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Remote sensing and geophysical studies for groundwater exploration in Osmania University campus, Hyderabad, India: A case study

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सार - उपग्रह संवेदकों के बढ़ते हुए वियोजन से, भूवैज्ञानिक पर्यावरणों के व्यापक क्षेत्रों के लिए उपग्रह छायाचित्रों के विश्लेषण के विशिष्ट लाभों का उपयोग सफलतापूर्वक करना संभव है। इस उद्देश्य के लिए मई महीने में (जो न्यूनतम वार्षिक अपवाह तंत्र / वनस्पति आवरण के संबंध में सही महीना है। आई.आर.एस.-आई.डी. से लिए गए ओस्मानिया विश्वविद्यालय (ओ.यू.) के 1600 एकड़ के (लगभग 6.5 वर्ग कि.मी.) परिसत से एल.आई.एस.एस.-III और पी.ए.एन. के समाविष्ट उपग्रह छायाचित्र प्राप्त किए गए। फिर इसके बाद इन उपग्रह छायाचित्रों को भूजल के स्रोतों के संभावित क्षेत्रों का पता लगाने के लिए डिजीटली संसोधित किया गया और उनकी दृश्य रूप से व्याख्या की गई है। चूँकि क्रिस्टलीय शैलों में भूजल पाया जाता है, अतः समूचे हैदराबाद के क्षेत्र में जल को इकट्ठा रखने वाले शैलों को सूक्ष्मरध्रता वाले गौण शैलों के साथ प्रायः संबद्ध पाया गया है। इस मामले में बल, स्थलानुरेखों के यथोचित क्षेत्रीय विस्तार का पता लगाने ओर उसके निरूपण पर दिया गया है। ओस्मानिया विश्वविद्यालय के परिसर के दक्षिणी भाग के भूभौतिकी अध्ययनों एवं बेदित कुंए/खुले कुंए की मिली सूचनाओं से प्राप्त की गई अधस्तल की विशेषताओं के मानचित्रों के आधार पर इस कार्यक्रम का भी विस्तार किया गया है। इस कार्य के साथ-साथ भूविज्ञानिक स्थितियों को और बेहतर ढंग से समझने के लिए और भूजल संसाधनों के संभावित स्थानों का पता लगाने के लिए उसके विभिन्न घटकों के पारस्परिक संबंध के लिए तीन स्रोतों से प्राप्त जानकारी को एकत्र किया गया है।

इन महत्वपूर्ण उपलब्धियों में तीन बड़ी नहरे, दो रनिंग ई.-डब्ल्यू. ओर तीन रनिंग एन.ई.-एस. डब्लयू. का पता लगाने की सफलता शामिल हैं। ग्रेनाईटी शैलों का समूचे परिसर के क्षेत्र के अपवाह तंत्र के पैटर्न सहित एन.-एस. रेखीय अनावरण तथा परिसर के दक्षिणी ओर की अनेक आड़ी तिरछी दरारों के मानचित्र भी तैयार किए गए हैं। इन परिणामों के आधार पर तथा सहायक भूभौतिकी/जलविज्ञान के आँकड़ों की सहायता से ओस्मानिया विश्वविद्यालय परिसर के भूविज्ञान/अश्म-विज्ञान संबंधी मानचित्र तैयार किए गए और भूजल के संभावित क्षेत्रों का पता लगाया गया है।

ABSTRACT. With the increasing resolution of satellite sensors, it is possible to fruitfully exploit the special advantages of image analysis for a wide range of geological environments. With this view, a LISS-III and PAN merged image of the 1600 acre (approximately 6.5 sq km) Osmania University (OU) campus taken from IRS-ID in the month of May (a fairly representative month in terms of minimum annual drainage/vegetation cover) was acquired. The image was then digitally processed and visually interpreted for potential groundwater resource regions. Since occurrence of groundwater in crystalline rocks, the host rocks for the entire Hyderabad region, is generally associated with secondary porosity, the accent was on determining and establishing lineaments of considerable surface extent. This was then augmented with maps of subsurface features as obtained from geophysical studies for the southern part of 0 U campus and available bore well/open well information. Subsequently, information from the three sources was integrated for a better understanding of the geological situation and the interrelationship of its various constituents to determine possible locations of groundwater resources.

The significant findings comprised the identification of three major dykes, two running E-W and the third running NE-SW. A major N-S linear exposure of granitic rocks, as also several criss-crossing fractures in the southern side of the campus, along with the prevailing drainage pattern for the entire campus area were mapped. Based on these findings and supporting geophysical/hydrogeological data, a geological/lithological map of Osmania University campus was prepared and prospective groundwater zones have been identified.

Key words – Remote sensing, Ground water, Geophysical studies, IRS-ID.

1. Introduction

Exploration of groundwater resources is motivated, by the fact that surface water resources contribute to only a small fraction of our total water requirements. For identification and quantitative assessment of potential groundwater zones, information about the geological and biophysical environment of the area is a pre-requisite. While mineralogical composition and structural characteristics constitute geologic controls, topography, climate and the resulting geomorphologic nature of the area under study form the other major controls of groundwater occurrence.

The scope of groundwater exploration broadly includes determining the vertical and horizontal distribution of aquifers and their regional boundaries and tracing tectonically disturbed zones affecting groundwater movement. In hard rock areas, the distribution and movement of groundwater is controlled (Murali and Patangay, 1998) by constituents of secondary porosity fractures, fissures, faults and joints that cross each other at various angles. These features are found in profusion close to the sun ace and reduce in frequency deeper down. Gramtes constitute the host rocks for the entire Hyderabad region and are characterized by 'sheeting' (patangay and Rao, 1971), which is horizontal jointing parallel to the surface.

Another major groundwater-bearing structure in crystalline rocks is the top mantle of unconsolidated material containing considerable pore space. This layer develops due to the forces of mechanical and chemical weathering and is well developed in areas where topography and climate combine to give weak erosive forces. Thus, low lying areas are characterized by abundant groundwater resources on account of a thicker weathered layer, lesser sub surface run-off; influent seepage from upland areas and better recharge conditions.

It is known that remote sensing is invaluable for efficient water resource management (Thiruvengadachari *et al.*, 1996). Further, while image analysis has been used for identification of prospective groundwater zones (Reddy *et al.*, 1996), it is a relatively new, though extremely promising resource evaluation tool in geophysical surveys directed towards locating possible aquifer zones. The main advantage accruing from image interpretation is the 'overview' or perspective advantage it affords. Broad geologic/geomorphologic units along with the major structural trends of features such as dykes, fractures, joints and faults - often indicators or even repositories of mineral/groundwater resources - are readily discernible. On the ground, these features sometimes escape notice as local morphological features such as weathering or vegetation cover and/or cultural features, such as roads and buildings, dominate them at places. Thus, incorporating remote sensing in conventional geophysical surveys promises time and cost economy without compromising on information content.

The present study aims at understanding the geological and lithological characteristics of Osmania University campus for determining possible resources of groundwater. The work strategy consisted of three components. The first component comprised of image analysis and interpretation. The objectives were to assess parameters such as, total drainage, drainage density and their mutual relationship with fracture occurrence and fracture direction, and their implications on groundwater occurrence. The end result of this analysis was a geological/geomorphological map of the area with special emphasis on tracing of various linear features such as fractures, faults, dykes and the prevailing drainage pattern.

The second component consisted of compiling all available geophysical and hydrogeological data over the area. This included magnetic survey results for geological evaluation and bore well/open well information for location and yields. The third component consisted of integrating the regional-scale image data with the detailed geophysical data to demarcate potential groundwater-bearing zones.

The methodology and final results of each component of the study, along with a brief account of the geological environment prevailing in the OU campus, are presented in the following sections.

2. Geology of the area

The Osmania University campus (78° 31' E longitude to 78° 32' 26" E longitude and 17° 23' 45" N latitude to 17° 25' 42" N latitude) is situated in an area of approximately 6.475 sq km. in a granitic terrain. Here three types of granites exist - pink, gray and the leucogranites (Balakrishna and Rao, 1961; Sitaramayya, 1969, 1971) and some pegmatite patches traversed by narrow white apatite veins, which intersect each other randomly. The granitic host rocks are intruded at places with doleritic dykes. The general geological section consists of a surficial soil layer underlain by weathered rock, which is in turn followed by fractured rock at a few places. The basement, occurring at an average depth of 15 m consists of hard impervious granite.

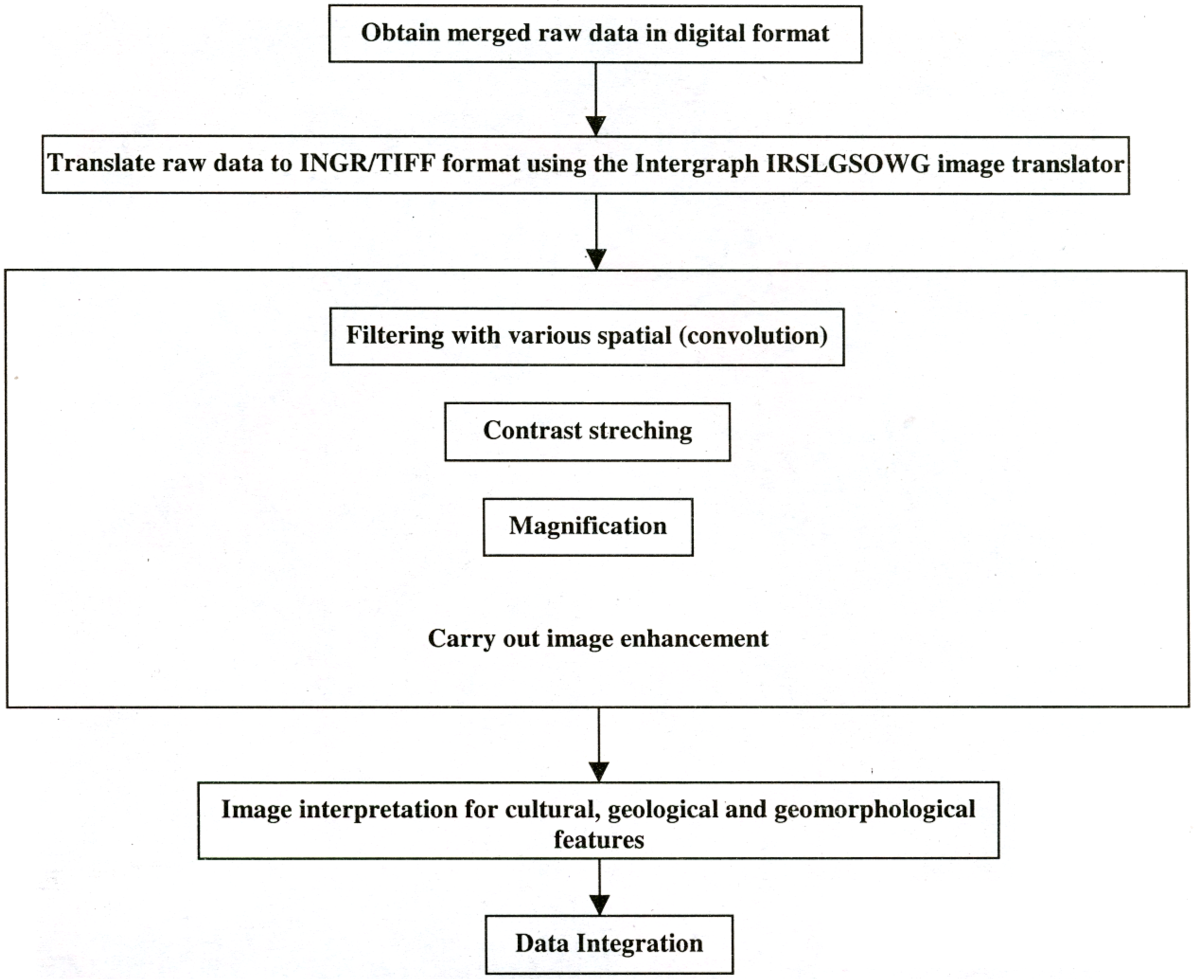


Fig. 1. Row chart for sequence of digital image processing operations carried out on the satellite image

3. Remote sensing

Keeping in view the total information as well as degree of resolution required, a LISS-III + PAN merged image of Osmania University campus was obtained in digital format from the National Remote Sensing Agency, Hyderabad: Merging data from the PAN and LISS-III sensors, each with its own referencing scheme, swath and other features has the advantage of combining the spatial resolution of PAN (5.8 m as against 23.5 m for LISS) with the spectral resolution of LISS-III False Color Coded images (four bands – 0.52-0.59 μm, 0.62-0.68 μm, 0.770.86 μm and 1.55-1.7 μm as against the single band of 0.5-0.75 μm for PAN).

A flow diagram of the sequence of digital processing operations carried out on the image is shown in Fig. 1. Digital processing/enhancement of the image is necessary prior to interpretation because the vast quantity of data involved in image 1Jnalysis is better handled digitally (Jensen, 1986). Further, with image enhancement the visual quality of the image is so improved that even minute tonal differences that escape the human eye are registered.

The raw image data was translated with the IRSLGSOWG image translator to a format suitable for analysis using Intergraph software 'Image Analyst'. Then the image (Fig. 2) was magnified and enhanced with contrast stretching. Contrast stretch is useful for discrimination of lithologically dissimilar rocks (Knepper and Raines, 1985). Since the band histograms showed non-Gaussian distributions (a Gaussian histogram has all brightness values falling within a single relatively narrow range), an exponential/logarithmic rather than linear contrast stretch was found to be better and was performed on the image.

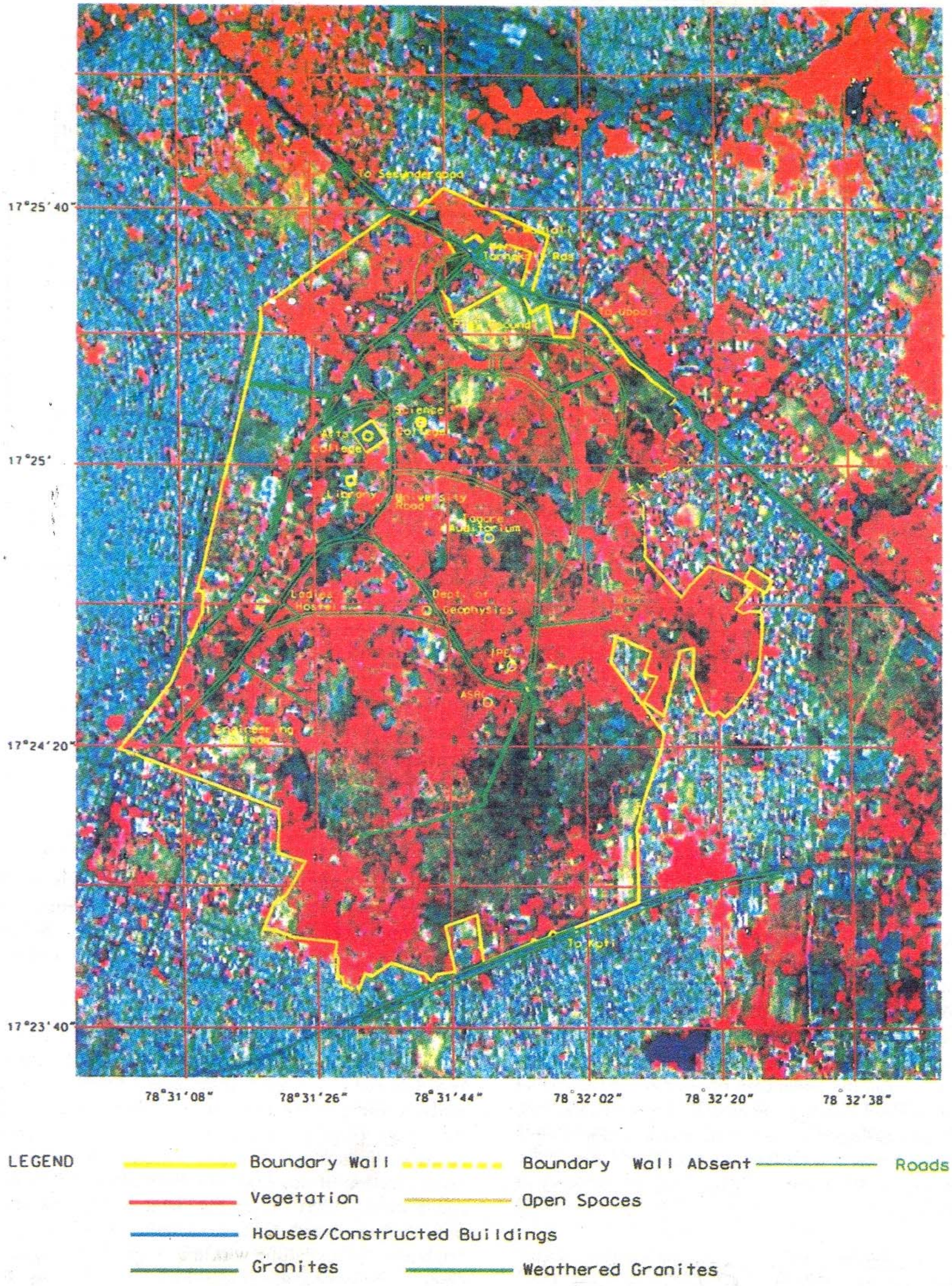
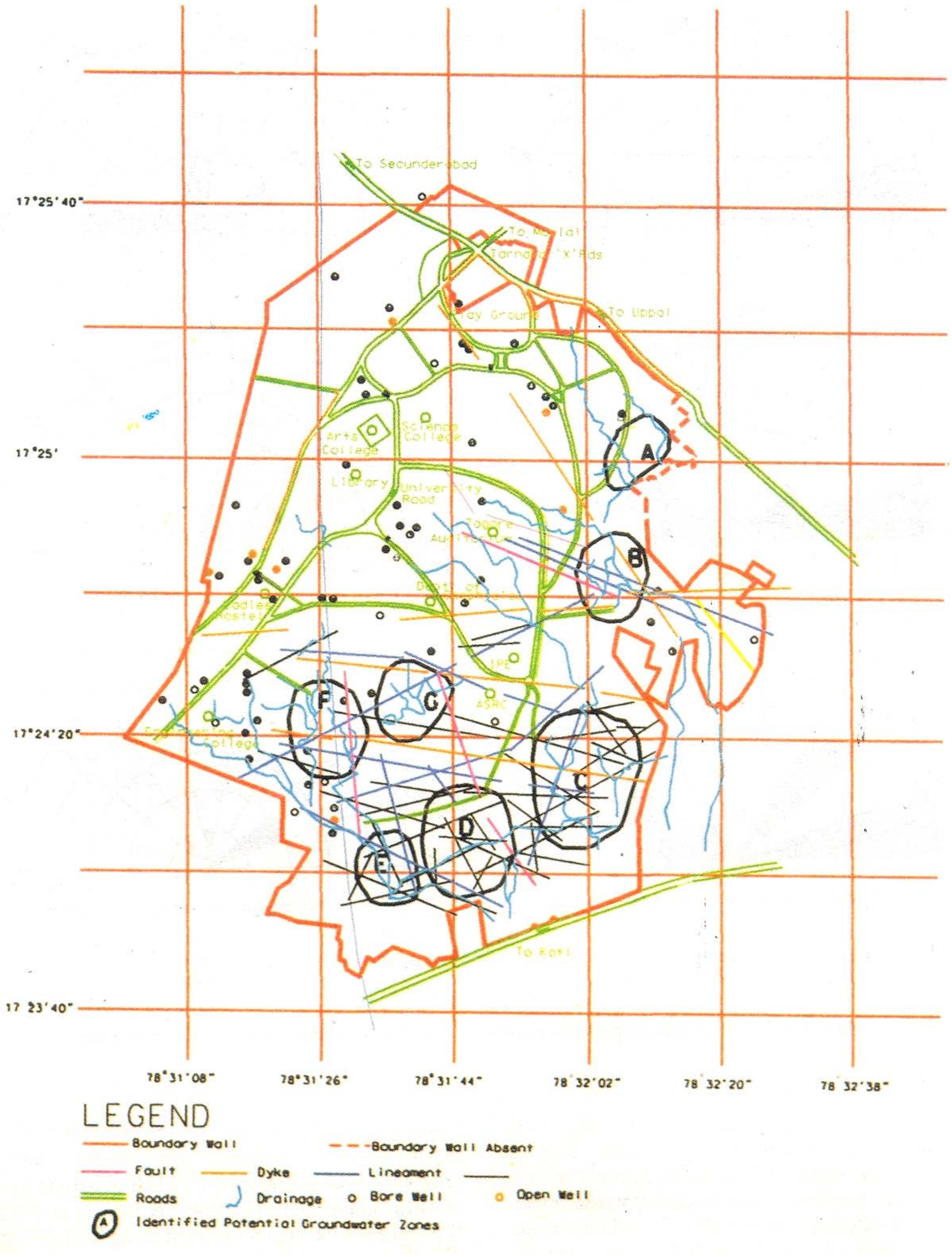


Fig. 2. IRS-ID P AN+LISS-III Merged image of Osmania University campus, Hyderabad, India (Date of image acquisition 01-05-1999)



Fig, 3. Lineaments and drainage as derived from the filtered IRS-ID image along with locations of Bore wells/open wells and identified potential groundwater zones in Osmania University campus

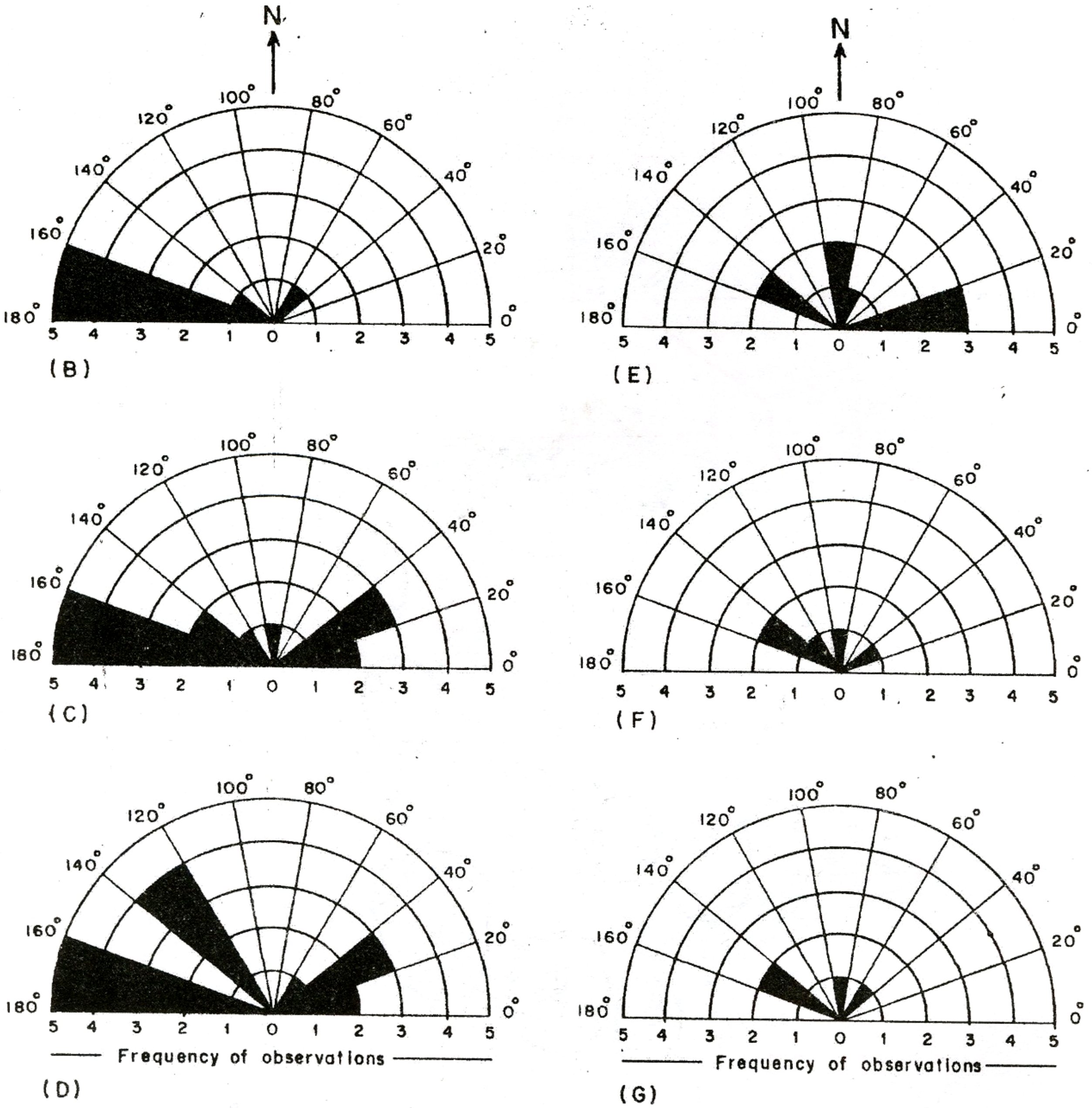


Fig. 4. Rose diagram of lineaments inferred from the image at selected locations in Osmania University campus

Then, various spatial filters were applied to the enhanced image to make the linear features more apparent. Spatial filtering is essentially a two-dimensional convolution process (Rosenfeld and Kak, 1976). Among the different convolution operators, the weighted high pass filter followed by a Gaussian filter applied to the original image was found to be the best. Then, the geographical co-ordinates (78° 31' E longitude to 78° 32' 26" E longitude and 17° 23' 45" N latitude to 17° 25' 42" N latitude) of the area were fixed along with the boundary of the campus and the image was annotated to locate some reference points. Accordingly, various roads and buildings were marked with a scale of 1:20,000 to give a layout map superposed over the image (Fig. 2).

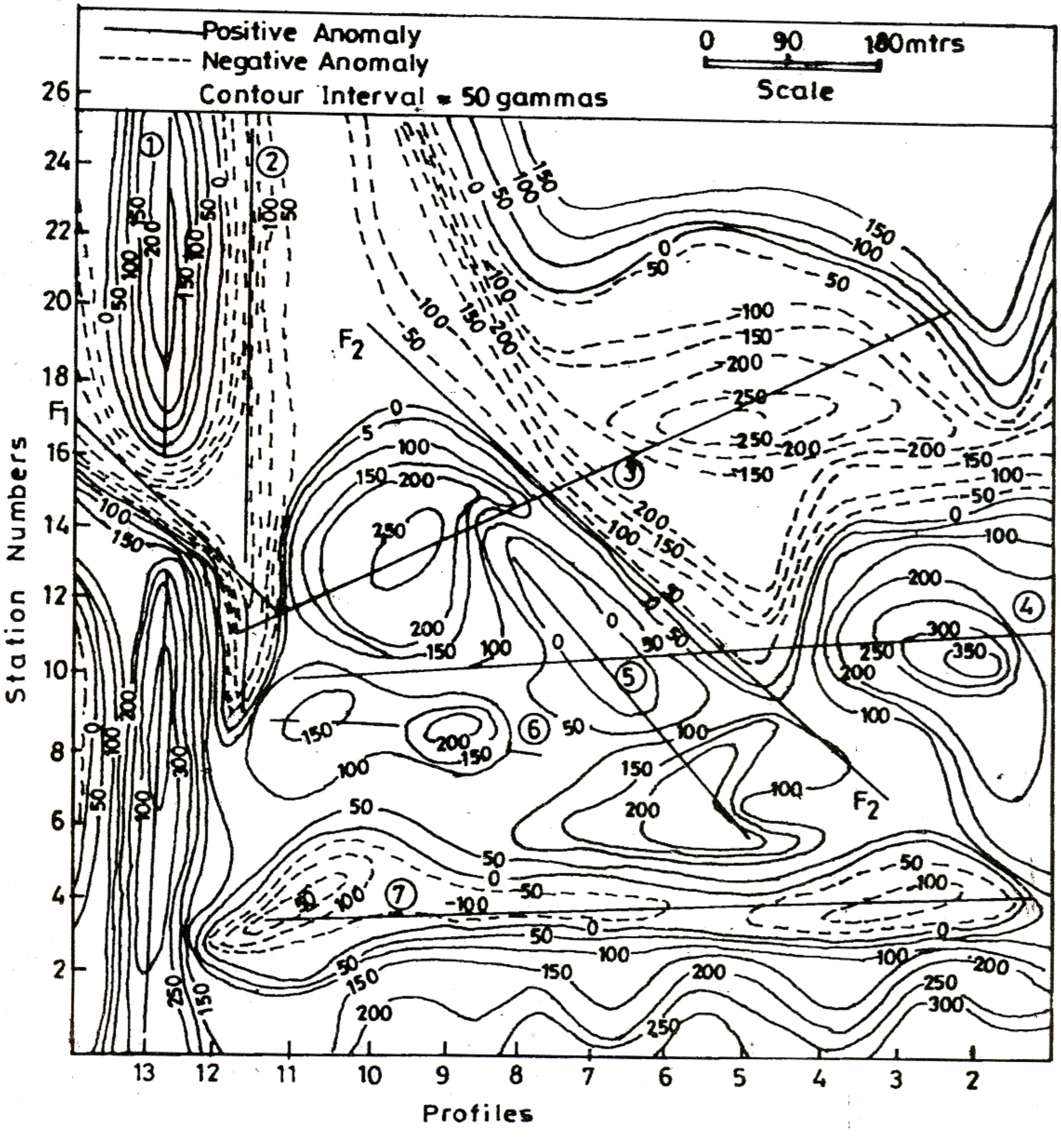


Fig. 5. Contour map of vertical component of magnetic intensity in the southern part of Osmania University campus

While tone/color, texture, pattern, shape, shadows, site and association are image characteristics, the drainage pattern, drainage density, topography/landform and erosion status constitute terrain characteristics (Rao, 1995). Image interpretation consisting of an examination of these image and terrain characteristics was attempted. Essentially the image has an intermediate tonal quality with fairly well distributed tonal units-vegetation (in red), granitic exposures (greenish), built-up areas (light blue), open spaces (yellow to white) and roads and linear features such as dykes and outcrops (dark blue to black). Further sub-classification of the landscape was guided by variations within these tonal units. Thus, green signatures surrounding darker green tones correspond to weathered granite.

The texture of an image refers to the frequency of tonal changes and tonal arrangement (Lillesand and

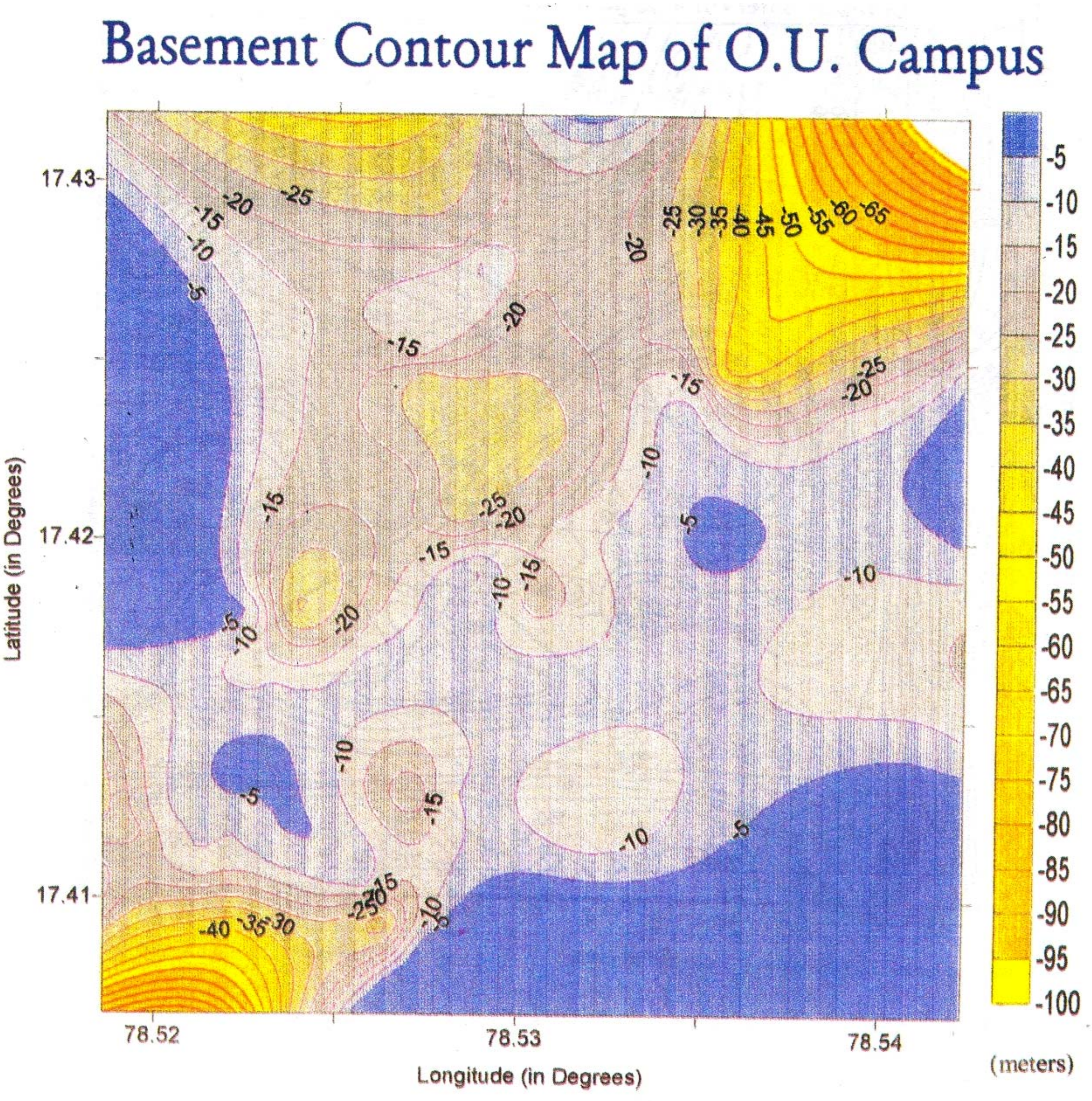


Fig. 6. Contour map of the basement of Osmania University campus as inferred from bore well data

Keiffer, 1996) and is produced by an aggregate of local features, which may be too small to be clearly discerned individually on the image. Texture is scale dependent and is a product of the individual shape, size, pattern, shadow and tone of scene elements and is thus meaningful only for relatively homogeneous sub- units of the image. The rich variety in landuse ranging from uninhabited wasteland/shrub land to densely built-up regions and preponderance of cultural features in the area contributes to an overall coarse texture.

The spatial arrangement of the objects in a scene forms the pattern. The repetition of certain general forms or relationships is characteristic of many objects, and gives

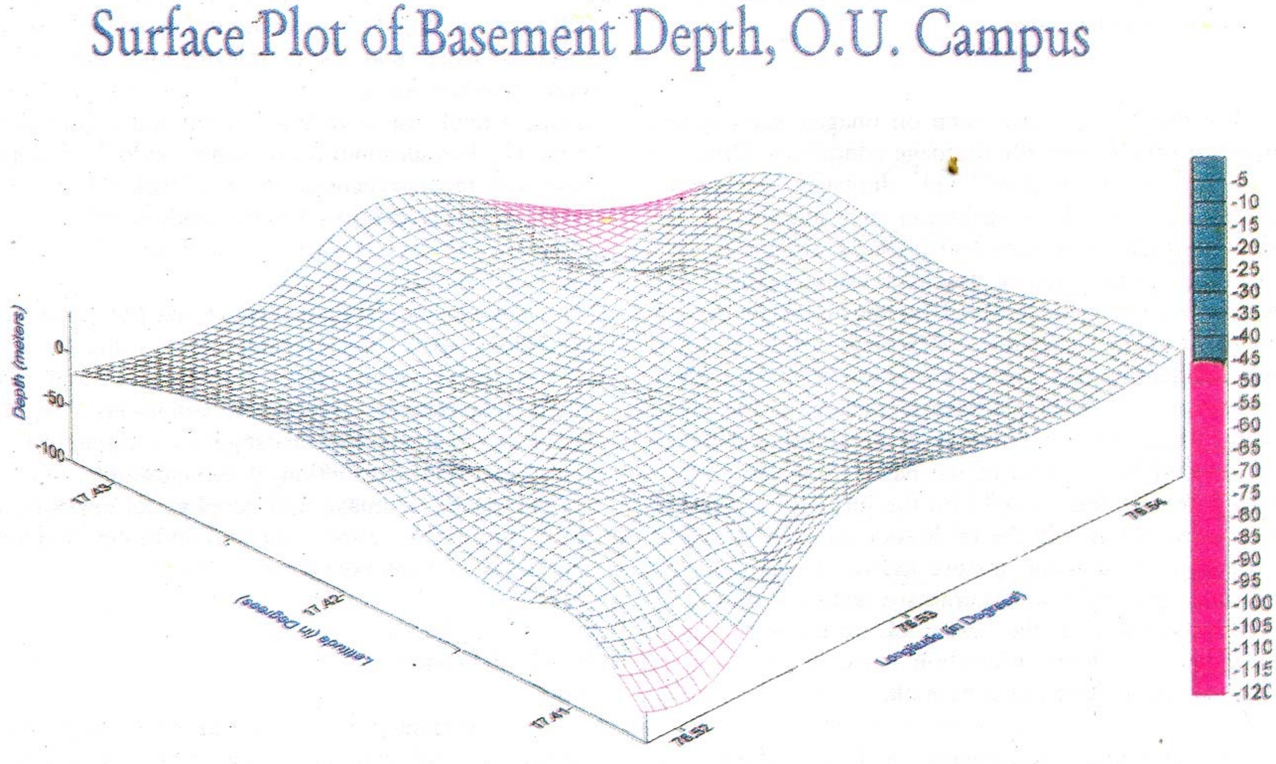


Fig.7. Surface plot of the basement of Osmania University campus as inferred from bore well data

them a pattern which aids the image interpreter in recognizing them. The close spatial association of natural as well as cultural features common in the university campus gives it a characteristic pattern.

Of the other image elements, shape, size and association were helpful in demarcating various cultural features such as roads and buildings. However, on account of the fairly regular topography of the area, shadow does not playa major role in image interpretation in this case.

It can be seen that major rock exposures occur in the southern and southeastern part of the campus. Other rock exposures in the area occurring in a dispersed manner are of small extent and are highly weathered. The extensive vegetation cover obscures the underlying geology at places and it is difficult to interpret the latter with any better resolution.

For the interpretation of linear features, especially, total analysis is perhaps the most important interpretation element. Sudden changes in total quality, presence of narrow long dark features running for considerable length etc. are all indicators of features such as dykes and faults (Fig. 3). Two major dykes running roughly E-W and another running NE-SW can be clearly seen. The N-S feature of approximately 15-20 m width and hitherto not mapped was established as a linear exposure of granitic rocks. The southern side of the campus is marked by several criss-crossing fractures trending in two main directions - NW-SE and NE-SW. A Rose diagram of the lineaments interpreted is shown in Fig. 4. The profusion of these features in preferred directions (NW -SE and NESW) suggests promising groundwater prospects in these zones.

Among the terrain elements, as topographic expression is subdued and masked by cultural features, topographical analysis can be made only from the drainage pattern and texture, which are good indicators of landform and bedrock type (Thornbury, 1986). Thus, from the dendritic pattern of the drainage seen on the southern and east-southeastern sides, a south-southeastward slope in the terrain was indicated.

The drainage patterns .seen on images also suggest soil characteristics and site drainage conditions. Drainage analysis (pattern, texture and drainage anomalies) provides clues to the distribution and attitude of the underlying rock formations and geologic structures such as bedding .planes, joints, fractures, foals, faults, etc. Drainage texture is determined by the drainage density and the drainage frequency (Chorley, 1972; Pandey, 1987). While drainage density is the ratio of total length of all streams of all orders in a basin to the area of the basin, drainage frequency is the number of streams in a drainage basin divided by the area of the basin (Mahajan, 1993). Drainage texture throws light on the infiltration capacity of the rocks. The higher the infiltration capacity of rocks, the coarser is the drainage texture and vice versa. It can be seen from Figs. 2&3 that the drainage texture is coarse, as can be expected; from the hard rock nature of the area. This indicates a high infiltration capacity of the host weathered and fractured granitic rock.

The drainage, lineaments and topography as evaluated from remote sensing and taken together along with the results of vertical magnetic studies and locations of existing bore wells and open wells shown in Fig. 3 (OU Dep. Rep., 1998) were evaluated to demarcate potential groundwater zones.

4. Integrated analysis

From Fig. 4, it can be seen that they coincide fairly well with the lineaments inferred from magnetic studies (Ramadass and Venkatachary, 1992) conducted over a small area in the southern part of the campus (Fig. 5), In the contour map of the vertical component of the magnetic intensity contoured with an interval of 50 gammas, local highs and lows of ±300 gammas are observed. The N-S lineaments inferred from the image as a linear exposure of granitic rocks is corroborated from the magnetic intensity map (1 and 2 in Fig. 4), which shows two closed, elongated and positive sets of contours in the N-S direction in the western side of the campus. They are separated by a fault F 1 that runs in a northwest-southeast direction. Lineaments 3, 4 and 7, ranging in direction from ENE-WSW to E-W were identified as dykes cut across by a fault F2 running NW-SE. Lineaments 5 and 6 correspond to rock exposures.

Well information was available for a total of 65 points including both, bore wells as well as open wells. The static levels ranged from 2.5 m to 16 m and the yields ranged from 3000 to 90,000 gal/day in monsoon. Summer yields are only half the monsoon yield (OU Dep. Rep., 1998). While Fig. 6 is the contour map of the basement as inferred from bore well information, Fig. 7 is the corresponding surface plot (3D-view) of the basement. Thus, a thick fractured zone is suggested at a depth of 5 m, which grades into fresh granite at 20-25 m depth. As expected, the basement occurs at a shallower depth in the northern side as compared to the southern side.

Potential aquifers are characterized by good recharge conditions, apart from adequate porosity and permeability of host rocks. While areas with good natural drainage imply favourable recharge conditions, significant frequency of fractures/joints suggests adequate subsurface movement and distribution of groundwater. Thus, based on the results of image and geophysical analyses, seven such promising zones for groundwater exploitation marked A to G were demarcated (Fig. 3).

5. Conclusions

An integrated survey comprising image analysis, geophysical and hydrogeological studies was carried out in the Osmania University (OU) campus with a view to delineate areas with good groundwater prospects. The significant results of the study are 1. Identification of a major linear N-S exposure of granitic rocks running discontinuously for almost the entire length of the campus, 2. Delineation of several NW -SE and NE-SW trending fractures in the southern side and 3. Demarcation of potential groundwater-bearing zones.

APPENDIX

Contrast Stretch is an enhancement operation performed on an image whereby, the significant range of the intensity values of the image is reset to the maximum range in the processing software. The *Gaussian* stretch fits the collected histogram (a graph of the frequency of occurrence for each pixel value to a normal or Gaussian distribution. In the *Exponential* stretch, new bin values are based on a constant raised-to-the-power of the normalized old bin value. This allows one to enhance the contrast (degree of difference between the light and dark pixels of an image. On the other hand, *Logarithmic* stretch lets one specify a multiplier that operates on the logarithm of the histogram's bin count. This allows one to enhance the contrast in the darker areas of the image, however one also loses contrast between the brighter areas.

Image Analyst (Intergraph Corporation) is a software that allows one to display, process, enhance (*viz*., define settings and options, perform contrast adjustments, modify image geometry, perform spatial enhancements, perform spectral analysis, perform training, classification and post processing and output raster data for various applications. One can manipulate aerial photographs, satellite images or any other raster data that has been scanned into file or read from *CD-ROM* or tape. Pixels in these files are displayed in a wide range of colors and shades. One can display monochromatic (black and white images), color index images and color composite images (displayed with red, green and blue components). Teamed with *MicroStation* (registered trademark of Bentley Systems, Inc.), it provides several tools to enhance, manipulate, display and process raster as well as vector data.

Image fusion (merging) is a process that is used to visually enhance low resolution, multispectral satellite imagery with higher resolution panchromatic imagery. With image analyst, we can register and resample the multispectral (*LISS-III*) satellite image to panchromatic image (*PAN*) whereby the multispectral bands are translated into intensity- hue-saturation (*IHS*) bands by a command that transforms the *RGB* color space into the *IHS* color space. The fused image is then created by replacing the intensity band of the *IHS* image with the higher resolution data. The result of the registration and resampling is thus a color RGB image with the same number of lines, pixels per line, pixel dimension and scan line orientation as the panchromatic image, which in turn implies an increased spatial resolution that 'sharpens' the image.

Image translator is an application to convert raw digital data from an image vendor into standard raster file formats. The *IRSLGSOWG* image translator reads an *IRS* (Indian Remote Sensing Satellite) image in *LGSOWG* (Landsat Ground Station Operators Working Group) format from a local tape device, *CD-ROM* or hard disk and stores the translated image on the disk as an Intergraph or TIFF (Tagged Image File Format) standard raster file. These images can be stored as compressed or uncompressed files.

Spatial filter is a filter for which the brightness value at a location in the output image is a function of some weighted average of brightness values located in a particular spatial pattern around it in the image.

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