CARTOGRAPHY

by

Alden P. Colvocoresses

INTRODUCTION

This paper is a condensation of the EROS Cartography Program's annual report to NASA for fiscal year 1970. It emphasizes the relationship between topographic activities of the U.S. Geological Survey and those of the NASA Manned Spacecraft Center.

This paper is divided into the following sections:

- Objectives
- Relationship to NASA aircraft program
- Space photomapping
- Support of ERTS
- Thematic mapping
- Conclusion

OBJECTIVES

The program objectives are to:

1. Apply remote sensing of the earth (basically from space) to
   a. Topographic and planimetric base mapping
   b. Rapid thematic mapping of significant temporal phenomena, such as open water, snow, vegetation, and the massed works of man, and the sequential spatial changes of these phenomena.
   c. Production of specially processed imagery from which useful information can be derived for a variety of disciplines associated with earth resources.
   d. Rapid location and portrayal of unpredictable phenomena.

Publication authorized by the Director, U.S. Geological Survey.

2. Provide a user-oriented research facility in which data-processing techniques (principally analog) can be developed and tested in conjunction with various user groups associated with earth observations from space.

RELATIONSHIP TO NASA AIRCRAFT PROGRAM

High-altitude aircraft photography is of a continuing and vital interest to cartography. As early as 1965 a request was made to NASA for the simultaneous procurement of panoramic and mapping (frame) photocoverage. Installation of the 12" focal-length mapping camera in the RB57 was also advocated. Although the simultaneous procurement of panoramic and mapping coverage has not been accomplished, the RB57 flights are of current operational value and their potential value to research and development is enormous.

The NASA RB57 program is producing photographic coverage of mapping quality with 6" and 12" cameras at about 60,000 feet, and the coverage is being applied within the Geological Survey to the following tasks as the films become available:

- Flight planning (for low-altitude coverage) and field identification in southern Florida.
- Field classification and possible direct use as a photobase for the Florida Keys. Figure 1 is a section of an RB57 12" color infrared photograph of the Keys (Bahia Honda).
- Orthophoto compilation, field classification, and aerotriangulation in the San Francisco Bay area.
- Experimental wetland categorization in the Chesapeake Bay area. Figure 2 is a 6" color infrared photo of the Chesapeake Bay area illustrating a clear demarcation of what presumably may be classified as wetlands.
- Experimental production of color photomaps of both the Florida Keys and the Phoenix area.
- Urban-area map revision and photomapping related to the "26-city" project.

Figures 1 and 2 demonstrate the value of the high-altitude air photos and also the information content of properly exposed color infrared film. No conflict with proposed space systems, or duplication of effort, is evident from this demonstration--in fact space and high-altitude aircraft systems appear to be highly complementary. The two primary national

mapping scales are currently 1:24,000 and 1:250,000, roughly a 10-fold difference. Consequently, obtaining images of the earth from altitudes of at least a 10-fold difference, say 20 kilometers and 200 kilometers, appears justified. Resolution is the dominant factor, but for similar sensors altitude is the key. A 10-fold difference in altitude (for the same sensor) means a 100-fold difference in the number of images. To the cartographer the representations are as different as the 1:24,000 and 1:250,000 scale maps, which are considered to be complementary in spite of their obvious differences. The cartographic program strongly supports the USGS recommendation that the complete high-altitude photocoverage of the United States be obtained at the earliest practical date, and one of the reasons for the recommendation is that the photocoverage will support and complement ERTS and other earth-imaging space systems.

SPACE PHOTOMAPPING

Sample photomaps at 1:250,000 and 1:500,000 scales were compiled, printed, and distributed. They cover areas in southern Arizona and adjacent States and were made from Apollo and Gemini photographs taken with Hasselblad and Maurer cameras, 80 mm and 76 mm focal length, at a nominal altitude of 125 nautical miles.

These products exemplify an effort to combine space images with conventional medium-scale line maps, with the potential of improving the content, currency, and even the accuracy of medium-scale maps. The photographs were rectified and scaled to the planimetric drawing of the existing line map. Although the photographs have neither the resolution nor the geometric fidelity that would be specified for a standard product, they were nearly orthographic after rectification and therefore could be reasonably well fitted to conventional map projections. The UTM grid was added for ease in scaling coordinates of map points. Some 3,000 copies of these photomaps were distributed to interested map users, with a request for comments. The comments received, which are in general highly favorable, will be considered in the development of a standard photomap rendition at medium and small scales. The comments of map makers, which as a whole are more critical, are also receiving full consideration as they reflect many technical problems that most map users are not aware of. Figure 3 illustrates the content difference between the line map and photomap, and figure 4 illustrates how currency and accuracy are both improved by the photoimage.

Color proofs at 1:1,000,000 scale were prepared from the same photographs, but a lack of adequate coverage and a suitable line base has postponed printing of a specimen photomap at this scale.

The application of ERTS to photomapping will be covered in the following section, but SKYLAB also promises some good source material for the photomapper. Experiment S190 (six 6" cameras recording on 70mm film) should provide ideal coverage for 1:250,000-scale photomaps, and because of the 50° orbit inclination could cover all the States but Alaska. However, the larger scales needed for many applications require a bigger camera. The USGS is recommending that the Hycon frame camera of 18" focal length developed for the Apollo program be flown on SKYLAB. The resulting photographs could be applied to a wide variety of map products at scales up to 1:100,000 or even larger.

SUPPORT OF THE EARTH RESOURCE TECHNOLOGY SATELLITE (ERTS)

Several tasks are underway in support of ERTS, as follows: (1) geometric analysis of the Return Beam Vidicon (RBV); (2) recommending format criteria for ERTS products and providing a map support system; (3) providing photoidentifiable ground control; and (4) definition of ERTS cartographic experiments.

All four of these tasks are covered in detail in the annual report of the EROS Cartography Program, but some highlights are summarized in the following paragraphs:

1. Precise positional measurements are being made of the 81 reseau marks on each RBV tube. When laboratory images are obtained and recorded with the RBVs, the reseaus are again measured on the images to obtain data for an analysis of distortions. This work is being performed in cooperation with NASA Goddard and RCA. A detailed report will be given at the 7th International Symposium on Remote Sensing of Environment (University of Michigan).

2. NASA has accepted the USGS recommendations for ERTS image format and annotations. The precision-processed images will be cast on the Universal Transverse Mercator (UTM) projection at 1:1,000,000 scale, to provide a photomap that can be directly correlated with line maps, such as those in the 1:250,000-scale series, since both will carry UTM grids. A metric coordinate reader, illustrated in figure 5, has been developed to facilitate measurement of grid coordinates on both gridded maps and precision-processed photos. Gridded 1:250,000-scale maps, currently a military product, are also being stocked by the USGS for "official use" and may be put on public sale if the demand warrants.

3. To produce precision-processed images, a sizeable bank of photo-identifiable ground control points is required. Points in the State of Missouri have already been filed, and negotiations are underway with NASA to enlarge the data bank to cover all 50 States.

4. Several cartographic experiments, at scales ranging from 1:250,000 to 1:5,000,000 are underway for ERTS. The areas of principal concern are the 50 States and the polar regions; and the projects concern planimetric photomapping, map revision, and thematic mapping (including change).

THEMATIC MAPPING

The development of automated or semiautomated image-processing and information-extraction techniques is the immediate goal of this effort. Density slicing is being investigated on contract with Philco Ford and International Imaging Systems (I^2S). In-house photoprocessing techniques have produced some enhanced images of potential value. Figure 6 is an enhanced image (produced by a sharp-mask technique) of the Ouachita River at flood stage as photographed on Apollo 9. The definitive separation of water from land areas is typical of the type of problem being attached. Figure 7 illustrates the result of processing an Apollo S065 photograph of Georgia, to separate land and open-water areas. If the geometry and photometry of image acquisition and processing can be properly calibrated and controlled, the mapping of themes characterized by distinct spectral signatures should become a reality. Likewise, controlled sequential thematic mapping of the same area will provide the necessary input for the mapping of change. The present approach is to use photographic (optical) processing insofar as possible and to bring in scanners and the digital approach only as it becomes necessary. Since the most versatile computer in existence is the human brain, it will also be directly used in the thematic mapping process for a long time to come.

USER RESEARCH FACILITIES

One of the basic objectives of the cartography program is to establish user-oriented research facilities. These facilities are primarily related to photographic processes although TV displays, scanners, and even a digital plotter are under development. The facilities are provided within the U.S. Geological Survey at Silver Spring, Md., except as otherwise noted. Instrumental developments are described in a separate paper, but the following is a list of the facilities available or in development:

- A file of aircraft and space film
- Precision enlargers, rectifiers, and viewers[1]
- A three-band additive viewer[2]
- A black-and-white and color[3] photoprocessing laboratory[1]

- Cartographic facilities[1]
- Density slicer (electronic)
- BAI optical correlator[4]
- Microdensitometer[4]
- Automatic plotter[4]
- Bendix Datagrid Digitizer[4]

1 Use is generally on a repay basis
2 On indefinite loan from the Air Force
3 Located in the GSA Building, Washington, D.C.
4 Located at the Research Center, McLean, Va.

In addition a precision color photographic laboratory is programmed for FY71.

CONCLUSION

Progress is being made and by the time ERTS flies, a system for image processing and dissemination should be operational. Several other sophisticated remote sensing systems will be in operation by 1972 and must be fully considered. But the view of the Cartography Program must also extend beyond 1972. At last year's meeting a geosynchronous system for earth sensing was suggested, and the USGS subsequently proposed such a system to NASA.

A few days ago the Program received a NASA Request for Research and Technology Objective and Plan for a Synchronous Earth Observation Satellite (SEOS-A), and this is most gratifying. The USGS is preparing to map the fixed and temporal features of the US and other areas from both space and aircraft. The various modes, which includes geosynchronous and film return systems as well as the ERTS type, must be fully tested so that optimum methods can be applied to the mapping tasks.

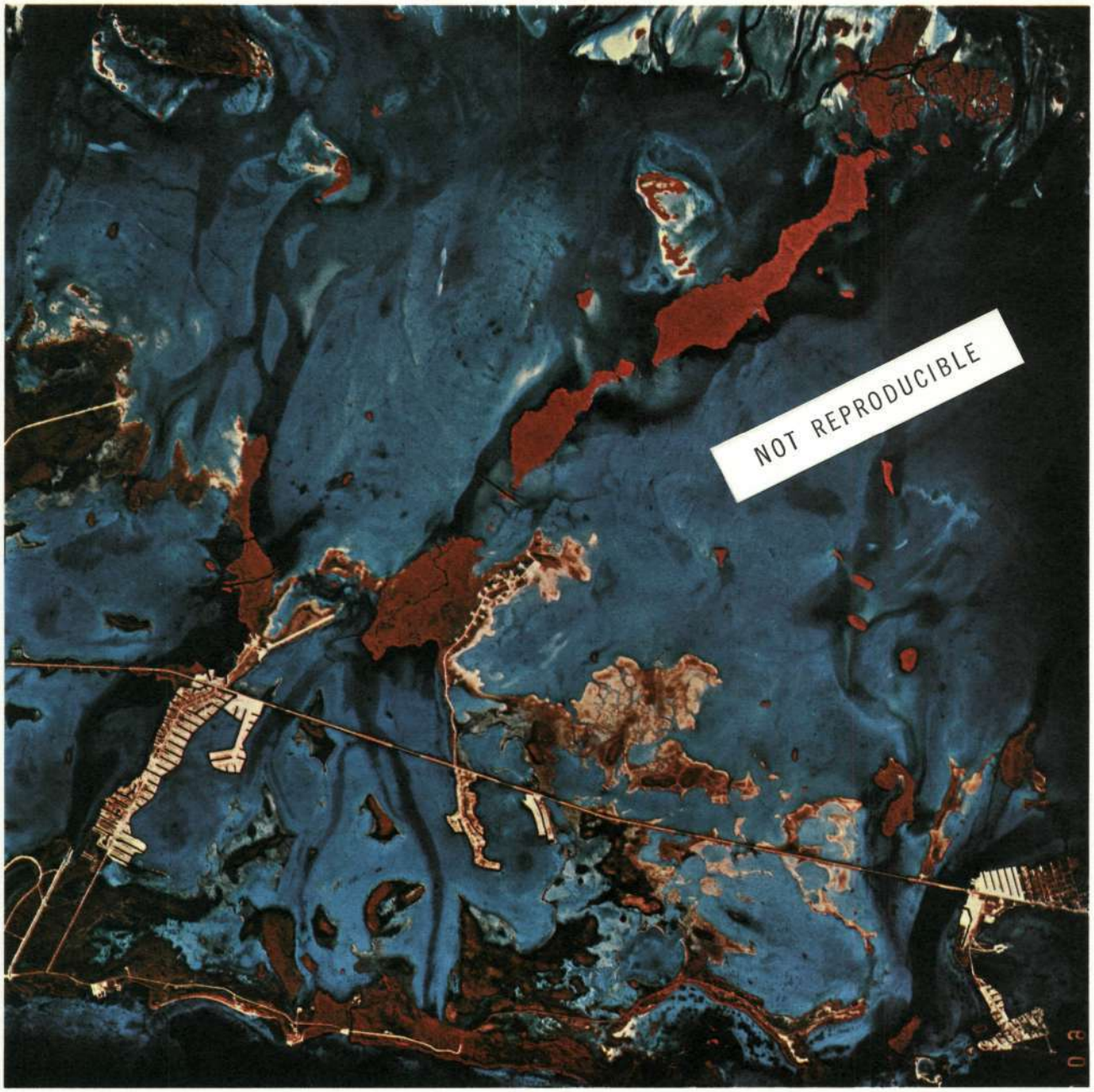


Figure 1--A section of the Florida Keys from 60,000 feet as photographed with a 12" focal-length mapping camera in color infrared (NASA photo).

Figure 2--Coastal wetland area as photographed from 60,000 feet with a 6" focal-length mapping camera in color infrared (NASA photo).

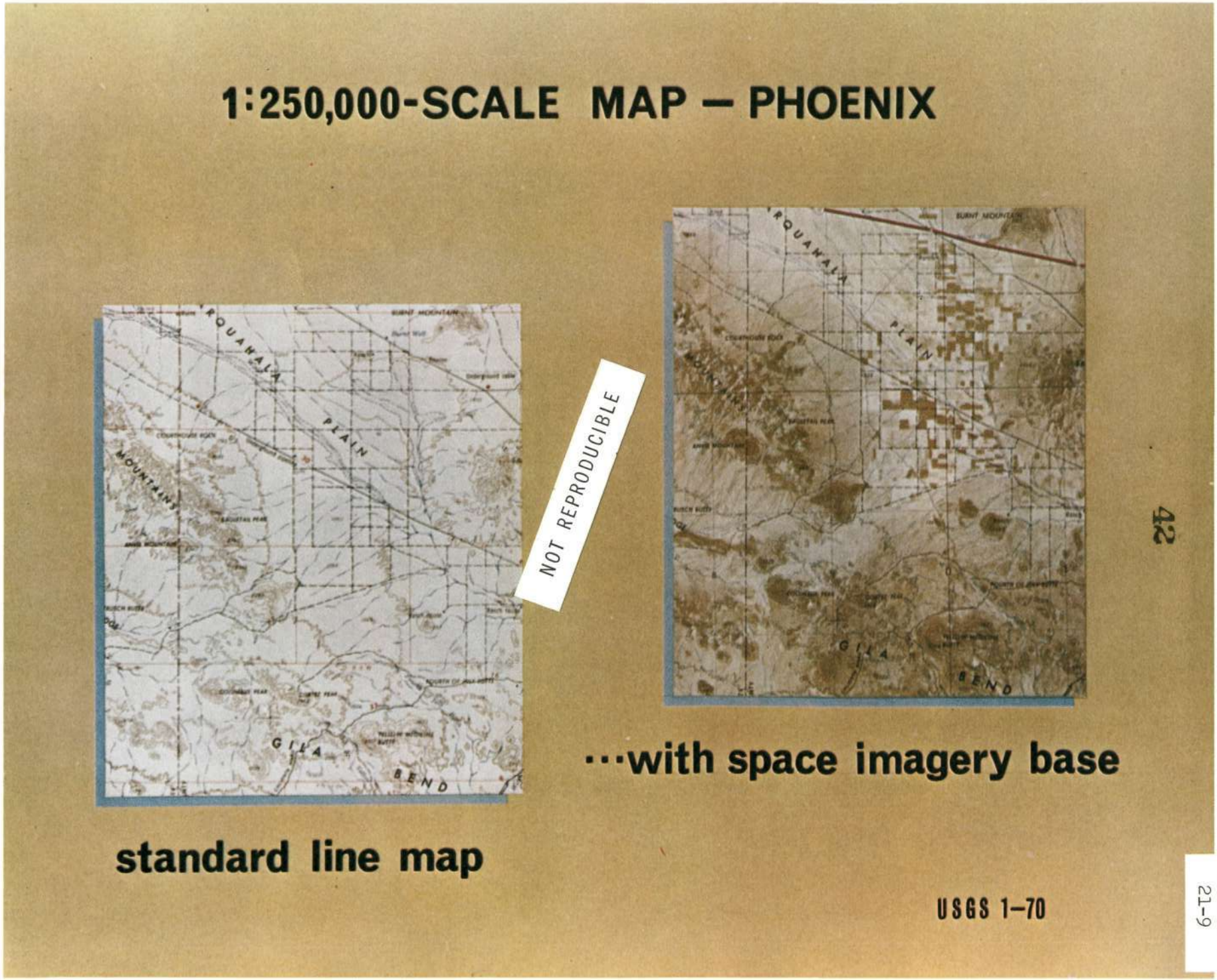


Figure 3.- 1:250,000-scale line map compared with the line map combined with space image.

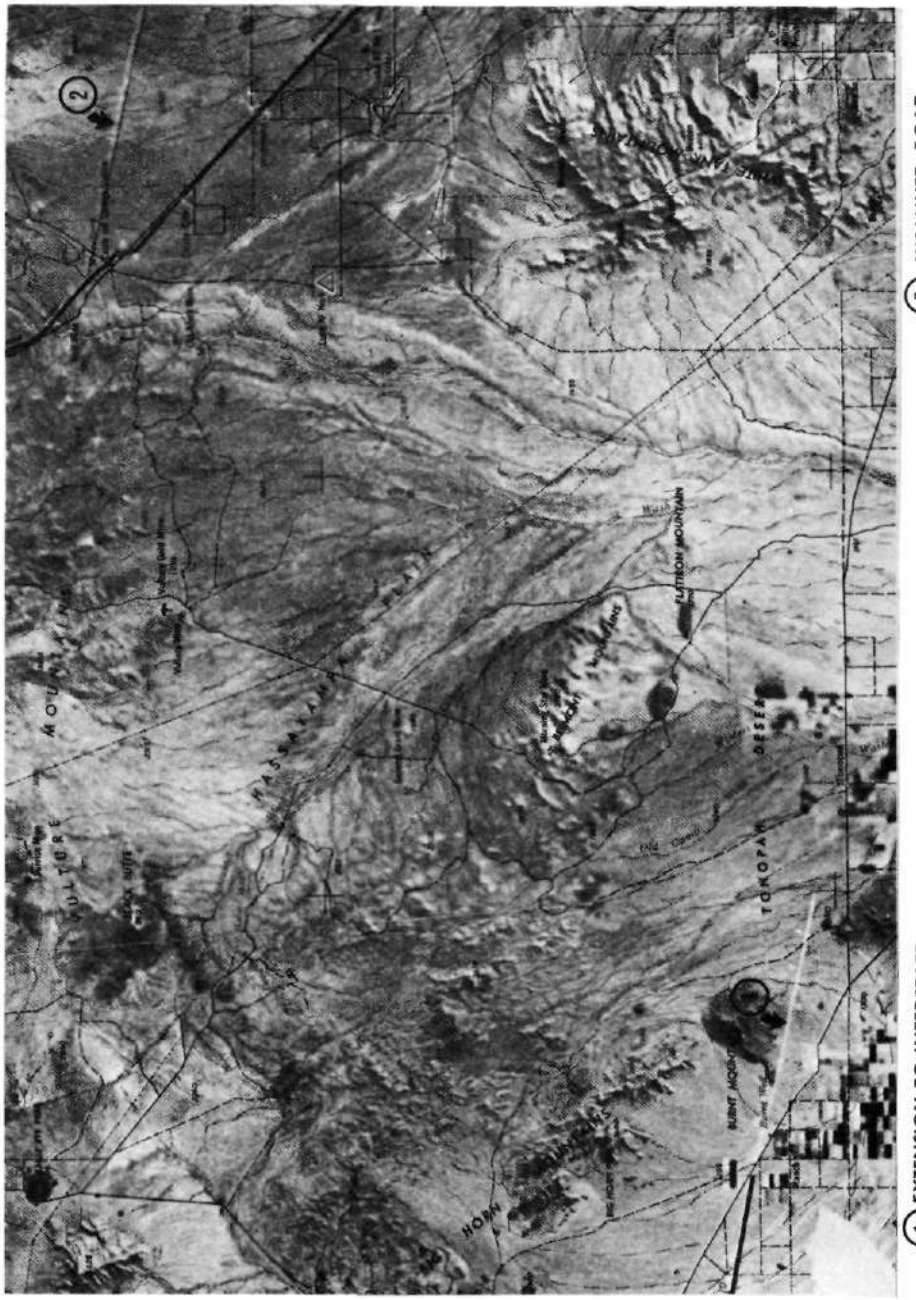
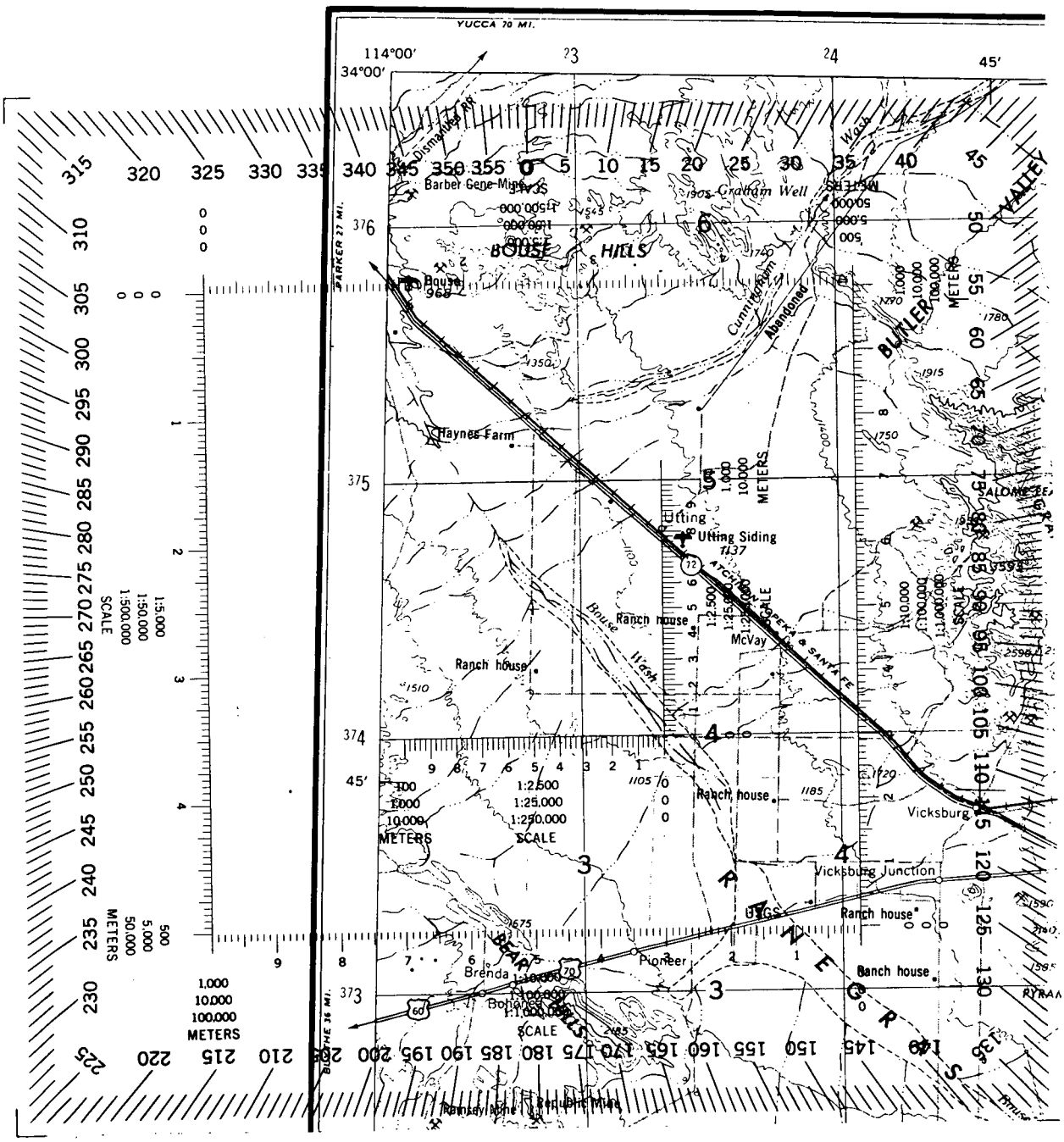


Figure 4.- The manuscript (1:250,000 scale, Phoenix sheet) was compiled by USGS from all available (other) sources and was considered current as of March 1969, which is the same date as the Apollo 9 (S065) space photograph. On this section of the space photo are indicated both additions and positional corrections to be made to the road net.



Metric Coordinate Reader

Figure 5.- A coordinate reader superimposed on gridded 1:250,000-scale map.

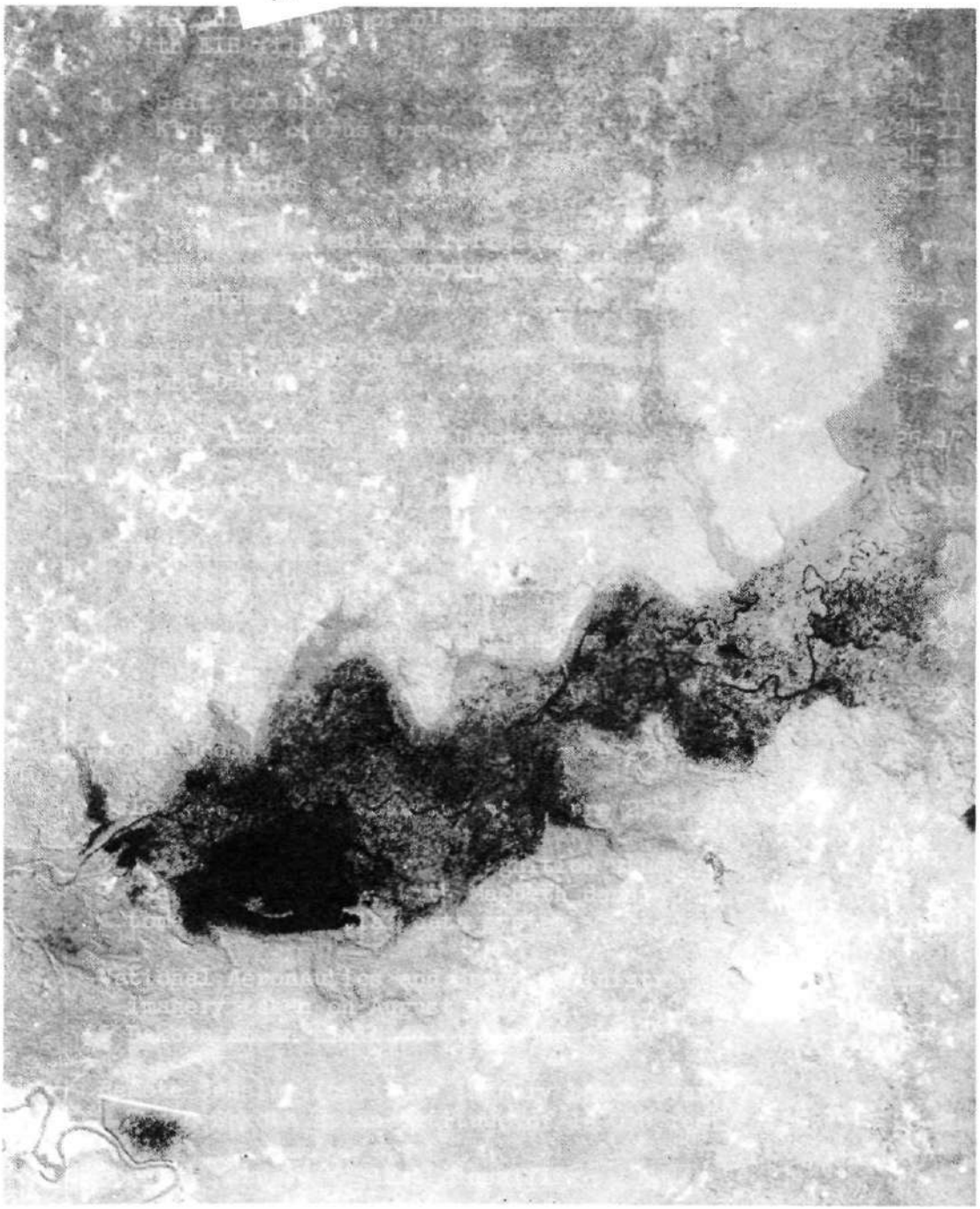


Figure 6.- Selected segment of exposure AS9-26C-3740, March 11, 1969 showing the Ouachita River in the Mississippi Valley at flood stage. Black-and-white enlargement was made from the IR (700-900 nm) band. A sharp-mask technique of image enhancement and exposure aimed at optimizing density differences were used.

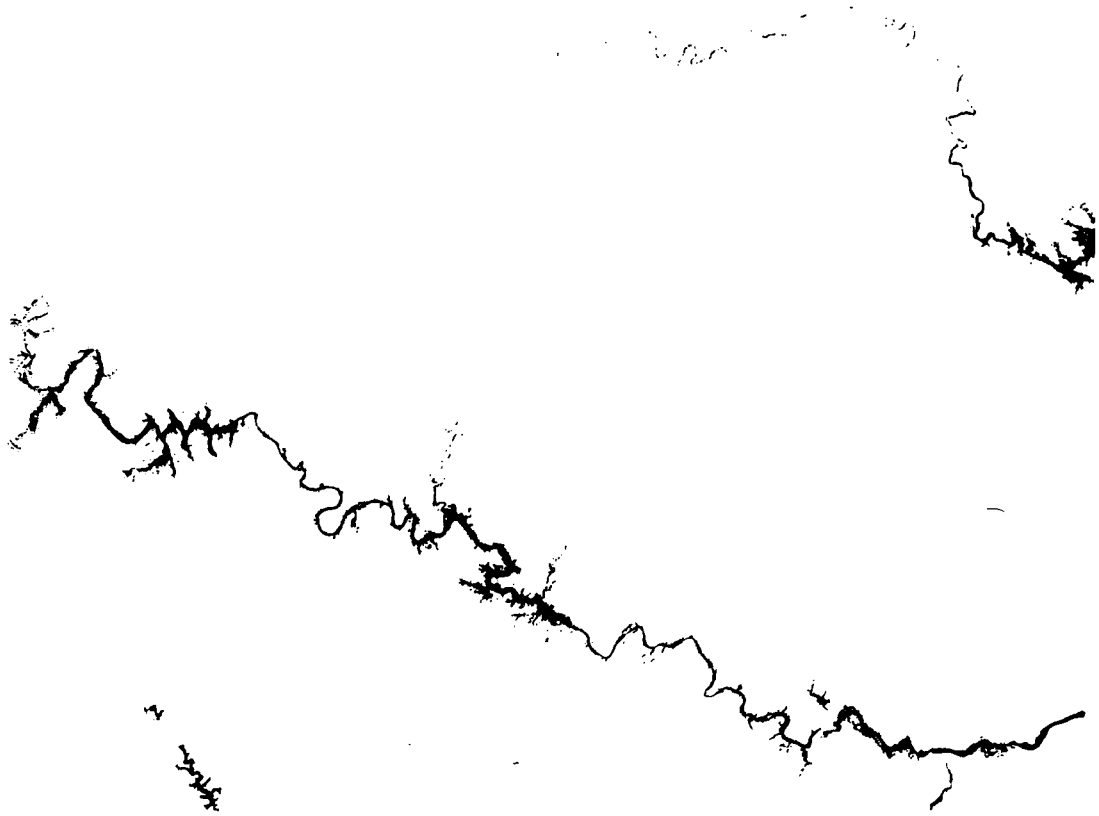


Figure 7.- Open water separated from land by photo-optical means (NASA Apollo photo).