LECTURE 7

USE AND INTERPRETATION OF AERIAL PHOTOGRAPHS - II

LECTURE OUTLINE

7.0 INTRODUCTION

In the previous lecture, you have learned important uses and features of aerial photographs. Using the pocket or mirror stereoscope, you learned how you could use the combination of relief and tonal variations in photographs to interpret the general geology of a given area.

Equipped with that knowledge, you are now ready to carry out the interpretation of aerial photographs for various structures and lithologies occurring in the field. Lecture 7 will provide you with the knowledge of how to recognize and interpret structures like beddings, dips, foliations, folds, faults, joints and other lithological characteristics in aerial photographic images. You will learn how to distinguish between sediments and meta-sediments, intrusive and extrusive igneous rocks, transported and residual superficial deposits. I believe this lecture will be another exciting chapter that will equip you with the necessary knowledge that will assist you to interpret the ground geology using the remotely sensed data from space – i.e., by the use of aerial photographic images.

7.1 OBJECTIVES

Objectives

At the end of this lecture you should be able to:

(a). Describe the distinguishable features that identify structures such as bedding, foliations, folds, faults, joints, etc and other lithological bodies in aerial photographs.

(b). Derive a probable photogeological legend in the interpretation of aerial photos.

(c). Distinguish the characteristic appearance of intrusive and extrusive acidic or basic igneous bodies in aerial photographs.

(d) Differentiate the characteristic features of sediments and metamorphosed sediments in aerial photos.

(e). Distinguish between residual and transported deposits as observed in aerial photographs.

7.2 INTERPRETATION OF STRUCTURES

The interpretation of geological structures using aerial photographs is an important exercise that can aid in deciphering the stratigraphy and geological history of a given region. The following sections discuss the distinguishing features of common geological structures such as beddings, folds, faults, joints etc. as observed in aerial photographs.

7.2.1 Bedding

Dipping heterogeneous sediments or meta-sediments are commonly depicted on a stereo model as a number of parallel ridges and valleys. This is due to the effect of differential erosion on dissimilar lithologies because rocks that differ in mineral constituents also differ in their erosional qualities. Resistant beds tend to form ridges along the lengths of their outcrops whereas the more easily eroded beds tend to form valleys. In addition, beds that differ in their mineral constituents also differ in their colour and reflectivity and this is portrayed by the difference in tone of these beds.

The lineaments resulting from a number of conformable, and dipping heterogeneous sediments or meta-sediments can be expected to show some or all of the following characteristics:

- Lineament should be continuous or persistent on the whole rock outcrop even though they may be short or interrupted by such features as joints.
- They should be approximately parallel to one another. An abrupt cessation of this parallelism provides evidence of other structures.
- They tend to be found in groups rather than singly.
- They tend to be definite and limited in number.

The fact that bedding structures are definite and limited in number distinguishes them from the lineament resulting from foliation, which in aerial photographs appears indefinitely thin and unlimited in number. For horizontal bedded sediments and those of low dips, a shape outcrop approximates the shape of the prevailing contours.

Outline the characteristics of dipping heterogeneous sediments as observed in aerial photographs

7.2.2 DIP

Dip slopes provide the most reliable indication on the direction of dip available to the photo geologist. Dip slopes (see Fig. 7.1) are often reliably recognized in stereo model than in the field. This is because a large part of the dip slope can be seen simultaneously and can be compared with other horizons with same group of sediments. However, the actual value of the dip is approximated and this is often in the ranges: < 10^o, 10 – 25^o, 25 – 45^o, < 45, and < 90^o dips.

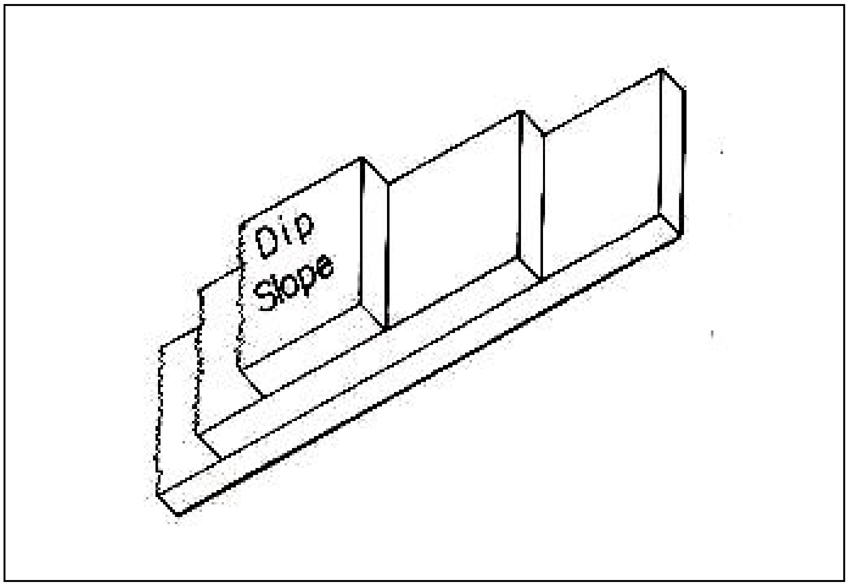

Fig. 7.1 Illustration of a Dip slope

7.2.3 FOLIATION

The term foliation is used to cover all types of mesoscopically recognizable S–surfaces (schistose) of metamorphic origin. The foliation or S–surfaces may result from:

- Lithological layering or preferred dimension of orientation of mineral grains
- Mineral grains
- Surfaces of physical discontinuity such as banded gneisses.

Lineament resulting from foliation tends to show some or all of the following characteristics:

(i) Tend to be parallel unless distorted or faulted by subsequent movements after their formation.

(ii) They are normally very numerous because the number of foliation planes in rock outcrops is often large. Hence foliation lineaments in photographs are very large.

(iii) The lineaments are short

(iv) They do not consist of long continued ridges or valleys like beds of bedding lineaments.

Generally it is believed that major lineaments represent beds and minor lineaments represent foliation.

7.2.4 FOLDS

Folds are wavelike bends in rock layers resulting from compression of the crust. Originally horizontal strata move up and down in response to compression to accommodate shortening of the crust. Folds range in size from millimeters to hundreds of kilometers in length and have various shapes. There are three main types of folds, based on their shapes:

- A ***monocline*** is a one-sided fold that typically occurs in flat-lying strata of stable continental areas.
- An ***anticline*** is an upward-closing fold with the deepest (and therefore oldest) rock layers in the center.
- A ***syncline*** is a downward-closing fold with the uppermost (and therefore youngest) rock layers in the center.

In anticlines and synclines the rock layers dip away from and toward, respectively, a central line of greatest curvature called the ***fold hinge***. The hinge is at 90^{o} to the direction of maximum compression. Anticlines and synclines are generally adjacent, forming alternating crests and troughs in the rock layers. Monoclines, anticlines, and synclines are illustrated in Figure 7.2. The hinges are the straight lines along crests and troughs of the folds.

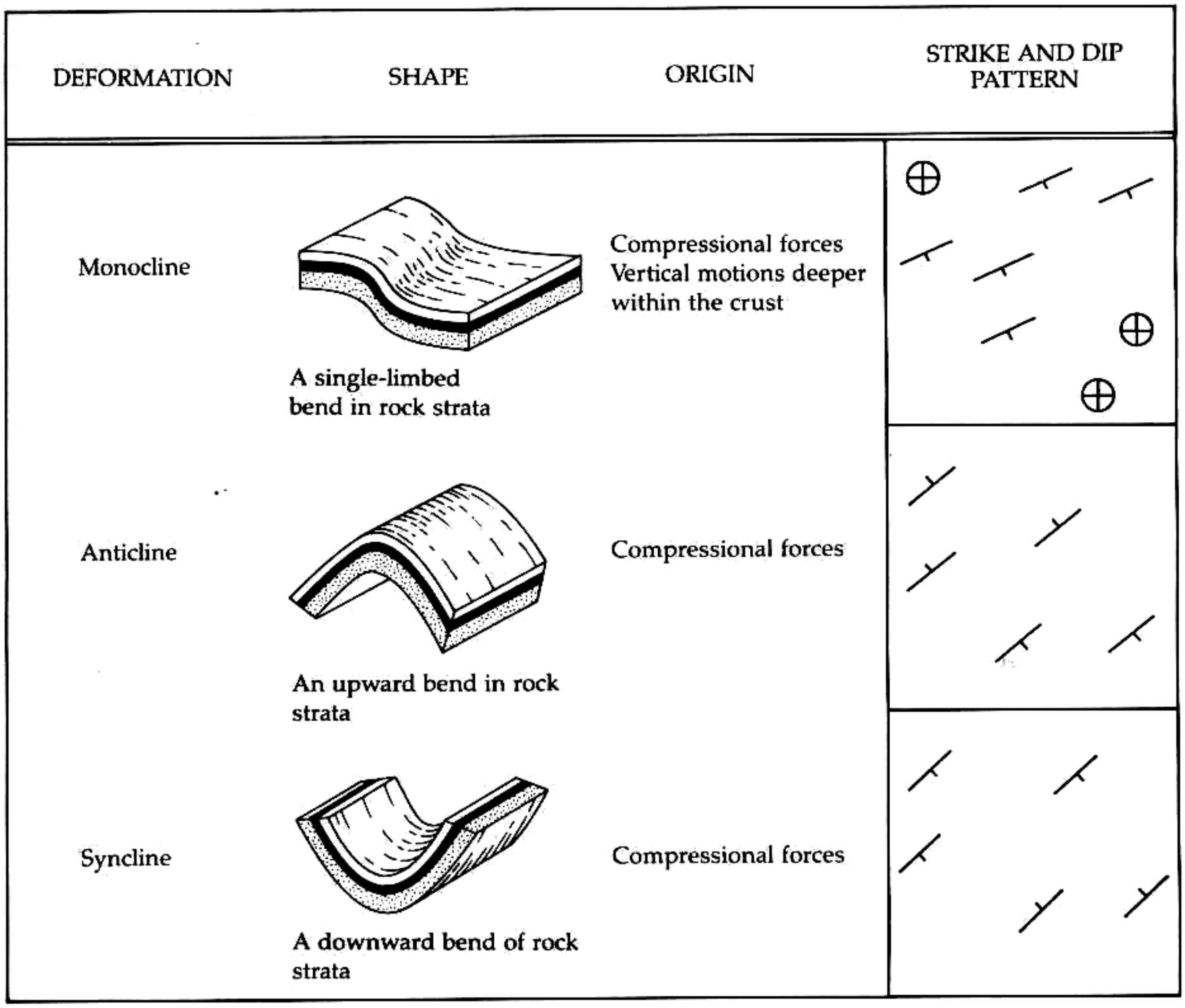

Figure 7.2. Types of folds.

Basins, ***domes***, and ***plunging folds*** are variations in the anticline and syncline fold shapes. Basins and domes are downward and upward bends that lack a linear hinge. They are oval or bowl-shaped, such that the strata dip away from or toward, respectively, a point rather than a line. Basins and domes, unlike most other folds, need not form solely from compression but may be due to a variety of factors. Plunging folds are anticlines that have a tilted hinge. These folds are illustrated in Figure 7.3.

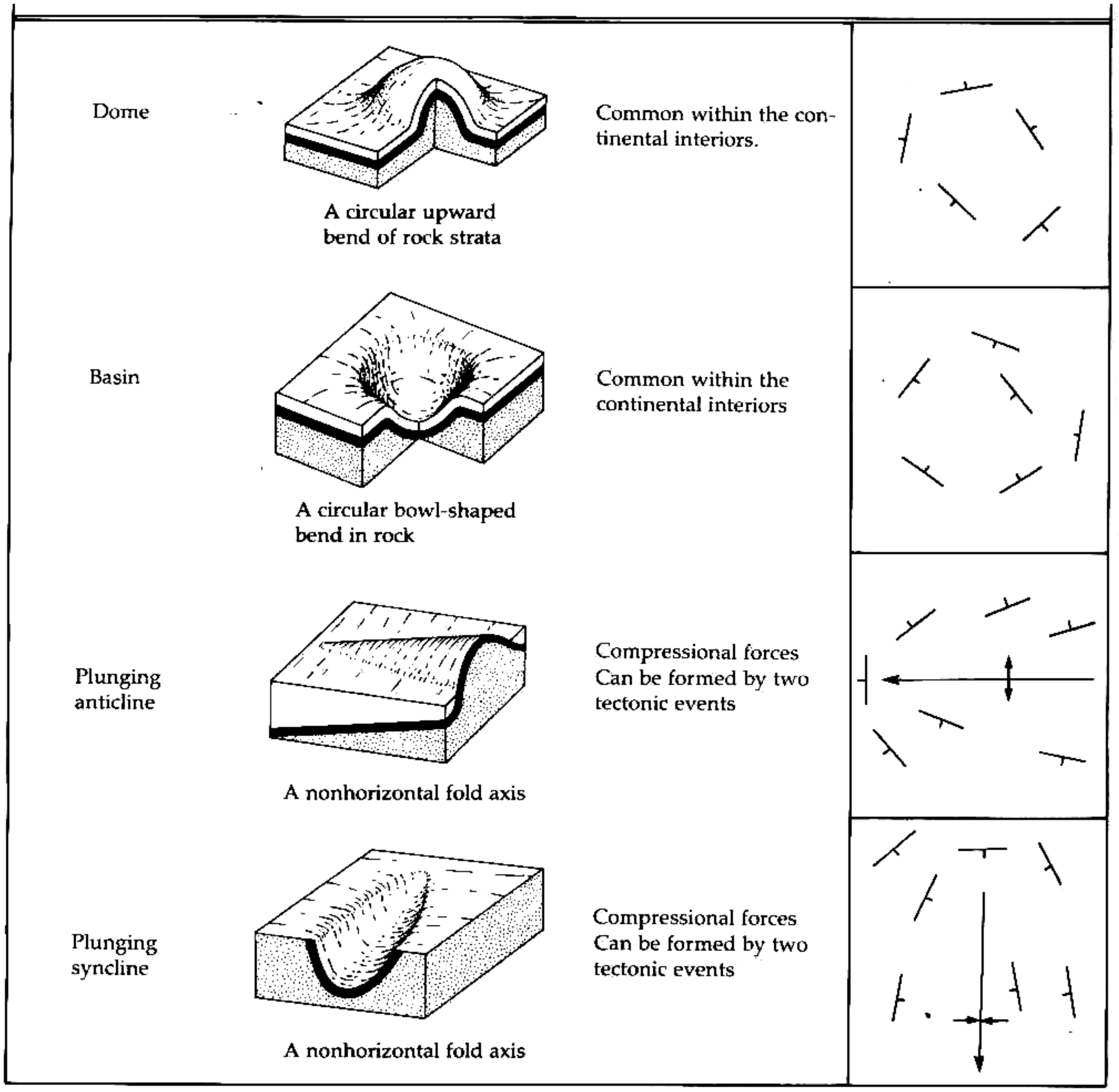

Figure 7.3. Subsidiary fold types.

Where the photograph indicate the direction and amount of dips or beds (see Fig. 7.1), it is possible from photo geological evidence alone to map the approximate position of the axial–trace of a fold and occasionally estimate its amount of plunge. By plotting bedding traces on aerial photographs, it is also possible to prove the presence of repeated folding (Fig. 7.4).

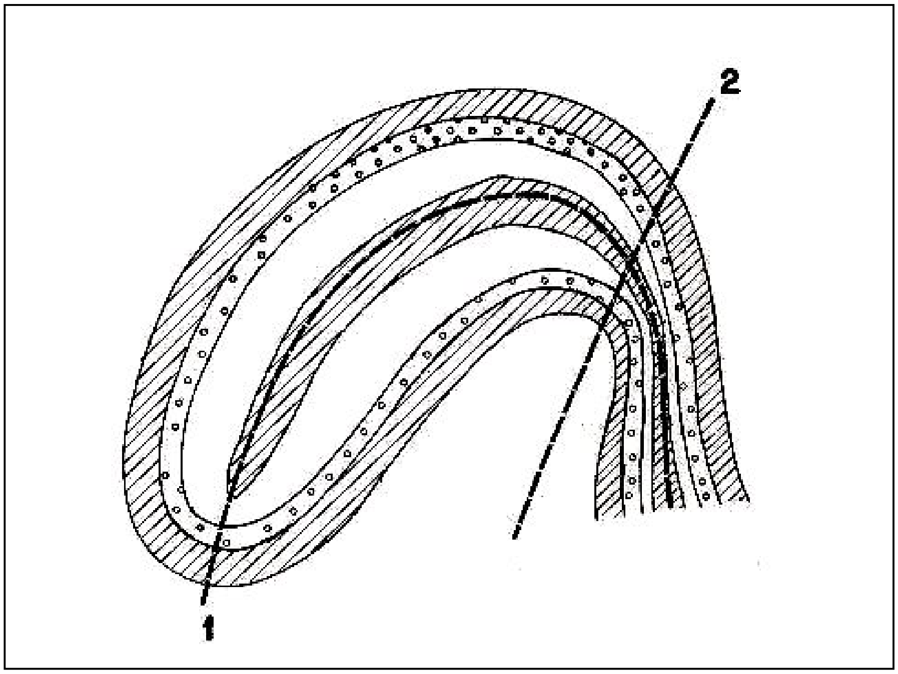

Fig. 7.4. Repeated folding event: **1**. Axial trace of the first folds; **2-** axial trace of the second folding.

Sometimes folds are depicted by vegetation following trends of beds, which are already folded as exemplified in Figure.7.5.

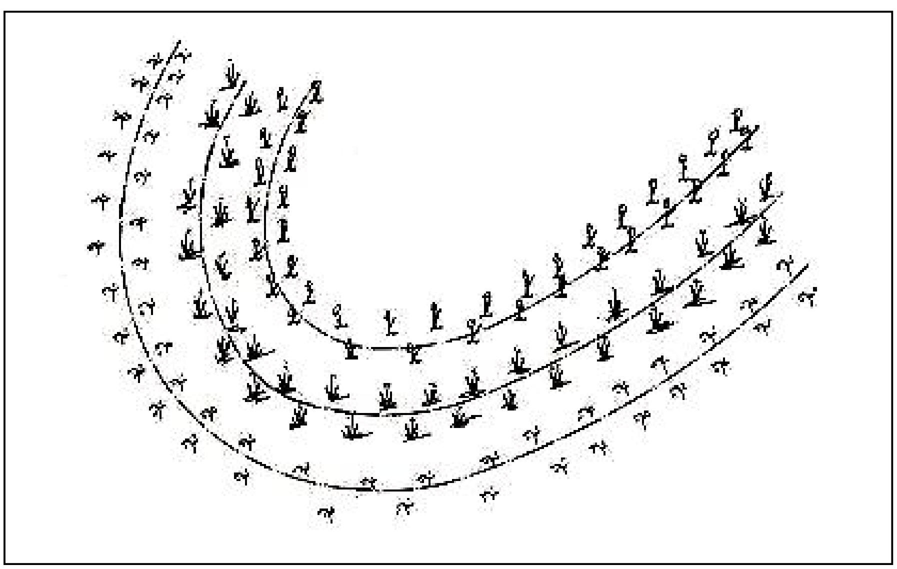

Fig. 7.5. Fold depicted by trends of vegetation pattern.

7.2.5 FAULTS

A fault is defined as a fracture along which there has been a slipping of rock masses against one another. Characteristically, they often form more or less straight negative feature (i.e. easily erodable) in the earth's crust and occasionally positive ones (i.e., more resistance rock units, see Fig. 6.6) if dykes and other intrusions occur along them. Before a lineament can be interpreted as a fault ***there should be evidence of movements***. In most areas, this evidence is shown by termination or displacement of other structures. However, displacement is a more reliable criteria. This is because termination can be caused by other structures besides faults. The displacement and termination can be of structures like:

(i) Dykes
(ii) Other faults
(iii) Intrusive contacts
(iv) Geological boundaries or beds
(v) Topography

> When the interpretation of a major lineament is in doubt, it is advisable to study all structures on both sides of the lineament, with care to see whether all the evidence considered simultaneously point to the presence of a fault.

7.2.6 JOINTS

Joints are characteristically represented on stereo models as straight negative features. They are thus similar in photographic appearance to faults. However joints are distinguished from faults in the sense that they don't cause any relative movement on both sides of any joint lineament unlike the case of faults.

7.3 LITHOLOGICAL BOUNDARIES

From the evidence provided by aerial photos, we shall address the issue of how lithological boundaries are delineated and interpreted as discussed in section 7.2.1 and section 7.2.2 here below.

7.3.1 Delineation Of Rock Boundaries

In most areas that are being fairly actively eroded, it is possible to differentiate the dissimilar rocks on aerial photos even though it is not possible to decide what the rocks consist of. It has also proved possible from the evidence provided by aerial photos to subdivide rocks that appear indistinguishable in the field. An example of this was the establishment of concentric ring dykes of the Chambe plateau in Malawi. In the field, the ring dykes with a central plug were not apparent but this was clear in the photos. An extensive collection of specimens for detailed study was done including petrographic investigations. The rings were established to be present and were found to be of different systematic composition. In general the lithological boundaries can be delineated in aerial photos after establishing the different beds. For example, this can be established from the:

- Differences in relief or tone of the beds
- Differences in structures such as joints or foliations that may occur in some beds but lack in others.

7.3.2 Lithological Interpretation

Lithological interpretation refers to the recognition of rock types from photo-geological data rather than geological data by field experience alone. The approach recommended combines geomorphology and structural analysis with the use of a generalized geological legend. In this case, each outcrop represented in the stereo model is considered in its local and regional geological environment. There is no first hand rule routine of interpretation but the following stages are typical:

(i) Recognition of climatical environment e.g. temperate, tropical rain forest, savannah, desert etc.

(ii) Recognition of the erosional environment e.g. very active, active or inactive.

(iii) Recognition and connotation of the bedding traces of the sediments or meta-sediments.

(iv) Recognition and delineation of areas with outcrops that do not indicate bedding. These could represent intrusions, horizontal bedded sediments or meta- sediments.

(v) Recognition and delineation of superficial cover that do not indicate bedding.

(vi) A restudy of the bedding traces around the fault noses to determine where possible the approximate position of axial traces.

(vii) Study lineaments that traverse the bedding traces to determine whether they represent faults, dykes, joints or a combination of these.

7.4 GENERALISED PHOTOGEOLOGICAL LEGEND

A photo-geological legend is used to assist in arranging the observable interpretative geological information in an aerial photograph in an orderly format. Except in the case of certain sediments that can be recognized specifically, a generalized photo-geological legend should indicate the type of rock (igneous, metamorphic, or sedimentary) rather than the name of the rock. The various groups of meta- sediments should be represented by numbers rather than by names of doubtful accuracy.

In general, the following features can be deduced from a normal aerial photograph:

- The photographic tone of rock body relative to that of the adjacent rock.
- Its resistance to erosion relative to the adjacent rocks
- Boundary of the whole rock body
- Its topographic expression as a whole
- The boundaries of individual outcrops
- The joint pattern
- The vegetation cover
- The bedding or the relict bedding lineament
- The fault pattern
- The regional geological environment
- The foliation lineament

- The drainage pattern - within the drainage basin, small channels called tributaries coalesce to form larger channels, which coalesce to form one large stream in an arrangement called ***drainage pattern.*** Drainage patterns may take several forms, depending on the nature off the underlying rock, the slope of the drainage basin, and the amount of rainfall. Figure 7.5 illustrates several kinds of drainage patterns.

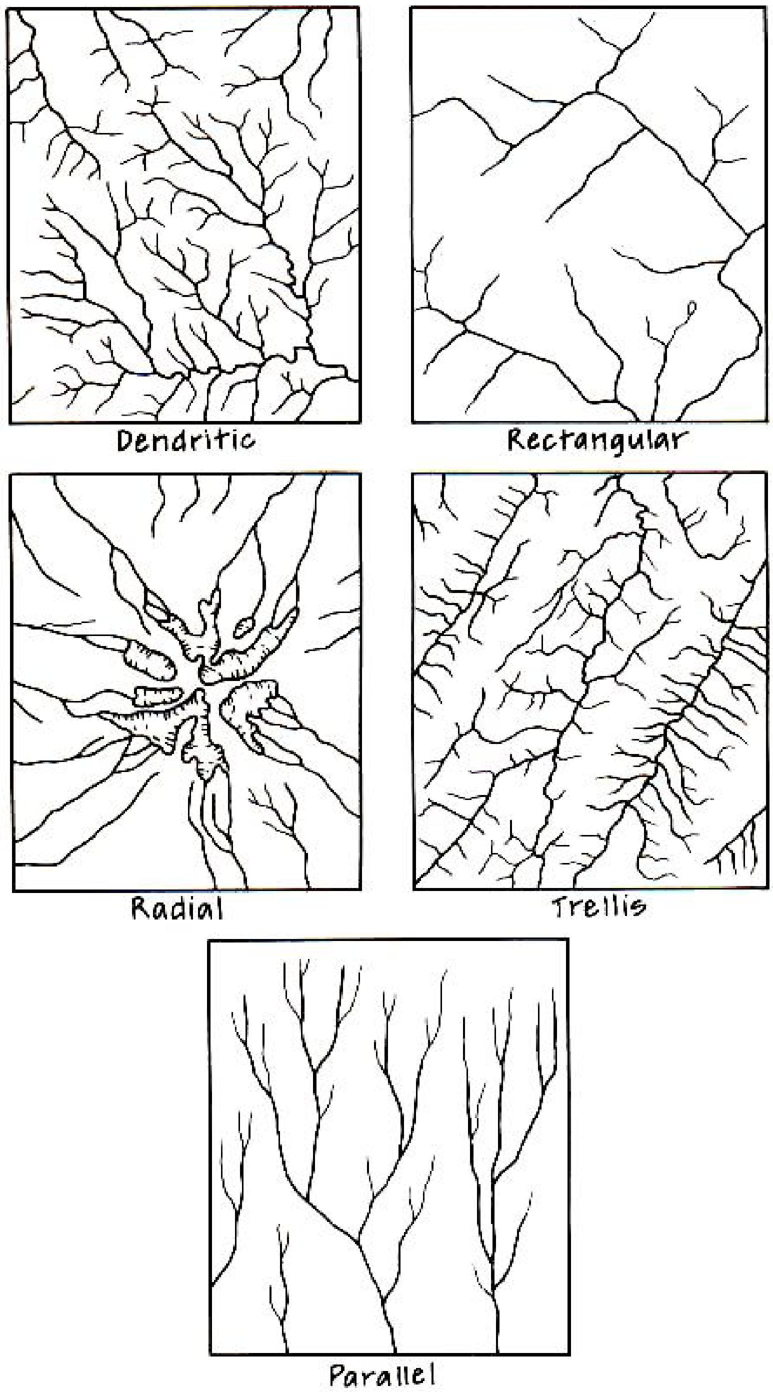

Figure 7.5. Common drainage patterns.

With respect to a generalized photo-geological legend, an example is presented in Table 7.1.

Table 7.1 Generalized photo-geological legend

Reference Number	**Description of observed geological feature**
1.	Superficial – Transported, residual
2.	Sediments – list in groups 1, 2 , 3 etc
3.	Meta sediments – groups 1, 2, 3 etc undifferentiated
4.	Permeation gneisses and migmatites
5.	Granitic rocks – these are mostly granites and granodiorites that in general are intrusive or autochthonous (in situ).
6.	Intrusive rocks – basic, acid
7.	Extrusive rocks – basic, acid
8.	Dykes – acid; basic, and general (i.e. intermediate between acid or basic)

7.5 SEDIMENTS AND META SEDIMENTS

Sediments are recognized on aerial photographs by their layered appearance. In general, these layering are represented by variation in both relief and tone and occasionally by any of them. In most areas, it is possible to differentiate between metamorphosed and un-metamorphosed sediments because metamorphism makes individuals beds in a pile of sediments more nearly equal in their resistance to forces of erosion. Hence, dipping meta-sediments tend to form ridges that are more rounded and subdued than those produced by un-metamorphosed sediments of similar dip.

If layered rocks are steeply dipping, tightly folded and associated with multiple intrusions, then metamorphism should be suspected. Conversely, flat land or gently layered rocks that are not associated with intrusions are less likely to be metamorphosed. In areas where both sediments and meta-sediments occur, lithological dissimilarity and structural discontinuity of the two rock groups makes their differentiation obvious.

Give a descriptive criterion that can be used to differentiate between metamorphosed and un-metamorphosed sediments in aerial photographs.

7.6 INTRUSIVE ROCKS

It is after a rock has been recognized as intrusive on structural ground that an attempt is made to decide whether it is an acidic or basic. If any part of the rock body is completely exposed, then the relative photographic tone may prove diagnostic.

7.6.1 Basic and Acid Intrusive bodies

On aerial photographs, the appearance of large scale rectangular jointing is commonly associated with acid rather than **basic** intrusive rocks. Basic intrusive rocks show generally dark tones. On the other hand, a**cid** intrusive rocks are typically relatively light toned and rectangularly jointed. They offer more resistance to erosion than the country rocks and form positive features. In general, the geological boundary of acid intrusive bodies with the country rock is curved because of their intrusive nature.

Explain why acid intrusive rocks show a more resistance feature to erosion than their basic counterparts.

7.6.2 Dykes

Because dykes are bodies of rocks that have been intruded along fractures or planes of weakness in the earth’s crust, many of them have some of the characteristics associated with joints or faults. Dykes are best distinguished when they show:

- A variation in tone, vegetation or relief with the country rocks
- Both positive and negative relief features

7.7 EXTRUSIVE ROCKS

Basaltic lava flow tends to show a relatively dark appearance. On the other hand, rhyolitic lava flows (with increased silica content) show relatively light toned appearances. Where extruded to cover underlying rocks e.g. sediments, the unconformable nature between the overlaying overflows and the underlying rock of section of the two rock groups is an important structural distinguishing criteria. However, the recognition of volcanic cones in aerial photographs is of great assistance in the interpretation of extrusive rocks.

7.8 SUPERFICIAL COVER

For photo-geological purposes, superficial cover is conveniently classified into two groups:

- Transported
- Residual

7.8.1 Transported Superficial Cover

The transported superficial cover is usually recognized or associated with the following characteristics:

i) It's almost total blanketing effect on the underlying geology. Structures in the underlying geology are not normally shown through transported superficial cover.

ii) The association of the cover with its means of transport e.g., river.

iii) Association of the cover with diagnostic land forms such as sand dunes, screes, meander belts, river terraces, river deltas, eskers and moraines. For example, photographs taken from high-flying aircraft reveal much about distribution of large tracts of desert sand. Some of these massive sand areas contain dunes that clearly reflect the direction of prevailing winds, but others consist of highly complex dunes that are difficult to interpret in terms of prevailing winds (Fig. 7.6).

iv) Its relatively sharp boundaries

> As soon as transported superficial cover is suspected, the question of its mode of transport should be considered.

7.8.2 Residual Superficial Cover

The residual superficial cover, which includes laterites and soils, has the following photo-geological characteristics;

i) It does not tend to blanket completely the underlying geology. Because it is formed in places from the underlying rocks, its composition and texture tend to reflect the underlying geology in some way.

ii) No means of transport for the cover can be recognized

iii) In places it appears to have gradational boundaries with rocks outcrops

ACTIVITY

1. List three distinctive characteristics of (i) transported and (ii) residual deposits in aerial photographs

2. Outline characteristics of extrusive igneous rocks in aerial photos.

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7.9 Summary

In this lecture it was noted that the interpretation of geological structures using aerial photographs is an important exercise that can aid in deciphering the Stratigraphy and geological history of a given region. Important distinguishing features of common geological structures such as beddings, folds, faults, joints etc. were described and illustrated as observed in aerial photographs. For example, dipping heterogeneous sediments or meta-sediments are commonly depicted on a stereo model as a number of parallel ridges and valleys. On the other hand, lineament resulting from foliation tends to be parallel unless distorted or faulted by subsequent movements after their formation, are short, and they do not consist of long continued ridges or valleys like beds of bedding lineaments.

It was further noted that before a lineament can be interpreted as a fault, *there should be evidence of movements*. In most areas, this evidence is shown by termination or displacement of other structures such as dykes, other faults, intrusive contacts, geological boundaries or beds.

On delineation of rock boundaries, this lecture showed that it is possible to differentiate the dissimilar rocks on aerial photos based on differences in relief or tone of the beds, as well as on differences in structures such as joints or foliations that may occur in some beds but lack in others.

Sediments are recognized on aerial photographs by their layered appearance. In general, these layering are represented by variation in both relief and tone and occasionally by any of them. On the other hand, dipping meta-sediments tend to form ridges that are more rounded and subdued than those produced by un-metamorphosed sediments of similar dip.

This lecture was able to show the characteristic appearance of both basic and acidic intrusive and extrusive rock bodies. On aerial photographs, the appearance of large scale rectangular jointing is commonly associated with acidic rather than **basic** intrusive rocks. Basic intrusive rocks show generally dark tones. On the other hand, a**cidic** intrusive rocks are typically relatively light toned and rectangularly jointed. They offer more resistance to erosion than the country rocks and form positive features. For extrusive igneous rocks, basaltic lava flow tends to show a relatively dark appearance. On the other hand, rhyolitic lava flows (with increased silica content) show relatively light toned appearances.

We noted in this lecture that a photo-geological legend is used to assist in arranging the observable interpretative geological information in an aerial photograph in an orderly format. Except in the case of certain sediments that can be recognized specifically, a generalized photo-geological legend should indicate the type of rock (igneous, metamorphic, or sedimentary) rather than the name of the rock of doubtful accuracy.

For most photo-geological purposes, it was noted that superficial cover is usually classified into two groups, namely: transported and residual. The transported superficial cover is usually recognized or associated with the following characteristics: an almost total blanketing effect on the underlying geology where the structures in the underlying geology are not normally shown; the association of the cover with its means of transport e.g., river; association of the cover with diagnostic land forms such as sand dunes, screes, meander belts, river terraces, river deltas, eskers and moraines; and it's relatively sharp boundaries.

On the other hand, residual superficial cover, which includes laterites and soils, has the following photo-geological characteristics: It does not tend to blanket completely the underlying geology; No means of transport for the cover can be recognized; and in places it appears to have gradational boundaries with rocks outcrops.

7.10 References

REFERENCES

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Atkin, B.C and Johnson, J.A. (1988). The Earth- Problems and Perspectives. Blackwell Scientific Publishers, pp 428.