



from the eighth century onward. The spatiotemporal relationships between objects of cultural historic relevance (such as temples, mural paintings, philosophical texts, and inscriptions) represent an important research focus. In this research network cartography and geography play a bridging role between the disciplines of art history, numismatics, Buddhist philosophy, and Tibetan and Sanskrit philology. The cartographers' goal is to facilitate internal scientific collaboration and the presentation of research results to the general public. The cartography group also assists participating scholars with their research tasks in the office and on field trips. It is for this reason that we produced a foldable topographic overview map of the Indian state Himachal Pradesh—one of the project's key places of interest.

Himachal Pradesh is one of India's twenty-eight states, situated in the northwestern part of the country, bordering China's Tibet Autonomous Region. The state takes in a land area of approximately 55,000 square kilometers. Shimla, the state capital in the Himalayan foothills, became famous as a summer retreat for the British-Indian colonial government. Himachal Pradesh's literal meaning is "the region which lies in the slopes and foothills of snow" (Ahluwalia 1998), an apt description considering that about 80 percent of the state consists of either "Shivaliks" (the first range of foothills) or the main Himalayan mountain range. Due to the geographical proximity there exists a strong cultural influence from Tibet, especially in eastern parts of the state and in Dharamsala, seat of the exiled Tibetan government and the home of Tenzin Gyatsho, the fourteenth Dalai Lama.

This article describes the design and production processes for making a topographic map compiled from a variety of sources—ranging from maps originally surveyed by the British to satellite imagery—converted to a publicly available reference map at the scale of 1:500,000. Production involved data preparation in ArcGIS and Natural Scene Designer and final map compilation in Adobe Photoshop and Illustrator.

## AVAILABLE TOPOGRAPHIC MAPS AND GEOGRAPHICAL DATA SOURCES

The Survey of India, the national mapping organization of India, restricts the release of topographical maps of Himachal Pradesh, especially to foreign institutions. Because the state borders China, the Survey of India considers topographic maps of this area military secrets. For our project, the best available topographic maps were those compiled by the British in the early twentieth-century (Figure 1). The British maps are generally inaccurate, sometimes incomplete, and greatly outdated. The U.S. Army Map Service and the Russian military have produced 1:250,000-scale topographic maps of Himachal Pradesh. These maps mainly derive from the preexisting British maps and in most cases are poorer in quality than the originals.

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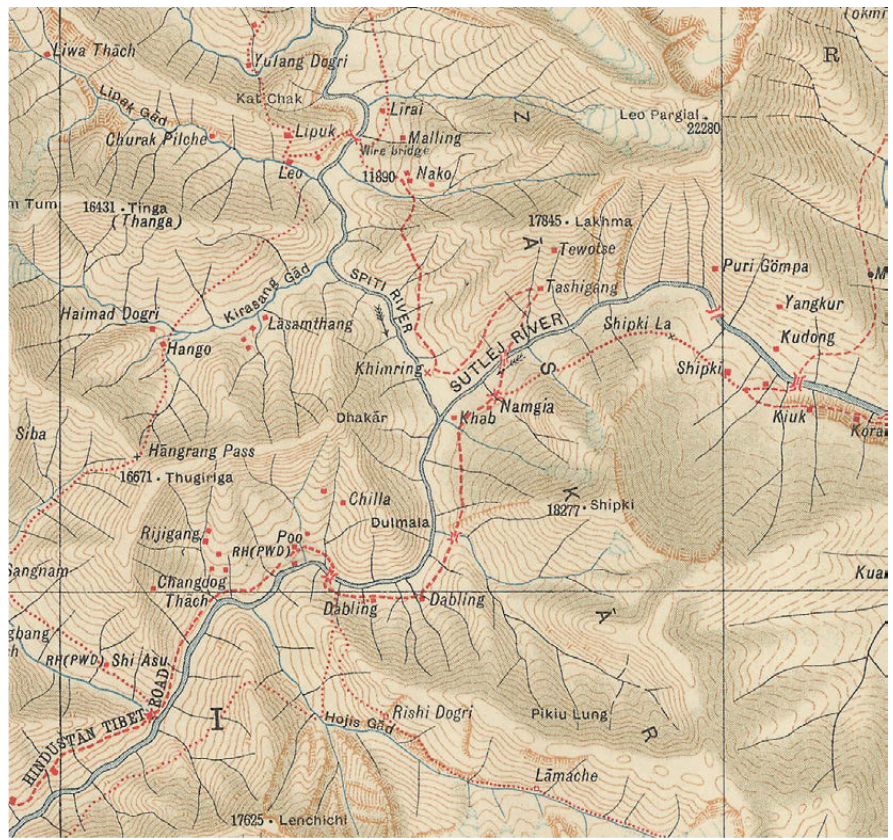


Figure 1. Topographic map of the Survey of India (1932), 1:253,440.

Although a wide variety of commercial maps of Himachal Pradesh exist at different scales, these products also suffer from poor quality. The information is often inaccurate, outdated, and/or inconsistent with other maps, and the graphical presentation is mostly crude. This lack of reliable and detailed topographic information led the project partners to ask the cartography group to produce a new topographic overview map.

Due to a tight budget, the idea guiding map production was to use only freely available geographic data and, if necessary, to digitize from existing maps. Main data sources were Shuttle Radar Topography Mission (SRTM), Vector Map 0 (VMAP0), the Digital Chart of the World (DCW), Global Administrative Database, GeoNames, Natural Earth II, vector data and Landsat satellite imagery from the U.S. Geological Survey (USGS). Printed maps for digitization and verification purposes were various Freytag and Berndt road maps (at scales between 1:2,750,000 and 1:4,000,000), The Book of the World (1:4,000,000; Bertelsmann 1995), the Himachal Pradesh Tourist Map (1:500,000; Eicher, 2007) published by Eicher Goodearth, Ltd., for the official state tourism bureau and the Leomann Trekking Maps series (1:200,000; Leomann 1998, 2005). Data from these sources were incorporated into a Web-based cartographic information system, parts of which were extracted for producing the printed topographic map.

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## SHADED RELIEF WITH NATURAL COLOR OVERLAY

The production of shaded relief with a natural color overlay was a multi-stage process. SRTM data (<http://www2.jpl.nasa.gov/srtm/>) with a geometrical resolution of 3 arc seconds (approximately 90m) was used as the underlying digital elevation model (DEM). Because the original SRTM data from NASA contained many voids (holes in the digital elevation model surface), especially in the high mountain areas, we used modified SRTM data from an alternative source. Viewfinderpanoramas.org offers DEM tiles with infilled voids based on the digitized contours of Russian military maps. However, even this modified elevation model was not free from artifacts. The infilled data did not blend smoothly with the original SRTM data. It was necessary to patch rough areas by manually touching up the DEM with a variety of Adobe Photoshop tools. Figure 2 illustrates shaded relief from original SRTM datasets (left) and from the enhanced blended tiles (right).

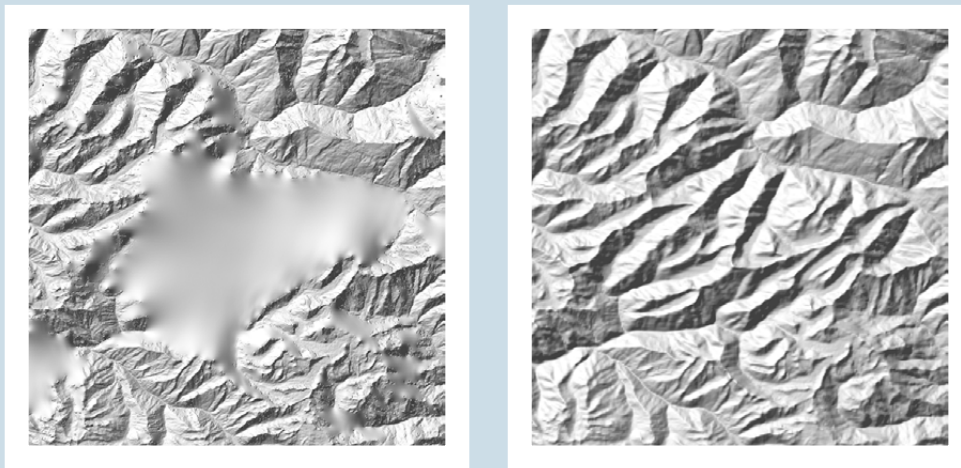


Figure 2. Inaccurate shaded relief from original SRTM data (left) and from enhanced blended tiles (right).

The revised DEM was downsampled to a resolution of 6 arc seconds (approximately 180m), and a soft blur filter was applied to decrease detail and noise in the resulting shaded relief. The shaded relief rendered with Natural Scene Designer resulted in two images: The first image was rendered as oblique hill-shading with standard north-west illumination; the second image depicted slope-shading by placing the illumination source directly overhead. Combining these two images in Photoshop produced a relief with familiar three-dimensional shading effects plus enhanced detail on the slopes. Because the shaded relief would combine with a colored environmental overlay on the final map, shadow tones were lightened and flat areas were kept white.

In the next step, we applied additional Photoshop enhancements to the shaded relief, employing the techniques described at [www.shadedrelief.com](http://www.shadedrelief.com). Using layer masks, we added a subtle yellow tint on illuminated slopes as well as a light blue tone on the shadow slopes. A height mask was used to increase saturation and lightness in higher areas as well as to decrease both in lowlands.

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Figure 3. Oblique relief shading combined with slope shading with yellow highlights and blue shadows.

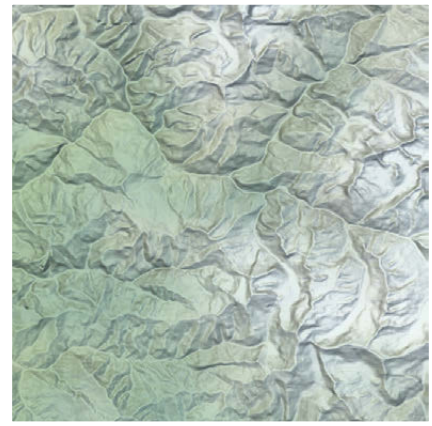


Figure 4. Shaded relief with environmental color overlay from Natural Earth data.

Figure 3 shows the combination of oblique relief shading and slope shading with yellow highlights and blue shadows. Nevertheless, room still exists for additional improvements to the shaded relief. For example, enhancing ridgelines on the underlying DEM could give these blunt features a chiseled appearance to better represent the alpine landscape.

One of the goals of the topographic overview map was to provide the map reader a general impression of the terrain and vegetation of Himachal Pradesh. This was accomplished with a natural color overlay created from landcover data. The Natural Earth raster dataset, derived from MODIS satellite imagery, was the first choice that we considered ([www.naturalearthdata.com](http://www.naturalearthdata.com)). Unfortunately, the spatial resolution of Natural Earth raster data is only 1.24 kilometers, six times coarser than the shaded relief. This resulted in a pixelated appearance when Natural Earth was upsampled to the higher resolution of the shaded relief. However, employing a blur filter in Photoshop helped remove pixel patterns—similar to the pan-sharpening processes applied to multi-resolution satellite imagery. Thus the natural color overlay was adapted for use with the higher resolution shaded relief (Figure 4).

## CONTOUR LINES, SPOT HEIGHTS AND GLACIERS

In an area where villages are found above 4,000 meters, and even higher passes serve as transportation corridors between far-flung cultural centers, elevation is an important factor. To give readers more information about elevation than what is available in the shaded relief, and to enable cartometric evaluation, contour lines derived from SRTM data were added to the map. Considerable manual editing was necessary to register the contour lines with the shaded relief and river network. The contour line interval is 500 meters. We created contour line labels with the Maplex extension in ArcGIS. Next, in Adobe Illustrator, where the final map assembly took place, the team deleted surplus contour labels and repositioned the remaining labels.

Additionally, a spot height dataset of prominent mountain peaks and passes was digitized from existing paper maps, mostly old topographical maps produced by the British and the U.S. Army Map Service.

In a high mountain area such as the western Himalaya, glaciers play an important role. They have shaped the landscape and are a source of the water supply. Glaciers have been—and still are—barriers to pilgrims and traders traveling the area. Many glaciers have spiritual significance for the local population. Unfortunately, no accurate vector datasets could be acquired for this area at the final map scale of 1:500,000. Therefore, the team had to interpret glacier extents from Landsat 7 satellite imagery at a resolution of 30 meters. Using summer images when ice and snow surfaces have a high albedo and distinctive spectral signature, we derived a spectral classification to identify the glaciers. However, moraines and glaciers covered by rocks or dirt were not detected by this classification. Solving this problem required manual edits and referring to existing maps, which resulted in a more or less complete and accurate glacier dataset. We then merged the glaciers with the shaded relief, depicted with a subtle transparent blue tint. This treatment of the glaciers provides enough contrast to differentiate them from the relief and draped natural color overlay.

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## ADDITIONAL MAP FEATURES

Administrative boundaries derive from the Digital Chart of the World (<http://www.maproom.psu.edu/dcw>) and the Global Administrative Database (<http://www.gadm.org>). We had to manually adjust the boundaries to register with the shaded relief and river network.

Roads and railroads derive primarily from the USGS global transportation datasets (scale 1:1,000,000), a secondary product of VMAP0, and partially from tourist road maps. Because parts of the road network obtained from the digital data were very crude, revisions to these from paper map sources were a necessity for mapping at 1:500,000-scale.

For rivers and lakes, the VMAP0 datasets served as the main source of information. However, the team had to manually adjust river courses to fit the shaded relief. The many smaller rivers, which create a dense network filling even the smallest valleys, were omitted to improve map legibility. Since VMAP0 does not contain names attributes for rivers and lakes, we acquired this information from topographic maps made by the British Survey of India and the U.S. Army Map Service.

The settlement layer originates with Digital Chart of the World and the GeoNames database (<http://www.geonames.org>). It contains numerous updates obtained from printed maps and other sources. The team recorded additional settlement locations, not found in the sources above, with GPS devices during a four-week field trip in summer 2007. The spelling of place names in this area is highly ambiguous due to the influence of different languages and cultures. Unfortunately, the most up-to-date maps by the Survey of India were not available to verify spellings. Therefore, the map editors had to rely on what other sources they could find, such as maps by



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the state tourist agency. Place names were additionally checked by project partners on their field visits to Himachal Pradesh. Despite this effort, many place name spellings on the map are still best regarded as provisional.

Because the topographic overview map supports the research and field activities of the project partners, cultural and historical sites of relevance to the project appear as a thematic layer on the map. These sites, selected in consultation with the scholars, include historic temples and monasteries. This layer and the other map layers, including a map frame, coordinate grid, and legend, were symbolized and assembled in Adobe Illustrator. Figure 5 shows a section of the final map that is available for download at the project Web page (<http://www.univie.ac.at/chis>). In 2009 we printed a small run of the map complete with a hardcover.



Figure 5: Section of the final map showing Beas Valley and Chandra Valley.

## CONCLUSION AND OUTLOOK

The first version of the foldable Himachal Pradesh Topographic Overview Map is now serving the needs of the project partners in the research network. The mapping of Himachal Pradesh is not yet finished, however. We will update information based on feedback received from those using the map in the field. Looking ahead, additional classes of information will be added, such as historical pilgrimage and trade routes, and modern trekking routes. Data acquisition for these layers is currently under way for the cartographic information system on the Cultural History of the Western Himalaya Web site (<http://www.univie.ac.at/chis>). A second map sheet at the same scale and with identical data layers is planned for the Ladakh/Leh region in the state of Jammu and Kashmir, which is north of and adjacent to Himachal Pradesh.

The need for continual updates to the Himachal Pradesh map and plans to produce sheets of other areas have led us to investigate ways to further automate the production process. Other projects conducted at the Department of Geography and Regional Research, University of Vienna, indicate the potential of high-quality vector map production with Mapyrus software (<http://mapyrus.sourceforge.net>). However, mapping the western Himalayas is very complex, and the quality demands are high. Ongoing research will reveal to what degree the production can be automated.

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