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ASSOCIATION ANALYSIS APPLIED TO THE INTERPRETATION OF AERIAL PHOTOGRAPHS*

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ASSOCIATION is a term which, when referring to aerial photographic interpretation or to aerial photographic interpretation keys, has different meanings to different individuals. As a result there is considerable lack of agreement with respect to the application and utility of association analysis and of the association type of aerial photographic interpretation key. It is thought that much of the lack of agreement is due to an inadequate understanding that an association is an organization of related elements and that the constituent elements are not of equal importance. An association is a logical unit for aerial photographic interpretation. In this paper a definition of association will be given, and the nature of an association and the utility of association analysis will be discussed.

An association is defined as a group of objects, features or elements which characteristically occur together, have specific relationships to each other and to their environment, and have a definite organization. Selected definitions of association from the Webster's New International Dictionary are:

1. An associating, or state of being associated; union; confederation.
5. The bringing of a person or thing into joint action with another.
7. Ecology a. A major unit in community organization characterized by essential uniformity and composition in structure, with usually two or more dominant species of a particular life form or habit. This unit is often taken as the fundamental entity in community organization.

- c. Any group of organisms, usually of similar life form, associated in a given environment and distinguishable as a group from neighboring groups of like nature.

Selected definitions of associations from the Shorter Oxford dictionary are:

1. The act of associating, or the being associated; confederation.
2. A body of persons associated for a common purpose; the organization formed to effect their purpose.
5. Conjoining one person or thing with another.
7. The mental connexion between an object and ideas (e.g. of similarity, contrariety, contiguity, causation).

These definitions do imply similarity to that first given. Most of them are not sufficiently specific for association analysis because they do not emphasize the specific relationships between the elements. Of these definitions the ecological definitions are closest to the desired definition.

It is understood that some use the term association to mean a group of objects which commonly occur together, that is without specifying that there are definite relationships between the objects and that there is a definite organization of them. There would be no point in coining a new term with a specific meaning as first defined because the term association is used in several disciplines essentially in agreement with the definition first given. The definition of association as used in this paper does not violate the association concepts of the several disciplines concerned.

In a qualitative sense each association

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is composed of several types of objects or features which will be called elements. Each association has a characteristic composition of such elements. Not all elements present in the association are of equal significance, that is with respect to characterizing the structure or organization of the association, determining the interrelationships of the elements, identifying the association, and indicating the significance of environmental or physical conditions within the area covered by the association.

The number of individuals per unit area or density of each element in an association is not identical, that is with respect to the density of each of the other elements. However, the relative number of each element may be characteristic. One element may be scarce and another may be abundant. A simple inventory of the kinds of elements and the number of each kind does not adequately distinguish the association.

There is a characteristic distribution of each element within the area occupied by the association. Not all elements are distributed in the same manner within the association. The individuals of one may occur singularly. But of another element they may occur in groups. Single individuals and grouped individuals may be distributed in a random, uniform, grouped or systematic manner. The distribution of each and all elements determines the homogeneity, or heterogeneity, of the association example.

The three dimensional shape and size of individuals of each element are additional characteristics. Very closely allied is the space occupied by an individual. The space characteristic is important with respect to its distribution in distance above the surface of the ground.

All examples of a given association are not expected to be exactly identical with respect to any one or all association characteristics. There is a certain degree of uniformity of character between all association examples. On the other hand there is a certain degree of variation between examples of the association, but this variation is within the range of the homogeneity characteristic of the given association.

Some elements are common to all examples and other elements occur in a varying percentage of the examples of an association. Of the elements common to all examples, some are "exclusive" to and

of course characteristic of the association. Others common to all examples, although not exclusive, may be "characteristic" of the association. The "exclusive" and the "characteristic" elements may be called collectively the "essential" elements. Still others, although common to all or practically all examples are not particularly characteristic of the association, because they also occur in other related and unrelated associations. These may be called "indifferent" elements. The elements which are not common to all or practically all examples of the association are generally not characteristic of the association and are generally in the "indifferent" group.

The quantitative characteristics of density, dispersion and distribution, together with the composition of all examples, provide an excellent characterization of the unit of abstraction, the association. There is a pronounced degree of homogeneity of the association and a less pronounced degree of variation within the association, that is between the examples of the association. Furthermore these association characteristics provide a reliable basis to correlate the similarities and variations of registration characteristics on aerial photographs of the specific examples of the association.

Two or more closely related associations may and do have certain characteristics in common but the composition, number of individuals, density, dispersion and distribution of each and all elements are not identical between all such related associations. There is a definite and detectable difference especially in composition and in density, dispersion and distribution of elements of each association. For each of the related associations there is usually a limited number of elements essentially exclusive to the respective association. Of course each "exclusive" element and set of exclusive elements is very characteristic of its respective association. There are also some elements which are common to from two to all of the related associations, but which are essentially exclusive to this group of related associations. Each of these "characteristic" elements, or each set of such elements, is characteristic of the respective related associations. Each association and each group of related associations is thus distinguished collectively by its "exclusive" and "characteristic" elements, or "essential" elements. These are char-

acteristic of the group of associations and differentiate the particular group from other groups of related associations. It has also been mentioned that there are elements which are not limited to one association, or a group of related associations, or in some cases related groups of associations. These were called "indifferent" elements. Thus, such an element or a set of them is not characteristic of one association or a group of related associations.

The composition characteristics of the association and group of related associations has been emphasized to this point of the discussion. The other association characteristics, that is the size, shape and space occupied by each element, number of individuals, density, dispersion and distribution are also important in characterizing and distinguishing an association and a group of related associations.

In reality an adequate understanding of an association, the importance of each element, their interrelationships, and the internal structure or organization of an association requires an analysis of representative examples of the given association, of each association of the group of related associations, and of the related groups of associations. It is essential that the analysis be made of at least one and usually two higher levels of grouping in order to determine the true role of each and all elements in the association. Then the "exclusive" and the "characteristic" elements, collectively the "essential" elements, can be differentiated from the "indifferent" elements. It will be found that the essential elements have important interrelationships with each other and that they comprise the essential structure or organization of the association. Only by this type of an analysis is it possible to determine the true role or significance of each component element both to the association and to the group of related associations. The essential nature and degree of homogeneity and of variation within an association and between associations can be determined by analysis of these exclusive and characteristic elements. The individual elements and set of elements which characterize and distinguish each association can be determined. These are the elements which give the association its particular and distinctive homogeneity. The variation within the association is on a relatively limited scale. The in-

dividual elements and set of elements which characterize and distinguish a group of related associations can also be determined. They distinguish a homogeneity of the group of associations which is on a broader scale than the homogeneity within one association.

It is essential that the true significance of component elements be determined and understood. Considerable lack of agreement exists concerning the association concept and the significance and application of the concept to aerial photographic interpretation and aerial photographic interpretation keys. This lack of agreement may very well be with respect to the "indifferent" elements which may be conspicuous but are not restricted in occurrence to one association, to a group of related associations or possibly even to related groups of associations. These are not essential elements of the structure or organization of the association. Their relationships to essential elements are less direct and of less importance than the relationships between the essentials. Even though these elements, which are not essential parts of the association organization, are usually present or "associated" with the essential elements, their presence must be carefully and properly evaluated. No assumption should be made of their significance entirely on the basis that they commonly occur in the association or in the group of related associations.

The association characteristics which have been mentioned determine directly the manner in which each and all examples of an association are registered on aerial photographs. The essential characteristics by which individual objects are identified are shape, size, shadow, tone, texture, pattern or layout, and position or location. In the case of association analysis the unit of interest is primarily the area covered by the association. An association covers an area much greater than that covered by a single object or feature, and the subject matter registered on aerial photographs is infinitely more complex.

Each type of element influences the registration essentially in proportion to the area of each individual and of all individuals exposed to the view of the photographic system. The more uniformly the individuals of each element are dispersed and distributed throughout the area of the association, the more homogeneous is the

registration of the association on the aerial photograph. Of course one element may tend to occur in small groups, and the groups may tend to be uniformly distributed throughout the association. Then this element may cause a mottled aspect which results in a homogeneously mottled pattern.

It is generally expected that the "exclusive" and "characteristic" elements have the major influence on the registration characteristics. It would also be expected that these elements provide the essential and evident homogeneity of the registration characteristics of each and especially all examples of a given association. If the "exclusive" and "characteristic" elements do influence a variation in registration, then this variation is limited within the bounds of the homogeneity which characterizes the association. It is undoubtedly due to the variation in dispersion and distribution throughout the association.

The "indifferent" elements are expected to have a minor influence on the registration characteristics. This influence is a variation but still within the bounds of the homogeneity determined by the "essential" elements. Although the indifferent elements would influence a variation within each example of an association, they have a more conspicuous influence than the variation between examples of a given association.

Each association is the result of a developmental process. It is the result of the operation of a peculiar and distinct combination of related interacting factors. The factors are climate, geology, soils and biota. Including man in the biotic factor would be a debatable issue which is beyond the scope of this discussion. The particular combination of features which has permitted the development into an organized association must have been operating throughout an area of some minimum extent.

The information concerning conditions on the ground is often the primary interest in aerial photographic interpretation or analysis. This is in contrast to an interest only in an inventory of objects which can be detected, recognized and identified. The image content of the aerial photograph is analyzed for indicators of the conditions. It has already been mentioned that an association element, even an

important element, may occur in more than one association. A given element, with the exception of an "exclusive" element, is expected to occur over a wider range of conditions than their range within a given association. Thus a given type of element is usually an indicator of a wider range of conditions than the range within an association.

An association has developed within an area where a particular combination of and a relatively limited range of conditions have been and are operative. The association which has developed is a reliable indicator of this particular combination of conditions and their particular range. It must be emphasized that each association is a reliable indicator of its respective range of conditions and that different associations indicate their respective but different ranges of conditions. Thus, the association, the characteristic group of related elements, is a better indicator of conditions than is a single element. The association indicates a narrower range of conditions than a single element indicates. Furthermore, the association, since it occurs over a relatively well defined area, indicates conditions on an entire areal basis, rather than on a point to point basis as indicated by a single element. With respect to the individual element, its indicator value is significantly greater when it is evaluated in a restricted setting, that is in the specific association in which it is present.

Classification systems are developed for purposes of organizing a large quantity of information in a manner which facilitates understanding and use of the large quantity of information. The association concept provides a logical basis for the development of a simple and very useful classification of information concerning all subjects over a very large and complex area. Association analysis facilitates determination of the essential elements of distinctive groups. It permits determination of the nature and degree of relationship of the various associations. Thus, a system of classification can be devised which groups associations according to their relationships to each other.

Association analysis by aerial photographic interpretation techniques has many advantages. As already mentioned the association is a better indicator of conditions than an individual element. The

indicator value of an individual element is greater when the element is evaluated on the basis of the specific association in which it occurs. Transitional areas which otherwise are problems are placed in their proper perspective, in the indicator significance of the transitional areas, and the constituent and grouped elements are readily determined and understood.

The association concept forms the basis of a simple procedure for the analysis of complete areas and of all subjects within those areas. It is the basis for making an orderly and simple unity of a supposedly unrelated group of heterogeneous objects or elements. The association concept also provides the basis for an understanding of homogeneity and of variation in their proper perspective. Association analysis is a technique which permits bringing any and all disciplines to bear on a problem.

The information of a large area can be compiled in a manual in the form of a series of association keys. The information can be readily extracted by a simple procedure from aerial photographs of an area, by an interpreter who has had no previous familiarity with the area and very little familiarity with the subject matter. Depending upon the desires and limitations established by the client, the information compiled in the manual, and later extractable from photographs of the area, range from general information to specific information concerning both associations and individual features and objects. The treatment can be and is such that dissimilar objects are related to an understandable, workable and significant whole. The treatment can be such that both the non-specialist interpreter and the specialist interpreter can report a greater quantity of more reliable information from aerial photographs. A more complete utilization of aerial photographs as a source of reliable information is thus made possible.

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