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Unfolding the time relationship of structural events through Landsat data: A case study from Khandia formation, Champaner group, Gujarat

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Abstract: Imprints of multistructural events recorded within the rocks are visualised through satellite data. The events of superposed folding and shearing at Koba-Rustampura area belonging to Khandia Formation of Champaner group has been studied. Classification of such multiple events becomes simple with the help of their respective trends. These structural events have been delineated by using visual image interpretation techniques to study the spatial pattern and textures on the Landsat image. By deciphering axial traces and directions of displacement, one can build the chronology of the structural events revealing the deformational history.

Keywords: Remote sensing, Time relationship, Koba, Rustampura, Champaner group

1. Introduction

Applications of remote sensing in geosciences are well established and widely accepted for identifying and correlating structures, regionally. Identification of structures on regional scale have been a necessity to understand overall deformational pattern of any terrain. Such attempts includes mapping of large scale features, extracting lineament patterns, identifying regional fold trends, quantifying the fault directions, etc and its correlation up to plate dynamics (Nama, 2004; Kenea, 1997; Heddi et al., 1999; Semere and Ghebread, 2006; Marghany et al., 2009; Maged and Mazlan, 2010; Stefouli and Osmaston, 1986; Shuichi, 2002; Stamouslis and Rogers, 2003; Yamaguchi and Naito, 2003; Rowan and Mars, 2003; Gomez et al., 2005; Harding and Berghoff, 2000; Misra et al., 2014; Joshi et al., 2014).

In order to establish the correlation, in terms of regional structures, it is prerequisite to appreciate the continuity from meso to micro scale. The present work reports a study on the time relation of structural events in Koba-Rustampura area which is situated 24 Km east of Vadodara district, Gujarat (falls under latitude and longitude 22o16'38.61" – 22o21'21.18" N and 73o28'25.63" – 73o38'51.38" E respectively). The study area belongs to Khandia formation of Champaner group, Aravalli Supergroup having meso-proterozoic age. The region has experienced polyphase deformational history and are characterised by lithological entities such as phyllite, quartzite, meta-conglomerate. Based on the Landsat image of 2016, acquired from the google earth portal, characterisation of rocks holding different structural trends have been attempted. The same have been delineated in a chronological order and supplemented by field as well as micro-structural studies.

2. Data used and methodology

The true colour composite of Landsat image of 2016 with 30m spatial resolution has been used to identify different structural events present within the study area. Deformational events from later to former have been interpreted by studying the spatial pattern on the image through visual image interpretation techniques. The information collected during ground truth carried out in 2016, have been used to build the time relationship and to understand overall deformational history pertaining to the Koba-Rustampura area.

3. Regional geological setup

The Koba-Rustampura area belongs to a part of Champaner group, which is well known for its low-grade meta-sedimentary sequence. The group consists of lithological entities such as quartzite, phyllite, meta-conglomerate, schist, impure dolomitic limestone and intermixed variety of granites and gneisses (Gupta et al., 1992, 1995; Joshi et al., 2014). Geographically Champaner group is surrounded on three sides (i.e. north, east and south) by younger plutonic intrusive (Godhra granite) and one side (i.e. west) by Deccan trap rocks. Geologically the Champaner group represent an example of inlier due to the presence of younger rocks neighbouring from all sides (Gupta et al., 1997).

Structurally, rocks of Champaner group display two significant trends of axial traces. D1 phase of deformation has resulted F_1 folds of E-W trend where as D_2 phase of deformation has resulted F_2 folds of N-S trend. The proximity of F_2 folds decreases from eastern end to western end of Champaner group (Jambusariya and Merh, 1967; Gopinath et al., 1977; Merh, 1995; Shah et al., 1984).

Interpretation of satellite imagery reveals that the Koba-Rustampura area manifests two major tonal and textural variations with a distinct elevation difference between them on the image (Fig. 1). The high land region consisting of quartzite and meta-conglomerate display light green tone with medium to rough texture, whereas the low lying areas consist softer rocks such as phyllites representing light brown tone and medium texture. The south-western part of the study area represents crescent shaped outcrop pattern whereas there has been development of broad sinuous curve over the linear ridge in the northern part. Furthermore, evidences of top to NW, top to NE and down to SE displacement can be appreciated, between the linear and crescent shaped ridge and within the 'C' shape outcrop pattern respectively.

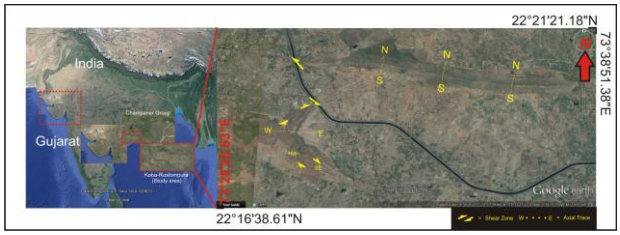

Figure 1: Location map and Landsat data of the study area

In order to appreciate the overall deformational pattern of the study area, chronologically, restoration of deformational events needs to be applied by unfolding the terrain sequentially. With the help of image interpretation, it can be seen that the latest event, which has occurred in the study area is shearing. Such idea can be profound due to its cross-cutting relationship embracing on later deformational patterns (i.e) folding.

The former structural event occurred in the study area is folding, which is represented in the form of 'C' shaped outcrop and broad sinuous curve over the linear ridge. The major fold event occurred in the study area has E-W trend whereas minor one suggest N-S trend of axial trace. Moreover, the N-S trending folds are developed on Km long limb of E-W trending fold.

4. Ground truth verification and inferences

The Koba-Rustampura area represents the part of Khandia Formation and located in the south-western part of Champaner group. The main rock type includes meta-conglomerates, quartzites, phyllite and breccia. The study area constitutes a mega scopic westerly plunging anticlinal fold. The northern limb is long in comparison to the southern limb and strikes E-W, having dip direction due north and due south respectively. Based on the attributes through stereographic projection the fold has its axial trace E-W with a plunge of 15^{o} in the direction of N 270^{o}. The axial plane is vertical, which strikes along the direction of fold axes (i.e. N270^{o}). Apart from that there has been generation of open folds on the northern limb having direction of axial plane N-S. Based on the overall structural pattern suggested by folding it can be said that there are two sets of folds superposed on one another. The first phase (F_1) having E-W axial trace has found to be superimposed by (F_2) having N-S axial trace (Fig. 2).

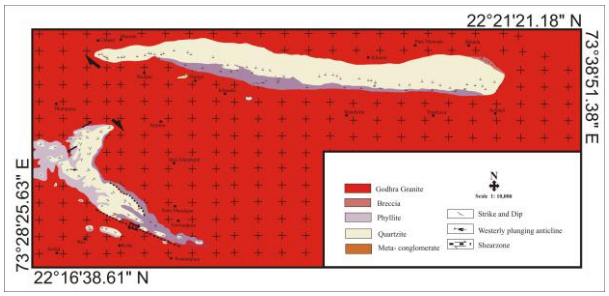

Figure 2: Geological map of the study area

With the same connection there are good evidences of shear present throughout the study area. The northern limb, which shows the displacement with the major fold present in the south-western part, shows the shear (i.e.) top to NW. Also, within the major fold morphology there has been generation of several shears resulting into intrafolial fold at the southernmost margin of the study area. The direction of these shear include top to NE shear and down to SE shear. The main litho-units affected by shears are meta-conglomerate and quartzite. The signatures include brittle fracturing and crushing of quartzite, elongation of clasts in meta-conglomerate, formation of breccia and dragging of quartzite ridge parallel to the shear plane. In addition to that microstructural analysis suggest dominant S-C fabric of oriented mica grains, quartz fish, group 2 mica fish and 'V' pull apart mechanism with domino like microstructure in quartz clast of meta-conglomerate. In quartzite evidences of shearing are supported by oriented mica flakes having inclusions of quartz aliened in the direction of shearing. Furthermore, breccia consists of medium to coarse grain angular clasts of quartz cemented by fine grained quartz and Fe rich matrix. Sweeping undulose extinction is observed within the coarser angular quartz clasts (fig. 3).

5. Discussion and conclusion

On the basis of satellite data interpretation and field observation/ ground truth, similarity exists between the fold morphology and shearing events. As per satellite image and field evidences the superimposed pattern of one fold event over the other has been confirmed. The N-S trending open folds are found to be superimposed over E-W trending gentle fold. Considering regional structural setup, it can be observed that the two significant fold events, F_1 and F_2 are occurred throughout the group. Furthermore, the proximity of F_2 folds in the Champaner group increases from W-E. Hence, in order to establish a time relationship between fold events, E-W represent the first fold event, whereas second fold event is characterised by N-S axial trace.

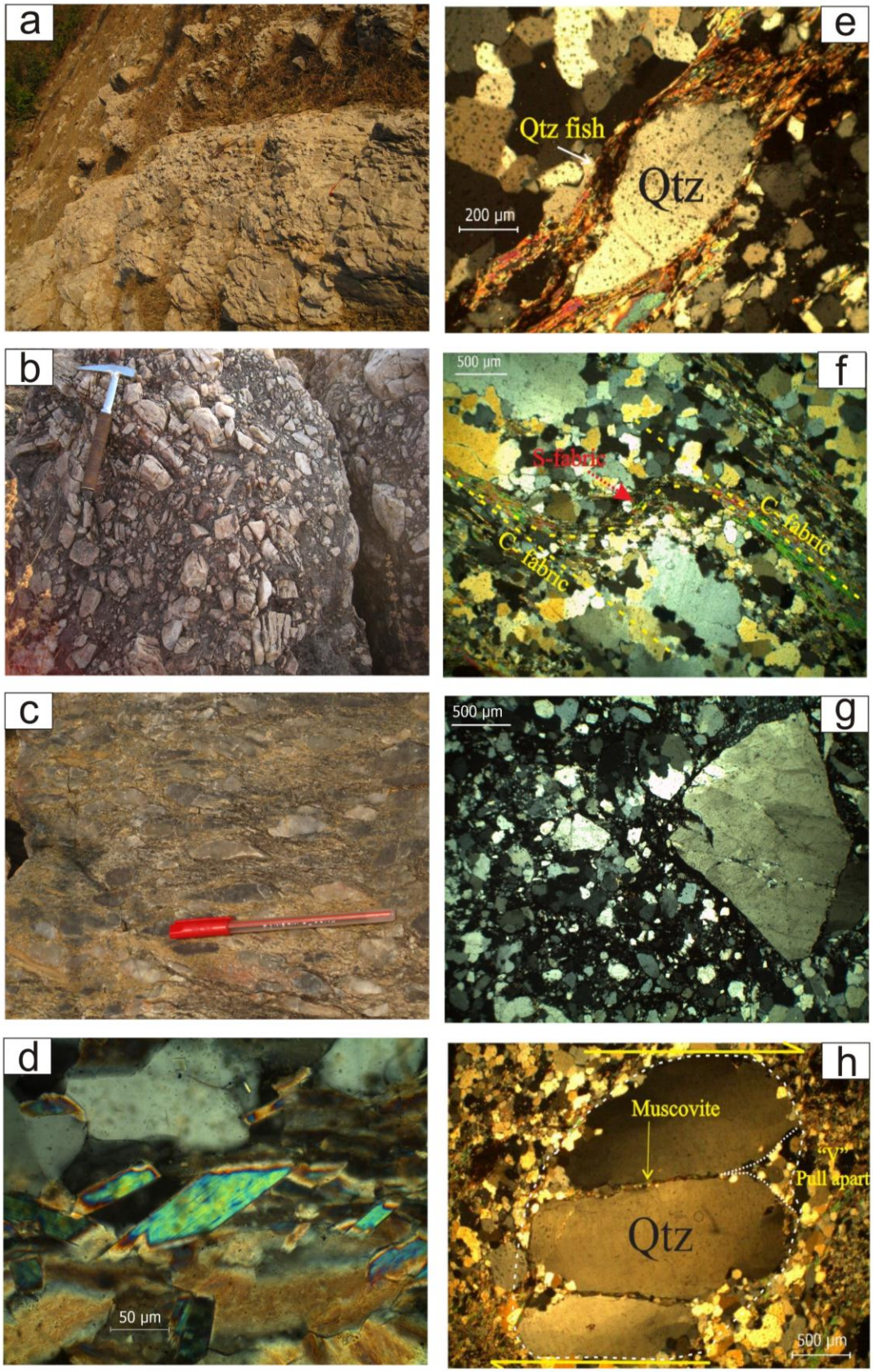

Figure 3: Field Photograph showing: (a) Closely spaced factures in quartzites. Loc. Koba village; (b) Breccia containing angular fragments of quartz embedded in ferruginous matrix. Loc. Rustampura village; (c) Elongated clasts of quatz in meta-conglomerate, ball pen signifies the stretching direction. Loc. Koba village; (d) Group II mica fish in meta-conglomerate (10XCN); (e) Quartz fish in meta-conglomerate (10XCN); (f) Development of S-C fabric of mica grains in meta-conglomerate (4XCN); (g) Breccia containing medium to coarse grained angular quartz clasts in ferruginous matrix (4XCN); (h) 'V' pull apart microstructure with domino like arrangement of quartz clasts, arrows indicated shear direction (4XCN)

These fold events have undergone post deformational shearing along the weak planes. Directions of these shears includes top to NW, top to NE and down to SE displacement. Field evidences, such as brittle fracturing in quartzites and elongation of clasts in meta-conglomerate, gives sustainable sense of shear. In addition to field evidences, supportive microstructural evidences are also envisaged. These include dominant S-C fabric of oriented mica grains, quartz fish, group 2 mica fish and 'V' pull apart mechanism with 'domino' like microstructure.

Based on the above facts the time relationship of deformational events is established. Chronologically it can be represented from older to younger as: 1. E-W trending folds; 2. N-S trending open folds on limbs of earlier folds; 3. Shearing.

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