Study of Lineaments in Polavaram Dam Project Area, Khammam, East and West Godavari Districts, Andhra Pradesh

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Abstract

Mapping of structural lineaments around the Polavaram Project, led to identification of several major faults /shear zones. The objective of the study was to aid the geotechnical investigations of the multi-purpose dam project. The methodology involved remote sensing studies of LANDSAT MSS and TM FCC imagery and black and white aerial photographs, followed by ground validation of 73 lineaments. The major lineaments in the area trend ENE-WSW to NE-SW. Based on the study, the lineaments are classified into faults, shear zones, fractures etc.

A number of faults/ shears were confirmed from field evidences such as abrupt change in landforms and/ or lithology on either side of lineament and other geological and structural features. A few faults were delineated in the vicinity of the dam site, such as, the major arcuate fault situated on the left bank of the river, 12 km northeast of the dam site; ENE-WSW fault across the Godavari River, 3 km north of the dam site and NNW-SSE fault, east of Devipatnam. Faults were also delineated around Bhadrachalam, Ashwaraopet etc, some of which mark the contact between the basement gneisses and Gondwanas. Proximity of Bhadrachalam temple town, known for seismic activity and also presence of significant morphostructures in the Godavari delta, calls for detailed study of Quaternary geology around the Project. Thus the evaluation of lineaments in terms of their status and seismic/ neotectonic significance would prove useful for the purpose of planning and safe designing of the multi-purpose Polavaram project.

Introduction

Lineaments are linear features of the earth and include traces of faults, shear zones, joints and fractures. Generally, rivers and streams tend to follow the lineament. Lineaments are of great significance to geoscientists, especially for engineering geology as they reflect various structural features of an area. Mapping and analyses of lineaments helps us in understanding the structural/ tectonic frame work and geological setup of the area. Remote sensing techniques have given a boost to lineament studies since identification and mapping of lineaments become relatively easy in the satellite imagery/ aerial photographs, because of synoptic view, availability of data in different bands and repetivity. Number of studies carried out in India and elsewhere, have shown that there is a definite correlation between many earthquakes and specific lineaments. In the Godavari valley area a number of lineaments are found, but all of them are not considered significant from the view point of geotechnical investigations. Many of them are not traceable on the ground due to absence of marker beds or presence of thick overburden, some of the lineaments identified on the aerial photos and satellite imagery were checked and confirmed to be surface traces of faults/ shears (Ramesh et al., 1991).

Lineaments are to be evaluated and their significance known for the purpose of planning safe design of important projects or studying the safety of existing one in an area. Detailed knowledge of active faults and the associated seismicity is required to quantify

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the seismic risk. In the present study, an attempt has been made to identify active lineaments of the Godavari valley by preparing a lineament map using satellite remote sensing data and aerial photographs and correlating the same with ground evidences and associated seismicity, if any.

Study area

The study envisaged mapping of lineaments in and around the proposed Polavaram dam project (Fig.1). The proposed multi-purpose project envisages construction of a dam across the Godavari River, 3.5 km north of the Polavaram village, about 35 km upstream of Rajahmundry. The dam is expected to create a reservoir spreading over a vast area upto Kunavaram in the north-west.

The area is bounded by lats 17° 0′-17° 45′ N and long 80° 45′-82° 0′ E and falls in parts of Khammam, East Godavari and West Godavari districts, Andhra Pradesh. The northern part of the area is generally rugged, hilly and forested and is relatively inaccessible when compared to the southern part.

A major part of the area to the north is occupied by the rugged hilly terrain of the Eastern Ghats. The ground elevation which is 20 m above m.s.l. in the coastal plain in the southern part rises to more than 50 m above m.s.l. in the Bhadrachalam area and upto 750 m above m.s.l in the hilly region, further north. In the eastern part of the area, the hills form inselbergs. Remnant planation surfaces are seen above 700 m to 760 m above m.s.l on either side of the Godavari River. A few stretches of floodplains occur breaking the monotonous rugged terrain.

The area forms the lower part of the Godavari basin, just above the delta. The meandering trunk channel of the Godavari has cut deep gorges across the hilly terrain downstream (SSE) of Kunavaram. The river has a southerly course upto Bhadrachalam from where it takes a left turn and continues to flow in a roughly east south east direction upto Kondapudi, where after the direction of the river becomes south-south east till it debouches on to coastal plains south of Polavaram. These major trends do not appear to be controlled by structure.

Data base and methodology

The following data were used in the study:

- Landsat Multispectral Scanner (MSS) / Thematic Mapper (TM) data (band products/ False Colour Composites) on 1:1 million/ 2, 50,000 scale.
- Geological and mineral map of Andhra Pradesh on 1: 500,000 scale.
- Aerial photos (black and white) on 1:60,000/ 30,000 scales

Major lineaments were mapped first from individual scenes of Landsat data (MSS/ TM, FCC) on 1:1 million scale to make a single mosaic map.

The methodology involved remote sensing studies of LANDSAT MSS and TM FCC imagery, bands 2, 3 & 4 of 1987 and interpretation of black and white aerial photographs, followed by ground validation of 73 lineaments.

Regional geology and subsurface setup around the dam site

The project area comprises Archaean crystallines, Gondwana sedimentaries, Deccan Trap, Rahjahmundry sandstones and Quaternary alluvium. The area to the east and southeast of Bhadrachalam is occupied predominantly by the Peninsular Gneissic Complex and the rocks belonging to the Eastern Ghat Supergroup. To the west and south of Bhadrachalam is known for the coal bearing Gondwana formations. The Gondwanas comprising both lower and upper are believed to be the result of taphrogenic sedimentation-the basin to be the result of trough faulting in WNW-ESE direction. The Gondwana sedimentaries show horizontal to sub-horizontal dips (except in the vicinity of faults). The area around Rajahmundry

exposes Traps and Rajahmundry Sandstone (Mio-Pliocene). The Gondwana sediments and Rajamundry Sandstone have been lateritised. The Quaternary alluvium comprising both 'Older' and 'Newer' alluvium is well developed along the banks of the Godavari River and its major tributaries.

The rock formations of the area have suffered polyphase deformation. The regional strike of foliation in the Eastern Ghats Supergroup is NE-SW with steep south-easterly dips. In the eastern part of the area ENE-WSW foliation and axial plane trends are equally prominent. Towards west, the rocks are folded into tight oppressed, isoclinal folds with south easterly axial plane dips. On the other hand, the eastern part is characterised by ENE-WSW trending open folds and doubly plunging folds.

The River Godavari is flowing in a rift valley of 50 km width and 900 km length in a NW-SE direction. The rift valley has undergone continuous tectonic disturbances right from the early Precambrian to the Late Tertiary period, as evidenced by occurrence of sediments of all periods and also associated with Cretaceous-Eocene volcanic activity. Along the eastern margin of the rift valley near Venkatapur, Holocene sediments occupy a narrow strip- 10 km wide and 60 km long. These sediments are also associated in this region with a high gradient of negative Bouguer anomalies falling by 70 m Gal in a distance of 40 km (Qureshy, 1970).

Refraction seismic surveys in Polavaram Project area were carried out by Keshavamani, Rama Rao and Krishna Rao (1990) with the objective of delineating the bed rock topography along the proposed alignments of the dam across the Godavari River, left bank saddle dam, housing the power block and the right bank saddle dams. The saddles on the banks were observed to be filled by thick organic clay and clayey silts, representing the back swamp along the river. Refraction seismic surveys employing geophones on land areas along the proposed dam alignments brought out a 3-4 layered litho-sequence comprising top soil (250 m/s to 350 m/s), sands and clayey silts (700 m/s to 1,600 m/s) and compact bedrock (5000 m/s). The thickness of top soil, sands and clayey silts, weathered or fissured rock at saddle dams varies from 3-10 m, 10-20 m and 0-20 m, respectively. Along the other alignment the thickness of top soil, sands and clayey silts, weathered/ fissured rock vary from 3-10 m, 10-40 m and 0-30 m, respectively.

In the river bed, the depth to compact bedrock varied between 30 m and 70 m from the surface. On the other hand, the depth to compact bed rock estimated along the alignments over the left bank and the right saddle dams varied between 10 m and 30 m from the surface.

The gravity surveys along the Mallisala-Kakinada in East Godavari district indicate increasing thickness of sediments towards the coast. Seismic surveys indicated shallow depth of Trap (300 m) towards south east near Peddapuram. The traps are inferred to extend from Katravupalle in ESE direction to Gollaprolu, and further east of Gollaprolu, the sediments are underlain by crystallines. Further east of Kattravupalle the Traps are overlain by alluvium of Eleru River. The Rajahmundry Sandstone extends upto Samalkot and further east it is covered by alluvium of Eleru River. The area north and east are covered by the Quaternary alluvium (Rao et al., 1971).

Lineament analyses and discussion

The lineaments in the study area mainly trend in the following directions:

i) NE-SW

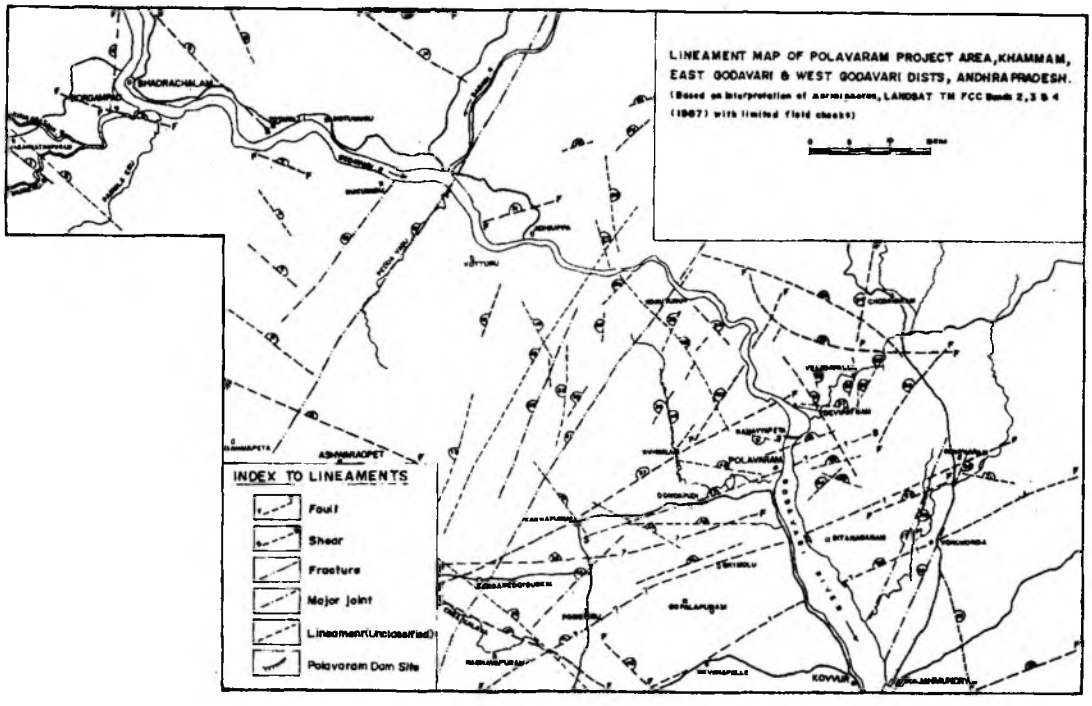
ii) ENE-WSW

iii) NW-SE

iv) NNW-SSE and

v) WNW-ESE

Among the above trends, ENE-WSW and NE-SW are dominant, of which the former trend



is the most important. The major lineaments not only extend for long distances, but also show en-echelon continuity. The lineaments also transgress geological formations of different ages (Ramanamurthy and Parthasaradhi, 1988). The prominent NE-SW and ENE-WSW trending lineaments (faults) occurring around Rajahmundry are related to the tectonic evolution of the coastal Godavari and Krishna troughs due to taphrogenic fragmentation and the emergence of the East Coast line along a NE-SW hinge line, closely parallel to the present coastline (Raja Rao, 1982).

The major lineaments delineated on the basis of the photogeological studies and field evidences, have been classified into five groups as under and shown in Table 1.

i) Fault lineaments

ii) Shear zone lineaments

iii) Fracture lineaments

iv) Master joint/ joint lineaments and

v) Unclassified lineaments

A number of faults and shear zones suspected during the photointerpretation were observed and confirmed in the field on the basis of evidences such as, alignment of drainage, abrupt change in the landform and/ or lithology on either side of the lineament, truncation and/ or dragging of beds, intense brecciation, pulverisation, silicification and

Table 1: Lineaments of Polavaram Project Area, Andhra Pradesh

Lineament No	Name	Direction (%)	Length (in km)	Classification of Lineament
3	Borgampad	N 74 49 W	15	Fault
4	Bhadrachalam	N 05 12 E	13	Fault
5	Totapalli	N 46 33 W	19.75	Shear zone
7	Amaravaram	N 69 42 W	6.25	Fault
11	Patwarigudem	N 67 54 W	25.75	Fault
13	Boddugudem	E-W	10	Fault
15	Pedda Vagu	N 32 06 E	58.75	Fracture
21	Sriramgiri (Jidiguppa)	N 73 26 E	9.25	Fault
31	Baineru Vagu	N 32 27 E	61.5	Fracture
35	Lakonda	N 33 E	4.75	Fault
37	Kannapuram	N 61 57 E	49.5	Fault
38	Srinivasapuram	N 79 54 W	38.5	Fault
40	Erra Kalava	N 63 27 W	23	Fault
41	Bhimolu	N 64 29 E	7	Fault
43	Chinnayagudem	N 47 40 W	7.25	Fault
47	Dondapudi	N 69 54 E	37	Shear Zone
50	Kondrakota	N 33 06 E	21	Fault
52	Gangavaram	N 0 54 E	30	Fault
54	Chodavaram	N 9 45 E	12.5	Fault
62	Velagapalli	N 36 12 E	15	Fault
67	NW of Korukonda	N 68 0E	10	Fault
69	Devarapalle	N 63 48 E	58.75	Fault
73	Rajahmundry	N 68 04 E	13.5	Fault

ferruginisation and emplacement of quartzo-feldspathic veins.

(i) Faults:

The ENE-WSW trending Jagannathapuram-Karicherlagudem-Bhimolu-Ragholapalli lineament (No. 41) extends for 80 km long and is marked on the southern side by a linear scarp formed by the flat bedded sandstone of Upper Gondwanas, whereas the northern side is a linear valley filled with alluvium. This lineament in the west marks the litho-contact between the crystallines of the Western Ghat Complex and Gondwana sedimentary sequence. The faulted contact noticed 6 km north of Annadevarapeta is evidenced by dragging of beds, ferruginisation and presence of gauge material and sliken sides. The effect of fault is seen in a 5-10 m wide zone.

The ENE-WSW trending Devarapalle- Eluru-Ernagudem major lineament (No. 69), occurring downstream of Polavaram, runs for more than 60 km crossing the Godavari River just north of Korukonda. This lineament is a basin margin fault and marks almost the southern boundary of the Gondwanas (Raja Rao, 1982).

Another roughly ENE-WSW trending lineament (No. 37) passes alongside Kannapuram - Pragadapalli. It is conspicuous by the presence of a spectacular linear scarp marking the obsequent slope of the cuesta developed on the Gondwana sandstones, inclined at 20º due south. The sandstones which are essentially flat bedded elsewhere attain anomalous dip upto 20º southerly. The cliffed, obsequent slope has resulted due to E-W trending vertical joints. The sandstone formation near this lineament shows structures such as, ridges and furrows and ribbed nature.

The E-W to ENE-WSW trending Srinivasapuram -Ramanujapuram fault (No.38) is encountered 3 km north of Zangareddigudem and 1 km south of Srinivasapuram. The fault demarcates the boundary between the Precambrians in the north and Gondwanas in the south, the latter upthrown and tilted to form spectacular E-W fault facing north.

The slightly arcuate roughly NE-SW trending, 12 km long lineament (No. 62) passes along Velagapalli-Gangapalli villages, east of Devarapalli. The evidences such as intense fracturing and silicification, anomalous verticality of beds and brittle nature of rocks indicate that that the lineament is a surface trace of a fault.

The important WNW-ESE lineament (No.3) occurs south of Borgampad, close to the southern bank of Godavari. The eastern part of the lineament marks the boundary fault between Gondwanas and crystallines in the east. Around Yeleru, the fault trends N 7º W-S 7º E. Here the Gondwana beds have a dip of 10- 20º. In general, the Gondwanas are horizontal to sub horizontally disposed. The moderate dips around the lineament are due to faulting.

An important WNW-ESE trending lineament (No. 11) within the Gondwanas extends from Patwarigudem on the west to Papidigudem in the east. Along the lineament the Gondwanas show dips upto 20º and extensive silicification and ridge and furrow structures, indicating the presence of a N 55º W-S 55 ºE fault.

A N-S lineament (No. 4) is seen conforming to the general trend of the Godavari River, north of Bhadrachalam. Field checks did not reveal any evidence of this lineament. However, indirect evidences such as, remnants of terraced point bars and lateral bars between Sitampeta and Ratan Gutta would indicate a relative uplift along this lineament (Pradhan, 1981). In the area south west of Bhadrachalam, an intrabasinal fault (No.2) is also noticed.

On the eastern side of the Godavari River, the arcuate Gangavaram lineament (No.52) trending in a general WNW-ESE direction is traceable from Kottapalli to north of Chinna Konda. This lineament swerves northwards of Kottapalli and extends upto

Koyyalagudem. It has a length of more than 25 km and exhibits shearing, brecciation and silicification all along indicating a fault.

A NNE-SSW lineament (No. 50) traverses the country rocks and extends for about 21 km. Shearing is observed in the stream course along this lineament. This appears to be a major fault passing north of the dam site. About 1 km north of Polavaram, another ENE-WSW lineament possibly a minor fault crosses the Godavari River.

Another lineament (No.54) more than 12 km long is noticed west of Chodavaram. It bears the evidences of faulting along the NNE-SSW.

ii) Shear zones:

An important lineament (No. 47) trending ENE-WSW extends for 37 km along Dondapudi and Polavaram. It bears the evidences of intense shearing. Another important lineament (No. 5) is noticed east of Bhadrachalam extending from Sitampeta to Totapalli in NW-SE direction. The small NW-SE trending nala east of Sitampeta exposes extensive silicification. Rock formations in this zone, such as quartzites, amphibolites, granite gneiss etc exhibit effects of intensive shearing. In the Turubaka Vagu, north of Sitampeta the rocks are highly sheared.

Along the northern border of the area, the E-W lineament (No.13) marks the trend of Lota Vagu. It extends from Boddugudem on the east to Katukapalli on the west. The amphibolite rocks here are sheared.

ENE-WSW trending lineaments (Nos. 56, 53 & 64) are predominant in the area NW of Polavaram and east of Devipatnam. They cut across the E-W to ENE-WSW foliation trends of the rocks at an acute angle. Brecciation, ferruginisation etc are seen along these lineaments. Most of these lineaments represent faults/ shears.

iii) Fractures:

The NE-SW trending Sabari lineament (No.15) delineated between Chinturu in the north and Gummadipalli in the south. The Sabari River, a tributary to Godavari follows the lineament upto Kunavaram. The lineament possibly represents a deep seated crustal fracture as evidenced by emplacements of plutons of syenite and nepheline syenite. The peripheral zones of the intrusives exhibit effects of shearing imparting a shattered look to the rock. The parallel lineament near Zangaredddigudem, also belongs to this category.

Fractures have also been delineated along Kovvada Kalava (No.55) near Erramatla, which exposes Older alluvium comprising oxidized gravel beds along narrow, cliff banked channels; and near Zangareddigudem and Buttayagudem (No.31) coinciding with Baineru Vagu course- along which 8-10 m thick, older gravel deposits are exposed along 60 km long lineament. Apart from these, there are several WNW-ESE trending lineaments through out the area which cut across the foliation trends. They represent cross fractures. There are also some NW-SE trending lineaments which run for short distances and represent cross fractures. They are mostly confined to the eastern part of the area.

iv) Master Joints/Joints:

Lineaments (Nos. 8, 9, 10) are noticed at the north eastern foothills of Paloncha, where the granite gneisses and amphibolites exposed along Munneru River, exhibit close spaced joints trending N 40º W-S 40º E. Similarly, the lineament east of Jagannathapuram is marked by several quartz veins trending N 40º W-S 40º E, in a zone of about 1 km wide. South of Lingareddipalli, there are number of mounds of ferruginous sandstones which exhibit joints trending N 40º to 50º W - S 40 º to 50 º E. Another 18 km long lineament (No.70) is noticed along Kateru-Korukonda-Gokavaram section.

v) Lineaments (unclassified):

A few lineaments, delineated based on remote sensing study, which could not be ascribed to any specific structural feature, have been included in this group. No ground

evidences in regard to their nature could be identified due to presence of thick overburden and other obscuring factors. A few of these include 1) NW-SE trending lineament extending from Katukapalli to Bhagawanpuram and 2) E-W lineaments between Devipatnam and Gangavaram.

NE-SW trending lineaments are predominant in the eastern part of the area. They are parallel or sub parallel to the foliation trend of the rocks. They appear to be genetically related to the NE-SW folding.

Seismicity and neotectonic activity

Quaternary geological mapping by Pradhan (1981) in the vicinity of Bhadrachalam has revealed that the Godavari had an initial high gradient and high flows resulting in gravel deposition. This was followed by lowering of gradient and reduction in the stream velocity causing deposition of finer clastics like silt and clay. Rise of the ground level with respect to sea level led to the dissection of the sediments and rejuvenation of the river during the Holocene. Though the southern peninsular shield of India was considered relatively free from seismicity, the earthquakes in Koyna in 1967, Bhadrachalam in 1969 and Killari in 1993, have shown that the region is seismically active. The Bhadrachalam region experienced an earthquake of magnitude 5.5 on April 13, 1969 which was felt at Hyderabad and several other towns of Andhra Pradesh. It has caused heavy damage to the coal town of Kothagudem. An earthquake of magnitude 4.7 had occurred earlier on 29-7-1968 in this very region. Though no perceptible movements are reported to have taken place along the Gondwana trough faults or other lineaments in the vicinity of the dam site, it will be prudent to examine these trough faults more seriously before arriving at any conclusion, in view of the fact that the Gondwana faults run for several tens of kilometres and are not situated far from the proposed dam site. It is also mentioned that Ramesh and Raju (1989) reported evidences of neotectonic activity in the Godavari delta around Narsapur and Razole towns. Moreover, Babu (1973) had reported occurrence of number of morphostructures in the Krishna-Godavari delta. According to him the NE-SW trending morphostructures are geomorphic expressions of buried landscape, confirmed by seismic surveys of ONGC around Tanuku, Narsapur and Amalapuram.

Conclusions

Remote sensing study around the Polavaram dam site has brought out number of major faults, shear zones and fractures which were not mapped earlier. The study has also brought to light extensive development of Pleistocene and Holocene terrace deposits exposed along the spectacular river banks even in narrow inland valleys. Analyses of a few of the river bank sections did not reveal any kind of disturbance in the essentially horizontally bedded fluvial gravel-silt sequences. However, in view of the nearness of Bhadrachalam town-known for its active seismicity and the neotectonic evidences in the Godavari delta a little downstream, a detailed study of Quaternary deposits around the project area may be useful to know the nature and extent of neotectonic activity, in the vicinity. The lineament map will prove to be a useful guide while conducting geotechnical investigation as it depicts all the important week zones in the project area.

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