N73-28250

Paper G 19

PRELIMINARY GEOLOGIC INVESTIGATIONS IN THE COLORADO PLATEAU USING ENHANCED ERTS IMAGES

Alexander F. H. Goetz, Fred C. Billingsley, *Jet Propulsion Laboratory, Pasadena, California*
Donald Elston, Ivo Lucchitta, *U. S. Geological Survey, Flagstaff, Arizona*
Eugene M. Shoemaker, *California Institute of Technology, Pasadena, California*

ABSTRACT

Bulk and computer enhanced frames of the Verde Valley region of Central Arizona, an area which has been well mapped, have been analyzed for structural information and rock unit identification. Most major rock units in areas of sparse ground cover are identifiable on enhanced false-color composites. Regional structural patterns are strikingly visible on the ERTS images. New features have been identified whi·h will aid in the search for ground water near Flagstaff, Sedon and Stewart Ranch.

1. INFORMATION

The purpose of our study in Central and Northwestern Arizona is to marry the techniques of computer image processing and field geologic mapping to attack some regional geologic problems of special interest. Work in only one of the three areas under study is discussed in this paper. This area is situated in north-central Arizona (Fig. 1) and is about 70 miles in north-south extent and 50 miles wide, and includes parts of the Colorado Plateau and the adjacent "Mountain Region" to the south. The area is centered on the Verde Valley, and on the west includes part of the Chino Valley. Flagstaff is on the northeast boundary and Prescott lies near the western boundary.

II. GEOLOGIC SETTING

In the Colorado Plateau area, Tertiary basaltic flows less than a hundred to a few hundred feet thick, derived from scattered eruptive centers during the past ~15 m.y., mantle nearly flat-lying sedimentary strata of Paleozoic age (Fig. 2). The Paleozoic beds aggregate several thousand feet in thickness. In the Verde Valley area, the Paleozoic strata rise structurally in a southerly direction, and the basaltic flows rest on successively older beds to the south. The southwestern most extent of preservation of Paleozoic strata in central Arizona occurs in the southern part of the map area (Fig. 2). In the western and southwestern parts of the area, the Tertiary basalts overlie a variety of Precambrian igneous and metamorphic rocks. A great deal of the area has been mapped geologically in detail, at scales of 1:62,500 and 1:48,000 (see references). The generalized geologic units shown in Figure 2, and the faults shown in Figure 3, were drawn principally from this published information.

Non-metallic deposits currently being exploited are limestone for cement, gypsum for plasterboard, volcanic cinder deposits and gravel deposits for road metal. Copper is the principal metallic mineral that has been mined. Production has come mainly from the Serome area and from south of Humboldt.

III. PRELIMINARY FINDINGS

The simple color composites of bands 4,5 and 7, computer stretched to increase contrast, show remarkably good correlation with the generalized geologic map shown in Figure 2. Areas not covered by Ponderosa pine exhibit color tones diagnostic of the individual geologic units, in spite of moderate vegetation cover in the form of Juniper bushes, sagebrush and grass. In the areas of sparse vegetation all major geologic units are identifiable. Areas mapped as Qg, gravel and sediment deposits, cannot be differentiated from the units from which they were derived. For instance in the northern Verde Valley the deposits derived from the Paleozoic Supai Formation have the same characteristic color as the original unit.

The major copper workings, as well as the tailings leach ponds, are highly visible down to one resolution element in size, because of the characteristic low sulfide reflectivity in the near IR compared to the visible. These areas appear bright blue on a false-color IR composite.

IV. FAULTS AND LINEATIONS

Well-developed regional structural patterns are strikingly visible on the ERTS images, particularly where Precambrian metasedimentary and metavolcanic rocks are at the surface (e.g. southern part of area; Figs. 2 and 3). The ancient structural grain trends predominantly northeast and north, and includes subordinate widely spaced east-trending lineations. Northwest-trending structures and lineations reflect comparatively recent structural adjustments and the development of the present geomorphologic form of the region. The northwest-trending linear features, for the most part, are less conspicuous than the north and northeast-trending lineations. ERTS images show that most of the eruptive centers for the basaltic volcanism on the Colorado Plateau are clearly localized along northeast and north-trending lineaments. This suggests that Precambrian structures were responsible for the localization of the eruptive centers, and that structural adjustments along the ancient trends occurred during the Tertiary volcanism. The Oak Creek Fault, for example, is inferred to overlie a north-trending fault system in the basement that is en echelon to the Shylock Fault Zone north of Humboldt.

The lineaments mapped photogeologically from the ERTS images locally supplement, and generally complement, the pattern of known mapped faults In unmapped areas, the lineaments constitute the only structural information, information which provides an overall sense as to the nature of the crackling of the crust. The lineaments range from very strongly developed sets of joints, to vaguely developed, almost indefinite groups of short linear features which together portray a possible structural grain. In some cases, the well defined lineations reflect stratification in metamorphosed rocks (south of Humboldt); in other cases, they reflect strong zones of fracture (in Paleozoic rocks near Sedona). It should be noted that northwest-trending fractures in the Sedona area are extremely abundant and closely spaced, and in images from low altitude are the overriding structural characteristic. The ERTS images of this area, however, display some very strongly developed northeast- and east-trending lineations which previously were unrecognized. Similarly, a strong north-trending lineament which parallels and lies east of the Oak Creek Fault was recognized as an element of the Oak Creek Fault system in light of the ERTS images. The ERTS images appear to provide a method for "seeing" important structural grain in sedimentary rocks beneath the basalt cap in the Flagstaff area. Structural discontinuities in the basement also may be traced even where concealed by thick valley-fill deposits. An example occurs in the Chino Valley where one or more lineations may be traced northwestward from Humboldt to past Stewart Ranch.

An example of directional filtering to remove horizontal banding and enhance small oriented features is shown in Figure 4. Several orientations of structural grain are visible over a wide area of the image. Such enhancements are useful to attract the attention of the viewer to subtle, oriented features. However the subjective evaluation of the mapper is necessary to exclude possible artifacts. A more detailed account of the various methods of image processing is given elsewhere in this volume (Billingsley and Goetz, 1973).

V. APPLICATION TO GROUND WATER RESOURCE PROBLEMS

The City of Flagstaff is presently in the process of developing a source of subsurface water from the Coconino Sandstone at two localities: (1) in the Woody Mountain area, where several wells have been drilled, and (2) in the lower Lake Mary area where one well has been drilled. The Coconino Sandstone appears to be saturated at these places and reliable producing wells depend on fractured ground. Areas marked by the intersection of differently oriented sets of fractures will be important for guiding the location of wells that are to be drilled this summer into the Coconino Sandstone, and the location of a planned deep well that is to test the stratigraphically much lower Redwall Limestone. Long range plans for the development of a large supply of water will require the structural evaluation of ground extending some 60 miles southeast of Flagstaff.

The lineaments shown on Figure 3 in the area of the Oak Creek Fault and Lake Mary have been informally provided to the City of Flagstaff and have been transferred to the city's working map of the Woody Mountain area.

Figure 3 shows that an area immediately southeast of Woody Mountain may be structurally favorable for subsurface water. Strongly developed northwest-trending lineaments impinge and appear to intersect north-trending lineaments of the Oak Creek Fault system. The utility of the minor lineaments and their relation to a regional fracture pattern remains to be demonstrated. A lineament map is to be made employing normal aerial photographs in an analytic stereo plotter to supplement the lineaments derived from ERTS images. RB-57 photography has been ordered to allow the compilation of lineaments for a more extended area at a scale of 1:62,500, which is compatible with anticipated drilling target areas. The latter will cover the area of intermediate and long range planning for the development of Flagstaff's water resources.

Sedona area: The State Geologist of Arizona and Water Resources Division of the U. S. Geological Survey, are concerned with discovering a new and extensive supply of water to serve the scenic and rapidly developing Sedona area of the Verde Valley. The potential aquifer is the Redwall Limestone, which underlies Sedona and the cliffs of Supai Formation and Coconino Limestone that bound Sedona on the north and east. Information needed includes elevation control on key horizons in exposed beds, which will provide data on the structural attitude and spatial position of the potential aquifer. Also needed is the distribution of fracture zones that would permit the interconnection of karst or cavernous ground anticipated in the lower part of the Redwall. In such cases, one can encounter virtual underground "rivers".

Existing ERTS images (Fig. 3) and high altitude RB-57 color photographs display the character of fracturing in the Sedona area. A few very well developed east-west-trending lineaments transect the more common NE-, NW- and north-trending sets of lineaments. We interpret that the scenic embayment in the Colorado Plateau margin in which Sedona is located resulted from erosion in an area that is somewhat more fractured than adjoining areas. The greater fracturing presumably reflects the existence of the fourth (E-W) set of fractures. Development of water resources will depend on the location of a favorable structural position for the potential aquifer and the existence of suitably fractured ground. We have begun discussions which may lead to the establishment of a cooperative effort toward the solution of this problem.

Chino Valley, Stewart Ranch area: Another area of interest to the State Geologist and Water Resources Division is in Chino Valley, near the Stewart Ranch. Here, substantial quantities of ground water occur near the surface, and flowing wells have been drilled. Control, source, and recharge areas for the water are not really known, although the existence of outcrops of Precambrian Mazatzal Quartzite in low hills nearby (Fig. 2) suggests some form of structural control on the aquifer (Redwall Limestone).

The ERTS images have revealed the existence of lineaments of Chino Valley which extend northwestward from Humboldt. These can be traced to and well beyond the Stewart Ranch area. They are provisionally interpreted to reflect structure in bedrock beneath the valley fill. Their existence suggests that the near-surface ground water is controlled by the existence of a heretofore unrecognized "dam" in the subsurface.

A structural evaluation of this area is needed to allow the proper development of ground water resources. ERTS images, and high altitude photographs, need to be analyzed for the distribution and character of lineaments. These, interpreted in light of structure t[illegible] be obtained from surface and subsurface studies, should shed light on water resources in this part of the Chino Valley. We tentatively pl[illegible] to carry out the required structural studies as part of a cooperative investigation with the appropriate federal and state agencies.

REFERENCES

Anderson, C. A., and Blacet, P. M., 1972, Precambrian Geology of the Northern Bradshaw Mountains, Yavapai County, Arizona: U. S. Geol. Survey Bulletin 1336, 82 p., 2 pl.

Anderson, C. A., Blacet, P. M., Silver, L. T., and Stern, T. W., 1971, Revision of Precambrian Stratigraphy in the Prescott-Jerome Area, Yavapai County, Arizona: U. S. Geol. Survey Bulletin 1324-C, p. C1-C16.

Anderson, C. A. and Creasey, S. C., 1958, Geology and Ore Deposits of the Jerome Area, Yavapai County, Arizona: U. S. Geol. Survey Bulletin 1230-F, p. F1-F19, 1 pl.

Billingsley, F. C. and Goetz, A. F. H., 1973, Computer Techniques Used for Some Enhancements of ERTS Images, ERTS Investigator Symposium March 5-9. Goddard Space Flight Center.

Huff, Lyman C., Santos, Elmer, and Raabe, R G., 1966, Mineral Resources of the Sycamore Canyon Primitive Area, Arizona: U. S. Geol. Survey Bulletin 1230-F, p. F1-F19, 1 pl.

Krieger, Medora H., 1965, Geology of the Prescott and Paulden Quadrangles, Arizona: U. S. Geol. Survey Prof. Paper 467, 127 p., 5 pl.

Lehner, Robert E., 1958, Geology of the Clarkdale Quadrangle, Arizona: U. S. Geol. Survey Bulletin 1021-N, p. N511-N592, 3 pl.

Twenter, R. F., and Metzger, D. G., 1963, Geology and Ground Water in Verde Valley--the Mogollon Rim Region, Arizona: U. S. Geol. Survey Bulletin 1177, 129 p., 1 pl.

Wilson, Eldred D., Moore, Richard T., and Cooper, John R., 1969, Geologic map of Arizona (scale 1:500,000): Arizona Bureau of Mines and U. S. Geological Survey.

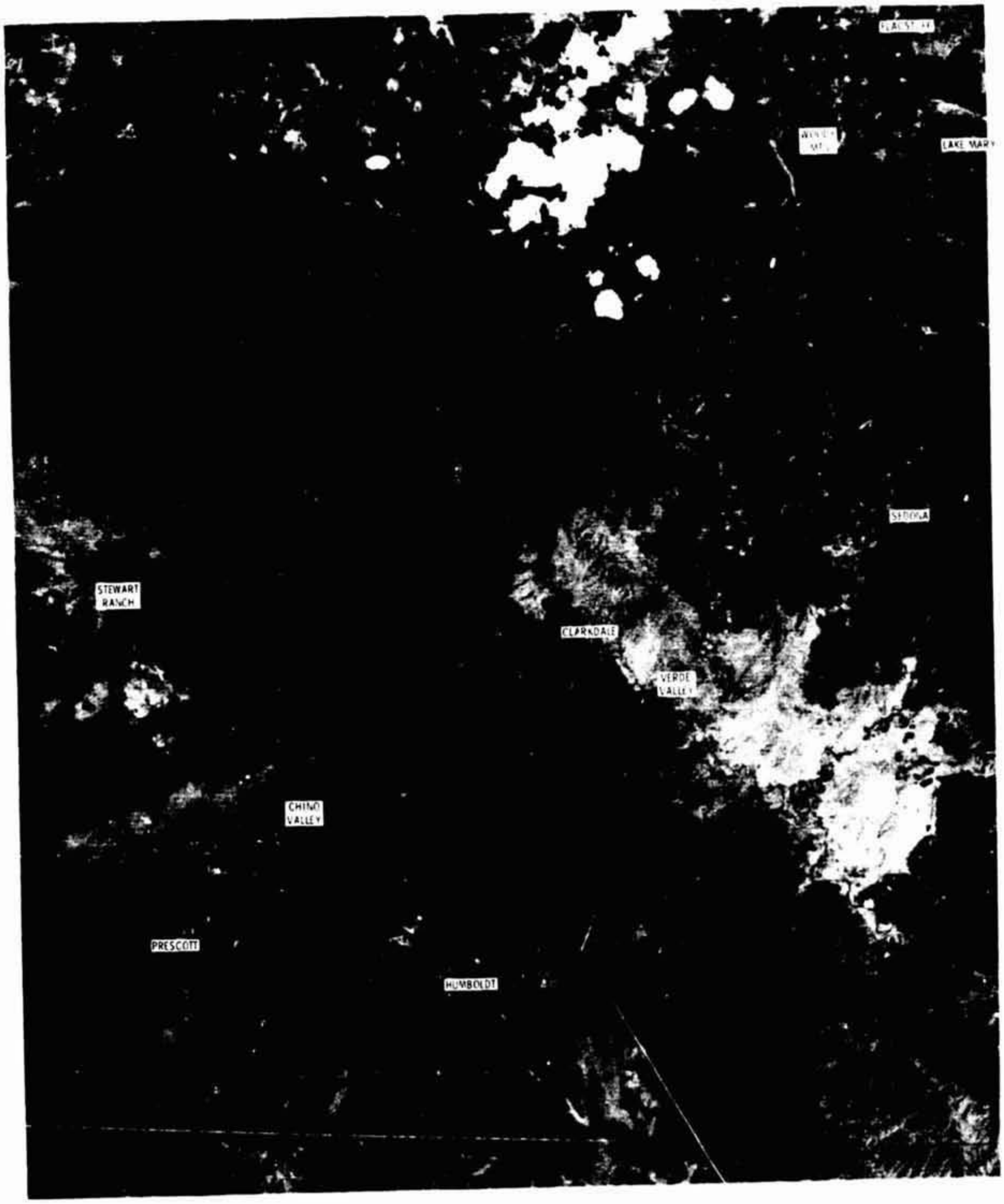

Figure 1. A portion of ERTS frame 1014-17375-7 showing the area under study.

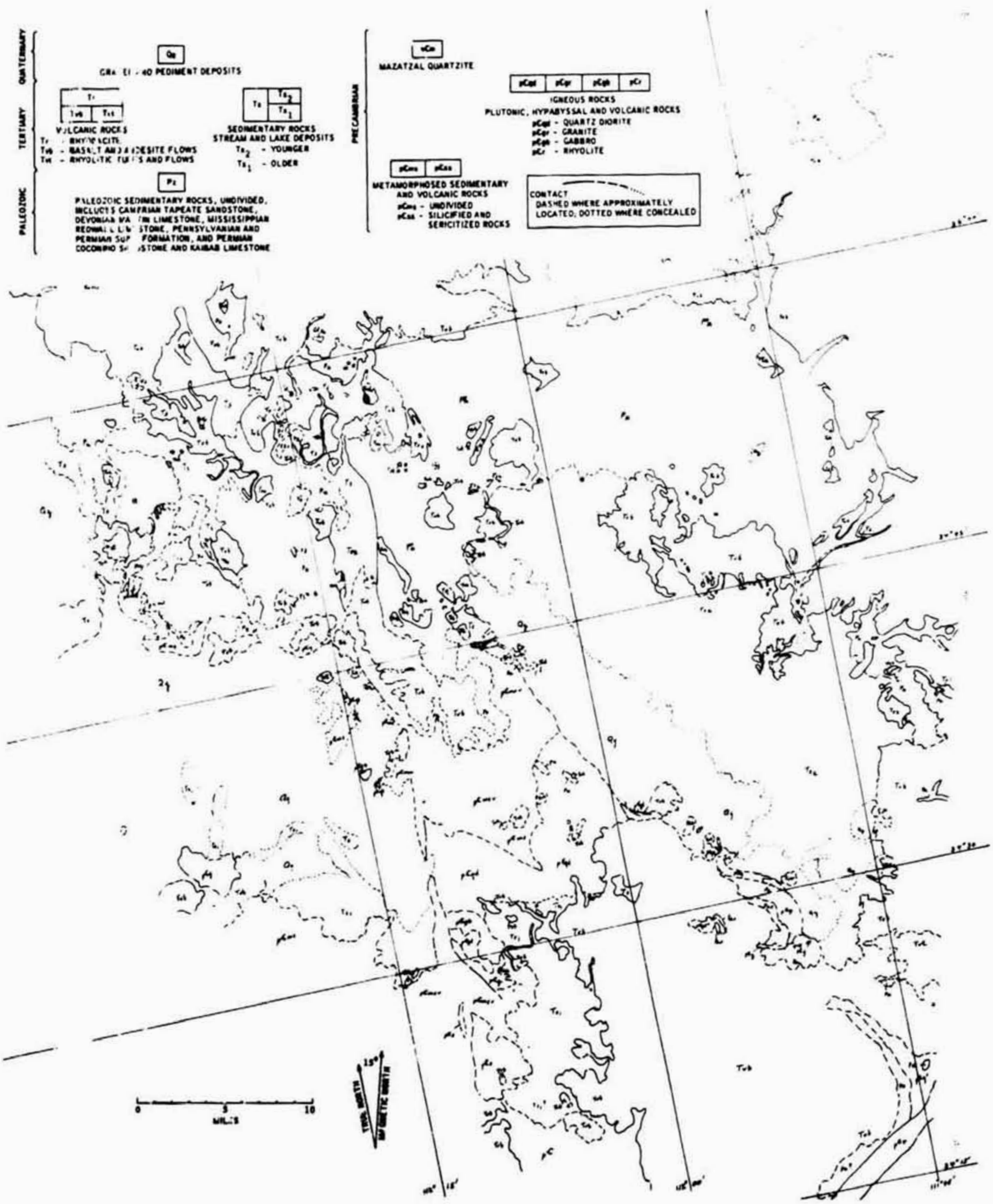

Figure 2. Generalized Geologic Map Compiled from the Listed References

Figure 3. Lineament map of the Verde Valley-Region. Heaviest lines denote mapped faults, other lineaments derived from ERTS photos.

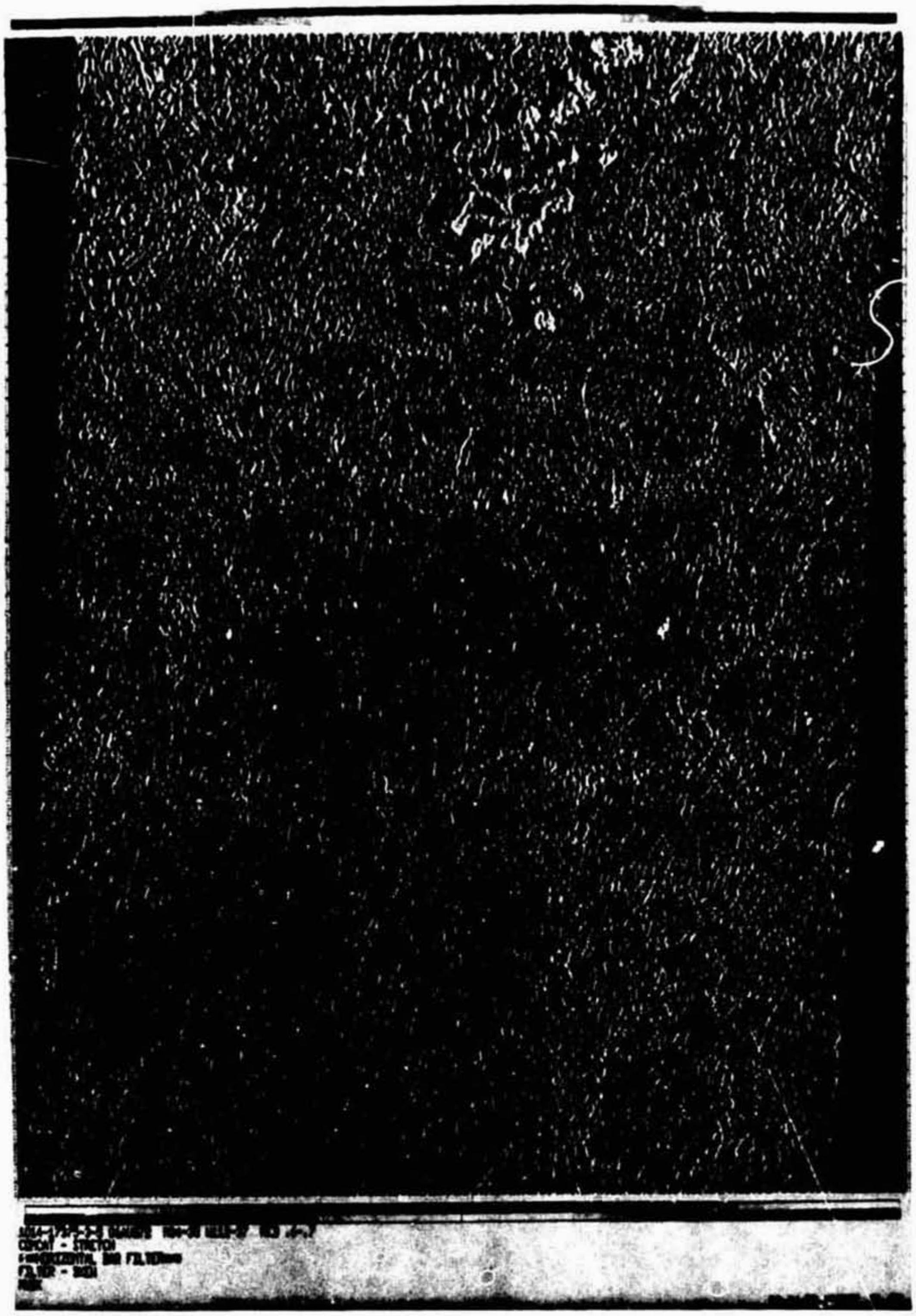

Figure 4. Computer enhanced product of Figure 1. The horizontal bar filter removes banding and enhances small linear features in other directions.