Topic Series 06

Fundamentals of Image-Interpretation

Photo-interpretation is generally called **IMAGE ANALYSIS** because the interpretation may not be of a hard copy "photo", but rather another type of image media. Normal color and panchromatic film produce hard copy photographs because they are imaging in the visible portion of the **EMS**. If we acquire a photographic record of something within human vision, i.e. with Color IR Black & White IR, we have an image. We can, for example, produce a photographic record from a thermal scanner - a heat map, if you will. An **IMAGE** of thermal emittance. All photos are images, but not all images are photos.

Image interpretation (photo-interpretation, PI) is defined as the act of examining images for the purpose of (1) identifying objects and (2) judging their significance. Interpreters study remotely sensed data and attempt through logical processes to detect, identify, measure, and evaluate the significance of environmental and cultural objects, patterns, and spatial relationships.

I. Photo-Interpretation: Art and Science

Photo-interpretation is an ART and a SCIENCE. You have to understand the underlying geometric relationships of an aerial image, before you can become a competent ANALYST. Subsequent lectures will deal with the geometry of photogrammetric measurements and image analysis.

As an image analyst, you will be expected to not only identify objects of features, but also to determine the significance of these things! In other words, the interpreter/analyst has two major jobs:

1. identification
2. determination of significance

Interpreters study remotely sensed data and attempt to detect, identify, measure, and evaluate the perception and significance of environmental and cultural objects, patterns, and spatial relationships.

Examples of Photo-Interpretation

Example 1: Let's suppose that you have successfully identified the following image characteristics:

1. A stand of Blackjack Oak, Post Oak and Hickory
2. on a ridge, with
3. basal area about 60 sq.ft. and height about 70 ft., and
4. crowns are relatively broad, flattened with
5. sparse understory.
5. The gully configuration is basically "**U**" -shaped.

Tell me about this site! What are your management recommendations? For timber? For wildlife? Recreation? First you made the identifications - a sparse, Blackjack oak, Post oak, Hickory stand on an upland ridge position in NE Mississippi; The position and the species composition and stand condition tells you that you have a dry site of low productivity; the soil, however, could be either sand or clay (species), both of which have low water-holding capacity, but the gully configuration tells you that it is **clay**.

Now then, you have all the information you need ... FIRST, what is the management objective? FIBER? convert to loblolly! Logging? All but wet weather - clay on 0 - 5% slope (ridge position); Wildlife Habitat Quality? For what species? Deer, Turkey, Squirrel? How would mast production be? Probably sporadic and yields would be generally low; little understory, so little browse - palatability? Probably on this site, understory would be huckleberry, persimmon, hickory, little sawbriar. Conclusion -- not a good habitat; also recreational potential generally low - not the best site for intensive day use, certainly not water-based activities. What is your recommendation? **CONVERT THE LOW QUALITY HARDWOOD STAND TO LOBLOLLY PINE**. Discussion????

<u>Example 2</u>: Interpretation is a psychological process involving both inductive and deductive reasoning! It is also a game of **PROBABILITIES!** What is the confidence level of your ID? How sure are you of you answer? The process is almost like working a **dichotomous key** - for example, you have an open grown tree in an upland position;

Conifer or Hardwood? **HDWD**
General Location? - **North Miss.**
Site? - **upland ridge**
Foliage Color (late spring, CIR) - **bright red**
Crown/Branch Characteristics? **Rounded, fine branching**

Possibilities
1. Southern Red Oak
2. Water Oak
3. Willow oak

Highly probable that it isn't Southern Red - coarse branches (comparatively), color isn't bright red, crowns not generally rounded; it probably isn't Willow Oak - although branching is fine, crowns rounded, it would be **off site** plus the color isn't as bright as Water Oak. Thus, a high degree of probability that it is **water oak**.

II. Applicability of Remote Sensing in Environmental Studies

Remote-sensor imagery has applicability to environmental studies for four basic reasons:

First, it presents a **synoptic view** of a large area of the Earth's surface from a perspective and in a format which facilitates the study of objects and relationships. It allows the viewing large areas in one scene to perceive spatial relationships we have never observed before. One image may cover anything from several hundred acres to 10,000 sq. miles.

Second, certain types of imagery can provide a **3-dimensional view** of the terrain and objects under investigation.

Third, it allows the **transformation of portions of the electromagnetic (EMS) spectrum to visible images**; even portions of the EMS beyond the visible can be transformed to images for study. Thus, the characteristics of objects not visible to the human eye can be transformed into image form.

Fourth, it provides the observer with a permanent representation of objects, phenomena, and relationships as they exist at a given time, thus a periodic or **temporal record**. It not only provides a permanent record of conditions at a given time, it permits the periodic viewing of the same area through time. Landsat images are refreshed every 14 days.

Imagery of large areas permits the observer to perceive the relations of objects and their surroundings which to an observer on the ground might not be apparent. Example: type mapping on ground and being in “holes”. The image interpreter can examine objects, patterns, and relationships in detail and can compare these data with maps and other reference material.

Stereoscopic viewing (creating the illusion of depth) enables the shape and height of objects to be determined. Perception of form makes it easier for the interpreter to identify objects and permits measurement of heights and slopes.

An image interpreter is a limited sensor. The interpreter perceives reflected energy in a narrow band of the electromagnetic spectrum. Sensor systems and photographic emulsions currently in use, however, enable the interpreter to view picture-like images of energy patterns beyond the limits of his vision. These energy relationships add significant information as the interpreter attempts to judge the significance of objects, phenomena, and relationships.

We perceive only a limited range of radiation, a narrow band of the EMS. Sensor systems and photographic emulsions currently in use enable us to study picture-like images of energy patterns beyond the **Visible** - Color Infrared, Black &White Infrared, thermal, radar, etc. These energy relationships add significant information in ID'ing and judging the significance of objects, phenomena, and environmental relationships.

III. Activity Sequence of Image Interpretation

Psychological analysis regards image interpretation as if it occurred in a time sequence. The sequence begins with the (1) detection and (2) identification of important objects. The objects are then (3) measured. Measurement is followed by consideration of the objects in terms of information from the interpreter's special field of knowledge. (4) Significance - The interpreter must then be able to communicate both his perception of objects and the significance of the objects.

In other words, the sequence is initiated with **detection and identification** of important objects; the objects are then **measured**; measurement is followed by a logical consideration of information from your specialized field of knowledge; and the final step is **communication** of both his perception of objects and **the significance** of these objects.

For example, the statement " I see a sawmill in the image." appears to be a rapid and elementary ID - **BUT** it implies all of the above steps. Measurement, in its broadest sense is the estimation of **size and shape**, and this has taken place .. The identification also required the use of surrounding objects - **SURROGATES** - based on your specialized knowledge. What do you look for adjacent to the mill itself? Log Pile, finished lumber, maybe a kiln? So, you measured, integrated information, analyzed the information, and communicated the result ... **a sawmill** (Pine or Hardwood?)

Another example will also illustrate the sequence of image interpretation activities. The statement, "I see a barn in the photograph," through it appears to be a rapid and elementary identification, also implies all of the activities described above. Measurement, in its broadest sense of estimation of size and shape, has taken place; the barn may have been identified by its unique proportions, the number of roof surfaces, or other measurable characteristics. The identification also required attention to such surrounding objects , surrogates , as livestock and silos, and the interpreter must have had prior knowledge of the function of barns. Finally, the word "barn" serves to communicate the results of interpretation.

Thus, image interpretation comprises at least three mental acts, which may or may not be performed simultaneously - (1) measurement of objects on the imagery, (2) identification of the objects imaged, and (3) appropriate use of this information in the solution of the problem at hand. The first two acts, measurement and identification, can be investigated by relatively simple means: they can be observed by the psychologist or described by the photointerpreter. The third act, problem-solving, is complex and requires mastery of basic information and both synthetic and analytic modes of thought.

IV. Attributes of an Image Interpreter

1. Acuity of Vision

    Stereo-acuity: ability to detect parallax differences.

2. Powers of Observation and Imagination

    Student A - It's a building
    Student B - It is a wood-using industrial building which manufactures pallets

3. Patience

    Like a jigsaw puzzle - you can recognize something here, something there; it may well take awhile to put it all together, but with patience you can do it.

4. Judgement

    Again, playing the odds - the probabilities.

5. Professional Background and General Knowledge

    The better you are in your particular field, the better interpreter you should make; especially if you have a good general background of knowledge. Travel, work in different forest regions, -- or even, when you watch TV, look at the background! I have seen TV backgrounds from Australia , New Zealand, Basil, the West Coast, and New England all within the past 6 months!

V. General Image Analysis

Photos are usually studied with a particular problem in mind, such as highway relocation, location of military installations, type mapping, recon surveys, etc. Most of the information, in many cases, will be obtained in the examination. Much of the information for the task of **problem-solving** will come from the examination of the imagery and the association of the imagery with identifiable features or objects; i.e. SURROGATE ANALYSIS. Perhaps determining subsurface topography from surface topo, rock outcrops, drainage, etc will provide clues. The photo interpreter must be good in his own field if he is to use photographs properly. Small details often become an indicator of other relationships.

Even though both vertical and oblique photos can be used for photo interpretation, the beginner can use the oblique photos easier because he is more accustomed to these sights. He can, however, easily become more familiar with vertical photos with a little experience and his association of the features on the ground to those on the photo will help immeasurably. The use of stereoscopes and measuring devices will help interpretation from vertical photos.

The first thing you should do with a stereo-pair is (after you turn shadows and align flight lines) is **determine the scale** -either actual or approximate. Actual by measuring photo distance of objects whose dimensions you know - cars, road widths, etc. -- or -- approximate by simply comparing objects, some of which you have a general idea as to size.

Tone ranges from white to black on all photos - summer photos are usually richest in appearance, while winter photos reflect drab coloration. These tone characteristics should remain the same both in the printing room or dark room.

Shadows should fall toward the observer for best results, particularly in mountainous terrain. Shadows often give you a clue as to what an object is but, in some cases, especially in infrared photos, they may obscure detail.

VI. Object Attributes for Interpretation

The 4-S's

SIZE - SHAPE - SHADOWS - SITE

The 2-T's

TONE - TEXTURE

Then **PATTERN AND GENERAL LOCATION**

1. **Size** - actual size in length, breadth and depth also relative size as compared with known objects. The normal eye can distinguish .001 inch lines or 2 x 0.001 light and dark.

Scale	Size of objects that can be seen	
1:31,680	5.28 feet	1/31680=(2 * 0.001)/D
1:20,000	3 feet	
1:15,840	2½ feet	
1:12,000	2 feet	1/12,000=(2*.001)/D
1:3600	1 foot	

2. **Shape** - regular or irregular outline, depth. The shape is related to scale and tonal contrast. There are few straight lines in nature (except for geologic faults).

3. **Shadows** - useful for both direct interpretation and their contribution to texture. Objects near the PP are sometimes difficult to see directly but can be identified by shadow. Height computations are made from shadows. Shadows range from dark tones in pan film to black in infrared.

4. **Site** - bottoms, terraces, ridge, side slopes - etc. Very useful in species identification. The specific set of edaphic conditions is very useful. Is it an upland ridge, sideslope, terrace, bottomland? Is it a clay soil, a sandy soil? Dry? Wet? North exposure, west exposure? All of this is very important when you are dealing with tree species identification, determination of wildlife habitat quality, road layout or locating appropriate sites for construction. There are, for example, about 100 different species of oak that could occur in Mississippi - if you can narrow down that number by site identification, you've fewer choices in your ID. Southern Red Oak vs. Cherrybark Oak; White Oak vs Chiquapin Oak, etc.

5. **Tone** - tone ranges from white to black, usually a shade of gray. Complete reflection of light gives white tone; complete absorption, black tone.

   Has inherent drawback for interpretation and should not form sole basis of identification. The tone of all objects depends upon:

   a) light reflectivity of object - hardwoods in leaf reflect light, softwoods entrap light.
   b) light sensitivity of film
   c) light scattering by the haze
   d) light transmission by filter, also optical properties of lens.
   e) sun angle - related to light reflectivity

6. **Texture** - refers to frequency of tone change. If there is little tone change, objects appear smooth such as still water. If there is frequent tone change, objects appear coarse such as the large crowns in an unevenaged stand. If there is little tone/color change, the texture is **smooth**; if there is frequent tone change, the texture is **coarse**. You can also classify texture

as **regular or irregular**; a cut-over, uneven aged hardwood stand will probably be **coarse, irregular**; an 60 yr-old even-aged pine stand will be **coarse, regular**; a plantation pine stand will; be **smooth, regular.**

In general, young vegetative growth and forest plantations (all even-aged) will appear <u>relatively</u> smooth while old growth (uneven aged) relatively coarse. There are gradations within each class. High-graded mature stands will appear coarse and irregular while uniform merchantable stands will appear coarse but regular.

7. **Pattern** - the pattern formed by the objects may sometimes indicate their nature. For example, orchard and plantations have a regular pattern. Just as nature is practically void of straight lines, it also avoids (anthropomorphically speaking) regular patterns. A pecan orchard, a peach orchard, a baled hay field have regular patterns; a plantation has a regular pattern. Archaeological sites have patterns. Large-crowned oaks along a main road with pine/hdwd stands on either side except for circular spots of large-crowned cedar/oak at the ends of the side ridges might indicate an entrance to an archaeological (home) site.

8. **General location** - coastal plain, peidmont, mountain; section of country, etc. This should really go back up with SITE; the first step is to find out what PHYSIOGRAPHIC PROVINCE you happen to be in. The world is a large and complex - a tremendous variety of timber types and earth features - almost infinite!! Therefore, you must define your area of examination -- Lower Coastal Plain, Middle Coastal Plain, Hilly C.P., Cumberland Plateau, Appalachians? Where? This in turn will key you in on Geology/Geomorphology, thus a broad perspective on soil associations. All of this **ANCILLARY INFORMATION** is **invaluable** in **PROBLEM-SOLVING THROUGH IMAGE ANALYSIS.**

   For example, if you know that your imagery is from the broad, undulating uplands of the Plateau proper, the associated soils are most likely Hartsells, Linker, and Enders, rocky phases. Soil fertility is low, moisture holding capacity is low to medium; desirable species for management are Loblolly pine, yellow poplar, Virginia pine, and shortleaf pine. Acceptable species would be white oak, SRO, Black Oak and N. Red Oak. SO -- if you identify a stand of Hickory, Sweetgum. Blackgum, Sourwood - your recommendation would probably be: 1. convert to pine, or 2. encourage red oak regen. -- **depending upon your management goals!**

   Another example -- you see a dense stand of 50 ft. conifers occupying a ridge above 4500 ft. altitude in the So. Appalachians: What is your best guess?? Red Spruce &/or Frazer Fir ... NOT loblolly/shortleaf/table mountain pine!!

VII. Rule of Thumb for Image Analysis

It would be difficult to single out any one object quality more important than the others. Identification depends upon a composite impression received by consideration of all. Perhaps a rule of thumb for interpretation might be given as follows:

1. Look at the entire area of coverage - Determine approximate location, general topography, rough scale. Where are you, what is dominant land cover type, is the terrain rolling or dissected; i.e., general landform? Large, small or medium scale imagery?

2. Assemble stereo-coverage around the object or feature of interest - examine the entire area covered by the photos; study the area as you gradually move toward the object.

3. Gradually narrow into an intensive examination of the object and the immediate vicinity of the object. Concentrate on detail on immediate area. Associative (or deductive) reasoning are very important.

4. If the ID is not apparent, go back to the entire overlap area and work your way in again, looking for keys, surrogates that might clarify the object - Associative or Deductive reasoning!!! O.K. - it **is** a structure, but what kind?? warehouse, sawmill, pulp mill, shopping mall, factory? The surrounding features should give you enough clues.

Just how would you tell the difference between a shopping mall and a factory of the same floor space? proximity to RRs and RR spurs, 4-lane highways, surrounding structures - urban, suburban, traffic - raw material piles, loading docks, heavy equipment].

VIII. Cultural Features - Geometric Shapes

A. "Linear" Features

Highway vs. Railroads - highways generally wider than R.O.W, shorter <u>tangents</u>, thus sharper curves - both horizontal and vertical curves. Tone is normally a poor characteristic because of variation in RR ballast; i.e., limestone, slag, gravel (explain tangents).

1. Primary highway - classify as to number of lanes and surfacing material. Asphalt dark tone, with ill-defined edges;

2. Secondary roads - gravel and dirt resemble concrete except edges are not well defined and roads are more narrow with sharper curves.

3. Railroads - long tangents, gentle <u>vertical</u> and horizontal curves. Rarely a true intersection; i.e., RR crossover; when there are crossovers, usually a wider road over a narrow RR and usually a different tone. Look back both "linear" features to observe characteristics.

4. Rights-of-Way - gas lines, generally wider than most transmission lines. Main distribution transmission line also wide. Look for periodic pumping stations or towers, or electric substations. REA lines generally straighter and more narrow than gravel, tertiary roads.

5. Canals or Channelized Creeks - usually dark toned water with light toned levees. Levees, however, may be partially or completely covered with vegetation. Cannot confuse with roads - look at gradients - streams won't run up over ridges.

6. Boundary trees and fence lines

7. Many other things can cause linear features. Surveyed and brushed lines, fire lines, etc. Some archaeological sites can also be identified by geometric patterns.

B. Structures. Also geometric shapes - linear or conic

In addition to size and shape, the location and identity of proximal objects or features is very important in correct ID. For example, a city has a certain internal spatial structure determined, to a large extent, by the location of particular socio-economic groups within the city. Most cities have distinguishable low, middle and high income residential areas bounding the city business district (CBD). Industrial and "strip" development usually occur on the periphery of the city. In older cities, however, there may be interior industrial complexes, particularly in the north.

1. Urban structures - residential, service (shopping centers), governmental, industrial - metal, metal fabricating, non-metallic chemical, textile, food. However, can ID only those types which have distinctive components or sub-units: i.e., black furnace, fractioning tower in petroleum. But to ID in 3 major groups - extractive, processing and fabricating (prod. or assembly of finished goods from materials produced by processing industry).

2. Rural Structures - farms and farm structures, nurseries, experimental farms, light industry (fabricating).

C. Agricultural Features - Patterns, Texture, Tones, Surrogate Features

1. Cropland - spring, tilled or in winter wheat. Summer Crops - raw or broadcast fall, harvest, crop residues.

2. Pasture or Hay Land - if pasture, animal marks, water bars, shade trees interior; light tone in drought and winter if improved pasture. Hay land usually lack animal marks, etc. May see hay bales (rolls) or machinery; hay

land usually smoother texture than pasture.

3. Fallow - weedy stage, then perhaps broom sedge, shrubs, then pine, gum, maple seedlings, etc.

4. Irrigated Cropland - tone dark if wet, light if dry - circular vs. ditch or other aerial.

B. Forestry Applications

1. Species compositon - Crown color/tone is <u>generally</u> **insufficient evidence** for ID - must use SITE, CROWN SHAPE/SIZE AND BRANCH CHARACTERISTICS as supplemental data. Exception - cypress/swamp tupelo gum (N. aquatica).

   Best time for hardwood species discrimination (general statement for MidSouth, but probably applies throughout Eastern and Southern U.S.) is <u>SPRING</u> before full leaf expansion; i.e., April/May, depending upon phenology; or <u>EARLY FALL</u> **before** onset of Fall leaf coloration - there is a period of chlorophyll shift prior to formation of the abscission layer where species differences are more reliable. Fall leaf coloration is deceptive both **within and between** species because of **<u>site differences</u> <u>and genetic differences</u>.**

2. Crown shape and size - Crown shapes are a function of branching habit and stand density: <u>excurrent</u> vs. "dendritic". Crown shape and size is a good indicator of species.

3. Tree height

4. Stand density

5. Site/location (topo position)

6. Drainage

General Points - in a closed pine stand, stand density/height plus **site characteristics** and **burn history** are surrogates of understory conditions. Corrollary - sparse stands will permit understory characterization, especially in LOWER MidSouth with evergreen/semi-evergreen understory species.

IX. Terrain and Drainage Analysis

References: Way, Douglas S. 1973. <u>Terrain Analysis: A Guide to Site Selection Using Aerial</u>

Photographic Interpretation. Community Development Series, Dowden, Hutchinson & Ross, Inc. Stroudsburg, PA

The Look of Our Land; An Airphoto Atlas of the Rural United States. U.S.D.A. Agricultural Handbook No. 384.

A landform is a terrain feature formed by natural processes, which has a definable composition and range of characteristics that occur wherever that landform is found. Landforms reflect similar surface and subsurface conditions. By identifying the landforms of a site, a resource manager can acquire an understanding of the physical conditions of the site and can adjust his management practices to in accordance with the potentials and limitations of the site. The aerial images used to identify landforms include:

topographic shape	erosional features
drainage pattern	landform boundaries
gully characteristics	land use types and distribution
photo color or tone	vegetation types and distribution

Drainage Textures. Drainage patterns are classified by their density of dissection, or texture, and by their type of pattern form. Drainage texture is indicated here by three categories, fine, medium, and coarse, based upon its appearance in photographs of 1:20,000 (1667 feet per inch).

Coarse-Textured (Figure 1). Coarse-textured patterns have first-order streams that are over 2 inches apart and carry relatively little runoff. These textures also generally indicate a more resistant bedrock which is permeable and which weathers to form coarse, permeable soils.

Medium-Textured (Figure 2). Medium-textured patterns describe channel spacing in which most first-order streams are from ¼ to 2 inches apart. The amount of runoff is medium, compared to that associated with fine and coarse textures. Soil textures are typically neither fin nor coarse but contain mixtures of materials.

Fine-Textured (Figure 3). Fine-textured patterns are those whose average spacing between tributaries and first-order streams is less than ¼ inch. Fine textured patterns typically indicate high levels of surface runoff, impervious bedrock, and soils of low permeability.

Drainage Pattern Types. An examination of drainage pattern types considers the entire drainage pattern, the gullies or first areas of channelized flow, the tributaries, and the major channels which themselves may be depositing eroded materials and forming surficial waterlaid landforms. The patterns discussed in this section include only the major categories.

Dendritic (Figure 4). The dendritic is the most common drainage pattern and is characterized by a treelike branching system in which the tributaries join the gently curving mainstream at acute angles. The occurrence of this drainage system indicates homogeneous, uniform soil and rock materials and is typified by the landforms of soft sedimentary rocks, volcanic tuff, dissected deposits of thick glacial till, and old, dissected coastal plains.

Pinnate (Figure 5). Pinnate patterns are actually modified dendritic patterns and indicate a high silt content of the soil; they are typically found in loess or fine-textured flood plains. Drainage follows a featherlike branching pattern in which tributaries intersect mainstreams at angles that are slightly acute upstream.

Rectangular (Figure 6). Rectangular patterns are also variations of a dendritic system. Here the tributaries join the mainstream at right angles and form rectangular shapes controlled by bedrock jointing, foliations, or fracturing. The stronger or more harsh the pattern, the thinner the soil cover. These patterns are often formed in state, schist, and gneiss, in resistive sandstone in arid climates, or in sandstone in humid climates if little soil profile has developed.

Angulate (Figure 7). The angulate pattern is a variation of the dendritic or trellis system in which faults, fractures, or jointing systems have modified the classic form. Sharp, angular bends are common in the mainstream; tributaries demonstrate control by rock features. The type and direction of angulations may also indicate specific rock type. For example, sandstone tends to develop parallel jointing patterns, while limestone develops joints that intercept one another at acute angles.

Trellis (Figure 8). Trellis patterns are modified dendritic forms with parallel tributaries and short parallel gullies occurring at right angles. This pattern indicates a bedrock structure rather than a type of bedrock and usually indicates tilted, interbedded, sedimentary rocks in which the main, parallel channels follow the strike of the beds.

Barbed (Figure 9). These patterns occur within other drainage systems that have been modified through warping or topographic uplift. The resulting barbed or spurred appearance indicates a degree of tectonic disruption.

Deranged (Figure 10). These patterns represent nonintegrated drainage systems resulting from relatively young landform having flat or undulating topographic surface and a high water table. Depressions contain swamps, bogs, marshes, bonds, or lakes. Regional streams may meander through the area but do not influence its drainage. These forms commonly occur on young, thick, till plains, end moraines, and flood plains.

Parallel (Figure 11). Parallel drainage systems develop on homogeneous, gentle, uniformly sloping surfaces whose main collector streams may indicate a fault or fracture. Tributaries characteristically join the mainstream at approximately the same angle. Such landforms as young coastal plains and large basalt flows are excellent regional examples of this drainage pattern.

Radial (Centrifugal)(Figure 12). A circular network of almost parallel channels flowing away from a central high point characterizes this pattern. A major collector stream is usually found in a curvilinear alignment around the bottom of the elevated topographic feature. Volcanoes, isolated hills, and domelike landforms exhibit this type of drainage network.

Annular (Figure 13). This type of pattern is developed on topographic forms usually similar to those associated with radial patterns, but in this case the bedrock joints or fracturing control the parallel tributaries. Granitic or sedimentary domes may develop this type of pattern.

Centripedal (Figure 14). This pattern is a variation of the radial system in which the drainage is directed downward toward a central point. This form generally indicates a basin or sink depression, or the end of an eroded anticline or syncline.

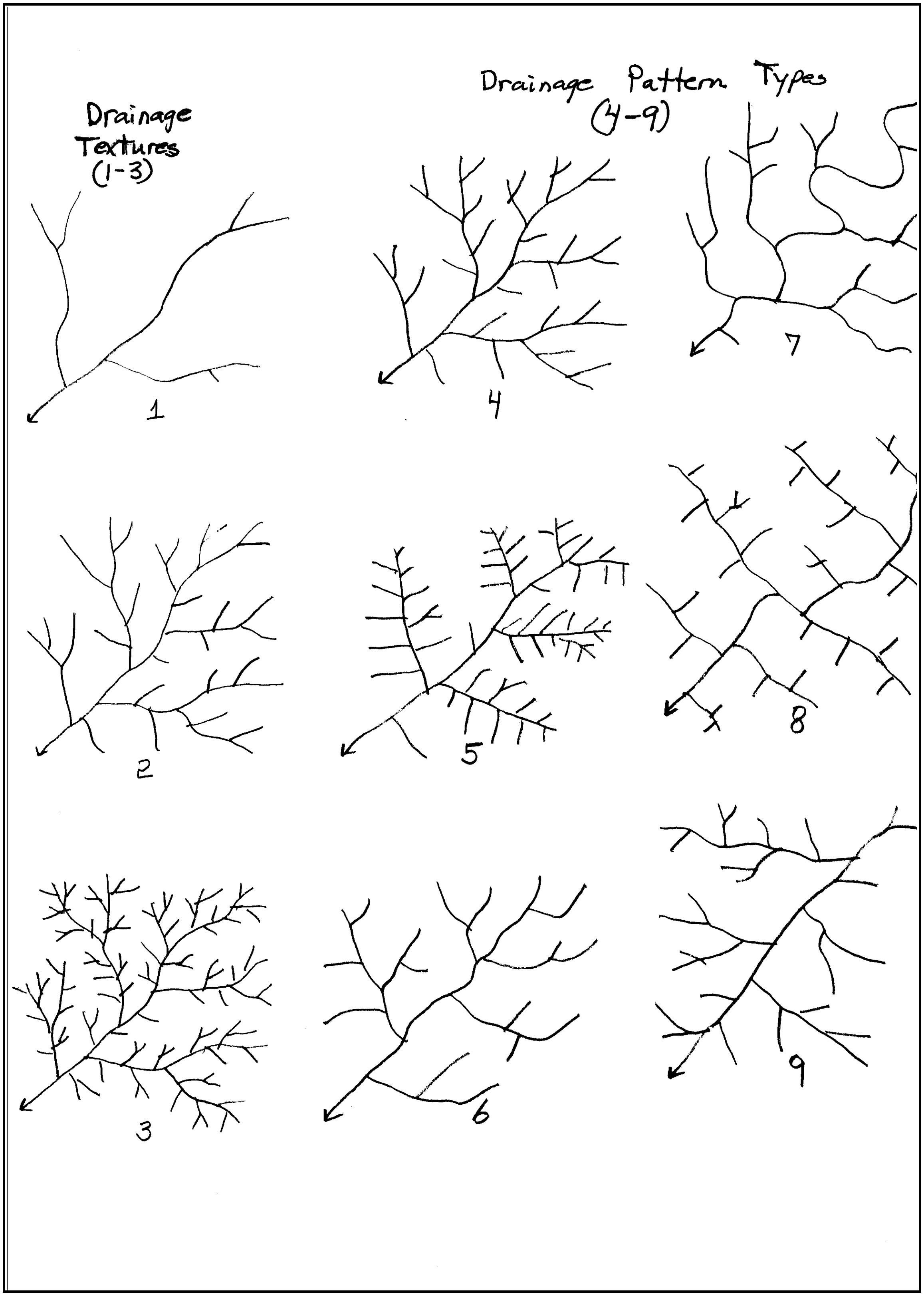
Thermokarst (Figure 15). These patterns develop in poorly drained, fine-grained sediments and in organic materials in regions of permafrost. Freezing causes many cracks to develop and thawing causes slumping settlement, and depressions. Streams crossing the area may connect rounded "button" depressions, exhibiting a beaded appearance. This type of drainage pattern with its associated hexagons and beaded ponds indicates the existence or precious presence of permafrost conditions (Figure 17). Table 1.1 lists other examples of permafrost features.

Braided (Figure 16). Braided patterns develop locally and do not represent a regional, integrated drainage system. They develop in the bottom of major stream channels and indicate coarse soil materials and unstable shifting channels.

Artificial (Figure 17). In humid climates in landforms of flat topography occupying low positions, there may be artificial drainage structures built in an attempt to lower the elevation of the water table. Dead furrows and ditches in fields and along roads indicate this condition; these are commonly found in glacial lake beds and low, broad flood plains. Irrigation ditches found in arid and semiarid climates, which bring water into the fields, should not be confused with drainage structures.

None. Small landforms with insufficient watersheds may not develop any drainage pattern. Landforms that typically do not develop drainage patterns are individual sand dunes, drumlins, eskers, kames, and igneous dikes.

Internal. The lack of an integrated drainage system is significant in the identification of landforms and parent materials. It is usually associated with granular materials having high permeability, with porous rock materials, or with soluble rock forms having underground drainage channels. Landforms with this apparent lack of surface drainage include limestone, coral, outwash terraces, alluvium, beach ridges, and sand dunes.


Drainage Textures (1-3)
Drainage Pattern Types (4-9)
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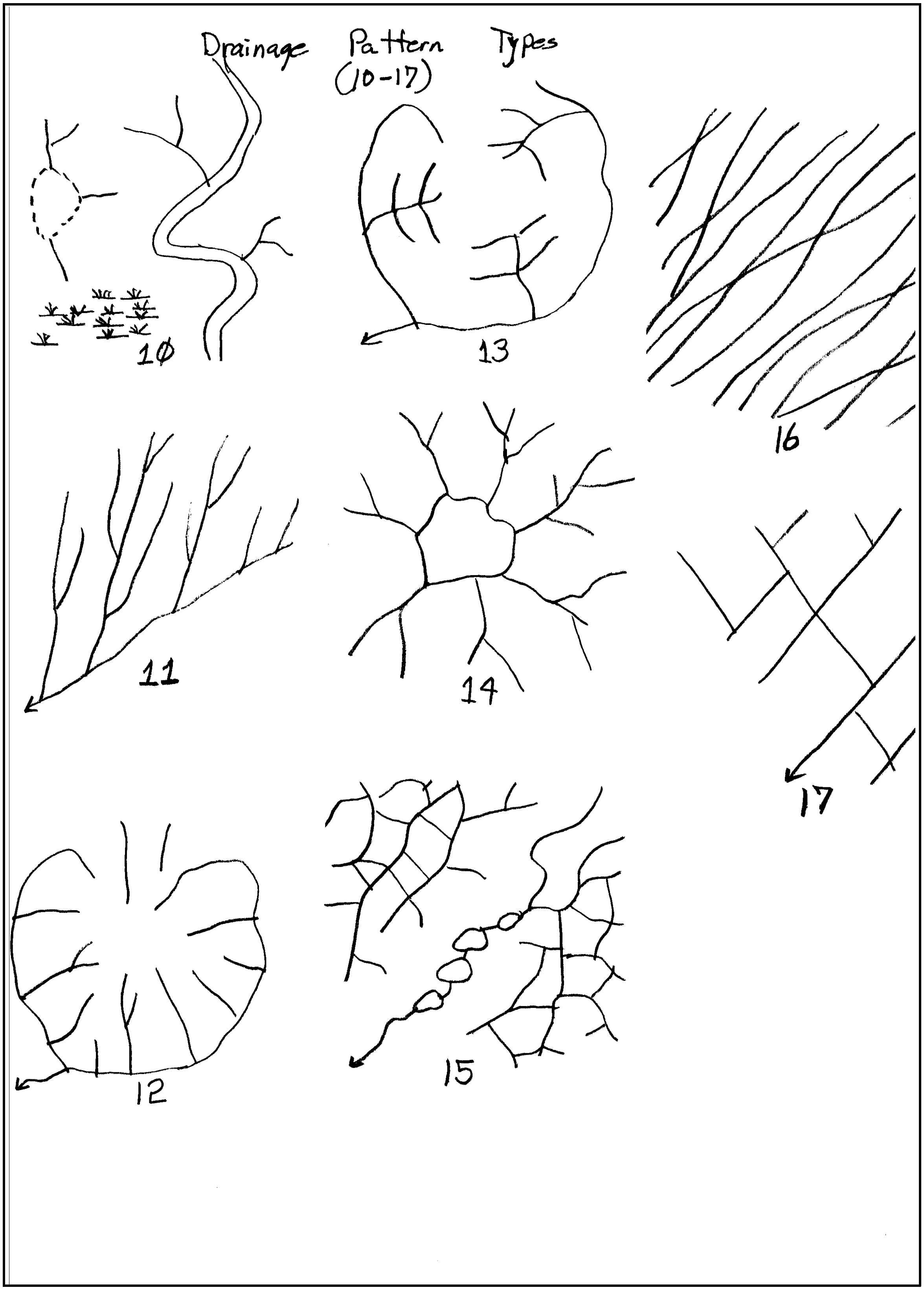

Drainage Pattern Types
(10-17)
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