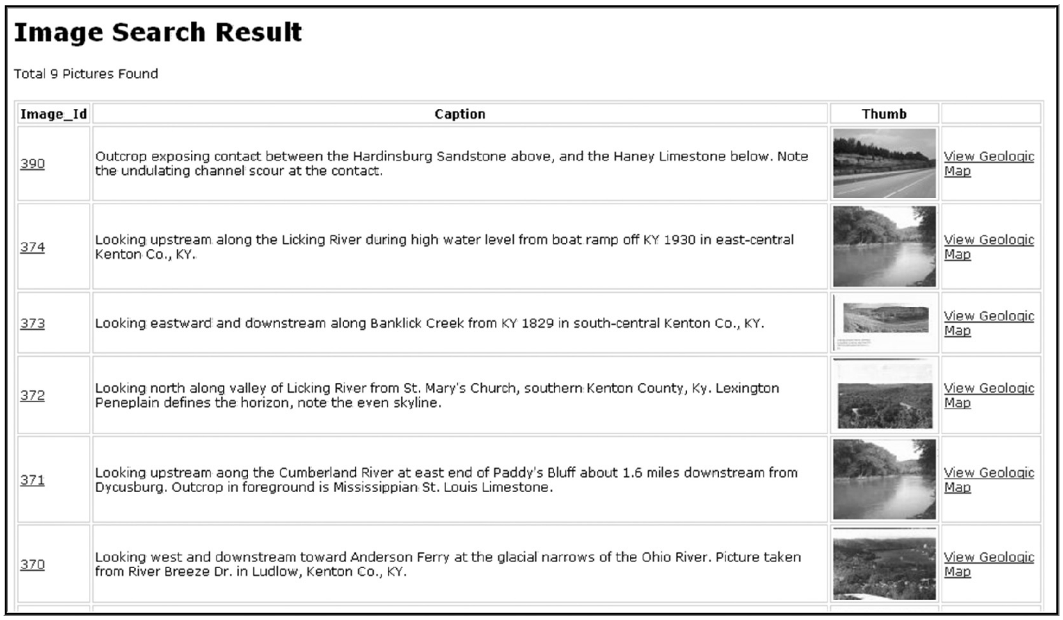

Image Search Result

Total 9 Pictures Found

Image_Id	Caption	Thumb	
390	Outcrop exposing contact between the Hardinsburg Sandstone above, and the Haney Limestone below. Note the undulating channel scour at the contact.		View Geologic Map
374	Looking upstream along the Licking River during high water level from boat ramp off KY 1930 in east-central Kenton Co., KY.		View Geologic Map
373	Looking eastward and downstream along Banklick Creek from KY 1829 in south-central Kenton Co., KY.		View Geologic Map
372	Looking north along valley of Licking River from St. Mary's Church, southern Kenton County, Ky. Lexington Peneplain defines the horizon, note the even skyline.		View Geologic Map
371	Looking upstream aong the Cumberland River at east end of Paddy's Bluff about 1.6 miles downstream from Dycusburg. Outcrop in foreground is Mississippian St. Louis Limestone.		View Geologic Map
370	Looking west and downstream toward Anderson Ferry at the glacial narrows of the Ohio River. Picture taken from River Breeze Dr. in Ludlow, Kenton Co., KY.		View Geologic Map

Figure 6. Photo search results page with links for detailed image information and a geologic map location.

GEOLOGIC ANECDOTES

The geologic map service provides information about the geology of Kentucky from published geologic maps, reports, and databases. However, some sources of information are unpublished, yet provide important context or explanation about the geology of an area. Unpublished evidence may include field notes from a mapping project, but often is represented as personal knowledge in anecdotic form. The Kentucky Survey sought a way of preserving this “institutional knowledge” and making it accessible to others. A simple form was developed to allow a geologist to submit such information to the existing geologic description database. The user must indicate his or her name and the geographic area to which the information applies (by assigning a value from the mapextents database). A description category is specified (e.g., geotechnical or hydrologic), and one or more geologic units can also be designated. The anecdote is entered as free text.

Using mapextent methods, anecdotal descriptions can be searched from the geologic map interface along with published descriptions. If the user’s map view overlaps the coordinate extent assigned to a particular description, it will be returned in a query. There may be concerns about making information of this kind available to the public, since it has not been formally reviewed. It is important, therefore, to advise users about the nature of the data.

REFERENCE

Weisenfluh, G.A., Curl, D.C., and Crawford, M.M., 2005,The Kentucky Geological Survey’s Online Geologic Map and Information System, in D.R. Soller, ed., Digital Mapping Techniques ‘05—Workshop Proceedings. U.S. Geological Survey Open-File Report 2005-1428, p. 5-10, available at http://pubs.usgs.gov/of/2005/1428/weisenfluh/index.html.