CO-477

IDENTIFYING COLORS ON EARLY GEOLOGICAL MAPS: A COMPARISON OF METHODOLOGIES

COOK K.
University of Kansas, LAWRENCE, UNITED STATES

BACKGROUND AND OBJECTIVES

Map symbols form a graphic language which conveys map content to map users. A modern geological map shows different rock types by means of colored and patterned area symbols designed according to established geological conventions. Employment as a cartographer for the Alaska Division of Geological and Geophysical Surveys in the early 1980s involved choosing colors for geological maps and aroused my interest in their history.

During the early nineteenth century in England and contintental Europe field observations and emerging geological concepts were compiled into the first geological maps of regions and countries. The choice of symbols for rock types was influenced by developing theories and knowledge about rock composition, formation and age, as well as the appearance of the rocks. The makers of geological maps found the perfect means of expression in thematic area symbols, at first colored by hand but later in the nineteenth century increasingly printed in color, primarily by means of new lithographic color-printing technology (Cook 1995). During the century geological map colors became more standardized under the aegis of recently established national geological surveys and, later, growing international efforts.

Despite the qualitative nature of color vision people have long sought to make color measurable and repeatable. The development of color systems for identification of mineralogical and natural-history specimens dates from at least the eighteenth century onward. Identification of color has also been important in the visual arts and manufacture, such as the weaving of tapestries. One example, the Munsell color system developed in the early 1900s was the first to employ a color solid within which colors are specified based on three color dimensions: hue, value (or lightness), and chroma (or brightness) (Berns 2000, 36-39). Because the steps between colors are perceptually uniform in the Munsell system, it became popular for user-focused research on map design later in the twentieth century and for many other uses. The Munsell color system is still in use today, although color science and its industrial applications have largely shifted to the more recently developed CIELab system (Berns 2000, 44-61). CIELab is an acronym for "Commission Internationale de l'Eclairage Lab" ("L" represents lightness, "a" represents the red/green axis and "b" represents the blue/yellow axis).

Several decades ago studying color on early geological maps involved travel to distant libraries and hours spent identifying map colors by matching them to a set of Munsell color chips. The Munsell system of visual color matching remains a respected method for identifying colors, but its results for maps viewed in different libraries are subject to variations in lighting conditions, artificial or natural, the latter also varying with weather and time of day. Current color science widely employs the more sophisticated CIELab color system and digital color-measurement technology. Many fields in art, industry and science routinely create, measure and control color digitally. During the past year I have reviewed the available methods searching for one suitable for my research. Criteria for comparing the options have been the type of color data collected, accuracy and consistency of measurement, portability, speed of measurement and cost.

APPROACH AND METHODS

A useful approach has been to compare different methods by using them to collect color data for the same map, Daubrée's 1851 geological map of the Département of Bas Rhin in the Alsace-Lorraine region in northeastern France (scale 1:200,000) (Daubrée 1851). The comparison is based upon a copy of this map in Spencer Research Library at the University of Kansas, as well as notes about copies seen in libraries in France and England. The three color-measurement methods used have been: (1) traditional visual color matching, (2) graphics software to analyze digital photographs of the map, and (3) a portable reflectance spectrophotometer.

Traditional color matching has been done using both a full set of approximately 1500 Munsell color chips (Munsell Color 1976) and the condensed ISCC-NBS charts of 267 centroid colors keyed to the Munsell system (Kelly and Judd 1976). Both methods position the colors numerically within the Munsell color solid, while the centroid colors are also named systematically, a convenience in writing about them. For example, I matched "Syénite et Porphyre" (syenite and porphyry) on the Bas Rhin map with centroid color 28.l.yPk (light yellow Pink), whose Munsell renotation is 1.9YR 8.2/4.6, while "Terrain houiller" (coal) matched centroid 79.l.gy.yBR (light gray yellow Brown), which converts to Munsell 9.7YR 6.4/2.5. Both colors are in the yellow-red section of the color circle of 10 color hues, each with 10 gradations (with each gradation thus amounting to 3.6 angular degrees). Light yellow Pink at 1.9YR is closer to red, while light gray yellow Brown at 9.7YR is closer to yellow. The vertical axis of value or lightness consists of ten steps ranging from white at the top of the color solid downward through successively darker shades of gray to black at the bottom. Light yellow Pink's value of 8.2 is lighter than light gray yellow Brown's value of 6.4. Light yellow Pink is also brighter, with a chroma of 4.6 compared to a chroma of 2.5 for light gray yellow Brown. Chroma or brightness is measured horizontally outward from the neutral central axis. The Munsell steps are perceptually equal along each dimension for small differences, although not for larger steps or between dimensions. For instance, later research has indicated that each value step is equivalent to 3.76 chroma steps (Farmer, Taylor and Belyavin 1979).

Visual Color Matching

When traveling to libraries in the past, time was limited, and my preference was to use the centroid color charts, because matching the smaller number of colors is faster. The less detailed results were good enough, because various factors can cause the same geological color to differ on different copies of the same map. These factors include lighting conditions during observation, differing application of hand color and use of fugitive pigments which fade over time, especially if exposed to light. However, the colors on color chips may also have become degraded over time. They also have the disadvantage of a glossy finish, while most map colors are matte, a difference which may affect color matching. In addition, centroid color charts are no longer being manufactured, having been superseded by digital methods. Clearly, it is worthwhile to investigate digital alternatives to visual color matching.

Computer Graphics Analysis of Digital Images

Another possibility is analyzing digital images of maps with computer graphics software. For example, the 1851 Daubrée Bas Rhin map is one of a group of mid-nineteenth-century Cartes géologiques départmentales de France viewable at the recently established website "HistMap: the European network dedicated to geology and maps" (Savaton 2005) as high-quality Zoomify digital images. The maps mounted at the website are in the collection of the library of the École des Mines in Paris, which also made the digital files of selected maps available on CD-ROM for comparison with the Internet versions. When viewed on my computer monitor, images of the same portion of the map taken from the website and the CD-ROM appear identical. Considering the high cost of purchasing photographs from library photographic services, free access to images on the Internet is an attractive option. The price quotation for high-resolution digital photography of the same six maps from another library, ordered for purposes of comparison, was nearly U.S.$1000. The colors on my own digital snapshot taken without flash in the École des Mines reading room of the same copy of the map look quite different. In fact, even professional photographs ordered from different libraries will vary in appearance, because photographic equipment and settings and lighting conditions will differ. Comparing digital images is possible but will be most valid if the photography is done under virtually identical conditions, as with the maps from the École des Mines displayed at the HistMap website.

My next step was to use computer graphics software to identify the colors of the 1851 Daubrée Bas Rhin map viewed on the Internet. The Kuler color website is a free Internet site associated with Adobe, which markets a suite of graphics software (Adobe 2011). Intended for designers, both professional and amateur, Kuler enables the user to create, save and download design themes of five colors. Colors can either be created or uploaded as colored images that can be sampled with a moveable pointer. Once the colors have been saved into a theme, it is possible to pull up color identification information for each color.

The Kuler website does have its drawbacks, though. A flat "solid" color printed by lithography actually has a fine, barely visible mottled texture. An area of apparently solid color printed lithographically will vary in hue, such as when green has been created by printing blue over yellow. Minute samples of the green will range from more bluish where the blue ink is thicker to more yellowish where the blue ink is thinner and more yellow shows through. Kuler offers no way of averaging the samples or knowing their relative frequency within the colored area, nor is it possible to mark the location of a sample point and return to that exact spot.

Another problem is that geological area symbols often contain patterns, as well as solid colors. On the 1851 Daubrée Bas Rhin map gneiss and granite share the same flat solid color which matches centroid color 31.pale yellow Pink, but gneiss has a superimposed diagonal red line pattern. While visible as a pattern, it also alters the apparent hue closer to red. In order to record and analyze a pattern, it is necessary know the size of the pattern elements and the frequency of pattern repeats per unit of length. This is problematic with the MapHist Internet images, because the Zoomify software does not indicate how the size of the image compares to the original. Graphics software like Adobe Kuler color and Zoomify are intended to aid visualization rather than scientific color measurement.

Portable Reflectance Spectrophotometer

In contrast, color scientists use equipment designed specifically for measuring color. This equipment utilizes the fact that color derives from the spectrum of light energy of different wavelengths interacting in the eye with light receptors sensitive to different colors. The color of an object can be identified by measuring the amounts of different wavelengths of light that it reflects.

Plotted on a graph, these data also form a spectral curve whose distinctive shape forms a color signature for a particular colorant (pigment or dye). It thus offers the potential of studying the historical pattern of adoption and use of different colorants. Identifying the colorant can also indicate which colors are likely to have faded or otherwise degraded over time. Of the methods tested, only the reflectance photospectrometer can provide spectral curve information.

Photometers and densitometers have long been in use in the printing industry for measuring color and ink density, but downsizing from bulky heavy equipment used only onsite to portable lightweight equipment has been a phenomenon of the digital age. X-Rite, a major producer of equipment for scientific and industrial color measurement has recently expanded its market by introducing Capsure, a handheld device intended for use by designers, such as in home decorating, for about U.S. $800 (X-Rite 2011a). Although Capsure identifies colors accurately, it does not provide spectral data. The portable reflectance photospectrometers that X-Rite offers range in price from about U.S. $1000 to $10,000. A portable reflectance spectrometer emits a flash of light, measures the reflected wavelengths of light and identifies colors independent of local lighting conditions. The Basic series i1Pro photospectrometer attaches to a laptop (X-Rite 2011b). It collects and downloads the same data as the more expensive models but lacks an elaborate graphic display.

Trials of a top-of-the-line model, used for soils research by a University of Kansas colleague, indicate that critical features for measuring geological map colors are the size of the aperture and the ability to position the light-emitting tip accurately. Legend boxes on early geological maps tend to be small, and the alphanumeric label usually placed at the center of the box is likely to influence the photospectrometric reading. While color measurements can also be made on the map body, the geological units there are usually be underlain by base information printed in black, and some geological units are always tiny wherever they occur. The 4.5mm-diameter aperture of the i1Basic should be sufficiently small, aided by the fact that it comes with a positioning target.

RESULTS

Comparison of Munsell color identifications for the 1851 Daubrée Bas Rhin map made by visual color matching and by photospectrometer reveals considerable variation. It is reassuring to know that photospectrometer readings are independent of local lighting conditions. Additionally, photospectrometric readings take only a fraction of the time required for visual matching. A portable basic-model reflectance spectrophotometer will provide more data more accurately and more consistently than either visual matching or digital photography with graphics software and, given its speed, with relative economy (by reducing travel costs).

CONCLUSION AND FUTURE PLANS

As my initial project employing a photospectrometer to study geological map color, I have selected the mid-19th-century Cartes géologiques départmentales de France. Conceived by French geologist André Brochant de Villiers in 1820, these maps formed the second phase of his plan to map the geology of France. The first phase, the Carte géologique générale de France published in 1840, received praise as the first official geological map of France. The second phase, geological maps of the administrative départements of France, was delegated to local authorities, who were instructed to organize and pay for the map of their département. The varying scales, symbolization, authors, formats and irregular sheet lines of the resulting maps hindered their utility. Never completed, the series gave way in 1868 to the Carte géologique détaillée de France, a model of uniformity.

The design variety of the Cartes géologiques départmentales contributed to the emerging official geological map image of France during the 19th century. Color data collected by the chosen method will reveal design relationships among these maps. Of course color is only one design variable, and the study will also consider the use of patterns in combination with area colors. Equally important, the graphic characteristics of geological symbols will be linked to the geological content being depicted. Investigating the influence of developing geological theories and knowledge on color and pattern choices will invest this study of map design with meaning for the history of science, both geological and cartographic.

This project is only one of the many ways that color science could be used to study early geological maps, not to speak of other types of graphic images. Here are a few ideas:

1) It would be possible undertake broader studies tracing the use of color on geological maps in different countries and even as far as the development of the current international color scheme for geological maps. Smaller topics invite attention, too, for example, the design treatment of a particular geological map.

2) The nineteenth century was a period of research and innovation in manufacture of pigments for watercolor paints and for printing inks. Using spectral analysis would make it possible to trace the introduction and spread of different pigments for map coloring.

3) A third idea would be a project to return a faded map to its original appearance, but virtually and reversibly, by means of color graphics software.

REFERENCES

Adobe. 2011. "Kuler: explore + create + share." Downloaded 13 February 2011 from URL: http://www.adobe.com/products/kuler/

Berns, Roy S. 2000. Billmeyer and Saltzman's Principles of Color Technology. 3rd ed. New York: John Wiley & Sons.

Cook, Karen S. 1995. "From False Starts to Firm Beginnings: Early Colour Printing of Geological Maps", Imago Mundi, 47:155-72.

Daubrée, A. 1851. "Carte géologique du Département du Bas Rhin." In Description géologique et minéralogique du département du Bas-Rhin, A. Daubrée. Strasbourg: E. Simon, 1852.

Farmer, Eric W., Robert M.Taylor and Andrew J. Belyavin. 1979. "Large color differences and the geometry of Munsell color space." Journal of the Optical Society of America 70, no. 2:243-245.

Kelly, Kenneth L. and Deane B. Judd. 1976. Color: Universal Language and Dictionary of Color Names. National Bureau of Standards Special Publication 440.Washington: GPO.

Munsell Color. 1976. Munsell Book of Color. Baltimore: Munsell Color MacBeth, A division of Kollmorgen Corporation.

Savaton, Pierre. 2005. "Cartes géologiques historiques de France." Downloaded 13 February 2011 from "HistMap: réseau européen pour l'histoire des cartes géologiques" at URL: http://www.hstl.crhst.cnrs.fr/i-corpus/histmap/cartesgeologiquesfrance/index.php

X-Rite. 2011a. "X-Rite Capsure portable color measurement tool." Downloaded 13 February 2011 from URL: http://www.xrite.com/documents/literature/en/L3-208_CAPSURE_Paint-A4_en.pdf

X-Rite. 2011b. "i1Basic affordable, professional spectral color measurement." Downloaded 14 February 2-11 from URL: http://www.xrite.com/product_overview.aspx?ID=1161