cartographic ⊕ perspectives

cartographic Φ *perspectives*

in this issue

Letter from the Editor

Dear Members of NACIS,

I am happy to report that with the publication of this issue, *CP47*, *Cartographic Perspectives* is back on publication schedule! That is probably news big enough to end this column on…but I will forge ahead never the less.

To ensure new ideas and a vibrant, thriving journal, I have assembled a very diverse editorial board for 2004 through 2006. I would like to dedicate some space in this column to introduce to you both new and returning members of *CP*'s editorial board. First off, *CP* welcomes the following five members: *Michael Leitner* from the Department of Geography and Anthropology at Louisiana State University; *Nadine Schuurman* from the Department of Geography at Simon Fraser University; *Erik Steiner* from the InfoGraphics Lab at the University of Oregon; *Dan Van Dorn* from Map Link in Santa Barbara; *Denis Wood* who is an

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about the cover
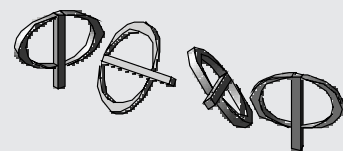
The cover image was created by Matt Knutzen, artist, cartographer and Assistant Chief Librarian of the Map Division of the New York Public Library.

Independent Scholar in Raleigh, NC. *CP* also welcomes back the following nine people, eight who are returning for a second term on *CP*'s editorial board: *Sara Fabrikant* from the Department of Geography at University of California in Santa Barbara; *Ken Foote* from the Department of Geography at the University of Colorado at Boulder; *Pat Gilmartin* from the Department of Geography at the University of South Carolina; *John B. Krygier* from the Department of Geology and Geography at Ohio Wesleyan; *Robert Lloyd* from the Department of Geography at the University of South Carolina; *Jan Mersey* from the Department of Geography at the University of Guelph; *Elisabeth S. Nelson* from the Department of Geography at the University of North Carolina in Greensboro; *Margaret Pearce* from the Department of Geography at Western Michigan University; *Ren Vasiliev* (serving a 3rd term) from the Department of Geography at the State University of New York, College at Geneseo. I very much look forward to working with is talented group of carto-geographers.

This issue of *CP* also marks a change in three section editors, as well as changes in two sections of *CP*. First off, CP welcomes *Chris Mixon* from Auburn University Libraries as the new **Map Library Bulletin Board Editor**. Chris has some great ideas for this section, so expect to see some new directions in this column. The **Essay Section** of *CP* is transmogrifying into the **Opinion Column**, which will be-

come an occasional piece in *CP*. Matt McGranaghan is stepping down as editor of this column and is moving on to more surf and sun in his life. Thank you Matt for your time and energies! Lastly, Jeremy Crampton has decided to step down as section editor for the **On-Line Mapping** column. After much discussion in Jacksonville, it was decided that this section would no longer be a separate theme in *CP*, but instead would be integrated into the other parts of *CP*. I want to extend special thanks to Jeremy for his foresight in bringing on-line mapping issues center stage, and for facilitating some great debates and research in this area.

As outlined in the last issue of *CP*, and now in this issue, *Cartographic Perspectives* has certainly experienced many changes in the past couple of years. These changes, I believe, make *CP* more than just a solid contribution to the cartographic literature. These changes are enhancing a unique publication that makes it possible for all members of our diverse cartographic community to have a voice… to put our thoughts and ideas out there for debate…to illustrate our diverse cartographies that coalesce to form this community we call the North American Cartographic Information Society…in color, if we choose.

So what's up for this year? This issue of *CP* is born in part from papers that were presented at the 2003 NACIS meeting and during Practical Cartography

Day in Jacksonville, FL. The lead off paper in this issue is Judy Olson's plenary titled *Cartography 2003.* Judy summarizes for us where she thinks cartography has been, where is it now, and some of the things we are likely to see in the future. Next is a paper by Tom Patterson and Nathaniel Kelso titled *Hal Shelton Revisited: Designing and Producing Natural-Color Maps with Satellite Land Cover Data*. This paper was part of the Practical Cartography Day, and provides a wonderful account of the work of Hal Sheldon, and its impact on visualizing satellite data. Last is a paper by Bob Churchill titled *Mapping September 11, 2001: Cartographic Narrative in the Print Media*. This paper shows how maps were used in the media to report on the terrorist attacks of 9-11. The Techniques Column in this issue has a piece by Nate Case that was also presented as part of Practical Cartography Day. This paper provides many tips for successful duplication of small type, screens and color in a PostScript offset printing environment.

The next issue of *CP*, #48, is a theme issue that will feature three papers on maps made by First Nations Peoples (i.e., indigenous cartographies) as well as a preface by G. Malcolm Lewis. The final issue for 2004, CP49 is taking shape at this time and will have papers on metadata for maps, and on representing confidential information on maps.

As always, I welcome any thoughts, ideas, or compliments you may have for Cartographic Perspectives.

Warmest Regards,

Scott Freundschuh, Editor

Cartography 2003

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Note from the Editor: This material was first presented at the NACIS banquet Plenary, October 10, 2003, in Jacksonville, FL.

Cartography 2003 is a rich and awesome topic. I am presenting here a sort of potpourri of topics and images that characterize the field in 2003. Not everything that is referred to is strictly from this year, but then, not everything we are or see today was invented or even updated in 2003!

My comments are in five parts: *enduring content* (that is, the stuff of the discipline that "stays with us" and is not new to the field in 2003), *the definition of cartography* (some general observations about how it has shifted over the years rather than any attempt at an airtight definition), *maps today* (which does distinguish contemporary cartography from earlier years), *ICC 2003* (a few comments about the International Cartographic Conference 2003 because it was indeed an event of this year and a significant one), and finally a few words about *where from here* (one modest observation in the grand scheme of where things might go from here that may be worth sharing).

"Cartography 2003 is a rich and awesome topic."

Everyone in cartography knows that it is a constantly changing discipline. I remember a white-haired, but definitely not old, British colleague, Harold Fullard, once commenting that he had lived from the Stone Age to the computer age. What he meant, of course, was that he started out in cartography when limestone lithographic printing plates were still around and he was still in the business as computers were becoming the tools for making and even displaying maps. People in my general age group have lived from SYMAP, that first user-oriented mapping program, to palm tops, map-bearing cell phones, and ubiquitous mapmaking -- or at least more or less ubiquitous map access.

". . . cartography . . . is . . . constantly changing . . ."

In its ever-changing condition, some components of cartography simply go away. Color separation techniques such as scribing and peelcoats are gone, as is the construction of projections from tables and formulas, a cartographic activity that is far more likely to elicit groans than nostalgic comments from those who remember. But those are technical things; we expect that principles are more enduring, and they are. The principles of matching symbol dimensions with data characteristics, choosing mapping methods, and manipulating data in sound ways for display are still largely associated with the term cartography. Certainly presentation mapping is in the bailiwick of the discipline, as is map design, at least if it is considered explicitly. Map projections, even since the post renaissance splitting of disciplines, have never been exclusively cartographic territory, but choosing them has been with us for many decades. Map appreciation, by which we are generally referring to knowledge about maps as opposed to skill in making maps, is also a part of cartography.

". . . the definition of the field has changed . . ."

This list of components is not exhaustive, but I mention these things because the definition of the field has changed and there are also things cartography no longer owns. It might be helpful to consider the very simple definition of cartography that I generally use in talking to my lower-level class about what it means. I say that, in simplest terms, cartography is "the body of knowledge about maps." This definition is short and it expresses cartography as an intellectual discipline rather than a skill or technique or

the activity of mapmaking. There are indeed skills and techniques that are part of cartography and we do make maps, but it is the head full of knowledge that skilled people bring to the execution of maps that makes them good at what they do. And there are theoreticians of cartography as well as practitioners, and intellectually they have a lot in common. It used to be, however, that just about anything to do with maps was called cartography. That has changed in recent decades. We now share a lot of territory with GIS and (geo)visualization.

This sharing of territory brings up the question of whether cartography is dead. Mapping certainly is not, and a rose by any other name is still a rose. There is, in fact, a lot of exciting mapping going on these days, and there is a lot of knowledge about maps as well, spread over more people, not fewer. Michael Goodchild has stated that cartography (as a discipline) is being marginalized (Goodchild, 2000). We can hardly deny that. In higher education there are fewer and fewer courses labeled cartography, and at my institution, at least, when we put such a label on the class, few sign up. We also find evidence when we look at the jobs being advertised in geography. A few years ago, I tracked the advertisements for positions in Jobs in Geography, published by the Association of American Geographers (AAG, various dates). The results are shown in Figures 1 and 2. These are primarily academic jobs, not all jobs associated with cartography, but they reflect what is going on in the incubators for cartographers.

The years covered were from 1981-82 through 1996-97. Figure 1 shows all new postings (top line) and the ones referring to cartography, GIS, and remote sensing. The total for all three of those areas is the highest of four lower lines, but it is not the addition of the separate numbers because many ads mentioned more than one of these areas. They are counted for each of the individual categories mentioned (the three lowest lines) but only once for the line representing all of three of them. The three areas accounted for a substantial portion of all ads, especially in the '90s. Individually, cartography peaked in '84-85, declined, and leveled out; GIS rose from first entries to the dominant of the three; and remote sensing remained relatively flat.

Figure 2 shows the proportion of all jobs mentioning any of these areas, and the shifting dominance is even more pronounced. Cartography declines, GIS rises, remote sensing fluctuates and levels off.

"We now share a lot of territory with GIS and (geo)visualization."

". . . cartography [jobs] peaked in '84-85 . . ."
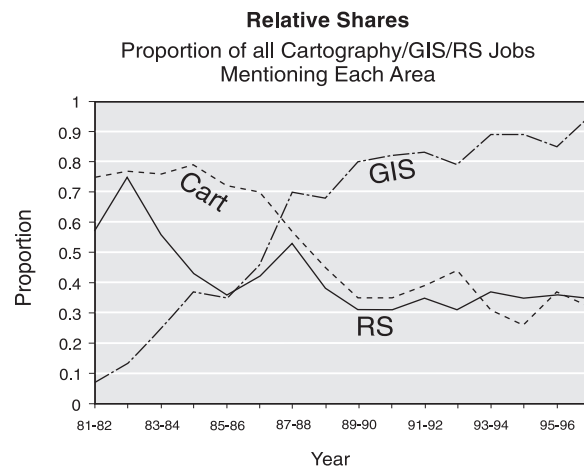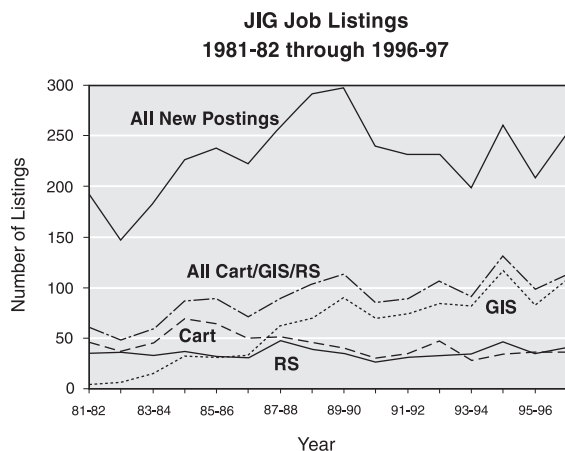
Figure 1. Jobs in Geography *(JIG) job listings, 1981-82 through 1996-97. The top line indicates the total number of new postings, the next one the number of ads mentioning cartography, GIS, and/or remote sensing. The remaining three lines indicate the numbers for each of cartography, GIS, and remote sensing; an ad mentioning more than one is counted in more than one line. Source: AAG, various dates. Acknowledgement: Amy Lobben assisted in the compilation.*

Figure 2. Relative shares. The values in Figure 1 are converted to proportion of all cartography, GIS, and remote sensing listings. Values do not add to 100% because some ads list more than one of these areas.

I was going to update this set of data to take the graphs through 2003, but that is not a straightforward thing to do. I recall that some of the ads in the time period of the graphs mentioned terms that were not explicitly geographic information systems, cartography, or remote sensing, and I may even have forgotten how complicated the vocabulary was. But here is some of the phrasing in 2002-2003:

> Geographic Information Science…with a focus on visualization or
>   health applications. (AAG, 38:7, p. 27)
> Digital Technology and Communication (35:7, p.22)
> Spatial Data Laboratory Supervisor/Instructor (38:7, p. 27)
> Society and Information Technology (35:7, p. 22)
> Assistant Professor GIS/Remote Sensing, PhD in forestry or related
>   discipline. (38:7, p. 27)
> Postgraduate Researcher..(diseases; fieldwork)…. A Bachelor's Degree
>   in economics…preferred…knowledge of GIS and image analysis and
>   spatio-temporal model(ing)…. (38:6, p. 18)

"The lexicon . . . has changed in recent years."

The lexicon, it seems, has changed in recent years. Yes, cartography does still appear in some of the job ads, as does GIS and certainly remote sensing, but many of the traditional terms have been replaced with new ones, reflecting new ways of looking at how geography is subdivided, and, more accurately, at the way departments are looking at the packages of knowledge and skills wanted in individual faculty members. The old terms (including GIS) do not have the cache they did a few years ago.

Whether all this is good or bad is open to interpretation. The relative number of new PhDs and new faculty members who identify explicitly with cartography dropped drastically enough in the '90s that it showed up as an age gap—a degree age gap that is, the length of time since someone completed their terminal degree. When the U.S. National Committee for ICA (International Cartographic Association; see ICA, 1999 and USNC, 2003) solicited applicants for travel funding to the International Cartographic Conference-Beijing 2001, the old guard, that is, those with older PhDs, were interested in going to the Conference, as were a cadre of young graduate students and assistant professors who might think of themselves as associated with GIScience, visualization, or cartography. But the mid-career applicants were largely missing—noticeably enough that for the next ICC (Durban, August, 2003), NSF granted funds not only for young scholars (as they have in the past) but to support a few mid-career cartographic scholars as well. Unfortunately, we could not get enough of them to Durban to use up the funds so allocated. Finding young scholars was no problem. Cartography might have become a marginalized term in recent years, but people are recognizing the common mapping interests among a variety of labels, and we are becoming comfortable with defining ourselves with multiple labels. Cartographer, GIScience person, visualization scientist, planner with interests in mapping and spatial data—we probably all have some combination of such labels at this point.

" . . . we probably all have some combination of . . . labels at this point."

Though the changing definition is important, and the jobs data are interesting, there are many more things going on in cartography and they are of far broader interest and visibility. Here are some examples of trends that characterize what is going on in the field at the moment, in other words, that characterize what has grown out of the recent history of the discipline. (1) Cartographic visualization and the use of maps for discovery has definitely come into its own and is inspiring a considerable

amount of the research at this point. Research on presentation maps, on the other hand, is far less prominent than it once was. (2) Cartographic critique, the application of critical theory within the discipline, is a prominent part of our literature and thinking. Brian Harley's (1989) seminal article is now but one of many examples as cartographers and critics have followed his lead. (3) "Publication" is now as likely to mean that something is being put onto the Web or onto some other digital medium, as it is to mean that it is being put into print. (4) Mapmakers have shifted to "almost anyone", although some of the "mapmaking" is a lot more like ordering a map than making one. (5) Agencies traditionally associated with the production of maps are now far more involved in producing and delivering data. *The National Map* might be considered a case in point for delivering data but actually takes us a step further. It is the digital replacement of our very aging topographic map series in the U.S. and is not just a large database coming from an agency, but is envisioned as "public domain core geographic data…that other agencies can extend, enhance, and reference as they concentrate on maintaining other data that are unique to their needs." (USGS, 2003-11-06). In other words, cartographic conceptualization is serving up infrastructure and is not simply delivering a set of data, much less producing a map in the traditional sense.

As we are making these transitions in our cartographic ways, we can point to many products and practices that give us more concrete images of cartography in 2003. Again I am being selective, but notice how these are knitted into the broad social context, and are not internal matters in our profession.

Anyone with an Internet connection can now get detailed location maps, and such products as the ones generated on <www.mapquest.com> are good examples of how people "order" maps instead of make them. One can change scale and location and a few other things but one does not need to make a whole lot of cartographic decisions. And when we have our (Mapquest™) map up on the screen, we can click on the air photo tab and see what the area looks like from that perspective.

In 2003, we take for granted the ability to find public domain reference maps on the web. A good example of a site with such maps is as *The World Factbook* (CIA, 2003). Figure 3 shows the CIA's map of Azerbaijan. With a reasonable printer we can produce our own paper copy and it will generally exceed the quality of anything we produced on the copy machine using the library's copy.

We can also use Google™ or other search engines to find most any place, including, say, a remote game reserve in Africa, and find just where it is. Last summer, for example, I found a map of South Africa showing Phinda, a private game reserve in South Africa, to share with member of my family curious as to where I was going on my way to the International Cartographic Conference in Durban.

In 2003 we can probably find out more about some stranger's property than most of us would think appropriate. Cabarrus County (2001), in North Carolina, for example, has a website that shows property configuration (Figure 4), and by clicking on the property we can find out who owns it, when they bought it, how much they paid, and various other pieces of information. On some property map websites, we can even pull up a map of the resident's polling place if we want to know where they vote. Fortunately, law protects their ballots! On some of these sites, the property maps come with background air photos. All of this information has long been "public" in the U.S., but why everyone in the world with an Internet connection should have such convenient and instant access to it is an appropriate question to ask. Cartography and related disciplines in

Figure 3. A public domain reference map of Azerbaijan. Source: CIA Factbook, 2003. (see page 65 for color version)
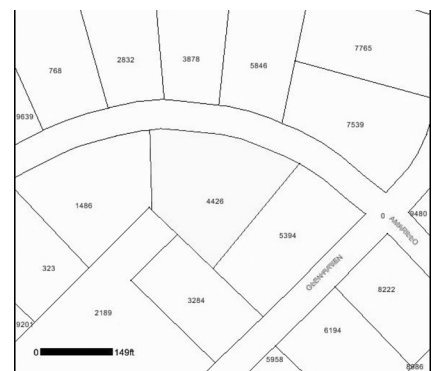

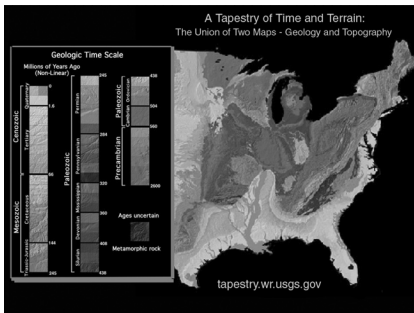*Figure 4. A property map on the web. Source: Cabarrus County, 2001. (see page 65 for color version)*

Figure 5. Excerpts from "A Tapestry of Time and Terrain." Image has been rearranged for this illustration. Source: Vigil et al., 2003. (see page 65 for color version)
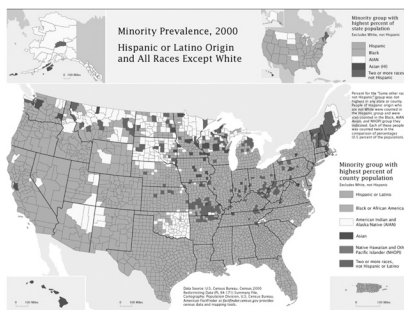

Figure 6. A map from *Mapping Census 2000*. Source: Brewer and Suchan, 2001. (see page 65 for color version)

2003 have some serious issues related to privacy and the balance between individual and public good (Curry, 1999).

As an example of the beauty and flexibility of modern mapping, **"**A Tapestry of Time and Terrain" (Vigil *et al.*, 2003) serves very well, even if it has been on the Internet for a few years now. A combination of the King and Beikman (1974) geologic map of the US and the Thelin and Pike (1991) landforms map, it is a stunning visual piece (Figure 5). Anyone with enough memory chips, a high quality printer, and a connection to the Internet can have a copy of it. Having helped a local theatre recently to decorate its stage and lobby for a production of *Lonely Planet* (Dietz, 1994), the play about AIDS that is set in a map store, I was especially interested to watch people during the intermission reacting to the patterns on this artful but reekingly-scientific map, which we had posted in the lobby.

After a dearth of thematic maps with the 1990 Census, we can now go onto the web and find *Mapping Census 2000* (Brewer and Suchan, 2001) (Figure 6), and we can print out high-quality copies on our local color printer. As an instructor in classes, it is refreshing to be able to print out multiple copies of high-quality maps of census data for students to use in class exercises and exams. The way in which we approach the teaching of map-related courses is, in fact, worlds away from a decade ago, in part because of the maps we can access, not just because we have different facilities for making maps.

And speaking of teaching, there are downloadable tools and materials on the web such as those from John Carnes's site on utilizing map grids (Carnes, 2002). His grid for zeroing in on UTM locations on topographic maps is a very useful tool for getting across to students the fundamental reason for using rectangular coordinate systems—convenience and speed. This little grid fits any one-km grid cell printed on any 1:24,000 topographic map in the US that is on the UTM projection (Figure 7), and the search-and-rescue mission example that Carnes uses to demonstrate the point is a captivating application and readily available.

We also have tools on the Internet for making maps rather than reading them. That sticky problem of selecting colors for maps is eased with ColorBrewer, with which one can select a reasonable set of colors with a few mouse clicks (Brewer, 2002). Select, say, 5 classes and her colorful red-yellow-blue scheme as illustrated in Figure 8, and the user can see it on the prototype map, learn that it should be fine for folks with color
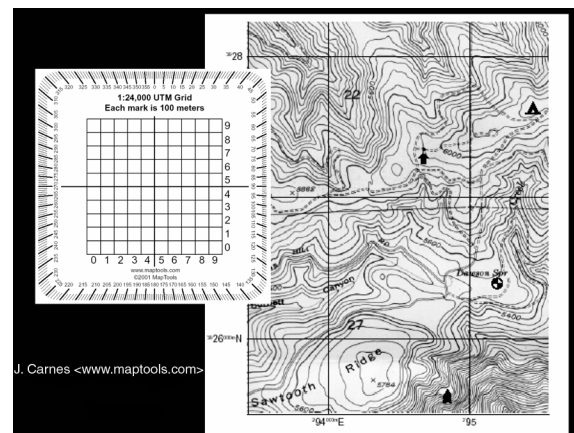

Figure 7. The location grid and example excerpt from a topographic map. The grid can be printed on transparent medium and placed over the map. Source: Carnes, 2002. Used with permission.

impaired vision (the eye icon, left column in lower left frame of the web page), will not photocopy well (second icon), will be fine on an LCD projector, laptop, or CRT (third to fifth icons), and might give problems on a color printer (sixth icon). Further, the user can display the specifications that should be used to print it with process colors or to display it on the computer screen with various software in common use by people making maps.

Animation has become a part of the arsenal of techniques in cartography, and Jill Hallden's population change in the U.S. is a fascinating example (Hallden, 1997; Hallden, 1999). It shows the progression of population across the U.S. from 1790 to 1960 and can be played through at a constant rate or one can click on the year of interest. Figure 9 shows the map image for 1910.

As to recent developments that are guaranteed to wow us, we only have to go to David Rumsey's website and look at the flyby over Yosemite Valley as depicted on an historical map draped on a digital elevation model (Rumsey, 2003) (Figure 10). Flying over an historic landscape is an experience indeed.

The wonders of modern technology are also mind boggling in the new Shuttle Radar Topography Mission results (USGS, 2003-09-25; JPL, 2003). In just 11 days in February 2000, this mission gathered elevation data for nearly 80% of Earth's land area. An example product is shown in Figure 11. Think of all the effort that went into collecting and mapping elevation since the inception of such elevation measurement and what early topographic surveyors would say if they knew about this 11-day mission! The form of land in areas where landform maps have never been made can now be portrayed with remarkable detail. In a similar category of wonderment is LIDAR, another radar technology that can be used to map even building form (TerraPoint, 2000).

Current cartography is also represented in the maps that win awards at the International Cartographic Association's map exhibit. Hundreds of current products are on display during the ICA's biennial conference, and in August of 2003, two of the awards went to U.S. mapmakers. NOAA won in the mapping-with-satellite-imaging category for their global coverage of nighttime lights (NOAA, 2000), a compilation of images based on data from the Defense Meteorological Satellite Program. Visitors to their website can interactively access the nighttime lights map of each continent. Figure 12 shows an easily recognized excerpt from the North America map.

The other U.S. award was in the CD/DVD category and went to Jim Meacham and Erik Steiner for the electronic version of the *Atlas of Oregon* (Meacham and Steiner, 2002). The still image in Figure 13 only hints at the nature and quality of their CD-Rom, which represents the state of the art of this type of medium. It has time sequences, rollovers, and flexible access; and it combines these interactive features with superb attention to the traditional aspects of maps such as color selections and mapping methods.

Anything entitled "Cartography 2003" must also address the matter of ICC 2003 (International Cartographic Conference and General Assembly) held in August of 2003 with a few points about its significance. It was the 21st such conference, and for the first time in its history was held on the continent of Africa. ICA met in Durban, South Africa, and as you can imagine, now that multiculturalism is the local theme instead of apartheid, the complexion of the conference was quite different from past ones. ICA elected its first Black African vice president (one of 7 vice presidents, elected every 4 years), Kenyan Haggai Nyapola. And a sort of mini confer-
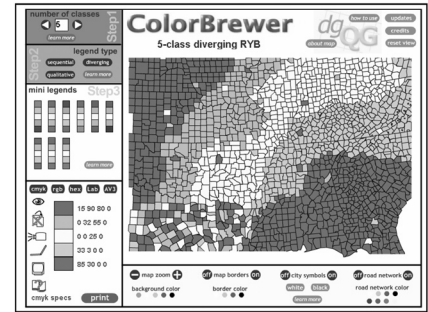
Figure 8. The layout of a Colorbrewer page. A diverging 5-class scheme is illustrated here. Source: Brewer, 2002. Used with permission. (see page 66 for color version)

Figure 9. The 1910 population image in Jill Hallden Harsha's U.S. population animation. Used with permission. (see page 66 for color version)

http://www.davidrumsey.com/GIS/3d.htm
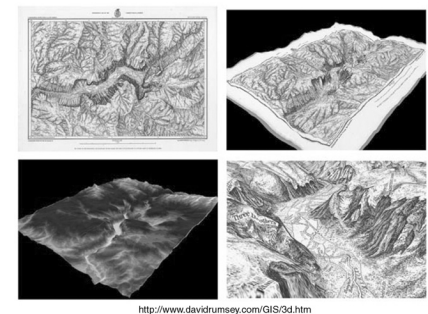
Figure 10. An historical map of Yosemite Valley, the current-day digital elevation model (DEM) of the same area, and the historical map draped over the DEM. The image in the lower right is a scene as one flies over the area. Source: Rumsey, 2003. Used with permission. (see page 66 for color version)
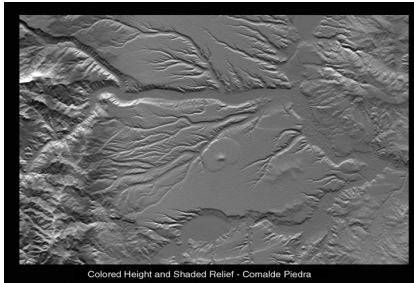
Figure 11. An image created from Shuttle Radar Topography Mission data. Source: JPL, 2003. (see page 66 for color version)

Figure 12. The southeastern U.S. excerpted from the North America segment of Nighttime Lights of the World. Source: NOAA, 2000.
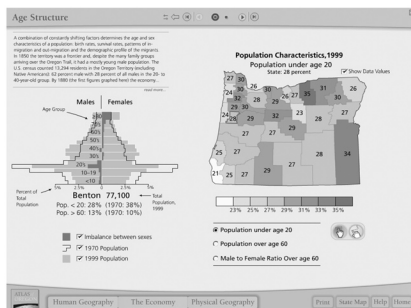
Figure 13. A screen capture of a page in the interactive Atlas of Oregon. Used with permission. Source: Atlas of Oregon CD-ROM, Copyright 2002, University of Oregon Press. (see page 66 for color version)

"ICC Durban is likely to go down in history as a highly significant event."

"[we need to] work [cartography] into other courses."

ence within the event resulted in something called the Durban Statement on Mapping Africa for Africans (GOOS, 2003), with a working group formed to continue the efforts started with that document. ICA has long had a policy of supporting developing nations, but the relationship took a very positive turn with the Durban conference. ICC Durban is likely to go down in history as a highly significant event.

I have referred now to everything from enduring content in the field of cartography to its decline as a recognized academic discipline (at least so far as use of the term in job ads is concerned) to the marvelous access and products that characterize cartography in 2003, which by whatever name(s) is a thriving enterprise. Much of the content has concerned the "whiz-bang" side of the field, but there are many things that could be described as such and they serve as the icons of current cartography and the benchmarks to be bettered in the future.

In looking to the future, however, I will not try to describe what the icons will be. Rather I will return to academia for a moment. Cartography is being done and we might say more and more of it is being done, but as an explicit topic of courses it seems to be appearing less and less. I began to realize recently that it is very much in the position that geography was in within the K-12 school system for many years. Geography was absorbed into social studies in much the same way cartography (and even GIS) are absorbed into geographic information science, visualization, and other descriptors. Cartography may be making somewhat of a comeback; I find my fellow GIS instructors at MSU anyway actually wanting cartographers to teach more cartography. But we are not going to return soon to the identity and acceptability that we enjoyed in the early to mid '80s. What happens, then, to the subject matter, the content of cartography? Do cartographic principles simply go by the wayside, to be rediscovered from time to time? I suspect that one step we need to take is to be creative and work it into other courses. Some of it is already taught that way, but not always very well. To take the step of increasing the quantity and quality of its teaching in other courses is not necessarily "giving up" on raising interest in more explicitly cartographic courses. It *could* just help to spur interest. GIS is being included across the curriculum and perhaps we need to include more cartography across the curriculum as well--in physical and cultural courses, in GIS and GISci, in regional geography, and perhaps even in related other departments such as geology, resource development,

soil science, and fisheries and wildlife. The entire educational model is changing anyway toward increased online and distance learning and mixed models of classroom and online learning. Cartography, like other areas, is adapting. Some good thinking into the sharing of materials, exercises, and ideas in new and creative ways is much in order in this transition.

There are ways to involve both academics and practitioners in making such adjustments. Practitioners have a tremendous store of knowledge and skill that academics have no time to acquire. As modules are produced for distance learning and mixed classroom/online learning courses, perhaps we all have an opportunity.

To wrap up, I am both impressed with Cartography in 2003 and concerned about where we go from here. I will close simply by stating my opinion that NACIS has certainly grown to be one of the most important organizations facilitating the discipline and I expect it to continue its innovative and resourceful ways as we move forward toward Cartography 2004 and beyond.

". . . we move forward toward Cartography 2004 and beyond."

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Mapping September 11, 2001: Cartographic Narrative in the Print Media

T he attacks of September 11, 2001 on the World Trade Center and the Pentagon were unprecedented in scope if not in their fundamental nature. While the United States moved toward resurrection of Reagan's Strategic Defense Initiative, known popularly as "Star Wars", and focused its resources on sophisticated weaponry, terrorists with primitive weapons turned commercial aircraft into guided missiles. The suddenness and enormity of the events, coupled with the fact that so many people were acquainted with victims of the attacks, created a sense of concern and confusion that was more pervasive and ubiquitous than evoked by either the 1993 bombing of the Trade Center or the 1995 attack on the Murrah Federal Building. In the immediate aftermath, the events of September 11 attracted the sympathies of the entire country, evoked both an outpouring of patriotism and a rhetoric of retribution, and temporarily redefined task saliencies (Wright, 1978) as firefighters and law enforcement officers became heroes of the moment.

The media also assumed a heightened level of importance as people turned to television, the Internet, and print for information and for insight and meaning. On September 11, the *New York Times* recorded over 21 million page views on their site, more than twice the previous record, and a six-month circulation audit by the *Times* following September 11 showed daily gains of approximately 42,000 newspapers (Robinson, 2002). Since the number of maps appearing in the media has grown rapidly with the advent of desktop computing and electronic publishing technologies (Monmonier, 1989; 2001), it is not surprising that much of the story of September 11 has been illustrated with maps. At the very least, these maps offer distinctive insights that help define both the events and the public reaction, but a paradigm shift that emphasizes their textual nature suggests that in addition to illustrating the attacks and the subsequent events, maps cast their own narratives of these events. Our purpose here is to explore these narratives through a systematic examination of maps that appeared in the print media in the period immediately following September 11.

MAPS, MEDIA, POLITICS AND PERCEPTION

Until recently, maps were most often regarded as objective, scientific documents: mirrors of reality to borrow a familiar metaphor (Harley, 1989; Edney, 1993; Thrower, 1996). But with the emergence of critical theory in cartography, there no longer can be any doubt that maps are propositional, that every map is an argument, and that maps shape our "realities" in the same way those realities are influenced by conventional text (Harley 1988; 1989).

In this regard, the influence of popular periodicals in shaping perspectives and points of view has been convincingly demonstrated. Lutz and Collins (1993), for example, explored the impact of *National Geographic* with special emphasis on the publication's photographic

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content. Because, as Sontag (1977:4) noted, "Photographed images do not seem to be statements about the world so much as pieces of it, miniatures of reality …", photographs are profoundly effective in purveying a particular world view. Photographs and maps are different, to be sure, yet as visual forms they may share more similarities than differences, and with digital technologies, the distinction between map and photograph has become blurred. Add to this the fact that contemporary society has become increasingly if not dominantly visual, and the impact of *National Geographic's* photographic reportage in shaping worldview is even more significant.

Moreover, the combined influence of artistic images, photographs, maps, and text almost certainly has a synergistic effect. Schulten (2001) constructs a compelling argument that the American view of the world – "the geographical imagination", in Schulten's words – in the first half of the 20th century was the collective construct of inexpensive and widely available maps, school atlases, and *National Geographic* magazine.

"... the combined influence of artistic images, photographs, maps, and text almost certainly has a synergistic effect."

With an even larger circulation than *National Geographic*, *Readers' Digest* defined the parameters of the cold war for a substantial segment of the American population and in so doing, demonstrated the ability of the print media to define the Other (Sharp, 2000). Similarly, in a comparative content analysis of newspaper reports on Bosnia and Rwanda, Myers, Klak, and Koehl (1996) demonstrated effectively how both rhetoric and maps were used to Other not only Rwanda but, by conflating the entire continent, all of Africa. And defining the Other, of course, is essential in establishing self-identity and as corollary, in promoting nationalism and patriotism.

The structuring if not the very construction of nationalism is dependent on cartographic representation (Anderson, 1991) to the point that it is imperative to ask if nationalism can exist without the map. Maps have been indispensable in efforts to foment nationalism (Herb, 1997) and to assert national hegemony (Edney, 1997). The map was the primary instrument in the creation of both the modern nation of Thailand and in articulating the nation's territory or "geo-body" (Thongchai, 1994). And if the Israeli nation was not created cartographically, then surely the territory was appropriated and consolidated with maps, while those same maps were used to expunge completely the Arab presence (Benvenisti, 2000).

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Perhaps because maps often serve as an icon for state unity and control, the focus in assessing the relation between maps and nationalism most frequently has been on the map as a significant instrument in exercising state hegemony, a form of power knowledge. But in exploring cartographic representations of Mother India, Ramaswamy (2001) offers a convincing argument that geographic perceptions, and the promotion of nationalism, in particular, can originate spontaneously in sources that are not controlled by the state. In a similar vein, Sparke (1998) offered an example of what he referred to as contrapuntal cartographies in which contrasting cartographic voices both reflect and effect views that are quite different yet in some ways complementary. While there can be no doubt that the map historically has been and remains an essential arbiter of political power (Harley, 1989; 1994), it is important to recognize a more subtle reciprocity of sorts in which the map can promote nationalism or state hegemony yet at the same time interrogate the underlying assumptions.

The recursive character of the map more generally – the map as both an agent-shaping viewpoint and simultaneously an expression of viewpoint – is especially worthy of attention in exploring the media maps

that appeared in the aftermath of September 11, 2001. For while these maps help define and articulate the events thereby molding perception of the situation, these very same maps promote particular perspectives and beliefs and values. Of special interest in the case of September 11 is the dynamic of this circularity: the rapidity with which perspectives and beliefs and values shifted in the immediate aftermath. In some sense then, media maps are a nexus of cartography, geographic self-image, and world image.

MAPS IN THE NEWS

In an effort to better understand the reaction to events of September 11 in general and the significance of media maps both in shaping and reflecting the American viewpoint in the weeks that followed, we examined all the maps that appeared in two major newspapers and three news magazines from September 11 through October 15, 2001. The *New York Times* and the *Los Angeles Times* were selected for their stature as major national newspapers. At the same time, because these two papers represent different regions and are acknowledged to have different editorial perspectives, they may provide some insight into the relative unity or diversity of responses politically and geographically.

Based on the assumption that weekly news magazines have time to be somewhat more contemplative and less hurried in their reporting, we also examined the maps in four issues each of *Newsweek*, *Time*, and *U.S. News and World Report* that were published during the same 35-day period. Due in part to greater lead time, the maps in the newsweeklies often tend toward more elaborate compositions that are designed not only to draw the reader into the story but to tell the story graphically and cartographically (Ohlsson, 1988).

While there is a set of objects that nearly everyone would agree is maps, arriving at a formal definition of a map is considerably more difficult (Vasiliev, et al. 1990). The challenge of articulating a working definition is further confounded by growth of electronic print media and consequent melding of artistic renderings, photographs, and satellite imagery with maps. Although it does not provide for unequivocal distinction of what is and is not a map, we are partial to the definition offered by Harley and Woodward (1987, xvi) for its breadth and inclusiveness: "Maps are graphic representations that facilitate a spatial understanding of things, concepts, conditions, processes or events in the human world." Accordingly, in this study, we include conventional maps, satellite images, and cartoons that include maps. We also include what we refer to as map images, i.e. map outlines or figures that are used decoratively or for iconographic purposes.

During the five-week period of the study, a total of 193 maps appeared in the selected publications: 152 maps in the two newspapers, and 41 in the three newsweeklies. As evident from a tabulation of fundamental characteristics (Table 1), maps were used frequently to provide general geographical information, yet nearly an equal number promoted an explicit message or position, most often through combining the map with photographs, artistic imagery, and expository text. Over one-half of the maps were accorded three columns or more, which undoubtedly speaks to the media's appreciation for their power and effectiveness. Not surprisingly, these larger compositions were most often those of an editorial nature, while general maps often were accorded only a single column. The majority of maps addressed two general subjects: attacks on the World Trade Center and the Pentagon and the search for and pros-

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SIZE

One Column	Two Columns	Three or More Columns	Full Page	Double Page
41	54	53	37	8

SCALE[2]

<1:10,000	<1:100,000	<1:1,000,000	<1:10,000,000	<1:100,000,000
44	20	11	28	75

LOCATION

Manhattan	Pentagon	Eastern U.S.	U.S.	Africa/ Middle East	Afghanistan	World	Other
53	11	17	6	29	54	9	12

SUBJECT

Attacks and Recovery	Domestic Security	Search for Suspects in U.S.	International Terrorism	War and Retribution
82	3	12	35	61

TYPE[3]

General/ Reportorial	Editorial/ Expository	Cartoons/ Map Images
92	86	15

SYMBOLOGY

Black-and White	Color
132	61

[1]What constitutes a map is not always obvious. Single compositions sometime involve more than one map: an inset at a different scale, for example, or repetitions of the same base map to show different themes or conditions at different points in time. Such compositions were tallied as one map. We also included satellite images, perspective views, cartoons, and map images used for decorative or iconographic purposes.

[2]For maps published without scale, the scale was determined as accurately as possible. No attempt was made to estimate scale for cartoons and map images used ornamentally.

[3]While use of map images for decorative purposes and in cartoons is apparent, the difference between general maps used in reportorial fashion versus maps used to editorialize or promote particular arguments is far less distinct. In this context, the first category includes maps that simply provide location reference and show accepted features without additional comment or embellishment. The second category includes maps that represent information subject to question or interpretation, compositions that blend maps with photographic imagery and expository text, and maps intended to support a particular storyline rather than giving simple geographic reference.

Table 1. Selected characteristics of maps.[1]

ecution of terrorists in the international arena. These seemingly simple generalizations, however, reflect more subtle temporal trends and transitions among underlying processes.

UNDER ATTACK

In the immediate aftermath of the attacks, the media focused on attempting to make the incredulous believable. The composition that appeared in

the September 12 *New York Times* (Figure 1) is quite representative. Like this one, nearly all of the maps that appeared were large-scale, detailed representations of the target areas, but these maps also reveal a good deal about the general mood of the country. The title alone, "Reclaiming Lower Manhattan" belies a sense of siege, and the map not only reinforces this impression but also delineates its areal extent. Depicted in black at the center of the map, the wreckage of the World Trade Center defines ground zero even before that rhetoric had found its way into the common vernacular. Damaged buildings around this area are depicted in gray, while toward the periphery of the composition undamaged structures are symbolized in white. Likely intended to provide location context, these unshaded symbols help to place bounds around the focus and suggest the visual metaphor of a target. As lines of crippled and disabled transportation infrastructure bound the area but also cut it into fragments, the map further evokes some sense of an open wound. Additional metaphors might be suggested, but what is apparent is that by its scale, focus, and imagery, this map not only documents the devastation but also evokes emotive reactions that color readers' perspectives.

Although large-scale maps of the Trade Center and the Pentagon dominated the initial cartographic coverage, a few smaller scale, regional maps addressed collective representation of the events of September 11. Like the map that appeared in the *Los Angeles Times* entitled "Morning of Terror" (Figure 2), these regional maps showed only the eastern seaboard of the country. While the focus is ostensibly on the geography of the events, what is particularly obvious in this *Times* piece is that the body of the map occupies less than a quarter of the frame. Moreover, the limited portion

"Additional metaphors might be suggested, but what is apparent is that by its scale, focus, and imagery, this map not only documents the devastation but also evokes emotive reactions that color readers' perspectives."
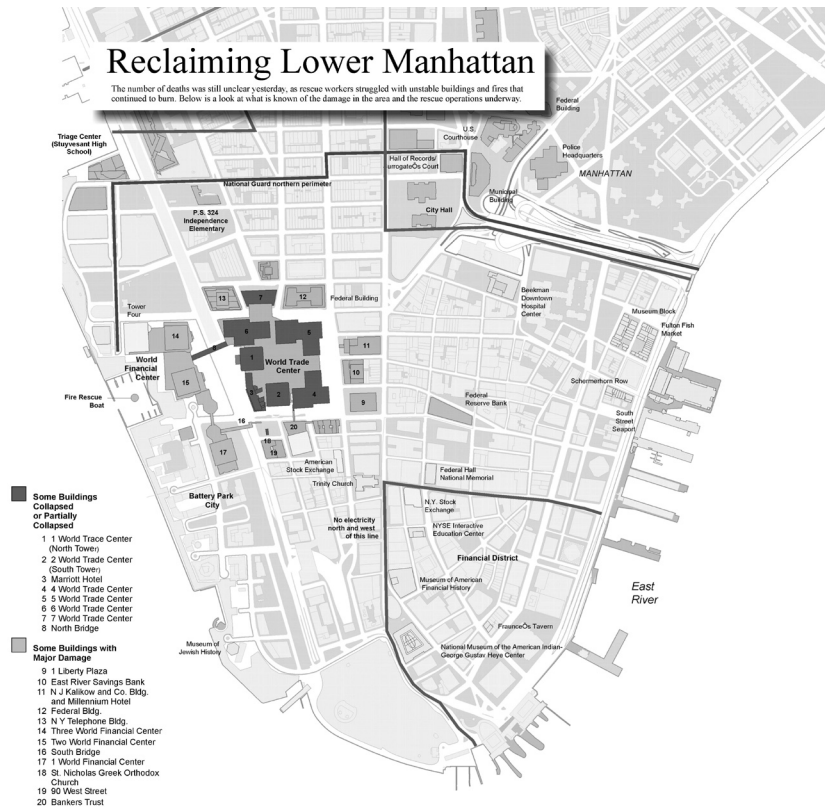

Figure 1. Detail from "Reclaiming Lower Manhattan", New York Times*, 12 September 2001. Copyright 2001,* New York Times*. Reprinted with permission.*

of the country that is depicted is shaded in deep gray and peeks out from the corner quite tentatively. Clearly this map was constructed hastily, and although it almost certainly was not the deliberate intent of the map-maker, it is tempting to suggest that the overall effect is one of ambiguous identity and withdrawal.

This suggestion is reinforced by similar maps that appeared in other publications and by the fact that in the days immediately following September 11, maps and images of the continental United States were almost non-existent, both in the formal reportage and in advertising and ancillary material. On the one hand, this seems logical given that the attacks – both successful and unsuccessful – all occurred along the eastern seaboard. Certainly the distribution of these events did not require a map of the entire country. Yet the absence of maps of the continental United States is made conspicuous given that the outline appears on everything from mud-flaps to advertisements for candy bars (Holmes, 1991) and has become a ubiquitous icon that invokes a sense of belonging and identity if not allegiance and control (Monmonier, 1989; King, 1996).

"The momentary disappearance of the United States map, which is curious at very least, is accentuated by the emphatic reappearance of the map within a week."

The momentary disappearance of the United States map, which is curious at very least, is accentuated by the emphatic reappearance of the map within a week. "One that didn't fall", a cartoon reprinted in the September 17 issue of *Newsweek* (Figure 3), depicts the continental United States as an inviolable skyscraper impervious to dramatic attack. This cartoon heralds not only the return of the U.S. outline to iconographic status, and its reappearance in media maps in general, but the reemergence of the state from its momentary period of retreat and introspection.

THE OTHER

While the devastation in New York and Washington continued to be of interest for some time, within a week the number of maps of domestic areas that appeared in the newspapers dropped markedly, while at the
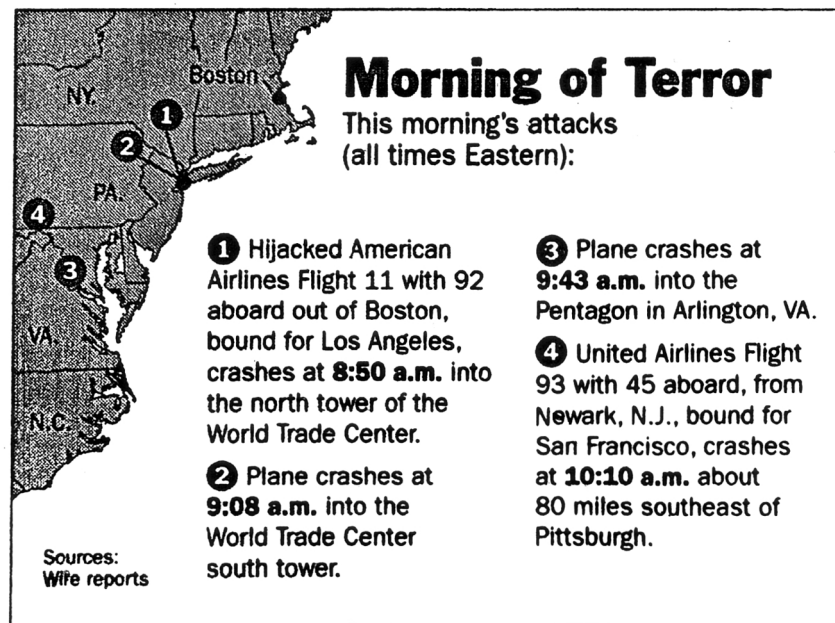
Figure 2. "Morning of Terror", Los Angeles Times, 11 September 2001. Copyright 2001, Los Angeles Times. Reprinted with permission.

Figure 3. "One that Didn't Fall", Dallas Morning News*, reprinted in* Newsweek*, 17 September 2001. Deore copyright 2001* Dallas Morning News*. Reprinted with permission of Universal Press Syndicate. All rights reserved.*

same time, the number of maps of foreign locations, especially maps of Afghanistan, increased noticeably as focus shifted from recovery, both materialistically and emotionally, to identification of the perpetrators and retribution (Figure 4).

Remarkably pliant, Americans' collective geographical cognition and perception can be stretched and reshaped as situations change (Schulten, 2001). Maps arguably serve as important agents in this process. There may be no better example than the way in which Afghanistan emerged as the primary culprit in the September 11 attacks. The need to define an enemy, of course, is not only essential in seeking retribution, but defining the Other is crucial to definition of self (Anderson, 1991). In the case of September 11, the Othering of Afghanistan not only served to reestablish and reassert self identity and integrity of the United States, but to contain the enemy within a geographical border, however tenuous and permeable, which undoubtedly contributed to a greater sense of security.

The *Los Angeles Times* map of September 16 (Figure 5) uses heavy, black ink and piercing callouts to identify a number of potential targets for retaliation, while the key at the bottom of the map attests to the United States' military might. The fact that these targets are identified as entire state entities is especially apparent. The conundrum here, of course, lays in the fact that terrorism is not state based, yet the experience of history demands a geographical container, a discrete entity on the map, in which to confine the enemy. Yet as a cartoon published a few days later (Figure 6) argues, even after state boundaries were used to delineate and contain the terrorist threat, the list was still too broad if not in terms of actual locations of terrorist activity, then in terms of the need to clearly articulate an enemy. Ultimately the necessary container for retribution was conveniently provided by Osama bin Laden's presence in Afghanistan. Also noteworthy here is that in some 35 maps that address international terrorism, Iraq escapes mention altogether. This seems ironic given that early justification for military action in Iraq was based on the premise that the state was harboring al Qaeda operatives and sponsoring terrorism, a claim that has persisted throughout the war and occupation.

"Remarkably pliant, Americans' collective geographical cognition and perception can be stretched and reshaped as situations change."

"Also noteworthy here is that in some 35 maps that address international terrorism, Iraq escapes mention altogether."
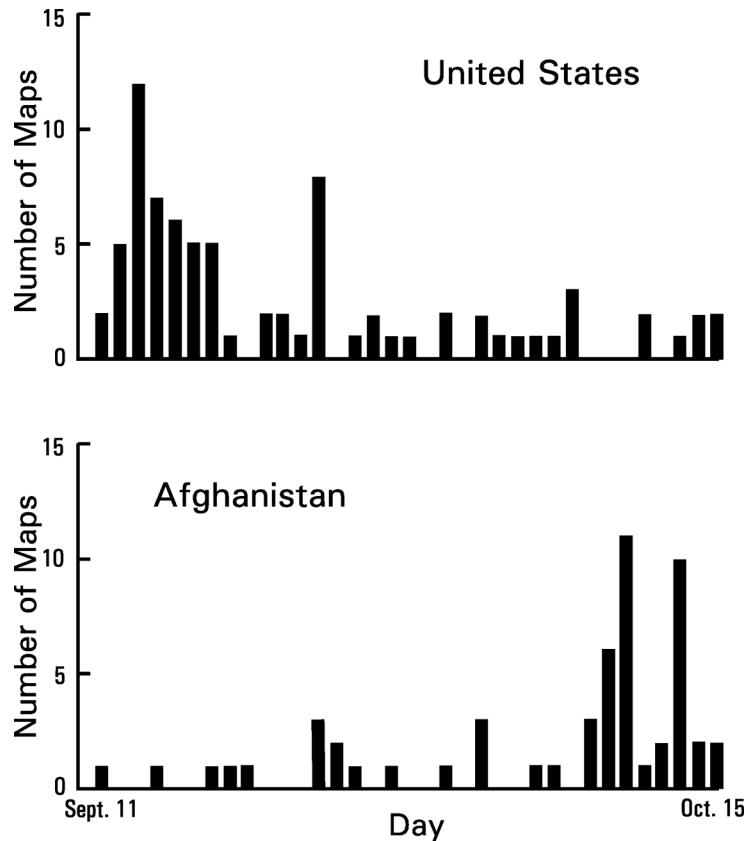
Figure 4. Number of maps published daily by the New York Times *and the* Los Angeles Times *that focused on the United States (top) compared to those that focused on Afghanistan (bottom).*

Time magazine's spread of September 24 (Figure 7) unequivocally identifies Afghanistan as the principal foe. With the map centered on the Mideast, the United States is nowhere to be seen and Europe is masked by the legend, but a number of the same states that appeared in earlier maps – Algeria, Sudan, and Pakistan, in particular – are highlighted in a muted but visually prominent orange. Yet in spite of the content, the title "Osama's World", the flashpoint symbols highlighting terrorist acts, and the extensive text frames detailing bin Laden's particular activities, the visual focus of the map is Afghanistan. Advancing off the page in bright orange, the addition of a magnified view surrounded in black leaves no visual doubt as to Afghanistan's sinister culpability.

By early October, the other suspects literally disappeared from the map. There no longer was any room for cartographic equivocation as to the identity of the enemy. Two maps further demonstrate this point: one from the *New York Times* and one from *Newsweek*. Although stylistically quite different, both are equally definitive and bellicose in tone. The *Times* map (Figure 8) resurrects the polar projection that was so popular during the cold war (Henrikson, 1980; 1991) to show geographical juxtaposition of the United States and Afghanistan. The United States is located at the top of the map, while Afghanistan occupies dead center, if not literally then certainly figuratively, as it is the only state on the entire map distinguished by its boundaries and encircled by radiating lines, ostensibly to show distance and ranges but, perhaps not entirely by coincidence, resembling a bull's eye.

"The Options for Battle" (Figure 9), a composition that is more elaborate yet similar in tone, appeared in *Newsweek* a week later and is some-

"There no longer was any room for cartographic equivocation as to the identity of the enemy."
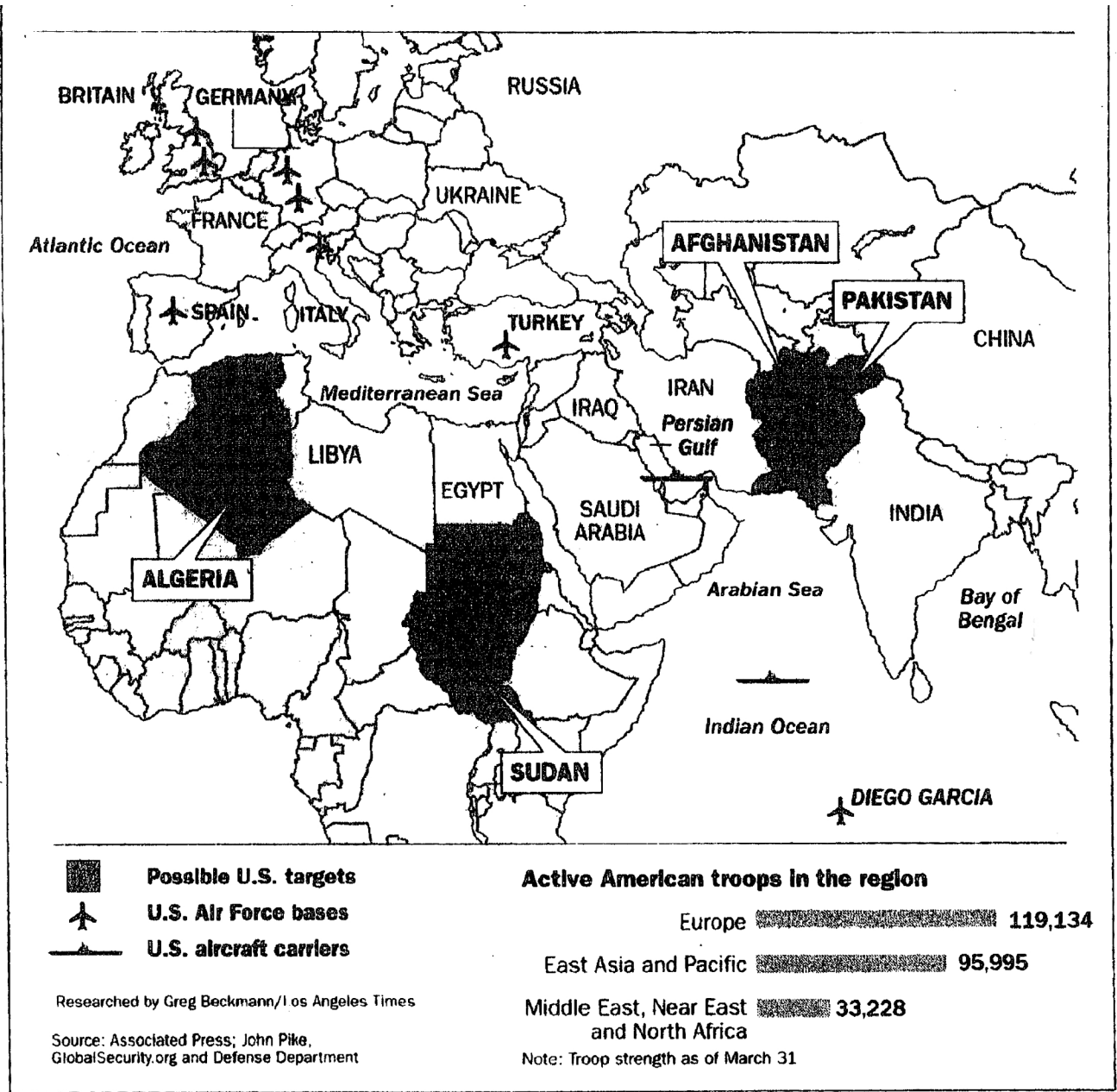
Figure 5. "Potential Launch Points", Los Angeles Times, *16 September 2001. Copyright 2001,* Los Angeles Times. *Reprinted with permission.*

thing of a primer on cartographic representation of force (Monmonier, 1996). Suspended helplessly at the center of the map, Afghanistan is penetrated from every direction by red arrows and completely encircled and contained by boxes that speak with images and text to the strength, resolve, and international scope of retaliation. Like the preceding offering from the *New York Times*, as well as other maps of the period, this composition moves well beyond Othering the enemy to foretell of inevitable defeat. Retribution has been achieved if not in actual fact then in cartographic construct.
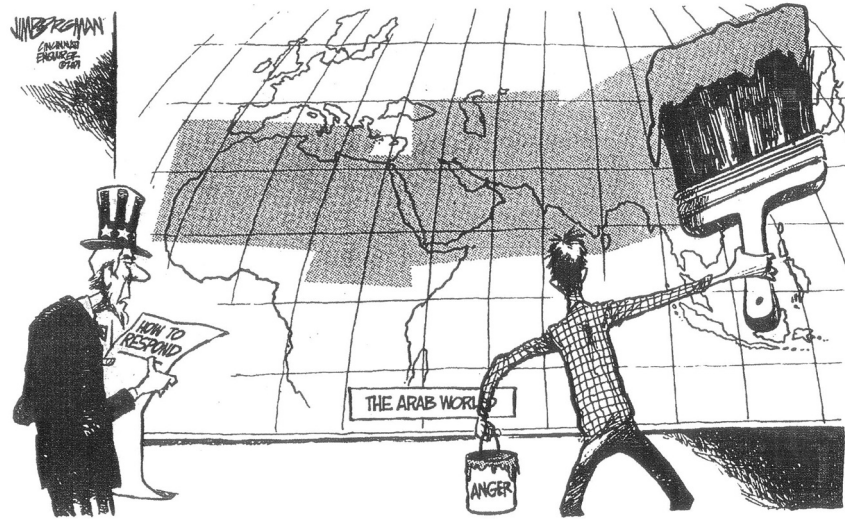
Figure 6. "Your brush is Too Broad", Cincinnati Enquirer, *reprinted in the* Los Angeles Times*, 21 September 2001. Reprinted with special permission of King Features Syndicate.*
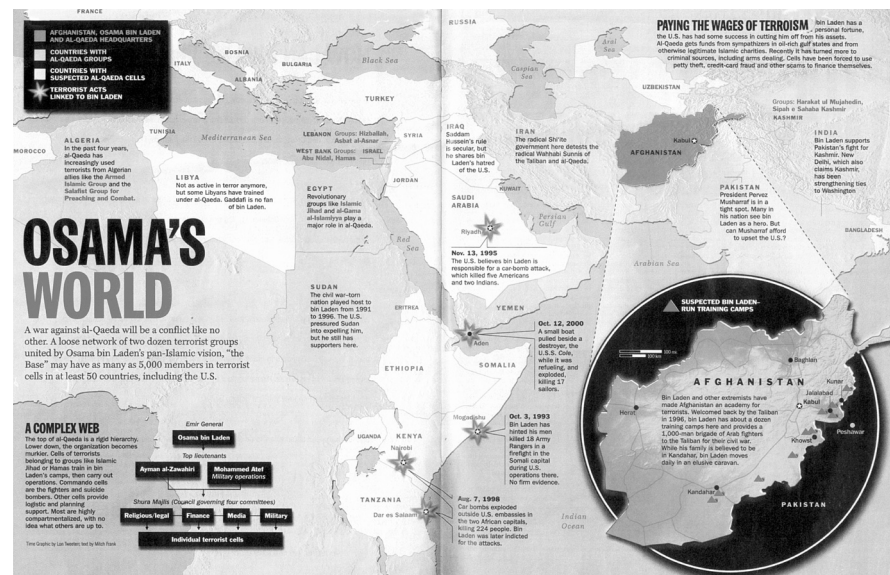
Figure 7. "Osama's World", Time*, 24 September 2001. ©TIME, Inc. Reprinted by permission. (See page 67 for larger color version)*

GATEKEEPERS

Because the public garners its geographic information principally from popular journalism, the media has been described as cartographic gatekeeper (Monmonier, 1989). Even though the inherent subjectivity of atlases and geographic reference works is now well rehearsed (e.g., Black, 1997), media maps tend to be far more expository and far more subjective in character. Maps in newspapers and news magazines depicted the precise location and extent of the September 11 terrorist attacks, but they often did so in ways that were subtly, and sometimes not so subtly, evocative and provocative. Maps articulated locations of terrorists, but they also vilified

The Long Reach

7,000

○ WHITEMAN AIR FORCE
    BASE, MISSOURI

B-2 stealth bombers
flew from Whiteman
Air Force Base,
Missouri, but will
return to Diego Garcia
in the Indian Ocean.

5,000

Two C-17 cargo
planes from
Germany dropped
packets of food and
medicine into
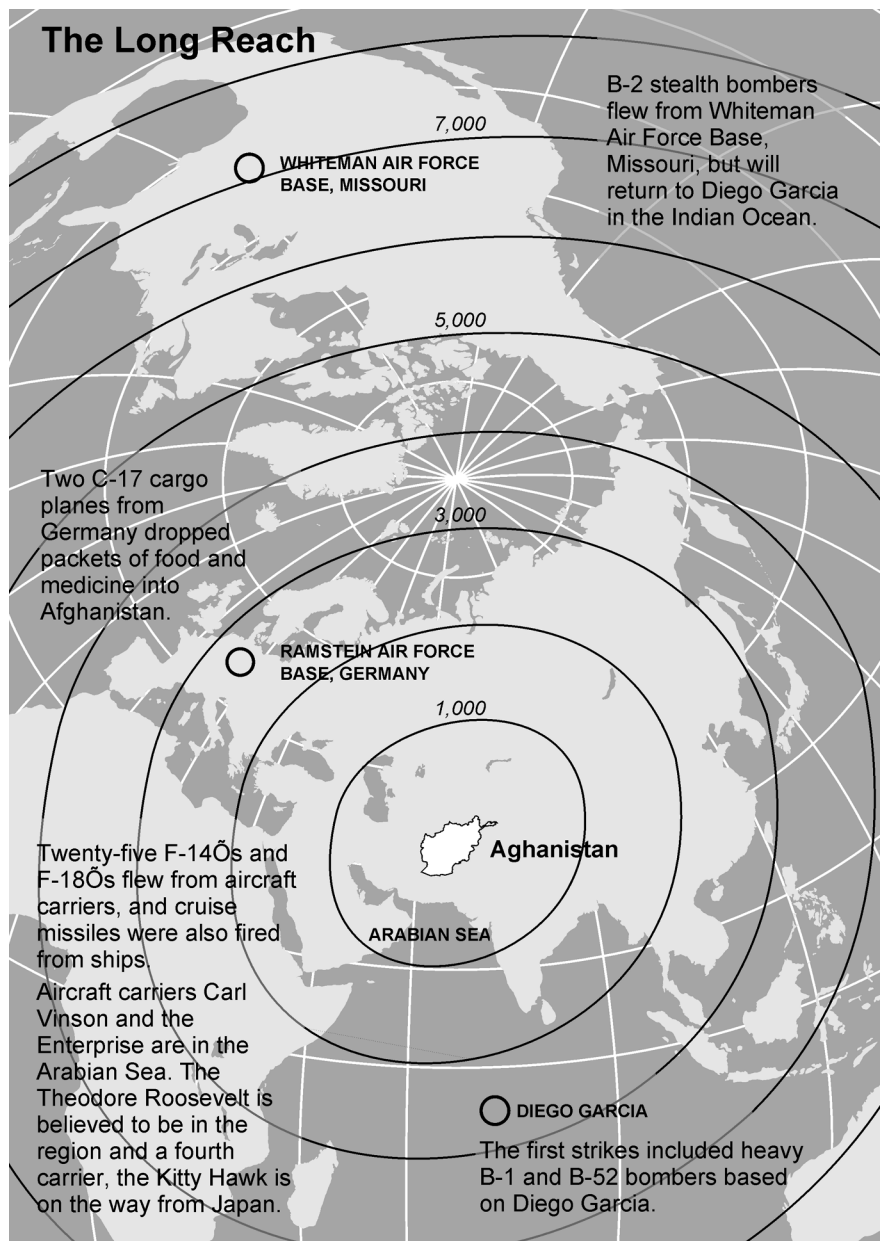Afghanistan.

3,000

○ RAMSTEIN AIR FORCE
    BASE, GERMANY

1,000

Aghanistan

ARABIAN SEA

Twenty-five F-14Õs and
F-18Õs flew from aircraft
carriers, and cruise
missiles were also fired
from ships

Aircraft carriers Carl
Vinson and the
Enterprise are in the
Arabian Sea. The
Theodore Roosevelt is
believed to be in the
region and a fourth
carrier, the Kitty Hawk is
on the way from Japan.

○ DIEGO GARCIA

The first strikes included heavy
B-1 and B-52 bombers based
on Diego Garcia.

Figure 8. "The Long Reach", New York Times, 7 October 2001. Copyright 2001, New York Times. Reprinted with permission.

even if it was first necessary to simplify. Maps detailed the geography of Afghanistan, but they also expressed patriotic fervor and military resolve in ways unlike those found in any reference atlas.

Although the view of the map that took root in the Enlightenment as an objective, scientific, and ever more accurate representation of reality (Edney, 1999) has been recently revised if not rejected by the academy, outside the academy the map continues to be viewed as objective and objectifying. While school children are taught that the written word can be crafted to present any point of view, the map is unassailable. It simply reports factual, geographic information. The visual character of maps reinforces this perception. Whether the map, like the photograph, can be construed as reality rather than as representation of reality, the frequent integration of map not only with conventional photographs but also satellite imag-

"While school children are taught that the written word can be crafted to present any point of view, the map is unassailable. It simply reports factual, geographic information."
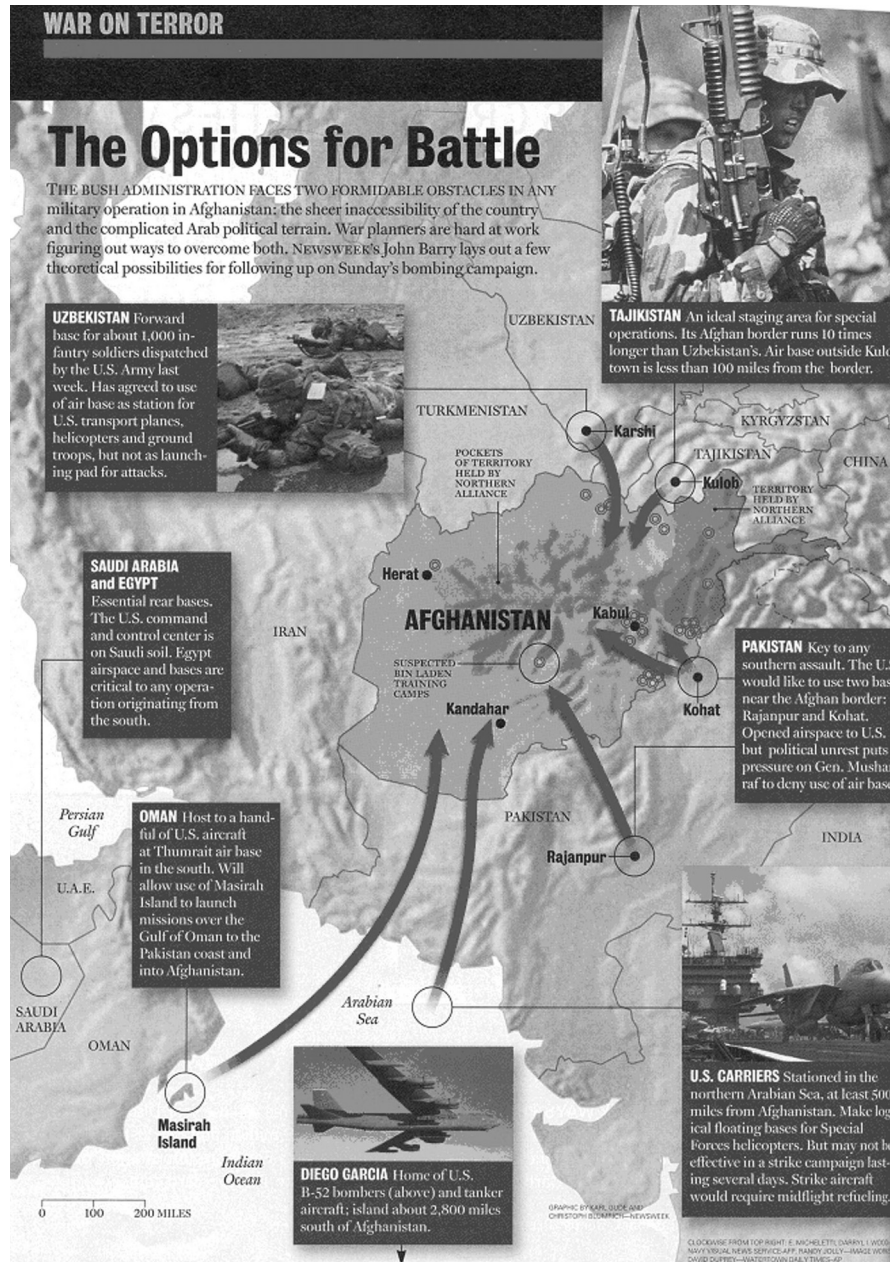
Figure 9. "The Options for Battle", Newsweek, *15 October2001. ©2001 Newsweek, Inc. All rights reserved. Reprinted by permission. (See page 68 for larger color version)*

"While media maps reflect editorial positions, those positions do not exist in isolation."

ery (e.g., Figure 9) obscures the distinction among them and underscores the veracity of the map. A photograph, Sontag (1977) argued, constitutes incontrovertible proof. To many readers, the message of the map is equally incontrovertible. So while the remarkable growth in the number of maps in the media is a direct consequence of technology, the underlying reason for this growth almost certainly lies in the appeal of the map, its effectiveness, and its authority.

Like all maps, those found in newspapers and news magazines reflect the values and viewpoints of their makers: ultimately the journalistic institutions from which they come. While media maps reflect editorial positions, those positions do not exist in isolation. Government, controlling corporate interests, and editorial policies, shape journalistic perspectives

but it also seems likely that they are affected by the social context in which those institutions operate. Media maps then may not only shape public opinion but arguably are influenced, even if tangentially, by that collective opinion. What is more certain is that because all of the controlling forces are fluid, maps document changes in prevailing influences. As the search for those responsible for the September 11 attacks was narrowed to Afghanistan – the "New Ground Zero", to borrow the title from a map that appeared in *Newsweek* – media maps quickly taught the public an unfamiliar geography. And as interest in Afghanistan faded nearly as quickly as it emerged, cartographic focus shifted to Iraq.

Beyond this general dynamic, the interplay among media interests, government position, public perspective, and other forces suggests that media maps often might assume different and even conflicting positions. At one time or in one particular publication, it might be argued, a map may promote the government position but at another time or in a competing publication, cartography may draw that position into question. In this context, what is striking about the maps surrounding September 11 is their remarkable similarity in tone and content across publications recognized for differences in positions and perspectives. There simply are few significant differences in the maps and their messages. Compare again "The Long Reach" (Figure 8) with "The Options for Battle" (Figure 9), for example, or consider that in mid October, all three news magazines published maps of Afghanistan, each somewhat different in design, but all similarly large and forceful and combative in voice. Crisis tends to generate convergence behaviors (Dacy and Kenreuther, 1969). Following the events of September 11, there was geographic convergence of supplies and support in all forms and an even more demonstrative convergence of public opinion. Perhaps it is not surprising then that there also was a convergence of cartographic representations not just of the attacks and recovery but also in the search for perpetrators and demands for retribution. What is less clear is whether the passage of time will give rise to divergent cartographic voices.

"Media maps then may not only shape public opinion but arguably are influenced, even if tangentially, by that collective opinion."

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Hal Shelton Revisited: Designing and Producing Natural-Color Maps with Satellite Land Cover Data

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This paper examines natural-color maps by focusing on the painted map art of Hal Shelton, the person most closely associated with developing the genre during the mid twentieth century. Advocating greater use of natural-color maps by contemporary cartographers, we discuss the advantages of natural-color maps compared to physical maps made with hypsometric tints; why natural-color maps, although admired, have remained comparatively rare; and the inadequacies of using satellite images as substitutes for natural-color maps. Seeking digital solutions, the paper then introduces techniques for designing and producing natural-color maps that are economical and within the skill range of most cartographers. The techniques, which use Adobe Photoshop software and satellite land cover data, yield maps similar in appearance to those made by Shelton, but with improved digital accuracy. Full-color illustrations show examples of Shelton's maps and those produced by digital techniques.

INTRODUCTION

Natural-color maps are some of the most admired physical maps. The combination of land cover colors and shaded relief brings to the printed map a colorized portrait of the landscape that closely approximates what people see in the natural world around them. Green represents forest, beige represents desert, and white represents ice and snow, and so forth. By basing map colors on the colors humans observe everyday in nature, the goal is to create physical maps that, despite their complex content, are easy to understand and more universally accessible to diverse audiences.

A discussion of American natural-color maps by necessity must start with the pioneering work of retired USGS (US Geological Survey) cartographer Hal Shelton for the Jeppesen Map Company during the 1950s and 60s. The first half of this paper offers a retrospective on Shelton's career and cartographic output, which, nearly fifty years later, still stands as some of the finest natural-color maps ever made (Figure 1). That he painted many natural-color maps with the apparent detail and realism of satellite images—years before the launching of the first satellites—is a visualization accomplishment worthy of our attention today.

The second half of the paper fast-forwards to the present day. Drawing upon Shelton's work as inspiration, we examine how to make natural-color maps digitally from raster land cover data derived from satellite imagery. We work with USGS National Land Cover Dataset and MODIS Vegetation Continuous Fields, produced by NASA and the University of Maryland. These two products detect, model, and classify land cover

differently, which in turn affects the use of these data for cartographic presentation. Step-by-step instructions and illustrations show how to create polished natural-color maps from raw data. The design focus is on small-scale continental maps similar to those made by Shelton.

HAL SHELTON AND NATURAL COLOR MAPS

Shelton's development of natural-color mapping evolved over several decades and was not, in his words, "part of a grand design." Nor was his entry into the cartographic profession.

The accidental cartographer

Shelton was born in 1916 in New York State and moved with his family at an early age to southern California, where he grew up. Today he lives in the Rocky Mountain foothills above Denver, Colorado. His cartographic career began in 1938 after he graduated from Pomona College, California, with a degree in scientific illustration. Launching a career during the Great Depression with a background in art posed a challenge for Shelton. The only work that he could find was with a USGS field topography team conducting plane table surveys, starting out as a rod man. Although Shelton enjoyed mapping and working outdoors, he had other career aspirations. After one year with the USGS, he went back to college, received a Master of Arts degree in education, and took a teaching position with the San Diego school district. Shelton's brief mapping career would have ended unnoticed at this point had it not been for the start of WWII (Shelton, 2004).

Because of his field mapping experience, during the WWII years Shelton found himself again employed by the USGS, mapping areas considered strategically important in the western United States. It was in the remote Jarbridge Mountains of northeastern Nevada that Shelton, now a full-fledged USGS topographic engineer, first began thinking about the presentation of terrain on maps, a process that would eventually lead him to natural colors (Shelton, 1985). Seeking place name information from the local residents, Shelton discovered that they could not read the contour map that he had just made. However, when he pointed across the valley to the rugged silhouette of the Jarbridge Mountains, the residents—there were seven in all—could readily identify Red Mountain, Old Scarface, and the other peaks. This experience convinced Shelton that the conventional symbology used on topographic maps was inadequate for depicting the landscape in a manner easily understandable by general audiences. The map symbology that he encountered was specialized and anachronistic even by 1940s standards. For example, the USGS manual at that time specified using a green tint for vegetation only for areas where you could hide a small detachment of troops or nine mules. Shelton—the artist, teacher, and by now a committed US government cartographer—was determined to find a better way.

Becoming a terrain artist

Shelton's subsequent government assignments took him away from the field and to Washington, DC, Kansas, and finally to Colorado, where he spent the remainder of his career. Working indoors now, he began experimenting with shaded relief presentation, an effort that eventually paid off with his appointment as Chief Cartographic Engineer for the USGS Shaded Relief Map Program. Under Shelton's direction the quantity and quality of shaded relief usage on USGS maps increased. His early shaded

Figure 1. A portion of Hal Shelton's 1:5,000,000-scale New Europe *map painted ca. 1968. The original measures 107 x 137 centimeters. Drainages and water bodies are photomechanical additions to the original art. Courtesy of Rand McNally & Company. (see page 69 for larger color version)*

"Seeking place name information from the local residents, Shelton discovered that they could not read the contour map that he had just made."

relief work included large-scale maps of Yosemite Valley, California, and Valdez, Alaska. These maps emphasized topographic form and relative elevation by combining brown shaded relief with a green lowland tint, overlaid with lightly printed contours. His relief presentation style during this time was strictly conventional.

Shelton's first attempt at natural-color mapping occurred while on temporary duty with the US Air Force. His primary assignment was designing aeronautical charts for use in airplane cockpits in low light conditions. Of greater relevance to our story was another assignment redesigning an aeronautical chart of a remote corner of the Sahara (for use under full lighting). The replaced chart used conventional symbology—a dense network of blue lines portrayed intermittent wadis and a green tint filled lowland areas all but devoid of vegetation. According to Shelton, using this chart "would tempt a pilot to land and go trout fishing." Referring to the realism of aerial photography, Shelton redesigned the chart to appear appropriately arid mimicking the view seen by a pilot flying over the area. Because lines rarely occur in nature (Shelton firmly believes in avoiding the use of lines on maps wherever possible), the new chart depicted wadis as light streaks across the brown desert floor. Shelton also depicted volcanic rocks with rough-textured dark tones. The original chart based on conventional symbology lacked a way to depict these areas, so its author resorted to a label stating "area of dark rocks." According to Shelton, such text labels are evidence of a map's failure to communicate. Nor is he keen about legends, which he views as unnecessary on a properly designed map. He defines a map as

> "A graphic instrument of communication that transfers information from the awareness of a person with information to the awareness of a person without that information."

"According to Shelton, such text labels are evidence of a map's failure to communicate. Nor is he keen about legends, which he views as unnecessary on a properly designed map."

Shelton thinks of map-making as a two-step process, each of roughly equal importance. The first step involves the accurate gathering of data. The second step is the depiction of that data using a "cartographic language or vocabulary" (1985, videotape interview) —terms he uses often and interchangeably—that others can easily understand. Map making is also an expression of Shelton's feelings for the land, especially wild places

> "It smells different on top of a mountain than it smells down in the valley, it sounds different at the top. As you climb… you're getting a tremendous amount of information." (1985, videotape interview)

To Shelton a successful map was one that permitted another person to

> "…to smell the mountain and hear the wind." (1985, videotape interview)

"Aviation and aeronautical charting played a central role in Shelton's early thinking about natural-color maps."

Shelton would often fly over the western states with his brother, who was a geologist and a pilot. These flights gave Shelton a firsthand impression of the land from above, a view unimpeded by the graphical filtering of maps. Aviation and aeronautical charting played a central role in Shelton's early thinking about natural-color maps. In the next phase of his career it became even more important.

The Jeppesen Natural-Color Map Series

Shelton began his natural-color map career with a USGS colleague by making freelance recreational maps of Colorado. These maps attracted the attention of Elrey Borge Jeppesen, a United Airlines pilot who had started a company that published aeronautical charts and other navigational information for pilots (NAHF, 2002). He also wanted to publish general maps catering to the ever-increasing numbers of air travelers. For the first time the public at large was seeing Earth from directly above and Jeppesen believed that Shelton's natural-color maps would provide passengers with more relevant information than conventional maps. Jeppesen and Shelton teamed up in the early 1950s. Their business association spanned two decades and yielded more than 30 titles in what was to become *The Jeppesen Natural-Color Map Series*. The contract work for Jeppesen provided an outlet for Shelton's creative talents and a public forum for his cartographic art, which received worldwide acclaim. The USGS never published any of his natural-color maps.

Jeppesen paid Shelton by the square inch for painting natural-color base maps. Depending on the complexity of an area, not all square inches were equal. Any given square inch might take anywhere from one hour to one day to complete. Initially Shelton used a Paasche AB airbrush to apply colors, but he thought the results looked too smooth and unnatural. Painting with 00 and 000 brushes, although slower, brought a more natural texture to his work. However, he still used the airbrush in splatter mode to speckle his maps with tiny green dots to represent widely dispersed trees and brush, such as the pinyon-juniper vegetation that typifies the Colorado Plateau. Because vegetation doesn't generally transition abruptly in nature, Shelton sought to depict these boundaries with soft edges on his maps.

Since this was the era of photomechanical reproduction, painting base maps on a stable material proved essential. One problem was seeing underlying compiled line work after applying the first layer of paint. The zinc plates used by the printing industry provided the solution. By etching line work 0.05 millimeters (0.002 inches) into the plates the compilation remained faintly visible (when illuminated obliquely) even when covered with paint, and the etchings did not interfere with reproduction. He would start painting by applying a white base coat to the zinc plate. He preferred acrylics because they yielded bright white and vivid colors. Next he painted swaths of flat color blending into one another to represent the land cover. At this point the map was ready for the application of shaded relief, achieved by painting light and dark tones based on each of the underlying land cover colors. Shelton painted the land tones extending well into water bodies with the idea that a water plate produced separately would clip these tones at the coastline later. Lastly, the map underwent a "balancing step" to give topographic features appropriate emphasis in relation to one another.

Large quantities of geographic information went into making natural-color maps that were easy-to-read and informative. Land cover, vegetation, topography, geology, and climate all factored into his interpretation of the landscape. Shelton was by no means alone in this effort. Jeppesen hired a team of geographers to compile base line work, which guided Shelton's painting. Shelton and the geographic team devised a standardized classification and colors for depicting land cover worldwide (Figure 2). Considerable discussion ensued over classifications and terminology—one person's scrubland was another's shrub land, or is brush a better term? Is chaparral a type of forest or should it be an entirely separate

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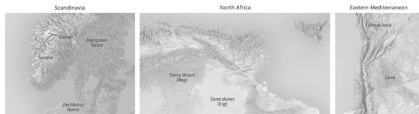
Figure 2. Shelton's standardized palette of natural colors captured the character of disparate geographic regions worldwide. Courtesy of Rand McNally & Company. (see page 69 for larger color version)
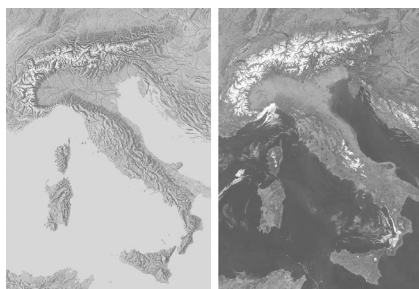

Figure 3. (left) Excerpt of a natural-color map painted by Hal Shelton ca. 1968. (right) NASA MODIS satellite image taken in 2003. Map on left courtesy of Rand McNally & Company. (see page 70 for larger color version)

"At this conference Imhof praised Shelton's natural-color maps . . . However, the two men did not see completely eye to eye."

category? The questions were as varied as the world itself. They settled on ten categories:

Ice and snow	Shrub land
Tundra	Farmland (irrigated)
Evergreen forest	Lava flows
Deciduous forest	Sand dunes
Grassland	Tropical forest

This mix of mostly vegetation zones and physiographic formations may seem eclectic at first glance. All of the categories, however, are well suited for distinctive depiction on a map. The goal after all was making readable and informative maps as opposed to classifying world land cover in a scientifically consistent manner. Thinking that too many colors might overwhelm the reader, Shelton favored using fewer categories but the other team members convinced him otherwise. Judging by the readability of the finished plates, his concerns did not materialize, no doubt because of the artistic skill he applied to the task. In a classification dominated by nature, the inclusion of farmland is noteworthy because it acknowledges the impact of humans on the land—a fact plainly obvious to anyone flying over the checkerboard fields of the US Midwest. With crosshatched brush strokes Shelton represented these field patterns on his maps. Built up areas are the one major land cover category conspicuously absent from Shelton's painted bases. Admittedly, however, urban sprawl was not nearly as widespread then as it is today. To depict urban areas on the Jeppesen maps, bright yellow area tones were applied photo mechanically in a second step for final printing.

Shelton/Jeppesen maps covered all areas of the globe. Uses included wall maps and textbook maps for schools and colleges, commercial promotion, and passenger maps for many airlines (Library of Congress, 1985). Because of their detail and realism, NASA used these maps to locate and index photos of Earth taken on early space missions (Figure 3).

In 1961, Elrey Jeppesen sold his firm to the Times Mirror Publishing Company of Los Angeles but remained as president. Shelton also continued working for the new owners until the late 1960s. In 1985, the HM Gousha Company, a subsidiary of the Times Mirror Publishing Company, donated 29 original plates painted by Shelton to the US Library of Congress. The Shelton Collection, as it is now called, has grown to some 33 plates and miscellaneous other materials. Rand McNally & Company in 1996 acquired the assets of HM Gousha, which no longer exists, thereby inheriting copyright ownership of Shelton's plates housed at Library of Congress (see Appendix A). The Shelton Collection can be viewed by appointment in the Map Reading Room.

Cartographic contemporaries

Shelton's colleagues in the cartographic profession influenced his thinking about natural-color maps, particularly those from the Alpine countries of Europe. The famous Walensee Map painted by Eduard Imhof in 1938, which masterfully combines land cover colors and shaded relief, directly influenced Shelton. Shelton and Imhof met in 1958 at the 2nd International Cartographic Conference in Chicago, the so-called "Rand McNally" conference. At this conference Imhof praised Shelton's natural-color maps saying, "there is nothing more that I can contribute." However, the two men did not see completely eye to eye. Afterwards Imhof visited Shelton at his studio in Golden, Colorado, for about a week.

According to Shelton, they politely agreed to disagree on the use of color on physical maps. Imhof favored using color exclusively for modeling topographic forms and depicting altitude, arguing that combining land cover colors with shaded relief only weakens the presentation of topography. Discussing Shelton's work in his 1982 text, *Cartographic Relief Presentation*, Imhof states

> "At the small scale, however, the relief forms and the ground cover mosaic are so finely detailed and often have so little relation to one another that in certain areas great complexity and distortions of the relief are unavoidable. As a result of the flatness and spaciousness of the "models," distinct aerial perspective hypsometric tints can scarcely be achieved by such combinations." (344-45)

Imhof's point is valid—if one's sole aim is portraying topography on a physical map. Shelton's approach to physical mapping, however, is more holistic. Shelton regarded the physical world not as a cartographic abstraction, such as elevation above sea level, but as the colors and forms processed by his mind from reflected light observed outdoors. What was on the terrain surface mattered as much as the terrain surface itself. If a landscape looked arid and sun bleached, so too should its depiction on a map.

Shelton's closest cartographic soul mate from Europe was, perhaps, Heinrich Berann of Austria. Like Shelton, Berann came from an art and illustration background and painted panoramic maps lavishly adorned with colors depicting land cover and vegetation (Patterson, 2000). Shelton departed from Berann's technique in using natural colors on plan maps viewed from directly above. Although Shelton never met Berann, he admired his work. He once had a German-speaking neighbor on vacation call on Berann to obtain his color formulas. A page and a half of detailed instructions on paint mixing resulted from the visit. However, Shelton found Berann's palette to be based more on artistic considerations than observed nature, so he devised his own. One of Berann's colors that did find its way into Shelton's palette, however, was yellow-green for depicting humid grasslands, pastures, and meadows. Bright and decidedly unnatural, this green occasionally detracts from Shelton's otherwise balanced colors, at least according to the authors' tastes. The primitive color printing of that time only exacerbated this problem. To be fair to Shelton, nearly all terrain artists from that era relied on this particular shade of green; such was the dominant influence of Heinrich Berann.

On this side of the Atlantic, Richard Edes Harrison was a contemporary of Shelton's in the arena of cartographic relief presentation. He was renowned for creating artistic "over-the-horizon maps" for *Fortune* magazine, and shaded relief plates containing fine physiographical detail. Both men were similar in that they came to cartography from illustration backgrounds, and they were both innovators and cartographic populists. Harrison colored his maps in a conventional manner, which offered no guidance to Shelton's development of natural colors. However, Harrison's monochromatic portrayal of textured lava flows, sand dunes, and other physiography influenced Shelton's mapping style, which gained in detail over the years (Shelton, 2004).

Why natural colors?

In terms of willingness to experiment with color, Shelton fell somewhere between the conventional colors preferred by Imhof and Harrison, and the

"Shelton regarded the physical world not as a cartographic abstraction, such as elevation above sea level, but as the colors and forms processed by his mind from reflected light observed outdoors."

"In terms of willingness to experiment with color, Shelton fell somewhere between the conventional colors preferred by Imhof and Harrison, and uninhibited end of the color spectrum preferred by Berann."
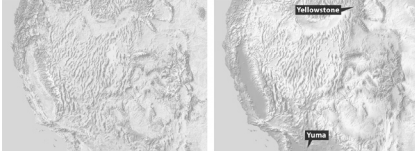
Figure 4. (left) A shaded relief map of south-western United States combined with natural colors. (right) The same map with blended hypsometric tints. Although hypsometric tints are attractive and show topography clearly, they can mislead readers about the character of the land. Forests cover the Yellowstone region and Yuma, Arizona, is an extreme desert environment. (see page 70 for larger color version)

"Creating a tabloid-sized map of moderate complexity required two to three weeks of work with the constant worry that the airbrush could splatter without warning and ruin everything."

uninhibited end of the color spectrum preferred by Berann. A half-century ago the key players in the field of relief presentation strongly espoused differing styles. Shelton was in the middle of this fray. The central point of debate then—which continues today but with considerably less fervor—was over appropriateness of hypsometric tints (colors assigned to elevation zones). Shelton regarded hypsometric colors as "arbitrary" and as bearing little relation to the actual color of the land, such as a green lowland tint filling parched desert basins, and red applied to uplands where forests grow. Classic hypsometric tints inverted the sequence of elevation-influenced natural colors observed by Shelton in the landscapes of the US West (Figure 4, right).

Based on the large quantities of maps that display hypsometric tints, an anthropologist a thousand years from now might conclude that our society was elevation-centric. However, the current popularity of hypsometric tints has more to do with production ease and pretty colors than it does with our interest in elevation. Making competent hypsometric tints requires mere minutes to accomplish with a digital elevation model and freeware software. Even the photomechanical techniques of yesteryear were relatively straightforward, albeit much slower. With hypsometric tints, the end result is often a map with pleasing colors that blend softly into one another in an orderly fashion, a design trait that people find attractive, even if they don't necessarily know or care about elevations. To the average reader the elevation zone between 750 and 2,000 meters in California, for example, which can assume any color in the rainbow on a hypsometric tint map, is artificial, abstract, and, to use Shelton's favorite term, arbitrary.

By contrast, natural colors on a map are less susceptible to misinterpretation. For example, color-sighted humans tend to associate green with the color of vegetation, brown with aridity, and white as the color of snow (at least people living in the mid and high latitudes). The Nevada residents interviewed by Shelton 60 years ago had named Red Mountain because of its distinctive cast. Recent psychological research suggests that bright colors attract our attention—not really a surprise—and that our memory retention improves on images comprised of natural colors compared to false colors or black and white (Gegenfurtner et al., 2002). Considering the potential for natural-color maps to easily, and perhaps lastingly, communicate geographic information to the user, why then are they so rare? The short answer: they are tremendously difficult to make.

The making of natural-color maps manually requires that a cartographer possess singular artistic talent, broad knowledge of physical geography, and patience—combined traits that are in short supply, particularly where costs are determining factors. Natural-color maps are handcrafted and expensive products. One occasionally sees gaudy, unrefined attempts at natural-color mapping published in tourist brochures, proof that not everyone qualifies for the job title: artist/cartographer. Working with colored pencils, airbrush, watercolors, and acrylics, one of the authors of this article tried over the course of many years to create such maps, but met with only limited success. Creating a tabloid-sized map of moderate complexity required two to three weeks of work with the constant worry that the airbrush could splatter without warning and ruin everything. Shelton was considerably faster in applying pigments to maps. Providing that he had a clear and accurate base to work from, a typical large natural-color map would take about 40 hours to paint (Shelton, 2004).

We must also bear in mind that natural-color maps are not appropriate for all types of general or even physical mapping. The merging of shaded relief and land cover, regardless of how delicately done, creates a level

visual weight and background complexity that may detract from other classes of information depicted on the map. Nothing good comes from printing area colors, such as polygons showing property ownership, on top of natural-colors, or on hypsometric tints for that matter.

Natural-color bases are suited for use with uncluttered general reference maps and thematic maps where the surface environment and interconnectedness matters most. They are most appropriately used at small and medium-scales where the natural colors combine with shaded relief to create textures that appear organic and plausibly realistic. Larger map scales, however, require supplementary bump map textures (a type of 3D embossment) to achieve similar results (Patterson, 2002). Although some cartographers may be loath to admit this as a valid use, natural-color maps make outstanding wall decorations. Even today the airline route maps published by Jeppesen are still one of the best uses ever found for natural-color maps.

Moving forward

Today, the foremost practitioner of natural-color mapping is Hungarian-born Tibor Tóth, formerly an employee of National Geographic, and now working freelance. Readers of the *National Geographic Atlas of the World* would quickly recognize Tóth's work. Showcased prominently, his painted plates of the physical world and continents are associated by many with the distinctive look and feel of National Geographic maps. Toth, a talented artist and cartographer in his own right, consulted with Shelton at his Colorado studio in early 1971. Tóth then developed a natural-color mapping style modified and distinct from Shelton's, which he first applied to a map of Africa later that same year (Tóth, 1986). Instead of showing existing land cover as Shelton did, Tóth's maps use color to show potential vegetation based on biogeographer AW Küchler's data. Potential vegetation shows readers a more abstract interpretation of the landscape without human influences. Imagine if you will, untrammeled North America before the first humans arrived from Asia.

Tóth—before switching to digital production—painted and airbrushed his maps from a standardized palette formulated by carefully mixing paints drop by drop (Tóth, 1973) (Figure 5). The National Geographic tradition in natural-color mapping continues today thanks to Tóth's successor, John Bonner (Tóth also continues to work freelance for NG). Bonner's magnum opus was a 3.35-meter-wide globe airbrushed and painted with natural colors that was on display at Explorers Hall in Washington, DC, for more than a decade, up until 2000.

In 1985 the Library of Congress, Geography and Map Division interviewed Shelton on videotape. During the 51-minute interview, Shelton stated his hope that new people and techniques would continue the process of natural-color mapping into the future. He concluded the interview with the advice:

"…that we can be flexible enough to recognize change, and be wise enough to understand those things that don't change so much, which is the need to have human beings to communicate."

Turning now to the digital part of this paper, we attempt to follow his advice.

"Natural-color bases are suited for use with uncluttered general reference maps and thematic maps where the surface environment and interconnectedness matters most."
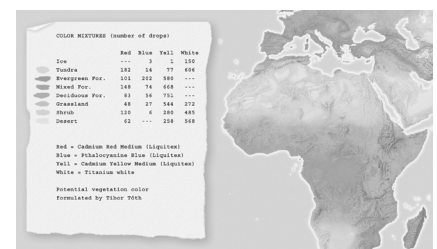

Figure 5. (left) Tibor Tóth's color formulas. (right) His colors applied to a map. Courtesy of National Geographic. (see page 71 for larger color version)
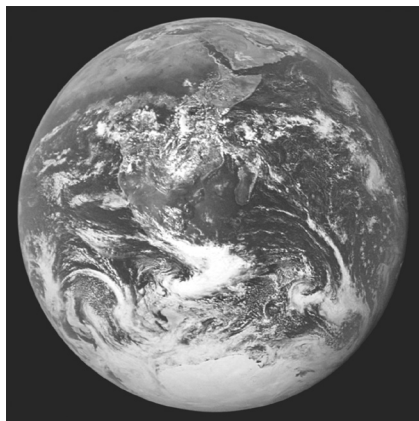
Figure 6. NASA's "Blue Marble" photograph shows Earth from a distance of nearly 48,000 kilometers (30,000 miles). Dominated by the Sahara and Kalahari deserts, Africa is usually the most cloud-free continent. Antartica is also visible in this image for the first time (NASA, 2002). (see page 71 for larger color version)

"But more than just a technical means to an end, space imagery has forever changed how people visualize Earth in a realistic context from afar."

SATELLITE IMAGES—SEEING THINGS DIFFERENTLY

If the growth of commercial aviation compelled Shelton to paint natural-color maps, going higher still, the advent of space flight largely defines the genre today as we settle into the digital era. The digital solutions offered in this article for making natural-color maps employ raster land cover data derived from satellite images. But more than just a technical means to an end, space imagery has forever changed how people visualize Earth in a realistic context from afar. The aptly named "Blue Marble" photograph taken by the Apollo 17 crew heading to the moon in 1972 gave us the first full view of oasis Earth set against the emptiness of outer space (Figure 6). Embraced as a symbol of environmental awareness, the "Blue Marble" has become one of the world's most recognized images. And as a natural-color geographical image with pop culture cachet, it is a rarity.

Starting with the launch of Landsat (originally called ERTS—Earth Resources Technology Satellite) in 1972, remotely sensed images of Earth in both natural and false colors have become increasingly abundant with each passing year. The sheer volume of remotely sensed data collected by a multitude of platforms and sensors is difficult to comprehend. A Google search in early 2004 using the key words "satellite images" yields 4,810,000 hits, a coarse, but nevertheless telling barometer of current popularity. Satellite images have also replaced maps as the dominant method of depicting natural color on geospatial products. However, as we shall discuss shortly, quantity and quality are not always directly related. Off-the-shelf satellite images are less than ideal for the presentation of natural color on maps.

Intended primarily for scientific, military, and economic use, satellite images find secondary (and sometimes gratuitous) application in television and print news, posters, coffee table books, and even silk screened on coffee mugs and t-shirts. That atlases sometimes use satellite images and space shots of Earth as cover art points to their marketing potential. These colorful images attract a buyer's attention and deliver a subliminal message that the contents within are scientifically based, accurate, environmentally concerned, and global in scope. Perhaps for similar reasons, a satellite image appears on the cover of the Spring 2002 issue of *Cartographic Perspectives*. Satellite images also serve as fine art. The traveling exhibit "Our Earth as Art" prepared by the Library of Congress, NASA, and USGS is currently showing in museums and other public venues. The 41 images in the exhibit (selected from 400,000 taken since 1999) treat audiences to eye-catching views of Earth from above that appear both surreal and abstract (Stenger, 2002). Trying to identify the images without reading the captions is a pleasurable challenge.

Several popular products containing global satellite data in natural color are available today. "The Living Earth" is one of the older and better-known commercial images (Figure 7, left). The original image derives from 1.1-kilometer-resolution AVHRR (Advanced Very High Resolution Radiometer) data, which NASA began collecting in 1978. While technically sophisticated when first introduced, AVHRR products are beginning to show their age. Contrary to what the name suggests, AVHRR images, judged by contemporary standards, appear coarse, with too much contrast, and contain tonal variations seemingly unrelated to land cover and vegetation. The Living Earth, Inc. now sells updated and improved natural-color images made from Landsat 5 and 7 data. They also have other promising products under development.

Another notable product is NASA's new "Blue Marble," named after the famous photograph taken by the Apollo 17 crew. The "Blue Marble"

derives from MODIS (Moderate Resolution Imaging Spectro-radiometer) data collected at 500-meter resolution and distributed to the public at one-kilometer resolution (Figure 7, right). The "Blue Marble" portrays arid regions with convincing natural colors but is less effective in humid regions, which appear as monotonous green tones. Meteorological interference in the form of snow cover and sea ice in the polar regions is visible, and areas of shallow water appear to have been arbitrarily added and appear discordant with rest of the image.

The "Blue Marble" comes pre-composited with shaded relief generated from GTOPO30 (Global 30-Arc-Second Elevation Data Set) that employs standard cartographic illumination from the northwest. "The Living Earth" image discussed previously also contains shaded relief made from GTOPO30. While the inclusion of shaded relief is a step in the right direction, its legibility diminishes at scales smaller than 100 percent of original size, and, with more significant reduction, disappears entirely. Shaded relief is not nearly as tolerant of reduction as the underlying color tones found in satellite images. While colors tend to blend pleasingly into one another when reduced, shaded relief becomes an unattractive dark smudge. These shortcomings aside, the "Blue Marble" is a remarkable dataset and is invaluable for making 3D visualizations and animations. It is also free.

Pictures vs. maps

Based on the popularity of satellite images, many of which appear in natural color, it would appear that Shelton's idea about depicting Earth more realistically has finally taken hold. Well, not quite. The graphical merging of satellite images and maps, two closely related geospatial products, has not happened to any great extent. It is a rare map that uses a satellite image as a raster base in conjunction with other map information, such as labels, lines, area tones, and point symbols. In the cartographic context, satellite images are perhaps most common in atlases as stand-alone thematic insets, decorative introductory pages, and the aforementioned cover art.

The lack of satellite images used as cartographic backdrops, in the same manner as shaded relief or hypsometric tints, has a simple explanation: they are not maps. Remotely sensed images contain traits that are incompatible with basic cartographic design conventions (Figure 8). Dense, detailed, colorful, and contrasting, satellite images tend to dominate all other classes of map information to the point of illegibility. Just as photographic snapshots often contain undesirable visual elements—a jet contrail in the sky above the Grand Canyon—satellite images are similarly afflicted. For example, clear-cut forests in the US Pacific Northwest appear on satellite images as a mottled pattern that distracts from everything else.

Other common problems with satellite images include:

- Meteorological interference — Because clouds on average cover 64 percent of Earth's surface (54 percent of land areas) at any given time, the odds of finding satellite images completely free of clouds and their shadows are slim at best (Warren, 1995). Even one small cloud on an image requires a cartographer to make a difficult choice—an exercise in cartographic situational ethics. Is it best just to leave the unsightly blemish on the image, or is it proper to quickly remove it with the Clone Stamp (Rubber Stamp) tool in Photoshop? After all, who would ever notice or object? Other meteorological interference encountered on satellite images includes snow-covered ground, frozen water bod-
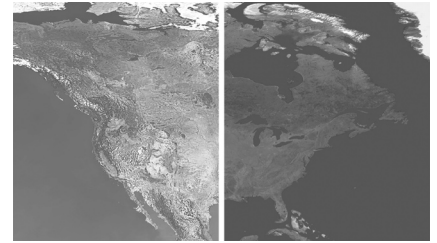

Figure 7. (left) "The Living Earth." (right) NASA's new "Blue Marble." (see page 72 for larger color version)

"Even one small cloud on an image requires a cartographer to make a difficult choice—an exercise in cartographic situational ethics."
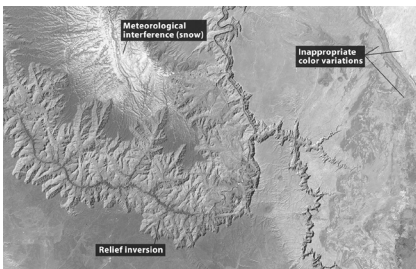
ies, smog, smoke plumes from wildfires, and lowland flooding. Such undesirable traits plague many of the satellite images available online for free, which are provided by organizations that monitor the environment and natural disasters. When using satellite images as backdrops on maps, boring is better.

- Inappropriate color variations — It is typical for natural color satellite images to contain at least some colors that are decidedly unnatural. Despite appearances, natural-color satellite images are not truly photorealistic. They typically consist of "bands" of electromagnetic radiation data from outside the visible spectrum. By inserting these data, in the form of 8-bit grayscale images, into the red, green, and blue channels of, say, a TIF image, the results are a concocted scene with ersatz natural colors—if the mixing and matching of data and colors are done correctly. The inappropriate color variations flagged in Figure 8 are in an area of uniform desert shrub. The cause of these pronounced variations, which are invisible to humans on the ground, might be differing mineral or moisture content in the exposed soil—information only of interest to a few people in specialized fields. Regardless of what the colors represent, they are too prominent compared to other colors on the image and do not belong on a general-purpose map.

"When using satellite images as backdrops on maps, boring is better."

- Relief inversion — The southeast lighting (lower right) found on most high-resolution satellite images when north-oriented causes an optical illusion known as relief inversion, whereby mountains appear as valleys, and vice versa. Because being able to tell up from down is so fundamental, the presence of relief inversion is completely unacceptable on maps. Removing the embedded shadows that cause relief inversion on satellite images is technically difficult and yields poor results, especially in areas of high, sharp relief where shadows are entirely black. Substituting neutral colors and textures to replace the shadows, whether by automated means or the Clone Stamp tool in Photoshop, is an inelegant solution at best. On another tack, overprinting the satellite image with shaded relief generated from a DEM (digital elevation model) using standard northwest illumination only serves to flatten and darken the topography. The shadows, based on opposing light sources, cancel each other out.

Figure 8. A natural-color Landsat image of the Grand Canyon made from bands 2, 4, and 7. Even the handsomest satellite images contain graphical elements inconsistent with cartographic design goals. Courtesy of the USGS. (see page 72 for larger color version)

Land cover—cartographically friendly data

In contrast to satellite images, raster land cover data derived from satellite images is well suited for making natural-color maps. Raster land cover data with its classified structure and generalization brings order to the tonal anarchy of satellite images. The product of sophisticated image processing techniques and often multiple data sources, raster land cover data is generally free of the problems that afflict raw satellite images, such as relief inversion. The result is reconstituted data that facilitates the production of natural-color maps. A satellite image distilled into a land cover classification of, for instance, a dozen categories is merely the raster equivalent of the polygons etched into zinc plates that guided Shelton's painting. Shelton colored his maps with brushes and acrylic paints. We will use software and pixels. Although the means of production has changed, the process remains essentially the same today as it was a half century ago—a cartographic version of painting by the numbers.

Next, we will examine how to make natural color maps from two different types of raster land cover data. Both are in the public domain and available online for free. Our primary software for manipulating the data is Adobe Photoshop. We will begin with National Land Cover Dataset.

NATIONAL LAND COVER DATASET

Produced by the USGS, National Land Cover Dataset (NLCD) is available for the 48 contiguous states at 30-meter resolution (Figure 9). It derives from Landsat Thematic Mapper imagery taken during the early to mid 1990s with 1992 as the oldest collection date. Coverage ends abruptly at the borders with Canada and Mexico and seaward at the 12 nautical-mile limit of US territorial waters.

NLCD is a type of categorical land cover data, which is the most common variety of raster land cover data available. With categorical land cover data, each pixel represents a sampled area on the ground and receives a classification as one type of land cover or another. For example, if the contents of a 30 x 30-meter sample of NLCD were 51 percent shrub and 49 percent evergreen forest, then the sample receives the shrub assignation entirely—the winner takes all. What categorical land cover lacks in subtlety, it makes up for in quantity. The millions of pixels that comprise these data when reduced in scale blend land cover colors together smoothly, a desirable trait on natural-color maps. The effect is much like Shelton's airbrush technique of spraying atomized color droplets.

NLCD uses a modified form of the USGS's Anderson Land Use and Land Cover Classification System (Anderson et al., 1972). The full Anderson classification system consists of four hierarchical levels and more than one hundred categories of land cover (occupying the two uppermost levels) and land use (occupying the two bottommost levels). The distinction between land cover and land use is an important one. For example, forest is a land cover category and bird watching or fire wood collecting are uses that occur in a forest. Because determining detailed land use information is impossible on a national dataset made from 30-meter-resolution Landsat imagery, the NLCD classification does away with land use altogether. It instead consists of a two-level system with nine level-one land cover categories and 21 level-two categories (Figure 10, left).

The USGS developed NLCD for scientific and analytical tasks. Therefore, to make natural-color maps, which are at heart artistic products, requires a change in thinking about what the NLCD classification does. Taking a cue again from Shelton, we next will transform the scientific NLCD classification into an artist's color palette (figure 10, right).

From classification to palette

The first step was reducing NLCD categories from 21 to 15 so as not to overwhelm the reader with too much information. Because every pixel is accounted for with categorical land cover data, reducing the number of NLCD categories required methods other than simple deletion to avoid the appearance of null areas on the final map.

Aggregation, a method that combines several categories as a single generic category, was the method most commonly used. For example, *cropland* in the color palette represents the aggregation of *row crops*, *small grains*, and *fallow* from the NLCD classification. These detailed and temporally sensitive agricultural categories do not contribute to our geographic understanding on a small-scale map of the US. Reclassification was an-

Figure 9. NCLD mosaic of the 48-contiguous states, using the USGS suggested color scheme. (see page 73 for larger color version)
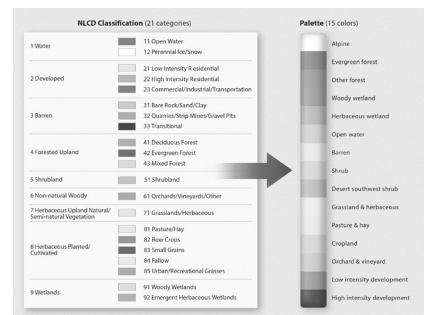

Figure 10. (left) The NLCD classification with USGS assigned colors. (right) The derivative color palette used for natural-color mapping. (see page 73 for larger color version)

other helpful method. For example, the NLCD category *transitional* mostly represents clear-cut and burned forestlands in the western US. Working under the optimistic assumption that the trees will eventually grow back, the palette reclassifies and groups *transitional* with *evergreen forest*. Similarly, the NLCD category *urban/recreational grasses* represent golf courses, schoolyards, and other open areas found in urban environments. Reclassifying this as *low intensity development* in the palette rather than as a subset of *herbaceous planted/cultivated* gave discontinuous urban areas on the final map a more concentrated appearance.

The transformation of NLCD into a palette also required the creation of new categories. On natural-color maps the appearance of white (snow) in lofty mountain areas tells readers that these areas are higher and colder than adjacent lowlands. In the continental US, however, the NLCD category *perennial ice/snow* occupies only scattered tiny areas in the Cascades and northern Rockies. To give high western mountains the emphasis they deserve, the palette contains a new category called *alpine*. It encompasses all areas above timberline and slightly lower in select places, such as the snowy and rugged Wasatch Range of Utah that barely reaches timberline. Because the elevation of timberline varies depending on latitude, continentality, and other factors, a DEM and biogeography references proved essential for delineating *alpine* areas. The procedure involved reclassifying all *perennial ice/snow, barren, shrubland,* and *herbaceous/grassland* as *alpine* for areas above the documented timberline elevation of each mountain range (Arno and Hammerly, 1984).

Another new palette category was *desert southwest shrub*. In the NLCD classification *shrubland* is the largest single category, representing 18 percent of the total area of the continental US and dominating vast tracts of the intermountain West to the exclusion of all else. The creation of the *desert southwest shrub* category recognizes that not all shrublands are the same and brings needed graphical variation to these otherwise monotonous regions. Using a DEM to subdivide the *shrubland* category by elevation zone, *desert southwest shrub*, which is depicted with a blush of red, represents the hot, low-elevation Sonoran, Mojave, and Chihuahuan Deserts of the southwestern US. The remaining area in the *shrub* category primarily represents the cold sagebrush steppes of northern Nevada and Wyoming.

Choosing colors for the palette was an exercise in subtlety. The USGS appropriately assigned bright colors to each of the 21 NLCD categories to make their patterns as distinct as possible. By contrast, the colors chosen for the natural-color palette were complementary and representative of natural environments to the greatest degree possible. With some categories, however, graphical pragmatism dictated using conventional map colors, such as blue for *open water*. The only colors in the palette not inspired by nature are the muted purples assigned to *low* and *high intensity development*—unnatural colors for unnatural information. The overarching goal was to achieve a soft impressionistic portrayal of land cover that could serve as an unobtrusive backdrop on general maps. Even though the palette contains 15 colors, compared to ten used by Shelton, the additional colors were not problematic because they represented land cover categories only slightly different from one other. For example, the similar yellowish colors depicting *grassland & herbaceous* and *pasture & hay* reflect land cover categories with similar characteristics. If these colors happen to merge together indistinctly in places, it is the small price that one must pay for creating cartographic art. Not all categories deserve equivalent strength on a natural-color map. Because trees are the most conspicuous vegetation—they are bigger than we are—the green depicting forest on a

"The only colors in the palette not inspired by nature are the muted purples assigned to low and high intensity development—unnatural colors for unnatural information."

"If these colors happen to merge together indistinctly in places, it is the small price that one must pay for creating cartographic art."

map deserves more prominent treatment than grassland, shrub, and other diminutive vegetation categories. Also worthy of prominent color treatment are land cover categories that are unique or important to humans, such as the developed land where we dwell. In the color palette, the emphasized colors/categories cluster at either end of the scale with muted background colors falling in between.

Some color choices in the palette were compromises. For instance, the light beige given to the *barren* category serves well at representing desert salt flats, pale Colorado Plateau sandstones, and sand dunes, but it is misrepresentative of lava flows comprised of dark basaltic rocks. Because lava occupies relatively small areas that are scattered in the continental US, this inappropriate color is barely noticeable on our map. Nevertheless, on a future update the map needs to depict lava in a more representative fashion. In the western US (where all the lava flows are found) sagebrush sometimes grows abundantly on flows, which the NLCD classification detects as *shrub*, obscuring their extent. The question arises: on a natural-color map is it better to show lava, a geologic feature, or the vegetation that grows on it? Considering the uniqueness of lava and ubiquity of sagebrush, lava is perhaps the better answer. Even choosing an appropriate color with which to portray lava presents problems—the logical choice, gray, is easily confused with shaded relief. A possible solution is dark red gray coupled with subtle 3D embossment and a hint of rough surface texture.

The grouping of colors in the palette attempts to acknowledge the non-hierarchical and interrelated character of the natural world. Although it looks like a conventional legend, further macro level groupings exist within the palette (Figure 11). The highest division is between the *natural* and *human* environments. Below this level the overlapping groups contain common colors to infer inter-categorical relationships. For example, the group *water* consists of *woody wetland, herbaceous wetland,* and *open water,* all of which contain blue in varying amounts. The color groupings, which are invisible to the reader, bring natural order to the underlying data and produce more harmonious colors on the final map (Figure 12).

Figure 11. Color groupings in the palette. (see page 74 for larger color version)

Figure 12. California and the southwestern US depicted with colorized NLCD and shaded relief. (see page 74 for larger color version)

Using NLCD in Adobe Photoshop

Having discussed what to do with NLCD, we now discuss how to do it.

First you will need to obtain NLCD, which is downloadable from two sites maintained by the USGS (see Appendix B for URLs). The USGS Seamless Data Distribution System provides unprojected data (sometimes called the Geographic or Latitude/Longitude projections) for user-selected areas in either ESRI (Environmental Systems Research Institute) compatible GRID format or as a GeoTIF. The USGS also maintains an FTP (File Transfer Protocol) site accessible with a web browser containing individual GeoTIF files for the 48 contiguous states in the Albers Equal-Area Conic projection. The 30-meter-resolution data on both sites is otherwise identical and tend to be large. To produce the map shown in Figure 12, we used a mosaic of NLCD data of the entire contiguous US at 240-meter resolution in the Albers Equal-Area Conic projection, an unpublicized product. The USGS kindly gave us this 19,322-pixel-wide TIF image via FTP in response to an email request sent from the link on their website.

Opening NLCD in GeoTIF format in Photoshop reveals an image with a kaleidoscope of colors similar to those shown in Figure 8. Although NLCD may look like an ordinary RGB (Red-Green-Blue) or CMYK (Cyan-Magenta-Yellow-Black) image, it is in indexed color mode, which is less familiar
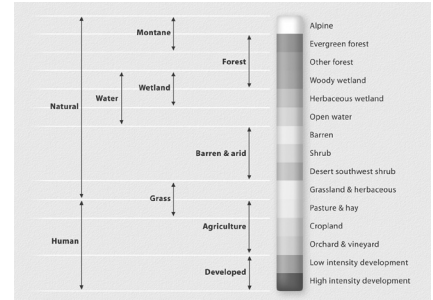
to many cartographers. The advantage of indexed color mode over, say, RGB color mode, is its compact file size, no larger than an 8-bit grayscale image, and the ability to manage colors, such as those representing land cover categories, via a color table. An indexed color table may contain up to 255 colors.

Going to the drop menu and Image/Mode/Color Table, accesses the Color Table dialog, where you can explore and modify the color palette. Toggling between the presets in the Color Table (Spectrum, Mac OS System, Windows System, etc.) vividly demonstrates how changes to the Color Table can change the appearance of NLCD. Although the jumble of multi-colored squares in the Color Table may look confusing at first, their positions correspond to the numbered categories in the NLCD classification. For example, NLCD category 11 is open water, which occupies the 12th color square in the top row of the Color Table (counting the first square as zero); category 43 evergreen forest occupies the 44th square; and, so forth. If you can count, you can manage indexed NLCD colors in Photoshop.

Changing colors in the Color Table is as simple as clicking on a square and specifying a new color in the Color Picker or using the Eyedropper tool to select a color from any open Photoshop image. Use the Eyedropper tool technique to select natural colors from other maps, scanned art, digital photographs, or any image found on-line. Stuck for a color with which to portray desert southwest shrub? A Google photo search using the keyword "Arizona" will yield a spectrum of choices. Or maybe a snapshot of your golden retriever might contain the ideal color. Hint: you may need to click the okay button to confirm your color table changes before the Eyedropper tool works as expected between uses. Once you have chosen new colors that you like, the modified Color Table is savable and loadable for use with later projects and sessions (Figure 13). The Color Table used in this project is available with the online version of this article (see Appendix B).

"If you can count, you can manage indexed NLCD colors in Photoshop."

Other tips for working with NLCD include:

- If you plan on reprojecting NLCD with GIS or cartographic software (NLCD is formatted to decimal degrees) use data downloaded from the Seamless Data Distribution System. For reprojecting in GIS, GRID (the default) or GeoTIF formats work equally well. After reprojecting is complete, save NLCD in TIF format (with no compression) to bring it into Adobe Photoshop. Should you find yourself with a standard grayscale or RGB image after reprojecting NLCD, in Photoshop going to Image/Mode/Indexed Color allows you to convert the data back to indexed color mode. However, be aware that Photoshop randomly generates new positions for the colors in the Color Table upon returning to indexed color mode. Therefore, it is best to apply the final colors via the Color Table prior to reprojecting NLCD.

- Indexed color mode images in Photoshop may interpolate incorrectly on screen with a jittery appearance at some zoom levels. If you are not seeing what you expected, zoom in or out until the image appears smoother.

- When resampling (changing the pixel dimensions) NLCD in Photoshop, it is key to use "nearest neighbor" interpolation to preserve the purity of colors assigned to land cover categories. Using "bicubic" (the Photoshop default) or "bilinear" interpolation for image resampling

and other transformations yields intermediate colors, which do not respond to Color Table manipulations.

- Photoshop's functionality is limited in indexed color mode (layers and filters, for example, are disabled). Therefore it is necessary to switch from indexed color mode to RGB or CMYK color modes for the final production of natural-color maps. Do this only after the application of final colors in the Color Table in indexed color mode.

- As a last step before compositing NLCD with shaded relief to make the final map, apply a slight amount of Gaussian blur (Filter/Blur/Gaussian Blur) to the data. Set the blur radius to 0.5 pixels as a starting point. Applying blur softens the harsh grainy appearance of NLCD, a condition that commonly afflicts images processed with nearest neighbor interpolation. Because making color changes to NLCD with the Color Table is impossible after applying Gaussian blur, as a precaution you should use a duplicate file for this final step. Also, excluding the open water category from blurring will preserve crisp, well-defined shorelines and drainages.
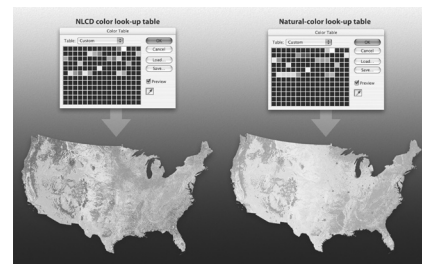

Figure 13. Using the Color Table in Adobe Photoshop with NLCD in indexed color mode to convert USGS colors (left) to natural colors (right). (see page 75 for larger color version)

The USGS is currently revising NLCD based on 2001-era Landsat 7 Enhanced Thematic Mapper Plus imagery. Limited areas of the US are now available in the same classification system as the 1992 NLCD just discussed. These upgraded land cover datasets are better able to accommodate mixed spectral signatures across image mosaics and multiple time captures of vegetation, which means that besides being newer, they are more accurate. Perhaps the new NLCD will include Alaska and Hawaii, too.

Modis Vegetation Continuous Fields

MODIS VCF (Vegetation Continuous Fields) is the second type of land cover data that we examine. It consists of three data layers representing forest, herbaceous, and bare land cover. Although three land cover categories may seem scant, VCF data possesses unique qualities that are amenable to making generalized natural-color bases. Afterwards, color modifications and additional data are applicable to the VCF bases as needed.

Fuzzy data

VCF is the product of two organizations. Like the "Blue Marble" discussed earlier, it originates from the MODIS sensor aboard NASA's Terra satellite platform, which traverses the entire Earth every one to two days in a polar orbit. The University of Maryland, Global Land Cover Facility created VCF from raw MODIS data collected by NASA in 2000 and 2001. The final 500-meter-resolution land cover data derives from monthly composites (they use seven bands of spectral information with emphasis given to bands 1, 2, and 7) processed to remove clouds and cloud shadows (Hansen et al., 2003).

Coverage includes all terrestrial areas of the planet except Antarctica and the polar fringes of Canada, Greenland, and Siberia north of 80 degrees latitude. VCF land cover layers for each continent (up to several hundred megabytes apiece) are downloadable for free from the University of Maryland website in either the Geographic or the Interrupted Goode Homolosine projections. If you plan on reprojecting these data, choose the

"Although three land cover categories may seem scant, VCF data possesses unique qualities that are amenable to making generalized natural-color bases."
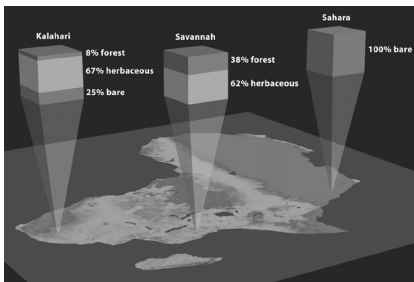
Geographic projection, which is better suited for use with most GIS and cartographic software. MODIS VCF data layers, provided in BIL (Band Interleaved by Line) format, readily open in Photoshop or GIS software. Note: Photoshop only opens single-channel (i.e. grayscale) BIL files in "Raw" file format, so make sure to note the row and column dimensions (in pixels) prior to opening the file. Downloads also include metadata and projection information (see Appendix B).

Unlike hard categorical land cover data such as NLCD, MODIS VCF consists of a matrix of continuous tone values. For any given 500 x 500-meter sample of Earth's surface, grayscale pixels represent the three land cover categories as percentages. Together they add up to 100 percent. For example, Figure 14 shows forest, herbaceous, and bare land cover for Africa loaded into the Red, Green, and Blue channels of an RGB image—a quintessentially scientific choice of colors. A sample selected from the relatively lush savannah of East Africa shows the content as 38 percent forest and 62 percent herbaceous. By comparison, a sample from the Sahara registers as 100 percent bare, as one would expect, given the extreme aridity of that region. Elsewhere in Africa the three land cover categories blend softly with one another much as vegetation does in nature. They also combine to form intermediate categories. Bare desert gradually transitions to semi-desert, semi-desert to herbaceous grassland, herbaceous grassland to savannah, and savannah to forest. Compared to categorical land cover data, this model better represents nature and Shelton's painted art where there are few stark boundaries between vegetation types.

Given the global extent, 500-meter resolution, and general nature of MODIS VCF land cover data, this product is most appropriate for making natural-color maps at small and medium-scales. Next, we will make a natural-color map of North America. With diverse natural environments ranging from tropical rainforests to ice caps, North America is a rigorous test of the capacity of VCF for natural-color map design.

Using MODIS VCF in Photoshop

Having downloaded, decompressed, and, perhaps, reprojected VCF, you will next need to open it in Photoshop as a raw raster file from the File/Open dialog. Note: to open Eurasian VCF layers that are more than 42,000 pixels wide requires Photoshop CS (v. 8.0) or later. North America and the other smaller VCF tiles are accessible to earlier versions of Photoshop, which are limited to a maximum file width of 30,000 pixels. When opened in Photoshop, VCF land cover appears as an ordinary 8-bit grayscale image. White areas on the image represent open water, so in effect VCF provides you with a bonus fourth category of information. The forest, herbaceous, and bare information appear as grayscale values with lighter values representing greater densities. They are analogous to photographic negatives. This trait makes VCF amenable for use as layer masks for modulating colors in Photoshop. After opening each VCF data layer as a separate Photoshop file, combine them into one multilayer image as follows:

1) Create a new Photoshop document with exactly the same pixel dimensions as the VCF data you just opened.

2) Create five new layers by selecting Layer/New Fill Layer/Solid Color in the drop menu or by clicking the "Create a new layer" button in the Layers palette.

Figure 14. Blended lands cover categories in MODIS VCF. The combined values for any sampled pixel on the map are 100 percent. (see page 75 for larger color version)

"With diverse natural environments ranging from tropical rainforests to ice caps, North America is a rigorous test of the capacity of VCF for natural-color map design."

3) Name the layers white background, herbaceous, forest, bare and water respectively from bottom to top.

4) Fill each layer with an exploratory color. Use white for the background, green for forest, yellow-green for herbaceous, beige for bare, and blue for water (these colors can be fine-tuned later in the design process).

5) Create a layer mask for each of the layers by selecting Layer/Add Layer Mask/ Reveal All, or by clicking the "Add layer mask" button in the Layers palette.

6a) To insert the VCF land cover data into their respective layer masks, copy and paste the data. Tip: you need to Option-click (Mac) or Alt-click (PC) on the Layer mask thumbnail to open the Layer mask itself for the pasting to occur.

6b) Alternatively, you can use the Apply Image dialog (Image/Apply Image) to insert the VCF land cover data into Layer masks (all VCF files intended for insertion must be open). First click the Layer mask thumbnail to activate it. Then open the Apply Image dialog and choose one of the VCF files as the source image. The target is by default the Photoshop file you are currently working in. Set blending to normal and opacity to 100 percent. Repeat these steps to insert for the two remaining VCF data files.

7) To color the land cover layers at the full intensity as chosen in step 4, activate the VCF layer mask for each layer mask as described in 6b above. Then use the Levels dialog (Images/Adjustments/Levels) to convert the grayscale data into a high contrast mask by adjusting the Input Levels settings to 0, 1.00, and 100 respectively from left to right.

8) To prepare the water layer, insert any one of the three VCF data files into the Layer mask on that layer. First, activate the Layer mask. Then use the Brightness/Contrast dialog (Image/Adjustments/Brightness/Contrast) to convert the grayscale data into a high contrast land/water mask by setting the contrast slider to plus 100. Lastly, invert the mask so that water areas appear white (Image/Adjustments/Invert).

Color adjustments

When finished you should have a Photoshop file that looks similar to Figure 15 (left side). Although preparing MODIS VCF for use in Photoshop is complex, the resulting file permits the easy application of colors to the data. We will start by globally colorizing the vegetation colors. Double clicking the foreground color in the Tool palette brings up the Color Picker and using the Fill command (File/Fill) delivers the new color to the layer (remember to click on the Layer thumbnail before filling). Assigning new colors to the forest, herbaceous, bare, and water layers takes only minutes. Changing the master opacity (keep the blending mode as normal) or manipulating the VCF grayscale data in the layer masks permits even finer global color adjustments. For example, to bring more emphasis to low-density forests use Curves (Image/Adjustments/Curves) to increase the value of these areas. In the North American example, employing this technique made the arctic tree line more distinct.
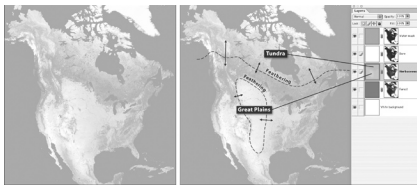
Figure 15. (left) MODIS VCF in Photoshop presented as uniform colors. (right) With environmental color adjustments applied to the herbaceous layer. (see page 76 for larger color version)

"Fixing this problem involved three steps—and two days of work."

Another even more powerful option is to locally adjust colors based on environmental factors. Doing this creates new land cover categories and adds geographically relevant color variations to the map. For example, in Figure 15 (left side) herbaceous land cover appears as the same yellow-green whether it shows cornfields in Iowa, rangeland in Montana, or tundra in Nunavut. Contrast this with Figure 15 (right side), where local color adjustments depict rangeland as yellow-gold and tundra as light gray-green. Applying local color adjustments is technically simple—just draw a selection boundary with the Lasso tool, apply feathering (Select/Feather) to taste, and fill with a new color. A more critical concern, however, is where the color adjustments are applied and the colors used. For accomplishing this task biogeography and climatic references are a must. Returning to the example of North American tundra, we considered a number of geographical definitions of the arctic for delineating this environmental zone. The 10-degree-centigrade isotherm for July average temperature, for example, generally defines the northern limit of trees worldwide. This definition, however, proved inadequate for subarctic regions, such as Labrador, where tundra-like muskeg and spruce-lichen woodland extend southward for hundreds of kilometers. To bring tundra coloration to these deserving areas we drew the diffuse southern boundary of the tundra zone to include the northern third of the boreal forest zone. Because the tundra coloration applies only to herbaceous land cover, the green forests remained undisturbed.

We applied similar environmental color adjustments to the bare VCF layer to accentuate the polar desert of the high arctic (muted purple), alpine areas (light gray), and the hot southwestern deserts (light red brown). Many other local adjustments are possible. For instance, according to the Köppen climate classification system, the 18-degree-centigrade isotherm for January average temperature defines tropical areas in the northern hemisphere. A slight increase in saturation for all land cover categories within this area (delineated by a diffuse boundary) would increase the vibrancy of tropical areas—bringing the colors on the map closer to our perceptions of geographic reality. Considering that tropical areas in North America account for a small percentage of the total area, as an added benefit (and depending on the design goals of the map) brighter natural colors could bring needed emphasis to the tropics.

Accessorizing MODIS VCF

MODIS VCF is not a complete data solution for making natural-color maps. While the natural manner in which it blends colors into one another is highly effective, it lacks important land cover categories one would expect to find on a map. To bring a natural-color map based on VCF to final completion requires supplemental data. For example, in VCF the "bare" category does not differentiate between sand, rock, and permanent ice and snow, etc. Any surface without biomass receives the bare classification, be it a gravel bar in Alaska or the concrete skyscrapers of Manhattan. Looking again at the map of North America, glaciers in northern Canada and Greenland appear with the same white color as the surrounding bare ground, rendering them invisible (Figure 15, left and right). Fixing this problem involved three steps—and two days of work. First, using the color adjustment technique discussed previously, we assigned a muted purple tint to all bare areas (including the glaciers) in the high arctic to depict polar desert. Next, we reprojected, rasterized, and imported DCW (Digital Chart of the World) vector data at 1:2,000,000-scale as white polygons, which contrasted with purple background in VCF to show glacier

shapes. As a final touch, in Photoshop we overprinted the white glaciers with gray-blue shaded relief to bring tonal modulation to their surfaces (Figure 16).

Although not applicable to our map of North America, large deserts completely devoid of vegetation, such as the Sahara and the Rub al Khali in Arabia, expose another problem with VCF data for the bare category. Completely lacking in tonality, these areas appear flat and homogenous when colorized. Furthermore, the addition of shaded relief to these areas is often not enough to break the monotony. To bring tonal variation to the deserts, selectively swap in the "Blue Marble" image discussed earlier in this paper. Also derived from MODIS, the "Blue Marble" is a close kin to VCF and merges easily with it. For best results lighten and recolorize the entire "Blue Marble" image as desert beige using the Hue/Saturation dialog (Image/Adjustments/Hue/Saturation). Then copy and paste the recolorized "Blue Marble" image to replace the flat bare color in the layered VCF file, retaining the bare VCF data as a mask. The Sahara will now appear as a mosaic of textured dune fields and rocky areas.

Cities are another category requiring outside help on MODIS VCF. Although VCF depicts large urban areas mostly as bare, they appear indistinctly. For the North America map we used the USGS's one-kilometer-resolution Global Land Cover based on AVHRR as an add-on (see Appendix B for URL). Placing the AVHRR city data in layer mask with an associated layer color permitted easy adjustments to color, opacity, and blending. Looking elsewhere, the water layer extracted from MODIS VCF may also require replacement. While it is reasonably good for delineating oceans and lakes, all but the widest rivers appear as discontinuous strings of pixels. Replacing open water areas and rivers with rasterized vector data from sources such as DCW is advisable in most cases. Doing this also requires the removal of the embedded water from the VCF land cover to prevent it from conflicting with the new water. We discuss a semi-automated Photoshop technique for removing embedded water in the next section. The portrayal of open water areas on natural-color maps also deserves consideration. The North America map in Figure 16 portrays open water with hypsometric tints and shaded relief derived from ETOPO2 (2-minute Worldwide Bathymetry/Topography) data. It is ironic that a mapping style that so stridently eschews hypsography for terrestrial areas happens to work so well with hypsography in water areas. On the other hand, since no human has ever seen the ocean basins without water, portraying them with blue hypsometric tints and shading is the closest approximation of natural colors that we have.

New MODIS VCF products are in the production pipeline based on more recent data. The University of Maryland, Global Land Cover Facility plans to expand the forest and herbaceous categories. Forest (woody vegetation, more precisely), will include needleleaf and broadleaf, and evergreen and deciduous subcategories. Herbaceous will include new subcategories for crops and shrubs. These new data will give cartographers even more tools to make refined natural-color maps.

DESIGN AND PRODUCTION TIPS

This last section provides design and production tips for making natural-color maps and managing land cover data. Because of space limitations and the ever-changing nature of software, the intent of Photoshop tips described here is to give you design ideas and point you in the right procedural direction. The website for this article contains additional resources related to the discussed tips (see Appendix B). Prior experience with
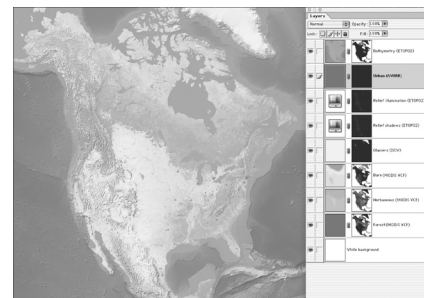

Figure 16. (left) The final map primarily based on MODIS VCF data. (right) The top five Photoshop layers contain supplemental data added to the MODIS VCF base. (see page 76 for larger color version)

"It is ironic that a mapping style that so stridently eschews hypsography for terrestrial areas happens to work so well with hypsography in water areas."

Adobe Photoshop is helpful. And given the large files involved, so too is a graphics workstation with large amounts of physical RAM, scratch disk space, and file storage.

Tip 1: Combining shaded relief and land cover data

Shaded relief is an essential component on all natural-color maps (Figure 17). However, the textures in shaded relief and those found in land cover, if clumsily combined, have the potential to become heavy and messy. The following will help you use shaded relief more effectively with land cover data:

"Excessive topographic detail at small map scales only pollutes the background landcover colors and detracts from our understanding of major topographic structures."

- Show shaded relief and land cover with roughly equal emphasis. Despite the considerable effort that goes into transforming raw land cover data into a natural-color base, for the greater graphical good, do not to print these colors too boldly. The same rule applies to shaded relief. The relative visual prominence of shaded relief and land cover varies on a map depending on viewing distance. Up close the shaded relief appears more dominant as a dimensional texture. By comparison, when viewed from farther away land cover colors on the map become the more noticeable feature, appearing as broad generalized zones.

- Generalize shaded relief at reduced scales. Although land cover colors reduce to smaller sizes with no visible harm, shaded relief is not as elastic. Excessive topographic detail at small map scales only pollutes the background land-cover colors and detracts from our understanding of major topographic structures. Repurposing a natural-color map from, for instance, wall map size to textbook size requires replacing the shaded relief with a more generalized version. As a general rule the resolution of a DEM used to generate shaded relief should be equal to or less than that of the land cover. For example, if a land cover image is 10,000 pixels wide, the DEM used to generate the shaded relief might be 7,000 pixels wide. The resulting shaded relief is then upsampled (or rendered) to 10,000 pixels wide for final compositing with the land cover. The need for generalized shaded relief applies to all maps and not just those with natural colors.

"A cleaner and brighter alternative is to let the land cover colors themselves do double duty as a base tone for the shaded relief."

- Remove shaded relief tones from flat areas. A typical shaded relief contains tonal values of 10 to 20 percent density in flat lowland areas. They serve as a neutral base upon which other topographic features, modeled by light and shadows, project upward or downward in a three-dimensional manner. While tones in flat areas are desirable for stand-alone shaded relief, the overall image becomes too dark when merged with land cover colors. A cleaner and brighter alternative is to let the land cover colors themselves do double duty as a base tone for the shaded relief. To do this use Curves (Image/Adjustments/Curves) or Levels (Image/Adjustments/Levels) to clip the tonal range of the shaded relief just enough to remove tones from the flat areas. This procedure works best with a shaded relief possessing a full tonal range including fine detail in the brightest highlighted slopes and densest shadowed slopes. Be careful not to remove too much tone, or the shaded relief will lack body and appear spindly. Using the Eyedropper tool and the Info palette permits the removal of tones with numerical precision.

- Show illumination. The illuminated slopes on a shaded relief are almost as important as shadowed slopes. They enhance the apparent three dimensionality of a shaded relief, giving it an embossed look and also lightening the image. To add supplemental illumination to a shaded relief, first create a Hue/Saturation adjustment layer (Layer/ New Adjustment Layer/Hue/Saturation). Next, copy and paste the grayscale shaded relief into the adjustment layer's layer mask. Then, in the layer mask, use Curves to choke the shaded relief tonal range so that all areas except illuminated slopes are black. For the final step double click on the adjustment layer icon to open the Hue/Saturation dialog and move the Lightness slider to the right until the illuminated slopes look appropriately bright. In Figure 16, the third layer from the top shows an illumination adjustment layer in Photoshop. A low-resolution version of this file is available on the website of this paper for you to download and examine.

The adjustment layer technique also works well for displaying shaded relief shadows. The advantage is that the darkening preserves the varying colors below. For example, forest green becomes a darker green, desert beige becomes a darker beige, and so forth. The final result is a natural-color map with more pure natural colors. Creating shadows with a Hue/Saturation adjustment layer is similar to the illumination technique described above. But this time invert the shaded relief (shadowed slopes should be lightest) and move the Lightness slider to the left (start with settings between –55 and –30).

Tip 2: Legend design

Despite Shelton's misgivings about their usefulness, legends do play an important role even on well-designed maps. Readers expect to find legends on maps, and cartographers are partial to displaying them. If a legend is a little redundant, that is a lesser problem than having no legend and uniformed map-readers. Having said that, the design of legends on natural-color maps is worthy of reexamination. The traditional map legend explains natural colors with small, rectangular color filled boxes arranged neatly in a row and separated from one another. Typically a black casing line bounds these boxes. Such a portrayal disassociates the legend colors from one another and, of greater concern, from their counterparts on the map. If the map uses shaded relief and the legend does not, the communication disconnect is even greater.

To improve the design of traditional legends on natural-color maps, consider doing the following: remove the black casing lines, place the colored boxes in a contiguous row, include shaded relief, and, perhaps, blend the colors (Figure 18, examples 1-4). The idea is for the legend to mimic colors on the map as closely as possible while still maintaining order. For another step toward this goal think about using a natural legend (Figure 18, example 5). Placing legend labels on an icon of the map itself communicates the meaning of colors directly and unambiguously to readers. Compared to traditional legends, the disadvantages of natural legends are that they require more space and are less tidy.

Tip 3: Mapping urban extents

Besides the making of natural-color maps, land cover data is a useful product for mapping urban areas as a stand-alone category on general

"Despite Shelton's misgivings about their usefulness, legends do play an important role even on well-designed maps."
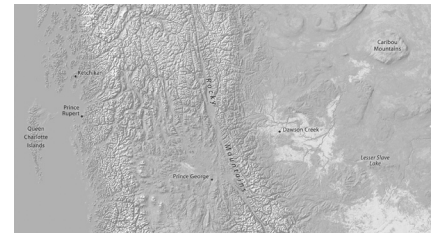

Figure 17. Shaded relief merged with a natural-color base made from MODIS VCF data. (see page 77 for larger color version)
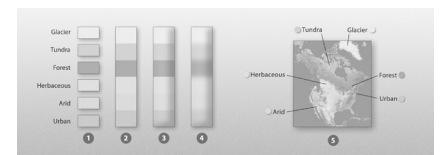

Figure 18. (1–4) Variants of the traditional legend. (5) A natural legend. Legend portrayal becomes less abstract and more cartographically realistic from left to right. (see page 77 for larger color version)
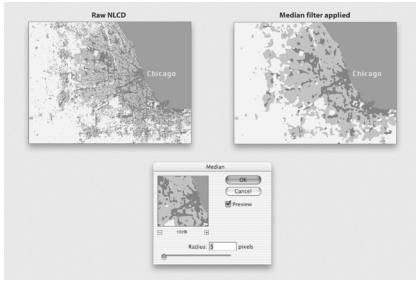
Figure 19. Using the Median filter to generalize urban land cover data. (see page 78 for larger color version)

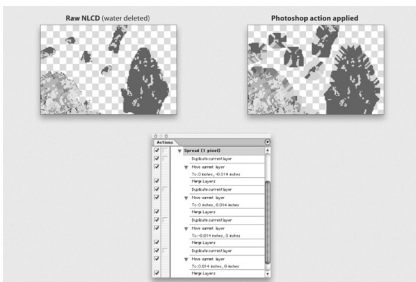*Figure 20. Using the Actions palette in Photoshop to spread shoreline pixels outward. (see page 79 for larger color version)*

maps. Isolating urban areas from the other categories in NLCD (and other categorical land cover data) is simple to do with the Magic Wand tool. Hint: set the tolerance to zero and do not choose the antialiasing and contiguous options. Having selected the urban areas, invert the selection (Selection/Inverse) and fill all of the other land cover categories with white. The image should now look something like Figure 19 (upper left). The next potential issue is one of generalization. Because the urban categories in NLCD include transportation, depending on the scale of your data, discontinuous roads and other stray pixels make for a noisy image. The Median filter (Filter/Noise/Median) in Photoshop permits the removal of unwanted pixels below a threshold of interest (Figure 19, upper right). Moving the radius setting to the right increases the amount of generalization. Be sure to apply the Median filter using nearest neighbor interpolation (Preferences/General/Image Interpolation) to prevent the urban colors from blurring.

Tip 4: Shoreline buffering

Any cartographer who has worked with data from two or more sources on the same map is familiar with the problem of misregistration, especially when merging raster images and vector linework. For example, matching raster land cover data to vector water bodies often reveals unwanted fringing pixels and data gaps—the stair-stepped pixel boundaries don't match smooth-edged vector shapes. This problem is solved by growing the land cover pixels outward—a process called buffering in GIS applications—so that they fall under the edges of vector water bodies (Dunlavey, 2002). A similar procedure is also available in Photoshop if you know what buttons to click:

1) To start, open your land cover image in RGB or CMYK color mode and double check that Photoshop is set to use nearest neighbor interpolation (Preferences/General/Image Interpolation).
2) Select and delete all water pixels so they are now transparent (Figure 20, upper left).
3) Duplicate the land cover layer.
4) Select the Move tool in the Tool palette. Then on the keyboard press the up arrow cursor once. The image will move up one pixel.
5) Merge the copied layer with original below.
6) Duplicate the merged layer and repeat steps 4 and 5. But this time nudge the copied layer to the right.
7) Repeat this process two more times, nudging the copied layer down and then to the left respectively.

Each cycle of copying, nudging, and merging the image grows edge pixels outward by one pixel. Apply the steps repeatedly as needed until all misregistration gaps disappear. Alternatively, record your steps in the Actions palette and the save the results for one-click replays (Figure 20, bottom). We have built a Photoshop action that automates this process. It is available on the article website for both Mac and PC.

Tip 5: Land cover removal

Just because a category for land cover exists doesn't mean that you have to accept it. For example, the pixelized depiction of rivers and lakes is often too noisy and irregular for display on a map, requiring removal

from the raster land cover data and showing it instead with vector lines in a drawing software application. Beyond issues of accuracy, considering that hundreds of thousands of pixels might be water on a land cover image, manually replacing them with the Clone Stamp tool is not a realistic option. The Dust & Scratches filter offers a quicker and more accurate solution. It reads the tonal contrast in an image and replaces pixels beyond a specified threshold with nearby unaffected pixels. In Figure 21, for example, the green forest color that dominates the image replaces the black lakes. Follow these steps to remove imbedded water from an image:

1) Select all water pixels and fill them with black.
2) Use the Dust & Scratches filter (Filter/Noise/Dust & Scratches) to infill the black-filled water bodies. (Be sure to use nearest neighbor interpolation.) Experiment with different radius and threshold settings until the black water bodies disappear. The settings will vary depending on the contrast range in your image.

Figure 21. Removing drainages from NLCD with the Dust & Scratches filter. (see page 80 for larger color version)

It is the authors' hope that this paper spurs renewed interest in natural-color mapping. The digital procedures presented in this paper, we believe, will permit many more cartographers to make natural-color maps. The combination of Adobe Photoshop software and raster land cover data now provides a means of producing attractive natural-color maps that, dare we say, rival those made by Shelton. But good looks are only part of the story. Compared to manual methods, digital production yields maps of much greater accuracy. Map-readers can confidently assume that the pixels representing forests, fields, and fells are where they should be. New land cover data, such as MODIS VCF, which blends land cover categories into one another, provides readers with insights about the indistinct vegetative boundaries found in nature. For example, the colors representing forest and herbaceous land combine in Africa to form a third category: savannah. The amount of blending between, say, green forest and tawny grassland allows readers to gauge intuitively the relative vegetative content for any given area. And the use of shaded relief provides additional insights about the relationship of topography and vegetation. Making complex geospatial information such as this easy for inexperienced map-readers to grasp is what cartographic communication is all about. That natural-color maps are also visually pleasing and attract and hold our attention only adds to their effectiveness, in the words of Shelton, as "instruments of communication."

Digital production has largely removed the economic and time disincentives that have been associated with the making of natural-color maps in the past. Most of the data discussed in this paper is in the public domain and available online for free (see Appendix B). Adobe Photoshop, although relatively expensive, is already part of the software toolkit on many cartographers' computers. Most of the time needed for making natural-color maps digitally is spent in tedious data management chores: finding and downloading large data files, converting obscure formats, and reprojecting and registering shaded relief and land cover data. Compared to the manual era, however, the time needed for making a digital natural-color map now requires days rather than weeks or months. Once the data is ready, the procedures and examples we have described explain how to design and produce natural-color maps. Switching your thought processes from data management mode to a more creative mindset is a key to success. Because critical design decisions occur at the end of the project when time is often running short, one must resist the temptation to rush to completion.
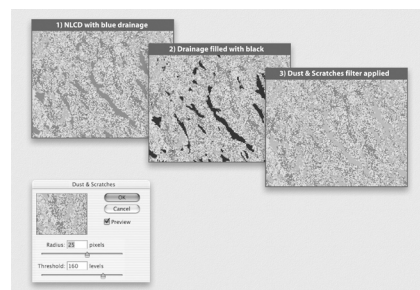
CONCLUSION

"The combination of Adobe Photoshop software and raster land cover data now provides a means of producing attractive natural-color maps that, dare we say, rival those made by Shelton."

While one no longer must be an accomplished artist/cartographer to make natural-color maps, good design sense and grounding in physical geography are still necessary prerequisites. Because of our tendency to overuse new design trends, cartographers must be mindful that natural-color maps are not applicable to all physical mapping situations. Shelton's claims of arbitrariness aside, hypsometric tints are acceptable, and they excel at showing elevation zones and topographic forms, if that is what one wants to emphasize on a map. Cartographic choice is a good thing.

Hal Shelton revisited: returning to art

Because this article began with a discussion of Shelton's early years in cartography, it is fitting that it should end with a few words about his later career. Art has become increasingly important in his life. After easing out of his relationship with the Jeppesen Map Company, Shelton turned his attention to painting ski area panoramas. His work included many of the major resorts in North America and a panorama of Grenoble, France, used by ABC TV for the 1968 Olympics. For his most famous panorama, "Colorado: Ski Country USA," Shelton received a lifetime ski pass to all resorts in Colorado, which he has put to good use for decades.

Shelton now devotes his time to painting—a return to his early art interest before it was interrupted by some 40 years of cartography. When creating art, Shelton finds that he is

"responding to a broader spectrum of realities than I was able to do in cartography."

The artistic and cartographic careers of Shelton came full circle in 1985 with an unusual request from the U.S. Library of Congress. The Geography and Map Division commissioned him to paint a landscape using the techniques he learned as a natural-color cartographer. Having applied his art training to cartography for so many years, the idea was for cartography to give something back to art. The result was "Canyon Lands," a 1.9-meter-wide triptych displayed behind the reference desk in the Map Reading Room (Figure 22). Although at the time of this writing "Canyon Lands" no longer is on display, you may view it privately by asking one of the librarians. The effort is worthwhile. Shelton's "Canyon Lands" repays cartography's debt to art most generously.

Figure 22. "Canyon Lands" by Hal Shelton. Millard Canyon, Utah, dominates the center of the scene and the snowcapped LaSal Mountains are faintly visible on the right horizon. The vertical triptych joints do not appear because of digital compositing. Courtesy of Library of Congress. (see page 80 for larger color version)

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Appendix A: Shelton Collection, Library of Congress

Africa Acrylic on zinc (1961) Lambert Azimuthal Equal-Area Projection Scale: 1:6,336,000 163 x 131 cm	**World: Eastern Hemisphere** Acrylic on zinc (undated) Parabolic Equal-Area Interrupted Projection Scale: 1:25,344,000 93 x 98 cm	**Palestine** Acrylic on zinc (1965) Lambert Conformal Conic Projection Scale: 1:1,000,000 91 x 60 cm
Arizona Acrylic on zinc (1955) Lambert Conformal Conic Projection Scale: 1:1,000,000 86 x 75 cm	**World: East Asia Gore** Acrylic on zinc (1957) Parabolic Equal-Area Non-Conformal Proj. Scale: 1:25,344,000 91 x 65 cm	**Nevada** Acrylic on zinc (undated) Lambert Conformal Conic Projection Scale: 1:1,000,000 92 x 65 cm
California Acrylic on paper-covered zinc (1959) Lambert Conformal Conic Projection Scale: 1,000,000	**Color Legend** Acrylic on zinc (1957) 18 x 29 cm	**Reno Area** Acrylic on paper-covered zinc (undated) Lambert Conformal Conic Projection Scale: 1:250,000 72 x 58 cm
Colorado Acrylic on zinc (1957) Lambert Conformal Conic Projection Scale: 1:1,000,000 48 x 65 cm	**Los Angeles Area** Casein on paper-covered zinc (1949) Lambert Conformal Conic Projection Scale: 1:500,000 51 x 56 cm	**Salt Lake City Area** Acrylic on paper-covered zinc (1950) Lambert Conformal Conic Projection Scale: unknown 53 x 39 cm
Eurasia Acrylic on zinc (1961) Lambert Azimuthal Equal-Area Projection Scale: 1:9,504,000 122 x 150 cm	**Middle East** Acrylic on zinc (1951) Lambert Conformal Conic Projection Scale: 1:5,000,000 102 x 123 cm	**South America** Acrylic on zinc (undated) Parabolic Equal-Area Projection Scale: 1:5,000,000 183 x 118 cm
Europe Acrylic on zinc (1957) Lambert Azimuthal Equal-Area Projection Scale: 1:12,038,400 51 x 61 cm	**World** Acrylic on paper-covered zinc (1951) Mercator Projection Scale: 1:31,400,000 102 x 157 cm	**Southern Hemisphere** Acrylic on zinc (1962) Polar Orthographic Projection Scale: 1:1,000,000 65 x 61 cm
New Europe Acrylic on zinc (undated) Lambert Conformal Conic Projection Scale: 1:5,000,000 107 x 137 cm	**North America** Acrylic on zinc (1956) Lambert Azimuthal Equal-Area Projection Scale: 1:6,336,000 145 x 119 cm	**South Polar Area** Acrylic on zinc (1957) Polar Stereographic Projection Scale: 1:25,344,000 48 x 53 cm
Western Hemisphere Acrylic on illustration board (1962) Global Projection Scale: unknown 58 x 44 cm	**Northern Hemisphere** Acrylic on zinc (1963) Polar Orthographic Projection Scale: unknown 56 x 57 cm	**United States** Acrylic on paper-covered zinc (1956) Lambert Conformal Conic Projection Scale: 1:3,000,000 102 x 175 cm
Eastern Hemisphere Acrylic on illustration board (1957) Global Projection Scale: unknown 43 x 33 cm	**New Mexico** Acrylic on zinc (undated) Lambert Conformal Conic Projection Scale: 1:1,000,000 79 x 71 cm	**Utah** Acrylic on zinc (1956) Lambert Conformal Conic Projection Scale: 1:1,000,000 91 x 65 cm
Hawaiian Islands Acrylic on zinc (1957) Lambert Conformal Conic Projection Scale: varies depending on island 65 x 89 cm	**North Polar Area** Acrylic on zinc (1956) Polar Stereographic Projection Scale: 1:25,344,000 55 x 73 cm	**Wyoming** Acrylic on paper-covered zinc (1953) Lambert Conformal Conic Projection Scale: 1:1,000,000 48 x 65 cm
World: Western Hemisphere Acrylic on zinc (undated) Parabolic Equal-Area Interrupted Projection Scale: 1:25,344,000 93 x 75 cm	**Pacific Northwest** Acrylic on paper-covered zinc (1962) Lambert Conformal Conic Projection Scale: 1:1,000,000 117 x 183 cm	

Appendix B: Internet Resources

The website for this article
http://www.nacis.org/cp/cp45/shelton/index.html
Satellite images
NASA "Blue Marble" (free)
http://earthobservatory.nasa.gov/Newsroom/BlueMarble/

Landsat images of the World (free)
https://zulu.ssc.nasa.gov/mrsid/mrsid.pl

NASA MODIS (free)
http://modis.gsfc.nasa.gov/gallery/index.php#

The Living Earth (commercial)
http://livingearth.com/

Worldsat International, Inc. (commercial)
http://www.worldsat.ca/

Land cover data
University of Maryland, Global Land Cover Facility
MODIS Vegetation Continuous Fields (free)
http://modis.umiacs.umd.edu/vcfdistribution.htm

USGS National Land Cover Dataset (free)
http://landcover.usgs.gov/natllandcover.asp
http://seamless.usgs.gov/

USGS Global Land Cover (free)
http://edcdaac.usgs.gov/glcc/glcc.html

European Commission Global Land Cover (free)
 http://www.gvm.jrc.it/glc2000/Products/fullproduct.asp

Boston University Global Land Cover (free)
http://duckwater.bu.edu/lc/mod12q1.html

GAP Analysis Program (free)
http://www.gap.uidaho.edu/Projects/FTP.htm

Elevation data
NOAA ETOPO2 Worldwide Bathymetry (free)
http://www.ngdc.noaa.gov/mgg/image/2minrelief.html

USGS GTOPO30 Global Topographic Data (free)
http://edcdaac.usgs.gov/gtopo30/gtopo30.html

SRTM - Shuttle Radar Topography Mission (free)
http://www2.jpl.nasa.gov/srtm//pub_dist.htm

Artist/Cartographers
Tóth Graphix Cartographic Art Studio
 http://www.tothgraphix.com/

<div style="border:1px solid; padding:4px">

cartographic techniques

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Note from the Editor: the content of this paper was presented at the Annual Meeting of the North American Cartographic Information Society, Jacksonville, FL, October 2003

Small Type, Screens and Color in a PostScript Offset Printing Environment

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As with any map design project, a conventionally printed map (i.e. halftone-tinted, offset-printed), is easier to create if a wide variety of colors are available for all aspects of the map. One place where this becomes challenging is in small type and symbols (for this paper symbols and type are considered the 'same'). In order for type to be legible, sense dictates it be printed in a solid color, as half-tone screens will render most small shapes illegible.

Logically then, a cartographer will fall back on solids of the inks he/she will be printing in, to determine what colors are available for small type. If one is printing in the standard CMYK process universe, this means three solid colors: black, which is fine; cyan, which is not the best possible blue but is certainly acceptable, and magenta, which is an unpleasant, acid color. No green, no brown, no gray….etc.

Historically, if a cartographer wants a good range of colors, it is useful to think in terms of printing outside the standard process palette of cyan, magenta, yellow, and black. Many national survey series are based on such alternate palettes, like the USGS 7.5' series'

familiar black, green, red, blue, brown, and purple.

Another alternative is to adopt an alternate four-ink process palette. In the mid-twentieth century, many U.S. oil company maps adopted a palette consisting of a light blue similar to cyan, a warm red instead of magenta, a yellow somewhat redder than modern process yellow, and a dark blue instead of black (Figure 1 is an example, a section from a Gousha-published Gulf Oil map of New Jersey form 1942). Though a desirable palette, Hedberg Maps adopted a different palette early in its publishing history that allowed for a somewhat larger range of colors, and was closer to CMYK for proofing purposes. This palette was also observed in the late Falk-Suurland's line: process cyan and black, combined with a warm red and reddish yellow.

The disadvantages of using such a non-CMYK process palette are more modest than a totally spot-color-dominated palette, but do include (1) incompatibility with off-the-shelf proofing and color-calibration systems, (2) problems integrating photography or client-supplied artwork, and (3) a modest additional expense from printers (especially for short print runs) involving press wash-up and ink costs.

In theory, of course, mapmakers can approximate most colors by using combinations of the modern process palette. The problem is that virtually all colors involve screen tints and these, as mentioned above, do not generally support the shapes of letterforms at small sizes—or that, at least, is the theory.

In the last few years, Hedberg Maps has switched to standard CMYK, and has maintained a relatively broad range of small type colors, by adhering to the principles and techniques outlined in this paper. These principles
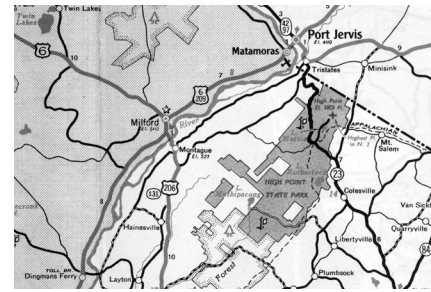
Figure 1. (see page 81 for color version)
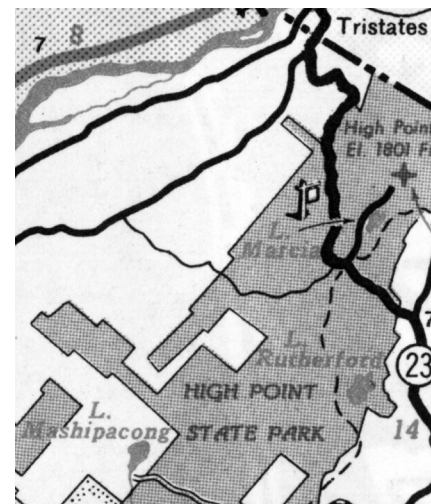
Figure 1a. (see page 82 for color version)

and techniques depend on good registration, so lower-end map printing applications need to adjust these rules judiciously. It has been noted that several other map companies are engaging in similar techniques, therefore this paper should spark further creative thinking about color and type.

1. Use The PostScript Edge

PostScript defines all letterforms by their outline. This hard edge is maintained all the way through processing a vector-based PostScript file, to the point where it is rasterized for the output device. Among other things, this means that halftone screen dots that cross the hard line will be cut cleanly along the line, maintaining the shape rather than distorting the edge fluidly towards the dot. If output is direct to plate, this hard

edge will be first-generation when it hits paper.

This is dramatically different from older manual techniques, where—especially over the life of multiple revisions—you could count on small but cumulatively significant optical distortions related to the overall set of shapes and their interactions, not to the specific shape objects. Figure 1 shows how the photo-film process caused water type in the same ink as the green tint behind it to meld with the blue screen portion of that tint.

2. Solid Ink Plus Screened Ink

A solid of one color is sufficient to hold a shape if open tints of a second color are added. Open tints are those formed by solid dots in an open space, i.e. screens under about 55% using most algorithms. The theoretical screen percentage where dots in a square grid would touch is 78.5%, but the convention is to switch positive and negative somewhere between 50% and 60%, so that in darker tints the pattern is not dark dots against paper, but paper dots reversed out of a solid ink If closed tints (those formed by open circles within a solid ink) are added to a solid of another color, there is a risk that in the event of off-registration, both inks trying to hold the letter-form shape will compete and accentuate the registration problem. By placing a series of dots against a solid of another color, you allow the solid to hold the shape, while the "shapeless" mass of dots in another ink only adds color.

3. Dark Ink Plus Light Ink

Most cartographers already so this to create greens and warm reds. In the CMYK world, yellow can be added in any screen percentage (including 100%) with near-impunity to any solid dark ink. If you are using non-CMYK inks,

any light ink will have the same effect. To judge an ink's lightness, consider its "L" value in the L*A*B color system. For example, in Photoshop (where one can determine L*a*b values in the color picker) black has an L*a*b lightness value of 0, cyan of 62, magenta of 48 and process yellow of 94 (Kennelly and Kimerling, 2003).

4. Solid Type Against Screened Line Work Not Including That Ink Color

Running any solid dark ink type against an open screen of another dark ink (or inks) works well, because the edge of the solid dark type remains intact. For many of our street maps, Hedberg Maps use a street line that's a combination of cyan, yellow and magenta. When street labels are printed in black ink, the line work and the type do not have to be kept totally separate (though of course it looks even better when they are kept separate).

This is not a carte blanche. One still can't print dark type over linework with too strong a contrast. As a principle, the contrast between your type and your overprinted linework should be greater than that between the linework and the background. Figure 2 illustrates two editions of Hedbergs Maps' Cambridge Street Map title. On the left is the first edition as printed in four spot colors. On the right, a modified process palette meant creating a street line color as a tint combination. This illustrates that the street line work was too dark.

5. Solid Type Against a Screen of the Same Ink Color: Text Line Weight should be at an appropriate ratio to the dot diameter.

Solid type can be placed in some situations against tints of the same ink color, but as the type gets smaller, the potential for legibility
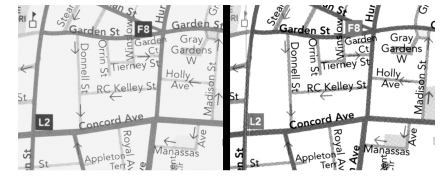
Figure 2. (see page 83 for color version)

problems gets greater. The letter shapes begin conflicting with the dots of the screen pattern. What appears to happen, in part, is that the reader's eye wants to average the dot pattern out as gray, but doesn't know what to do when a dot is also affecting the shape of a small piece of type. The end effect is often one where some pieces of letters seem to disappear as they move in line with rows of dots, and where other pieces of type become "filled in" as other dots close gaps and breaks in letter shapes.

An initial subjective look at samples, for example in Figure 3, seems to indicate that the determining factor is dot size versus the width of lines forming the letter
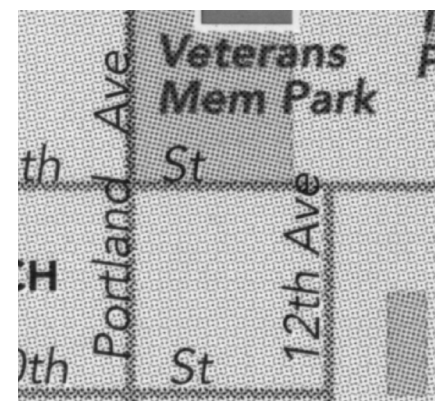

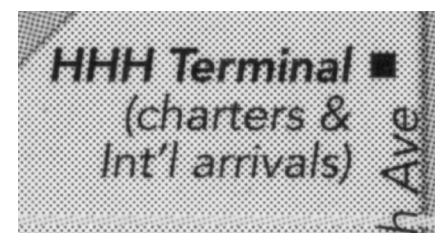*Figure 3a. (see page 83 for color version)*

Figure 3b. (see page 84 for color version)

form. This makes sense intuitively: if a dot is dramatically smaller than a line it overlaps, it may not read as a related shape, whereas if a screen dot approaches the density of a shape within a letterform, it may become hard to tell them apart when reading or scanning at full speed. Of course, other factors creep in to affect legibility: small type in general can be hard for many to read, and fonts in themselves can be easier or harder to read depending on size, and at very small point size (under 6 point, and especially under 5 point) great care must be taken in choosing fonts for legibility.

To use this principle, it helps to have an idea of dot size and the width of lines within letters. To calculate dot diameter *d*, given a screen frequency *f* in dots per inch (dpi) and a tint percentage *p*, the relationship can be initially stated as:

$$\frac{p}{100} = \frac{\left(\dfrac{d^2 \pi}{4}\right)}{\left(72\dfrac{1}{f}\right)^2}$$

This can be reduced to:

$$d = \frac{\sqrt{p}}{f} \times \frac{14.4}{\sqrt{\pi}} \approx 8.125 \frac{\sqrt{p}}{f}$$

This formula will give *ideal, theoretical* dot size. RIPs and output devices distort this in order to make up for dot gain, and once on press dot gain can make a mockery of the numbers thus derived. Nevertheless, Figure 4 is a table giving ideal dot diameters in points for common tints and screen frequencies.

The easiest way to calculate the line weight of a font is to set a piece of type at 10 points, and on-screen to draw a line that matches a thin line within the test. The

Screen percent	50 dpi	72 dpi	100 dpi	133 dpi	150 dpi	200 dpi
5%	0.36	0.25	0.18	0.14	0.12	0.09
10%	0.51	0.36	0.26	0.19	0.17	0.13
15%	0.63	0.44	0.31	0.24	0.21	0.16
20%	0.73	0.5	0.36	0.27	0.24	0.18
25%	0.81	0.56	0.41	0.31	0.27	0.2
30%	0.89	0.62	0.45	0.33	0.3	0.22
40%	1.03	0.71	0.51	0.39	0.34	0.26
50%	1.15	0.8	0.57	0.43	0.38	0.29

Figure 4

crossbar of the small letter "e" is a good example, or the crossbar of a capital "T". One can then multiply by one-tenth the actual text (i.e. line weight of 6 point type will be .6 times the 10 pt weight).

A few basic examples: Adobe's Helvetica Regular has a minimum line weight at 10pt of .69 pt and Helvetica Bold is .91 pt. In Hedberg Maps' "house font", Avenir, the weights are: Book, .54 pt; Roman, .66 pt; Medium, .72 pt; Heavy, .89 pt; and Black, 1.02 pt.

The acceptable ratio of letter line weight to dot diameter is really an individual decision. In different situations, a reasonable lower limit is somewhere between 1:1 and 1.5:1. For Helvetica then, if 1.5:1 is chosen as the threshold, then using the chart above, at a 133dpi screen, 6 point type (with a line weight of about .6 x .69 pt = .41) could offer nothing lighter than about a 22% tint (with a dot diameter somewhere around .28 pt), and a 10% tint (dot diameter of .19pt) would work with type no smaller than 4 pt (line weight of .28pt).

Serifs make the calculations almost impossible at a numeric level. Instead, a variant on the test performed in Figure 4 is suggested. Here a 50dpi screen series is laid against 10pt type for various fonts. Working at this large scale will allow a few things: first, what will be discerned is what the acceptable dot-font size ratio is, without regard to whether the type works well in general at a small size.

Second, the test can be performed without utilizing expensive high-end output; 50 dpi screens have pretty accurate dots on most modern laser printers, though some laser printers (e.g., Xerox) tend to make dots form into diamonds as they approach 50%.

As an example, if on such a test you decide that a 50dpi screen of 20% is as dark a screen as can be tolerated for 10pt FontX, that means a dot diameter of .73 is your minimum at 10 pt. Size changes are proportional, so at 5 pt FontX, the maximum dot diameter is .5 x .73 or .37 pt. If printing at 133 dpi, this means the threshold for screen darkness is a little lighter than 40%.

This technique is in need of more rigorous testing with a larger sample of fonts and font styles. In particular, while this series of measurements works fairly well for fonts with nearly even line widths throughout, the numbers fall apart for serif fonts, where line weights vary dramatically. Times Roman, for example, varies at 10 pt from about 1 pt down to about .35 pt. Italic versions (which are conventionally used as hydrologic labels, often over a tint of the same blue ink the type is printed in) are even more variable. A font-by-font analysis would be necessary, and perhaps the technique outlined above will allow us to make better judgements for specific fonts.

6. Light Lines

The same basic principles work for light lines. On Hedberg Maps' campus and community map series, very light lines are used to outline buildings. Over the years, Hedberg Maps has used lines both in a CMY color combination and in a black tint. In both cases, lines of hairline (.25 pt) and .5 pt weight have also been tried. As Figure 5 shows, which color model is used
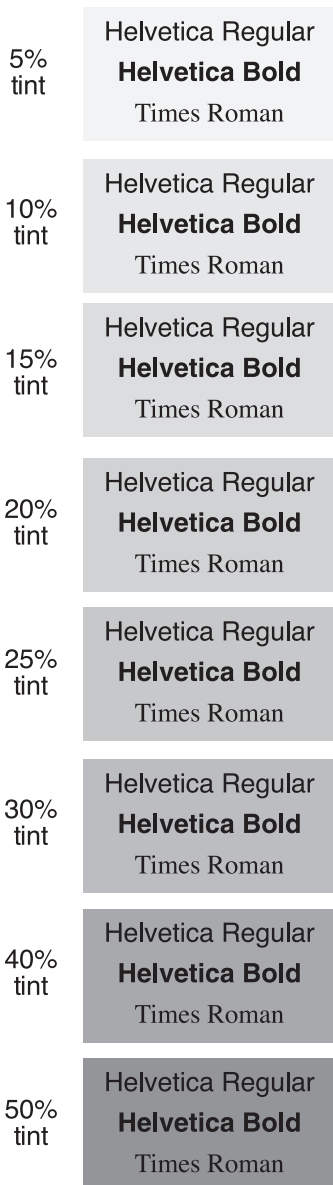
All type is 10 point
All screens are 50 lines per inch

5% tint	Helvetica Regular **Helvetica Bold** Times Roman
10% tint	Helvetica Regular **Helvetica Bold** Times Roman
15% tint	Helvetica Regular **Helvetica Bold** Times Roman
20% tint	Helvetica Regular **Helvetica Bold** Times Roman
25% tint	Helvetica Regular **Helvetica Bold** Times Roman
30% tint	Helvetica Regular **Helvetica Bold** Times Roman
40% tint	Helvetica Regular **Helvetica Bold** Times Roman
50% tint	Helvetica Regular **Helvetica Bold** Times Roman

Figure 5

makes little difference. In both cases, .5 pt is necessary.

In this case, it is the space between dots that is important. In a 133 dpi screen, the dots are a little over .5 points from center to center. A similar effect could have been achieved with a proportionally narrower line if the screen frequency were higher.

7. Screened Type

Figure 6 illustrates an example of screening type. While it was noted earlier that screened type does not hold up well, at some point the shapes become large enough to hold up even when viewed through a screen. As in the above section on lines, the key seems to be the ratio of the line weight to the distance between dot rows. Extensive testing has not been conducted on this, but the type appears legible when the letter type weight is about 2 to 2.5 times the distance between rows (i.e. the inverse of the screen frequency).

The above applies to open screens. For closed screens, the ratio can get much closer, down to 1 to 1.5 times the dot-to-dot distance. In these cases, the goal is that nowhere will a "hole" or inverse dot cut across a piece of type so as to distort the type. As in screening behind type, both open and closed screen tints of type itself are much easier in simple sans serif fonts than in serif fonts.
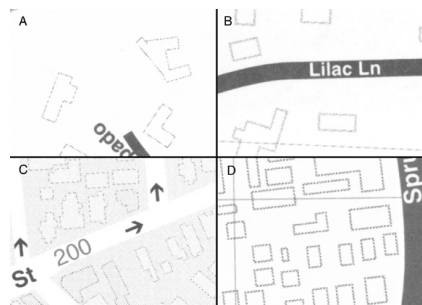
Figure 6. (see page 84 for color version)

Conclusion: Think In Inks

In the digital age, comparatively little time is spent thinking about separations and how they will work together when compared to the era in which each separation was assembled manually from a variety of elements. The automatic nature of separation makes life easier, but it also takes away some awareness of how using the four (or more) separate ink colors can expand our design options. Thinking in terms of inks is still important.

For better or for worse, though, this technique may be moot in a few years time. Stochastic printing has its own design challenges (screens of light graduated tints, for example, look quite different), but it does make type composed of almost any ink combination a viable option. As it appears stochastic is finally working its way into the mainstream, color printing will in the near future have resolved most of what is discussed in this article, opening up yet further design options to cartographers.

Acknowledgements:

References

Kennelly, P. and Kimerling, J.A., 2003. *Analytical Hillshading with Luminosity from Aspect*. Paper presented at the Annual Meeting of the North American Cartographic Information Society, Jacksonville, Florida.

The Man Who Flattened the Earth: Maupertuis and the Sciences in the Enlightenment

By Mary Terrall
Chicago: University of Chicago Press, 2003. 408 p., 3 halftone illustrations, 23 line drawings, bibliography, index. ISBN 0-226-79360-5, hard-cover. $39.00

Reviewed by Judith A. Tyner, Ph.D.
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Long Beach

Pierre-Louis Moreau de Maupertuis (1698-1759) is not a household name. He is not as familiar to most as are Newton, Voltaire, Cassini, or Celsius, other seventeenth and eighteenth century names in science and literature. Maupertuis made no great discoveries and many of his theories were contested at great length and frequently acrimoniously.

Maupertuis was a polymath who studied and wrote on mathematics, geodesy, astronomy, biology, and metaphysics. He was elected to both the French Academy of Science and the Académie français (literary society), a rare honor for a scientist. He was asked by Frederick the Great to head the reformed Berlin Academy of Science and Belles Lettres. A high point of his career was his expedition to Lapland to prove that the earth was flattened at the poles rather than elongated.

The Man Who Flattened the Earth: Maupertuis and the Sciences in the Enlightenment is an intellectual biography of the man and what it meant to be a man of science in the Enlightenment, a time when the way to such a career was not clearly defined. The emphasis of the book is on the subtitle; only two chapters deal with the "flattening of the earth"—one on the expedition to Lapland and one on the polemics that followed.

The book consists of eleven chapters in roughly chronological order that trace Maupertuis's life and thinking from his birth in St. Malo to his death in 1759 in Switzerland. Each chapter deals with one or more of Maupertuis's often controversial papers or books. The expedition to Lapland is described in detail, but the following chapter, "Polemical Aftermath of the Expedition," is the more entertaining. Here the author details the acrimonious writings of Cassini and others who denounced Maupertuis's work as faulty at best, and definitely shoddy because a certain procedure was not followed, and the rejoinders by Maupertuis and Celsius that pointed out that the new instruments they used did not require the procedure. It makes some modern debates among scientists seem cordial.

Another of Maupertuis's controversial works, *Vénus physique*, is discussed in "Toward a Science of Living Things." This chapter describes Maupertuis's forays into biology and natural history. Maupertuis had, throughout his life, performed numerous experiments on animals from tiny water creatures to dogs. He was interested in reproduction and the formation of the embryo—in the eighteenth century it was not known how the sperm and egg connected. *Vénus physique* was written as a popular book and directed toward a specific unnamed woman explaining how animals and humans reproduced. As usual, his theories were controversial as was the nature of the book. Because it was written to a woman, erotic in itself, and in somewhat the style of contemporary pornography, it created quite a stir.

Vénus physique was only one of Maupertuis's "popular" works.

Especially since he wanted to be elected to the select Académie français, Maupertuis wrote a number of works designed to explain various aspects of science to the educated public and to promote himself as a man of letters; one of these was *Elements of Geography*.

The Prussian king, Frederick the Great, when still crown prince, desired to reconstitute the inactive Berlin Academy of Sciences and Belles-Lettres. His intent was to establish an academy that would rival those of England and France. As early as 1738 Voltaire approached Maupertuis to be the head of the new academy. The Berlin Academy was re-established in 1744 and Maupertuis assumed the position of President in 1745. For this he had to resign from the French Academy and relocate to Berlin where he remained until two years before his death. Many of his writings at this period were not only to advance his own reputation, but also that of the academy and the king.

Along the way, we are given insights into science and society of the time—the discussions in cafes and salons, the interactions with king and court, and the rivalries and alliances between scientists at the time. Discussions in cafes and salons were important forums for scientists and writers then. These were not casual chats over coffee as we might have now, but quite often formal presentations. Well-known salons were presided over by wealthy, educated women who invited prominent scientists and authors to participate. Maupertuis was known in this milieu for his social skills, witty stories, and anecdotes.

Maupertuis, the man, comes across as ambitious, somewhat arrogant, and at times annoying, although contemporaries found him charming and sociable. He was relentlessly self-promoting. Today, we would say that he set

goals and knew what it took to reach them. His great desire was to build a reputation "among the social and intellectual elite, including technically adept men of science" (p. 8). His advice to a colleague was to publish small works often to keep one's name in the public eye. This isn't bad advice for junior faculty today.

This is a scholarly book, not designed for the casual reader. There are copius footnotes on every page, usually over 100 per chapter (one reaches 192). There are 22 pages of bibliography and a 16-page index. The author, Mary Terrall, clearly is well-versed not only in her subject, Maupertuis, but also in the time and the science of the time. She is totally at home in the period and knowledgeable of the science, scientists, and scientific disputes. The book is thoroughly researched. Maupertuis's works were in French as were the manuscript sources (correspondence and some of Maupertuis's unpublished manuscripts). Professor Terrall did all of the translations herself rather than rely on an outside translator so these are not filtered through another's views. Often the original French is provided in the footnotes.

The author assumes familiarity with the period of the Enlightenment and the people and places. A reader who is not so conversant with the time, may find him/herself wishing for a cast of characters at the front of the book as in 1930s mystery novels. Professor Terrell's familiarity with the period has led to some odd omissions; latitude and longitude are carefully explained to the reader, but some terms unfamiliar to a modern reader, e.g. *fluxions*, are not. This is not a fast read or a fast-paced story focusing on one event or theory. Seeing the title, one might assume that the book is concerned primarily with the story of the Lapland expedition, a book along the lines of Dava

Sobel's highly popular *Longitude*. Anyone expecting that will be disappointed, but one who is looking for a thorough, scholarly treatment of science and society in the eighteenth century will be pleased.

Cataloging Sheet Maps, the Basics
By Paige G. Andrew
New York: The Haworth Information Press, 2003
ISBN 0-7890-1482-3, hardcover; 0-7890-1483-1, paperback
$24.95, xv, 240 pp., tables, illustrations, appendix, bibliography, index.

Reviewed by Christopher H. Mixon
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If I have learned anything from my experience as an Army Reserve officer, it is this: You do not have to know everything—just where to find the answers. Now, I am not by any means an experienced cataloger. I have no formal training to speak of. However, I have been learning by doing in the company of some very fine experts for over three years now. Some of my teachers, in addition to the author, are acknowledged in this book. I also owe a great deal to bosses and coworkers who show me the ropes every day. I realize that this review is about the book and not about me, but I feel it is important to point out a bit of my background because I think it will help to emphasize how vital this book is to those learning to catalog maps. In the forward, Alice C. Hudson points out that increasingly map catalogers and curators are not map specialists, that the job of map cataloging has been placed upon many who are

unfamiliar with the intricacies of maps and map making. While this is certainly true, and a key audience for this book, my situation is quite different. Having received a geology degree and gone on to study cartography in graduate school, I have always dealt with maps. Even as a child I was fascinated by maps and became the family navigator while on vacation. As a map cataloger/curator, I do not know which is more difficult: having a good understanding of maps but no cataloging experience or vice versa. For the past three years, I have made use of the various sources on cataloging: *Anglo-American Cataloging Rules*, Second Ed., *Cartographic Materials*, MARC 21 *Concise Format for Bibliographic Data,* to name a few. These essential tools have been helpful yet often confusing. *Cataloging Sheet Maps, the Basics* brings the myriad of cataloging resources into focus and points directly to the particular manuals and rules that pertain to specific tasks in properly describing a map.

Cataloging Sheet Maps, the Basics consists of five sections, each with clear illustrations and, where necessary, multiple examples of various cataloging situations. The first section, "In the Beginning," consists of a bit of background into why basic map cataloging is so important as more and more libraries are making the decision to bring their maps up to the level of the rest of their collections where cataloging is concerned. It asks, "What is a map?" And "Why bother to catalog maps?" These are two very basic questions but certainly worth asking. A cataloger who is new to maps might do better knowing what is considered a map and may just be surprised by the answer. Knowing and understanding the parts that go into a map is the key to describing them. As for the second question, I believe that anyone would agree that anything worth having in a

library collection is worth describing for their patrons. In the second chapter of the first section, the author jumps right into the nuts and bolts of map cataloging. He begins with some advice on methodology and quickly points out that each cataloger has to develop his or her own style. Keep in mind, however, that his advice comes from many years of experience and dedication to the craft, which has helped shape some of the rules we use currently. The third chapter describes the various publications that a map cataloger needs to have at his/her disposal in order to adequately describe cartographic materials. This list of resources is quite extensive but is broken down into basic, essential, and helpful tools. Some are strictly electronic sources, some strictly paper, and some are both. The basic tools are those that should be found in any cataloger's arsenal whether they deal with maps or not, such as *Anglo-American Cataloging Rules, Second, Ed.* (AACR2R). The essential tools are those that every map cataloger should have at hand such as *Cartographic Materials: A Manual of Interpretation for AACR2R*, and a measuring device with centimeters on it. The helpful tools include articles published on map cataloging, helpful websites such as Western Association of Map Librarians "Map Librarians Toolbox" and many others. Section One finishes with the chief source of information (the map and/or its container) and prescribed sources of information as outlined in AACR2R that one can use to derive the content that will go into the various parts of the bibliographic record.

Section two, "Coded Fields," describes the fixed fields and the variable fields in the bibliographic record, describing first those fixed fields that are specific to cartographic works and then those fixed fields that are general. The

variable fields are treated in the same manner but in much greater detail—naturally since this includes the 007 or physical description field, which is mandatory and must relate consistently with the physical description or 300 field and any notes that relate to physical description. If a particular field is repeatable and/or mandatory and under what conditions is also spelled out here.

Section Three, "Description of the Map," is by far the largest and with obvious reason. After all this is what it's all about—describing the map. It begins with a chapter on Main Entry and Statement of Responsibility. Main entry under personal author versus corporate body and the issues one encounters when dealing with maps can be sticky for a cataloger accustomed to working with monograph titles. This section offers explanations of the rules involved and lists terms one might find on the map to aid in making informed decisions. The next chapter under "Description of the Map" concerns entry of a title in the record. This may seem like an easy task and often is; however, as the author points out, there are many situations where the title is not immediately obvious. Many maps will often have more than one title which may pertain to the same main map or two titles for two separate but equally important maps on one sheet. Sometimes maps bear no title at all. There is information here for dealing with just about every situation regarding titles. Next is a chapter on edition, which describes the importance of a map's edition in a description due to a map's graphic nature and how small changes in a map from one edition to the next could have a marked impact. The next chapter concerns the mathematical data area, which makes me thankful that I have a cartographic background. To many catalogers start-

ing out with maps, this can be like learning a new language. This will become easier with exposure and experience, as the author points out. Much of this chapter is a bit of a lesson in basic map reading and discusses concepts related to map scale, projection, and map coordinates. Map scale and how it is depicted on a map, concepts of large scale versus small scale, and how to correctly enter this information in the record are discussed at length. I have seen professors of Geography become confused about scale so you can imagine how this subject can scramble a new map cataloger's grey matter. Using clear language and illustration, the author does an excellent job of describing scale and how it is to be depicted in the map record. Projection, while a potentially difficult concept to grasp, is not discussed in great detail primarily because it is not necessary to fully understand the idea in order to place it in the record. Recording the map's coordinates is not as simple, however, and although optional, the author urges its use whenever possible as this allows for mathematical access to maps contained within the stated coordinates. This chapter carefully outlines the process of recording coordinates and even extrapolating coordinates where the mapped area extends outside of the printed coordinates. A boxed section in this chapter gives a quick look at rules of thumb and provides situational examples for recording coordinates. Publication information is discussed in the next chapter. This is information that is not always evident on many maps. Even dates can be nonexistent or encrypted on some road maps. Publication date versus date of situation is discussed here also. Next is an extensive chapter covering the physical description area or 300 field. For this area in the record, the author describes various ways that maps

can be put together such as map sets, map series, a map on multiple sheets, and how they should be dealt with. In this section the descriptions start with the simplest situation and end with the most complex situation for the physical description. The chapter then continues with how to record a color versus monochromatic map and how to deal with two sided maps and the application of recto and verso. Finally the chapter discusses measuring the map and how, where, and when it is appropriate to measure the map and/or its container. This is where that tape measure with centimeters is put to good use. Section three concludes with a chapter devoted to including notes in the record. This chapter contains a list of essential notes and additional information notes pertaining to cartographic materials. There are examples listed categorically dealing with map description at the end of the chapter.

Section four, "Other Access Points," deals with other items in the record to assist the searcher in finding the right map. Beginning with classification using the Library of Congress (LC) G-schedule, the author breaks down a typical LC call number into its component parts and discusses each thoroughly. LC is the only classification discussed in the book since it is the most widely used classification system for maps. Then the section moves on to a chapter on subject analysis for maps. This chapter refers heavily to specific resources related to subject analysis. This provides a close look at geographic subject headings and guidelines for indirect and direct geographic subdivision. The section ends with a chapter dealing with how and when to place added entries in the record and its justification.

The fifth and final section, "Historical Sheet Maps and Special Cases," begins with the fact that individuals rather than corporations or agencies are more often given main entry and that it is important to include everyone involved in statements of responsibility. Secondly, titles can be a special problem in historical maps and there are references to the rules on how to handle these. Scale conversion from historical units of measurement to today's units based on miles is listed under mathematical data as is projection and conversion of coordinates. Like scale, coordinates require conversion to today's system and this is explained here. The chapter discusses how to provide publisher, place and date of publication and how to deal with placenames that have changed since the map was made. There is some discussion about the rules that govern physical description that reflect how the map was produced. The chapter lists unique notes that are essential in describing historical maps such as the description of a watermark or information regarding donor or previous owner. Finally, subject subdivision and particular subject practices are covered, such as the use of current geographic names over historic names in the subject entry. The final chapter relates to special formats and situations, starting with specially mounted wall maps and how this affects physical description. Next, the author covers cataloging map series by touching on each element of the bibliographic record, including relevant coded fields, title, mathematical data, physical description area, etc. The next item discussed covers the handling of indexes, text, and other supplementary items relevant to the map itself. Then finally a reference to resources on how to handle various map reproductions completes the final chapter.

The appendix consists of practical exercises, with answers, where the reader is asked to supply appropriate entries in 034 field (projection), the 052 field (geographic area code), and 300 field (physical description).

In my opinion, *Cataloging Sheet Maps, the Basics,* accomplishes the long overdue task of bringing together everything one needs to know to create good map records. It does not supply all of the answers, but it provides excellent examples, and refers you directly to the sources of authority on every aspect of a good map record. I not only recommend this book but I urge anyone cataloging maps to include it in their arsenal, whether you know map cataloging or are new to it all. With this tool in hand, the various resources will be so much easier to navigate when answers are needed. Obviously, if you are an experienced cataloger new to maps, it is the cartographic stuff that is most troubling and this book will definitely ease your mind. For me, however, *Cataloging Sheet Maps, the Basics* will become my portal into the vast cataloging resources available for cataloging sheet maps.

Cartography 2003

Figure 3. A public domain reference map of Azerbaijan. Source: CIA Factbook, 2003.
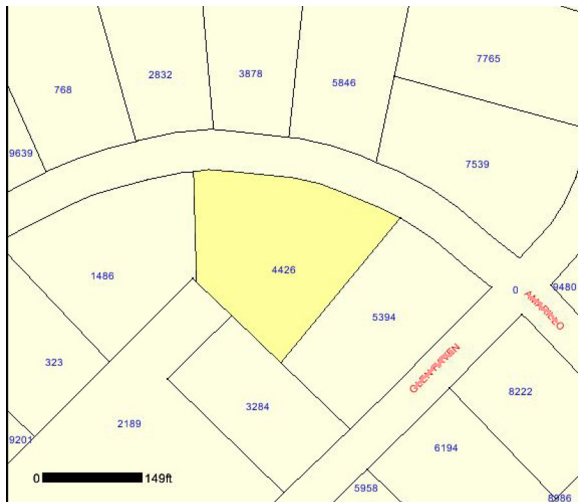
Figure 4. A property map on the web. Source: Cabarrus County, 2001.
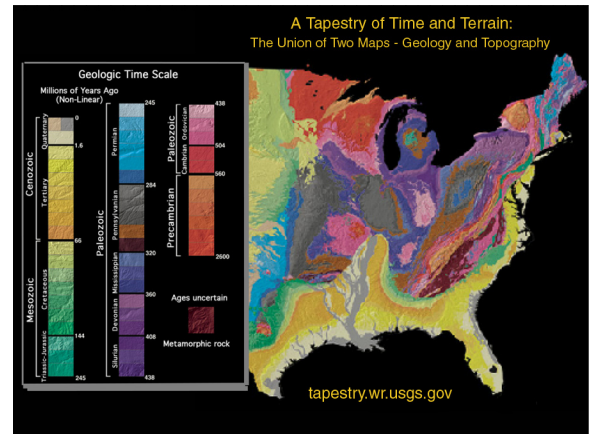
Figure 5. Excerpts from "A Tapestry of Time and Terrain." Image has been rearranged for this illustration. Source: Vigil et al., 2003.
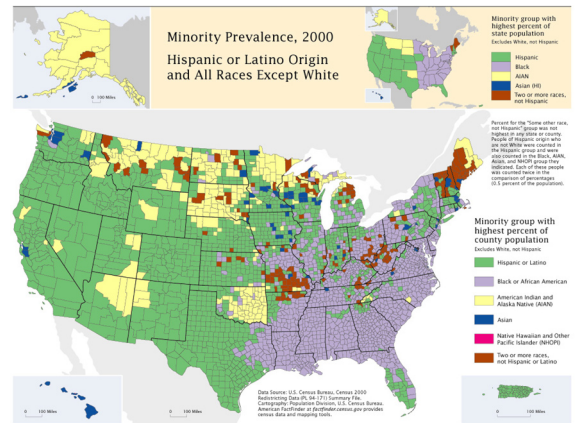

Figure 6. A map from *Mapping Census 2000*. Source: Brewer and Suchan, 2001.
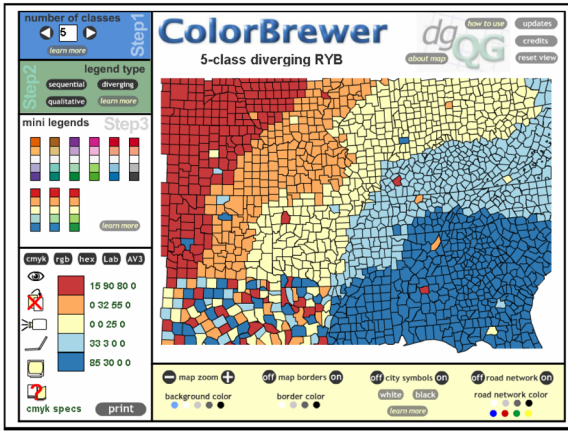
Figure 8. The layout of a Colorbrewer page. A diverging 5-class scheme is illustrated here. Source: Brewer, 2002. Used with permission.
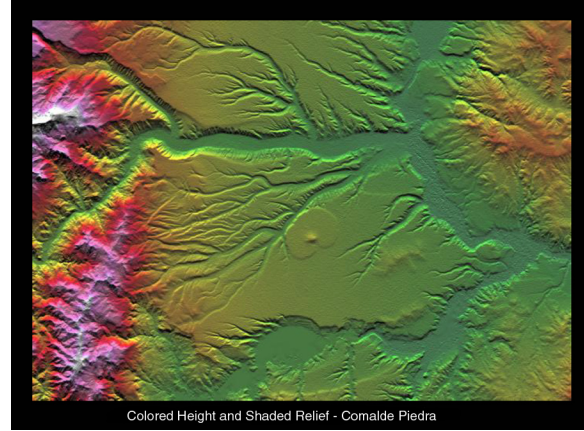
Figure 11. An image created from Shuttle Radar Topography Mission data. Source: JPL, 2003.
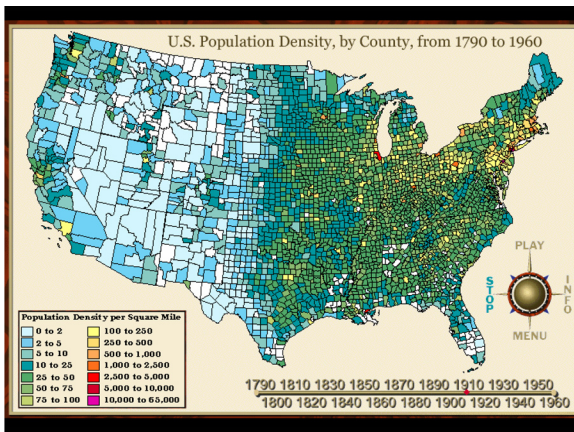
Figure 9. The 1910 population image in Jill Hallden Harsha's U.S. population animation. Used with permission.

Figure 13. A screen capture of a page in the interactive Atlas of Oregon. Used with permission. Source: Atlas of Oregon CD-ROM, Copyright 2002, University of Oregon Press.

http://www.davidrumsey.com/GIS/3d.htm
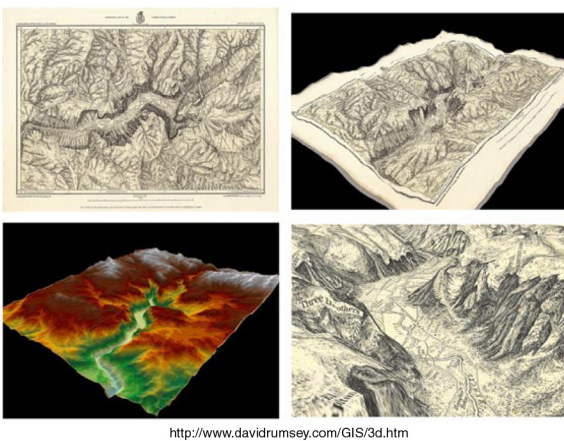
Figure 10. An historical map of Yosemite Valley, the current-day digital elevation model (DEM) of the same area, and the historical map draped over the DEM. The image in the lower right is a scene as one flies over the area. Source: Rumsey, 2003. Used with permission.

Mapping September 11, 2001: Cartographic Narrative in the Print Media

Figure 7. "Osama's World", Time, 24 September 2001. ©TIME, Inc. Reprinted by permission.

Figure 9. "The Options for Battle", Newsweek, 15 October2001. ©2001 Newsweek, Inc. All rights reserved. Reprinted by permission.

Hal Shelton Revisted: Designing and Producing Natural-Color Maps with Satellite Land Cover Data

Figure 1. A portion of Hal Shelton's 1:5,000,000-scale New Europe *map painted ca. 1968. The original measures 107 x 137 centimeters. Drainages and water bodies are photomechanical additions to the original art. Courtesy of Rand McNally & Company.*
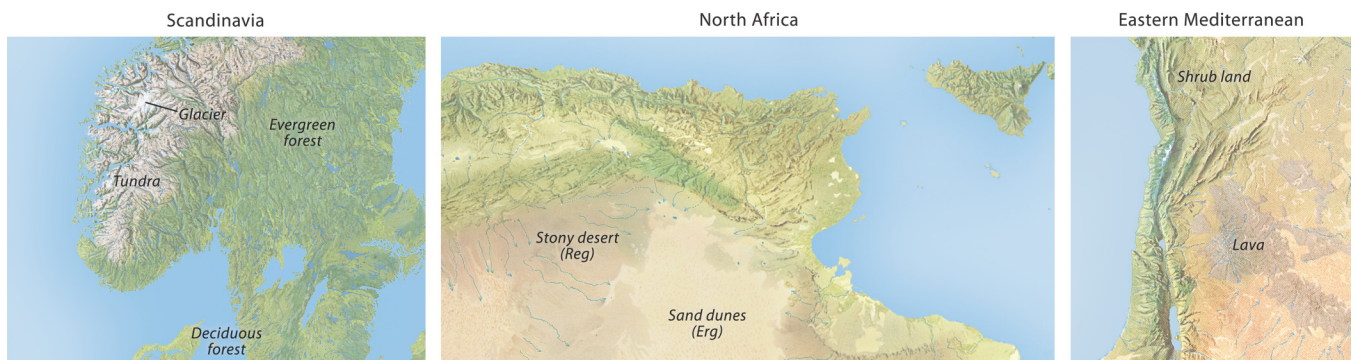
Figure 2. Shelton's standardized palette of natural colors captured the character of disparate geographic regions worldwide. Courtesy of Rand McNally & Company.
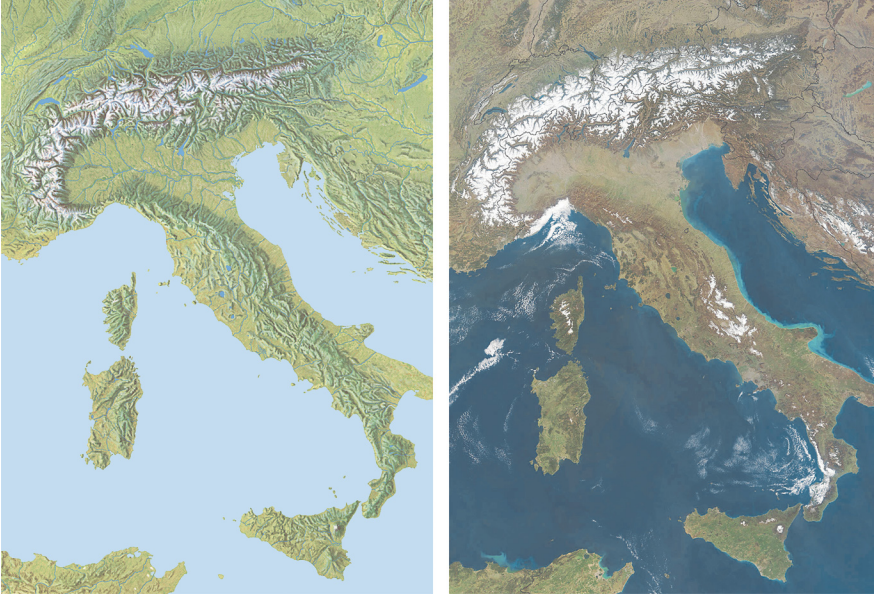
Figure 3. (left) Excerpt of a natural-color map painted by Hal Shelton ca. 1968. (right) NASA MO-DIS satellite image taken in 2003. Map on left courtesy of Rand McNally & Company.
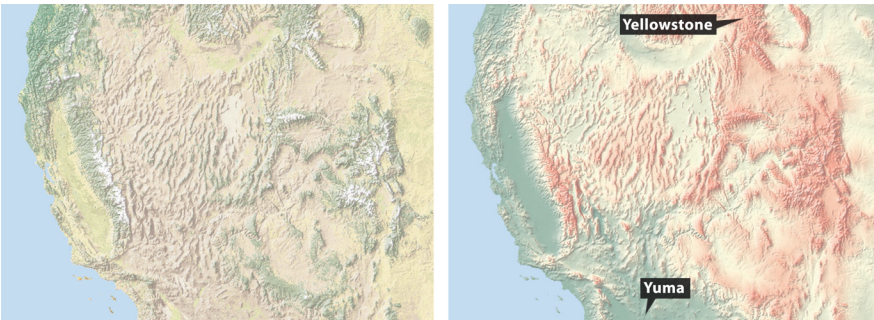
Figure 4. (left) A shaded relief map of southwestern United States combined with natural colors. (right) The same map with blended hypsometric tints. Although hypsometric tints are attractive and show topography clearly, they can mislead readers about the character of the land. Forests cover the Yellowstone region and Yuma, Arizona, is an extreme desert environment.
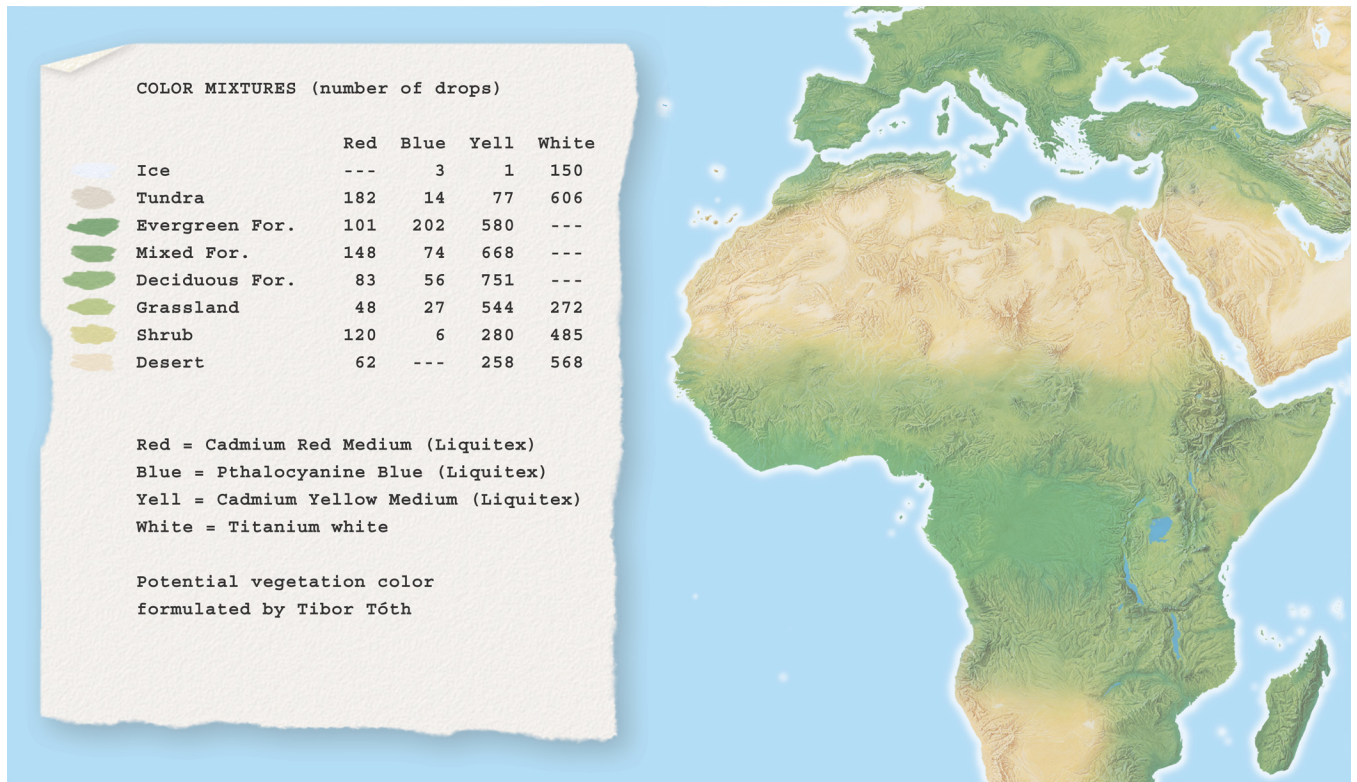
Figure 5. (left) Tibor Tóth's color formulas. (right) His colors applied to a map. Courtesy of National Geographic.

Figure 6. NASA's "Blue Marble" photograph shows Earth from a distance of nearly 48,000 kilometers (30,000 miles). Dominated by the Sahara and Kalahari deserts, Africa is usually the most cloud-free continent. Antartica is also visible in this image for the first time (NASA, 2002).
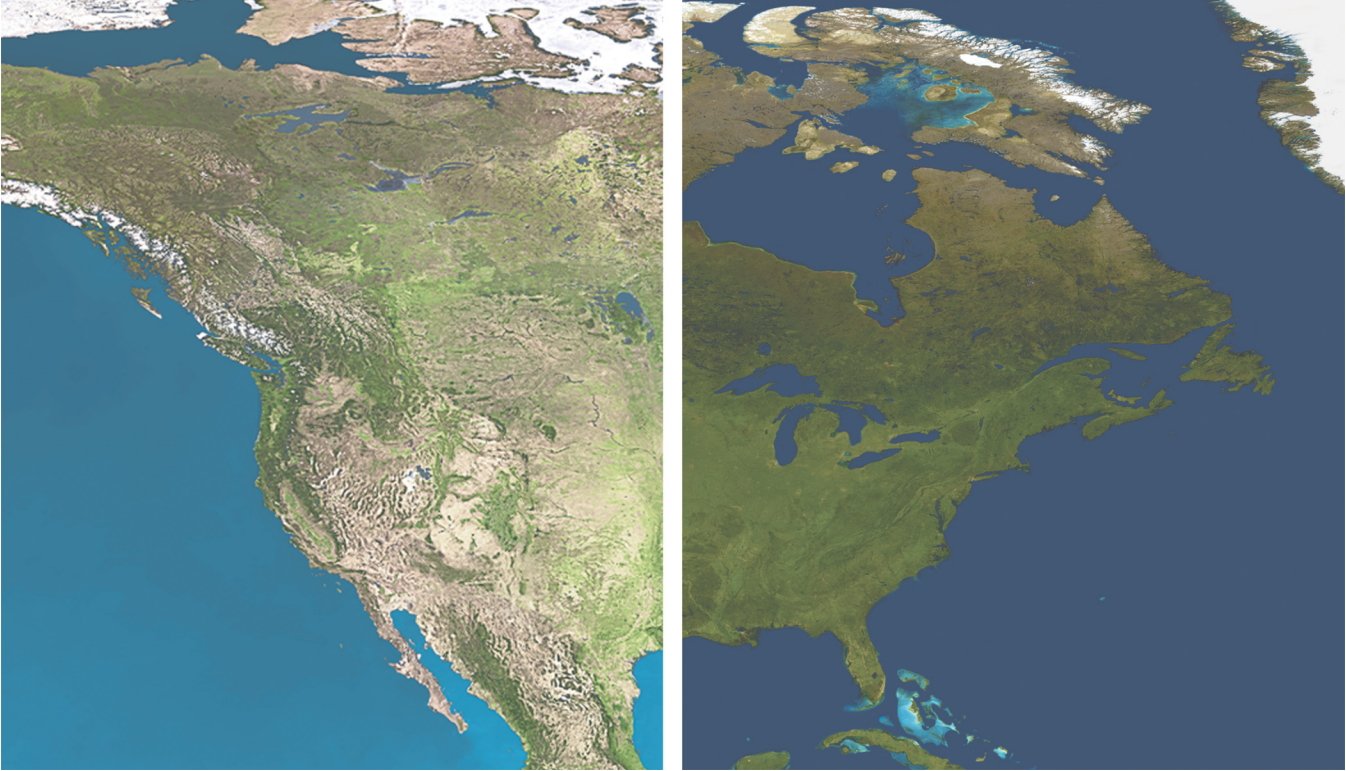
Figure 7. (left) "The Living Earth." (right) NASA's new "Blue Marble."
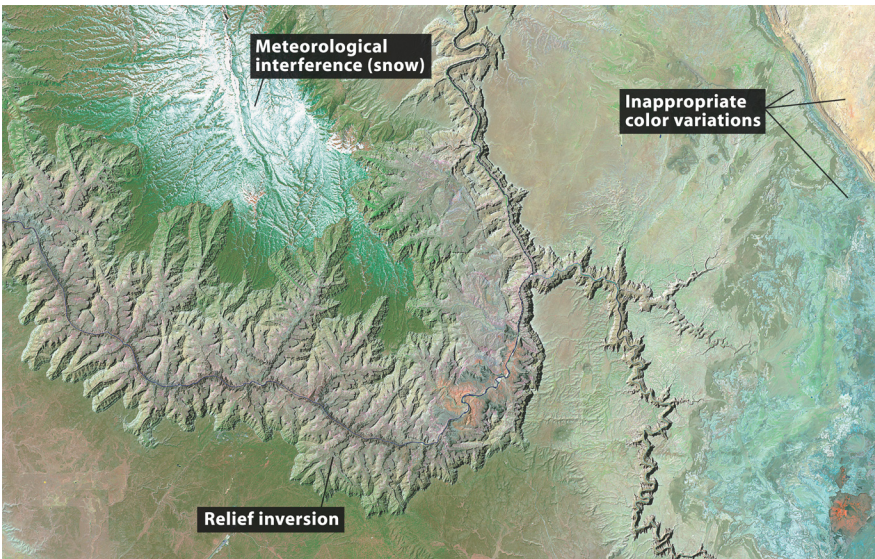
Figure 8. A natural-color Landsat image of the Grand Canyon made from bands 2, 4, and 7. Even the handsomest satellite images contain graphical elements inconsistent with cartographic design goals. Courtesy of the USGS.

Figure 9. NCLD mosaic of the 48-contiguous states, using the USGS suggested color scheme.

NLCD Classification (21 categories)

1 Water	11 Open Water
	12 Perennial Ice/Snow
2 Developed	21 Low Intensity R esidential
	22 High Intensity Residential
	23 Commercial/Industrial/Transportation
3 Barren	31 Bare Rock/Sand/Clay
	32 Quarries/Strip Mines/Gravel Pits
	33 Transitional
4 Forested Upland	41 Deciduous Forest
	42 Evergreen Forest
	43 Mixed Forest
5 Shrubland	51 Shrubland
6 Non-natural Woody	61 Orchards/Vineyards/Other
7 Herbaceous Upland Natural/Semi-natural Vegetation	71 Grasslands/Herbaceous
8 Herbaceous Planted/Cultivated	81 Pasture/Hay
	82 Row Crops
	83 Small Grains
	84 Fallow
	85 Urban/Recreational Grasses
9 Wetlands	91 Woody Wetlands
	92 Emergent Herbaceous Wetlands

Palette (15 colors)

Alpine
Evergreen forest
Other forest
Woody wetland
Herbaceous wetland
Open water
Barren
Shrub
Desert southwest shrub
Grassland & herbaceous
Pasture & hay
Cropland
Orchard & vineyard
Low intensity development
High intensity development

Figure 10. (left) The NLCD classification with USGS assigned colors. (right) The derivative color palette used for natural-color mapping.

Figure 11. Color groupings in the palette.

Figure 12. California and the southwestern US depicted with colorized NLCD and shaded relief.
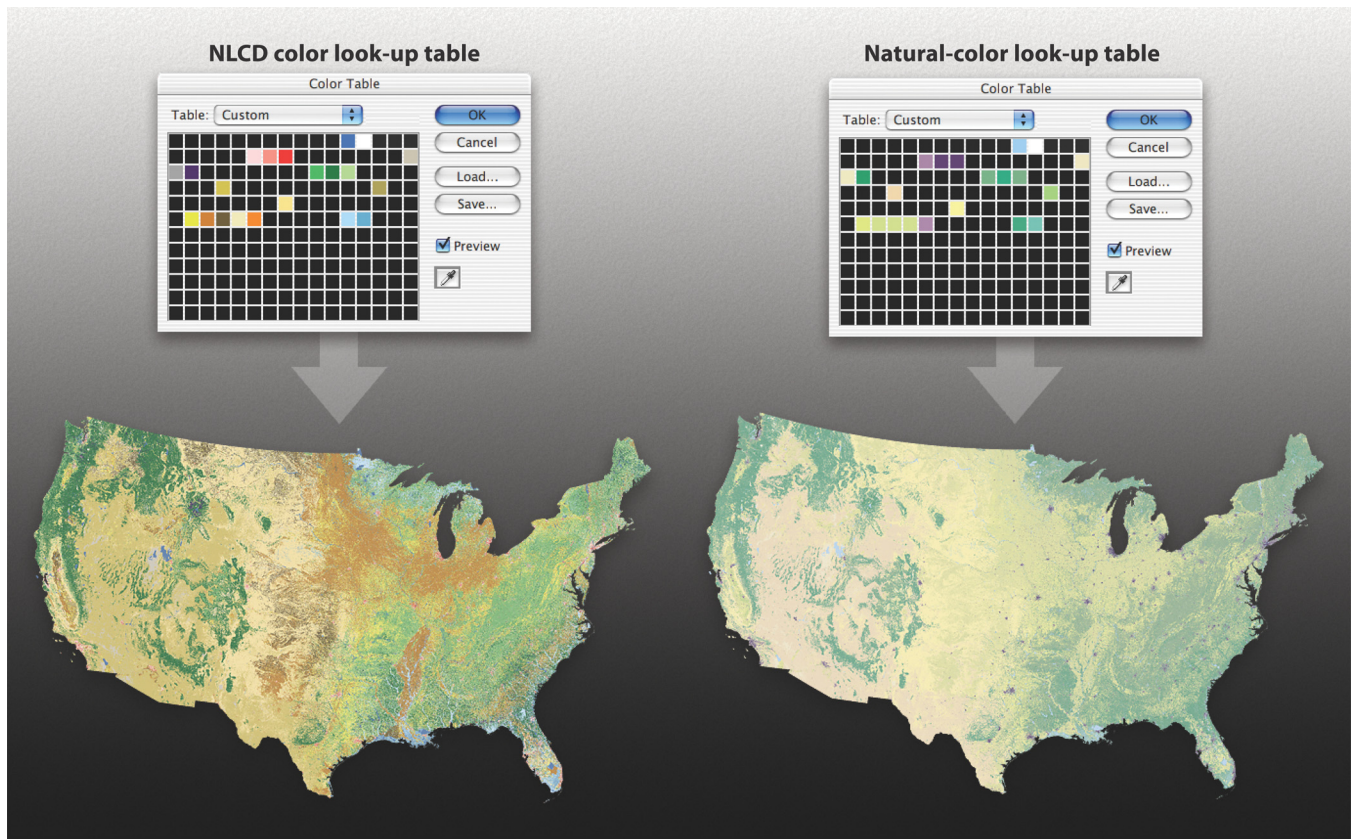
Figure 13. Using the Color Table in Adobe Photoshop with NLCD in indexed color mode to convert USGS colors (left) to natural colors (right).
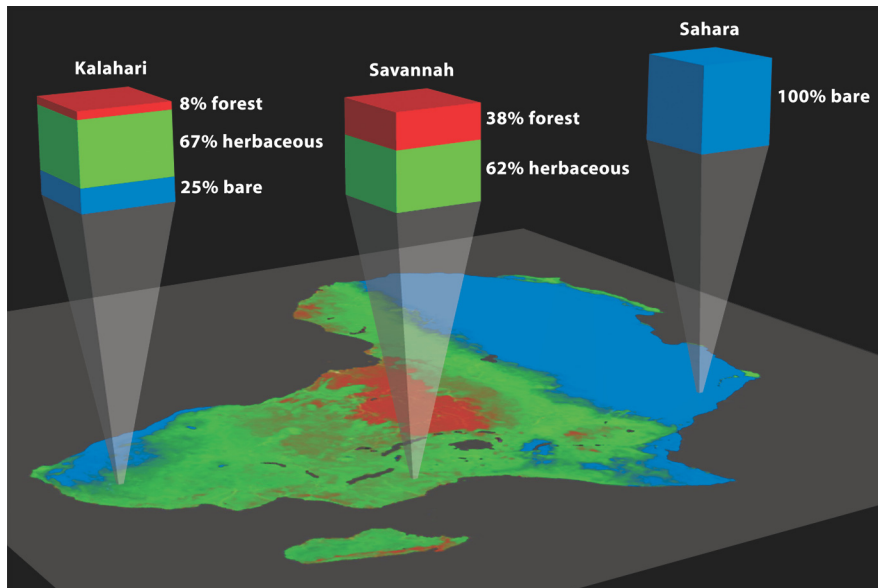

Figure 14. Blended lands cover categories in MODIS VCF. The combined values for any sampled pixel on the map are 100 percent.

Figure 15. (left) MODIS VCF in Photoshop presented as uniform colors. (right) With environmental color adjustments applied to the herbaceous layer.
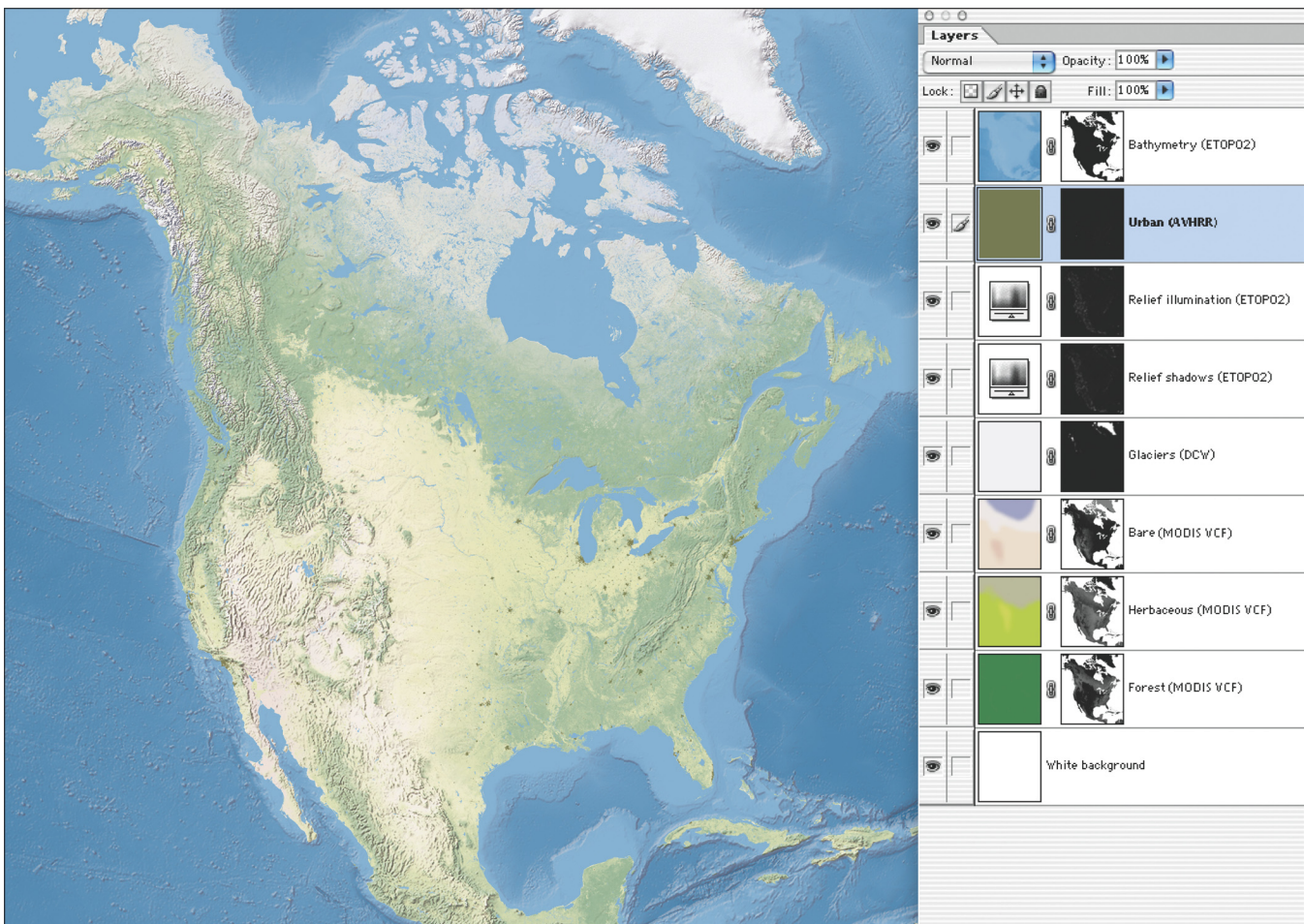
Figure 16. (left) The final map primarily based on MODIS VCF data. (right) The top five Photoshop layers contain supplemental data added to the MODIS VCF base.

Figure 17. Shaded relief merged with a natural-color base made from MODIS VCF data.
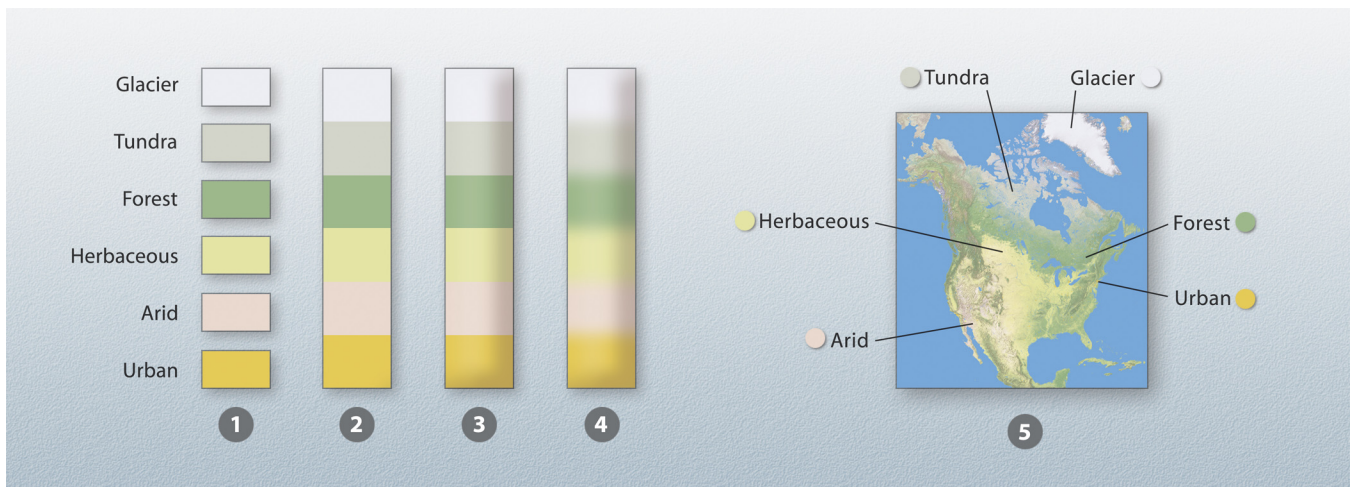
Figure 18. (1–4) Variants of the traditional legend. (5) A natural legend. Legend portrayal becomes less abstract and more cartographically realistic from left to right.
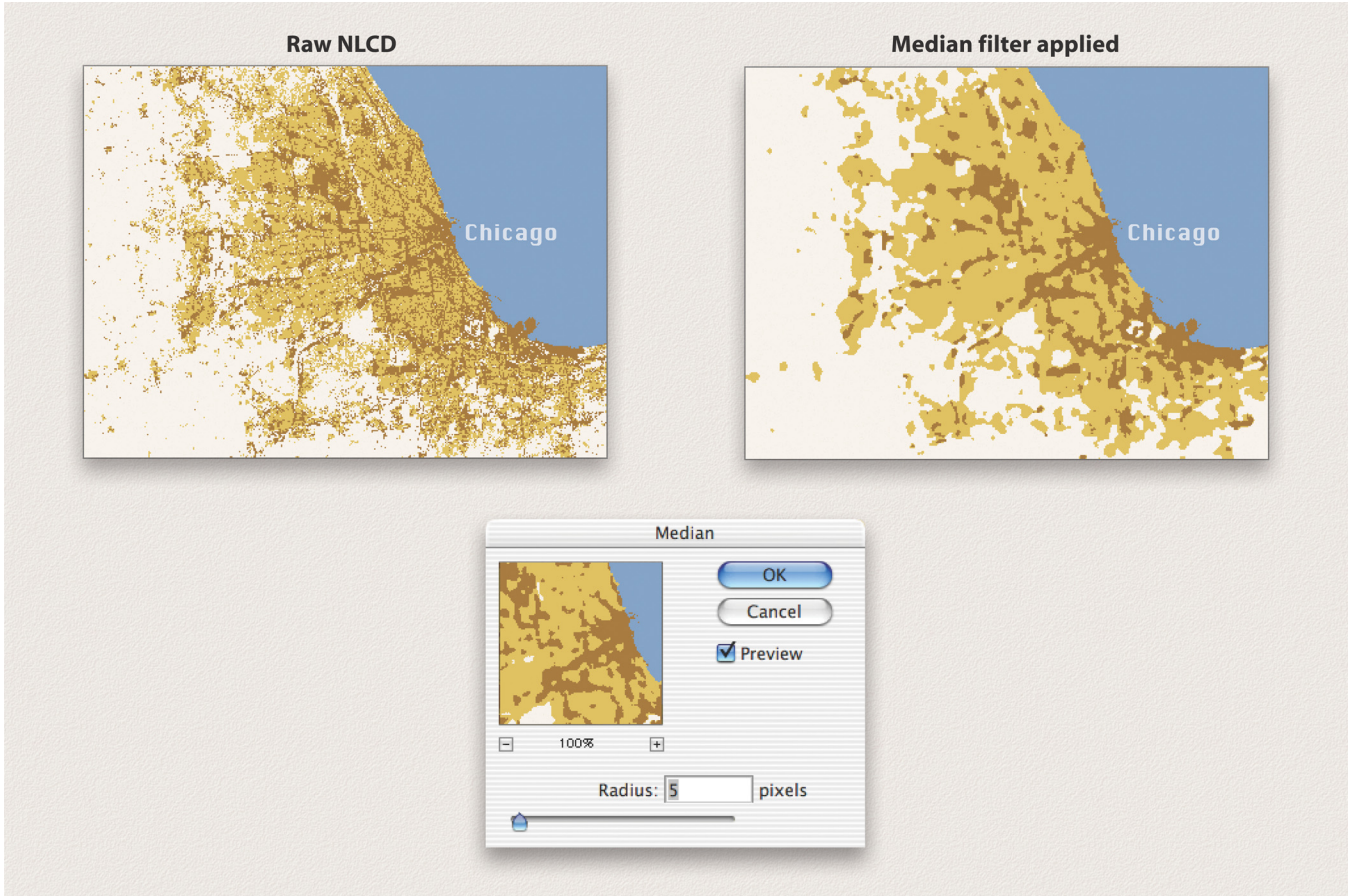
Figure 19. Using the Median filter to generalize urban land cover data.
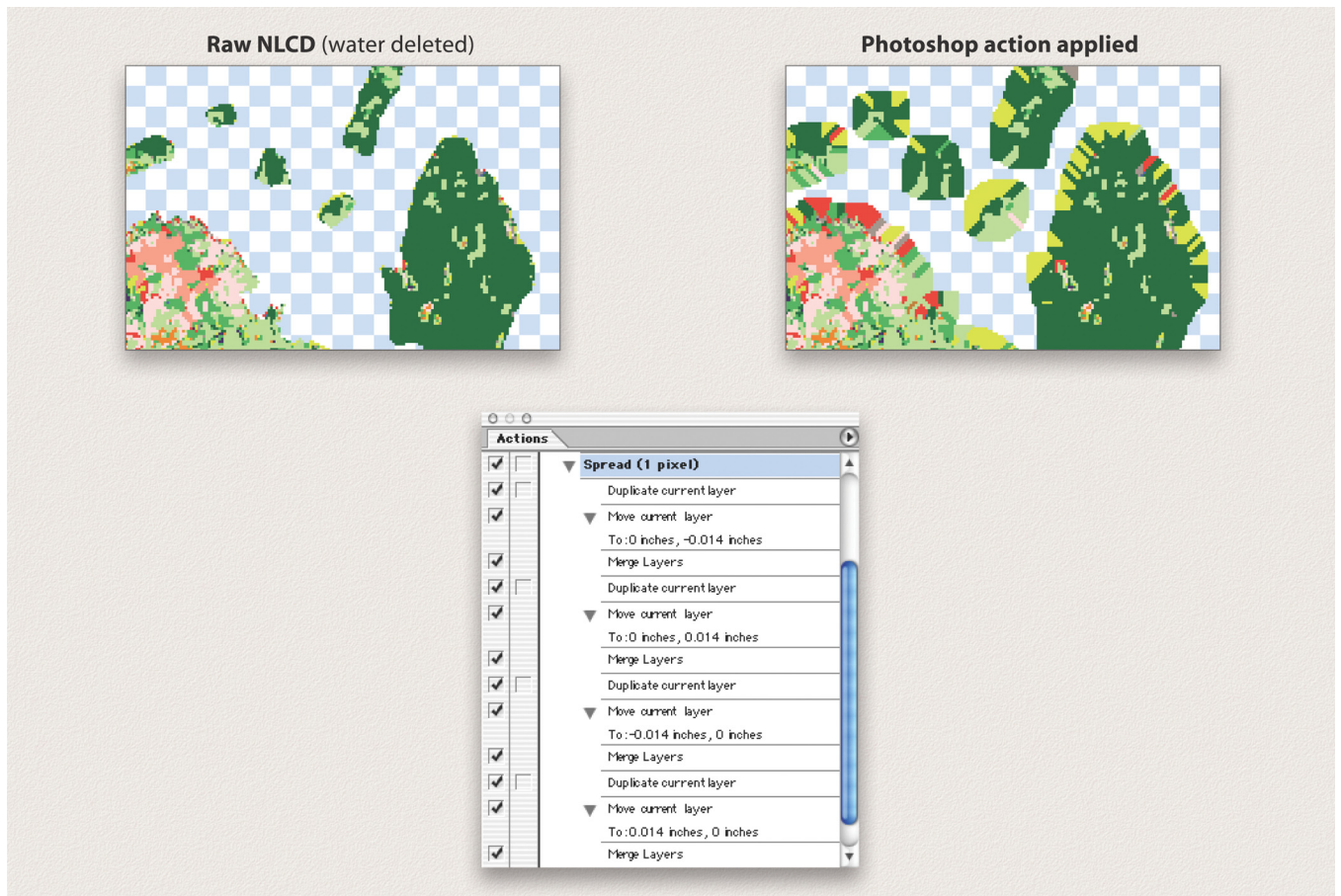
Figure 20. Using the Actions palette in Photoshop to spread shoreline pixels outward.
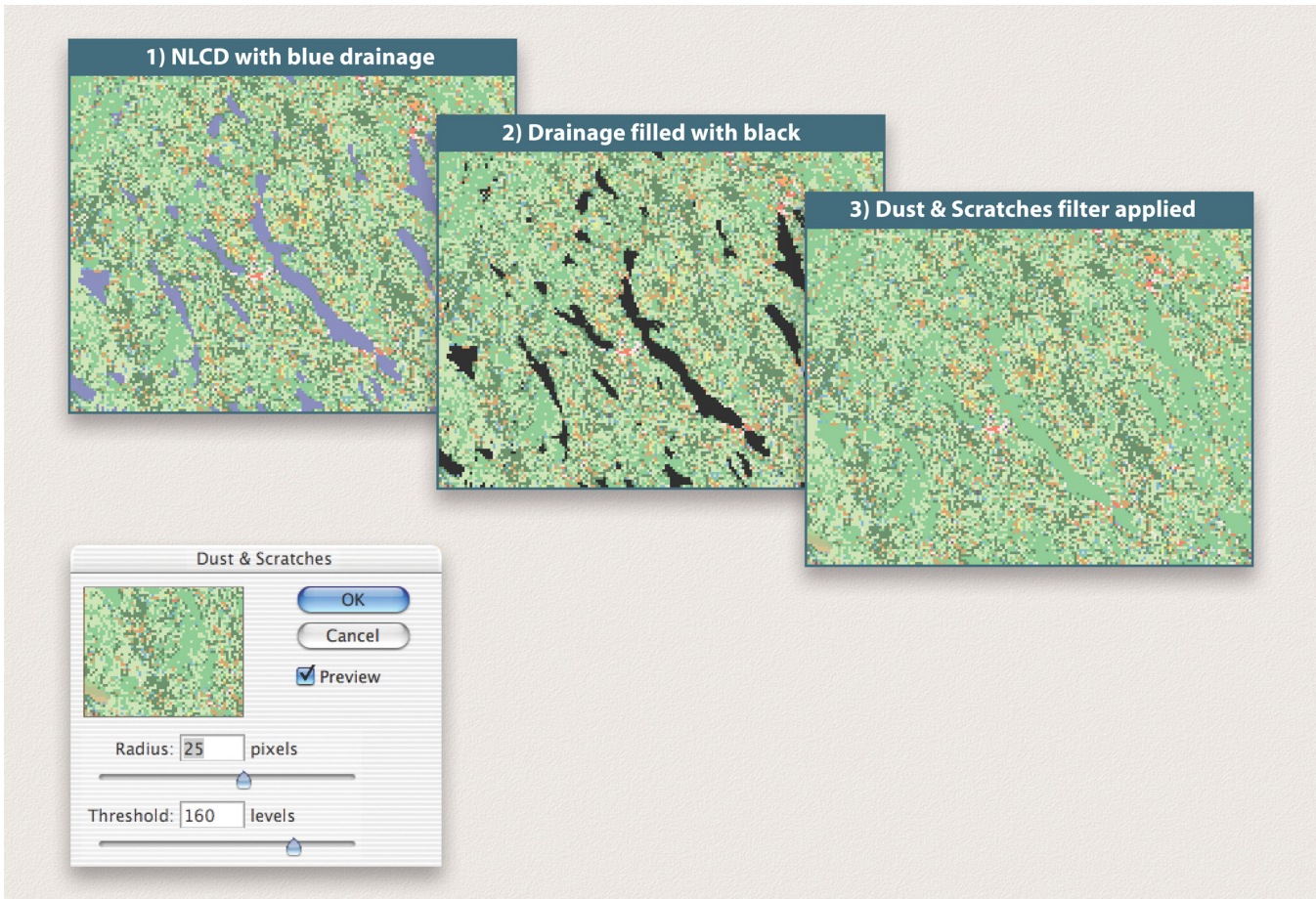
Figure 21. *Removing drainages from NLCD with the Dust & Scratches filter.*

Figure 22. *"Canyon Lands" by Hal Shelton. Millard Canyon, Utah, dominates the center of the scene and the snowcapped LaSal Mountains are faintly visible on the right horizon. The vertical triptych joints do not appear because of digital compositing. Courtesy of Library of Congress.*

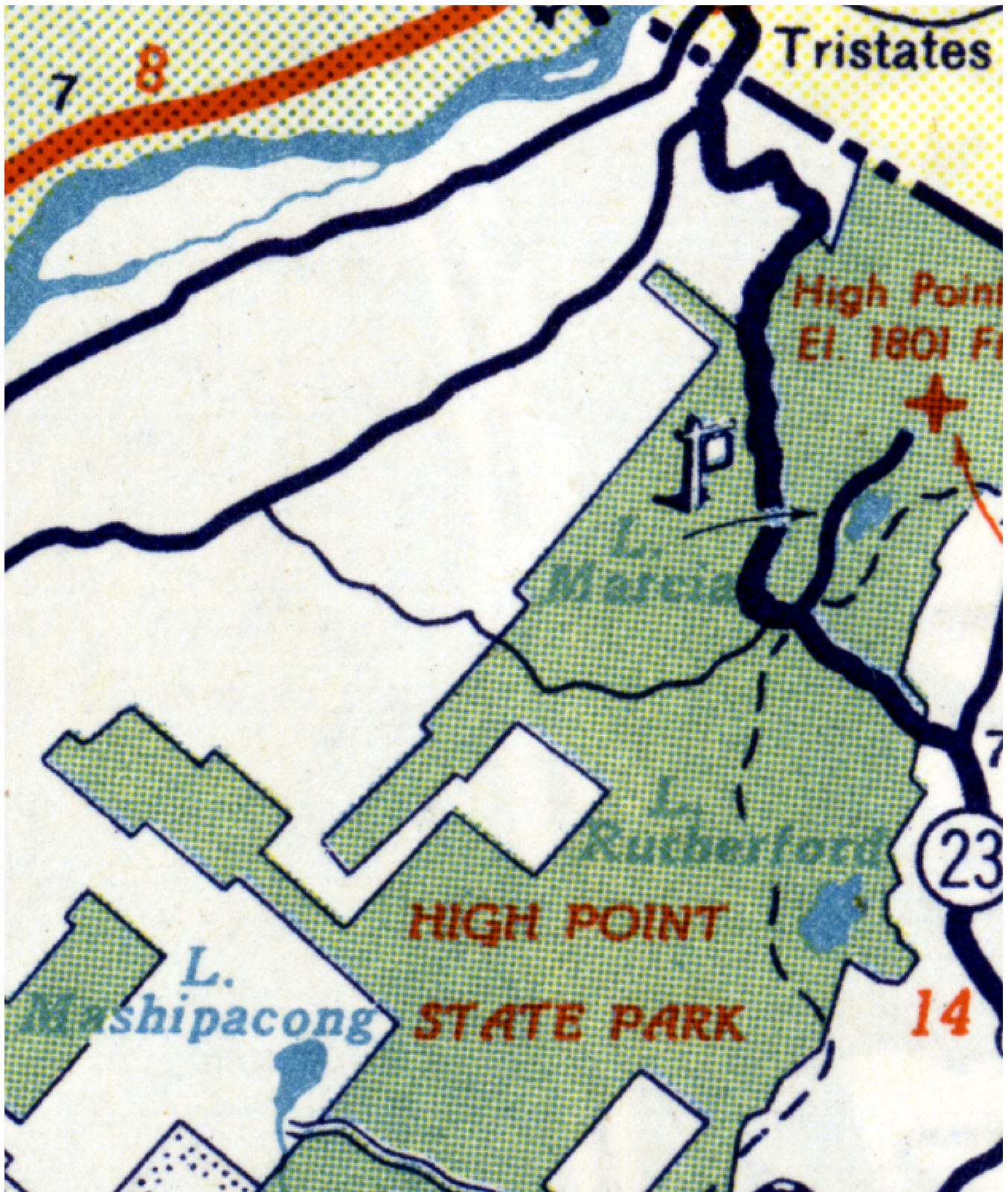Small Type, Screens and Color in a PostScript Offset Printing Environment
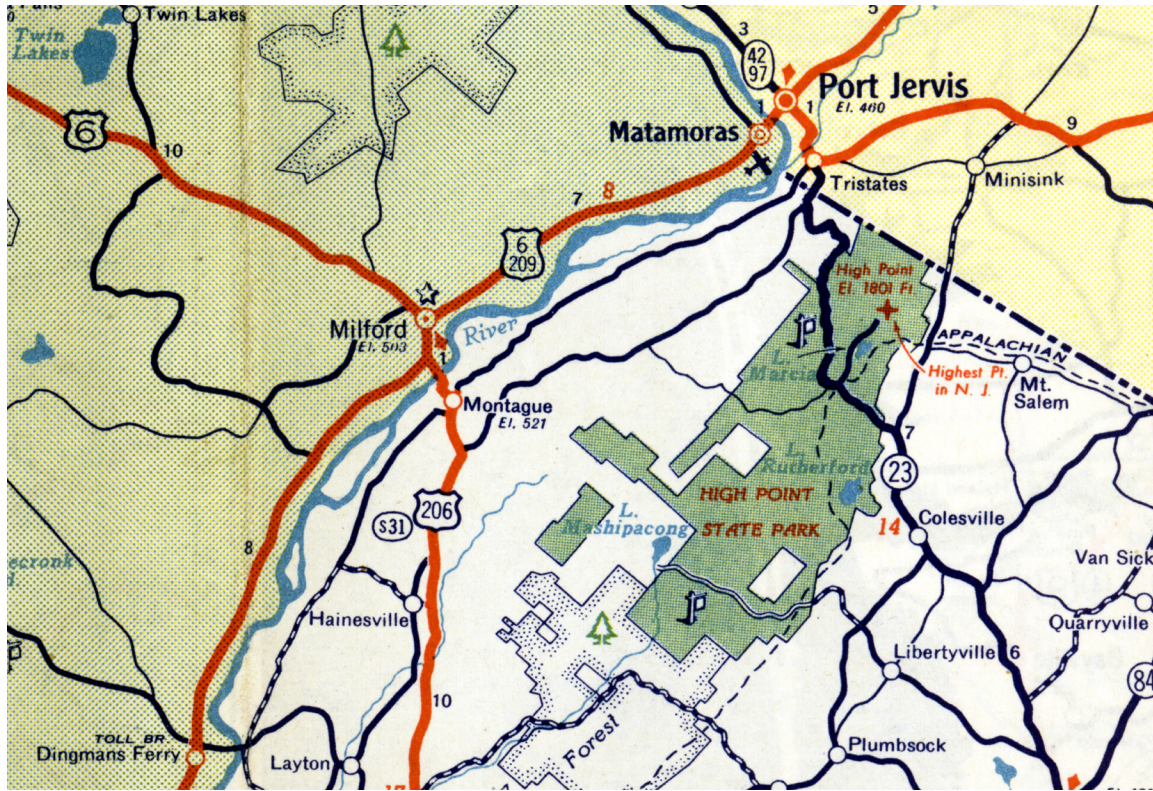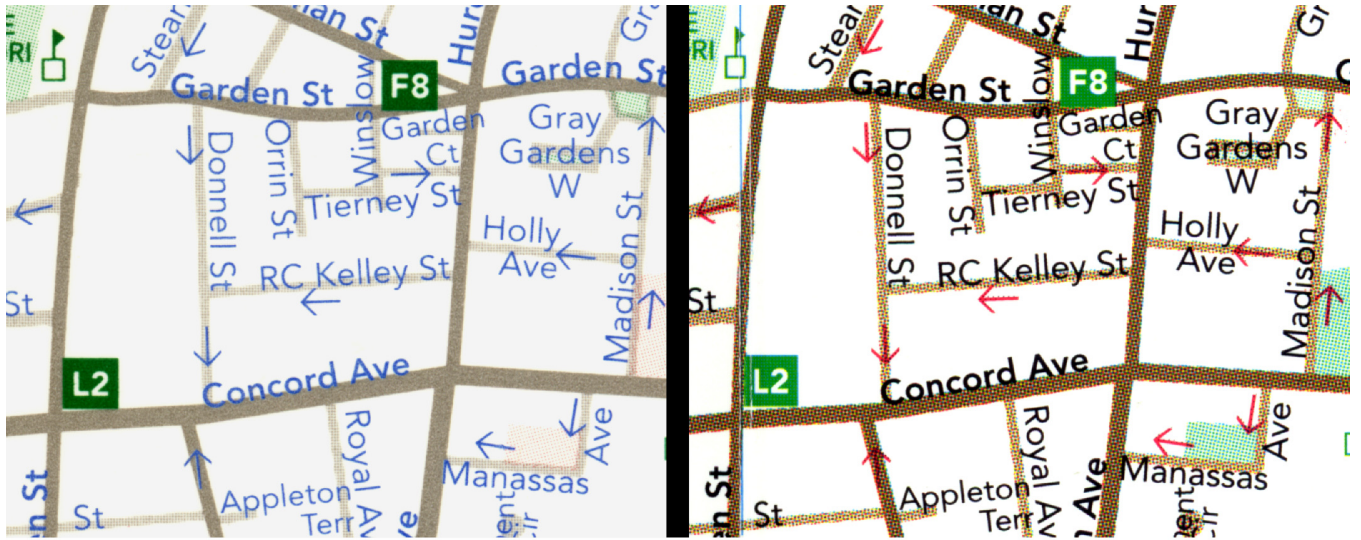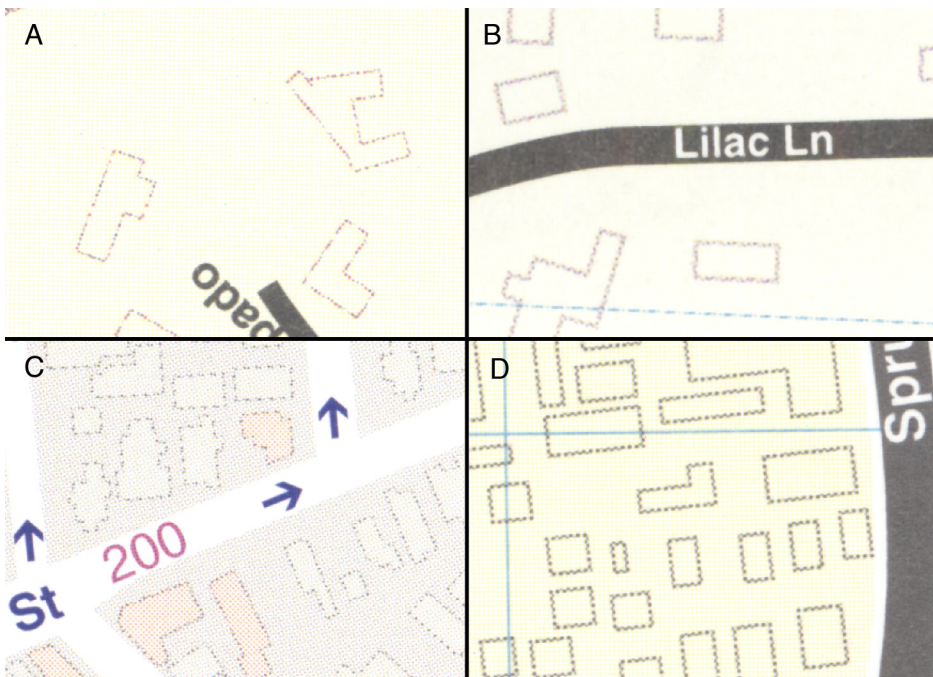

Figure 1.

Figure 1a.

Figure 2.

Figure 3a.

Figure 3b.

Figure 6.