THE FIVE FACETS OF AERIAL PHOTOGRAPHY*

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HOW do *You* look at an aerial photograph? And how much do *You* see? Everyone has two filters built in between his eyes and his brain. One is an "*interest*" filter and the other an "*experience*" filter. The interest filter cuts in first.

If I handed photos to five different people in this audience and asked them what impressed them, I would get 3 to 5 different evaluations. A specialist tends to look at a photograph through his "*specialist*" filter. This invisible device cuts out "wave lengths" that carry other types of information to those working in different fields. For example, an engineer-specialist might examine a photograph and not realize that the area contained an unusual stand of hardwood. But a forester, recognizing this stand immediately, might completely overlook a gravel deposit that was quite evident to the engineer.

Then the experience filter cuts in and further affects the amount of information gained from the photographs. This says, in effect, that even though definitely interested in some special field, the amount that you can see (or extract from the photographs) depends upon experience.

The "interest" filters can be considered as being in red, green, yellow or other colors, but the "experience" filter comes in shades of gray. The more experience a man has, the lighter the gray becomes because he has learned how to see more. Because of this, the field of aerial photography can conveniently be divided into five facets, or uses. And what you see depends upon how you look at the photographs.

Before looking closely at these five facets, we should examine the problem common to all of them—the people. We talk about the problems of restitution, of image motion and of various forms of distortion, but what about distortions due to human handling?

Have you ever thought of what you mean when you say a "photo interpreter"? If you mean a jack-of-all-trades in aerial photography, then you have hit it as well (and no better) than some of the military personnel. However, when considering the problem of providing organized and commercially acceptable interpretation of aerial photographs, we should acknowledge that one man cannot interpret in every field.

The operation of providing information and recommendations from aerial photography includes analysis *and* interpretation. *Analysis* means breaking the photographed area down into soil, rock and other subdivisions. This saves a specialized interpreter's valuable time and he uses his experience in interpreting the ground conditions in terms of his specialty.

An example may help to illustrate the difference between an interpreter and an analyst: A package of aerial photographs comes to an office. An analyst lays them out, studies the over-all objectives of the job, and proceeds to divide the area into flood plains (low elevation), terraces (intermediate elevation), and hills and mountains (highest elevation in the area). The analyst then goes back to the first major division (flood plains) and subdivides it on the basis of soil texture and drainage conditions. He repeats this action on the intermediate area and marks special features that occur in this zone. The upper area is divided into rock types, amount of soil cover, etc. The amount of detail in each area is dictated by the job requirements.

This man has analyzed the photographs and has mapped conditions that he has inferred from the soil and rock patterns. Suppose, now, that two interpreters, specializing in different fields, huddle with the analyst. One interprets the lowland in terms of suitability for cropland; the second, an engineer-interpreter, works on levee location for flood control of the same area, and on a highway location on higher ground. If damsites, geology, aggregates or other requirements were a part of the job, an engineer-geologist would concentrate on the area of hills and mountains.

From this typical case, important dis-

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tinctions are extracted. These are:

1. An *analyst* may not be able to interpret skillfully.
2. *Interpreters* need not be, and often are not, skilled analysts.
3. A man needs ground experience in something besides photography before he should try to interpret.

Finally, there are regional and climatic characteristics that limit an interpreter—and an analyst (but to a much lesser degree). A geologist or an engineer experienced in Panama will be of limited value in the arctic or in Arabia; similarly, a ground water man from Texas will do well in North Africa but, in the northern U.S., his rating may slip markedly simply because he has had no experience in that type of area.

Today, the analyst does not appear in the military picture because he is not used. Military "PI" todays means recognizing installations, or vehicles, or weapons, that have military significance. Even then, the man that performs the recognition work merely reports what he sees. It is left to the Intelligence Division or others to determine the significance in terms of the combat situation.

Good quality analysis and interpretation do not result from a part-time occupation taken up casually. The result of a man spending X years in merely looking at pictures is not competence as an analyst. As a guide to competence this test should be made:

1. Does the man *really* use a stereoscope?
2. Has he served an apprenticeship in the field checking his analysis against ground conditions?
3. Has he had previous experience in this type of area?

If there is not a firm "yes" to all three questions, the man is an amateur.

When is an Expert Not an Expert?

The obvious answer to this facetious question is, "When he is not qualified." We now have a way to make a measurement.

The Agronomy Department at Cornell, assisted by members of the Soil Survey Division of the United States Department of Agriculture, carried out tests that give some numbers for use in making a determination.

Two areas in northern New York State were selected as sites for test mapping and three individuals, experienced in photo-analysis (*but not in Agronomy*) were designated as "experts."

The first two, called *X* and *Y* were given stereo triplets and a stereoscope. That was all they had. They had never seen the area, had no way of knowing its exact location, and had no reference material.

The third person, called *Z*, mapped the same area, but had access to reference material. Also as a separate action, he was permitted to make a limited reconnaissance of the area; he thus had the opportunity for improving his maps.

The maps made by these three were judged on the basis of a "100% Accuracy Map" compiled by the USDA soil mappers. The results are certainly not biased as regards aerial photography because all the ratings were made by the soil mappers, and most practicing soil surveyors are reluctant to go into the use of aerial photographs beyond the base map stage.* Photo mapping does not, and is not intended to, replace all ground investigations. The combination of *skilled* photo-analysis with spot checking in the field produces accurate maps in a minimum of time. An unsupported analysis of this type is *never* considered a complete job.

In the test, the data show the differences in the ability of persons who had been called experts. That there is a *difference in experts* is important.

The three, *X*, *Y* and *Z*, were not experienced in interpretation in agricultural soils, but they produced these results for use in determining their qualifications as experts.

Parent Material—This means the origin, texture, mineralogical composition of coarse fractions, depths of leaching, or relative acidity; they are rated as firm, very firm or compact.

The ratings of *X*, *Y* and *Z* are shown on Figure 1.

As a matter of interest, the two conventional ground surveyors rated 97% each.

Slope Classes—(No instruments used; ground surveys use an Abney level)

In this test and as shown in Figure 2, *Y* was twice as expert as *X*.

When *Z* checked his own work in the field, he raised his 67% to 78%. Even so

* Rourke and Austin, Photogrammetric Engineering, Vol. XVII, pp. 738–747; *Soil Survey Manual*, 1951, *USDA Handbook* No. 18.

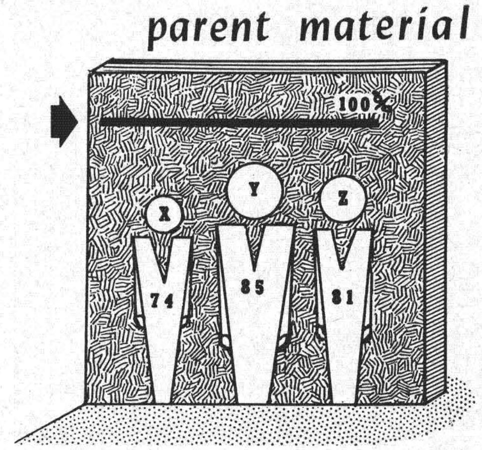

FIG. 1. Ratings of parent material.

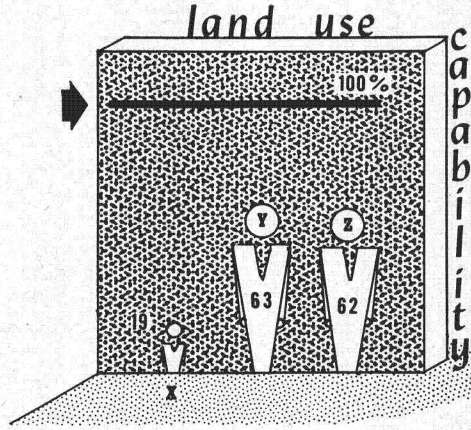

FIG. 3. Ratings of land use capability.

this was somewhat less than that of *Y* without any field checking.

Erosion Classes

X−100%; *Y*−99%; *Z*−94%

When *Z* visited the area, he raised his 94% to 100%.

Land Use Capability

As shown by Figure 3, *Y* was three times as expert as *X*. Following a quick field check of his work, *Z* raised his 62% to 68%.

Areas in Complete Agreement

(It should be noted that this means acidity, color, and every other basis in use by the pedologist.)

The results are given in Figure 4.

As a result of *Z* checking his work in the field, his rating of 27% was increased to 54% or 10 times that of *X*.

The results in rating *internal drainage* were poor and incomplete because of the absence of any local basis of reference for the straight interpretation phase. On this basis, one interpreter mapped half of the area correctly. With the chance for field reconnaissance, Z rated 76% correctly against a low of 80% for the complete ground study.

The preceding figures can be analyzed as follows:

First, experts (so-called) vary in their ability to map various elements. In some instances, where their experience is equal, as in Erosion Classification, they do equally well. But in many cases, it will be observed that one man is consistently at the top, and his average is three times that of the poorest expert. Thus one learns that all experts are not equally expert.

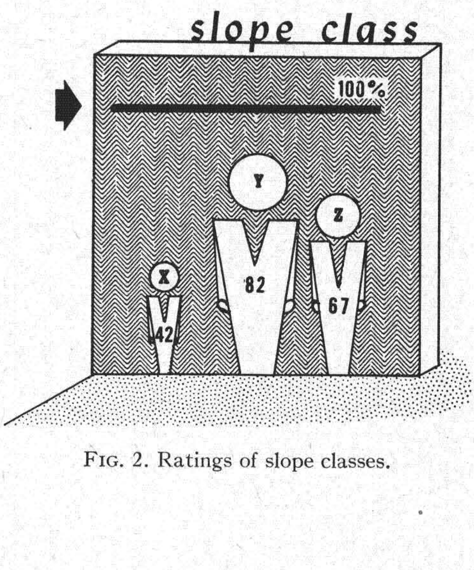

FIG. 2. Ratings of slope classes.

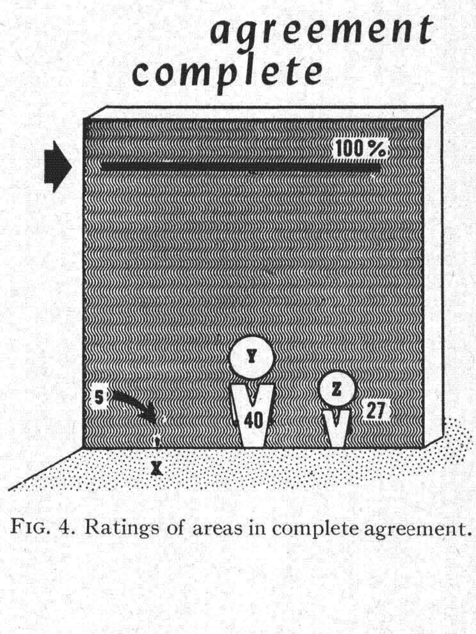

FIG. 4. Ratings of areas in complete agreement.

A second, and equally important, point is that experience *does* help. The explanation of X having a low rating may well be that he has had little experience and should not have been considered as being an expert in aerial photography as applied to agronomy. But a low rating does not necessarily mean that he cannot learn more; nor does a low rating resulting from X, Y and Z now lacking skill and experience mean that "it can't be done with aerial photographs."

The work of the three men was obviously far from perfect. Nevertheless, the amount of information that they extracted from the photographs was amazing.

Integrity

All engaged in photogrammetric work have seen the visitor to the workshop who bluffs his ability in stereo vision; the expression on his face· evidences that he couldn't get the photos into register. This also occurs in the field of analysis and interpretation. When a man bends over a stereoscope and focuses his eyes on the prints, he is in a world alone. He can make two types of mistake, One can be excused as ignorance and experience; the other mistake is bluffing.

No one should misjudge the value of any of these facets of aerial photography because he has encountered an "inexperienced expert," or one who doesn't mind risking the good name of aerial photography through running a bluff.

There is also the man who "doesn't know what he doesn't know." He's the fellow who says, in effect, "It can't be done because I don't understand it."

The Loyal Opposition

Opposition to the uses of aerial photography is carried on mostly by those whose early field experience pre-dates the general availability of airphotos. There isn't any one in photogrammetry who hasn't fought the old-time surveyor who said, as late as 1940, "You can't make me believe that any airplane picture can be turned into a topographic map." Proof and acceptance by others didn't prevent that old-timer from ruling out photogrammetry and turning an important job over to a hastily organized group of survey parties.

In *Soil Science Proceedings*, April 1953, J. K. Pasto comes right to the point in his paper entitled, "Soil Mapping by Stereoscopic Interpretation of Airphotos." The following is quoted from the section appropriately headed, "Mental Block":

> "A major problem in the application of this technique is not technical, but rather it is an obstacle in thinking. Many soil surveyors dogmatically believe that soils cannot be mapped without observation of the profile.
>
> "To them a soil boring is the acme of finality, and any other process of soil separation is too subjective. Others will immediately realize that profile examination itself is a subjective process, for no two men feel the same texture, see exactly the same colors, or even visualize the same number of horizons!
>
> "Furthermore, all soil maps have some error because soil boundaries are not finite. Thus there also is inherent in profile examination a degree of error not always predictable."

In an article in PHOTOGRAMMETRIC ENGINEERING (Vol. XVII, No. 5 p. 737) an old-timer in "*ag*" mapping said, "A good growth of vegetation along draws in sloping land may give a pattern resembling dark soils in swales," and then adds that, "The use of a stereoscope helps to avoid some mistakes."

This emphasizes the age-old problem of getting people to use a stereoscope. If they expect to see anything in aerial photography, they *must* use a stereoscope.

Having covered those basic problems, the various facets of aerial photography will be discussed.

Phototopography

This is the largest facet of them all. Dwelling on this subject in this publication is unnecessary.

Engineering

The engineering facet of aerial photograph has many important features that are still unseen by the majority of firms and organizations dealing with engineering problems.

At present, the topographic work is well advanced and more widely accepted than in the past by highway departments. Highway and railroad locations accomplished by private concerns and separate authorities are almost invariably based on phototopographic mapping. Almost every type of organization uses the pictures as base maps and, with that, they do elementary interpretation work that might be more accurately termed "recognition."

But circumstances have made us take

a closer look at aerial photographs and, in doing this, we see more. We find that competent analysts and interpreters are carrying out mapping for highways that includes soil mapping, rock excavation problems, hydrology, trouble areas caused by seepage and, of vital importance in many cases, landslide mapping. As a result, a location map for the preliminary line of a highway has, in addition to contours, bounded areas that delineate the occurrence of bedrock that requires cutting; soil areas that are significant *at this stage*, i.e., areas of three acres or more in size that will influence location, such as muck, clay, gravel or sand; the location of wet areas and zones of seepage; and the exact location of existing and potential landslides

The preceding is not a listing of what *might* be done; it's a description of what *is being done* in this phase, or facet, of aerial photography.

On a final location, the soils are mapped in detail, giving the common physical properties of liquid limit, plasticity index, texture, "year-round" moisture variation, and watershed areas related to culvert locations.

If these things are being done, what is the special advantage in doing them from aerial photography? The answer is that when properly done, the method is faster and more accurate than the conventional field methods. The time required runs from one-third to one-twenty-fifth of that normally needed. Aerial photography has a running start on accuracy when the interpreters know their business.

On one midwestern road job, the photographs were analyzed and were matched against a soil survey made by a field crew. Without even the field phase of the photo job being undertaken, seven significant areas of soil were located and described that had been overlooked by the ground party. In Canada, we located, mapped and sampled impervious fill for a dam. This was a one-million cubic yard deposit occurring locally that had been overlooked by geologists and others, either not using aerial photography at all, or using it improperly.

A hundred different uses of aerial photographs are to be experienced in and around large engineering projects.

Agriculture

Agriculture has so many divisions within itself that it is difficult to account for each one. Basically, they all draw the same type of information from the aerial photographs. Primarily, the important uses in agriculture are:

a) *Soil Mapping* for agricultural soil maps based on pedologic principles.
b) *Soil Classification*, as practiced in various ways by the several agencies (irrigation, soil conservation, etc.)
c) *Land Capability* classification (future use).
d) *Land Use* (present).

These are presently accomplished with various degrees of usage of aerial photography. Regardless of today's attitudes, tomorrow's mature judgment may be forecast by the results of the comparative tests earlier mentioned that were conducted by the soil mappers themselves. These are not necessarily indications of the accuracy to be anticipated elsewhere. Nevertheless, taking them at face value, it is found that even in an area of extreme complexity, the individuals who had never seen anything of the area except the stereopairs, and who were not qualified as "experienced" in these specialized phases of interpretation, mapped the area with the following degrees of accuracy. (And I cannot give adequate emphasis to the fact that this procedure is never normal in airphoto mapping.)

	X	*Y*	*Z**
Land Use Classification	18	26	12/53
Slope Classification	44	82	80/83
Erosion	100	94	100/100
Stoniness	56	31	56/73

In cropland, where tones and other details can be seen in some degree, *X*, *Y* and *Z* mapped 92%, 97% and 96% of the entire area in agreement with the standard. In heavy tree-covered (non-crop) areas, their results dropped to a low of 10%, 8% and 1%, as would be expected. This means, figuratively speaking, that detailed agricultural soil mapping cannot be carried out in a densely forested area without some ground reconnaissance.

Natural Resources

The facet of aerial photography labeled Natural Resources is complex and per-

* *Z*'s results are shown as a fraction. The numerator is his score after reading literature on the area; the denominator, after making a field reconnaissance.

haps will later be divided into other major subdivisions.

Today we go beyond oil, coal and minerals and include forestry, soils and ground water; gravel and sand, in some areas, and clay in others.

In the field of *forestry*, Losee tabulates these uses of aerial photographs:*

"1. To determine volumes of available wood,
2. To determine the success in establishing a new crop—that is, regeneration surveys,
3. To determine cut-over areas and residual stands,
4. To assess the damage caused by fires, high winds, insects and fungi."

"For logging purposes we have:
1. Road location surveys,
2. Logging plan surveys,
3. Water delivery surveys.

There are many other types of surveys, but those mentioned have one thing in common, which is: better results for the same cost can be obtained if photogrammetry is applied to them."

In the ground water field, work is going on in many countries and states. To cite a typical example, the following is quoted from an UNESCO science report entitled "Science and You," by Maurice Goldsmith:

"The 'water diviner' need no longer keep his feet on the ground. In fact, he will probably do much better if he takes to the air—and gives up his forked stick for the aerial camera. That has been the experience of a United Nations technical assistance mission in Iran. Three experts were asked by the Iranian Government to help in the location of water supplies. With the use of aerial photographs, and special viewing from a plane where photography was not practicable, they were able to survey the whole country to determine its potential water resources. Using normal means, the job would have taken ten times as long.

"Aerial photography made it possible to report on 29 separate areas, and to indicate nearly one well site per day. This is ten times quicker than the ordinary field method. The aerial photographs gave a perspective of an area in a minute that takes weeks to achieve on the ground.

"The experts recommended that a well be drilled south of Teheran, and an adequate water supply was found there, Through the discovery of a supply of water at Hamadan, they were able to make savings of 30 kilometers of pipeline construction and maintenance.

"Aerial photographs in the hands of experts are used for the identification of various geological indications of sub-surface water. The pictures are used for distinguishing between the types of sandstone, limestone, and shales and for the recognition of granites and volcanic rocks. They also permit the direct identification of soils as sand, silt, gravel or clay.

"With this information readily available the water expert can ascertain probable new sources of water, the possible yield, and the depth of drilling required with a high degree of accuracy."

There is a growing use of aerial photography for township and county inventories. These are principally directed to the purpose of providing a photo mosaic with a number of overlays carrying master plans for road improvement and water supply. The location of gravel and sand deposits, clay banks, quarries and outcrops is shown. On a state-wide basis, the Rhode Island Development Council has applied aerial photography in a thorough presentation of land and ground water resources.

In the field of prospecting for oil and minerals, and in geologic mapping, geological survey people find themselves engaged in the same controversy as the soil mapping people. In both fields, young men are growing professionally in their skill and experience and, as they learn in the field, they also learn to use aerial photography. They are in a better position to judge than the older men whose field experience predated the availability of aerial photography.

Research in this field is more difficult to achieve and more expensive to conduct. Therefore, there is less progress than in the soils field, for example. Nevertheless, this facet of aerial photography can be expected to be one of the largest and brightest in the near future.

Urban and Land Planning

In the development of industrial areas, new agricultural lands, and in the modernization of cities, the planners are using aerial photography to extract basic facts hard to obtain otherwise.

We are using soil texture, slope and internal drainage as a basis of zoning in residential areas, larger lots being required

* "The Applications of Photogrammetry to Forestry in Canada," S. T. B. Losee, Photogrammetric Engineering, Vol. XIX, No. 4.

when the soils are slow to absorb the effluent from septic tanks. Industrial sites are carefully studied with reference to ground water supply especially important in the chemical, power and distilling industries. Flood protection measures and transportation facilities are common problems well solved by surveys based upon aerial photographs.

In Ethiopia, Burma, India and elsewhere, intensive surveys requiring skill and experience are applying aerial photography to the field of urban and land planning.

Conclusion

Aerial photography goes a long way in solving all these problems. It's a sad fact that much field work (excluding ground control) is done in a haphazard and incomplete manner, and competent fact-finders are rare and expensive. Aerial photography in all of its five facets, when in the hands of qualified analysts and interpreters, is performing a necessary and valuable service.

TIMBER ESTIMATES FROM LARGE SCALE PHOTOGRAPHS*

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Abstract

A study of the possibility of greatly reducing or eliminating field work for forest surveys of high accuracy was undertaken by the author.

A block of 72 square miles in Northwestern Ontario was selected as an experimental area. This area was photographed at a scale of 1:7,200 with a standard camera and, in addition, strips crossing the area at mile intervals were photographed at a scale of 1:1,200, with the Photographic Survey Corporation's Panning Camera. Tests showed that this camera eliminated 66% of the blur due to image motion.

Twenty-two uniform forest types ranging in size from 3 to 20 acres were sampled on the ground by 0.1 acre plots to an accuracy of ±5% at 0.95 probability for average height, average crown cover and average basal area. Measurements of crown diameter, crown length, and full descriptions of each plot were also recorded.

After testing a number of methods of height measurement on the photographs, average heights for each area were determined by means of a parallax bar mounted on a parallel motion protractor on both scales of photography. The average error for the 1:7,200 scale was +0.6′ ±2.1′, and for the 1:1,200 scale +2.1′ ±0.5′, both at 0.95 probability.

After a series of experiments, a new method of crown density measurement was devised which permitted the determination of crown density on the 1:7,200 scale with an average error per type of −1.3% ±9.9%, and on the 1:1,200 scale with an average error per type of −0.3% ±5.5%, both at 0.95 probability.

Crown diameters were measured on the 1:1,200 scale with an average error of −0.09 ±0.33′ at 0.95 probability, but could not be satisfactorily measured on the 1:7,200 scale.

Stand volume tables were prepared from the field data using average stand height, average crown cover and average crown diameter. Applying the measurements of these quantities on the photographs to the stand volume tables, volumes of merchantable pulpwood were obtained and compared with the volumes measured on the ground. The average error for the 1:7,200 scale was +7.7% (+0.31 ±0.88 cunits per acre per type at 0.95 probability) and for the 1:1,200 scale, +4.3% (+1.14 ±0.48 cunits per acre per type at 0.95 probability). These results are very satisfactory and indicate the feasibility of eliminating all field work except for collecting the data for stand volume tables. Further tests are planned under other forest conditions.

It is proposed to use the two scales of photography in combination, with the large scale serving to provide samples which can be readily and accurately measured.

* Paper delivered at the Semi-Annual Meeting of the Society in Rochester, N. Y., on September 25, 1953.