MR. BIGELOW: The hardest part in industrial interpretation is to tell what is happening inside the building. In New England, for example, there are many large, old-fashioned textile mills that have gone out of business and have been taken over by a number of smaller companies which may be manufacturing anything from collar buttons to shoe horns; there is frequently no way of telling the kind of business unless one can actually read the signs on the outside.

CONSIDERATIONS IN THE PREPARATION OF KEYS TO NATURAL VEGETATION*

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ABSTRACT

Photo interpretation keys to natural vegetation are discussed in terms of objectives and manner of presentation. It is pointed out that keys should be constructed for a specific purpose, and the advantage of subdividing an area into regions is discussed. Several keys are reviewed from the standpoint of presentation. The problem of terminology and consideration of the reproduction process are also presented.

A DISCUSSION of considerations entering into keys to natural vegetation inevitably covers problems common to keys in general. A key to aircraft and a key to tree species of Maryland involve many common problems. In this paper we will attempt to relate these considerations to natural vegetation and to emphasize those of special importance in this field.

The preparation of photo interpretation keys involves two major groups of considerations. First, there are those related to the *purpose of the key:* what are its objectives? Second, there are those related to the *presentation of the key:* how can its objectives best be fulfilled?

PURPOSE

Purpose of a key involves consideration of *what*, *where* and *who*. What vegetation species or species groups will the key recognize, where will the key be applicable, and who, in terms of training and experience, will use it?

Natural vegetation is one of the most complex of universes. It comprises nearly 250,000 species, most of which are identifiable only after close, detailed examination. Limiting this universe to trees of the United States we find about 845 species. The range in shapes of vegetation species is infinite, and heights may vary from less than an inch to more than three hundred feet, depending on species, age and growing conditions. Distribution is also a complicating factor, varying from patches of a single species to areas wherein dozens of species are thoroughly intermingled.

Although *natural vegetation* comprises a broad and complicated universe, *certain characteristics facilitate its analysis* on aerial photographs. Because of its demands for sunlight and growing space, most vegetation is exposed to aerial view and consequently can be photographed with the aerial camera. Even seaweed may be sufficiently exposed for photographic inventory as described by Cameron (1950). The components of natural vegetation, whether considered as individual species or as plant associations, are more or less consistent in their physical appearance and site requirements, thus providing features and clues useful for their recognition on aerial photographs.

Since a key is never an end in itself but is merely a training or reference tool to be used on a particular job, it should be constructed to *illustrate the specific information* required for that job. It is seldom necessary, and usually would be impractical, to identify all species in a given area; therefore the interest of an individual investigator generally is limited to certain species or groups of species. For example, a forester is primarily concerned with

* This is a part of the Panel on Photo Interpretation held on March 8, 1955 during the Society's Annual Meeting.

trees, while a grazing investigator is more likely to be interested in grasses and shrubs.

Within each major field of interest, detail requirements vary greatly. Some timber surveys require identification of individual species; others require only species groups, such as pines, swamp conifers or upland hardwoods. In still other cases it may be of interest to separate only forest from non-forest. Where investigations demand quantitative data as well as species identification, it may be necessary to determine sizes, volumes and densities based on such criteria as height, stem counts and crown closure. To repeat, it is seldom feasible to construct a key which will satisfy many uses—*the key should be prepared for a particular job.*

Where is the key to be used—that is, for what geographical area is it applicable? Largely due to influences of climate and soil, natural vegetation varies from region to region in species composition and, to a certain extent, in physical appearance. Because of these differences, keys are *prepared for areas which are fairly homogeneous with respect to climate and soil and, concomitantly, to vegetation.* These areas may vary from one to many thousand square miles, depending upon homogeneity of vegetation and the purpose of the key. Although a single key could be prepared for the entire eastern United States, it would be extremely complicated because of the variety of growing conditions and the large number of species involved. Throughout the eastern United States there are at least ten commercial and several non-commercial pines. If all pine species were keyed out individually for this large area, the key would be complicated to prepare and difficult to use. A much more practical approach would be to subdivide the area into several relatively homogeneous regions (Figure 1) and prepare a key for each. This would reduce the number of species to be considered in each key. In the pine forest of the Lake States, for example, there are only three species of pine. The individual species could be keyed more readily if a separate key were prepared for this Lake States region. As a rule, the smaller the region, the finer the detail possible. Conversely, as the area is broadened, the more the classes or groups must be generalized in order to maintain a workable key.

The third consideration—*who will use the key—is especially important* with respect to terminology. Whether the user is a military photo interpreter, a soils expert, or a sub-professional will have a bearing on the extent to which technical language may be used without detailed explanation.

Presentation

Presentation, the second major group of considerations, is discussed under three general headings: *photography, organization* and *reproduction.*

PHOTOGRAPHY

It will be presumed that photography is available and adequate to meet the minimum standard necessary for the type of vegetation analysis required. As an example of a minimum standard, a pulpwood survey in Minnesota might require summer photography, a scale of 1 to 15,840, and infrared film with minus-blue filter. If photography is to be taken primarily for vegetation analysis, guidance may be found in previously published material relating to appropriate season, scale, and film-filter combinations. In keys for some purposes, ground photos are useful as a supplement to aerial photos (Steigerwald, 1950), since they aid in appraising ground conditions.

ORGANIZATION

The organization of keys may be in one of two basic forms: *selective keys and elimination keys.* The Report of Commission VII (1952) states that selective keys are so arranged that the photo interpreter simply selects the example corresponding to the image he is trying to identify, and elimination keys are arranged so that the photo interpreter follows a prescribed step-by-step process leading to the elimination of all items except the one he is trying to identify. Both types usually consist of text and stereograms. In selective keys the text supplements the stereograms; in elimination keys the text is basic and the stereograms supplementary.

A number of keys were analyzed by the authors of this paper, and several representative samples were selected for discussion here. A set of stereograms illustrating various vegetation types in the Lake States area were assembled by the U. S. Forest Service (1947) for the guidance of

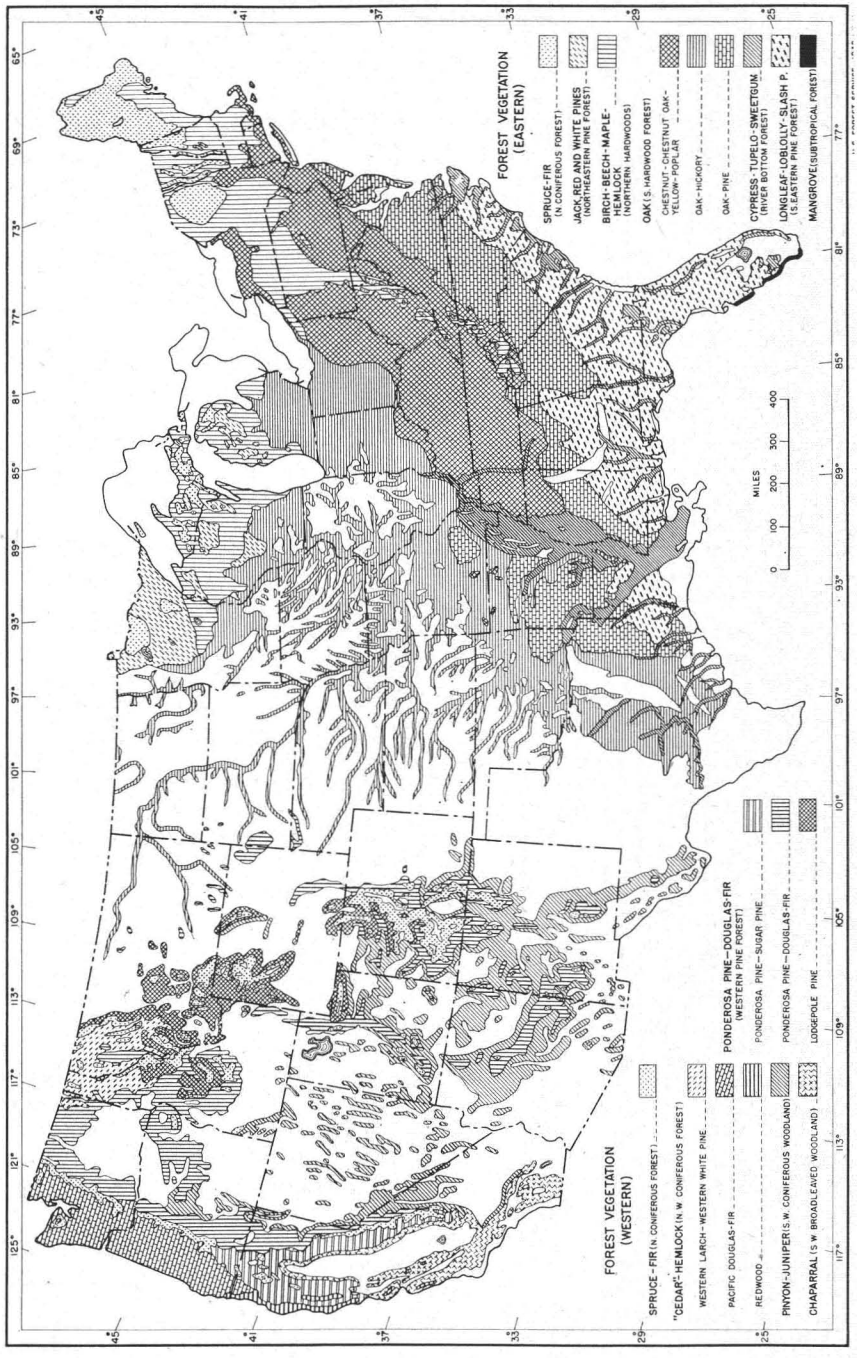


FIG. 1. Forest vegetation of the United States. These broad subdivisions, based on important species, genera and associations, might provide suitable primary regions for a key covering a major portion of the country, as for example, the area east of the Mississippi. Further subdivision could be made, depending upon the intensity or detail of the key. (Adapted from Shantz and Zon's "Natural Vegetation" map of the United States in the "Atlas of American Agriculture.")

its photo interpreters on timber surveys (Figure 2). This is one type of selective key in which each vegetation type is identified by name but no recognition features are enumerated. A weakness of this particular key is the lack of site identification, which is frequently an important clue to recognition. A key should relate a vegetation type to its environment, if only through textual description.

Another type of selective key is Stone's study (1948) of vegetation, which was

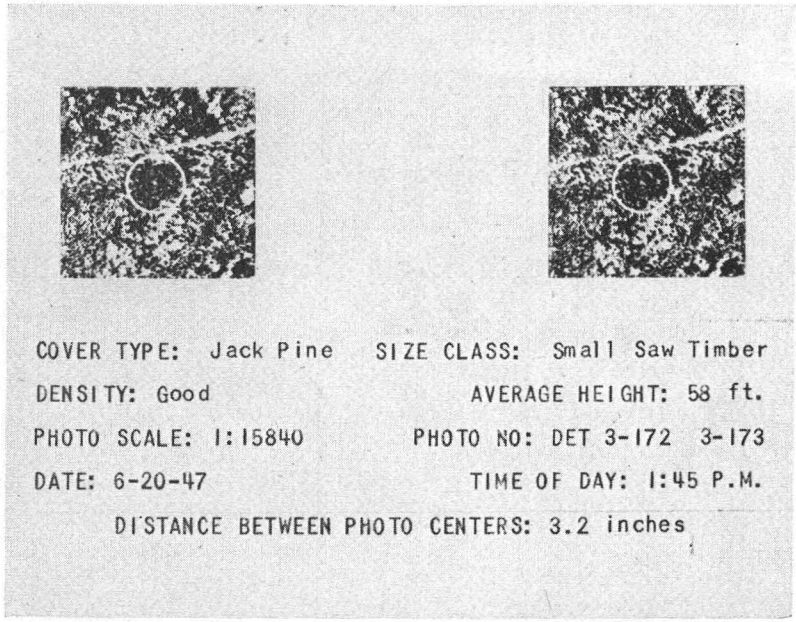


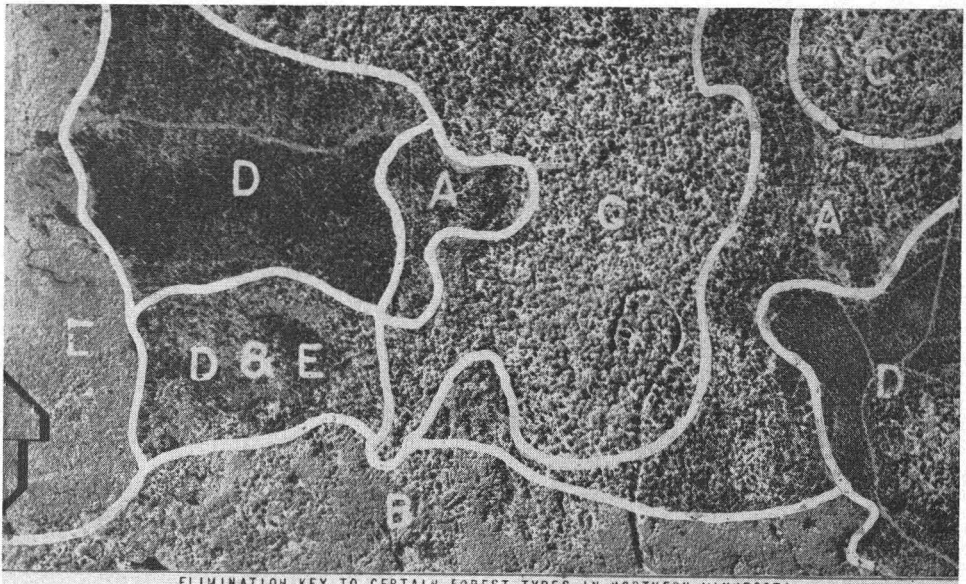
FIG. 2. Sample stereogram from a selective key to tree species, size and density. (Courtesy U. S. Forest Service.)

developed for classifying land in the vicinity of Anchorage, Alaska. In this study each vegetation type is illustrated by a stereopair, and the tone, texture, stereoscopic appearance, shape, and distribution of each type is fully described. In this treatment, textual description points out the significant features of the illustrations and serves to impress the images more firmly in the mind of the photo interpreter. The correlation of stereopairs and textual description results in a more complete key.

Raup and Denny's key (1950) to vegetation along the Alaska Highway is an example of an elimination key. This key was developed in connection with terrain studies for military intelligence. Here, lengthy descriptions of recognition features and contrasting site conditions are presented with only incidental use of photos. Schulte (1950), in his study of various film types for tree identification, presented an elimination key which is in two parts, one for panchromatic photography and one for infrared photography. Figure 3 illustrates a simple elimination key. All these elimination keys and other photo studies make use of site, size, shape, tone and texture as identification criteria. Of these, site is probably the most easily defined and is most frequently used as the primary consideration. Size and shape are relatively easy to define and are also widely used. In the case of tone and texture there is a problem of precise terminology; "soft" and "fluffy" textures and "light-gray" and "medium-gray" tones are examples of the descriptive terminology which prove rather elusive to the photo interpreter.

A step toward increasing the effectiveness of elimination keys through more precise terminology would appear to lie in the use of scales. This problem was previously noted in the Report of Commission VII (1952) which presented scales for tone, size, density, pattern, shape and texture. Although we have not observed their use in any vegetation key, it is felt that their adoption would do much to sharpen terminology. Tone, size, density, pattern and shape are features for which standard scales can be readily adopted. However, a scale for texture is more difficult to standardize and might have to be developed on an individual key basis. This problem was noted by O'Neill (1953) who suggested the possibility of using various fabrics as the basis for a texture scale.

Because, as mentioned before, elimination keys place primary dependence on textual descriptions, they must employ precise terminology as expressed by scales



ELIMINATION KEY TO CERTAIN FOREST TYPES IN NORTHERN MINNESOTA
Modified Infrared Photography, Scale 1:15840

1. Occurrence on upland sites	(See 2)	
1. Occurrence on bottom land sites	(See 4)	
2. Tone – medium to light gray	(See 3)	
2. Tone – dark gray to black		UPLAND CONIFERS (A)
3. Canopy uniform; texture fine; crown diameter less than 10 feet		ASPEN-WHITE BIRCH (B)
3. Canopy uneven; texture coarse; crown diameter up to 30 feet		NORTHERN HARDWOODS (C)
4. Tone – dark gray to black; height over 15 feet		SWAMP CONIFERS (D)
4. Tone – medium gray; height less than 15 feet		LOWLAND BRUSH (E)

FIG. 3. Elimination key illustrating integration of text and photography. A stereogram would be preferable to the single print used here. (Courtesy U. S. Forest Service.)

or actual measurements. Lacking such scales or measurements, selective keys usually are more effective.

REPRODUCTION

The final consideration, the method of reproduction of the key, should be decided before actual preparation of the key itself is under way, because method of reproduction influences priorities accorded the various criteria used for identification. For example, when photolithography is used, tone and texture should be given lower priorities than features of site, size, pattern, shape and density, which are not appreciably affected by screening. Once the method of reproduction is selected, the key must be geared to the limitations inherent in the method.

SUMMARY

Two points appear worthy of emphasis:

1. A key should be prepared for a particular job, a particular region, and for the capabilities of the interpreters.

2. More attention should be given to sharpening terminology by development and use of scales.

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Discussion of the Paper by Mr. Simontacchi, Mr. Choate and Mr. Bernstein

QUESTION: What use do you see for color photographs in the preparation of keys?

MR. SIMONTACCHI: I have looked into that use and have asked about it. I understand that for making keys, the best type of photography is panchromatic. There are certain characteristics that can be brought out by color photography, but there are also disadvantages—the cost and so on—as well as defects in color vision.

DR. ROSCOE: One of the difficulties in making keys with color photography is the tremendous cost of color reproduction; this makes dissemination limited. Perhaps twenty or thirty photo copies can be made but photographic reproduction of two or three thousand copies is prohibitive.

QUESTION: How do you take care of photographic and processing differences in your keys? I think the difficulty would be very considerable.

MR. SIMONTACCHI: Your mean as to what would affect tone?

QUESTION: Yes, tone and the other various characteristics.

MR. SIMONTACCHI: Photographs may be overexposed or underexposed, resulting in varying tonal values for the same objects. That is why I emphasized that tone is given less priority than the other identification criteria.

QUESTION: I noticed that if keys are reproduced, they lose their sharpness and definition; sometimes the lines are so thick that you don't see anything underneath. I wonder what the best method would be to reproduce keys. Should they be enlarged or reproduced at contact scale?

MR. SIMONTACCHI: I prefer keys that are made from the same scale or by enlargement, not reduced.

QUESTION: Do the photo interpreters put on their keys the size and scale of photographs, information by which the key is supposed to be worked? Or is that supposed to be common knowledge?

MR. SIMONTACCHI: Each vertical airphoto in a key has a bar scale at the lower right-hand corner and a representative fraction in the caption.

QUESTION: In the publication of these keys, there is much loss through reproduction by any method other than that of actually attaching photographic prints. To what extent do you think it is desirable to have real photographs, rather than reproduction by lithograph or any other method?

MR. SIMONTACCHI: Real photography is preferred but again there is the expense of reproduction. Other factors concerning these keys have not yet been worked out satisfactorily. Something has to be done about getting a foundation upon which to build these keys. Scales, identification criteria, and a precise terminology must also be established.

DR. RABBEN: There are a number of ways of working with the problem of retaining a quality in the key, which approaches that of the original photography. The best method, I think, is to attach photos. But that isn't the only way to make a photographic key. It is also possible to have excellent negatives—negatives which lose as little in quality as possible. A very careful photographic control has to be used. The sections and corners have to be cut up and laid in exactly, and then printed as if the entire page was a negative. The result is a photopage which retains a great deal of the original quality. The objection to this is the expense, not only in the lay-down, but in reproducing large numbers of pages for a wide distribution of the key. One possibility of avoiding this, or at least minimizing the expense, is to reproduce photographically by other than the conventional processes, namely the ozalid or similar dry processes. But there are objections to these. For one thing, the usual PI's objection is that the tone is not black but

brownish; secondly that they are not sharp; thirdly, that they fade. I certainly have seen dry photo process prints which were easily as sharp as the conventional wet process prints. They are much cheaper, and while they may fade in time, if they do fade, the cost of making another book or one particular copy to replace a faded one is so low that it is still a feasible proposition.

DR. ROSCOE: It is very interesting to note that these questions came from the Royal Canadian Air Force. About three weeks ago it sent keys of portions of Canada to our Air Force. They were partly in panchromatic photography, partly in color photography and partly in hand-colored maps.

It took two weeks in the laboratory and the time of a draftsman for one month to reproduce and assemble just one copy of the key. While the keys eventually produced were of fine quality, this example of time and cost is cited to show that the problem of dissemination of panchromatic and especially of color photography in keys is not a simple one to solve. I might also add that to reproduce the normal-sized military PI key photographically, the cost runs between $60 and $250 a copy, and this is not for labor, but just for the photography. The photolithic copy costs $0.60 to $2.50 per copy.

QUESTION: I have experimented slightly with photo gelatin processes and screens. Has anyone on the panel had satisfactory results, using those methods?

DR. ROSCOE: The Government has used both the photo gelatin process and the 300-line screen, half-tone process, for large quantity reproductions of keys. The 300-line screen process is very difficult to work and very few commercial printers want to accept a contract of this type. It is the finest screen that is normally available. (There is a 400-line screen, but this is only practical for individual photos, and there are only a few of them in the country.) The difficulty with the 300-line screens is that the ink collects between the dots on the plate. Unless a very high quality paper of coated stock is used a poor image results. The best method of reproducing these is by having a photo interpreter at the printing press when the first sheet is run off. He examines the press-run and tells the printer to go ahead or repair any images that need fixing.

In utilizing the photo gelatin process, it must be remembered that while this does not give a half-tone effect, there is no doubt that the total number of copies which may be run is somewhat limited, and that every time the gelatin plate comes against a sheet of paper, it changes the formula left on the plate, with the result that you do not have the same quality with each imprint. Although there is only a slight change each time, the total variation is quite great. The samples of photo gelatin work which people can show, are excellent, but large press runs usually turn out to be inferior in some respects.

QUESTION: Has anyone made any vegetative keys using color film or color prints, and if so how successful were they? Also has any quantitative analysis been made comparing color prints and/or color transparencies with panchromatic prints or transparencies?

DR. COLWELL: To my knowledge there has been no such key produced in published form. You have probably seen a few isolated examples. Dr. O'Neill, from Catholic University of America, has made color prints in publishing various keys. I happen to have first-hand and painful knowledge of a particular key that is awaiting publication; it would have something like 27 color plates in it, and it is estimated that the cost for preparing one such plate, size 4 by 5 inches, or thereabouts, is $500, for the 4-color preparation process. This means that reproducing a key of the following composition would cost about $15,000, for 4,000 copies. The composition would be 72 pages in all, with 27 of the 4 by 5 color plates, and about 27 black and white plates to accompany them. The latter would only cost about $800. The remainder would be the cost of type-setting, paper, and so forth; so in a key such as this, well over half the cost is in making the color plates themselves. I am told that once this is done, additional cost of reproduction is not appreciably greater than printing in black and white.