Application of Remote Sensing Technique in Identifying The Structurally Controlled Landforms And Geomorphic Processes of Kalimachak Riverbasin, (Sub-basin of Narmada)

Dissertation submitted to Jawaharlal Nehru University
in partial fulfilment of the requirements for
the award of the Degree of
MASTER OF PHILOSOPHY

K. S. Meera

CENTRE FOR STUDY OF REGIONAL DEVELOPMENT
SCHOOL OF SOCIAL SCIENCES
JAWAHARLAL NEHRU UNIVERSITY
NEW DELHI—110067. INDIA

1988

JAWAHARLAL NEHRU UNIVERSITY
SCHOOL OF SOCIAL SCIENCES
CENTRE FOR THE STUDY OF REGIONAL DEVELOPMENT

Telegram : JAYENU
Telephones : 652282
667676
New Delhi-110 067

25th June, 1988

DECLARATION

Certified that this dissertation entitled "APPLICATION OF REMOTE SENSING TECHNIQUE IN IDENTIFYING THE STRUCTURALLY CONTROLLED LAND FORMS AND GEOMORPHOLOGICAL PROCESSES OF KALIMACHAK RIVER BASIN (NARMADA)", submitted by Mr. K.S. Meera, in partial fulfilment of the requirements of the award of Master of Philosophy (M.Phil.) degree of this University, is a bona-fide work to the best of our knowledge and may be placed before the examiners for evaluation.

Dr. S. PADMAJA
Supervisor

Prof. A.K. MATHUR
Chairperson

ACKNOWLEDGEMENT

I express my deep felt gratitude to my supervisor Dr. Padmaja whose continuous guidance and valuable suggestions played a vital role in completion of this work.

I wish to thank Dr. K.S. Sivasamy, for his kind help and encouragement.

Thanks also due to the faculty, staff and friends.

K.S. MEERA

C O N T E N T S

FIGURES

TABLES

APPENDICES

1. CLUES TO RECOGNISE AND PREDICT THE MASSMOVEMENT FROM AERIAL PHOTOGRAPHS

2. SINUOSITY INDEX

PREFACE

Remote sensing is a Science of deriving information about an object without any physical contact. This significant technique has been used in various fields i.e.,

1. In understanding and Prediction of weather Phenomena
2. Detecting the ocean and surface winds
3. Measuring of cloud top temperature,
4. Fire detection in forest
5. Differentiating the sharp edges of water impoundments
6. Picking lineaments which are very much useful in identifying water and mineral resources etc.,
7. Soil & vegetation mapping
8. Monitoring the environment
9. Rural and urban land use planning etc.,

Remote sensing plays an important role in Gemorphological investigation. It is very much useful in identifying the relief features. First and Second order features like continents, oceans and plains, plateaus and mountains can be identified through satellite imageries and small scale photographs. Third and fourth order relief features like valleys, ridges, alluvial fans, channel scars etc., can be identified clearly through large scale aerial Photographs. Detecting the minute streams which is very much useful in density

study, identifying parallel ridges of large area, differentiating the rock types, delineating the minor landforms, analysing the different geomorphic processes and above all preparing a good geomorphological map, all are successfully done with the help of large scale aerial photographs.

In this study an attempt is made to analyse the various structural and process oriented landforms with the help of aerial photographs. An attempt has also been made to correlate the present landuse with the landforms to ascertain the importance of environmental parameters and conditions on land use.

chapter - i
general introduction

CHAPTER - I

GENERAL INTRODUCTION

1.1 INTRODUCTION : -

Gemorphology constitutes the study and interpretation of land forms. It is considered as a branch of geology ~~with~~ which deals with the land forms which are controlled by geological forces. These forces that are responsible for shaping the earth can be classified into endogenetic and exogenetic processes. The endogenetic processes that originate within the earth include fold, fault, volcanisim, earthquake etc. The exogenetic processes originate outside the surface of the earth crust include denundation, (degradation and aggredation) which are performed by various gradational agents such as running water, ground water, glaciers, wind etc. The effects of both these processes on the surface of the earth are prominent.

Landforms produced by different geomorphic processes are influenced by various factors such as the geographic location, climatic zone, geological set up in terms of lithology and structure and sub-aerial denundational agencies of the area. The landforms owe their origin to both exogenic and endogenic forces while the Endogenic paves

the way for structural landforms in the form of fold, fault and lineaments etc. The exogeny modifies and carves out various relief orders at various levels attributed to dominant denundational agents.

Difference in rock composition and structure controls the development of landforms and the fluvial pattern. River flows according to structure till the discharge increases to erode the landform. So drainage pattern differs according to the structure.

Structural control over a region can be identified through lineaments which are especially resulting from faults, off-setting streams, straight course of stream, Gullies, vegetation and long valleys etc.

Different geomorphic processes especially weathering, mass wasting and fluvial processes produce their own distinct land forms. A geomorphic process changes the landscape in a slow but constant manner. These processes operate in an open system frame work and influenced by various parameters and understanding of such processes is complicated in terms of multivariability on space and time.

Geomorphic processes affect the land utilization of any region for example in the case of meandering river the losses at the convex curves are generally counter

balanced by comparable gains of land in the convex banks of the meander. The land lost is often situated higher and thus is more or less safe from flooding. Soil formation has made this area agriculturally more valuable than the newly gained low lying areas.

In the above context, to study how the structure controls the land forms, and to understand the various geomorphic processes of any particular region where the fluvial erosion also dominent and to know the impact of these geomorphological processes over land utilization of the area, the Kalimachak river basin which is a sub-basin of Narmada has been chosen, as this region offers a variety of structural landforms as modified by fluvial action.

1.2 REVIEW OF LITERATURE :-

The Geomorphic studies on various aspects using aerial photographs and sattellite imageries have been large and few of them are dealt here.

✓Fairbridge (1968)[1] has explained about the purpose, advantages,symbols and different legends of geomorphological map. He has described that geomorphological map must give information about the appearance, the dimension, slope values, the origin and the age of each form.

---

1. *Fairbridge (1968) 'Geomorphological mapping' Encyclopedea of of Gemorphology*

Robert G. Reeves (1975)[2] has described about the lineaments which are identified for various regions as follows :-

(a) Oklahoma region by Rich (1978) here lineaments have been recognised along dark green linears

(b) Transverse linears of Texas and Parras belts of the South western United States and Mexico have been identified and mapped from ERTS and skylab imagery

(c) Across Pine Mountain (California) lineaments were identified through ERTS image of transverse range

(d) Lineaments of Machenyie river at the western end of the Great Slave lake are identified by Rumsey(1970).

Bismal Ghose A. S. Singh etc (1975)[3] have used aerial photogrametry techniques for watershed planning by studying the geomorphic characteristics of the basis. They stressed that if a small head water stream increases its lengths by one meter, its effective catchment area has also increased by several square kilometer.

Alois Sieber (1975)[4] has identified lineaments of the West German Coal mining area with respect to their areal occurence and their orientation, they could partly be related to know fracture systems of the deeper carbonic layer.

---

2. *Robert Reeves (1975) Manual of Remote Sensing Volume II.*

3. *Bismal Ghose, S.Singh. etc. (1975) 'Aerial Photogrammetry and Photogeomorphology' The Indian Geogrophical Journal Vol. 1. No. 2.*

4. *Alois Sieber (1975) 'Remote Sensing applied to energy related problems' mote sensing - Energy related studies Edt. by Nejat Vezirolu. H sphase publ. Co. Washington, London.*

K.Krishnaunni (1976)[5] has studied lineaments of of Gujarat region and found that thick alluvial deposits over the sedimentary cover has the lowest lineament density and the hard rock area has higher lineament density. He has suggested that linear direction noted in the sedimentary and alluvial tracts are far useful clues in appreciating the structural setting of the underlying formation than the much more predominant closely spaced patterns to the exposed hard rocks.

P.V.L.P. Babu (1976)[6] has made Geomorphological studies on aerial photographs of the Hoogly dealta to the south of Calcutta and found that the fructures mostly control the drainage as the drainage pattarn reacts sensitively to the tectonic movements and zones of weakness.

Barrett (1976)[7] has explained that the study of lineaments transerve to the bedding help to determine whether they represent faults, dykes, joints, or combination of there. He has analysed the lineaments of some regions as follows.

(a) oblique aerial photograph of the fraser river area,

---

5. *Krishnaunni (1976) "Mega Lineament Pattern of Gujarat from land sat Imagery as attempt to fit into the geological frame work PHOTONIRVACHAK Joor. Ind Society. Photo. Int. Vol. IV No. 1 & 2 P. 21-28*
6. *P.V.L.P. Babu. (1976) "A review on the oil & Gas prospects of the bengal basin based on Photogeomorphologidal studies"PHOTONIRVACHA Jour. Ind. Photo. Int. Vol. IV No. 1 & 2.*
7. *Barrett and F.C. Cortis (1976) Introduction to Environmental Remote Sensing. Page No. 239-251.*

Canada, shows the lineaments is the surface which are made easily visible by the snow collecting in the lineaments depression. Both short and long lineament features are displayed.

(b) Lineaments of Italian Peninsular have been obtained from land sat I data. There lineaments show the main fault systems.

K.N. Prudhuvi Raju and R. Vaidyanadhan (1977)[8] have used aerial photographs for the study of landforms, land use and land units of a part of krishna district. Andhra Pradesh. They have identified major individual landforms such as hilly and flat uplands, Piedmont deposits, rolling plain and some miscellaneous features. Besides landforms, six classes of land use and nine types of land units are also demarcated by them. They have concluded that fracture, fault lines and old river courses can provide a very satisfactory basis for the planning of exploratory drilling programme for ground water. They have also suggested that Geomorphology can play a significant role in the land use and land unit studies and for predicting land capacity, their limitation and thereby to suggest proper land management and planning in problematic areas.

---

8. *K.N. Prudhivi Raju and R. Vaidhyanathan (1979) "Study of landforms, landuse and land units of a part of Krishna district A from Aerial photographs" PHOTONIRVACHAK, Jour. Ind.Soc. Photo.Int. Vol.V. No. 2. 1977.*

G.S. Srivastava, R.B. Sharan etc., (1977)[9] have interpreted a major lineament in ladakh region on landsat imagery and concluded that the Numbra-Gartang superlineament is a major fault which has been active till recent times. They also found that the major part of the lineament is occupied by broad glaciated valleys.

Suresh Chopra (1977)[10] has identified some structural features such as faults and joints of the southern fringes of Meghalaya. He has analysed drainage of the study area and found that it is mostly structure controlled and the pattern is either rectangular or parallel to sub parallel.

V.V. Peshwa and A.G. Desai (1977)[11] have done lineament analysis of North west of Poona (India) area. They have drawn rose diagram for the identification of direction of lineaments of the region. They also mapped different areas to show different drainage patterns which are controlled by structure.

B.M. Singh (1977)[12] has dilineated ravines of area near Sailana. M.P. He has suggested that the shallow

---

9. *G.S. Srivastava, R.B. Sharana and R.P. Sharma (1977) "Numbra Gartang Superlineament its Geological singificance and relation with the indus uture" PHOTONIRVACHAK Jour Ind. Soc. Photo. Int. Vol.V., No. 2.*
10. *Suresh Chopra (1977) "A role on Photogemorphological mapping of the cretaceous tertiary formation in Southern fringes of Meghalaya PHOTONIRVACHAK Jour. Ind. Soc.Photo. Int. Vol. V., No. 2.*
11. *V.V. Peshwa and A.G. Desai (1977) 'Structural trends in Deccan trap area NW of Poona. A study based on candsat-I imagery interpretation PHOTONIRVACHAK Jour Ind. Soc. Photo. Int. Vol.V No. 1,*
12. *Singh B.M. (1977) 'Interpretation of Satellite imagery for delineation of ravines'. PHOTONIRVACHAK Jour. Ind. Soc. Photo. Int. Vol. V ., No. 1.*

ravines could be economically reclaimed for agricultural purposes and deeper ravines may be afforested as future land reserves of the country.

D.P.Rao (1977)[13] has classified the lineaments of Godavari delta into major (faults) and minor (mostly reflecting the joint or fracture pattern).

V.N.P. Sinha (1978)[14] has studied weathering of Palamav upland. He has explained that in the case of rocks such as sandstone, basalt, dolemite, quertzite, shale, slate, schiest etc., the costituents of rocks are of different colours which absorb heat to different extents and posses different coefficients of expansion. So the denudation of these rocks is different.

Rajkumar (1980)[15] has done thorough field study of Sonar Bearma river (tributaries of Ken river). He has identified the structural and geomorphic features of the region and also analysed different geomorphic processes such as weathering masswasting and fluvial erosion. He also

---

13. *D.P. Rao (1977) 'Neotectonic and lineament analysis of landsat imagery for oil and mineral exploration-as example from Godavari delta - Eastern Ghats area'. PHOTONIRVACHAK. Jour. Ind. Soc. Photo. Int. Remote Sensing Vol.V. No.2 pp. 67-70.*

14. *V.N.P. Sinha (1978) 'Weathering in Palamav upland' Indian Geographical Studies Research Bulletin No. 12.*

15. *Raj Kumar Rai (1980) 'The terrain assumes special significance for the development of agricultural lands.'*

has examined the impact of geomorphic features on the human life of the basin.

Shubbada Badha (1981)[16] has made an attempt to analyse the lineaments and drainage pattern of Dhansin valley in Assam. He found that the drainage pattern of the area is controlled by tectonic activities and reflects the tectonic framework of basement. The lineaments recognised by drainage elements are directly controlled by the surface trace or jointing developed in adjacent to faulting at depth.

K.K. Sinha and A.U. Khan (1981)[17] have studied major geomorphic units of Dihang river basin. Land use and land capabilities in respect of each geomorphic units have been noted by them. They have given some suggestions for better utilisation of land. They found that low relief, dissected hills are mainly structurally controlled and are characterised on aerial photographs by medium to dark grey tone, coarse texture, high degree of dissection with sharp 'V' shaped valleys, and dendritic drainage.

---

16. *Shubbada Badha (1981) 'Landsat analysis of Dhansi Valley PHONIRVACHAK Jour. Photo. Int. Remote Sensing Vol. 9. No.2.*

17. *Sinha K.K. and Khan. A.U. (1981) "Geomorphology and landuse of Pasighat - Jonai Bazar area. A photo based study in a part of Dihang river basin, Arunachal Pradesh and assam" PHOTONIRVACHAK. Jour. Photo. Int. Remote Sensing. Vol. 9. No.2.*

S.P. Deopurkar and V.V. Peshwa (1981)[18] have identified two different groups of lineaments (of Madura and Sonrai area UP) based on photographic tone such as dark toned lineaments and light toned lineaments. These two lineaments also classified according to the physiography as positive lineaments occuring as linear ridges and negative lineaments occuring as narrow linear valleys.

L.S. Suryanarayanan and P.Prabhakara Rao (1981)[19] have described that the lineaments controlled drainage of Dharmapuri exhibit elbow turnings in two western tributaries and confluencing in the two eastern rivers.

Cooke R.V. and D. Brunseden (1982)[20] described that the chief aim of a geomorphological map is to provide a statement of the location of different forms and to indicate their respective age, origin, dimension and material composition. It also reveals about what happens between contours. He has also suggested that 'Since the Camera cannot distinguish the relevant from irrelevant, it is essential that a preliminary interpre-

---

18. *S.P. DEOPURKAR, V.V. Peshwa (1981) 'Interpretation of lineaments from precambian rocks in madura and Sonrai area calitpur district - op' PHOTONIRVACHAK Jour. Photo. int. & Photo. int. & Remote sensing. VOl. 9 No.2*
19. *Suryanarayanan L.S. & Prabhakarann Rao P. (1981) 'Drainage reversal in Dharmapuri area in Tamil Nadu and its effects PHOTONIRVACHAK Joor. Photo. Int. and Remote Sensing. Vol. 9,No.1*
20. *Cooke etc. (1982) Urban Geomorphology in drylands in drylands. Oxford Univ. Press.*

tation of the aerial photograph is carried out by geomorphologists before field work begins in order to gain an insight into the character of the terrain.'

B.G. Wagle (1982)[21] has described that lineaments of coastal zone of Goa are the result of fractures in the bed rock which in turn affect the drainage, texture and composition of the soil cover. Some lineaments are manifested by an abrupt changes of topographic level

Ahuja and S.S. Khanna (1982)[22] have identified five major landform units of Ghaggar river basin of Haryana anu Punjab. Geomorphic processes of the region also analysed by them. They explained that Geomorphic processes which are the result of geological processes gives as idea of nature of sedimentation , their deposition and formation.

V. Raghavaswamy (1982)[23] has studied the kemang river basin Arunachal Pradesh. He has divided the basis into four land systems such as structural, denudational piedmont and fluvial. Each system has been analysed

---

21. *Wagel B.G. (1982) "Lineaments in the coastal zone of Goa" PHOTONIRVACHAK Joor. Ind. Soc. Photo. Interpretation and Remote sensing Vol.10, No.1.*

22. *R.L. Ahuja and S.S.Khanna (1982) "Soil Scaper, Geomorphic processes and soil taxonomic new subgroups identified in the Ghaggar river basin of Haryana and Punjab". PHOTONIRVACHAK. Jour. Ind. Soc. Photo. Int & Remote sensing. Vol. 10. No.1*

23. *Raghavswamy (1982) "Role of Satellite Remote Sensing in land system mapping. Land Resources Inventory and land use planning. A sample study of Kemang River Basin. Arunachal Pradesh." PHOTONIRVACHAK Journ. Ind. Soc. Photo int. & Remote Sensing. Vol. 10. No.3.*

with respect to eight land water - land use parameters for proper land use and environmental management of the river basin. The base map has been directly prepared from the visual interpretation of landsat imageries. He has given a table for the land suitability, potential land use and the productivity/development strategy ranking. He has measured areal extent for each land unit. Drainage patterns have been analysed and the general characteristics of the land and soil are given in a table.

Sambasiva Rao (1982)[24] has evaluated the Cauvery delta land through modern remote sensing techniques. He has prepared separate maps to show landfors, land use, hydromorphic units, drainage and flood intensity of the delta.

A Bhattacharya (1983)[25] has explained that the landscape development of an area largely depends on the underlying rock types and their geological structure. Sandstone due to its hard and resistant nature normally forms hills whereas the shale due to its softer and

---

24. *Sambasiva Rao. (1982) 'flood intensity and land evaluation in the cauvery delta. Tamil Nadu applying modern Remote sensing Techniques.' PHOTONIRVACHAK. Jour. Ind. Soc. Photo Int. : Remote Sensing Vol. 10. No.3. Page 23.30.*

25. *A. Bhattacharya (1983) "Geologic and Geomorphic controls in landuse patterns. Examples using Remote Sensing techniques PHOTONIRVACHAK. Jour. Ind. Soc. Photo. int. : Remote Sensing Vol. II. No. 3.*

erodable character forms valleys. He has prepared geomorphic map for Baitarani deltaic area.

Dikshit (1983)[26] has identified that two charactristics of drainage such as direction of river and valley forms are influenced by the tectonic lineament.

Negi and Koti Reddy (1983)[27] have identified Sota-Sabi lineaments and they concluded that Sabi River flowing through the study tracks is being controlled by the prominent linears.

/ Ravindra and P.C. Bakliwal (1983)[28] suggested that lineament pattern can be correlated to the structural and geomorphic events while most of the lineamants are structurally controlled, some are topography relief lineament seen as the straight river course, narrow but long valles or the charge in topography along certain lines. /

R.S. Murthy and Pofali (1984)[29] have analysed landforms under different climatic environments of

---

26. *Dikshit K.R. (1983) Geomorphology. Contribution to Indian Geography page no. 332 concept publication.*
27. *Negi R.S. & Koti Reddy B.B. (1983) 'Floods in Sati River. A Geomorphic study.' PHOTONIRVACHAK. Jour. Photo. Int. Remote sensing. VOl. II., No. 2.*
28. *Ravindra R. and Bakliwal P.C. (1983) 'Geological and Geomorphological significance of a few mega-lineaments of north eastern Rajasthan'. PHOTONIRVACHAK . Jour. Int. Remote sensing VOl. II, No. 2. Page No. 31-37.*
29. *R.S. Murthy and R.M. Pofali (1984) "Geomorphological map of Gujarat from Landsat imagery analysis" PHOTONIRVACHAK. Journ. Ind. Soc. Photo int. & Remote Sensing vol. 10. No.3.*

of Gujarat area. Boundaries of Spatial distribution of various landscape features have been shown in the Geomorphological map of this area.

S.M. Ramaswamy, Monohar Sinha etc. (1984)[30] have made Gemorphology and land use study of Medchal taluk AP. They prepared Geomorphological and land use map of the area. They suggested some remedial measures for the planned exploitation of natural resources without damaging the environment.

S.D. Singh and A.K. Goel (1984)[31] have analysed various geomorphological features associated with fluvial processes of the river Satluj and mapped using photo interpretation techniques (1.25000) with a view to assess the environmental status of the area in the north-east of Ludhana and they have classified the region intc 7 Geomorphic units based on landform analysis.

Suresh Chopra and A.K. Mathur (1984)[32] have prepared photogeomorphological map of a part of Umngi river Balat,

---

30. *Ramaswamy Manohar Sinha S.M. & Dev. Prasad. C. (1984) "Environmental Evaluation of Medchal Taluk. A.P. using aerial Photograph". PHOTONIRVACHAK. Jour. Ind. Soc. Photo. Int. & Remote Sening. Vol. 12, No. 2 Page no. 39-46.*

31. *Singh S.D. and Goel. A.K. (1984) "Fluviomorphological investigations in the floods plain area of river satlej in the north east of Ludhiana using photo interpretation techniques. PHOTONIRVACHAK. Jour. Ind. Soc. Photo Int . & Remote sensing Vol. 10. No.3.*

32. *Suresh Chopra and A.K. Mathur (1984) 'On the oscillation of Balat river, District Khasi and Garo hills, Meghalaya' PHOTONIRVACHAK. Jour. Ind. Soc. Photo. Int. & Remote Snsing Vol. 12., No.2*

Meghalaya, They have classified the region its five geomorphic units and studied various geomorphic features such a river terraces, fan cut terraces, sand and gravel point bars, sand splays and abandoned channel fill deposits.

G.L. Amursky (1984)[33] has explained that Remote sensing technique is an efficient method in identifying the lineaments and he has described about the lineaments of various regions identified by many authors as follows.

(a) Kosmicheshayer (1983) has prepared structural map with lineaments of Buzuchi peninsular and made more detail on the basis of interpretation of photo landscape anomalies on space imageries.

(b) Shardanore (1983) has identified lineaments for Caspian depression and Siberia platform space images He has concluded that volgograd Bayganias zone of lineaments spilit mega blocks. Linements of Siberian Platform are connected with recent activisation.

(c) V.S. Tsotsur (1983) identified the lineaments of Southern Gurovskayu oil fields along fault system.

(d) V.G. Gatskov and A.M. Kutergin have identified lineaments of Devlekanovskayer oil fields - along with fault systems.

(e) N.N. Soloyer has drawn lineaments of Davletabad-

---

33. *Amarsky G.C. "Application of Remote Sensing for oil and gas exploration." Remote sensing proceedings of the 27th International (Congress Moscow.*

lineaments along mesa fructures have been deciphered.

A hydrogeomorphic and lineament tectonic study was made in the lower reaches of polar river by A.S. Thirunavukarasu etc. (1985)[34]. The study revealed varied ground water conditions in the area which were helpful in planning for groundwater development in the area. Based on this study tested drilling were made in several location along the lineaments and away from the lineaments.

Bonham (1985)[35] has described that the presence of lineaments, detected either from remotely sensed images, air photographs, geophysical surveys or topographic maps, may be useful guides to the style, intensity and direction of structural deformation. If lineaments are indeed a reflection of geological structure, and given that structure is an important control or many types of mineralization, then there will a relationship between lineaments and mineral deposition. A lineament refers to any linear to curvilinear features expressed tonally on remotely sensed imagery in continuous or discontinuous fashion. Obvious cultural features have been eliminated.

---

34. *A.S. Thirunavukarasu etc., (1985) 'A lineament study as a hydrological factor case study from Tamil Nadu' National Seminar on Remote Sensing for planning and environmental aspects of urban and rural settlements. 29-31 January, 1985.*
35. *Bonham - Carter (1985) 'Statistical Association of Gold occurrences with landsat - derived lineaments, Timmins - Kirkland lake area', Ontario-Canadian Journal of Remote Sensing - Vol. 11, No.2. Pub. by Canadian Aeronautics and space Institute, 222, Somerset Street, west, suite- 601 Ottawa.*

/ S.V.B. Krishan Bhagvan and K.C. Ramana Rao (1985)[36] have recognised different geomorphic landforms such as hogback ridges, piedmont fars, valley fills, river fuilt plain, abandoned channels, point bars, V.Shaped valleys, piedmont zone, colluvial plain, residual hills, besides lineaments of Nellore district. They fcund that in that region the ridge and valley topography were resulted due to lithological and structural control. Pied mont fans with different degrees were identified and mechanical fluvial erosion and masswasting have been attributed as a major process in the region. They classified lineament/fault and fracture systems into two such as (1) the lineaments that extend along or across stream course and in the proximity of of alluvial/ colluvial zones (ii) the lineaments traversing the higher slopes above denadational hills and cuesta terrain. Lineaments are of direct importance with regard to the occurrence of ground water and also as propective zones for the development of ground water./

---

36. *S.V.B. Krishna Bhagavan and K.L. Ramana Rao (1985) Geomorphic features of a part of Cuddapah and Nellore districts, A.P. using remote sensing technique, PHOTONIRVACHAK. Jour. Photo- Int. & Remote sensing Vol. 13 - No. 2.*

Mahalakshmi (1985)[37] has made Geomorphic studies of Pedda Vagu basin. He has classified the landforms of the study area into destructional and constructionl land forms. He has also identified lineaments of the basin. He has suggested that linements can be delineated from aerial photographs by certain indications-displacement and abrupt truncation of rocks, right angled off-setting of stream causes, the alignment of small gullies, linear pattern of tonal variation and some times alignment of vegetation.

S.K.Subramanian & D.P. Rao (1986)[38] have studied the temporal variations in relation to massmovement of Kosi catchment area by using panchromatic aerial photographs taken on two dates separated by a time span of 22 years were studied. They classified the massmovement of the area into 4 types such as debris slide, slumps, gully erosion and lateral erosion.

---

37. *Mahalakshmi K.B. (1986) 'Geomorphic studies in evaluation of Pedda Vagu basin - A.P. Pn.D. Thesis - Waltair University.*

38. *S.K. Subramanian & D.P. Rao (1986) "Massmovementstudies in Kosi Catchment, Nepal - A Semi quantitative approach using Aerial photographs." PHOTONIRVACHAK . Jour. Ind. Soc. Photo. Int & Remote Senssing Vol. 14. No.1.*

/ Barbara Daniel Danielska and Starislaw Kibitlewski etc., (1986)[39] have interpreted lineaments from landsat satellite imagr of vistula Delta plain, North Poland. They described that the surface tracer of burried tectonic linear disjunction developed in the brittle series of the upper cretaceous calcareous rocks and projected as faults through the soft and loose cainozoic sediments onto the recent surface./

Lu Defu, Zhang Wenhua etc., (1986)[40] have identified major and minor lineaments of Sichaun province in China using landsat imagery and geological maps. Rose diagrams were analysed to assess direction and frequency of lineaments. Lineaments are clearly determined as fault zone, fractured structure, linear river valley, linear tonal anomely zone etc., They found considerable differences between lineament rose diagrams from landsat and the geological map./

---

39. Barbara Daniel Danielska etc., (1986) 'Geological *analysis of the Satellite lineaments of the vistula Delta plain, Zulaway Wistare, Poland.'*

Remote Sensing for Resources Development and Environmental Management Edt. by- M.C. Damen etc., Rotterdom/Boston

40. *Lu Defu, Zang Wenhua etc., (1986) 'Analysis of lineaments and major fractures in xichang - Dukou Area, Sichuan Province as interpreted from landsat images.' Remote sensing from Resources Development and Environmental Management. Edt. by M.C. Damen etc., Rotterdom/Boston.*

Arwan Rhys Jones & Andrew Millington (1986)[41] have suggested that the directional data on the lineaments was more useful than the number of lineaments.

Varoujan Kh. Sissikia (1986)[42] has suggested the main procedure for recognition of massmovement from Aerial photograph is that the three main parts of the movement such as the root area or the crown (Scarp area), the tongue area (displaced material) and the toe should be observed. Recognition becomes more difficult when these parts are already removed or flattered by erosion processes. He has given some clues (Appendix-I) to recognise and predict the massmovement from aerial photographs. He has also mentioned some of the clues, for massmovement, which are geological conditions, weathering, vegetation, human activities and tectomic activities.

1.3 AIMS AND OBJECTIVES

The present study aims at identifying the landforms (which are structurally controlled) and geomorphological

---

41. *Arwan Rhys Jones & Andrew Millington (1986) 'Spring mound and aioun mapping from landsat TM imagery in South - Central Turisia. Remote sensing for resources Development and Environmental management. Etd. by M.C. Damen etc., Rotterdom/Boston.*

42. *Varoujan Kh. Sissatian (1986) "The study of messovement from aerial Photographs". Remote sensing for Resources Development and Environmental Management.*

Edt. by M.C., Damen/G-Sicco Smit/V.TH. Verstappen . A.A. Balkemer/ Rotterdom (Boston.

and land use
processes of the Kalimachak River basin which involves the following pattern of framing the various aspects.

1. To identify the landforms and drainage pattern, which are controlled by structure;
2. To identify the lineaments which are directly correlated with the structure of the region;
3. To analyse various geomorphic processes which are acting on the region such as weathering, mass-movement and fluvial processes;
4. To delinate the landforms which are the output of the Geomorphic processes.
5. To correlate Geomorphic processes and landforms with present land use

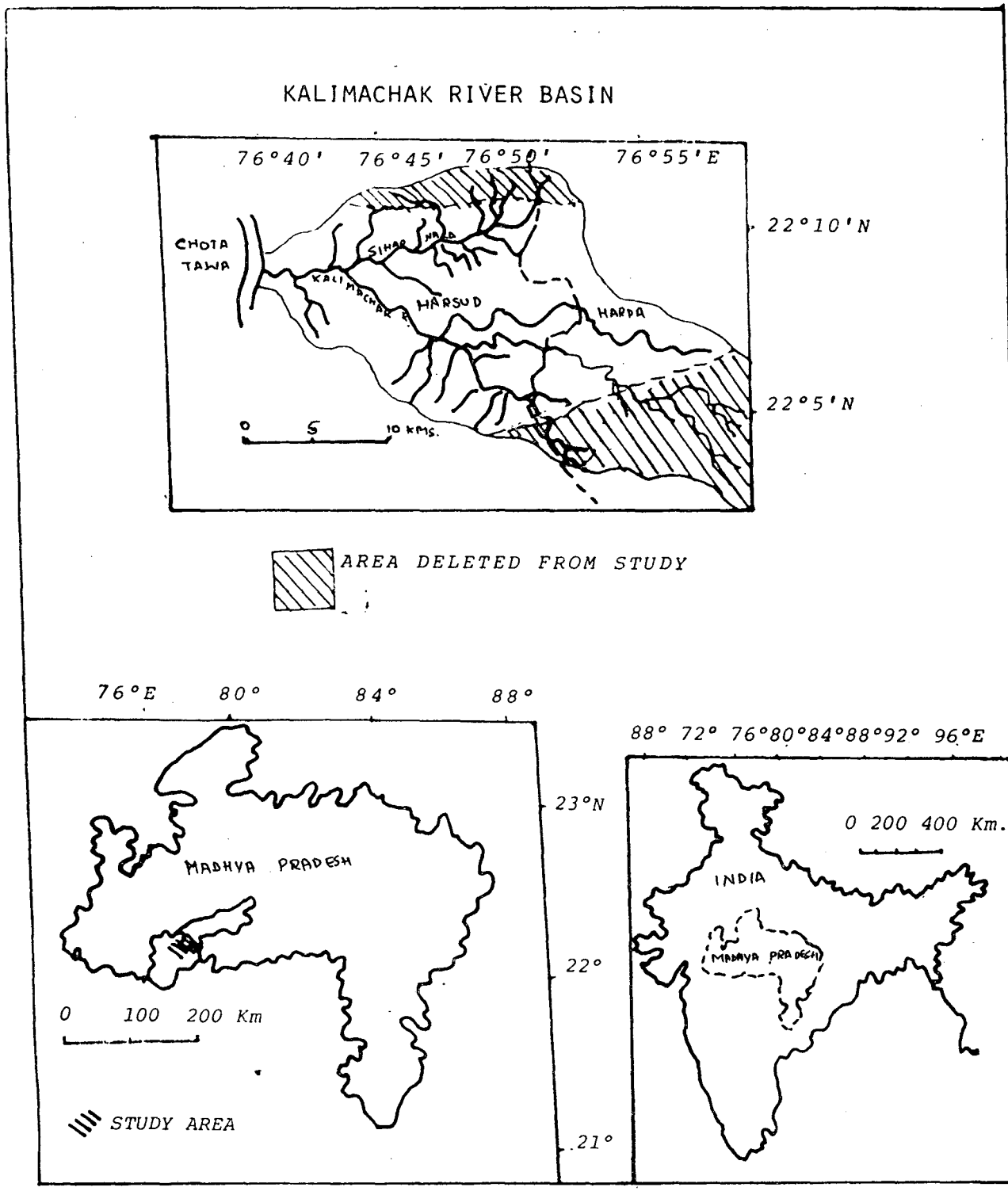
1.4 STUDY AREA

The study area is the Kalimachak river basin, a sub-basin of Narmada. This consists of about 741 sq.k.m. Kalimachak river basin lies between 21^{o} 54' N to 22^{o} 12' N and 76^{o} 40'E to 77^{o} 11'E of latitudes and longitudes respectively. The boundary line of East Nimar and Hoshangabad districts of Madhya Pradesh lies in the middle of the basin. The western side of the basin falls in Harsud Tahsil and the eastern side falls in Harda Tahsil.

1.5 LIMITATION

The Aerial Photographs for a small portion of

STUDY AREA


KALIMACHAK RIVER BASIN
76°40'
76°45'
76°50'
76°55'E
22°10'N
22°5'N
CHOTA TAWA
SIHAR NALA
KALIMACHAK R.
HARSUD
HARDA
0 5 10 KMS.
AREA DELETED FROM STUDY
76°E
80°
84°
88°
23°N
22°
21°
MADHYA PRADESH
0 100 200 Km
STUDY AREA
88° 72° 76° 80° 84° 88° 92° 96°E
36°N
32°
28°
24°
20°
16°
12°
8°
0 200 400 Km.
INDIA
MADHYA PRADESH

the southern part of the basin which is covered by forests and the northern part of Sihar Nala basin were not available. These together comprise around 156 sq.kms. of an area. Identification of landforms of these regions were not therefore possible.

1.6 METHODOLOGY AND DATA BASE

For the identification of structurally controlled landforms and for the analysis of the Geomorphological processes the method best suitable is that of remote sensing which has been adopted here. In the case of an aerial photograph, since a vertical overview is obtained, no part of the landscape is hidden and relatively large surface can be visualised simultaneously. Hence accurate mapping, irrespective of accessibility, is an additional advantage in remote sensing. Accurate measurement of the dimensions of the various physical features too can be done through photogrammetry of the aerial photographs. The Satellite Imageries serve such studies for very large areas but since the study area is relatively small (approximately 741 sq. Km^2) it is much more fruitful to adopt aerial photographs in this case.

Aerial photographs help in understanding and studying the landscape to an extent which is not possible through topographical sheets. Quantitative analysis of slopes,

drainage density and numerous other landform elements can be done successfully through aerial photograph. Study of dynamic geomorphology especially clear depiction of former river courses can be done through stereovision..

The overlap of the Aerial photographs used here is 60%. If the overlap is 60%, every point on the ground is represented on at least two consequctive photographs.

It is therefore possible to divide the photograph into two sets, each of which covers the whole area. One set will consist of photographs 135 etc., (alternate photographs) and the other of photographs 2,4,6 etc., (Conjucative photographs)

Mosaic of the Kalimachak river basin has been pre - pared according to the following method was suggested by Alham (1969)[43] for geologists.

1. The alternative photographs have been separated from their conjucate pairs for inspecting them to ensure that they provide 100% cover of the area.
2. Adjacent alternate photcgraph has been selected for super imposing corresponding points of photo-graphic details.
3. The photographs have been overlapped to hide the tilting strip.

---

43. *J.A.E. Allum (1969) Photogeology and Regional Mapping Pergamon press oxford, London Edinburg New york Toronto etc.,*

4. Alternate photographs of south strip have been selected immediately to get the photographic detail of the edge.

5. South Western corner of each new photograph has been viewed with the south eastern corner of the previous photographs.

6 Third and subsequent strips to the south are added in the same way.

The names of the principal towns, Villages and rivers are marked with the help of topographical sheets. The boundary of the basis has been demarcated from the vision and the approximate latitude and longitude of the area have been marked with the help of topographical sheets.

From the aerial Photograph geomorphological map has been prepared and the lineaments of the basin were identified and mapped separately. Geomorphic map for each stereopair has been drawn separately and then compiled to obtain geomorphic map of the whole basin. The scale of the Geomorphological map was prepared same as scale of aerial photographs and the reduced to present scale. The scale along both the coordinated is not very accurate owing to radial displacement errors in the photographs. Similar method has been adopted

by Pridhuvi Raju and Vaidyanathan (1977)[44]. The Geomorphic symbols used have been adopted from the fairbridge (1968)[45] and from V. Subramaniyan (1988)[46] The colour for this map has been adopted from Mahalakshmi.[47] land use map has been prepared with the help of aerial photographs.

For the identification of the lineaments the following factors have been taken into consideration :-

1. Displacement and abrupt truncation of rocks.
2. Right angled off setting of stream courses
3. The alignment of small gullies.
4. Linear pattern of tonal variations
5. Linear alignment of vegetation
6. Ridges more resistance to erosion
7. Difference in elevation.
8. Straightness of the scarpline;
9. Straight course of stream;
10. A long narrow long valleys.
11. Higher slope above the denudational hills and cuesta terrain.

---

44. *K.N. Pridhuvi Raju and R. Vaidyanathan (1977) op.cit.*

45. *Fairbridge (1968) op.cit.*

46. *V. Subramaniyam (1988) op.cit.*

47. *Mahalakshmi (1986) op.cit..*

With the aid of these map analysis of the structurally controlled landforms and the geomorphological processes of the areas have been done.

The chief materials used for the study are Aerial Photographs and topographical sheets of the area. The information regarding aerial photographs is as follows:-

a) Scale of the photograph is 1 : 25,000;
b) Sortie number is 670-B;
c) Flight numbers 5A, 4B, 3A and 2.
d) Serial numbers of photographs are (41-57) 5A, (44-65) 4B, (47-63) 3A and (41-59) 2.

The following topographical sheets of survey of India have been used :-

55 B/12, 55 B/16, 55 C/13 and 55 G/1 These topographical sheets are of the scale 1 : 50000.

Information regarding geology of the area has been obtained from the following sources :-

1. Report of Narmada Sagar dam;
2. Gazitteer of districts - East-Nimar, Hoshangabad of Madhya Pradesh.

1.7 UTILITY OF THE STUDY

Geomorphological maps provide statements of the

location of different forms and indicate their respective age, origin, dimension and material composition. Hence these maps are of great use in planning purposes like that of land use, agriculture and Irrigation, Forestry, construction of roadways and railway lines and settlement areas etc., It helps in assessment of land resources and in rapid classification of the character of the large areas of the land. The relationship between land use and Geomorphic processes can be analysed.

By relating the observations carried at rock out crops to the associated land forms, geomorphic maps can help for the analysis of geological phenomena.

The mapping of lineaments also serve a large number of users. Water retaining capacity is high along the lineaments. Hence these zones can be harnessed for obtaining water especially during drought season. Identification of ore bodies from the mapping of lineament give an indication of the zones of weakness, the regions where gully erosion bound to be high can be demarcated. Thus it is of great use for agricultural purposes.

Both Geomorphological and lineaments maps can be utilised for ecological conservation schemes.

1.8 ORGANISATION OF CHAPTERS

The First chapter is an introduction to the nature of the study comprising of Review of literature, aims and objectives, the jurisdiction of study, limitation for the study, Data base and methodology and utility of the study.

The Second chapter discusses the general characteristics of the basin such as physiography, climate, soil and geology.

The Third chapter concentrates upon the identification of landforms associated with faults, structural control over drainage pattern and lineaments.

The Fourth chapter has three sector deal with geomorphological processes and their impact on land use.

The Fifth chapter summarises and concludes.

chapter ii
general characterisation of the basin

CHAPTER - II

GENERAL CHARACTERISATION OF THE BASIN

2.1 INTRODUCTION

The Kalimachak basin is roughly of an elongated shape lying in Southeast - Northwest direction. It comprises about 741 sq. km. area and the length of the river is 77 kms.

Samri Nadi which is the main tributary of Kalimachak river originates from east Kalibbat reservedforest (654 m) and flows towards the north west. At relatively lower altitudes (350 m) it attains meandering characteristics. The river takes name the Kalimachak after it is joined on its right bank by another tributary which flows from Syani protected forest. The Bori Nala, Bichpuri Nala and Patal Nadi are the major leftside tributaries. In the northern part of the basin, the Sihar Nala joins the main stream on the right side.

The Bori Nala originates from Choril Pahar (616 mts) and flows west and within half a kilometre altitude becomes 500 mts. Then it flows northwest and after 2 kilometers it turns north. Because of the sudden decrease in altitude here, the deposition of the load in the river bed takes place. Within the 6 kms from the origin the river attains meandering course and joins the Samri Nadi.

Patal Nadi is a major left side tributary of the Kalimachak. Its length is 42 kms. Near the eastern side of Degarkheri settlement the Arwa Nala joins the Patel Nadi.

Sihar Nala originates from a plateau at a height of 302 meters and flows west to join the Kalimachak Nadi. Its total length is 21 kms. Kodyakhal Nala joins the Sihar Nala in its right.

2.2 PHYSIOGRAPHY

In general the region represents a well dissected topography because of the fractures that are particularly well developed in the Vindhyan Plateau. The general slope of the basin is from Southeast to Northwest.

The Southeastern portion of the basin is rugged, uneven and hilly comprising the highest elevations. Parallel ridges run throughout the basin but their prominance is very great in western and north western part.

The middle portion of the basin is relatively gentle and even. This is the region where the river takes meandering courses. But here and there residual hills are present.

The hilly region of the South eastern part is an extension of the Satpura range. Most of the hills are above 500 mts. from the mean sea level. 654 mts is the highest elevation of the region. The lowest elevation (240 meters) of the basin is at the region where it joins Chotatawa river.

2.3 GENERAL GEOLOGY OF THE STUDY AREA

The Kalimachak river basin lies in the Narmada son line which is affected by succession of tectonic events from Archaean to post trap times. The hard inlier area exposes the Archaen granite greisses Bijawar meta sediments. Vindhyan sediments are over lain unconfirmably by Deccan bosaltic lava sheets and occupies the higher elevation. The basalt which initially occupies lowland is buried by the pre-trappean rocks. The Deccan trap is very much affected by erosion. High intensity of erosion has resulted in the formation of exhumed topography which is again undergoing modification due to the fluvial agents acting on it.

The Archaens, Bijawar and Vindhyans have all suffered considerable faulting mainly along ENE-WSW to E-W direction. A major ENE-WSW fault traverses granites, the Bijawans and Vindhyans which is part of the Narmada mega lineament.

THE BIJAWAR SYSTEM

This system is found in the western side of the basin comprising of quartzites hornstone breccia and chest banded limestone and laying uncomformably over granites, forms a hummochy topography. Unaltered sandstones are sometimes conglomerate.

THE VINDHYAN SYSTEM

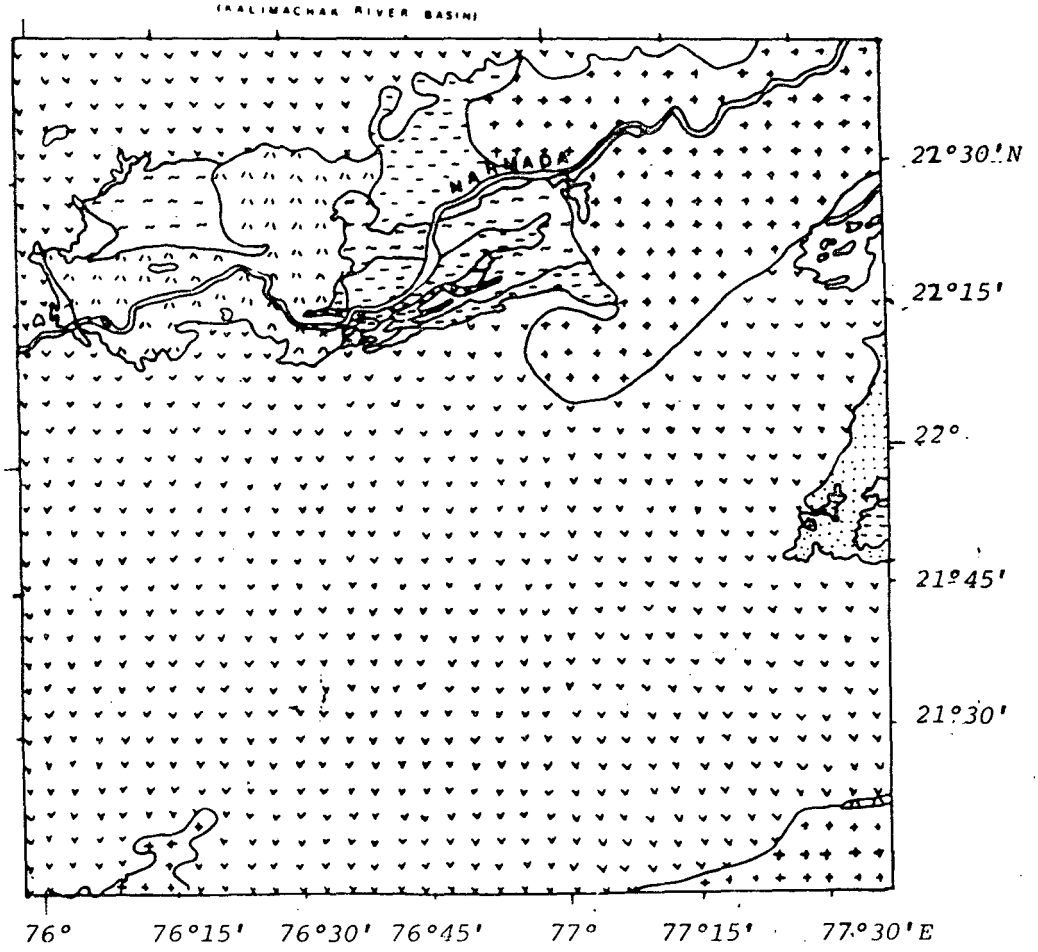
This Vindhyan formation is found in a South eastern side of the basin consisting of sandstone, shale and conglomerates. The sandstone is found with sub-ordinate shale intercalations. Bedding of sandstone is easily materiable and separate beds are of small thickness. Local metamorphism may be the main cause for the formation of quartzites.

RECENT ALLUVIUM

Recent Alluvial deposits are found everywhere along the stream courses. Alluvial deposition also found in the North eastern side of the basin.

GEOLOGICAL MAP

(KALIMACHAK RIVER BASIN)



DECCANTRAP

ALLUVIAM

SANDSTONE, CLAY

SHALE, SANDSTONE

ARCHAEN

BIJAWAR

SANDSTONE

SCALE

0 1 2 kms.

GENERALISED GEOLOGICAL SEQUENCE

Recent	- Alluvium
Upper cretaceous	- Basaltic flow
	-- unconformity --
Cretaceous	- Conglomerate sandstone and quartzitic and stones, calcareous gritty sandstones with associated sandy clays lametas.
	-- unconformity --
Algonkian	- Vindhyas Sandstones, Grey Quartizitic sandstones with intercalation of shale silt stones and conglomerates.
	-- unconformity --
Upper precambian Bijawar	- Quartzitic breccia, hamatite breccia and conglomerates.
	-- unconformity --
Archaens	- Granites, granitic gneisses etc.

TABLE - 1

HYDROGEOLOGICAL CONDITON OF THE KALIMACHAK RIVER BASIN

Area	Age Group	Lithology	Porous formation	Ground water Potential
		(Consolidated fissured formaton)		
Harsud Tashil	Mesozoic and Paleozoic	Basalt with intertrappean clay	Groundwater restricted to weathered residium fracture zone having secondary porosity	Large yield prospects 20 m^3/hour
		(Unconsolidated and semi-consolidated porous formation)		
Harda Tashil	Quaternary	Recent alluvium clay, silt, sand gravel, Pebble, calcareous, concentration etc.	Fairly thick and regionally extensive confined/unconfined 300 m.	Limited yield prospects below 350 m^3/hours

SOURCE : Hydrogeological map of India

2.4 CLIMATE

This area comes under the dry region of India. The Khardwa observatory records the month of May as the hottest month with ever recorded maximum of 47.2°C.[1] December is the coldest month of the year and the lowest fall is recorded upto 6°C.[2]

The average daily temperature in May is 34.55°C[3] and in December 19.96°C.[4] The range of day and night temperature is low during the rainy season and high during the winter months.

The mean wind speed is 13.4 Kms[5] per hour. The highest is in June while it is lower 3.7 Km.[6] per hour in November and December.[7] Hot winds which strengthen with the advance of summer blow from west and north west. During the monsoon season the winds blow from SW and NE.

The average annual rainfall of the district is 880mm (34")[8].July is the rainiest month with the highest number of rainy days. The monsoon advances into the study basin around 10th of June and withdraws by the beginning of the October.

---

1. *Gazetters of districts (East Nimar) of M.P. 1969.*
2. *Ibid*
3. *Ibid*
4. *Ibid*
5. *Ibid*
6. *Ibid*
7. *Ibid*
8. *Ibid*

Except during the rainy season the relative humidity is generally low. In summer months it can be as low as 10%.

2.5 SOIL STRUCTURE

The study basin comes under off-shoots of Satpura range, consisting of thin soil, rocky topography and some regions of barren land.

Soil of this region can be classified into 7 categories as follows :

1. KABAR - II

   Kabar - II is a deep black soil and can be classified into two types such as Thal and Mamuli. The former is found in low lying areas and round about a millah (Gatas or Ghelas). This is best in retaining moisture and production. The latter type is found in ordinary level ground.

2. MORAND - I

   Morand - I is a light coloured soil found over 2'[1] in depth which consists of small limestones and is friable.

3. MORAND - II

   Morand - II is an inferior and light coloured soil

---

1. *Gazitter of Districts - East Nimar,Hoshangabad of M.P.*

which consists of much limestones and generally is found from 1½' to 2' depth[1].

4. RANKAR

This is a light soil consisting of large proportion of limestones, pebbles and sand and this soil has rock at a depth of about 1' to 1-3/4'.[2] This soil is found generally in uneven region. Shallow black soil, deep red and yellow soil also fall in this category.

5. KHARI

Khari soil is found about 8"[3]. in depth. The colour of the soil is yellow and red. Where this soil is black in colour, it is deceptive in appearance.

6. KHARI - II

Khari - II is very light coloured soil and it has a depth of 4" or 5".[4]

7. BARRA

Barra is stony-ground.

---

1. *Gezitter of districts - Ibid East Nimar M.P*
2. *Gezitter of districts - Ibid*
3. *Gezitter of districts - Ibid*
4. *Gezitter of districts - Ibid*

So based upon this classificaton, we can divide these into three groups as follows :

a) Kabar and Morand - I are forming good soils

b) Morand - II and rankar are forming Medium soils

c) Khari and barra are forming poor soils

chapter iii
structural landforms

CHAPTER - III

STRUCTURAL LANDFORMS OF KALIMACHAK RIVER BASIN

3.1 INTRODUCTION

The topographical characteristics of any area on the earth's surface is controlled largely by the structure and the geomorphic processes acting on it. Irrespective of tectonic nature, the variations in structure results in variation in the surface features. Weaker zones in the crust have been such zones where geomorphic changes are most likely to take place. For example, along the zones of weakness rivers have acted to produce differential erosion and weakening of the crust.

"Landforms which are due to the exploitation by weakening and erosion of weakness in the crust to the differential wearing away of rocks which leaves some areas greatly worn down and the other areas upstanding are called structural land forms" (Twidale 1968).

Joints and fault lines are prominent zones of weakness which are worn of easily than the surrounding areas which will be relatively more resistant.

The major types of rocks found in the study area are sandstone, shale limestone and granitic quartzite.

The structure plays an important role in controlling the drainage pattern of an area. Regions of high drainage density indicate more structural control. Traverse faults play a significant part in guiding stream courses. Joints, for example are abundently developed in sandstone which generally form ridges, and these joints are clearly exploited by streams. Another structural factor is associated with calibre and density of debris available for stream transport. Strike streams and their tributaries vary in elevation according to the bed rock in which they develop.

The drainage patterns prominently found in this study area are trellis, denritic, parallel and sub-parallel.

Trellis drainage pattern is the most predominant pattern in the study area. It is aligned with strike of rock formation. Where it crosses or passes the ridges it takes a right angle turn. The pattern appears as sub-parallel. The main tributaries are at right angles to the main stream. And these are parallel to main river. Parallel faults have brought alternatively strong and weak rocks and there the fault trellis patternshave been developed.

Regular spacing of parallel streams which are structurally controlled are mostly depicted on the slopes of this region.

Sandstone is the most predominant here. It is a clastic sedimentary rock consisting of small fragments bound together by cement which may be calcareous. Most sandstones have high prosity (average 18%)[1] and permeability. These generally form unstanding hills, depicting the toughness of the rock. The sandstone also forms domed inselberg and sheet structure. In the case of sandstone outcrop, each fracture is weathered and the bedding causes layer appearance. The intervening beds are left outstanding. Major verticle joints are also formed in sands stone area.

Shales are composed of feldspar or clay minerals in large measures. Being chemically very reactive they are succeptible to attack by water. Hence shale outcrops in general are relatively rapidly worn out in comparison to limestone and sandstone. Commonly valleys and plains are formed but prominent ridges are also underlain by shales which have massive bedding and jointing.

Granite is a crystalline rock with low porosity (average 1%)[2] and permeability. Its interlocking crystals prevent the easy passage of water through it. It is closely dissected. So the landscape consists of sharp crested and steep sided ridges with separate deep valleys of V shaped cross sections.

---

1. *Twidale (1968) - Analysis of landforms.*

2. *Twidale (1968) - Ibid*

In the case of dendritic pattern, horizontal, uniform sedimentary structure is the main cause for its formation. Here the structural control is very less.

Any linear alignment which is structurally controlled can be called a lineament. This represents the lithological horizons, faults, joints, unconformities, rock boundaries, veins and mineral banding. Lineaments which are formed due to fault can be identified through differences in elevation and straightness of the scarp. Here the linear straight basement can be terminated by beds. Numerous relatively short sub-parallel lineaments also can be deciphered and these are the influence of local stress fields.

The following structurally controlled landforms have been indentified in Kalimachak river basin :-

1. Fault and its associated features;
2. Structurally controlled fluvial pattern;
3. Lineaments.

3.2 FAULT AND ITS ASSOCIATED FEATURES

Faults are formed due to disturbances of the beds in their neighbourhood. The Kalimachak river basin is largely affected by faulting which is reflected in its topography by higher elevations (SSW-NNE), lower valleys,

easily eroded brecciated zones, weak and strong rocks on two sides of the fault. Since faults are zones of weakness, the denudational processes are strong and there is possibility even of disappearance of some of the faulted features. In some places rivers are controlled by faults and in some cases they flow along fractures.

In this region, faults can be easily identified because the fault features are conspicuous by not being buried in recent alluvium.

Such important fault associated features found here are fault scarp, fault line scarp, cuesta, mesa, Butte, fault line valley, fault terrace, resistant and denuded ridges etc.

3.2.a) FAULT SCARP AND FAULT LINE SCARP:-

The study area consists of fault scarp, this is scarp which is produced directly by fault and fault line scarp which is the erosional affected fault scarp consisting of rocks of varying resistance. The fault scarp which is found in this study area is young as indicated through the steep scarp except in the case of some scarps which are denuded. The weak rock is upthrown in this area and the obsequent fault-line scarp can be easily identified with the help of different erosional characteristics in upland and low land areas.

There are few similar characters for both fault scarp and fault line scarp in the study area and they are abrupt and imposing front face, linear base to a scarp, V shaped conyons, increase in stream gradient tranguler facetedspur etc.

Fault scarps here can be diagonised through the soft materials present on both sides of the scarp, small alluvial fans at the base of the scarp, steep slopes of stream terraces and low scarps found across the alluvial plains.

Retreating of the scarps of cuesta, mesa, and fault scarp are due to the denudational processes as evident in scarps of north-western part of the study area. Because of the erosional processes, weathering and massmovement, the straight scarpe have become sinuous and have irregular appearances.

Numerous long fault and fault line scarps are found in the south-eastern side especially in Syani protected forest. Here the fault scarps are richly vegetated and hence tends to resist erosion. But the fault line scarps are sparsely vegetated and depict erosion by stream. Soft rocks are eroded rapidly and the bed rock of the gorge is clearly depicted in the stereovision.

Fault scarps of the east of Anjrut settlement, and east of Ghogra ghat are examples for fault scarps which are protected by vegetation which are found near the edge of steep slope.

A long fault scarp found near the south of Dagarkha settlement is very prominent and indicates a fairly high resistance to erosion.

The lower part of a scarp which is linear is found near the southern side of Hathnara settlement. The upland portion is very less eroded and this is indicated by the smooth resistant surface of the sandstone of which it is composed.

Triangular spur end scarps occur near the south and NE of pipalya settlement and to north east of Palani settlement. The Sandstone spur end is relatively much free from erosion.

Fault produced graben formation occurs near NE side of Pipalya settlement.

North western side of Amkhal settlement fault line scarp is affected by weathering and the scarp foot is filled by weathered materials.

A long fault line scarp has been developed near the confluening point of Sihar Nala and the Kalimachak and is largely eroded by the streams.

3.2.b) SCARPS OF CUESTA, MESA AND BUTTE :

Scarps of cuesta, mesa and Butte features are clearly visible through stereoscope. Their steep slopes are dark in tone and the gentle slope is of light colour.

Front slope of a cuesta can be called structural escarpment. In the study areas, the front face of escarpments are generally seen on the north and north east.

The cuesta scarp face is eroded by streams and so face is inundated especially near the pipalya settlement. The scarps which form the front slopes of cuesta may be straight and imposing topographic features to begin with but as weathering, mass-wasting, and erosion attack them, they recede down the dip of the strata and become sinuous or irregular in outline (Thornbury 1969). True to this statement, the present study area's escarpment develop sinuous and irregular out line due to weathering especially near west of Amkhal village, and almost all other escarpments are due to denudational processes and attain the sinuous out line. Escarpment with steep cliff is found near northern side of Nawalpura settlement.

Cuesta's face is detached by the stream activity and become outliners of cuesta. Such a Cuesta near north western side of Harsud is detached by stream erosion

of the soft rock.

Bevelled cuestas are well developed in the north-western side of the study area especially western side of pipalaya settlement. These cuestas are related with a series of features from west to east such as hogback, cuesta and mesa. Mesas are reduced as butte in some areas. The mesas found in the study areas are rimmed by a scarp which is formed by resistant cap rocks.

Different sizes of mesas are found in this region, their shape and size depending upon the erosional activity of the particular region. Scarps of mesa found near north west of Chhirwan and west of Jaitapur khurd are stream eroded. Large extension of mesas are found in SW of Temblabari. Here the mesa is made up of hard sandstone rock and the rim is less affected by stream action and this can be called structural bench land.

Mesas are also found in north of Mahtapur, west of Dagakhai and north of Muktapur, west of Dagakhai and north of Muhal Khurd settlement. The rims of all these mesas are also only slightly affected by erosion.

In certain areas like SW of temlabari and west of pipalya settlement, the gentle slopes of cuestas are cultivated. Cuesta found to the W of Bathya khurd settlement is unique in characteristic as its one side is bound by steep cliff and the other side is an extensive level highland.

Butte is generally found to the west of Dagakhai settlement which is separated from the mesas by denudation. Butte is also found near south of Kanpura and to the east of Jaitupur Khurd. These are isolated due to erosion and not associated with mesa.

Mesas associated with butte are found to the south of Harsud settlement. It is characterised by its relatively greater hights in the northern side and much lesser altitude in the south. This mesa hence has a general slope towards south. This mesa has a prominent appearance and is characterised by its dark grey colour in the aerial photo.

3.2.c) FAULT LINE VALLEY :

A valley formed along a fault line is called fault line valley (Robert 1980)[1]. This valley is developed by headward erosion in the soft, crushed, relatively weak material along a fault zone. Fault line valleys are found prominently in Syani forest region, north of Khurupari and also to the east and west of Ramtek steelement.

3.2.d) FAULT TERRACE :

A irregular terrace-like tract between two fault scarps, produced on a hill side by step faulting, in which the down throw side is systematically on the same side of

---

1. Robert 1980 - 'fault line valley' Glossary of Geology.

two approximately parallel faults is called as fault terrace (Robert 1980)[1]. Fault terraces found in the study area are characterised by undulated topography. They are found in between Ghograghat and Anjrut settlement and to the west of Harsud settlement.

3.2e) STRUCTURAL HILLS :

Hills ranging from narrow, rocky, broad crests to sharp conical and rounded summits are present in this region. Hills which are present in south east side of the study area are generally more than 500 mt. height. At the centure of the plateau also, small hills are found especially in Syani forest. The hills are eroded by streams. Deep valleys and gorges are found in between these hills.

3.2.f) DENUDATIONAL HILLS :

The denudational hills are narrow, wide and have conical summits. They range from 300 to 350 mt. in altitude. These hills are denuded by numerous rills. The easternside of the hills situated near Jaitapur Khurd settlement is eroded by the stream.

3.3 STRUCTURAL CONTROL OVER FLUVIAL PATTERN

Drainage patterns of the Kalimachak river basin have well adopted to the structure and flow along lines

---

1. *Robert - (1980) Op.cit.*

of weakness in the underlying bedrock straight sectors between curves of the river, as well as the arms of some curves appear parallel in pattern and are controlled by the structure.

Fault trellis drainage pattern is developed where a series of parallel faults have brought together alternating bands of hard and soft rocks. Such a pattern is found to the south eastern part of the study area, that is in west of Syani protected forest, north and east of Kothni settlement and west and north west of Ramtek settlement. These streams depict little depth. This is because the rock pattern is relatively hard and so structural control is predominant in this pattern. Streams take right angled direction and flow beside the resistant ridges. They are directed along the weakness of the region. Streams flow along the fracture and long valley also.

Parallel streams is Sihar Nala area represent slopes of the region. These streams are regularly spaced and indicate the alternate arrangement of hard sandstone and soft shale rock.

Structural control over fluvial pattern is less over the central portion of the study area especially over the shale region. Here the river attains meandering course.

As per sinuosity Index (Appendix - II) of this region the topographic sinuosity Index is 44% and Hydrologic sinuosity Index is 55%. These values well indicate that south-eastern side and western side of the basin are well controlled by structure. In the rest of the region there is a lack of structural control more so in the central portion.

3.4 LINEAMENTS

Lineaments in the Kalimachak river basin are directly correlated with the structure of the region. Different trends of lineaments especially NNW to SSE occur in the area. Lineament trend towards SW to NE reflects the fault scarps and high resistant ridges. W-E and NW-SE trend represents the cuesta scarps and fractured trends. N-S and W-E trend depicts the weak zones of the gully especially near the banks of the streams.

Tremination of lineaments in this region is mainly due to denudational agencies. But in different parts, the termination is due to varying reasons. For instance, the lineaments along straight stream courses are terminated due to the hard resistant out crops. The lineaments along fault line scarps have been terminated due to stream action resulting in the wearing away of soft rocks. The

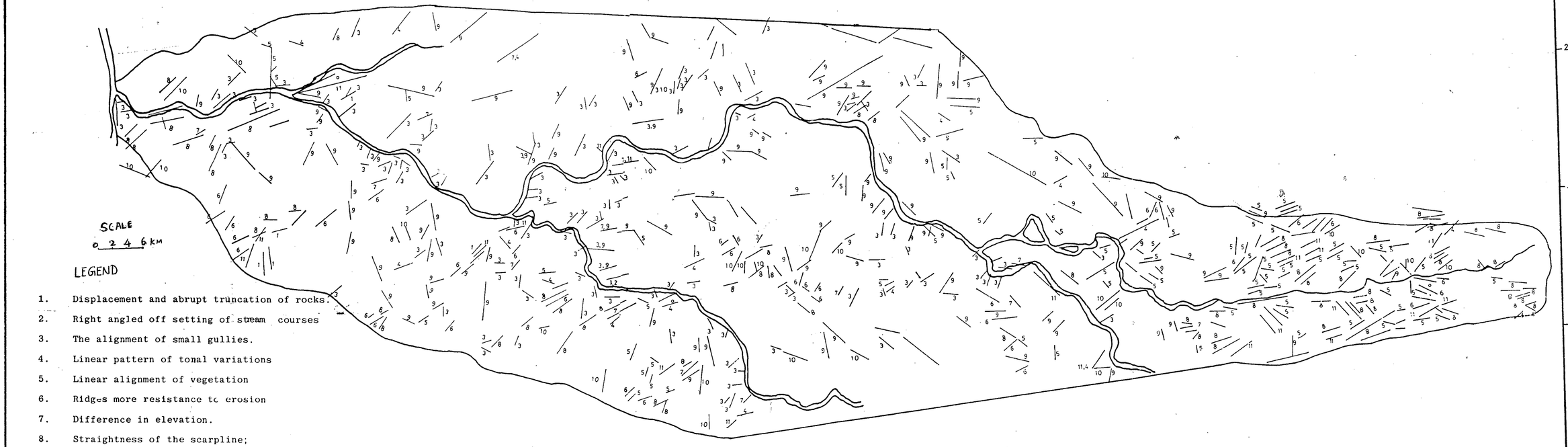
lineaments along tonal variation are terminated because of the sudden difference in elevation.

Lineaments of Kalimachak river basin have been identified according to various factors, the chief among them being, the identification along scarps, tonal variation, resistant ridges and variation in elevation and linear alignment of vegetation etc.

Topographic lineaments are identified along the straightness of the scarplines. The main causes for the topographic lineaments occuring in this area are weathering and erosion along joints. Such lineaments are found near pipalya, Amkal, Dhan-wanitheka, Nawalpura, Rewapur, Maujwar, Dagarkhai, Dharu Khari, Kanpura, Temlapari and Charwa settlements.

Vegetation lineaments are the resultant of linear alignment of trees. This pattern of vegetation occurs mainly due to fractures in the bed rock. Such vegetation patterns are found where the moisture potential is high, for instance, they are found near the zones of weakness. The tonal colour of the ground appears dark grey in such cases. This type of linear alignment of vegetation is found in the Kalimachak basin near Jaitupur Kalan, Pilani, Bothikalan, Partappura, Jatpura, Karoradhi, Chhorikhal, Margarhi,Ghograghat and Mughalkaru settlements. Thick linear vegetation is found more in Syani protected forest near the scarp face and along the bed and bank of the Sihar nala.

LINEAMENTS OF KALIMACHAK RIVER BASIN



LEGEND

1. Displacement and abrupt truncation of rocks.
2. Right angled off setting of stream courses
3. The alignment of small gullies.
4. Linear pattern of tonal variations
5. Linear alignment of vegetation
6. Ridges more resistance to erosion
7. Difference in elevation.
8. Straightness of the scarpline;
9. Straight course of stream;
10. A long narrow long valleys.
11. Higher slope above the denudational hills and cuesta terrain.

chapter iv
geomorphological processes-landuse

CHAPTER - IV

GEOMORPHOLOGICAL PROCESSES - LAND USE

4.1 INTRODUCTION

Geomorphological processes are the gradational processes which include degradational and aggradational processes. These processes are very slow but when these are concentrated locally are much faster and violent. The form and intensity of these processes are affected by relief, soil, rock type and land use etc. Energy for these processes is mainly derived from Solar energy.

Three types of denudational processes are identified in the kalimachak river basin, which are weathering, mass wasting and fluvial action by running water.

Weathering is a static process, the decomposition and disintegration of rocks in situ. It involves a group of process which act together at and near the earth surface. Solid rock masses are there by reduced to the clastic stage. It doesnot involve the seizure and removal of particles by a transporting agency. Alternate wetting and drying causes the disintegration of rock out layers. Weathering processes are significant for soil formation. The depth of the weathered material varies according to the rate of weathering process occuring over the region.

The bulk of movement of masses of rock debris downslopes due to the direct influence of gravity is called massmovement. It is accelerated by the presence of water but the water here is not to such as extent as to be categorised as a transporting agency. Gravitation produces the massmovement of weathered material from higher slope to the lower land. This masswasting depends upon the lithologic, stratigraphic, structural, topographic and organic factors of the region. Soil creep, talus creep, rock creep, debris fall are the out come of massmovement.

Fluvial process is the dominant process found in the kalimachak river basin. This process includes erosional, transportational and depositional processes. Each process produces distinct landforms in each stage. In the youth stage of a stream, the debris contained in it is much less and hence erosion will be very active. Downcutting is the prominent phenamena at this stage resulting in the formation of valley deepening. Thats why characteristic features such as Gorges, Canyons are formed in the upper course of the river.

When the stream flows down to the level region the velocity of the stream decreases and valley widening becomes the dominant processes. At this stage the river attains meandering. At this stage point bar etc. are its associated features.

At the final stage, when the stream is at its old age, it is loaded with large quantities of debris. Hence erosion is very much diminished and the deposition becomes the prominent phenamenon. Delta fans etc. are the associated features of the old stage of the stream.

Geomorphological processes and different landforms influence and affect the pattern and type of the land use of any region. An undulated ridge topography limits the agricultural landuse in comparison to homogenous plain topography. In a valley where the floodplain is bound by a series of river terraces of different height and age, the younger lower terraces will have richer soils than those of the higher older terraces. The farmers are very much aware of rill, gully, soil and sheet erosion which directly affect the agricultural land. Erosion removes much of the soil, organic matter and finer mineral fractions which provide water and nutrient supplies for plant growth.[1]

4.2 WEATHERING

The rate of weathering process of Kalimachak river basin could be identified through the Aerial Photography by studying the characteristics of the landform.

---

1. *M.J. Kirky (1980) 'The Problem' Soil Erosion - Ed. by M.J. Kirky A wiley Inter Science Publication.*

Weathering varies from place to place according to the parent material, topography and the vegetation. The basin consists of sandstone, shale and limestone. Sandstones are mixture of minerals grains and rock fragments coming from naturally disaggregated products of erosion of rock of all kinds.[1] The Sandstone is relatively resistant to weathering because of the strength of its cementing agents. Therefore it produces a massive bold topography with steepslopes.[2]

The ralative resistance of particular rock type to weathering is affected by lithology and texture etc. and rocks with a course grain size tend to weather rapidly than fine grained rocks which are very suceptible to weathering. Approximate average porosities and relative permeabilities for sandstone, shale limestone and granite varies according to the texture associated characters[3] (Table - 2).

The rate of weathering is very less in sandstone areas of the basin which could easily be identified with the help of observing very thin soil formation formed over that particular region. Thin layer of soil is found along the ridges, scarp, mesa, buttes etc. Since the foot of the scarp receives much accumulation from the higher elevation

---

1. *Pettijohn Potter (1972) Sand and sandstone Springer - Verlin. Berlin etc.,*

2. *V. Subramanyan (1988) op.cit.*

3. *Arnold Heineman (1979) Process in Geomorphology Edt. Clifford Embleton and John Thorner.*

TABLE - 2

APPROXIMATE AVERAGE POROSITIES AND RELATIVE PERMEABILITIES FOR DIFFERENT ROCKS.

ROCK TYPE	*POROSITY*	*RELATIVE PERMEABILITY*
Sandstone	*18*	*500*
Shale	*18*	*5*
Limestone	*10*	*30*
Granite	*1*	*1*

SOURCE : Arnold Heineman op.cit.

the thickness of soil is comparatively high. In lower elevation especially where the accumulation is found, the thickness of the soil formation is relatively high.

Weathering also takes place where the headward erosion is found and also in some high land places of the fault scarps.

Topography of the Kalimachak river basin has a profound effect on the nature and rate of weathering processes for example the region consists most of the areas of steep slopes and the areas which are affected by continuous erosional activities are also not favourable for the weathering.

4.3 MASSMOVEMENT

Massmovement of Kalimachak could be identified through Aerial photograph by studying the landforms which are resulted by massmovement. Some of clues to recognise massmovement from Aerial Photographs are suggested by Varoujan Kh. Sissakia (1986)[1] (See Appendix - I). Massmovement is process whichinvolves the transfering the weathered material from higher to lower ground surface without assistance of fluid transporting agent. Massmovement of Kalimachak river basin is very slow. Usually massmovement occurs only when the disturbing forces overcomes the resistance of slope.

1. *Varoujan Kh. Sissakia (1986) op. cit.*

The study area consists rock types of sandstone, shale and limestone, out of which shale is more susceptible to weathering and masswasting. These weathered material consists much of quartzite which gives very light tonal variation in Aerial photograph. The Massmovement occur almost everywhere where the high land, steep scarp, residual and conical hills, plateaus are present. The areas of headward erosion are important for the accumulation of colluvial material. The landforms identified resulting out of massmovement of the study area are Soil, creep, continuous creep and pediments.

4.3.a) SOIL CREEP :

Soil creep have been identified almost all over the region except the areas of North eastern side where alluvium is present. Soil creep is a downward movement of superficial soil. The location of the soil creeps have been shown in Geomorphic map. The character of the soil creep in Aerial photograph is its white tonal variation with concave profile. The main source for this soil creep is the parental rock of the basin. These soil creeps are found on slopes which are completely free from vegetation except some screes which consists shrubs.

4.3.b) CONTINUOUS CREEP :

The deformation of slope material is continuous where the hillslopes are affected by weathering and force

of gravity. This movement is called continuous creep which is identified in the study area near the vicinity of Kanpura settlements. Aerial photographic characteristics of this feature are light tonal and coarse texture.

4.3.c) PEDIMENT

From the residual hills and steep scarps some of the sand and gravel extended to the plain region. Pendiments found around the hills in the study area example near Bhawarli settlement. Pediments found in the study area have a thin veneer of debris and these could be identified on aerial photographs by their light tonal reflectance. These pediments have concave surface.

4.4 FLUVIAL PROCESS

Fluvial Process is the dominent Geomorphic Process of Kalimachak river basin. This process includes Erosional, transportational and depositional processes. Each process produces distinctive landforms.

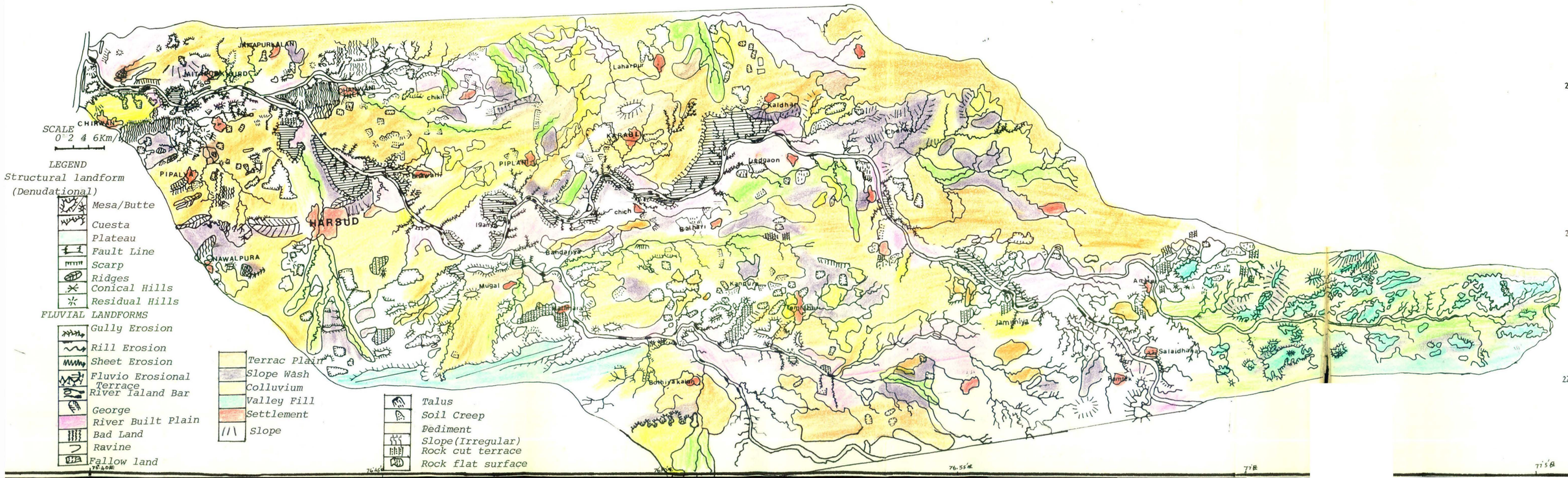
4.4.a) EROSIONAL PROCESSES:

Erosional processes are the processes which are constantly transfering material from the land to the sea.[1] The rates of erosion depends upon the relief, soil type,

---

1. *D.R.Stoddart (1969) 'World erosion and S-dimentation' Introduction to fluvial processes - Edt. by Richard J. Chorley Methuen & Co. Ltd.*

GEOMORPHIC MAP : KALIMACHAK RIVER BASIN



intensity of rainfall and the amount of sediment. The rates of denudation can be determined by measuring the sediments.

Erosion is already clearly in evidence and the erosion hazard expresses the intensity of the erosion process and the degree of soil loss. Both are determined by the permanent factors such as climate, relief and soil.[1]

The aerial photo interpretation is the best method for better understanding of the mechanism and causes of physical erosion and a more accurate assessment of the damages which are caused. The chemical erosion is caused by heavy rainfall and severed due to lack of vegetation.[2]

Erosion is mainly assesed on cultivated land or natural vegetation for agricultural purpose and not for engineering purposes such as road or dam construction and sedimentation or river pollution.[3]

Different types of erosional processes have been observed such as soil erosion which includes rill, gully and sheet erosion, channel erosion which includes vertical and lateral erosion. The resultant landforms are also identified and explained.

---

1. *Bergsma E (1981) "Method of reconnaissane survey of erosion hazard near merida spain" Assessment of soil erosion Edt. De Boodt & D. Gabriels.*

2. *Belpomme M (1980)"For an application of the soil world" Assessment of soil erosion Edt. De Boodt & D. Gabriels*

3. *Riquier J (1980) "Small scal mapping of present and Potential erosiion" Assessment of soil erosion Edt. De Boodt & D. Gabriels.*

4.4.a(i) SOIL EROSION :

Soil Erosion is a removal of soil by denudational processes of water. Since the study area consists of sandstone which is predominant in the region so the infiltration of rainfall is less hence the over landflow is the resultant process which is a major cause for the removal of the soils of the basin.

Soil Erosion includes rill, gully and sheet erosion. The water flows over the irregular surface especially on hillslopes. It fills the depression and when some small linear streams flow into the depression the over land flow discharge increases and the linear downslope water flow would be produced. As the discharge increases the power to overcome the strength of soil and vegetation that also increases and the erosional processes to erode the channel will begin. The flowing water causes the small channels called rills and this rill system converts into dentritic network which can be identified in the western side of Harsud and easternside of Jaitapur Khurd settlement.

Rills are formed during storms especially when the water flowing over the surface of soil is deep enough to become turbulent and erosive. Rill erosion is dominant processes of the north of Harsud, pipalya and Dhanwanitheka

settlement. Here the rills organinate from the highlands where the rocks are easily erodable in nature. Absence of vegetation and slope of these areas accelerate the erosional processes. Rills are also originate from the hillslopes found in the south of Ramtek settlement.

The narrow ridge found in westernside of Ghagra settlement is badly eroded by rills and a hill situated in the south of Salaidhara settlement is also denuded by rills.

Rill erosion is indicated by very narrow strips ranging from dark grey to black on black and white photos, shallow gullies close to 1 mt in depth are indicated by light grey on black and white photograph.[1]

When many rills merge and enlarge Gullies are produced. Gullies are defined as the surface channels formed when rills combine and develop to the extent that they cannot be eliminated by normal tillage operations. Rills are usually deep, soil upland channels and commonly occur in the areas of deep friable subsoils. They are characterised by an overfall at the gully head that advances upstream.[2]

---

1. *Pihar (1980) "Soil Erosion detection using infrared colour oblique aerial photograph"* Assessment of soil erosion *Edt. by De Boodt & D. Gabriels.*

2. *Kent Mitchel (1980) "Soil loss estimation"* Soil Erosion *Edt. M.J. Kirk by A Wiley Interscience Publication.*

Severe soil erosion associated with gully erosion can initiate mass movements from steepened slopes around the gullies. Such massmovements play an important part in the total sediment removal.[1]

Gully erosion is more vigorous in the north and north west of Chhirwan settlement. Here the streams are originating from the cuesta and eroding the cuesta scarp and removing the soils of erosional terraces.

Gully erosion found in the south west of Jaitupur Khurd settlement removed much of the soil and the resultant feature is a long ravine and undulated topography.

The riverbuilt plain of the north west of Dhanwanitheka rural settlement is deeply eroded by Gullies and this reduces the amount of cultivable land.

North of the Harsud settlement rills are enlarged into gullies and remove the soils of sandstone intercalations with shale and here many linear valleys are formed due to this Gully erosion.

According to G. Richter[2] the erodibility of soil derived from sandstone is increased and the average decrease of soil profile is 4.8 cm per degree of declination.

---

1. *M.J. Kirky (1980) op.cit.*

2. *Richter G. (1980) "Soil erosion mapping in Germany and in chechoslovatcia" Assessment of soil erosion. Edt by M.De Boodt. D. Gabriels.*

Gully erosion is more vigorous also in north and east of Igariya and the vicinity of Chich settlements.

Headward gully erosion found in the easternside of Karauli Settlement and western side of Piplani settlements are very much dangerous for the agricultural land use. This headward erosion is continuous and increasing the amount of land of the gully erosion.

Some of the regions of East of Bothiyakalan, and south of Runjhun are also affected by gully erosion.

The areas which are very badly affected by gully erosion are also found in the westernside of Jaimalpur settlement, southeast of Temblapuri settlement and south of Charwa settlement.

This layer of the continuous sheets of water flow over the surface of the land can be called as sheet flow or sheet flood. Erosion does not take place when the sheet flow is very shallow. Where the vegetation cover is poor, and slopes are favourable there the sheet erosion takes place.

Sheet erosion occurs when the water flowing over a relatively smooth slope. It is important in pediment formation. Sheet wash is very effective erosional processes as it covers large areas of slope than rill wash.

Rills and Gullies remove larger volume of soil per unit area than does sheet wash because the depth of farmer is more than later.

The areas of sheet erosion observed in Kalimachak river basin are in the south of Dhanwanitheka rural settlement, north of Dhanwanitheka settlement, South of Bhawali settlement (where the sheet erosion is vigorous and remove more soil) and also in northwest of Mugal settlement.

Bad land and ravines are important resultant landforms identified in the study basin. Bad land found in the eastern side of the Chhirwan settlement has three elements of slopes which are small pediments at the base, steep slopes of scarps and thirdly dissected upland area where rill erosion is dominant. Here rill erosion is continuous and these are also found along the lineament where the structural control plays an important role. Badland is completely free from vegetation.

A long narrow ravines are also found in this region. These are resultant of gully erosion. A ravine, found in this region. They are resultant of Gully erosion. A ravine, found in the confluencing point of Kalimachak river with Chotatawa main river, is best example.

The slopes of ravines appear in white colour. The bed of ravine appears as dark grey colour in the white and Black photographs where the water stagnates during rainy season.

4.4.a)(ii) CHANNEL EROSION

Channel erosion is an erosional process of the main stream which includes vertical erosion and lateral erosion. Both the processes performed in different stages.

Vertical erosion is performed in the initial stage where the steep gradient, gravitational force and impervious rocks are present. As the gradients decreases the intensity of the down cutting is also reduced and when the river flows in more or less plain regions i.e., the first stage of maturity i.e., meandering processes develop which is result of lateral accretion. There the dominant process is constructive. Fluvial construtive action is complex; it involves a simultaneous degradational and depositional process, or sequence of the processes and the resultant landform is depositional - erosive in character.

In Kalimachak river basin the vertical erosion is performed in the Syani protected forest which is located in the southeastern side of the basin. There the altitude

varies from 654 mts to 340 mts. with in 15 km distance. Here because of the steep gradient and presence of sandstone intercalations with shale rock the vertical cutting is vigorous. The steep scarps of the plateaus are eroded very deeply and the resultant land forms are deep valleys and Gorges which are most dominantly found in the eastern side of the basin. Though these plateaus are thickly vegetated the erosional processes are vigorous because of the rock type. The gorge is eroded till the base and friable quartzites present inside the gorge could be easily identified through the aerial photographs. Here lowering the plateau hights and removing all these soft rocks by vertical erosion are the dominant processes. When the river flows after 340 mt especially when it enters the plain region the velacity of the river and downcutting reduced. So the vertical corrasion is proportional to the gradient of the river.

Almost 90% of the study area lies in the gentle gradient topography between 340 to 240 mts. Here the lateral erosion is caused by main channel. So in the study area lateral erosion becomes relatively important. Meandering pattern of the Kalimachak river basin is mainly due to bank erosion and point bar development.

The intensity of the bank erosion is more along the concave banks where the river flows rapidly and hits the banks than convex banks where the depositional process is the dominant process. The concave banks which are found in the south of Piplani and Karauli settlements are eroded by lateral erosion and this is accelerated by presence of non cohesive material. It is also important to note here that not all the concave banks are affected by lateral accretion in Kalimachak river basin. Some concave banks especially near south west of Jaitpur Khurd settlement are not eroded because of the availability of the energy to erode is less due to the contribution of heavy load of some subsidiary streams especially where the Delta bars are present.

Bank vegetation exerts a strong control over bank stability and it has some influence on channel form. Bank vegetation is almost completely absent in the study area except along Sihar Nala tributary where some vegetation over lateral erosion is less in the study basin.

The banks which are affected by lateral erosion are shown in the Geomorphic map. The banks are eroded

and the eroded materials are deposited inside the channel. This depositional features could be easily identified thorugh aerial photographs. These features reflects white tonal variation. The shape of these features varies according to the rate of bank erosion. The rate of bank erosion varies according to the cohesiveness of the bank material.

Lateral erosion is the chief cause of the widening of channel occurs wherever the lateral erosion is dominant. Widening also occurs in the west of Chich, Southwest of Jaitpur Khurd settlement, north west of Harsud, Southwest of Igaria and north west of Khaldhar due to the presence of river island and gentle bank slope towards eastern direction.

The materials eroded by Gullies, vertical and lateral erosion are transported very less distances approximately not more than 3 or 4 Kilometers because of the presence of many bends in the river as in the case of west of Salaidhana settlement. Here spill resistance of the channel is present because of the sudden reduction of the velocity.

4.4.b. CONSTRUCTIONAL PROCESSES

The constructional action of the river could be recognized by the development of the meandering course of the river. Constructional processes of the Kalimachak

river basin could be easily identified through the aerial photographs by analying the distinct depositional features. Different types of bars have been identified which are point and delta bars. A point bar is a deposit formed on the inside or convex side of a river bend by lateral accretion. The term point bar is roughly equivalent to meander bar, meander scroll or scroll meander.[1]

Delta bars are formed by tributary streams building deltas into the channel of the mainstream (Thornbury 1954). The tonal reflectance of both point and delta bars in the aerial photographs is light grey to white. These constructional landforms are also subjected to erosional action of the main river. So these landforms can be called as constructive erosional land forms.

In the study basin, numerous delta bars have been identified and these delta bars are found more in number especially in central part of the basin example southwest of Haripura where the river takes meandering course. Tributaries are eroding the soft shale region through gully erosion and bring a lot of load and deposit where it joins with main river, north of Harsud and northwest of Dhanwanitheka rural settlement modified by the channel erosive action which reveal the dynamic nature of fluvial process.

---

1. K.B. Mahalakshmi - op.cit.

Different shapes of the point bars have been identified in the study basin. The linear shape of the bars are found in the westernside of Chhirwan settlement. Here the chance of eroding this bar by the channel action would be less because these are parallel to the river flow direction. Cresent shaped point bars have been identified in the southwest of Jaitapur Khurd South of Piplani and south of Karauli Settlement. Here internal distortion would occur because of the presence of these point bars.

Internal distortions also would occur near west of chick, south west of Jaitapur Khurd and south of Khaldhuri because of the presence of undulation topography of the channel. Here the possibilities of riffles would be found. Riffles are zones of accretion. Sediment size may decline from bar head (gravel) to bar tail and structures would change in successive floods.

River also deposits the materials where even the convex meander bends are present especially near Piplani and Haripura settlement.

Constructive processes also could be identified through analysing some other land forms like River built plain, valley fill deposits terrace deposits etc.

Weathered and masswasting materials are deposited in the adjacent long and broad valleys by many small streams. These deposits are reflecting dark tonal reflectance. These valley deposits have been identified in the study basin in south of Harsud, north of Bhawarli, South of Laharpur and Pakharni settlements. The long tributaries flowing in these valleys take a straight course. The valley found in the north of Chikhil is completely filled by thick deposit.

Different types of terraces identified in the Kalimachak river basin are river terraces which include parallel, non-parallel terraces and structural terraces which are formed in higher elevation especially these are affected by main stream, Strath terraces where flat valley bottoms are present, bed rock terraces where very thin veneer of weathered material is found, fluvial erosive terraces where the terraces found close to main river and it is affected by Gully and lateral erosion. Location of all these terraces are shown in the Geomorphic map. Here strath terraces are found in the Syani protected forest where the plateaus are deeply eroded. Strath is a term used by Bucher to the parkes strath in the Applachian plateau region (Thornbury 1954).

TABLE - 3

PHOTO-CHARACTERISTICS OF SAND STONE AND SHALE OF KALIMACHAK RIVER BASIN

ROCK	TONE	TEXTURE	DRAINAGE	RESISTANT AND EROSIONAL LANDFORMS	STRUCTURE	VEGETATION	SURFICIAL COVER	HUMAN INFLUENCE
Sandstone	Light to medium	Medium to coarse	Low density joint and fracture controlled Trellis patterns	Plateau, mesa, boardered high escarpment, denudational hills	Joints, clear-bedding low dips towards WNW	Moderate	Thin soil cover	Less near villages land used for cultivation
Shale	Dark	Fine	High density dentritic lack of structural control	Gully is dominent	Horizontal sedimentary	Sparse	Thick soil cover	Extensive land use.
Granite	Light	Coarse	Sub-parallel to rectangular	Parallel resistant ridges	Few Out crops	Sparse	Thin soil cover	Less use

Structural terraces are controlled by local dip of the rock (Thornbury 1954). Such kind of terrace clearly identified through Aerial photograph. This type of terrace is found in north of Chirrwan settlement etc. Two bedrock terraces are low and high land rock terraces have been identified and shown in the geomorphic map. The aerial photographic character of these features is white tonal reflectance.

River built terraces like parallel and non-parallel terraces have been identified. Parallel terraces are found in Siharnala tributary and north eastern side of patalnadi. Non parallel terraces found in the center of the basin where river takes its meander course.

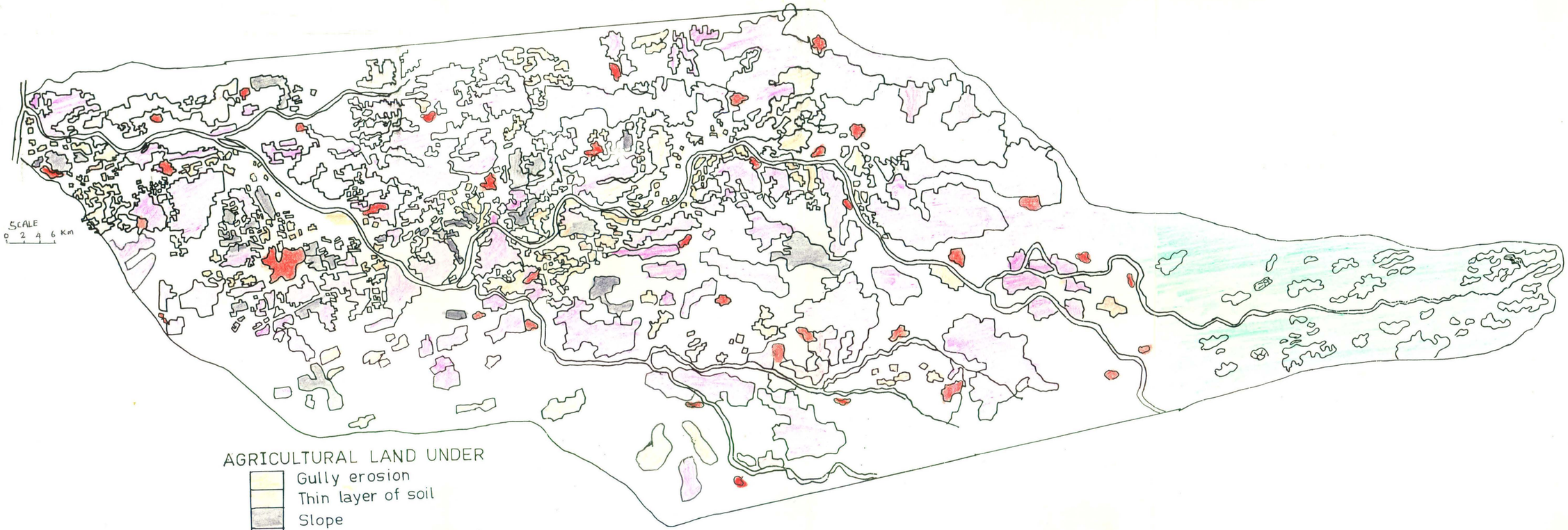
Fluvial erosive terraces found along the main river. These erosional terraces are predominant in the north of Harsud, south of Kaldhar and south west of Piplani settlement.

4.5 LAND USE OF THE STUDY BASIN

Land uses of the study area can be classified under different categories such as agricultural, barren, sattlement and for other purposes.

The plain region found in northeast of the study area is completely used for agricultural purposes.

LAND USE - KALIMACHAK RIVER BASIN



The west and south of the study basin where mostly the land is very undulated and the amount of land used for cultivation is comparatively less. Here the land has very thin veneer of soil compared to eastern part of the basin where the recent alluvium is thick and consists fertile soil for the cultivational purpose. The gentle slope region, valley region, flood plain, terraces are also used for agricultural purposes. Some of the land found on the cuesta slope, mesa top which are possessing very thin layer of soil are also used for cultivation. Some small amount of land available even inbetween erosional terraces are also used for cultivational purposes. River Island terrace which is found in north of Chirrwan settlement is used for agricultural purpose.

The southeasternside of the study area Syani protected forest is completely plateau region. Some plateaus are also found in southwest of Patal Nadi.

Barren land includes bad lands, fallow lands, fluvio erosional terraces, irregular steep slopes, bed rock terraces, irregular steep slopes, bed rock terraces, flat rock surfaces and the region affected by gully erosion, soil creep, colluvial materials etc. High safety lands are occupied by settlements.

For some other purpose also land has been used such as transportational lines, lakes, wells etc.

4.6 IMPACT OF GEOMORPHIC PROCESS OVER LAND UTILISATION

Geomorphic processes influence and affect the land utilization of any region. Every process in a given geomorphological environment leaves characteristic traces in the landforms which enable us to identify the processes which caused them. Another clue directing further study is obtained when the processes clearly affect the pattern and type of land utilization. An understanding of the naturally occuring geomorphological processes is essen for a healthy agricultural system. For example in a where the flood plain is bound by a series of river of different height and age, the younger lower terrac will have rich soils than those of the higher terrac

All the three geomorphic processes of Kalimachak river have certain impact on land utilization of the region.

Weathering processes affect the landuse pattern according to the rate of weathering. Since the study area consists of sandstone which is not very much affected by weathering. The soil formation, is very thin in sandstone areas, which directly affect the agricultural land use. The land of hill and cuesta slopes, where very thin

veneer of soil present, are also used for agricultural purpose. Butte agricultural yield would be less here than the yield of plain alluvial photography.

Masswasting also affecting the land utilization. The regions with soil creep, talus cone and pediment are not used for agricultural purposes because of the nature of the topography. The regions of colluvial material also not used for cultivation. Some shurbs are found in this area.

Since the study area is under severe fluvial erosion, the amount of agricultural landis reduced by gully, rill and lateral erosion. The region affected by different erosions have been delineated and shown in Geomorphic map. The areas of high steep slope and soft rocks accelerate the fluvial erosion. Some of the settlements like Jaitupur Khurd, Harsud and Igariya are also affected by linear fluvial erosion.

chapter - v
summary and conclusion

CHAPTER - V

SUMMARY AND CONCLUSION

Remote sensing technique has been used for the present study to analyse the landforms which are structurally controlled, the lineament pattern and its predominent direction, the different geomorphic processes found in the region and the impact of these geomorphic processes on land utilization. These studies made with the help of aerial photographs. It is reassessed that the eastern portion of the basin which comes under forest and northern portion of Siharnala tributary are not able to study with the aerial photographs because of its non availability.

The study area Kalimachak river basin was affected by tectonic disturbances and at present it is completely undergoing the severe fluvial erosion. So it provides ideal conditions for this study.

The region consists of primarily sandstone, shale and limestone rocks overlying Deccan traps unconfirmably. Sandstones are very distinctive in this region and it forms bold, massive flat-topped mesa like hills and this type of land forms are present in the western and southern side of the region.

The region made up of shale especially in the central portion and north west of the study area are undergoing severe gully and channel lateral erosion.

The eastern side of the region consists recent alluvium and plain topography which is completely used for agricultural purpose.

The Kalimachak river basin is affected by faulting which can be identified from the topographical features such as sandstone higher elevations, lower valleys, easily eroded, brecciated zones and also presence of weak and strong rocks on both the sides of fault.

Some of the important fault associated features identified in this region are fault scarps, fault line scraps, cuesta, mesa, butte, fault line valley, fault terrace, resistant and denunded ridges etc.

The characteristics of fault scarp, fault line scarp, cuesta scarp, mesa scarp, Butte scarp have been analysed. Some similar characters for both fault scarp and fault line scarp are abrupt and imposing front face, linear base to a scarp and V-shaped canyons.

Retreating of the scarps of cuesta, mesa and fault scarp are due to the denundational processes. Some fault

scarps are richly vegetated and hence tend to resist erosion. Soft rocks are eroded rapidly and the bed rock of the gorge is clearly depicted in the stereovision. Triangular faceted spur end scarps are also identified in the study area.

Scarp face of cuesta, mesa and Butte are inundated by stream erosion. Bevelled cuestas related with a series of features from West to East such as hog back, cuesta and mesa are also found in this region. Some mesas are reduced to Butte and some mesas top consist resistant cap rocks. The size of mesas varies according to the intensity of erosion. Structural bench land where mesa is made up of hand sandstone and where the rim is less affected by stream is also identified in the study area. Mesas have prominent appearence and are charactrised by their dark grey colour in the aerial photograph.

Fault line valleys are found predominently in the Syani protected forest.

Fault terraces characterised by undulated topography in between two fault scarps are also observed in the study area.

Structural and denundational hills, which have different summits ranging from narrow rocky, broad crests to sharp conical and rounded, are identified in the

present study area. Numerous parallel ridges are found in the West and South central portion of the study basin.

Some of the fluvial patterns which are controlled by structure are identified. These are fault trellis drainage pattern, parallel drainage pattern. Because the rock pattern is relatively hard, the depth of fault trellis drainage pattern is less. Presence of alternate hard and soft rocks produce parallel and sub-parallel drainage patterns. Dentritic pattern is developed on the high Bad land topography flows along the lineaments. The value of topography flows along the lineaments. The value of topographic sinuosity index 44% indicates that some regions depict lack of structural control especially North eastern part of the basin where plain topography with thick alluvium is present.

Different trends of lineaments are identified in the study basin. Topographic lineaments are found along the fault scarp, fault line scarp, resistant ridges, tonal variation, variation in elevation and vegetation lineament are found along the linear alignment of vegetation are deciphered in the Kalimachak river basin.

South West to North East trend reflects the fault scarp and the W to E and NW to SE represents the cuesta scarp and N to S NS and W to E trend depicts the cuesta

zones of gullies found in the study basin. Some of the lineaments are terminated by fluvial erosional activities.

Three types of Geomorphic processes such as Weathering, massmovement and fluvial processes are analysed in the study area. Among all, fluvial process is the dominant process which dissects the land to a great extent.

Physical weathering occurs because of the difference in temperature and chemical weathering is because of the presence of shale which is very susceptible of chemical weathering. Very thin layer of weathered material is found in the sandstone area which is relatively resistant to weathering. Some of the fault scarp bluffs are affected by weathering process.

Massmovement is also identified in the study area. It is a very slow process and the resultant land forms are soil creep, continuous creep, talus creep which are present especailly at the foot hills and base of fault and fault line scarps. Pediments are found around the hills are dominent in north of Piplani and west of Harsud settlement.

Soils of the study basin are very much affected by rill, gully and sheet erosion. Gully erosion is predominent and it is very badly dissecting the potentially

rich agricultural lands. The resultant landforms of this type of soil erosion are ravines and bad land landforms which are also analysed in the present study.

Channel erosion includes vertical and lateral erosion and the resultant land forms are also examined in the present study. Here vertical erosion is vigorous in the south eastern side of the basin where the gradient, rock type are favourable. As the gradient decreases the river flows in gentle topography where the vertical erosion becomes less and the lateral erosion begins especially in the centre portion of the study area where river takes its meandering course.

Bank erosion is vigorous in the study area because of non-cohesiveness and lack of bank vegetation. The intensity of lateral erosion is more along the concave banks than along convex banks. The boundary of the channel also is changed by the bank erosion. The width of channel becomes widened in some places because of the presence of river islands and also due to lateral erosion.

Constructional processes of the river also analysed in the present study. The important landforms due to constructional activity of the river are point bars, delta bars, flood plain etc.

Different shapes of point bars such as cresent and linear shapes are found in the study area. These are again eroded by main river.

Delta bars are found in the beginning and end of the meandering course of the study area.

The causes of internal distortions of the channel are also analysed.

Different types of terraces like Strath, parallel, non parallel, bed rock, fluvial erosional terraces and structural terraces are identified in the study area.

General land use pattern is also discussed in the present study where maximum land is used for agricultural purposes. Apart from agricultural land, other types of land use are also identified and mapped in the region.

Geomorphic processes influence the land utilization of the study area. Endogenic and exogenic process produce distinctive landforms which directly affect the land use. Presence of numerous faults, parallel ridges, Mesas, Buttes reduce the amount of agricultural land. Gully erosion is affecting the present agricultural land. The resultant of lateral erosional processes of erosional terraces are not utilized for any purpose.

The above study reveals that Kalimachak river basin has not only experienced massive tectonic movements in the recent past but it is also undergoing intensive fluvial dissection along the river courses. This basin depicts various structural land forms associated with faults namely fault scaps, fault line scaps, structural hills, mesas, Buttes, Innumerous lineaments are also observed in the region which control not only the drainage pattern in the form of modified terrelis patterns but also vegetal cover of the basin. Intensive dissection has been made possible by thepresence of innumerous rills and gullies which not only erode a large part of the catchment but also expand at a rapid rate by headward erosion into numerous agricultural patches. Apart from hills and gullies the main channel also undergoes lateral and bank erosion which are easily identified from the Aerial photographs.

The land use of the basin has been categorised into four categories and it is represented accordingly in the map form. The impact of denundational processes on the agricultural land is remarkably identified in the Aerial photographs. Such regions have been delineated and represented in the land use map. Such an identification of denudational pockets leaves further scope for detailed investigation to Macro level with elaborate field work which can ultimately save the land from further degradation.

APPENDIX - I

Some clues to recognise massmovement from aerial photographs are :

1. Existence of cracks on steep slopes
2. Hummocky slopes
3. Erosion front in the foot of a steep slope which faces stream
4. Existence of bulges in the foot of the slopes
5. Existence of steepscarps on a slope
6. Existence of concave or spoon shaped slope
7. Existence of accumulated mass at the bottom of a steep slope or cliff
8. Steep slope having large masses of loose soil and rock
9. Steep break(s) in a slope giving it a steeped shape
10. Existence of ponds on slopes
11. Narrowing of a valley which faces a steep slope and has no apparent relation with underlying bed rock
12. Changes in the direction of a valley in arch shape, facing the instable slope with a clear widening of the valley, both below and above the arched section.
13. Assymmetrical valley with active erosion on the steeper side
14. Internal drainage on slope
15. Existence of highly saturated areas which show a different tone on slopes
16. Seepage zones
17. Sudden change in valley gradient
18. Accumulation of scree on slopes

Some clues to predict the massmovement from aerial photograph are :

1. Cracks on steepes, when big enough to be visible on the photographs
2. Thick colluvial soil on steep slopes
3. Clear bedding planes dipping towards the slope
4. Highly saturated areas and seepage zones
5. Old mass movement areas
6. Active erosion at the foot of slopes
7. Areas showing disturbed vegetation
8. Hummocky surfaces
9. Small depresssion on slopes

APPENDIX - II

SINOSITY INDEX OF KALIMACHAK RIVER BASIN

Channel length = 77 Km

Valley length = 55 Km

Air = 37 Km

Total sinuosity = $\frac{77}{37} = 2.08$

Index of topographic sinuosity = VL/Air = 55/37 =1.48

Hydrologic sinuosity Index = $\frac{CI-VI}{CI-1}$ %

$\frac{2.08-1.48}{2.08-1} = \frac{06}{1.08} = 55\%$

Topographic Sinuosity Index = $\frac{VI-1}{CI-1}$ %

$\frac{1.48-1}{2.08-1}$ % $= \frac{048}{1.08} = 44\%$

REFERENCES

1. R.L. Ahuja and S.S. Khanna (1982) 'Soil Scapes, Geomorphic Processes and soil taxonomic new sub groups identified in the Ghaggar River basin of Haryana and Punjab'.*Photonirvachak Jour. Ind. Soc. Photo. Int. & Remote Sensing Vol. 10, No.1.*

2. Alois Sieba (1975) 'Remote Sensing applied to energy related problems' *Remote Sensing - Energy related studies Edt. by Nejat Veziroglu Hemisphere Publication & Co., Washington, London.*

3. JAE. Allum (1969) Photogeology and Regional Mapping *Pergamon Press, Oxford London, Edinburg, New York Toronto etc.*

4. Amursky G.L. (1984) 'Application of Remote Sensing for Oil and Gas Exploration'. *Remote Sensing Proceedings of the 27th International Congress Moscow.*

5. Arnold Heineman (1979) Process in Geomorphology *Edt. Clifford. Embleton and John Thorner.*

6. Arwan Rhys Jones etc. (1986) 'Spring Mound and aioun mapping from Landsat TM Imagery in South-Central Tunisia'.*Remote Sensing for Resources Development and Environmental Management. Edt. by M.C. Damen etc., Rotterdom/Boston.*

7. P.V.L.P. Babu (1976) ' A review on the oil & Gas prospects of the Bengal basin based on photogeomorphological studies' *Photonirvachak Jour. Ind. Photo. Int. Vol. IV No. 1&2*

8. Bonham CArter (1985) ' Statistical Association of Gold occurrences with landsat - derived lineaments, Timmins - Kirkland lake area' *Ontario - Canadian Journal of Remote Sensing Vol. II, No.2, Pub. by Canadian Aeronautics and Space Institute, 222, Somerset Street, West, Swite - 601 Ottawa.*

9. A. Battacharya (1983) 'Geologic and Geomorphic controls in landuse patterns Examples using remote Sensing techniques'. *Photonirvachak' Jour. Ind. Soc. Photo. Int. & Remote Sensing Vol. II, No.3.*

10. Barbara Daniel Danielska etc., (1986) 'Geological analysis of the Satellite lineaments of the vistula Delta Plain, Zulaway Wislane, Poland'. *Remote Sensing for Resources Development and Environmental Management, Edt. by - M.C. Damen etc., Rotterdom/Boston.*

11. Barrett and F.C. Cortis (1976) Introduction to Environmental Remote Sensing. Page No. 239-251.

12. Belpomme M (1980) 'For an application of the soil world'.*Assesment of Soil Erosion. Edt. De Boodt. & D. Gabriels.*

13. E. Bergsma (1980) 'Method of a reconnaisance survey of Erosion hazard near Merida, Spain'. *Assessment of Soil Erosion, Edt. De Boodt & D. Gabriels.*

14. Bismal Ghose etc. (1975) 'Aerial Photogrammetry and Photogeomorphology' *The Indian Geographical Journal Vol. 1. No.2.*

15. Cooke etc., (1982) 'Urban Geomorphology in drylands' *Oxford Univ. Press.*

16. S.P. Deopurkar, V.V. Peshwa (1981) 'Interpretation of lineaments from precambrian rocks in Madura and Sonrai area Lalitpur district - UP ' *Photonirvachak, Jour. PHoto. Int. & Remote Sensing Vol. 9 No.2.*

17. Dikshit K.R. (1983) Geomorphology - Contribution to Indian Geography page no. 332 concept publication.

18. Fairbridge (1968) 'Geomorphological mapping' *Encyclopedia of Geomorphology.*

19. Kent Mitchel, Gary D. Babenza (1980) 'Soil loss estimation' *Soil Erosion Edt. M.J. Kirkby & R.P.C. Morgan. A Wiley Inter Science Publication.*

20. M.J. Kirky (1980) 'The Problem'*Soil Erosion Edt. by M.J. Kirky, A Wiley Inter Science Publication.*

21. S.V.B. Krishna Bhagavan and K.L. Ramana Rao (1985) 'Geomorphic features of a part of Cuddapah and Nellore district, A.P. using remote sensing technique'. *Photonirvachak, Jour. Photo. Int. & Remote Sensing Vol. 13 No.2.*

22. Krishnaunni (1976) 'Mega lineament pattern of Gujarat from landsat Imagery an attempt to fit into the geological frame work' *Photonirvachak Jour. Ind. Society Photo Int. Vol. IV No. 1 & 2 p. 21-28.*

23. Lu Detu, Zhang Wenhua etc., (1986) 'Analysis of lineaments and major fructures in xichang - Dukou area, Sichuan Province as interpreted from Landsat images' *Remote Sensing for Resources Development and Environmental Management. Edt. by M.C. Damen etc., Rotterdom/Boston.*

24. Negi R.S. & Koti Reddy B.B. (1983) 'Floods in Sati River. A Geomorphic study'. *Photonirvachak Jour. Photo. Int. Remote Sensing, Vol. II, No.2.*

25. Mahalakshmi K.B. (1986) 'Geomorphic Studies in evaluation of landscape and Resources of Peddavagu Basin - A.P.'.*Ph. D. Thesis - Waltair University.*

26. R.S. Murthy and R.M. Pofali (1984) 'Geomorphological Map of Gujarat from Landsat imagery analysis' *Photonirvachak. Jour. Ind. Soc. PHoto Int. & Remote Sensing Vol. 10, No.3.*

27. V.V. Peshwa and A.G. Desai (1977) 'Structural trends in Deccan trap area NW of Poona. A Study based on Landsat - I imagery interpretation'. *Photonirvachak, Jour. Ind. Soc. Photo. Int. Vol. V, No.1.*

28. Pettijohn Potter Siever (1972) 'Sand and Sandstone' *Springer - Verlag - Berlin Heidelberg, New York.*

29. J. Pihar (1980) 'Soil Erosion detection using Infrared colour oblique Aerial Photograph'. *Assessment of Soil Erosion Edt. De Boodt & D. Gabriels.*

30. K.N. Prudhvi Raju and R. Vaidyanathan (1979) 'Study of landforms, landuse and land units of a part of Krishna district A from Aerial photographs' *Photonirvachak, Jour. Ind. Soc. Photo. Int. Vol. V, No.2.*

31. Raghavswamy (1982) 'Role of Satellite Remote Sensing in land system mapping. Land Resources Inventory and land use planning. A sample study of Kemang River Basin. Arunachal Pradesh'. *Photonirvachak Journ. Ind. Soc. Photo Int. & Remote Sensing. Vol. 10, No.3.*

32. Raj Kumar Rai (1980) 'The terrain assumes special significance for the development of agricultural lands'.

33. Ramaswamy Manohar Sinha S.M. & Dev. Prasad C (1984) 'Environmental Evaluation of Madchal Taluk A.P. Using aerial Photograph' *Photonirvachak. Jour. Ind. Soc. PHoto. Int. & Remote Sensing, Vol. 12 No.2, Page No. 39-46.*

34. D.P. Rao (1977) 'Neotectonic and lineament analysis of landsat imagery for oil and mineral exploration - an example from Godavari delta - Eastern Ghats area'. *Photonirvachak. Jour. Ind. Soc. Photo. Int. Remote Sensing Vol. V. No.2 pp. 67-70.*

35. Ravindru R. and Bakliwal P.C. (1983) 'Geological and Geomorphological significance of a few Mega - lineaments of north eastern Rajasthan'*Photonirvachak Jour. Ind. Soc. Photo Int. Remote Sensing. Vol.II, No.2, Page No. 31-37.*

36. Richter G. (1980) 'Soil Erosion Mapping in Germany and in Chachoslovakia' *Assessment of Erosion Edt. by M. De Boodt & D. Gariels.*

37. Riquier J. (1980) 'Small scale of present and potential erosion' *Assessment of Soil Erosion Edt. De Boodt & D. Gabriels.*

38. Robert L. Bates and Julia A. Jackson (Editors) (1980) 'Glossary of Geology'. *American Geological Institute falls Church, Virginia.*

39. Robert Reeves (1975) Manual of Remote Sensing. Vol.II.

40. Sambasiva Rao (1982) 'Flood intensity and Land evaluation in the Cauvery delta, Tamil Nadu, applying Modern Remote Sensing Techniques'. *Photonirvachak, Jour. Ind. Soc. PHoto. Int.& Remote Sensing. Vol. 10, No.3, Page 23-30.*

41. Shubhada Badhe (1981) 'Landsat Analysis of Dhansi valley' *Photonirvachak, Jour. Photo. Int. & Remote Sensing, Vol. 9, No.2.*

42. Singh B.M. (1977) 'Interpretation of Satellite Imagery for delineation of ravines'. *Photonirvachak, Jour. Ind. Soc. PHoto. Int. Vol. V. No.1.*

43. Singh S.D. and Goel A.K. (1984) 'Fluviomorphological investigations in the floods plain area of river Satlej in the north east of Ludhiana using photo interpretation techniques'. *Photonirvachak, Jour. Ind. Soc. Photo. Int. & Remote Sensing, Vol. 10, No.3.*

44. V.N.P. SInha (1978) 'Weathering in Palamav upland' *Indian Geographical Studies, Research Bulletin No. 12.*

45. Sinha K.K. and Khan A.U. (1981) 'Geomorphology and landuse of Pasighat - Jonai bazar area. A photo based study in a part of Dihang river basin, Arunachal Pradesh and Assam'.*Photonirvachak, Jour. PHoto. Int. Remote Sensing. Vol.9 No2.*

46. G.S. Srivastava, R.B. Sharana and R.P. Sharma (1977) 'Numbra Gartang superlineament its Geological significance and relation with the Indus suture'.*Photonirvachak Jour. Ind. Soc. Photo Int. Vol. V., No.2.*

47. S.K. Subramanian & D.P. Rao (1986) 'Mass movement Studies in Kosi Catchment Nepal - A Semi quantitative approach using Aerial Photographs'. *Phctonirvachak. Jour. Ind. Soc. Photo. Int. & Remote Sensing, Vol. 14 No.1.*

48. Subramaniyan V. (1988) 'Analysis of the Processes Lecture Notes DST - sponsored winter School IIT - Bombay - India.

49. Suresh Chopra (1977) ' A note on photogeomorphological mapping of the cretaceous tertiary formation in Southern fringes of Meghalaya'. *Photonirvachak Jour. Ind. Soc. Photo. Int. vol. V, No.2.*

50. Suresh Chopra and A.K. Mathur (1984) "On the Oscillation of Balat river, District Khasi and Garo Hills, Meghalaya'. *Photonirvachak Jour. Ind. Soc. PHoto Int. & Remote Sensing Vol. 12, No.2.*

51. Suryanarayanan L.S. & Prabhakara Rao P (1981) 'Drainage reversal in Dharampuri area in Tamil Nadu and its effects' *Photonirvachak Jour. Photo. Int. and Remote Sensing Vol.9, No.1*

52. A.S. Thrunavukarasu etc. (1985) 'A lineament study as a hydrological factor - case study from Tamil Nadu' *National Seminar on Remote Sensing for Planning and environmental aspects of urban and rural settlements 29-31 January 1985.*

53. Twidale (1968) Analysis of land forms.

54. Varoujan Kn. Sissakian (1986) 'The study of mass movement from aerial photographs'. *Remote Sensing for resources development and Environmental Management Edt. by M.C. Damen/ G. Sicco Smit/ V.T.H. Verstappen. A.A. Balkema/ Rotterdom/Boston.*

55. Wagle B.G. (1982) 'Lineaments in the coastal zone of Goa' *Photonirvachak, Jour. Ind. Soc. Photo Interpretation and Remote Sensing Vol. 10, No.1*

56. William D. Thornbury (1954, 1969) Principles of Geomorphology Wiley Eastern Limited,New Delhi, Bangalore, Bombay, Calcutta, Madras, Hyderabad.

1. Gazetteers of district of East Nimar district M.P. (1969).

2. Report of Narmada Sagar dam Narmada division, Central Water Commission Board, New Delhi, India.

3. Hydrogeological Map of India.