UNITED STATES DEPARTMENT OF THE INTERIOR

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PRELIMINARY MAPS OF PHOTOLINEAMENTS ALONG PARTS OF THE WESTERN SIERRA NEVADA FOOTHILLS AND EASTERN COAST RANGE FOOTHILLS, CALIFORNIA, BASED ON LANDSAT IMAGES AND U-2 AIRCRAFT PHOTOGRAPHS

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I. Introduction

The accompanying photolineament maps represent a preliminary interpretation of and comparison between Landsat images at a scale of 1:1,000,000 and color infrared film transparencies at 1:125,000 taken from U-2 aircraft. The purpose of the study was to assess the relationship of photolineaments to past and potential surface faulting in the Sierra Nevada foothills belt and eastern Great Valley, specifically with regard to the siting of nuclear power plants. The project was funded by the U.S. Geological Survey's Reactor Hazard Program. These maps are intended for use only as guides to further analyses in field investigations.

Lineaments were identified according to type and are so indicated on the maps. The majority are drainage alignments, that is, anomalously straight segments of individual or multiple streams. Where specific drainage courses were not apparent but topographic elements (escarpments or ridges) are aligned, the same symbol was applied. A somewhat related designation applies to those lineaments clearly controlled by strike, stratigraphic unconformity or disconformity, or petrologic fabric. This type of lineament is reflected in the topography but a separate designation seemed appropriate if the relation to structure or stratigraphy was readily apparent. The third type of lineament is expressed by a change in color or tone of the ground surface due to changes in vegetation, rock type, soils, moisture content, or some indeterminate cause. This type is most susceptible to misinterpretation because of the inherent difficulty of sorting out cultural effects.

II. Method

Black and white Landsat film transparencies were obtained for spectral bands 4, 5, 6, and 7 of pertinent, good quality (i.e. no cloud cover) images. From these, color composites were made using Diazo film foils (Seitz, 1977), with sunlight as the illumination source. Bands 4, 5, and 7, exposed on blue, yellow and red film respectively, produced the most useful composites. Lineaments were mapped on an overlay at the film scale of 1:1,000,000. The whole package was then mounted on a Kern PG-2 stereoplotter and scaled for monoscopic transfer to 1:250,000 base maps. Final plots were adjusted for obvious topographic discrepancies. An effort was made to indicate qualitatively the relative reliability or significance of the lines drawn; the most convincing are designated by the number 1, least convincing are numbered 3.

One frame, #E-1380-18113, covering about a 1.5° square bounded approximately by 36°30' and 38°00'N latitude, 119°30' and 121°00'W longitude, was subjected to considerable computer manipulation and enhancement at the U.S. Geological Survey's facility in Flagstaff, Arizona. Color-ratio images, which effectively eliminate topographic visualization, were judged not useful for purposes of lineament analysis. A program specifically designed to enhance lineaments by incorporating a narrow band filter that suppresses the horizontal scan lines, producing a horizontal derivative, appeared to emphasize edge effects, but the unrealistic portrayal of the terrain obscured the known structural lineament pattern; the resulting image was unsuitable for the objectives of this study in this particular region.

The product finally selected as best was a color composite of bands 5 (blue), 6 (green), and 7 (red) with a sinusoidal stretch. An enlarged transparency was analyzed and results plotted monoscopically on the PG-2 stereoplotter. No significant improvement in quantity or definition of lineaments was apparent on the computer-enhanced version as compared with a Diazo composite of the same frame. The approximate cost of the computer processing (in 1975-76) was on the order of $1200, whereas that of Diazo materials was about $15-20 (plus minimal staff time for exposure, development, and compositing). My conclusion from this very limited experience is that, at least in a region as highly vegetated as the Sierra Nevada foothills, the use of computer enhancement for purposes of lineament analysis cannot be recommended on a cost-benefit basis. The Diazo color composites, on the other hand, are a substantial improvement over the black and white Landsat films or prints and are well worth the time and effort invested to produce them.

The area was also examined on color infrared photographs taken from U-2 aircraft at approximately 60,000 feet. Flights that generated the film products used here were made in 1973-74. Contact film transparencies were mounted on the Kern PG-2 stereoplotter, and lineaments drawn on AMS 1:250,000 base maps directly from the stereo image. As in the Landsat analyses, the lineaments were identified by type as drainage or other topographic, tonal contrast, and structural-stratigraphic. However, no reliability ratings were applied on these maps.

A comparison of the results from the two data sets used for this study suggests at once the strengths and weaknesses of each. As would be predicted, lineaments identified on Landsat images represent the broad regional trends or integrated systems, whereas the larger scale U-2 photographs permit identification of smaller and more discrete lineament segments. The high resolution (about 3 m) and stereo coverage of the aircraft films, together with the superior accuracy of the Kern plotter used stereoscopically, are distinct advantages to the use of U-2 photographs as opposed to the spacecraft imagery (resolution of about 10 m) for lineament analyses. The principle disadvantage is the relatively limited field of view, particularly when used with the Kern plotter, so that regional trends may not be apparent during the plotting process.

Side-looking radar images of the east side of the Sacramento valley, flown by Westinghouse, also were examined. The mosaics were scaled approximately to 1:250,000 but not accurately enough to permit direct overlay, or transfer to the AMS base maps on which the Landsat and U-2 analyses had been plotted. However, on these images, also, the major lineament systems are clearly apparent, as well as many of the minor ones. Topographic detail is well portrayed in radar mosaics, whereas in Landsat images, topography is much less clearly discerned.

Skylab color photographs (scale 1:720,000) also are available for most of the area of interest here, but the prints examined afforded no significant improvement over either the U-2 films or Diazo composites. Skylab photos have a linear resolution of about 6 m, but structural trends were not nearly so well portrayed as in the Landsat films.

III. Preliminary analysis

The overall lineament trends clearly reflect primarily the regional northwest structural grain of the Sierra Nevada, Central Valley, and Coast Ranges. The predominant subsidiary trends appear to be NNE and ENE; the latter trend may be due partly to normal consequent drainage WSW from the Sierras, but distinctly linear segments are anomalous in any case in a normally dendritic system. A pervasive problem with lineament analysis in this part of California, especially in the Central Valley, is that not only are most structural trends oriented northwest, but many cultural features (roads, railroads, canals, transmission lines) are also.

The fact that major known structural trends are reflected in the lineament maps suggests that lineaments whose trends or locations were otherwise unknown may have some significance. For those lines that are unusually long, whose trends are decidedly anomalous, or whose existence is unambiguous, field investigation is clearly warranted in order to determine both the reality and the extent of structural or tectonic control.

IV. Acknowledgements

George Reid prepared excellent Diazo color composites for this study and his assistance was invaluable. Richard V. Lugn adapted the Kern Stereoplotter to the monoscopic peculiarities of Landsat imagery and was indispensible to the operation of that machine. Discussions with numerous geologists -- notably Denis Marchand, Alan Bartow, Désirée Stuart-Alexander, David Harwood, Michael Doukas, and Edward Helley, all of whom are engaged in various stages of field work in the area -- provided essential background. Comments and suggestions by Désirée Stuart-Alexander, Alan Bartow, and Denis Marchand considerably improved the present report.

V. Related publications

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