Geological Investigation of Rahatgarh Waterfall of Sagar (M. P.) through the Field Survey and Satellite Remote Sensing Techniques

Kuldeep Pareta[1] and Upasana Pareta[2]

***Abstract*—** Satellite remote sensing technology and field survey methods have been used for geological investigation of Rahatgarh Waterfall of Sagar district in Madhya Pradesh (India). A reconnaissance survey is undertaken in geological study and mapping of the area. During the course of geological mapping various methods are adopted while depends upon the shape and nature of the terrain as well as on the outcrop pattern. LandSat-7 ETM+, IRS ResourceSAT-2 LISS-III satellite imageries and IRS-P5 CartoSAT-1 DEM were used to classify the various geological units found in the study area, and discriminate the lithology and structure of this area. A wide variety of digital image processing techniques were applied such as principal components analysis, and ratioing analysis. After the DIP, visual image interpretation, and comprehensive field survey, a geological map has been prepared. The author has also presented the stratigraphy, lithology, and structural aspect of the area in detail.

***Keywords*—** Geological Mapping, Remote Sensing, GIS, and Rahatgarh Waterfall

I. INTRODUCTION

The study of rock and mineral, and earth material in their natural environment with their natural relations constitute the field geology. Field geology is essentially an earth science and forms the basis requisite for any laboratory investigation as well as for economic exploration. Remote Sensing has become an important and effective aiding tool in geological studies. Earliest use of remote sensing techniques (visual interpretation) for geological studies started with aerial photography, and then came space photography followed by space multispectral scanning. Remote sensing techniques, generally used now-a-days include analysis of various types of multispectral scanner imagery, SLAR and space borne radar. The geological studies include making surface observations, identifying the relevant terrain features and drawing inferences about the surface conditions, and representing them on the map in their proper perspective and interrelationship so that they can be translated into applied geoscientific aspects.

II. DESCRIPTION OF THE STUDY AREA

The area under study around Rahatgarh Waterfall has situated on Bina River at Rahatgarh Tehsil along the Sagar-Bhopal road, 40 Kms away from Sagar town, and located between 23.69 to 23.84 N latitude and 78.29 to 78.50 E longitudes (Fig. 1). Bina river has originates from Rashidpur village of Raisen district in Madhya Pradesh at about 666m (78.14 E longitude, & 23.32 N latitude). The study area falls in Survey of India (1:50,000) toposheets No. 55 I/05. The area comprised mainly two types of rocks, namely igneous rock represented by the Deccan Traps, and sedimentary rocks represented by the Vindhyans. Vindhyan constitute roughly 11% of the area marked and Deccan Traps constitute 89% of the area. Deccan Traps showing denoted topography while Vindhyan formation constitute narrow ridges with dips escarpment slope and displaying sedimentary structure such as ripple marks, current bedding, current lineation, bedding planes, etc.

III. DATA USED AND SOURCES

S. No.	Data Layer / Maps	Source
1.	Topographical Map	- Survey of India Toposheet at 1:50,000 Scales - No. 55 I / 05
2.	Remote Sensing Data	- ResourceSAT-2 LISS-III Satellite Imagery with 23.5 m Spatial Resolution - LandSat-7 ETM$^+$ Satellite Imagery with 30.0 m Spatial Resolution - IRS-P5 CartoSAT-1 (DEM) with 30m Spatial Resolution
3.	Geological Map	- Sagar District Geological Map has been collected from GSI and updated through IRS-P5 CartoSAT-1 (DEM), ResourceSAT-2 LISS-III, and LandSat-7 ETM$^+$ Satellite Remote Sensing Data with Field Check
6.	Slope Map	- Slope map has been created using Spatial Analyst Extension in ArcGIS-10.1 software, and ASTER (DEM) @ 30m Spatial Resolution / CartoSAT-1 (DEM) @ 30m Spatial Resolution
7.	Drainage Map	- Drainage network has been generated in GIS environment using ASTER (DEM) data, CartoSAT-1 (DEM) Data and ArcHydro Tool in ESRI ArcGIS-10.1 software

[1] Head (Geo-Science Division), Spatial Decisions, B-30 Kailash Colony, New Delhi 48 INDIA (corresponding author phone: +91-9871924338; Fax: +91-11-29237246, e-mail: kpareta13@gmail.com).
[2] Lecture (Mathematics), P.G. Collage, District Sagar 470002, Madhya Pradesh, INDIA (e-mail: rpareta22@gmail.com).

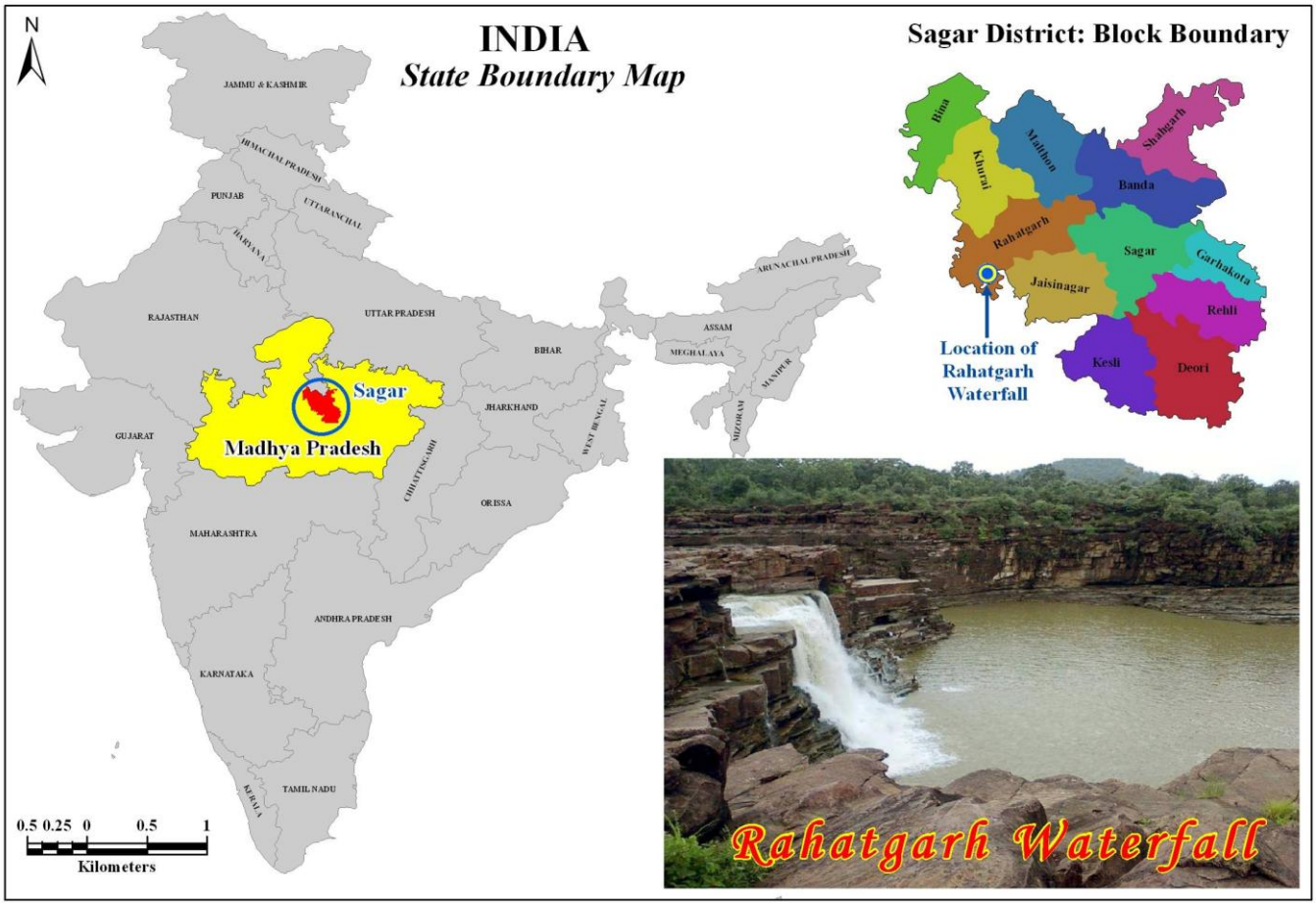

Figure 1. Location map of the study area

IV. FIELD METHODS FOR GEOLOGICAL MAPPING

A. Reconnaissance Survey

In order to have an intimate knowledge and familiarity of the rock formation of the area, to draw a scheme of the method to be followed for mapping and to the traversal depending upon the pattern of outcrop. Different field methods have been used for geological mapping.

B. Contract Following Method

In this method the boundary of two geological formations is located on the base map by a contact point and some that point. The contact is followed all along the contact by tacking forward bearing and measuring up all the rocks behave differently to change of environment various criteria are used, these are:

Break in Slope: The topographic break in the slope affords one of the surest criteria to distinguish the contact between the two flows in the case of Deccan Trap. The break in slope result due to change in the physical properties of the two flows is resulting in a step like appearance of a trap ridge.

Difference in Vegetation: Since, different type of rocks generally gives rise to different type of soil (Change in type and colour of soil) and changed in the tone or vegetation can be used to determine the contact. Vindhyan are characterized by less vegetation and dense vegetation in Deccan Traps. The soils of Vindhyan are generally sandy, while Deccan Trap soil in black in colour.

Difference in Soils: The rock formation wheather in due course of time giving rise ultimately to different type of soils. Like the parent rock formation the soils that are formed by them have different characters. The area have cites an example about how different the soils could be, if they are formed by different rock formation. Deccan trap give rise to black cotton soil which is black in colour, while Vindhyan form red coloured soil of sandy fed. It is hence, the soil that forms another basis for demarcation of contact between rock formations.

Lithological Changes: The presence of different rock formation an either side's givens a clue regarding the contact of the two formations. As the rock formation exhibit different characters even when observed in the field and they are easily identified, it is the best clue to mark the contact in the basis of lithological variations.

C. Rectilinear Offset Method

In this method form a base line like a round marked on toposheets at regular intervals, offsets are taken up to the contact and the offset points are connected to mark the contact. In this method, the base line must be such that it must be more or less parallel to the contact.

D. Radial Plotted Method

In this method from common predetermined control point of a hill or outcrop, radial offsets are taken in all the direction up to the contact point and the measured distances along the offset are marked and the outcrop pattern completed.

E. By Measuring the Thickness

In case of Inliers constituted by horizontal formation such as Deccan Trap and Vindhyan from the contact point up to

the base of inlier. The slope distance and slope angle in measured and thickness computed. Deducting the thickness of the inlier from the top of the entire hill, the contour in constructed between the two formations.

F. Contour Fixing Method

This method can use for mapping the Deccan Trap. They were not mapped by contour following method as adopted in case of Vindhyans. On the controversy as traps are mostly horizontal several features are measured, differentiated the flows by fixing the elevation with the help of level Abney or by contour breaking technique. In this way, the elevation at which each flow traps up is recorded and average before it is represented as the map.

The contact between the lower and upper flow was found as elevation of 1610 to 1615', 1620 to 1625' and the average worked about at 1620'. Hence, on the map the contact was marked all along the 1620' contour to demark the lower and upper flow.

V. REMOTE SENSING BASED GEOLOGICAL MAPPING

LandSat-7 ETM+ (30m), IRS ResourceSAT-2 LISS-III (23.5m) satellite imageries and IRS-P5 CartoSAT-1 DEM (30m) were used (Fig. 2). The ETM+ imagery were chosen for their large spectral resolution and their appropriate spatial resolution, LISS-III imagery was used to provide detail information about the texture, and CartoSAT-1 was used to provide the information about the topography of the ground surface. The images were geometrically corrected and represented in UTM projection, WSG84, using topographic maps (SoI) at scales 1:50,000. The geological map (GSI) at scale 1:250,000 and 1:50,000 were scanned and geometrically corrected. The ERDAS Imagine software was used for digital image processing. This provided useful lithological, structural and mineral information.

The Principal Component Analysis (PCA) is a statistical technique widely used in remote sensing, which allowed to extraction of lithological information. LandSat ETM+ imageries have a large number of spectral bands, which were very useful for lithology, soil and terrain pattern differentiation. Band Ratioing Analysis (BRA) method was also used for lithological and alteration mapping in this study. This method is used by [19], [1], and [2] to extract spectral information from multi-spectral imagery. Author has also used the band ratioing analysis method for more geological information in the study area (Fig. 3).

VI. GEOLOGY OF THE STUDY AREA

Geology of any area comprises essentially of three aspects, namely: a. Stratigraphy of the area, b. Lithology of the area, c. Structural aspect of the area.

A. Stratigraphy of the Area

The stratigraphy of the area around Rahatgarh is very simple, composed chiefly of two major formations, one represented by a magmatic phase and the other by sedimentary phase of rock formation. The igneous formations are represented by a series of volcanic flow belonging to fissure type of eruptions, known as "Deccan Traps", while the sedimentary formations represented by massive irregularly bedded ortho-quartzite known as "Vindhyan" formation. Minor formations of less importance are represented by "Intertrappeans", and "Resent Alluvium".

Vindhyan: Vindhyan of Indian stratigraphy constitutes the Super Group of Pre-Cambrian formation of Proterozoic age. These rocks have been classified into two major groups, namely, lower and upper respectively. These two groups are further classified into various stages.

The Vindhyan around Rahatgarh belongs to Rewa Stage of Upper Vindhyan Group mostly represented by irregularly bedded massive, variegated coloured ortho-quartzites. These are intercalated at various places with thinly bedded flog stones.

Good Vindhyan patch around Rahatgarh area are seen at Rahatgarh Ruins waterfall, conical hill, Kalianpur, Dehri, Russalpur, and Mankapur.

Deccan Traps: The close of the cretaceous heralded the down of the intense volcanic activity which inundated the Indian Peninsula, from a number of fissures constituting what is known as Deccan Traps in Indian stratigraphy. These traps constitute roughly about 200000 Sq Miles of the Indian sub-continents. These traps have been classified into three groups of flows, namely;

Deccan Traps	Upper Flows: Characterized mostly by Ash Beds Middle Flows: Lower Flows: Characterized mostly by Intertrappean and rarely Ash Beds

The volcanic flows around Rahatgarh are characterized by the presence of Intertrappean and come under the Malwa Plateau; belong to lower flows of the Deccan Traps of Indian stratigraphy. These traps are represented by plateau basalts occurring as horizontal lava flow.

Traps are well exposed at various sections, but all the eight flows are seen at only two places, namely Mirzapur, and Chandrapura respectively.

Infratrappaeans: These occur as thinly bedded, gravely breccias in between Vindhyan and Deccan Traps. They occur over the Vindhyan and below the traps, hence, called Infratrappaeans. They are mostly composed of angular to sub angular Vindhyan quartzite cemented by ferruginous material. This is well seen at Kalianpur Bridge and Nandian nallah.

Intratrappaeans: These are found in between flows and indicate paucity during the time of eruption of the basaltic flows. Intratrappaeans are mostly represented by an impure calcareous facies; comprising principally cherty limestones. The limestones display lateral variations along the strike resulting from an impure cherty limestone to pure crystalline limestone composed of Aragonite. Outcrops are scanty and occur as pitches of small magnitude. It is seen at elevation of 1550' between 2nd and 3rd flows as seen at Hanothia Khurd and at 1750' between the 4th and 5th flow as seen at Chandrapura and at only one place (Chandrapura) at an elevation of 1870' between the 7th and 8th flows. This Intratrappaeans found at 1870' were mostly cherty and marly containing unmistakable, incipient fragmentally wood fossils.

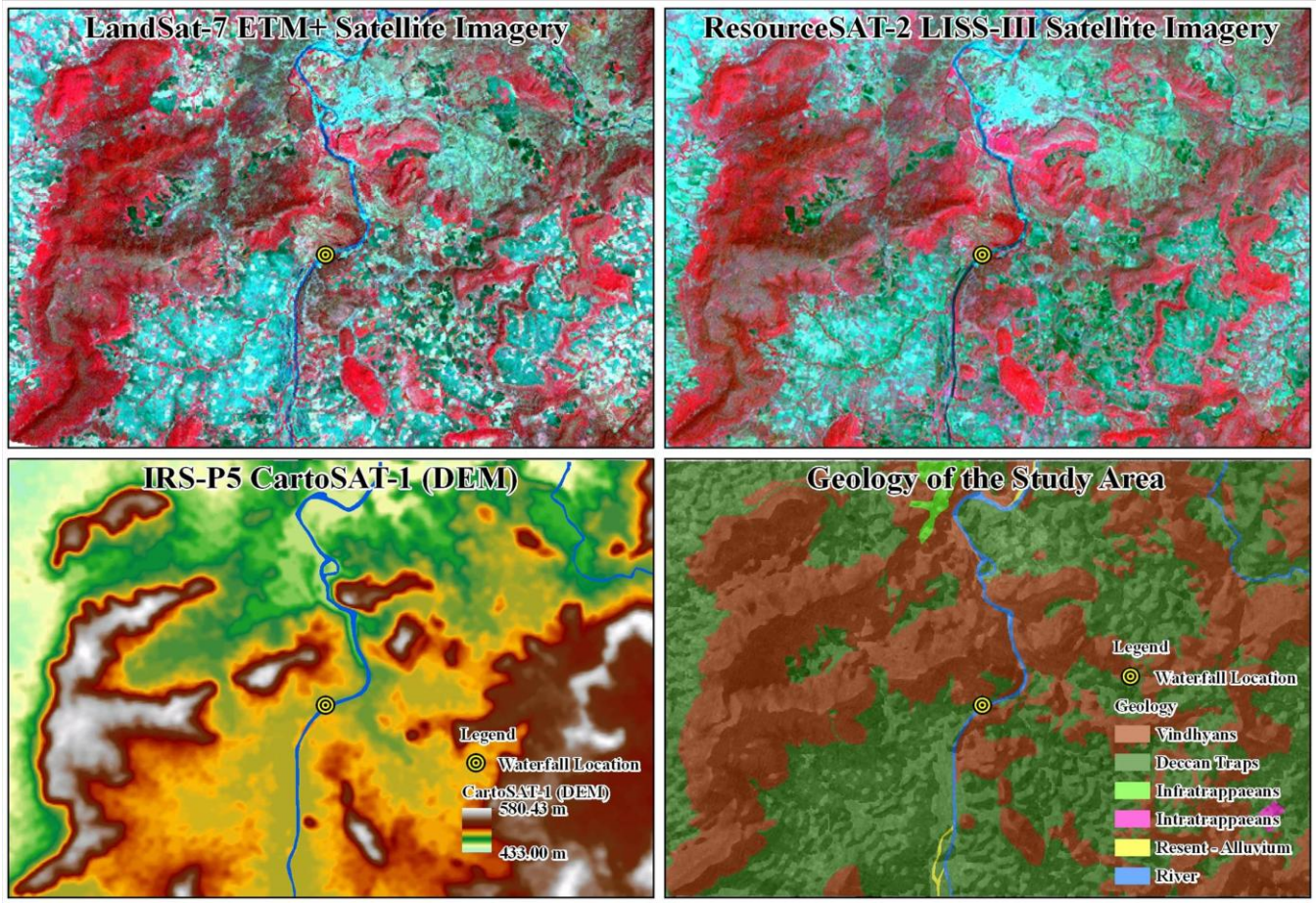

Figure 2. LandSat-7 ETM+, IRS ResourceSAT-2 LISS-III satellite imageries, IRS-P5 CartoSAT-1 DEM, and geological map

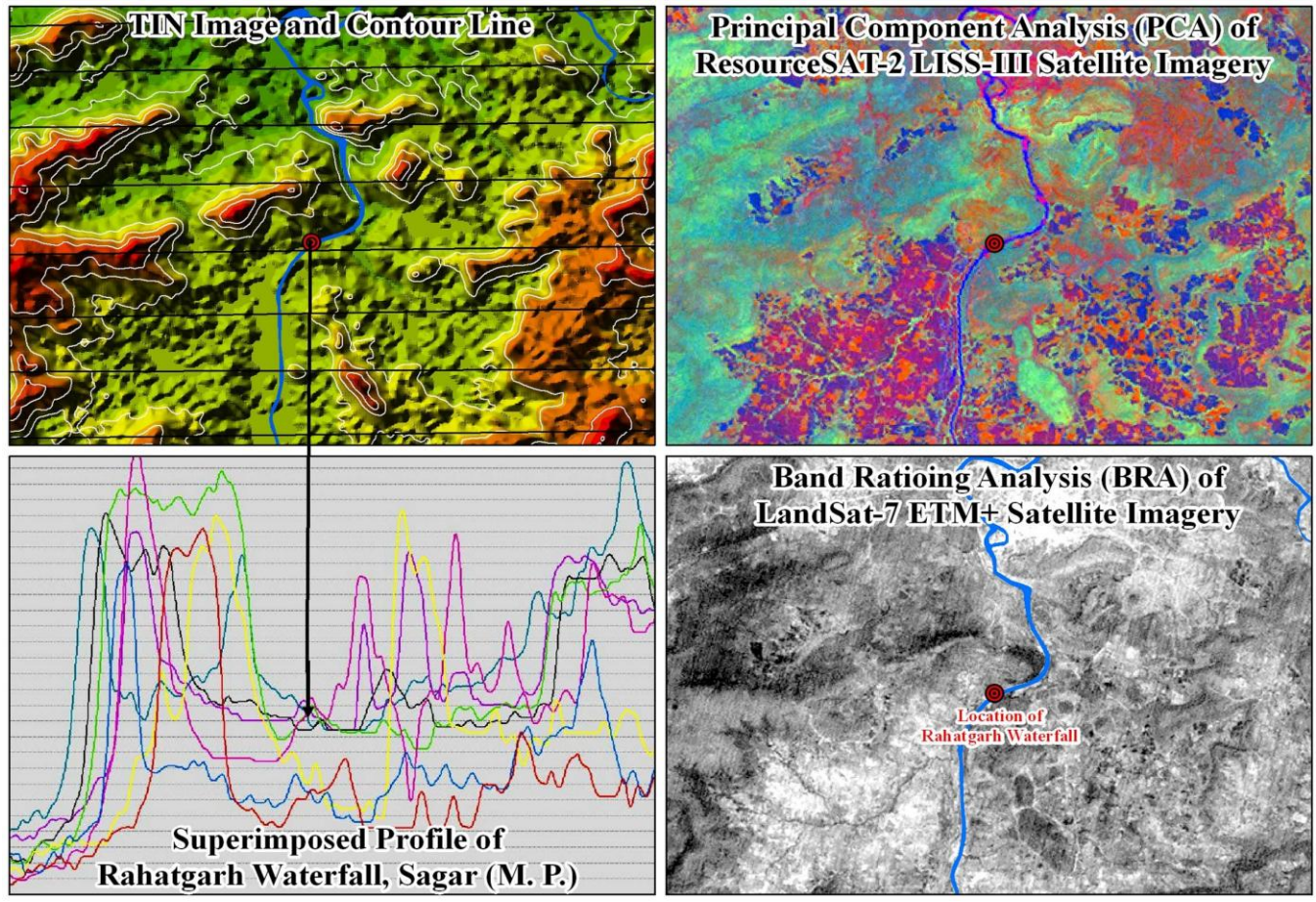

Figure 3. Principal Component Analysis (PCA), Band Ratioing Analysis (BRA), TIN, and Superimposed Profile of Rahatgarh Waterfall

Resent - Alluvium: This is mostly seen on the river banks as at our composite which is actually an alluvium island composed of resent alluvium covering the Vindhyan.

B. Lithology of the Area

The lithology of the Vindhyan has already been eluded in stratigraphy. They are presented mostly by fine grained, dense, compact ortho-quartzite, displaying irregular bedding and quite a few sedimentary structures. The sedimentary structure seen in these are: a. Current bedding, b. Current lineation, c. Ripple marks, d. Stylolites, d. Salt and pepper structure, e. Oblique bedding, f. Joints.

Intercalated with these massive ortho-quartzites are the thinly bedded flog-stones showing fine, thin laminations. The Vindhyan rocks display a galaxy of colors ranging from red, brown, pink, rose blue and grey. Most of the quantized display sacchroidal and mosaic texture in hand specimens.

Deccan Traps: The Deccan traps are mainly represented by basalt, which display are array of field and petrographic characters to distinguish then megascopically as well as in the field. The area around Rahatgarh comprised eight flows totaling a thickness of 500', the heights elevation of the trap area being 1932' and the lowest 1450'. The various field criteria used to identity there are presented below:

Flow No. 1: Generally exposed in inner beds and nallah cutting in the field and occurs as a highly weathered outcrop. Its bottom is not exposed. Exposers are found at Mirzapur, Bina River bed etc.

Flow No. 2: This flow is characterized by prominent rectangular to columnar jointing and its dark looking and mostly fresh. The horizontal and vertical jointing in this flow produced a fissile nature. The top of this flow is highly weathered displaying onion-shell weathering resembling to stone flower. Its thickness are various between 40' - 50' and crops up between 1490' and 1533'. Exposures are found at masque hill, Mirzapur and Hanothia Khurd.

Flow No. 3: It is mesocratic and characterized by irregular, generally closed spaced jointly resulting in boulders of various sized. It displayed differential weathering resulting in large spurs having dirty greenish and grey aspect. Often, it is highly fissile. It has a vesicular top full of secondary minerals. It occurs between 1535' to 1620' constituting the marker flows.

Flow No. 4: A melanocratic and characterized by regular and widely spaced jointly resulting in big blocks. It also displayed differential weathering giving rise to a highly buggy appearance to the flow at the top and filled in by secondary minerals. Thickens vary between 80' to 90' and crops at elevation of 1620' to 1720'. Good Exposures are found at Mirzapur and Lalbagh.

Flow No. 5: Occurs as huge, irregular, erratic blocks and comes off into sharp clips on breaking with a hammer. Often they display radiating structures on fresh surface. On weathering it shows light yellowish grey colors. It is a thickest slow varying in thickness between 90' to 100' and crops at 1710' to 1810' exposures at Mirzapur, Hanotia Khurd, etc.

Flow No. 6: This flow resemble very much to dyke in it mode of occurrences and appearance being constituted by small to big boulders with lot of ferruginisation. On weathering it resulting into light, dirty green coloured rocks. It estimated thickness was found to be 50' and crops at 1810' to 1860'.

Flow No. 7: IT occurs as hue erratic blocks, often situated at the top and invariably full of weathering pits. The top is vesicular. In many section, it is highly lateralized except in Mirzapur hill, when lateralized it taken on a phisolitic appearance. Its thickness was found to be about 50' and occurs between 1860' to 1900'.

Flow No. 8: It occurs as big brown red boulders, very closed resembles a dyke to flow No. 6. However, it can be distinguished from the relating size of the boulders. The boulders peel off in layers. Its top is not exposed and the thickness estimated in the hill section at Mirzapur was found to be 32' about the elevation of 1900'. The variation in the thickness of flows in the eight measured sections, as well as the averaged thickness of the eight flows is presented in fig 4.

Distinguish the flows exposes at Rahatgarh a village near Sagar along Sagar-Bhopal road. The traps at Rahatgarh constitute 208 Sq Kms making 93.7% of the area. The traps are basaltic belonging to "FISSURE" type of eruption. The flows are all horizontal producing stepped hill, buttes. The traps are distributed all over the area, mostly constituting hills which are as high as 1932'. They are also found in plains and valley at an elevation of as low as 1400'. In all eight flows have been recognized in the area. And the various criterions used to distinguish them are as follows:

1) The Presence of Bends of Intertrappeans: which indicate intervals of quiescence between the successive periods of volcanic activity, e.g. flow No. 3 is distinguished from flow No. 4 and flow No. 7 from flow no. 8 by this criterion.
2) The Presence of Secondary Minerals: A zone of vesicles or amygdales filled in by secondary minerals (flow No. 1, 3, and 7).
3) Break in Slope: A break in slope or terraced appearance, e.g. flow No. 5, and 6.
4) Zone of Lateritization: A zone of laterization at the top e.g. flow No. 2 and 7. Besides these criteria used to demarcate the contact between the two flows, other criteria used in conjunction with them are:
5) Weathering: Characteristics like spheroidal weathering (flow No. 1, 2, 3, and 4); onion shell weathering (flow No. 7); weathering resulting in to small boulders (flow No. 2, 6, and 7) or weathering into big boulder (flow No. 5, and 8) are used.
6) The Nature in the Distribution of Joints: Joints may be closely spaced (flow No. 2, 3, 6, and 7), or widely spaced (flow No. 1, 4, 5, and 8), regular (flow No. 5) or irregular (flow No. 2, 3, and 76), again they may be columnar (flow No. 2 and 4), or ball and socket type (flow No. 1, and 3).
7) Soil Type: These criterions have to be used continuously as the soil might have got admixture along the slope (flow No. 4, and 5).
8) Frequency of Boulders: It is a very useful criterion in case of slopes covered by rolled boulders. Also the disappearance of boulders of one type which climbing up the hill given a position clue about the end of the flow (flow No. 5).

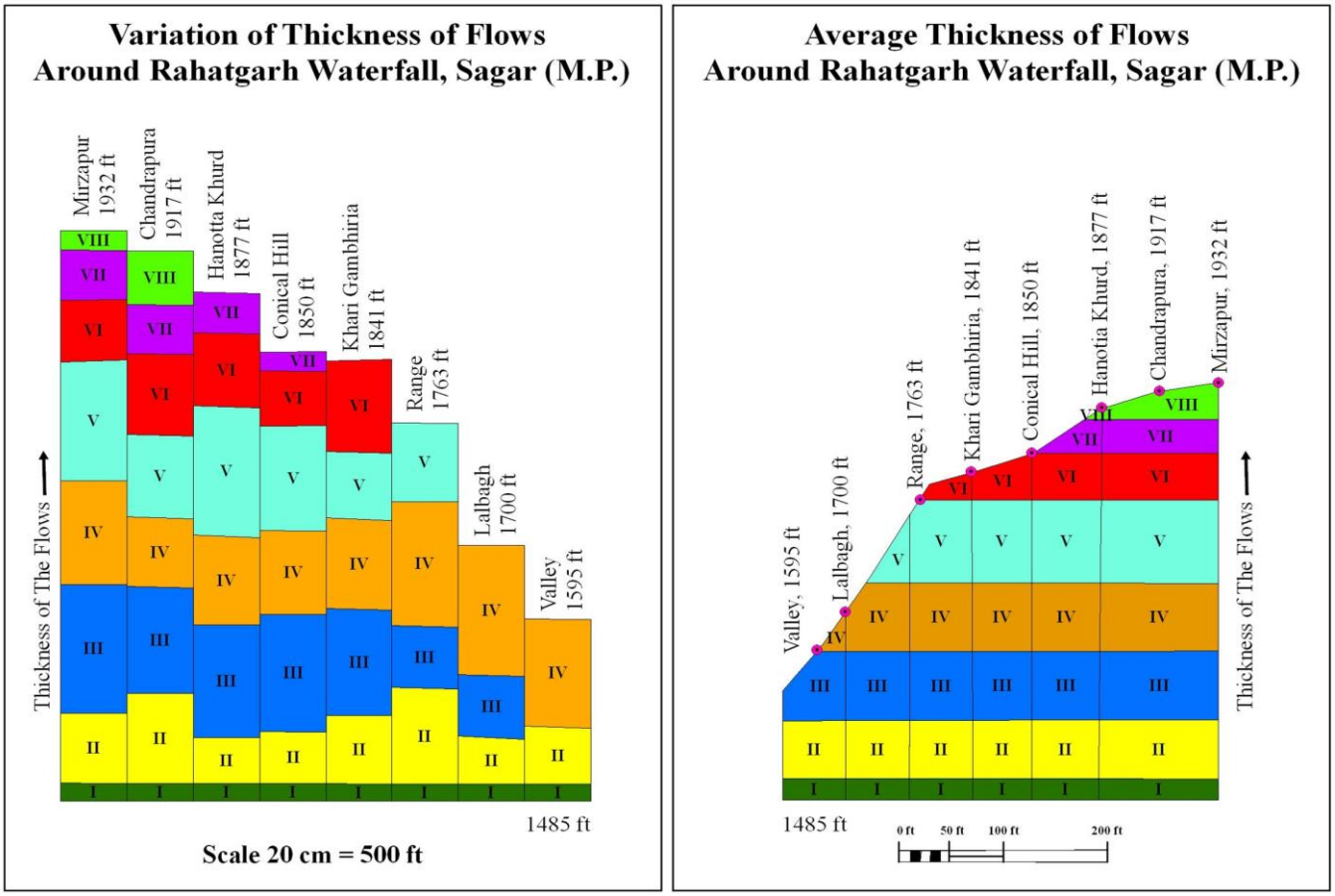

Figure 4. Variation of Thickness, and Average Thickness of Flows - Around Rahatgarh Waterfall, Sagar (M. P.)

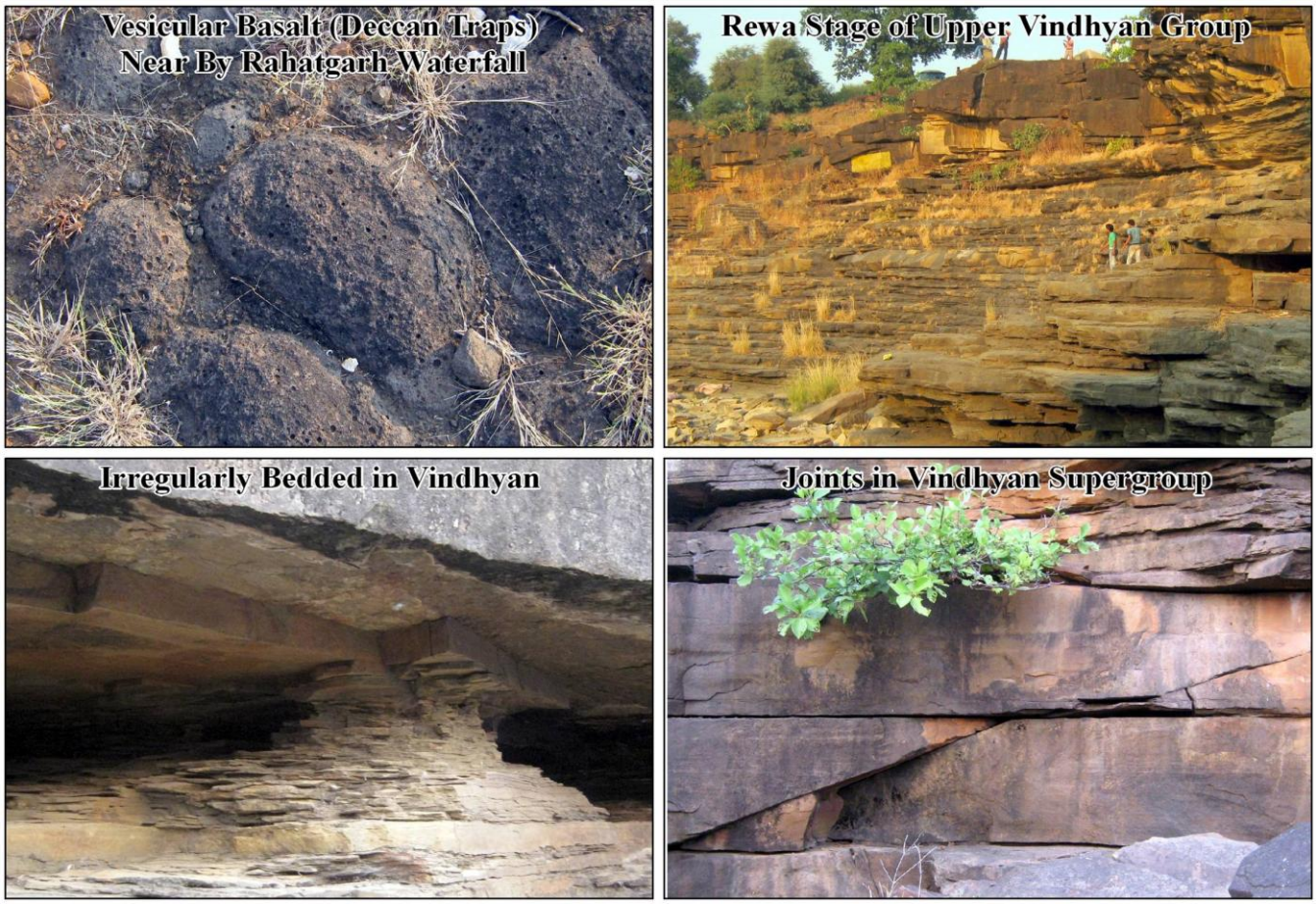

Figure 5. Different Rock Formation of Deccan Traps, and Vindhyan Supergroup - Around Rahatgarh Waterfall, Sagar (M. P.)

C. Structural Features of the Area

The area has structurally undisturbed constituting practically horizontal formation. The Vindhyan however, in a few places show gentle dips ranging from (20 to 160), forming up to raping and down buckings. The upwards are in the form of broad open occurs. One such map is seen at Kalianpur. The incompetent flog stone intercalated with the massive ortho quantized show Penecontemporaneous Deformation owing to the super incomitent pressure of the competent ortho quantized.

Joints are numerous in Vindhyan rock and these are both strikes as well as dip joints extending over considerable distances and constituting Master Joints. They are also bedding and other oblique joints. An analysis of joints of Vindhyan is shown in fig. 5.

The Deccan Traps are mostly horizontal and almost keeping uniform thickness and the only structural feature seen in them are the joints. The joints are of various types ranging from regular closely spaced to irregular widely spaced joints. In flow No. 2 and 3, spectacular columnar joints are seen; ball and socket joints are also seen.

VII. MINERALOGY OF THE AREA

Minerals of economic importance are not found in the area. However, minerals of academic impotence are found in basaltic rocks. The minerals are mostly confined to the top of lava flows and are mostly of secondary origin. They may be grouped into:

Silica Mineral: The silica minerals are mostly of secondary and represented by cryploxline forms. They are mostly seen on the top of 2nd and 4th flow formation huge and goods filling, and amygdales. The various silica minerals observed are, Opal: Two varieties are seen namely milk opal, and pine opal. Agate: It is bluish grey in colour and bonded variety is not uncommon. Plasma: Red variety of silica seen occasionally. Chalcedony: These forms 'COPRA' like structures forming cavity fillings. Carnelian: Yellow variety of silica seen rarely.

Carbonate Minerals: Carbonate minerals are mostly found at the top of second flow and intertrappean. The carbonate mineral seen in intertrappean is Aragonite, while the carbonate mineral seen in basalts is calcite. It occurs in various forms, namely as crystal and massive forms. The colour is variable seen vine yellow to block and grey. It is transparent of opaque.

Zeolite Group of Minerals: These are very abundant are basalts and seen at various levels confined to the top of the 2nd flow, 3rd flows, and 7th flow. Each flow is characterized by a particular variety of Zeolites, which is useful in identification of flows. The Zeolites seen are, Chabazite: Occurs as Pseudo-cubic forms, whitish grey colour and displaying interpenetration twin. It is characteristically seen on the top of 2nd flow. Stibite: Occurs as acicular and radiating crystal, forming amygdder, seen on the top of 3rd flow. Heulandite: It is white in colour and occurs as crystal on the top of 3rd flow. Scolicite: This is seen mostly on the top of 7th flow exhibit bladed habit and is rarely seen in 2nd flow. Mesolite: this is seen intimately associated with silica minerals in flow No. 2 forming fibrous wary margins.

Miscellaneous Minerals: The miscellaneous minerals included secondary green earth minerals, namely, celadomite, chloropharite. Celadomite is bluish green, such as amorphous crystals are the top of 2nd flow, while chloropharite is seen confined to all flows. However, clove brown variety is seen in 3rd flow and black variety in other.

VIII. ECONOMIC IMPORTANCE OF THE AREA

Vindhyan quartzite exhibiting master joints can be quarried for the purpose of foundation stone, while the flag stone intercalated with it, because of their laminar can be used as roof stone. Here and there the Vindhyans have been lateralized into yellow and red ochres, which can be used for anguants and pigments.

Deccan Traps comprising mostly basalts, because of the ability to heal up formation are excellent as road ballast. Some of the flows which are fine grained hard and compact, exhibiting columnar jointing can be easily quarried for building stone. The lower flow, which are mostly confined to plains and vallies are excellent block cotton soil (Regur) for agricultural green revolution. Lastly the 3rd flow which weathering and where the weathering 2nd flow is as deep as 1st forms wheat is locally know as Moran, constitute excellent ground water potential for dug wells as well as tube wells.

IX. CONCLUSION

This study showed that remote sensing techniques are an efficient tool for geological mapping other than reconnaissance field survey. Different image processing techniques i.e. Principal Component Analysis (PCA) and Band Ratioing Analysis (BRA) were applied to get the geological information. Moreover, remote sensing has also proved a valuable aid in exploring mineral resources in comparison of reconnaissance field survey.

ACKNOWLEDGEMENT

We are profoundly thankful to our **Guru Ji Prof. J.L. Jain**, who with his unique research competence, selfless devotion, thoughtful guidance, inspirational thoughts, wonderful patience and above all parent like direction and affection motivated me to pursue this work.

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Dr Kuldeep Pareta (M'35) has obtained M.Sc. Degree in Geography and Ph.D. degree in Geomorphology & Hydrogeology from Dr. H.S.G. University, Sagar (M.P.) INDIA. Presently, he is working as Head (Geo-Science Division) in Spatial Decisions, New Delhi, India. He has published 2 International Books, and over 36 Research Papers in various National and International Journals. He was conferred Univeristy Gold Medal in 2001 and M.P. Young Scientist Award in the year 2004.

Upasana Pareta (FM' 29) has obtained M.Sc. in Mathematic from RDV University, Jabalpur (M. P.) INDIA. Presently, she is working as Lecture (Mathematic) in P.G. College, District Sagar (M.P.) India, and she has published over 23 research papers in various Journals.