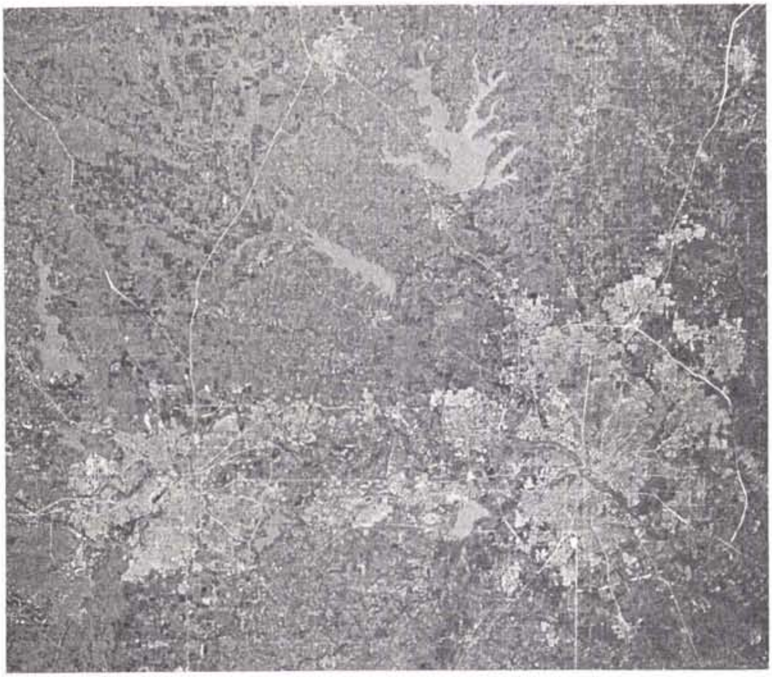

FIG. 1. Apollo VI near-vertical black-and-white reproduction of color photograph (As6-2-1462) taken from an altitude of approximately 128 miles encompasses the entire Dallas-Fort Worth area.

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# Patterns from Apollo VI Photos

**The environments of the Dallas-Fort Worth area are studied through an interdisciplinary approach using space photos.**

(*Abstract on next page*)

## INTRODUCTION

WITH THE launching of the Earth Resources Technology Satellite (ERTS-A) in July 1972, scientists will acquire orderly, sequential multispectral imagery of earth for the first time. In anticipation of this, we examined Apollo VI photographs of the Dallas Fort Worth area with an aim toward evaluating interdisciplinary approaches to interpretation of these urban/rural photographs. Our goal was to evaluate existing and possibly new uses of this imagery in identifying, locating and measuring patterns related to urban development. The problem was approached obliquely; we began work on these photographs independently and then compared results and added to them jointly.

Space satellites are of immense value in providing a new perspective for viewing

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earth's surface. Even with the unclassified sensors presently available, these platforms can be used to generate invaluable earth-resource data for a better understanding of our environment. Remote-sensing imagery from space is a new aid to planning the wise use of planet earth's resources. (Colwell, 1968; Pecora, 1972).[1,2] But the applicability of this tool benefits from a multidisciplinary approach.

## Apollo VI Photographs

Apollo VI was placed into a low-latitude equatorial orbit aboard a Saturn booster rocket on April 4, 1968. In many ways Apollo VI was unique. It was the first space flight in which the on-board camera had a fixed mounting. A 70-mm Maurer model 220 G camera was mounted in the hatch window. The film used was Kodak Ektachrome, High Resolution Aerial, SO-121. The exposure interval, set at approximately 8.64 seconds, gave all frames at least a 50 percent overlap which makes stereo-viewing possible. When the camera system was first activated, the lens was pointed away from earth. The spacecraft attitude was corrected so that along one flight line a continuous series of photographs was generated from the west to the east coast of North America. This flight line crossed the continental land/water interface over Baja California, near Puerto Santo Tomas, Mexico, passed over west-central Texas, north Texas, and left the continent near the Georgia-South Carolina border. Just east of Dallas a continuous, almost total, cloud cover obscured the surface of the eastern United States.[3]

Some of the most significant photographs generated along this flight line were over the Dallas-Fort Worth metropolitan area (Figure 1). Specifically, frame numbers As6-2-1462 to As6-2-1464 were more or less centered on Dallas-Forth Worth. The spacecraft altitude was approximately 127 to 128 miles at the time these photographs were taken.

The frames listed above were selected for study primarily because they were available from NASA. But there were additional reasons for using these exposures rather than others along the flight line. These are: (*1*) they are of excellent resolution, (*2*) they are cloud free, (*3*) they are near vertical and give essentially an orthographic view because of the narrow camera lens used, (*4*) the continuous stereo coverage results in different viewing angles of the same earth area, and because of resulting changes in view-angle, phenomena masked or obscured in one frame may be identifiable on the next, (*5*) this area has been mapped in detail for numerous purposes and the maps serve as important reference checks for comparison with these photographs, and (*6*) perhaps most important to this study, they provide an excellent mixture of physical and cultural detail of an urban/rural environment.

Abstract: *Interdisciplinary study of Apollo VI photographs of the Dallas-Fort Worth area demonstrated their applicability to a variety of urban concerns. The geology, hydrology, land use and transportation net of this area were established from the photographs and compared with known ground-based data. Close correlations indicate the potential usefulness of the Earth Resources Technology Satellites that was successfully launched in July 1972. The sequential multispectral imagery to be obtained will enable careful monitoring of many aspects of city growth. This research also demonstrates that the study of specific features will be enhanced through the use of camera and/or projection filters. Such features may include areas of recent growth or reconstruction within the city, bedrock types with certain moisture-holding capabilities, and sediment patterns in streams and reservoirs.*

## Urban Patterns

The occupied space of the Dallas-Fort Worth urban area agglomeration is clearly visible on these photographs. Less apparent but still detectable is the urban land use of smaller central places. Figure 2 is a map of central places and gross urban land use in the Dallas-Fort Worth area. The map represents one of the most significant potential uses of space photography, that of sequential coverage of a rapidly expanding urban area. The map shows the extent of built-up urban areas as indicated on 1:250,000 U. S. Geological Survey maps compiled in 1954. The Apollo VI photographs were enlarged to a scale of about 1:250,000 using a vertical-reflecting projector, and the present built-up urban areas of central places on the plates were superimposed upon the patterns extracted from the maps.

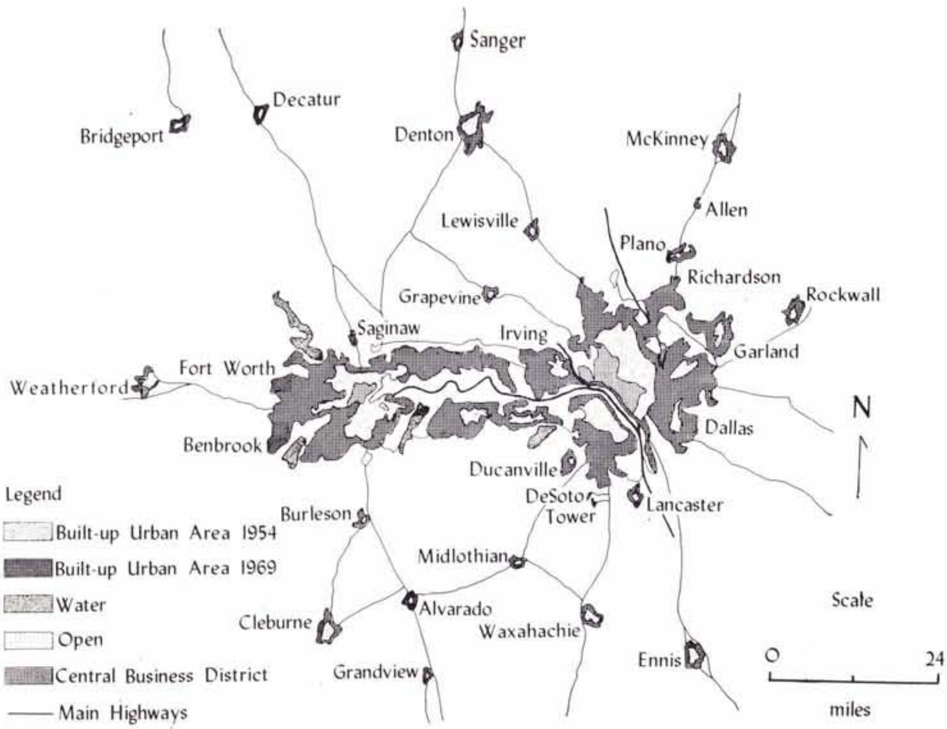


FIG. 2. Map showing contrast in urban development between the years 1954 and 1959 reveals multiple growth patterns for the numerous central places around the Dallas-Fort Worth area.

Examination of Figure 2 reveals considerable growth in almost all central places in the 14 years between map compilation and image generation. The one exception is the town of Italy, located south of Dallas (not shown on this figure). Although these photographs offer no clues as to why Italy has not grown, the uniqueness of this situation suggests that further study such as analysis of viability by an urban researcher is desirable (Hodge, 1965; King, 1961).[4,5] By measuring the amount of occupied urban space and counting other observable variables such as network centrality, it may be possible to predict population of central places within rough parameters.[6] Such predictions would be of extreme value in intercensal years, in remote areas, during or immediately following natural disasters, or where political obfuscation makes it impossible to collect population data.

Space photographs are excellent tools for locating and mapping new central places not identified on older maps. North of Dallas-Fort Worth such new places as Allen, Richardson, and Saginaw can be located; south of the city, DeSota and Tower are recent additions which do not appear on relatively new maps.

Although growth of almost all central places is clearly demonstrated, of special interest is the direction and pattern of this buildup. An example of Burgess' classical hypothesis of city growth by concentric zones is shown on the east side of Dallas. The urban development projected toward each other from Garland and Richardson represents the present active outer growth ring; future growth will probably merge Lewisville, Plano and Rockwall in a still more distant ring. The growth of Dallas and Fort Worth that occurred between 1954 and 1969 gives the gross appearance of concentric bands of varying width. The reasons for the varying widths of these bands, which more or less surround the 1954 built-up urban areas, raises a series of important morphological and process-oriented questions for the urban geographer. Can they be correlated temporally with boom and bust periods in the local economy or with changes in zoning requirements over time?

Theories in social-area analysis (Shevky and Bell, 1955)[7] and recent empirical studies in factorial ecology (Berry, 1971)[8] suggest that cities may grow in specific patterns. Each pattern has been identified with a particular type of a social organization. For example, development can occur in sectors or as nodes. Different aspects of urban growth have been linked to each of these spatial patterns (concentric zone, sector, nodal) in a complex that is a composite of these theories, and a large city such as Dallas or Fort Worth probably contains elements of each type of growth. An examination of the 1954 to 1969 growth patterns of Dallas and Fort Worth reveals samples of each growth form. It is now necessary to identify particular patterns with specific observation variables just as the patterns have been linked to specific socio-economic phenomena.

Dallas and Fort Worth are growing toward each other, along what has been described by Nunley as *field lines*.[9] From the northwest and southwest edges of Dallas and the northeast and southeast edges of Fort Worth, east-west projections have almost merged, enclosing an unoccupied zone along the Dallas-Fort Worth Toll Road. The projections exhibit the growth and interaction of two metropolitan areas. This closely parallels the spatial interaction predicted by gravity and population-potential models which up to now have been applied primarily to intra-urban planning functions (Carrothers, 1956; Carroll and Bevis, 1957).[10,11]

As Isard has shown due to economics of scale, theoretically the growth of smaller central places can be expected to be distorted in the direction of their nearest larger neighbors.[12] This is not always true in the Dallas-Fort Worth area. Evidence of growth away from the major city is shown by Decatur, Weatherford and Duncanville. Reasons for this unusual *directional growth* suggest another fertile area of investigation for the urban researcher and transport analyst. Growth of these cities may be responding to physical or cultural barriers not perceptible on the imagery or changes in network centrality not immediately clear without more numerical examination (Haggett and Chorely).[13]

Continuity exists in the shape of urban development; once urban shape is established it tends to be remarkably persistent. This is most clearly demonstrated by an examination of the builtup areas' shape in 1954 and the succeeding growth of those areas as extracted from Apollo VI photographs. This persistence of shape is clearly demonstrated by Waxahachie and Weatherford, and it is recognizable in other smaller population centers such as Decatur, Cleburne and Ennis. Both persistence of shape and direction of growth can be identified in the larger urban areas of Fort Worth and Dallas, although to a lesser extent in the latter. Denton and Plano are marked exceptions to persistence of shape. Once identified, shape and directional growth trends should be a vital factor in all city, county and regional planning. It certainly should be of extreme interest to real-estate developers and long-range land speculators.

Although geology and physiography generally change slowly with time, the cultural landscape is more dynamic. Because of rapid growth, cultural detail on topographic maps prepared by the U. S. Geological Survey is frequently out-of-date before the map is printed. Sequential imagery generated from space, such as these Apollo photographs, offers perhaps the most efficient and expedient guide to updating small-scale topographic maps, city and county maps, and state highway maps. New population centers can be rapidly and accurately spotted; the size, shape and growth direction of central business districts of the larger urban areas can be readily detected; and unoccupied spaces within the urban area can also be clearly located.

## Gross Land Use

Several interpreters—both experienced and inexperienced—were asked to discern gross land-use patterns from the Apollo VI photography. Two of the interpreters had some familiarity with the agricultural practices in the Dallas-Fort Worth area. Because this imagery was studied some 9 to 10 months after the photographs were taken, it was impossible to verify land use by real time, on the ground survey. Three major categories of land use were delineated—urban, rural, and hydrographic.

A number of workers have demonstrated the feasibility of utilizing space photographs for rural land-use mapping.[14] Careful study of the Dallas-Fort Worth photographs and projected positive transparencies defined several subdivisions of the rural land-use category. These subdivisions were based on observations of broad generalizations visible on overlapping frames that included field size, color, texture, organization and direction of field pattern. Although no ground truth data were available from the time period when these photographs were generated, several interpreters conducted field checks of the study area in April, 1969, and confirmed the generalizations.

The dark-screen pattern in Figure 3 is interpreted as newly-sprouted cultivated fields which occur interspersed among abundant pasture. This is similar to Category 4, interpreted to be predominately newly-

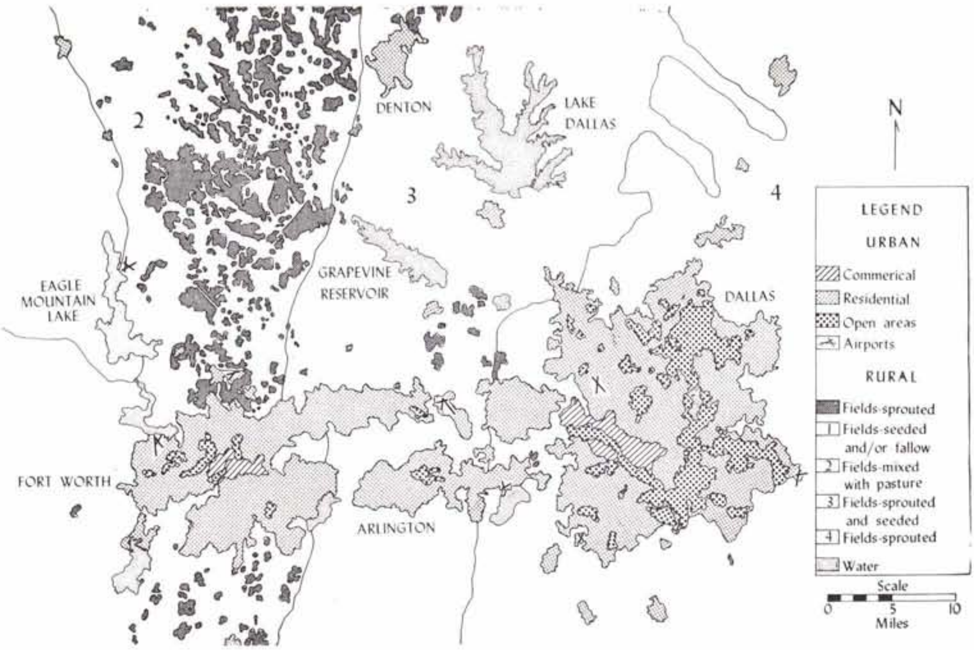


FIG. 3. Major categories of urban and rural land use identified from the Apollo VI photographs.

sprouted cultivation but with less pasture (Figure 3). Parallelism of land-use patterns with bedrock geology is striking. The boundary between fields seeded or fallow (category 1 on Figure 3), and those mixed with pasture (Category 2), closely approximates the contact between the Cretaceous Paluxy and older formations on the west, with Goodland-Duck Creek-Grayson, and associated units to the east. Likewise, rural land use (category 3) essentially follows the Eagle Ford-Woodbine outcrops and (Category 4) defines the Austin and younger Cretaceous and Eocene rocks.

Research with remote sensing imagery generated from space over urban areas has indicated that usable data can be extracted for urban research, although the small resolution capability limits the kinds of data which can be observed (Wellar, 1969).[15] In this study three sub-categories of urban land use were identified. The first is commercial land use, mainly the Central Business Districts in the larger urban areas. The CBS's of both Dallas and Fort Worth are clearly visible in Figure 1. The second and largest sub-category is the built-up residential area interspersed with smaller nodes of commercial and industrial activity. Generally, these nodes occupy such limited geographic space that their signature is indistinguishable from surrounding residential areas. The third sub-category is the open or nonbuilt-up urban area such as the unoccupied flood plain of the Trinity River which is clearly visible trending through downtown Dallas in Figure 1.

## IDENTIFYING TRANSPORTATION ROUTES

Use of space photography for identifying transportation routes has already been established. The USGS prepared a road map of Tucson, Arizona and vicinity from rectified Gemini VI photographs.[16] Simonett and Henderson (1969) compared percent of actual length of roads known in four selected counties with roads identified on Apollo VI photographs for this same Dallas-Fort Worth area.[17] Our concurrent study was different; we attempted to interpret the visible road net on the entire photograph. It was our aim to identify all roads and place them in one of three categories based on road width and highway classification by state or federal agencies. Our road categories are: (*1*) primary (which includes Interstate and state highways receiving federal aid); (*2*) secondary (including all paved state highways not receiving federal aid, park roads, farm to market roads); and (*3*) other paved roads.

Table 1 is a comparison of road categories identified on Apollo VI photographs. This table reveals that we were able to recognize most of the roads in the primary category, although we downgraded (placed in a lower category) 50 percent of them; thus our per-

TABLE 1. A COMPARISON OF ROAD CATEGORIES IDENTIFIED ON APOLLO VI PHOTOGRAPHS

| *Road Categories* | *Total Length of Road Identified From Map* | *Roads Identified Correctly From Photo (%)* | *Roads Upgraded From Photo (%)* | *Roads Downgraded From photo (%)* | *Roads Missed From Photo (%)* |
|---|---|---|---|---|---|
| Primary | 651.9 cm. | 15.6 | — | 50.1 | 34.4 |
| Secondary | 361.5 cm. | 18.4 | 6.6 | 12.3 | 62.7 |
| Other | 552.1 cm. | 17.1 | 7.4 | — | 75.5 |
| TOTALS | 1,565.5 cm. | 16.8 | 7.1[a] | 36.6[b] | 55.5 |

[a] The total percent of roads upgraded is computed from the total length of roads identified in the *secondary* and *other* categories—*primary* roads cannot be upgraded.

[b] The total percent of roads downgraded is computed from the total length of roads identified in the *primary* and *secondary* categories—*other* roads cannot be downgraded.

formance in this absolute category identification was a poor 15.6 percent. Although we had a slightly higher percentage of correct identification for the secondary (18.4 percent) and primary (17.1 percent) road categories, the percentage of roads missed went up dramatically in these lower categories. Table 1 indicates that about 64 percent of all primary roads were identified, a percentage much lower than that attained by Simonett and Henderson. Figure 4 is a map of the interpreted road net.

We concur with the finding of Simonett and Henderson that width is the prime factor in road recognition. Our work indicates that, in addition to width, other conditions affecting correct identification and classification of roads include: (*1*) nature (composition) of the road surface, (*2*) age of the road, especially with respect to the vegetative development along the right-of-way, (*3*) degree of straightness of road, (*4*) condition of road shoulders and immediately adjacent background, (*5*) position of the road with respect to sun angle, (*6*) direction of the road in relation to the *grain* of land-use patterns in the immediate background area, (*7*) proximity to and penetration of built-up urban areas, and (*8*) general relationship, proximity, and number of other linear cultural features present such as pipe lines, fences, power lines, drainage channels.

Actually about 21 percent of the features identified as roads proved to be other linear features. Figure 4 indicates that we were able to correctly identify 45 percent of all roads even though we placed them in incorrect categories. Clearly, if space photographs are

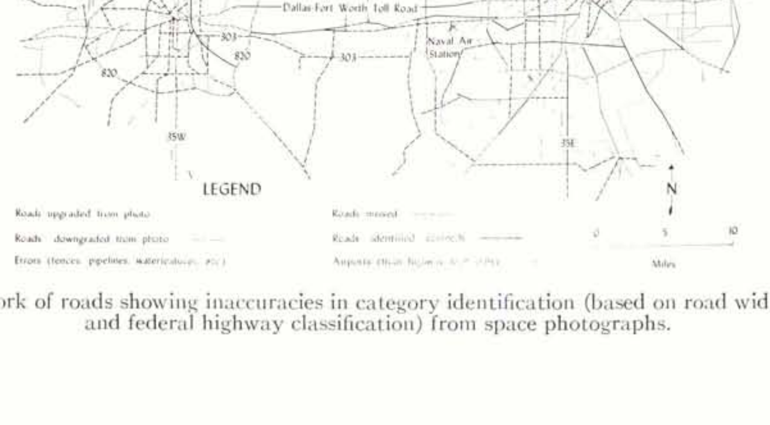


FIG. 4. Network of roads showing inaccuracies in category identification (based on road width and state and federal highway classification) from space photographs.

to be used for mapping road networks, procedures for positive road identification will have to be improved. Some suggestions which would help in this regard are: (*1*) preparation of color separation plates (as was done by Simonett and Henderson), (*2*) use of enlargements, both transparencies and contact prints, (*3*) application of edge-enhancement techniques, and (*4*) more careful selection of film and filter combinations which are more sensitive to *road signatures*.

One of the most prominent signatures on the Apollo VI photographs is that produced by airports. The peculiar geometric arrangement of the runways, their strong response and the carefully cropped vegetation surrounding them, combine to make them readily apparent. Even minor *one-strip* facilities are identifiable on the photographs.

## Hydrographic Features

In recognition of the importance of water to urban areas, special attention was given to the surface drainage system in and around the Dallas-Fort Worth area. A drainage map was prepared from enlarged Apollo VI photographs at a scale approaching 1:250,000 (Figure 5). This drainage pattern was then compared with USGS topographic maps of the same area and scale. Only about 20 percent by length of the existent drainage was correctly identified from the space photographs. Although disappointingly low, this figure reflects the myriad tributary streams which have little or no effect on the patterns of land use and go unseen because their size is below the minimum resolution elements of these photographs. These smaller tributary streams are observable on larger-scale photographs generated from sub-orbital aircraft and are used to compile the USGS topographic maps. Our work indicates that exposed, open water in streams is rarely visible on space photographs unless the stream is of major proportions. Generally, if drainage patterns are visible, it is due to a contrast in land use, particularly vegetation—usually the trees and brush along the stream course.

The major drainage lines, those most likely to be useful in establishing a large surface reservoir for an urban population, were identified correctly (Figure 5). Unlike transportation routes, these drainage lines are generally clearly distinguishable within areas of greatest urban buildup. In the Dallas-Fort Worth area this is the result of changing land use; the floodplains of major streams are not occupied in the built-up urban areas of these cities. This change in land use results in varying spectral responses.

Of special interest is the clear delineation of the distribution of high-sediment content in the water of the lakes and reservoirs. Precipitation records of the U. S. Weather Bureau stations in both Dallas and Fort Worth reveal only a slight amount of rainfall

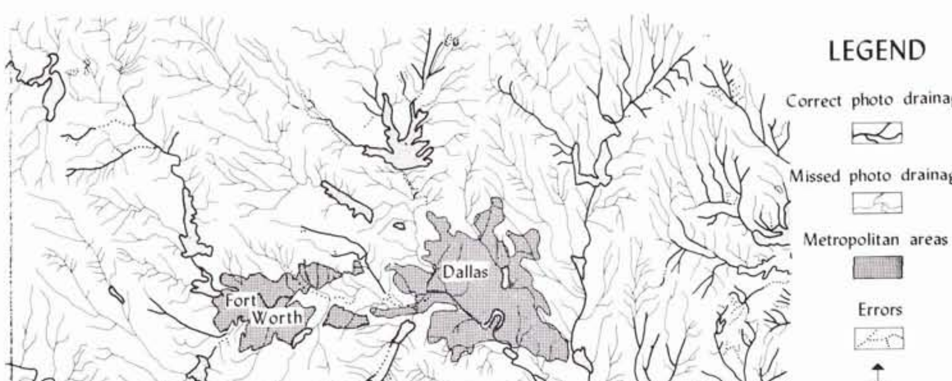


FIG. 5. Surface drainage map derived from Apollo VI photographs reveals large number of tributary streams not observed.

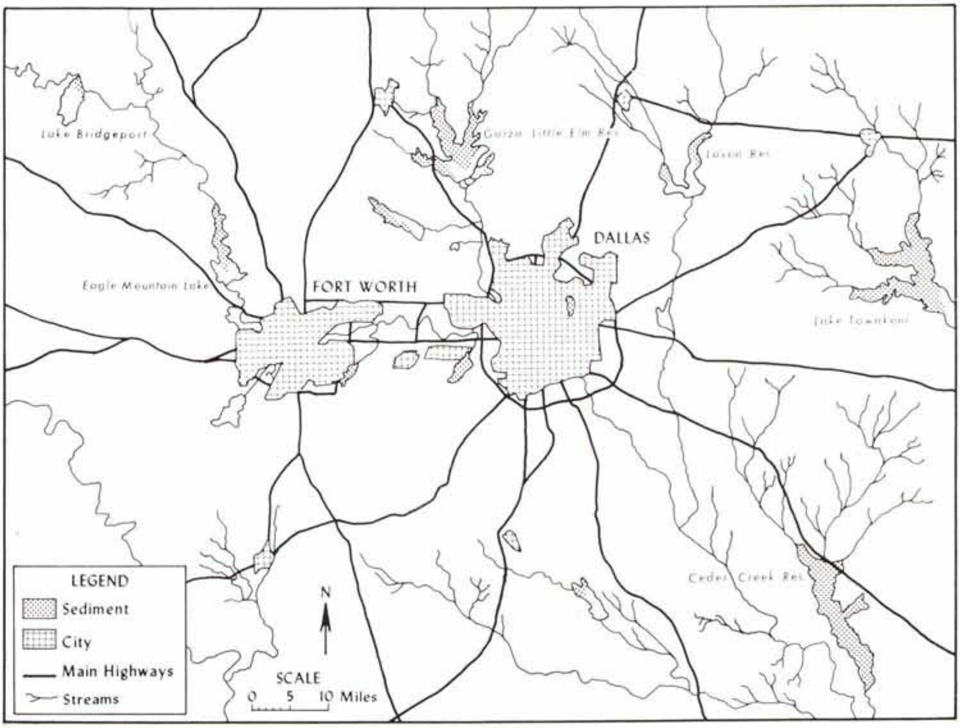


FIG. 6. Sediment-clear water interface of lakes and reservoirs in the Dallas-Fort Worth area.

for several days preceding this flight, although there were heavy rains on March 19th and 20th.[18] However, some bodies of water (e.g., Cedar Creek Reservoir, Lake Towakoni, Garza-Little Elm Reservoir (also known as Lake Dallas), and Eagle Mountain Lake) indicated considerable sediment influx (see Figure 1). These lakes with the clear water-sediment interface of each are shown on Figure 6. Rock type in the drainage basins may be largely responsible for this sediment, as sandstones and associated fine clastic rocks predominate there. In contrast, Lavon Reservoir and Lake Bridgeport show little sediment influx, and the streams which feed them flow largely on limestone. No attempt was made to evaluate the effect of different land-use patterns on the rate of sediment transport, although this concept is certainly a factor to be explored, especially when sequential coverage becomes available. It should be pointed out, however, that the only meaningful way to evaluating sediment transport is by correlating sediment samples and space photographs obtained simultaneously.

By the use of ERTS photography, it should be possible to monitor sediment transport in first-order streams and reservoirs during most phases of the local climate, especially immediately after heavy rains. Sequential monitoring should provide some evaluation of the filling of reservoirs with sediment, especially if color tones and water depths can be accurately correlated. The results may dictate future uses of the land in the major watersheds, as well as suggest the most suitable sites for future dam construction. It is evident from this research and previous studies that space photography is an important new adjunct to hydrographic research.[19,20]

## GEOLOGY

Photographs obtained from satellites have proved useful for making geologic maps (see for example Lowman and Tiedeman, 1971; Sapp, 1971).[21,22] Rock types commonly can be distinguished because of bedrock color differences or textural variations. The resulting soils may be recognized from tonal contrasts they impart or the patterns of the vegetation that they sustain. A geologic map of the Dallas-Fort Worth area, which compared favorably with existing maps done by conventional field-based methods, was prepared from the Apollo VI photographs (Figure 7). Boundaries of the units included within the areas mapped as Paluxy and Woodbine are distinct, as in the Glen Rose, except where

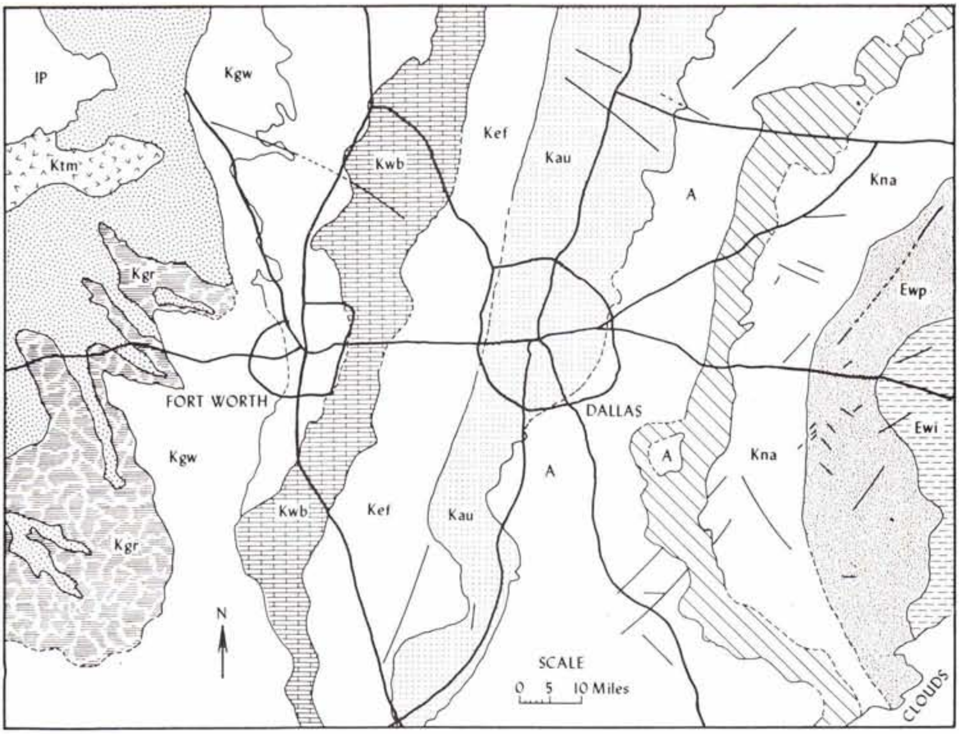


FIG. 7A. Generalized geologic map of Dallas-Fort Worth area demonstrates ability to obtain useful geologic data from space photography. (Legend is shown in Figure 7B).

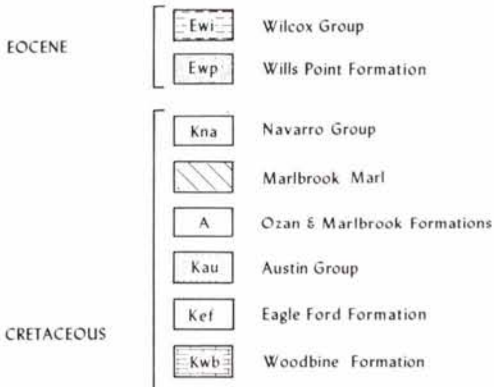


FIG. 7B. Legend for Figure 7A.

crossed by the Brazos River. Contacts of the Goodland (and associated units), Austin and Eagle Ford also show up as distinct zones in most places. Greatest difficulty was encountered in subdividing the units labeled *A* and marked by slant lines (on Figure 7), between the Austin and Navarro groups. Presence of the Trinity River flowing through this region is a deterring factor as it masked the land-use patterns.

Perhaps the most prominent geologic feature is the eastern boundary of unit *A*. Surprisingly, it is not a formation boundary, but has been identified in the field as a thin ledge-forming limestone lithosome *within* the Marlbrook. The geologic quadrangle map of the *Geologic Atlas of Texas* for this area being prepared by the Bureau of Economic Geology, The University of Texas at Austin, does not include this feature. Although the limestone lithosome was known from field investigations, its distinctiveness is not as evident on conventional ground-based air photographs.

Special-purpose maps emphasizing specific features of the landscape based on the geology can also be quickly ascertained with the aid of space photography. Among these are maps featuring lithic facies, moisture-retention variations, soil types, and slope-stability characteristics. Knowledge of these conditions will enable more prudent utilization of the land and will govern uses such as the types and distribution of construction; exploitation for mineral resources such as sand and gravel, chip limestone, and clay, including potential for land reuse; and the long-range pattern of water-resource planning and reservoir construction. Other values of space photography for geologic map purposes and for their relation to environmental problems have been clearly demonstrated by numerous studies (e.g., Lowman, 1968; Mohorich, 1971; Wobber, 1969).[23,24,25] Sequential space photography will serve to monitor these uses and alert planners where changes in the patterns of uses are occurring. The photographs should also be of value in aiding the formulation of developmental plans and in providing inputs which can be used by policy-decision makers.

## Projection Filtering

In an attempt to improve our interpretive capabilities, we experimented with over 30 Kodak Wratten filters by placing them between the projected image and the screen. Modifications of this technique have been used by other researchers to provide edge enhancement or signature contrast (Colwell, 1968).[26] Several of the filters were useful for specific purposes.

The first of these is a blue-absorption filter (Wratten 16) that passes wave lengths beyond 510 nanometers. By darkening the areas of blue-green on the photograph, it enhances the contrast, allowing: (*1*) emphasis of highways and urban areas and their subdivisions (such as concentrations of commercial activities); (*2*) clearer definition of sediment patterns in the lakes; (*3*) better delineation of certain stratigraphic subdivisions (the Paw Paw-Grayson-Woodbine exposure is especially sharp when the photograph is filtered in this manner) (Figure 7); and (*4*) accentuation of differences in natural vegetation and agricultural plant growth.

In contrast, by using a minus-red filter (Wratten 45) with peak transmittance in the 400–500 nanometer region, a masking of tonal difference is achieved. Gross patterns, especially those of linear features which transect different vegetational types, can be traced more readily. An example is the contact of the Eagle Ford formation that trends N. 10°E, and the Austin Group which can be followed southward through Dallas (Figure 7).

Use of a minus-green filter (Wratten 32), which has almost complete absorption in the band widths betwen 510 and 595 nanometers, accentuated the brighter signatures of certain features on the map—especially roads, urban development, and sediment trends in water bodies.

Use of these filtered photographs did not reveal features not already observable on the photographs. But by fading background response, or apparent increased edge enhancement, or fading very bright responses, certain features are accentuated allowing them to be more readily identified. We were also able to locate some features more accurately (for example, the land/water interface of reservoirs).

## Conclusions

This study of Apollo VI photographs demonstrates many potential uses of space photographs. It is clear that urban patterns can be detected, interpreted and their changes measured. Thus the rate and direction of future growth can possibly be predicted, and approximate populations of these urban places can be enumerated, especially if on-site field investigations are conducted at the time of image generation. Major transportation routes can be identified, and with improved camera systems, film/filter combinations, various look angles, seasonal imagery, and more experienced interpreters, most of the road net should be able to be mapped in detail.

It would be difficult to develop a highly detailed drainage net from space photography. But land-use maps which can be prepared are important to hydrologists because of the runoff characteristics. Reservoirs and major streams are visible on space photography but important problems in identification remain. Definition of sediment-clouded waters in reservoirs should prove valuable to hydrologists in evaluating erosional problems, particularly if research is related to ground truth measurements.

Reasonably detailed geologic patterns can be mapped from space photographs. These patterns are more a function of observed land use than the underlying geology. Regional geologic patterns are more evident and occasionally the smaller scale of space photography produces insights of gross geologic patterns which are not evident on larger-scale photographs or maps.

A number of workers have experimented

with filtering of projected space photographs. This technique is a valuable interpretive device. It does not produce any *new* or additional information from photography, but filtering can make certain patterns or signatures more apparent.

Finally, we emphasize the need for an interdisciplinary approach to the interpretation of space photographs. Major changes in land-use patterns visible on the Apollo VI photographs have excellent correlation with bedrock geology. This correlation may have gone unnoticed to a single interpreter. The pattern of urban details so significant to a geographer is part of the *cultural clutter* which obscured detail for the geologist. Therefore cooperative research and interpretation offers the best possible insight into the useful application of space photographs.

## References


1. Colwell, R. N., Remote sensing of natural resources. *Scientific Am.*, 218 (1): 54–69, 1968.
2. Pecora, W. T., Remote sensing of earth resources: users, prospects and plans. *Thirteenth meeting, Panel on Science and Technology, Committee on Science and Astronautics*, U. S. Govt. Printing Office, Wash., D. C., 8 pp., 1972.
3. *Apollo 6 and 7 Synoptic Photography Catalog.* Technology Application Center, University of New Mexico, Albuquerque, New Mexico. 50 pp. (undated)
4. Hodge, G., The prediction of trade center viability. *Regional Science Association, Papers and Proceedings*, 15: 87–118, 1965.
5. King, L., The functional role of small towns in Canterbury. *Proc. Third New Zealand Geographical Soc. Conf.*, 139–149, 1962.
6. Holz, R. K., D. L. Huff, and R. C. Mayfield, Urban spatial structure based on remote sensing imagery. *Proc. Sixth Intern. Symp. on Remote Sensing of Environ.*, Ann Arbor, Michigan, October, 1969.
7. Shevky, E. and W. Bell, *Social Area Analysis*, Menlo Park: Stanford University Press, Stanford, California, 1955.
8. Berry, B. J. L. (ed.), Comparative factorial ecology. *Economic Geography*, (special supplement) July, 1971.
9. Nunley, R. E., Living maps of the field plotter. Commission on College Geography, *Tech. Paper 4. Assoc. Am. Geog.*, Washington, D. C., 1971.
10. Carrothers, C. A. P., A historical review of the gravity and potential concepts. *Jour. Am. Inst. of Planners*, 22: 94–102, 1956.
11. Carroll, J. D. and H. W. Bevis, Predicting local trend in urban regions. *Regional Science Association, Papers and Proceedings*, 3:153–187, 1957.
12. Isard, W., *Location and Space Economy*, N. Y., p. 272, 1956.
13. Haggett, P. and R. J. Chorely. *Network Analysis in Geography*. UK, E. Arnold Press, 1969.
14. Wiegand, C. L., et al., Multibase and multiemulsion space photos for crops and soils. *Photogrammetric Eng.* 37(2): 147–156, 1971.
15. Wellar, B. S., The role of space photography in urban and transportation data series. *Proc. Sixth Intern. Symp. on Remote Sensing of Environ.*, Ann Arbor, Michigan, October, 1969.
16. United States Geologic Survey, *Road Maps of Tucson, Arizona and Vicinity* (undated).
17. Simonett, D. S. and F. M. Henderson, On the use of space photography for identifying transportation routes: A summary of problems, *Proc. Sixth Intern. Symp. on Remote Sensing of Environ.*, Ann Arbor, Michigan, October, 1969.
18. U. S. Department of Commerce, *Local Climatological Data of Dallas and Fort Worth*, March and April, 1968.
19. Brown, W. L., F. C. Polcyn, and S. R. Stewart, A method for calculating water depth, attenuation coefficients and bottom reflectance characteristics. *Proc. Seventh Intern. Symp. on Remote Sensing of Environ.*, Ann Arbor, Michigan, 1: 663–682, May, 1971.
20. Schneider, W. J. and M. C. Kolipinski, Applications of color aerial photography to water resources studies. *New Horizons in Color Aerial Photography*, The American Society of Photogrammetry and the Society of Photographic Scientists and Engineers, June, 1969.
21. Lowman, P. D., Jr. and H. A. Tiedeman, Terrain photography from Gemini spacecraft: final geologic report. Report X-644-71-15, Goddard Space Flight Center, Greenbelt, Md., 75 pp., 1971.
22. Sapp, C. D., Evaluation of space and high altitude imagery for the Department of the Interior. *Proc. Seventh Intern. Symp. on Remote Sensing of Environ.*, Ann Arbor, Michigan, 1: 435–451, May, 1971.
23. Lowman, P. D., Jr., *Geologic Orbital Photography: Experience from the Gemini Program.* Goddard Space Flight Center, Greenbelt, Md., 34 pp., 1968.
24. Mohorich, L. M., The role of geologic input in urban planning. *The Mountain Geologist*, 8(4): 209–219, 1971.
25. Wobber, F. J., Environmental studies using earth orbital photography. *Photogrammetria*, 24: 107–165, 1969.
26. Colwell, R. N., Determining the usefulness of space photography for natural resource inventory. *Proc. Fifth Symp. on Remote Sensing of Environ.*, Ann Arbor, Michigan, April, 1968.