The Digital Geologic Map of Afghanistan

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ABSTRACT

The 1:500,000-scale Russian-published geological map of Afghanistan (Abdullah and Chmyriov, 1977) was digitized and attributed with ArcGIS. Topology was created and maintained in ArcGIS and then the spatial data were converted to ESRI shapefiles. A lookup table for the map units was created from the Arc GIS Workstation coverages and then manually edited. The edited result is a one-table database that is the basis for drawing the map units for geologic maps as large as 1:250,000-scale, 1-degree x 2-degree sheets. The shape files were imported into Adobe Illustrator with MAPublisher from Avenza Systems, Inc. Custom graphic styles were linked to a map unit in the joined spatial attributes and the lookup table through MAPublisher stylesheets. Faults and contacts were assigned graphic styles separately. The map units, faults and contacts were combined to produce the geologic map. The current database is being reverse-engineered into a modern relational database. This final database will be useful in making mineral assessments, oil and gas assessments, hydrogeologic studies and as base information for road construction and environmental restoration.

INTRODUCTION

Project Framework

The U.S. Geological Survey (USGS) works in several science activities in Afghanistan in support of the Afghanistan Reconstruction Project (ARP). This project is carried out under the auspices of the United Nations (UN) with the United States as the major contributor. "The ARP carries out research and public education about selected issues related to the rebuilding of Afghanistan's institutions, society, and economy. The project supports efforts by the Afghan government, Afghan civil society, the United Nations Assistance Mission in Afghanistan, and donors to carry out a more effective reconstruction mission." (CIC, 2005).

The USGS Project

The U.S. Department of State's Agency for International Development (AID) and the Trade and Development Agency (TDA) facilitate USGS involvement in the ARP. AID funds geologic mapping and other USGS earth science efforts. TDA primarily funds energy resource studies.

Geographic and Geologic Setting

Afghanistan is in Central Asia. On the north, its neighbors are Turkmenistan, Uzbekistan, and Tajikistan. On the east the largest part of the border is with Pakistan. China borders Afghanistan on the east end of the narrow arm (the Wakhan Corridor), extending to the east from the northern part of the country. Pakistan wraps around eastern and southern borders of Afghanistan. The country's western border is shared with Iran.

The country ranges from low desert in the northwest and south, to high mountains and deep valleys in the central and eastern sections of the country. The climate is arid. The main source of moisture is melt water from ice and snow in the mountains that reaches the lowlands in rivers and groundwater.

Afghanistan is at the western edge of the Himalayas between the Indian/Asian and Arabian/Asian collision zones. Rocks exposed at the surface range in age from Archean to Quaternary. Alluvial and fluvial deposits cover large portions of the west and south. Eolian sand forms prominent dune fields in the south and northwest.

History of Regional Geologic Mapping

The nations mentioned above have had recent geologic maps compiled and interpreted in light of modern thought concerning plate tectonic theory, particularly as concerns the collision of the many plates that make up the Afghanistan of today. Afghanistan, however, has had little benefit from recent geologic studies because of persistent and extensive warfare and unrest throughout the country. The general consensus among project participants is that geologic investigations and analysis in Afghanistan are ten to fifteen years behind those conducted in neighboring countries.

Numerous efforts have been made to map the geology of Afghanistan. The most detailed countrywide map is the Russian 1:500,000-scale geologic map (Abdullah and Chmyriov, 1977). German geologists (Wittekindt and Weppert, 1973) made a map of the south and central parts of Afghanistan, which USGS participants in Flagstaff, AZ have digitized and attributed. A series of fifteen 1:100,000-scale maps by French geologists has been scanned but not yet digitized. This paper reports only on our work with the Russian geologic map.

THE CURRENT STATUS

We started with digitized geology: the attributed vectors and polygons for the 1:500,000-scale Russian geologic map. The attribute information was summarized into a "lookup" table using the FREQUENCY option under ANALYSIS and STATISTICS in ArcGIS Toolbox. Attribute items were added to this table for geologic time, lithology, map unit labels, and map unit descriptions. Some map units are rendered by patterned polygons on the original map. For GIS purposes, we identified these as separate map units. When we had sufficient information to proceed, we identified large lithologic groupings or composition changes by geographic region or tectonic province.

In addition to the geologic map data, we have acquired published and unpublished data for:

- Georeferenced images of the fifteen pieces of the original Russian geologic map
- Mineral locations
- Plutonic rock composition database
- Further explanations of the geologic map data
- Shuttle Radar Topography Mission (SRTM) digital elevation model—90 meter resolution
- UN AIMS (2005) data for cities, roads, provincial and international boundaries, and spelling for place names in Afghanistan
- Some scanned Russian topographic mapping
- LandSat 7 TM imagery, and Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) imagery.

Standards Issues

We followed where appropriate the relevant standards for geologic time, labeling of map units, line styles for boundaries between map units (contacts and faults), polygon fill colors, and patterns with color. As this map was compiled by the Russians (Abdullah and Chmyriov, 1977), we decided to use the geologic time scale from the International Commission on Stratigraphy (ICS, http://www.stratigraphy.org). The version of the ICS stratigraphic time scale chosen was that colored and organized according to colors traditionally used by the USGS (ICS, 2004).

The draft U.S. geologic line and symbol standards (USGS, 1999) were used, with the exception that the typical Russian symbol for foliation or layering in igneous rocks was used for the location of a strike and dip direction identified from aerial photography.

Because the map contains more map units than can be represented by the colors in the ICS chart, we chose a range of colors related to each major time period represented on the ICS chart. In addition, we chose colors and patterns for the plutonic rocks more for contrast with the group "layered" rocks than to designate age. For volcanic and some sedimentary rocks, we chose to add patterning so that the number of color choices would be held to a minimum. We deviated from the ICS standard by using "Quaternary" in the traditional sense, in order to remain consistent with the Russian source map. We show map unit labels with a custom font that has many subscripts to indicate epochs and stages.

Challenges

The Russian geologic map (Abdullah and Chmyriov, 1977) was produced on fifteen sheets, each 3 degrees in longitude by 2 degrees in latitude. Our copy of the original map is a set of scans of these fifteen sheets. Nowhere can we find information about the map projection scheme or any related information. The scans were georeferenced to WGS84 geographic coordinates and transformed to the project-adopted Transverse Mercator projection with the same datum and spheroid. From careful checking with data sets from AIMS (2005), we're confident that the map is registered to within national map-accuracy standards of 250 meters (at the map scale of 1:500,000).

Another simple but important problem was the scale at which to render the map. We chose a map scale of 1:850, 000 because the map fits on 54"-wide plotter paper. This results in a substantial savings when printing the map on large-format Hewlett-Packard plotters.

The Construction of the Geologic Map

We decided to use Adobe Illustrator with Avenza's MAPublisher to render the finished map. We recognize that a complete ArcGIS geodatabase would allow more and varied analyses to be done with the digital map; however, the Afghan Geological Survey (AGS) has few modern computer facilities and fewer personnel to use these computers or complex software like ArcGIS. Paper maps are the preferred medium for conveying geologic information to those in the country. Secondly, data sharing in this environment, when possible, is done with ESRI shape files and DBF databases. The choices of Illustrator and MAPublisher allow a small GIS capability such as table joins and queries and a sophisticated way of presenting the results of such queries easily on paper maps. This choice has also allowed project participants to easily construct several 1:250,000-scale geologic maps that are almost ready for publication.

The first hurdle we overcame was how to represent map units with color and fill patterns in a consistent and reliable manner. MAPublisher uses a "Map View" to control such things as georeferenced feature layers and placement of map information on a printed page. In addition, MAPublisher uses a "Map Stylesheet" to control the association of Illustrator graphic styles, symbols, and text fonts with map information.

Graphic styles in Illustrator can be created for both polygon fill and complex line representations through the "Graphic Styles palette" in Illustrator. For polygon fills, graphic styles are composed of one stroke layer (for the fill boundary) and (or) one or more fill and pattern layers, and a transparency and mode. This method allows us to control the total appearance of polygon fills on a style-by-style basis. In the Map Stylesheet, one can examine attributes associated with each of the polygons or lines. Each Stylesheet has a column that can be chosen from one of the attribute columns associated with feature types in the Stylesheet, and a column with the graphic styles that are available in the current drawing. If one desires to fill polygons based on chronostratigraphic divisions, an attribute column might contain such designations as "Cambrian, undivided" and "Cambrian limestone" and if one labeled newly created graphic styles with the same names, then all that remains to be done is to associate the graphic style with the appropriate attribute in the Stylesheet; MAPublisher will then fill with the graphic style "Cambrian" all polygons that have the attribute "Cambrian".

We have imported geologic symbols from the U.S. draft standard (USGS, 1999) into Illustrator, as "Symbols" in a symbols library; these can be associated in a MAPublisher Stylesheet to data in an imported point shapefile. Symbols can be rotated counterclockwise based on a numeric column attribute.

In all of the above cases, we chose to put a minimum of information in the attribute fields of the feature shapefiles, and to keep the repetitive attributes in a look-up table. The lookup tables were exported to DBF format and then changed to Microsoft Excel files. We added to (and deleted from) the attribute columns originally present to arrive at a lookup table that contains all of the attributes by which we might want to query this table. After converting back to DBF format, we used MAPublisher to join the feature shape file attribute data to the lookup tables, in order to connect attributes like map unit name with a geometric object. We make the assumption (and try to edit the data so) that every entry in a feature file has a corresponding value in the look-up table. We then proceed to graphically represent the feature shape file data as described above. Errors in attributing both the polygon or line feature data can be rectified using the MAPublisher facilities to edit attribute data and then have the Stylesheet function refill the polygons with the proper style.

The Russians labeled map units in a complex fashion that to our knowledge cannot be reproduced in any common word processing software. The map unit labeled "N11" on the Russian map would have the first "1" as a superscript and the second "1" as a subscript directly under the superscript. Illustrator has no direct mechanism to allow this construct in a text string without considerable label-by-label work. To keep the map unit symbol as close to the one on the original map, we designed a True Type font with subscripts of needed characters and symbols for Paleogene, Cambrian, and Proterozoic. In international usage, the Triassic period is represented by a "T". This font works both on a PC and on a Macintosh running OS X, and allows map unit labels with many subscripts to be placed as a text string in Illustrator without manual intervention to make the subscripts. In addition to working in Illustrator, the font also works in Microsoft Word and Excel, and in ArcGIS.

We used the latter application to label the polygons with ArcGIS (as an Illustrator layer), because MAPublisher has no way to easily plot polygon labels that fit entirely within a polygon, as does ArcGIS. We developed a workaround for this MAPublisher limitation,creating a map of the polygon shapefile in ArcGIS at a scale of 1:850,000 (the scale of the final map), labeling the polygons using the custom font (the polygon boundaries of the polygons were turned to light gray with no polygon fill color), and writing the map to a PDF file which was then imported into an Illustrator layer. This layer was then manually aligned with the contact layer, and then all of the polygon borders were erased, leaving the labels.

Some other limitations of working in MAPublisher are:

- No queries involving more than one attribute column directly in the Stylesheet.
- One look-up table per layer.
- No Open DataBase Connectivity (ODBC) capability.
- The current version of MAPublisher will not handle more that 50 graphic styles without manually editing a preferences file with a text editor.
- No multi-column primary keys for the database.
- Clearing of a table join is done by deleting the joined attribute columns one by one.

Some of the limitations of this look-up table are:

- No good way of handling hierarchical data. Every hierarchy must be explicitly entered into this table.

- The number of attribute columns can become quite unwieldy.
- Data integrity is difficult to maintain.
- Numeric data must be entered as real (or floating point) data for column joins to work successfully without manually editing the DBF files to ensure compatibility.

ACCOMPLISHMENTS

As a result of this work, some of the last of the 1:250,000-scale geologic maps to be compiled took only hours instead of days to complete. Editing and reviewing of these maps has become much simpler since color fills, patterns, and line weights, patterns, and colors are standardized for this project. The maps are therefore a much more consistent product even though they were created by different project participants.

Current Products

We have generated from these data sets:

1. A preliminary geodatabase in ArcGIS 9.1: this geodatabase was derived from the ArcGIS Workstation coverage made from the original digitization of the Russian geologic map. It uses the lookup table built in ArcGIS Workstation and modified as described above.
2. Maps including geologic maps clipped from the above database for the creation of 1-degree by 2-degree, 1:250,000-scale geologic maps. The project participants have generated 32 of these geologic maps. They are being published as USGS Open-File Reports in cooperation with the Afghanistan Geological Survey. SRTM data was used for a shaded relief background on each of these maps.
3. Clipped and corrected LandSat 7 TM data for each 2-degree quadrangle. Project participants at the USGS office in Flagstaff, AZ office have provided LandSat 7 TM data that has been corrected for the atmosphere and vegetation.
4. Geologic maps combined with geophysical mapping (mostly seismic survey data) for a preliminary petroleum analysis of the Ama Darya basin in northwestern Afghanistan.
5. A national geologic map of Afghanistan at a scale of 1:850,000, for which this work was primarily done.
6. A national geologic and minerals location map produced in cooperation with Jeff Doebrich (USGS, Reston) and Craig Wandrey (USGS, Denver) (Doebrich and Wahl, in press), which uses the map developed in (5) above.

WORK TO BE DONE

The remaining work on the look-up table entails three steps. First we will ensure that every attribute we could want to use in a query is in the table. Second, Wahl intends to reverse-engineer these look-up tables into a relational database that can, with a simple query, re-create the look-up table and perhaps other "views" of the data, but still have the reliability and data integrity of a true database. Third, we want to expand the database to allow for larger scale (1:100,000-scale) geologic mapping in phase two of this project. Most of the geologic data will be collected from the analysis of Landsat 7 TM and ASTER imagery, because the cost and effort needed to conduct field work in Afghanistan now is extreme.

REFERENCES

Afghanistan Information Management Service (AIMS), 2005, Various GIS data sets for Afghanistan, accessed at http://www.aims.org.af/.

Abdullah, Sh., and Chmyriov, V.M., eds., 1977, Map of mineral resources of Afghanistan: Kabul, Afghanistan, Democratic Republic of Afghanistan, Ministry of Mines and Industries, Department of Geological and Mineral Survey, V/O Technoexport USSR, scale 1:500,000.

Center for International Cooperation (CIC), 2005, Conflict Prevention, Recovery and Peace building, accessed at http://www.cic.nyu.edu/conflict/conflict_project4.html - overview.

Doebrich, Jeff L., and Wahl, Ronald R., in press, Geologic and mineral location map of Afghanistan: U.S. Geological Survey Open-file Report, scale 1:850,000.

International Commission on Stratigraphy (ICS), 2004, International stratigraphic chart (using the color codes according to the United States Geological Survey), accessed at http://www.stratigraphy.org/chus.pdf.

United States Geological Survey (USGS), 1999, Public review draft—Digital cartographic standard for geologic map symbolization (Postscript implementation): U.S. Geological Survey Open-file Report 99-430, available at http://pubs.usgs.gov/of/1999/of99-430/.

Wittekindt, H., and Weppert, D., 1973, Geological map of central and southern Afghanistan: German Geological Mission to Afghanistan, Geological Survey of the Federal Republic of Germany, scale 1:500,000.