PART C

CHAPTER VIII

Application of Remote Sensing: Landsat Imageries and Aerial Photographs

APPLICATION OF REMOTE SENSING TECHNIQUES AND AERIAL PHOTOGRAPH INTERPRETATION IN LANDFORM ANALYSIS OF MAYURBHANJ UPLAND

Remote Sensing may be defined as the science and art of obtaining information about an object, area or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area or phenomenon under investigation (Lillesand and Kiefer, 1979). In remote sensing techniques, use of various sensors are done to remotely collect data that may be analysed, and also to obtain information about the objects, areas or phenomena being investigated. Of late, technicians have started operating electromagnetic energy sensors from airborne and spaceborne platforms to assist in inventorying, mapping and monitoring earth resources associated with various surface features. These sensors acquire data on the way when various earth surface features emit and reflect electromagnetic energy and these data are analysed to provide information about the resources under investigation.

The two basic processes involved in remote sensing are : (a) data acquisition and (b) data analysis.

(a) The elements of the process of data acquisition are : energy sources, propagation of energy through atmosphere, energy interactions with earth surface features and air-borne and/or space-borne sensors which result in the generation of sensor data in pictorial and/or numerical form. In brief, sensors are used to record variations in the way earth surface features reflect and emit electromagnetic energy.

(b) The data analysing process involves examining the data using various viewing and interpretation devices to analyse pictorial data, and/or computer to analyse numerical sensor data. Reference data about the resources being studied (such as soil maps, crop statistics, or field check data) are used when and where available to assist in the data analysis. With the aid of the reference data, the analyst extracts information about the type, extent, location and condition of the various resources over which the sensor data were collected. This information is then presented, generally in the form of maps, tables, and a written discussion or report. Typical information products are such things as landuse maps and crop area statistics. Finally, the information is presented to users who apply it to their decision-making process.

In any approach to applying remote sensing, not only must the right mix of data acquisition and data interpretation techniques be chosen, but the right mix of remote sensing and 'conventional' techniques must also be identified. It must be recognized that remote sensing is not an end in itself but is applied in concert with others. However, when remote sensing is used properly, one can often obtain a better view of the topography and associated environment than he could through any other method of observation.

Remote sensing affords us the capability to literally see the invisible. From remote sensing's aerial or space vantage point we can obtain a synoptic (even global) view of earth resources. We can begin to see components of environment on an 'ecosystem basis' so that remote sensing data can transcend the cultural boundaries within which much of our current resource data are collected. Remote sensing also transcends disciplinary boundaries. It is so broad in its application that no body 'owns' the field. Important contributions are made to and benefits derived from remote sensing by both the <u>pure</u> scientists interested in basic research and the <u>applied</u> scientists interested in operational application.

<u>Remote Sensing and Space Exploration</u> :

The merger of two disciplines of remote sensing and space exploration and the combination of two technologies have enabled man as a researcher to study the earth from space and this technique has evolved from the realm of pure research to that of world-wide, day-to-day application. This technique helps man in various types of work ranging from topographic analysis, mineral exploration, crop production, weather forecasting to even deep-sea fishing and pollution detection etc.

In the present work the author has studied the landsat imagery of the Mayurbhanj Upland for the analysis of the major topographic features of the area which provide the background to resource inventory in such a remote area and therefore, before describing the results obtained by the application of the method, perhaps it will be convenient to mention a few words regarding the early history of development of remote sensing from space as well as the various techniques used in the interpretation of imageries.

Early Experiments :

The subject received its first impetus through remote sensing from rockets as early as 1891 when a private concern in Germany sent a rocket-propelled camera system to space in order to get a bird's-eye photographic view. Arrangement was made to recover the camera by parachute. Within next 16 years the concept of gyrostabilization to rocket camera system was introduced and after about five years a huge camera system, weighing 41 kg was sent successfully to a height of 790 metres.

The first attempt of remote sensing in true sense from space was made during 1946-1950 when V-2 rockets fired from New Mexico carried small cameras. During succeeding years rockets, ballastic missiles, satellites and manned space-craft helped in space photography. Since 1960 meteorological satellites started taking pictures of both terrestrial and atmospheric features and interest grew in collecting data on water, snow and ice features.

During 1960s the manned space programme of Mercury, Gemini and Apollo were sponsored and with that began a new era in remote sensing from space. On 5 May, 1961 about 150 photographs of sky, cloud and occean were taken from a 15 minute sub-orbital Mercury flight. On 20 February, 1962 John Glenn took 48 coloured photographs of clouds and water as well as of deserts of northwest Africa. Later on, on Mission GT-4 of the Gemini Programme was directed mainly at geology for the first time and vertical overlapping photographs of the southwestern U.S.A., northern Mexico and other areas of North America, Asia and Africa were taken which helped in making exciting discoveries in geology and geomorphology.

By the end of Gemini programme, more than 1100 high quality colour photographs were obtained for earth resources application covering a major part of the earth's surface lying between 32°N and 32°S on a scale 1:2,400,000 each having a side of 140 km. These photographs established the value of space photography for such purposes and scientific community showed growing interest in obtaining systemmatic, repetitive image coverage of the globe.

In the next stage of development, just before the lunar landings, the Apollo programme (Apollo 9) enabled the scientists to obtain about 140 sets of multi-spectral imageries for earth resource studies for the southern part of North America.

More than 35,000 images of the earth were taken in 1973 with the Earth Resources Experiment Package (EREP) on board the Skylab, the first American Space Workshop. The supplementary nature of photography and electronic imagery from space was demonstrated for the first time by the EREP experiments.

The ERTS Programme :

The Earth Resources Technology Satellites (ERTS) programme was initiated in 1967 by NASA in collaboration with the U.S. Department of Interior which put into space six satellites in a planned sequence. The ERTS - 1 was launched on 23 July, 1972, operated until 6, June, 1978. It was the first unmanned satellite specifically designed to acquire data about earth resources on a systemmatic, repetitive, multiaspectral basis. The result obtained from the experiment exceeded most of the expectations of the scientists of different nations who were invited to take part in evaluation work. Later on, the ERTS programme was renamed by NASA as 'Landsat' programme. and ERTS - 1 was retrospectively named Landsat-1. Landsat-2 was launched on 22 January, 1975 and Landsat-3 on 5 March, 1978, all with the intention of obtaining data on earth resources.

Landsat Satellite Characteristics :

A landsat satellite system is about 3m long and 1.5m wide with solar panel extending to about 4m. The weight is about 815 kg ; the orbit is circular whose elevation varies from 880 km to 940 km. The time of orbit is 1 hour and 43 minutes which allows 14 orbits a day. The orbit passes within 9° of North and South Poles and crosses the equator at an angle of 81°. Successive orbits are about 2760 km apart at the equator, and photographic coverage is only 185 km and so there are large gaps in image coverage between successive orbits on a given day. But there is a regular diurnal shift of the orbit westward which enables us to obtain images that overlap successively. The overlap is minimum (about 14 per cent) at the equator and maximum (about 85 per cent) at 81°N and S latitudes. It takes 18 days for the landsat orbit pattern to progress westward to the point of coverage repetition. As such, the satellite covers the globe once every 18 days or about 20 times a year. The satellite orbit is sun-synchronus in the sense that the satellite always crosses the equator from the south at precisely the same local time (sun time). This has been made possible by making the orbital period 1 hour 43 minutes and the equatorial spacing between successive orbits 2760 km so that the satellite keeps precise pace with the Sun's westward progress as the earth rotates. Sun-synchronization ensures repeatable sun illumination conditions which help mosaicing adjacent tracks of imagery.

However, sometimes the satellite may not be in operation while passing over an area. Also there may be cloud cover during its passage over the area or the sun angle may not be favourable during that time (slanting rays of winter sun usually gives a better view). As such, the actual number of useful good quality photographs taken per year may be much less than 20. This means that in order to do proper study of an area one should select images taken on different dates during the year which will show ground condition (say, snow cover, vegetation condition, soil moisture condition, surface flow of streams etc.) during different seasons of the year.

Effective Resolution :

The smallest adjacent ground features that can be distinguished from each other, or the effective resolution of landsat imageries, is about 79 m on the MSS images and about 30 m on Landsat-3 RBV images. However, distinguishing a feature does not depend solely on its dimensions but, to a great extent, on its relative reflectance. Linear features only a few metres wide, which have a reflectance that contrasts sharply with that of their surroundings, such as concrete bridges on water bodies, two-laned unmetalled roads etc. can be easily identified on landsat images, whereas features having a very low reflectance contrast with the surroundings, even if they are much larger than 79 m across, may not be detected so easily.

Stereo View :

The images can be viewed in stereo only in areas of sidelap on adjacent orbit passes. It has already been mentioned that the side lap varies from about 14 per cent at the equator to about 85 per cent near the poles. As such, only a limited area of the globe can be viewed in stereo. Also the vertican exaggeration is much smaller than that given by air photos. This is because of the extreme platform altitude (900 km) of the satellite compared to the base distance between the images. Stereo Landsat vertical exaggeration varies from about 1.3 X at the equator to less than 0.4 X at latitudes above 70 while stereo air photos may have a 4 X vertical exaggeration. In spite of this, stereo viewing in landsat overlap areas is quite valuable in geomorphological studies. But the interpretation of landsat imagery is mostly made monoscopically mainly because in most cases side-lapping imagery does not exist, and even if it does, the relief displacement for stereo viewing is very small. Except in the areas of very high relief, the images contain very little relief displacement because of the very high altitude of the platform and very narrow field of view (11.56^{o}). The properly processed images can however be used as planimetric maps at scales as large as 1:250,000.

Proper Choice of the Band :

A proper choice of band of landsat imagery is necessary for interpretation work. The different bands with their corresponding wave length are given below :

TABLE XVIII

Band No.	Wave Length : in μm	Band No.	Wave Length : in μm
1	0.380-0.440	7	0.660-0.700
2	0.440-0.490	8	0.700-0.740
3	0.495-0.535	9	0.760-0.860
4	0.540-0.580	10	0.970-1.060
5	0.580-0.620	11	9.75-12.25
6	0.620-0.660		

Band 4 (green) is good for studying areas having a cover of deep, clear water since it can penetrate a greater depth of water. Band 4 and also Band 5 (red) are good for detecting cultural features like roads, rock quarries, urban areas etc. Band 5 usually gives a better view with a higher contrast image because of the better atmospheric penetration of red wave-lengths. Because of the above quality band 5 is also good for showing the flow of silty water into clear water as is usual in inland lake areas or in deltaic areas. Band 6 and 7 (reflected infra-red) help delineation of water bodies since it is absorbed by water and hence does not reflect back giving a very dark tone to the water bodies. Wet soil with little vegetation as well as asphalt-surfaced pavements etc. also react in the same way.

It is obvious from the above discussion that different bands are to be used for different purposes and also that not a single band but a number of bands may have to be examined for interpreting and analysing the different aspects of even a single theme like geology, topography or geomorphology.

Landsat Images vs. Aerial Photographs :

It is to be remembered that the landsat images are of much smaller scale than the conventional, low-altitude, large-scale aerial photographs. To give an example, more than 2,300 aerial photographs at a scale 1:20,000 with no overlap are required to cover the area of a single landsat image which is prepared on a scale 1:1,000,000. As such, landsat images should be considered as a complementary interpretive tool instead of a replacement for aerial photographs. As an illustration it may be stated that the presence of a geologic feature such as a huge dome or basin with a diameter of tens or hundreds of kilometres and well represented in a single landsat image might be represented only in fragments in a large number of large scale aerial photographs. In such cases aerial photographs would be of little use in geomorphological studies of the feature as a whole while landsat images would be of much help in the study of the form or structure and topography of the unit in a broader perspective. For micro-level features like housing quality, vegetation type etc., however, large-scale aerial photographs are much more useful since individual houses or trees cannot be resolved on landsat images. Moreover, aerial photographs give better three-dimensional views, which is an added advantage over the landsat imageries.

Use of Landsat Imageries :

Landsat image interpretation has already been of great help in many fields like geology, geography, agriculture, forestry, landuse planning, botany, pedology, civil engineering, cartography, land and water resource analysis, oceanography and environmental monitoring. Landsat is used by various countries and agencies for different purposes. The United States Geological Survey has published image maps and mosaics of selected areas at scales varying from 1:250,000 to 1:1,000,000. The Defence Mapping Agency has been revising global environmental charts and preparing up-to-date hydrographic charts of shallow sea areas with the help of landsat data. The World Bank uses landsat images for economic geography studies, particularly the landuse, in different parts ofthe Third World. The multi-national petroleum companies are already using landsat data and images in petroleum exploration.

The Imagery Used in the Present Work :

The image which the authord found as valuable during the course of the present study is the landsat image taken on band 7 on 30 March, 1975 under good weather condition which gives a satisfactory picture of the geomorphological features of the area.

At the first sight of the imagery, one can see the location of the Mayurbhanj Upland in relation to its surroundings i.e. the physical setting of the area under study. On the eastern side of the Upland is found a vast low-lying surface with a range of forest-clad hills in the southeast and scattered hillocks in the northeast. On the western side of the Upland again a vast level surface occurs which separates the Upland from the Keonjhar hills further west. This level surface is drained by the south-flowing Baitarani river which originates from the north of the Keonjhar Hills.

Certain large-scale lineations are observed in the area obviously indicating the location of vertical or nearly vertical faults. One pair of such lineations occurs in a west-northwest to east-southeast direction crossing the Baitarani river in its lower course while another pair trends in an approximately north-south direction across the upper course of the same river.

Satellite Imagery showing the Mayurbhanj Upland and its surroundings

The oval-shaped Upland tapers to a point at the southernmost end and merges with the Nilgiri Hills further south while in the north it merges with the iron-ore series of Badampahar.

The western boundary of the Upland as depicted by the imagery, is convex to the west while the eastern boundary is more or less straight. The arcuate western boundary has several concentric arcs formed by different arcuate ridges inside the Upland. It is interesting to note that the Keonjhar Upland further west is also composed of similar arcuate ridges which extend to great distances to the north and south and appear to be concentric with similar ridges of the western part of the Mayurbhanj Upland. This suggests that the structure of the Mayurbhanj Upland is not an isolated one but is a part of a gigantic structure whose centre is located in the Mayurbhanj Upland itself.

The important macro-features of the Upland and its surroundings are thus clearly evident from the imagery. These peculiarities of the study area and its surroundings could not be identified either from the large-scale topographical maps or from the aerial photographs because of their larger scale and consequently smaller area of coverage. Even the small-scale topographical maps could not reveal the three-dimensional effect

Satellite Imagery showing the Mayurbhanj upland of the landform which is so conspicuous in the landsat imagery.

The meso-features of the landscape are the concentric arcuate disposal of the ridges in the western half of the Upland. The dark tone shows the forest-clad ridges while the alternate bands of lighter tone represent the bare rock faces. Even in the flattish upland the darker tone represents the forest covered area while the lighter tone shows the bare surface devoid of vegetation.

Another important set of meso-features is represented by the lineations of relatively smaller dimensions which occur in the central and eastern part of the Upland where fault-guided streams follow straight courses with sudden change in direction in certain localities. Parallelism of certain stream courses with the arcuate ridges on either side of the channel suggest definite control of structure on drainage development in the area. In addition to the major basin structure of the whole Upland, the occurrence of another very characteristically circular pattern of landform on the northeastern border of the Upland cannot be overlooked. The feature is a basin structure not represented in the geological map of the area. It is rimmed by a circular ridge around a depression, of which the central part is occupied by a small hillock. Adjacent to the above structure and to the south of it lies a set of parallel faults which run in an east-northeast to west-southwest direction. Almost exactly similar features are also observed in the southern part of the Upland where several streams are found to occupy the depressions formed by the faults.

So far as micro-features are concerned the imagery could not give much information and for that reason the author had to depend on aerial photographs and other tools.

Aerial Photographs :

One of the most common and economical forms of remote sensing is aerial photography. It gives a bird's-eye-view of relatively large areas (though not as large as that of landsat imageries), enabling us to see the earth surface features in their spatial context. In fact, all observable earth features are recorded simultaneously. With the proper selection of camera, film and flight parameters, it is possible to record more spatial detail on a photograph than one can see with the naked eye. This is because the film can record even a wave-length range of 0.3 to 0.9 /um i.e. about twice as broad as that of the human eye (0.4 to 0.7 /um) ; this has been possible after the development of photography with infra-red and ultra-violet rays which cannot be detected by ordinary eyes. Aerial photographs, on analysis, can give correct values of slopes, heights, distances, areas and volumes. With the help of these data obtained from aerial photographs, topographic maps are being produced of late, which serve various purposes.

Early History of Aerial Photographs :

Photography developed first in 1839 and as early as 1840, Argo, Director of the Paris Observatory suggested the use of photography for topographic surveying. The first aerial photograph was taken in Bievre, France in 1858 from a balloon which ascended to a height of 80 metres. The use of kites for aerial photography began in 1882 although they were used earlier for collecting meteorological data. The air plane, though invented only in 1903, was used for the first time as early as in 1909 for taking aerial motion pictures over Centocelli, Italy, during one of the training flights made for Italian Naval Officers by Wilbur Wright. Photography from airplanes received special attention in the interest of the military reconnaissance during World War I and particularly during World War II when more sophisticated techniques were developed.

In the initial stage black and white panchromatic film was being used for aerial photography. This continued as standard film type till in 1941. In fact, human eye can discriminate many more shades of colour than it can do on tones of grey. This is an additional advantage to the use of colour photographs and is essential in many applications in air photo interpretation.

Types of Aerial Photographs :

Aerial photographs are usually classified into two types : Vertical and Oblique. Oblique photographs are again sub-divided into two groups viz. (i) High Oblique photographs which include an image of the horizon and (ii) Low Oblique photographs which do not include the horizon. Vertical photography is, however, the most common type of aerial photography used in remote sensing applications.

Vertical Photographs :

Vertical aerial photographs are mainly taken with frame cameras along flight lines or flight strips. Nadir line is the line followed by the aircraft during photography. It connects the image centres of the vertical photographs. At least 50 per cent overlapping of successive photographs is essential for total stereoscopic coverage of an area. To ensure this, usually 55 to 65 per cent overlap is made while taking successive photographs. Stereopairs consisting of adjacent pairs of overlapping vertical photographs, give two different perspectives of the ground area in their region of overlap. A three dimensional stereo model is thus perceived when the successive overlapping photographs are viewed through a stereoscope.

In order to cover a large area, multiple flight line passes with sidelaps of about 30 per cent are chosen in order to obtain complete stereoscopic coverage.

Scale of Aerial Photographs :

Aerial photographs are obtained on different scales in different countries mainly for serving different purposes. In India the usual scale of available photographs for general purpose is 1:60,000 while photographs on larger scale such as 1:25,000 or 1:20,000 are also available for more detailed study of some selected areas. In the present work air photos on the scale 1:60,000 were consulted for identifying the features of geomorphological interest.

Airphoto Interpretation :

Airphoto interpretation involves identification of objects on photographs and communication of the information to others. The raw photographic data contained in air photographs need processing by human interpreter's brain, in order to obtain from it usable information. Some of the objects depicted in the photographs are usually easily identifiable while others are not. The identifiability of an object depends mainly on the interpreter's own perceptions and experience.

The photographs represent the ground features at the time of photography. In order to do proper interpretation one needs the photographs along with other supporting documents such as field reports as well as topographic maps. The study and interpretation of aerial photographs involve certain basic characteristics such as size and shape, pattern, shadow, tone, texture etc.

The scale of the map must be kept in mind while estimating the size of an object which will help in identification. Understanding of the shape i.e. form, configuration or outline of the object is also very important. Pattern or the spatial arrangement of objects also help in its identification.

The shape of a shadow aids interpretation while the objects covered by it often remain unidentified. Tone gives relative brightness of objects by which deciduous trees may be distinguished from conifers or wet soil from dry soil. Texture gives the frequency of tonal change on photographs. Only tonal differences can reveal the shape, texture and pattern of the objects.

Use of Air Photos :

Aerial photographs are used for geologic, landuse, pedologic mapping as well as for application in agricultural, forestry and water resources studies. In addition, their application in water pollution detection, flood damage detection, wetland mapping, urban and regional mapping, wildlife ecology, archeological studies, environmental impact assessments etc. also have because very important of late. However, in our present study we are concerned with geomorphological studies primarily, which, of course, are not totally unrelated with the other subjects mentioned above.

For the purpose of geological and geomorphological evaluation of an area the air photos are usually taken during mid-morning and mid-afternoon with the sun at high angle when the shadows have a minimal effect. On the other hand, shadow pictures obtained from photographs taken in early morning or late-afternoon (when the sun lies less than 10° degrees above horizon) reveal subtle differences in relief and textural patterns not visible on the former photographs.

The main terrain characteristics that can be studied with the help of air photos are lithology, depth of unconsolidated materials, topography, slopes, soil texture, drainage conditions and susceptibility to flooding. These characteristics are important to geologists, geographers, pedologists, engineers, planners and others who wish to evaluate the suitability of an area for various land uses.

Soils are classified in various ways for satisfying the needs of the users. Simple classification based on texture may be made as follows : gravel (2.0-76.2 mm), Sand (0.5-2.0 mm), Silt (0.002-0.05 mm) and Clay (below 0.005 mm). Usually the materials containing more than 50 per cent silt and clay are considered fine-textured while those containing less than 50 per cent silt and clay as coarse-textured. In fact texture is an important factor determining the quality of the soil.

The drainage conditions of soils depend on various factors like surface run-off (which again is governed by lithology, structure, slope etc.), soil permeability and internal soil drainage. On the basis of drainage conditions soils may be classified into three major groups : (i) poorly drained, (ii) moderately well-drained and (iii) excessively drained. Poorly drained soils are those in which natural removal of water from the soil is so slow that it remains wet for the major parts of the year. In moderately well drained soils the natural removal of water from the soil is somewhat slow, but not too slow to hinder agriculture. In excessively drained soil the natural removal of water from the soil is very rapid. Such soils are usually located on steep slopes and/or are highly permeable.

Terrain characteristics are, in many cases, the determining factors in evaluating the suitability of land surface for different landuses. In an Upland like the area under investigation, the gentle slopes are used for agriculture and settlement while steeper slopes are given to forest, which in turn, becomes ideal habitat for wild life.

The key elements that are studied stereoscopically from air photos for terrain evaluation are topography, drainage pattern and texture, erosion, photo tone, vegetation and landuse.

Topography : If different landforms are found in an area then there is observed a distinct topographic change at the boundary between two areas of different landforms.

Stereoscopic view usually exaggerates the height of an object about three or four times if the vertical photographs of a stereopair has an overlap of about 60 per cent. The slope angles are therefore apparently increased considerably. The usual proportion of this apparent increase on slope may be expressed thus :

$\tan \theta = 3 \tan \phi$, where θ is the apparent slope angle and ϕ is the true slope angle.

Drainage Pattern and Texture : These are the reflections of lithology, structure and landform as well as the indicators of soil and drainage conditions. As for example, dendritic pattern indicates homogeneous rocks like granite, sandstone etc. which do not exert any structural control. Rectangular pattern reflects right-angled joint structure, while trellis pattern suggests the existence of folded sedimentary rocks, and radial pattern indicates domal structure or volcanic cone type of structure and landform. Centripetal pattern develops on basin type of structure or in depressions formed by volcanic crater etc.

Again, fine textured drainage develops on rocks having low permeability where the surface rocks and soils have poor drainage condition and high surface run-off while coarse textured drainage pattern develops on rocks having high permeability with good internal drainage and little surface run-off. Also coarse-textured drainage pattern develops on hard, massive rocks such as granite, whereas fine-textured pattern develops on soft, easily eroded rocks like shale.

Gullies : These are the smallest drainage features that can be identified on aerial photographs. These develop mainly on unconsolidated or semi-consolidated and impermeable materials. The shape and character of the rills and gullies depend on the nature of the materials on which they develop. Fine-grained materials like clay or silty clay soils produce long gullies with gently rounded cross-sections, silty soils give rise to U-shaped cross-sections while coarse materials like sand and gravel produce short gullies with V-shaped cross-section.

Photo tone : 'Brightness' at any point on a panchromatic photograph is termed photo tone. An interpreter must analyse the relative time values instead of absolute values since photo tone depends not only on terrain characteristics but also on photographic particulars like film-filter combination, exposer and photographic processing as well as on meteorological factors like haze, inclination of the sun, cloud shadows etc. Thus a dark tone may indicate a low land and a fine-textured soil, an wet soil, or high organic content of the soil. The tonal differences are caused by differences in sunlight reflection due mainly to the varying moisture content of the soil. The lighter tones may form on slightly raised soils (even a few decimetres) standing above the moist, dark-toned and poorly drained soils in an area. The degree of contrasts between darker and lighter-toned bare soils varies depending on the moisture content of the soils.

Soil texture has a definite influence on the sharpness of the boundary between darker and lighter-toned areas. Fine-textured soils usually have gradual gradations between dark and light tones while coarse-textures soils have sharper gradations. This is because of the higher capillary action in finer-textured soils than in coarser-textured soils.

Although panchromatic films are mostly used for general purposes, the colour films usually give a more clear picture of even minor differences in soil and rock characteristics while colour infra-red films help detect minor differences in soil moisture and vegetation growth.

Terrain vs. Vegetation : Differences in terrain condition are often reflected in the differences in vegetation, natural or cultivated. For example, well drained soils are essential for the cultivation of certain types of activities like fruit growing, tea cultivation etc. whereas some other types of agricultural activities need organic soil with greater moisture content. Seasonal change in vegetation growth may however, create confusion since the dense vegetation growth in the post-monsoon period may obscure the soil and topographic characteristics. These facts are to be kept in mind while interpreting the stereo-pairs in order to discern the types of terrain or vegetation.

Process of Interpretation : An analysis of the elements of photo interpretation viz. topography, drainage pattern, texture, photo tone, erosion, vegetation and landuse helps an interpreter to identify various terrain conditions and draw boundaries between them. An experienced photo-interpreter can identify certain recurring air photo patterns almost instantaneously. However, air photo interpretation process is never expected to stand alone ; even the most thorough and careful air photo interpretation needs field verification for its perfection. In addition to a selective field check, the interpreter should also consult topographic, geologic, soil and vegetation maps if available. The air photo interpretation techniques can be used as supplementary to expensive and difficult field work during periods of bad weather and also can help more efficient field operations.

Topography on Granitic Rocks :

Intrusive rocks vary from gabbro, a dark-coloured, coarse-grained rock composed mainly of ferro-magnesian minerals and feldspar, to granite, a light-coloured, coarse-grained rock composed mainly of quartz and feldspar in addition to a number of intermediate varieties like diorite and grano-diorite. However, the light-coloured, coarse-grained, intrusive igneous rocks are usually termed granitic rocks which typically occur as large masses. These are massive, unbedded formations, usually strongly fractured into a series of irregularly oriented joints. They are resistant to erosion and often form exfoliation domes due to peeling of concentric shells because of mechanical weathering process. The dept of residual soil cover is observed to be not very thick in granitic areas.

Topography produced by granitic rocks consists of massive, rounded, unbedded, domal hills with steep (often convex) side slopes.

and variable summit elevations. The rocks are often highly jointed and along the joints topographic depressions are formed which favour soil accumulation and vegetation growth as well as water accumulation and channel development. As such, linear pattern of vegetation is found in certain localities having depressions controlled by joints. In certain cases the features may appear prominently in aerial photographs even without any topographic depression associated with it. Dendritic pattern of drainage with coarse texture develops as the rock is of uniform character without any definite structural control. The streams often have a tendency to curve around the bases of the domal hills. Joints encourage the development of secondary drainage channels. Gullies do not develop except in some restricted areas with deep residual soil.

Light rock colour gives a light photo tone. Dark tones are found along joints which form depressions.

Vegetation in humid climate is usually dense particularly in and around the base and also on the lower slopes with some bare rock outcrops.

Granitic country often resembles sandstone country in photo tone. In order to distinguish the two it is to be remembered that topographically granitic areas have variable summit elevations while sandstone cap rocks usually form plateaus ; but granitic rocks form rounded cliffs while sandstones form vertical cliffs and granitic micro-features are rounded while sandstone micro-features are blocky. Moreover, sandstone is bedded (thick or thin) while granitic rocks are unbedded. Also sandstone usually has a joint system consisting of two or three principal directions while granitic rocks have an irregular joint pattern with some distinct linear depressions.

Topography on Extrusive Igneous Rocks :

These include mainly lava flows and pyroclastic materials. The pyroclastic materials such as cinders and ash are ejected from the volcanic vents whereas the lava flows are formed from the solidification of molten rock that issues from fissures or volcanic cones without much explosive activity. The form of the lava flows is governed by the viscosity of the material. The viscosity varies directly with the proportion of Silica (SiO_2) and alumina (Al_2O_3) in the lava. The most viscous (i.e. least fluid) are the Rhyolite lavas which contain about 85 per cent silica and alumina. They form steep-sided cone-shaped volcanoes made up of alternate layers of lava and pyroclastic materials. The slope of the surface often exceeds 30°. The least viscous lavas are the basaltic lavas, also called flood basalt or plateau basalt, which contain about 65 per cent silica and alumina. They form broad and nearly level plains or plateaus whereas andesite lavas, having about 75 per cent silica and alumina content, are intermediate in viscosity.

Viscous lavas (andesite and rhyolite) form thick flows with steep edges. Fluid lavas (basalt) form thin flows, seldom exceeding 15 m in thickness. Well-developed drainage pattern is rarely found in lavas. The area is usually well-drained internally. The colour of unweathered, unvegetated lava is light-toned for rhyolite, medium-toned for andesite and dark-toned for basalt. Weathered vegetated flows are usually lighter-toned than recent unvegetated flows. Weathered flows are good for agriculture. Recent flows are rarely cultivated.

Flood basalt or plateau basalt deposits are formed by horizontal and overlapping flows of very fluid lava that issue from fissures. A basaltic cap-rock usually conceals the original undulations of the pre-trap land surface with its hills and valleys and forms a relatively featureless plain. Individual flows are typically 15 to 30 m thick. Sometimes lava flows of much greater thickness are also observed. At many places fluvial, lacustrine or residual soils are found entrapped between successive lava flows indicating thereby considerable time gap between them.

Flood basalt deposits show columnar jointing, hexagonal in pattern, with about 25 to 100 cm wide. They form because of the solidification of lava at a high temperature and subsequent contraction of the basalt as it cools down to the air temperature.

A nearly level surface of a plain or a high plateau, with deep valleys cut by some major streams is the typical topography formed by basalt cap-rock. Basaltic area is usually well-drained because of the highly jointed character of the rocks, as such, very few surface streams develop in such areas.

Gullies may develop only in deep residual soils developed on basalt ; rest of the areas having bare rock may not show any conspicuous development of rills and gullies.

Dark tone is observed on the bare rock and particularly along escarpment faces and valley walls where soil development is negligible and little or no vegetation has grown.

Agriculture flourishes well only in areas where irrigation water is available, rest of the areas remaining fallow or being used as grazing ground for animals.

Landslides are frequent in steeper slopes particularly on escarpments or overhangs formed by the undercutting made by the streams at the base of the cliff.

In certain respects flood basalts resemble sandstones in airphotos and hence the following distinctions must be kept in mind :

i) Sandstone gives a light tone while basalt gives a dark tone ; ii) Sandstone has excessive joint systems with two or three principal directions while flood basalt shows columnar jointing which gives rise to canyons and cliff edges ; iii) Sandstone canyons and cliff edges have a rocky appearance whereas those produced by basalt have a serrated appearance ; and finally iv) Sandstone has a low drainage density at places controlled by the joint system (otherwise somewhat dendritic) while flood basalt has mainly internal drainage.

Alluvial Fans :

Alluvial fans occur in serial photographs as fan-shaped features of subdued topography with a slope of 2 to 15 per cent directed towards the outer margin radially from the apex. Usually surface drainage is very much limited and gullies are few while internal drainage is excellent. Distributary channels are numerous. Photo tone is generally light while distributary channels appear darker. There is a general lack of vegetation along the distributary channels. Surface water percolates through the materials which are permeable, but the water reappears again at the surface near the fringe of the fan i.e. at the outer margin, where vegetation growth gives a darker tone. Some of the areas on the fan are cultivated with the help of rain water which is available during the summer.

Geomorphology of Some Selected Areas :

Some of the geomorphological peculiarities of the area, as depicted by aerial photographs are described below :

Air Photo No. 1 shows distinct lineation in a northeast-southwest direction which occurs in the southwestern part of the upland. The major lineation runs diagonally across the area and gives a dark tone because of the growth of vegetation along the line. Accumulation of water along the weak zone causes more rapid chemical decomposition of rocks and formation of soils which, in turn, favour growth of vegetation along the line. In the northern section of the line a stream has got entangled with it ; the stream is unable to meander freely because of the structural control. The stream bed gives out more light and hence appears lighter in colour as compared to the vegetation. A similar lineation in the northwestern part of the area shows the same direction of alignment i.e. northeast to southwest and is represented by a thin, dark line. Further to the west lies another such lineation, although much wider and more irregular. Here the vegetation has grown beyond the line of structural weakness and has formed a wider and more irregular outline.

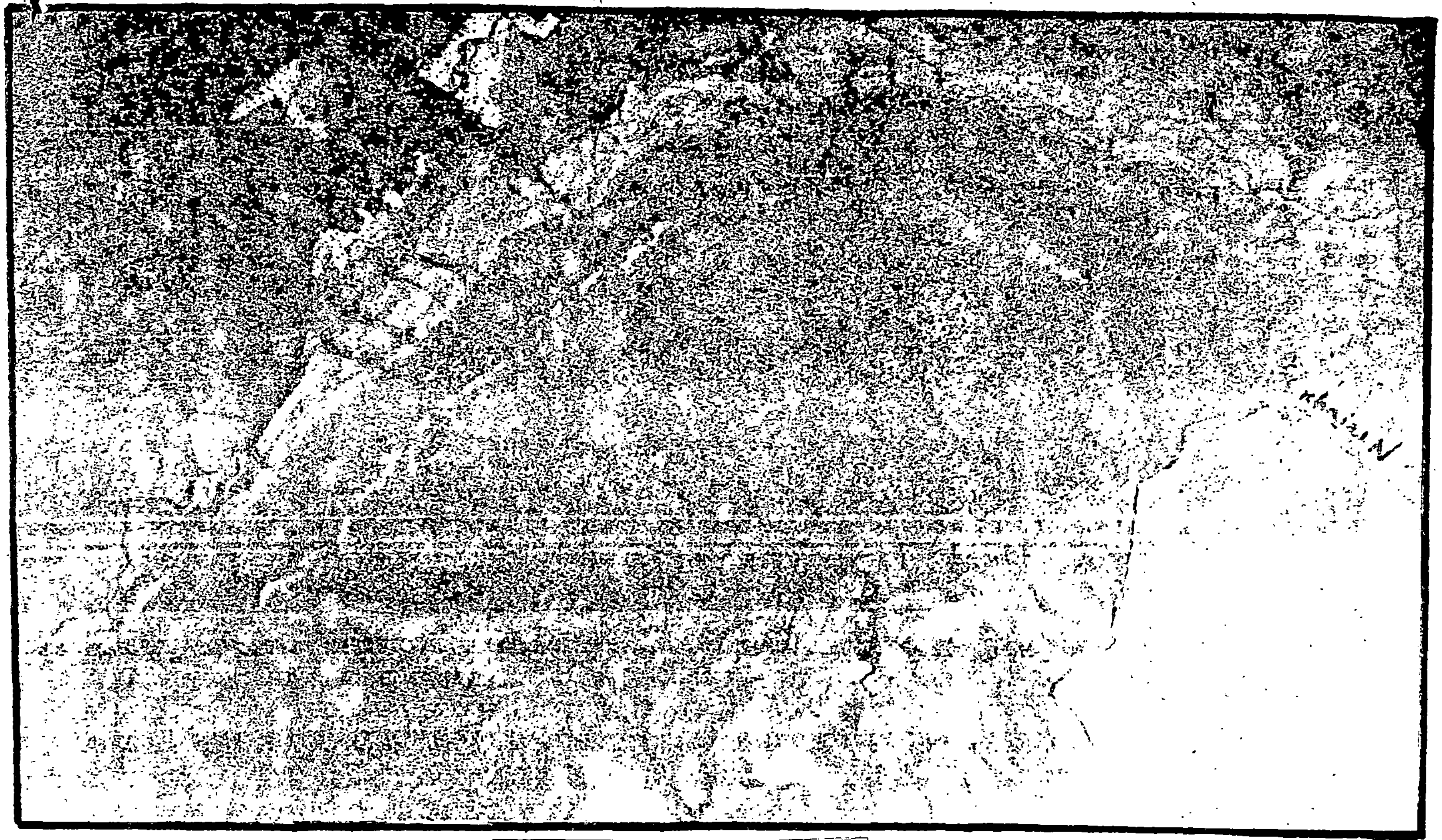
Air Photo No.2 shows a typical quartzite escarpment with an arcuate disposal which is widest in the southwestern part of the area covered by the photograph located in the northeastern part of

Aerial Photograph No. 1

the area under study. The curvature of the out-crop has a diameter of about 12 kilometres while the southernmost tip is almost straight with a trend to the southeast. The in-facing dip-slope is covered by forest as is evident from the dark tone while the out-facing escarpment slope is bare of vegetation which is reflected in its lighter tone. Some dark lines across the escarpment show the stream courses while some patches of lighter tone beyond the escarpment in the southwestern part of the area represent man-made clearings (in the otherwise dense forest) for human settlement and agriculture. Settlements in these clearings occur as dark dots and perennial streams as dark meandering lines.

Air Photo No.3 represents a part of the central upland where dens forest and flat plateau without any forest cover remain side by side. The dark tone shows the forest area while the light tone represents open land. In this particular case the forests occupy the gently sloping hill slopes while the clear land is a gently rolling upland where settlement and agriculture dominate the landscape. The river flood plains in the forest are also shown by light tone. Some segments of the river in the forest bound area have unusually straight course which suggests structure control, while free meanders elsewhere are not uncommon.

Air Photo No. 4 The narrow strip of the air photo (No.4) has been selected for illustrating a typical geomorphic feature



Aerial Photograph No. 2

which is neither exposed by the satellite imageries nor by the topographical maps on any scale. The photo represents several peculiarities of some channels which may be described as follows :

(a) The channels appear light-coloured while the surrounding area has a dark tone.

(b) Some of the streams (five in number) originate in the south and flow to the north while some others (four in number) originate in the north and flow to the south i.e. exactly opposite to the former streams.

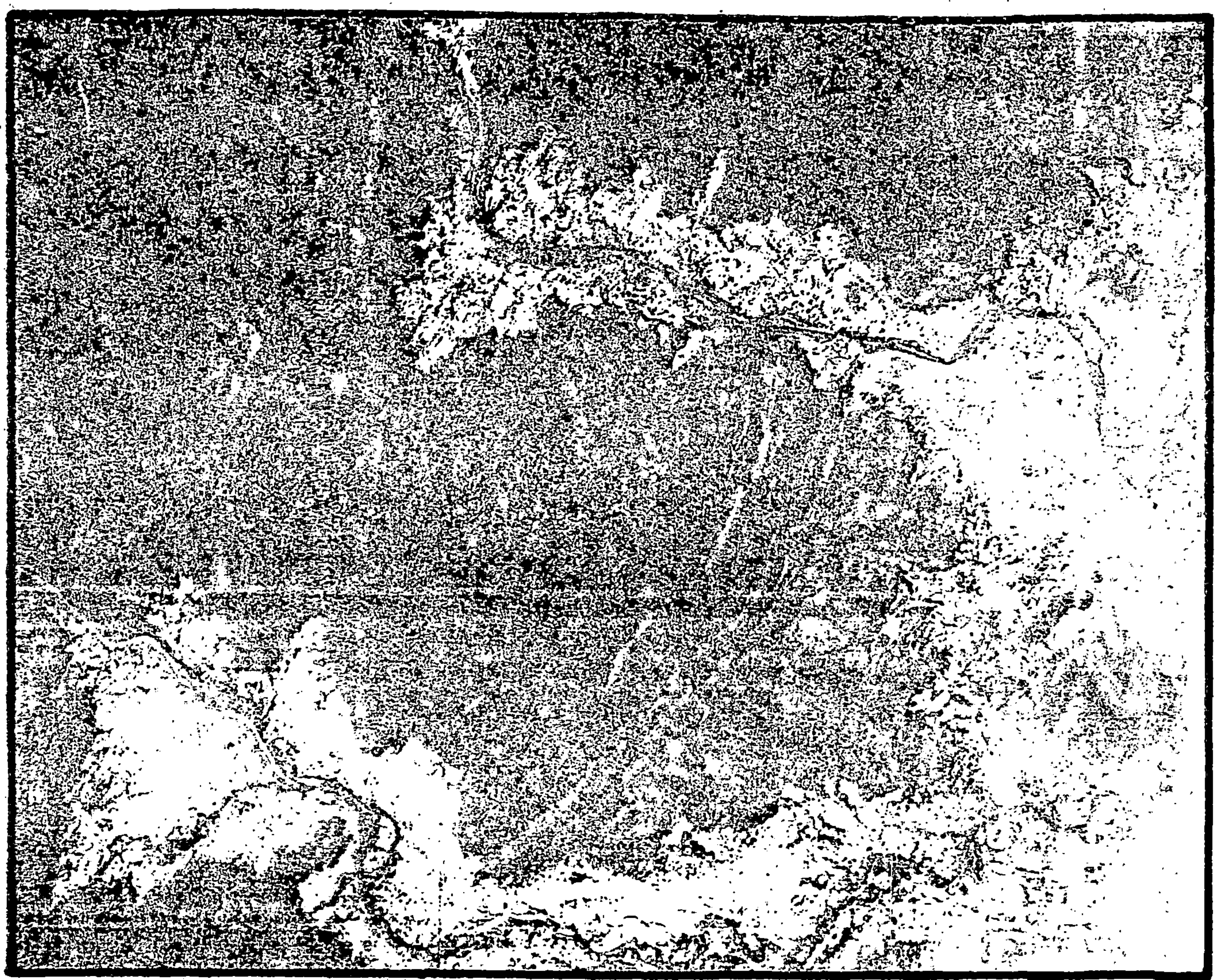
(c) The sources of most of the channels, particularly of the major ones, along with their upper courses, lie in a perfectly straight line which runs in a north-south direction.

(d) The lower parts of the channels are aligned in an east-west direction i.e. perpendicular to the upper parts.

(e) All the channels end abruptly at points which, if joined together, give another straight-line which is exactly parallel to the straight line described in (c).

From the above description the following conclusions are derived :

(i) It may be concluded from (a) that the channels do not



Aerial Photograph No. 3

contain any water at all. They are dry beds inside a dense forest.

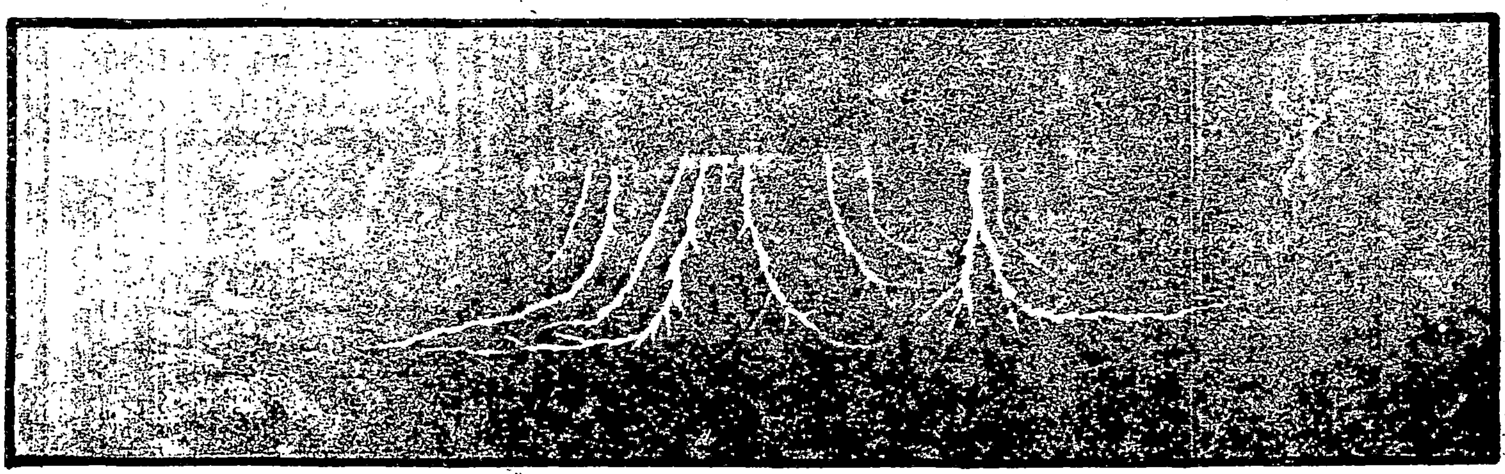
(ii) Conclusion derived from descriptions (b) and (c) is that the sources of the dry beds are located along a high-angle fault (as suggested by straight line character). It is assumed that the fault is not-of very recent origin since the area is a part of a stable block belonging to the pre-cambrian age.

(iii) Description (e) suggests that the channels end abruptly along another fault-line where upthrow side lies in the downstream direction which has formed a physical barrier across the course of the channel.

(iv) Descriptions (c) and (e) suggest that two parallel faults occur in the area of which the western one gives rise to a few non-perennial channels which are fed by the seepage water from the bottom of the east-facing escarpment and the eastern one has opposed the flow of the channels across it where a west-facing escarpment has been formed.

Obviously the area represents a rift-valley bounded by two fault scraps on either side.

Fieldwork in the area in late March, the driest month of



Aerial Photograph No. 4

the year showed no water in the channels. The bounding escarpments also were not very prominent. Debris from the basaltic escarpment slopes have mostly obliterated the structural peculiarities although physiographic, especially drainage peculiarities, as depicted by the aerial photographs, give definite clues to the existence of such structural characteristic as described above.