DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

MISCELLANEOUS INVESTIGATIONS SERIES
MAP I–1257–K

INTRODUCTION

The use of lighter and darker shades to represent three-dimensional shapes is a technique that has been used by artists for centuries, but using digital elevation models (DEMs) to create hill shading for shaded-relief maps is a comparatively new idea. Our map was created using DEMs and further developed on the Scitex Response-280 computerized cartographic system. This shaded-relief map accompanies a series of other thematic maps of San Mateo County, Calif. (for example, see, Mark and others, 1988). The major characteristic of shaded-relief maps is that they depict the surface as though it were illuminated from a specific direction and sun angle but without the shadows that would normally obscure some topographic features. Early efforts using computers to generate shaded-relief maps from DEMs began in the late 1960's and early 1970's (for example, Yoëli, 1967; Batson and others, 1975). An extensive summary of the history and theory of shaded-relief maps is presented by Horn (1981).

Shaded-relief maps help users to visualize the land surface and to see land forms or patterns, such as fault traces and large landslides, which might not be discernible on standard topographic maps. Although the shaded-relief image resembles a photograph, it does not show the distortions (caused by parallax) or shadows that commonly obscure features in photographic images. We have included elevation contours, lakes, streams, roads, and other cultural features on our map to provide additional information and to use with standard topographic maps.

The direction of illumination for shaded-relief maps can be selected to highlight particular features. Usually, the light source is from the northwest (Horn, 1981), but, for this map, we selected illumination from due west to better display the land forms associated with the San Andreas fault. In addition to using shaded-relief maps to enhance the topography and geologic structures, the maps are used as a base-map image for other thematic maps. For such applications (for example, geologic or landslide maps), the shaded-relief image is shown by lighter shading to enhance the thematic image of the map.

To create a high-resolution shaded-relief map by computer, a high-resolution digital image of the topographic surface is required. For our map, a unique topographic data set was generated by scanning contour lines of 1:24,000-scale maps (fig. 1) into a Scitex Response-280 system using an optical scanner. The data were translated into standard digital-elevation-model (DEM) format (Elassal and Caruso, 1984) for our use. The DEMs, at 30-m grid spacing, were converted to the shaded-relief model on a VAX-11/785 using an algorithm that computes the angle between a specific sun direction and the normal to the ground surface (fig. 2; Horn, 1981). The normal is computed by fitting a quadratic surface to each 3-by-3 subgrid (Mark and others, 1988). The amount of vertical exaggeration can be adjusted to vary the contrast, which produces the apparent relief.

To perform the calculations for this map, we used a sun azimuth of 270° (due west) and an elevation of 30° above the horizon. The final shaded-relief image was generated on the Scitex system using computed light intensities divided into 10 levels of gray. A composite printing screen for the 10 levels of gray was generated from the Scitex using a laser drum plotter. The contours, drainage, and cultural features were added using conventional photographic overlays.

We have demonstrated the feasibility of preparing a shaded-relief image as a base image for Scitex-generated thematic maps. Shaded-relief maps emphasize topography and geologic structures and can provide a useful alternative to the standard topographic base-map image.

REFERENCES CITED

Batson, R.M., Edwards, Kathleen, and Eliason, E.M., 1975, Computer-generated shaded-relief images: U.S. Geological Survey Journal of Research, v. 3, no. 4, p. 401-408.

Elassal, A.A., and Caruso, V.M., 1984, Digital elevation models [USGS digital cartographic data standards]: U.S. Geological Survey Circular 895-B, 40 p.

Horn, B.K.P., 1981, Hill shading and the reflectance map: Proceedings of the Institute of Electrical and Electronic Engineers, v. 69, p. 14-47.

Mark, R.K., Newman, E.B., Brabb, E.E., 1988, Slope map of San Mateo County, California: U.S. Geological Survey Miscellaneous Investigations Series Map I-1257-J, scale 1:62,500.

Yoëli, P., 1967, The mechanization of analytical hill shading: The Cartographic Journal, v. 4, p. 82-88.

Figure 2. Geometry relevant to intensity calculation.

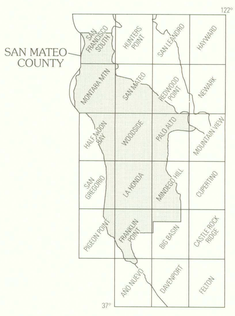
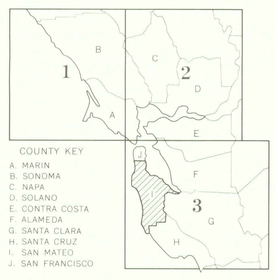


Figure 1. Index map of 1:24,000-scale quadrangles covering San Mateo County.



INDEX MAP OF THE THREE SAN FRANCISCO BAY AREA REGION SHEETS SHOWING AREA OF THIS REPORT

Base from U.S. Geological Survey, San Francisco Bay Region, Sheet 3, 1:125,000, 1970. Park boundaries revised 1981

5000-meter Universal Transverse Mercator grid ticks, zone 10

APPROXIMATE MEAN DECLINATION, 1990

SCALE 1:62 500

CONTOUR INTERVAL 200 FEET
DOTTED LINES REPRESENT 40-FOOT CONTOURS
NATIONAL GEODETIC VERTICAL DATUM OF 1929
DEPTH CURVES IN FEET—DATUM IS MEAN LOWER LOW WATER
SHORELINE SHOWN REPRESENTS THE APPROXIMATE LINE OF MEAN HIGH WATER
THE MEAN RANGE OF TIDE IS APPROXIMATELY 4 FEET IN THE PACIFIC OCEAN AND 5 FEET IN SAN FRANCISCO BAY

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SHADED-RELIEF TOPOGRAPHIC MAP OF SAN MATEO COUNTY, CALIFORNIA

By
R.K. Mark and D.S. Aitken

1990

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