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Structural foot prints extraction from rocks of Lunawada region, Gujarat through IRS LISS III data

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Abstract: Application of remote sensing is wider in all fields, but it has been a very useful tool in interpreting different trends of deformational events associated with the Precambrian rocks of Lunawada group, through visual image interpretation. Image selected for present study is False Colour Composite of IRS 1C LISS III data of 24m spatial resolution having band combination of 532. The study area is located in the NE part of Gujarat representing the part of Aravalli domain which is known for complex deformation and structural history. Stratigraphically rocks of this region belong to Kadana formation, which is the youngest formation of Lunawada group. The area is interesting in structural point of view due to the availability of regional folding and faulting in the form of curved as well as off-set ridges respectively. An attempt has been made to extract possible structural foot prints by applying the technique of visual image interpretation. Further ground truth has been carried out in order to cross check the data generated through visual image interpretation which reflects curved ridges are plunging folds while dislocated ridges are nothing but faults.

Keywords: Structural footprints, Lunawada, Remote sensing, IRS LISS III

1. Introduction

Mesoproterozoic rocks of Kadana formation are exposed in the study area located in the NE part of Gujarat (Gupta et al., 1997). These rocks are the part of Southern Aravalli Mountain Belt (SAMB) having area of about 300 km^2. The extent of the study area is from Kadana reservoir in the north till Panam reservoir in the south. Geographically the study area is in the north of Godhra town having Latitude 23°00'6.5"-23°24'25.8"N Longitude 73°34'37.8-73°52'42.3"E. Major towns such as Lunawada, Santrampur and Kadana lie within the study area and are shown in the satellite imagery. Rocks of this region belong to Kadana formation of Lunawada Group, which is the second youngest group in Aravalli supergroup (Gupta et al., 1992, 1995). Only Kadana formation falls within Gujarat while rest all other formations are distributed in parts of Rajasthan and Madhya Pradesh (Iqbaluddin, 1989). Major rock types associated with Kadana formation are quartzite, metapelite, calc silicate, bands of dolomitic limestone and pegmatites (Gupta et al., 1980, 1992, 1995). However quartzite intercalated with metapelite with thin bands and lenses of calc silicate are found to be exposed within the study area. Structurally rocks of this region are characterised by three phases of deformation viz. D_1, D_2 and D_3. The first two deformational events are coaxial that resulted in NE-SW trend of axial trace while last phase of deformation is seen in the form of varying trend of axial trace from E-W to NW-SE (Mamtani et al., 2000).

Identification of these structures in turn can help in understanding crustal movements that have shaped the present terrain. Remote sensing offers a broader perspective through synoptic view of regional scale which is much different than point ground observations. Studies pertaining to structural features by applying the remote sensing techniques have been carried out by (Mohan et al., 2007; Singh et al., 2007) and (Bhatt et al., 2008). The present study highlights the key factor of remotely sensed data by considering useful information on spatial pattern and surficial relief of structural elements pertaining to the rocks of Lunawada region. An attempt has been made to study various structural foot prints of different visible fold as well as fault pattern through satellite imagery and to analyse the accuracy through field mapping (Fig. 1).

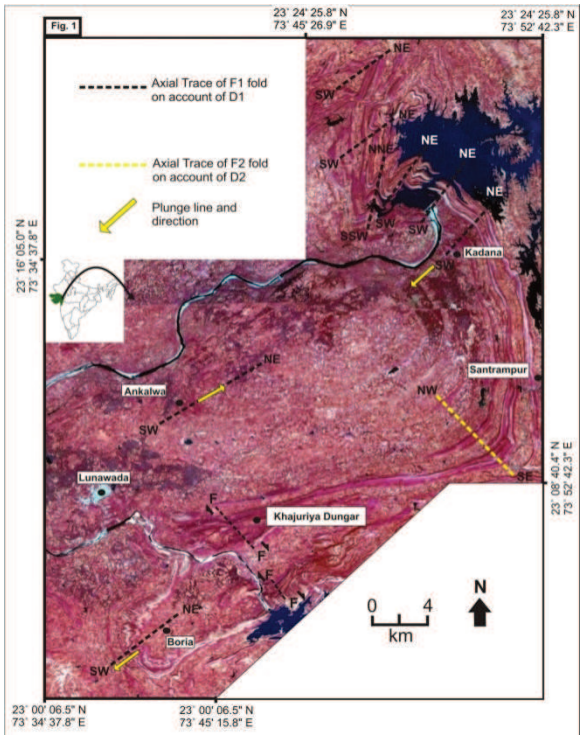

Figure 1: Satellite image of the study area

2. Data used and methodology

Indian Remote Sensing satellite data (IRS-1C, LISS III) of 2008 with a spatial resolution of 24 m is used to identify the structural features present in the study area. Image enhancement techniques and different band combinations were applied for better visualization and interpretation. It is found that structural foot prints of the study area are best seen in band combination 532 (i.e. short wave infrared band, red band and green band). Based on the satellite data possible trend of structural features were mapped through visual image interpretation and same were cross checked by ground truth verification in order to validate the accuracy of interpretation.

3. Geological setup

Geologically the study area continues as a part of SAMB in the north, while it is bounded by Deccan traps in the eastern as well as in the western margin, further it gets terminated by Godhra granite in the south (Gupta et al., 1997). Major rock types exposed in the study area are quartzite and metapelites which reflects through different tone and texture in the satellite imagery. Dark red colour and fine texture are represented by quartzites while light red colour with medium texture are represented by metapelites. Due to spectral variation of both these rock types it becomes easier to demarcate the possible trends of structural features through visual image interpretation.

3.1 Structural analysis through satellite imagery

With the help of satellite imagery it can be said that the quartzite ridges are more or less 'C' as well as 'V' in shape and it has been very well seen from the satellite data on account of synoptic view. The north-eastern part of the study area around Kadana reservoir are characterised by chevron type or 'V' shape pattern having 'V' closure in NE direction. Further, these ridges stretche right upto south of Santrampur in a linear fashion and attends a new set of 'C' shape curvature having 'C' closure in SE direction. Finally these quartzite ridges attain its overturned nature in the south near Boria village having 'C' closure in SW direction. Based on visual image interpretation possible trends of axial trace which can be demarcated and are as follows: 1. NE-SW direction near right abutment of Kadana reservoir, Ankalwa and Boria area; 2. NNE-SSW direction near left abutment of Kadana reservoir; and 3. NW-SE direction near south of Santrampur. In addition to that clear off-set of linear ridges near as well as south of Khajuriya dungar can be very well seen through satellite data. The trend of this fault matches exactly with the NW-SE axial trace.

3.2 Structural analysis through field studies

Further ground truth has been carried out in order to cross check the data generated through visual image interpretation. It has been found that on account of isoclinal folding, the area shows outcrops of linear as well as sinuous quartzite ridges with intervening low lying areas occupied by their softer counterparts i.e. metapelites (Fig. 2a). At places along with metapelites in the form of mica schist there are thin bands and lenses of calc silicate. Structural data generated through field helps us to cross check the trends of regional scale fold. The area near right as well as left abutment of Kadana reservoir exhibit tight chevron type pattern with minor deflections in the axial plane. The fold morphology on the basis of inclined axial plane reflects overturned in nature. The axial plane of these folds strikes NE-SW and have gentle plunge in SW direction with an amount of 55^{o} (Mamtani, 1998). The outcrop pattern of the quartzite ridges near Ankalwa seen to form crescent shaped structure and can be very well depicted through satellite imagery. The northern limb strikes NE-SW direction while the southern limb strikes almost due E-W. In addition to that foliation plane in the quartzite in the northern and southern parts dip gently in the northerly direction giving rise to an overturned fold, the axis of which plunges gently due NE forming a synformal structure (Fig. 2b). Such supported evidences are also envisaged by Joshi et al. (2013a). Similar generation of fold are also observed through satellite data in south of Lunawada town near Boria village, having fold closure in SW direction. Here the axial surface trace trends NE-SW direction and the fold plunges gently with an amount of 20^{o} in the direction of $N252^{o}$ suggesting an antiformal structure (Fig. 2c). In addition to that type III interference of superposed fold or hook shaped pattern indicating coaxial folding is present on regional scale near Boria. However such pattern cannot be appreciated through satellite imagery. Finally the area situated south of Santrampur has a new set of an open fold significantly found through LISS III data having axial surface trace in NW-SE direction. On the basis of mapping of structural elements, it has been found that the foliation planes of one limb strikes N-S and dip steeply to the westerly direction, while the other limb strikes almost E-W and dip gently in the northern direction. This fold plunges gently in due NW direction with an amount of 30^{o} suggesting a synformal structure (Fig. 2d).

Other important structural features remarkably seen through satellite data are off-set ridges, which suggest the presence of faulting. At Khajuriya, off-set of ridges is 700m, while south of Khajuriya dungar it is 370m. Other than off-set ridges straight segment of river and fault scarps also supports faulting. Structural features which are found megascopically are preferred mineral lineation in the metapelite (Fig. 3a,b) and fault breccia in quartzite (Fig. 3c). Evidence of faulting also exists even up-to micro scale, in the form of mica fish in meta-pelite (Fig. 3d) and angular fragments of quartz in ferruginous matrix in fault breccia (Fig. 3e). The trend which is derived from these evidences matches exactly with the NW-SE trend of axial trace of fold present in the study area (Joshi et al., 2013b).

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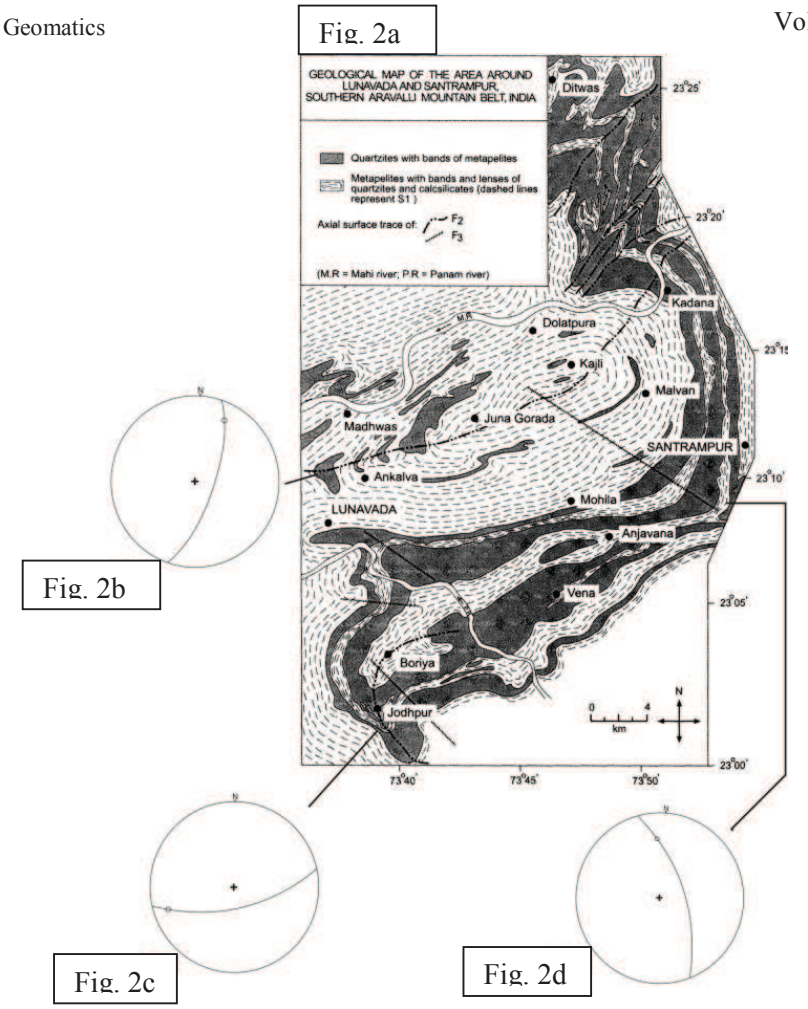

Fig. 2: (a) Geological map of the study area, modified after Mamtani et al., 2000; stereonet showing axial plane and gentle plunge of (b) Ankalwa fold; (c) Boria fold; and (d) fold situated south of Santrampur

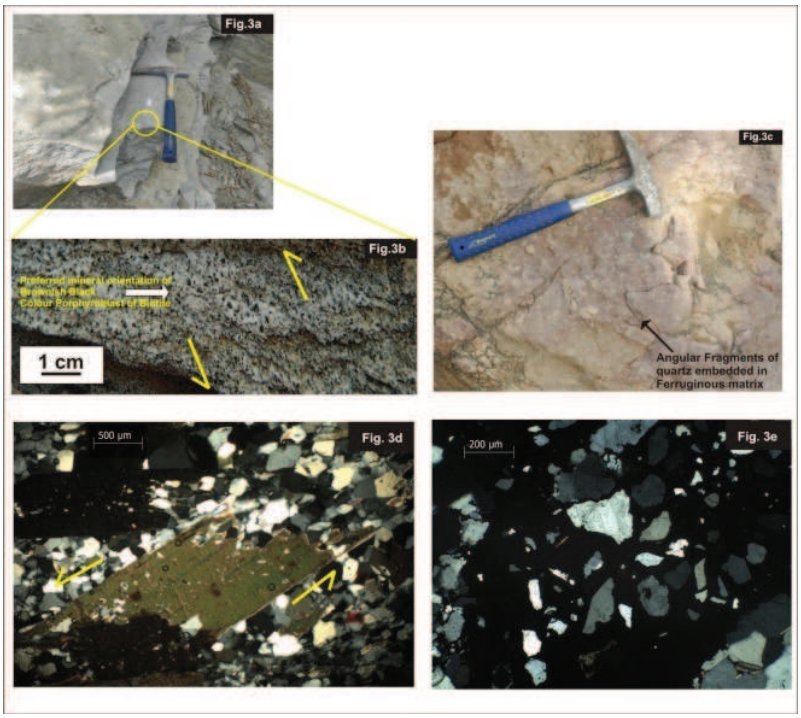

Fig. 3: Field photographs of foot hills of Khajuriya dungar showing (a) gently dipping meta-pelite outcroup; (b) enlarged view of meta-pelite showing preferred orientation of biotite flakes; (c) outcrop of fault breccia having angular fragments of quartz; (d) photo micrograph of metapelite showing development of biotite fish, arrows indicate the sense of shear 10XCN; and (e) photo micrograph of fault breccia showing angular fragments of quartz embedded in ferruginous groundmass 4XCN

4. Discussion and conclusion

The various combinations in which successive deformational events have affected different parts of the area are well reflected in the overall outcrop patterns at the regional scale, such evidences are also substantiated on the basis of satellite image. For example plunging folds in the study area are depicted in the satellite imagery in the form of 'C' or 'V' shaped ridges. It has been found that there is a strong relationship of 'C' or 'V' shape ridges with its plunge line. 'C' or 'V' pointing in opposite direction of plunge of fold axis indicates that it is a 'Synform', while 'C' or 'V' pointing in the direction of plunge of fold axis suggests that it is an 'Antiform' (Joshi et al., 2013). Based on the trends marked through visual image interpretation it can be said that there are two major deformation events present in the study area viz. D_1 and D_2. D_1 comprising varying trend from NNE-SSW to NE-SW direction while D_2 comprising NW-SE trending folds.

Based on the field as well as lab investigation it can be said that there are three deformational events present in the study area viz. D_1, D_2 and D_3. The first two deformational events were coaxial and resulted in NE-SW trending folds while the third episode of deformation have varying trend from E-W to NW-SE direction (Mamtani et al., 2000). In addition to that the trend of faults which are present matches exactly with the trend of last phase of deformation of Lunawada region. It can be said that the faulting might have been developed during last episode of deformation (i.e.) D3 (Joshi et al., 2013c). Hence with the help of visual image interpretation high accuracy can be achieved in mapping the structural features present in the study area but ground survey is always necessary to incorporate the structural details and to validate the accuracy.

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