Penecontemporaneous Deformational Structures in the Glauconitic Sandstone, Semri Group (Vindhyan Supergroup), Sonbhadra District, Uttar Pradesh, India and their Structural Analysis

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Abstract: The Glauconitic sandstone is well exposed in the Newari area of Sonbhadra district of Uttar Pradesh, India. Conjugate pairs of kink bands are confined within the laminated sandstone and are present half km west of Newari near the confluence of a tributary with the Son river. The conjugate kink bands are plunging at 13^0 and 36^0 in SE ($S58^0E$) and NE ($N56^0E$). This shows that ephemeral compressional stress regime was responsible for the development of conjugate set of kink bands. The stress axis would have been oriented from NE-SW direction. A major fault F_1 passes through the glauconitic sandstone in the west of the Newari village. This fault is a reverse fault and strikes at N25ºW - S25ºE. Another fault F_2 oblique to F_1 passes in the direction N70ºE-S70ºW. In view of the fact that the kink bands are confined within the laminated sandstone, it is inferred that they have been formed as a result of penecontemporaneous deformation and suggest seismic activities that might have occurred around 1080±40 Ma ago as a result of activation of the faults present in the Newari area of the Sonbhadra district, Uttar Pradesh, India those may be companion faults of the Son-Narmada Fault system.

Keywords: Penecontemporaneous deformational structures, Glauconitic sandstone, Sonbhadra district, Vindhyan Supergroup, India.

1. INTRODUCTION

The Proterozoic Vindhyan Supergroup is only mildly deformed, but contains penecontemporaneous deformational structures at several levels [1]. The rocks of this Supergroup are exposed in a vast area in the central part of India (Figure **1a**). The Vindhyan sedimentary rocks are considered as predominantly marine that deposited in an E-W elongated and westward-opening basin [1, 2]. Conglomerates, sandstones, shales, limestones and porcellanites are the key sedimentary rocks of the Vindhyan Supergroup. Glauconitic sandstones are best exposed around Newari village of Sonbhadra district. Nearly half km west of the Newari village near the southern bank of the river Son, good exposures of glauconitic sandstones are present along a tributary [3]. Auden [4] recorded a major fault near the Newari village which passes through the glauconitic sandstone. Also, trace fossil *Muniaichnus* has been recorded from the glauconitic sandstone of the Sonbhadra district, Uttar Pradesh by Kumar [5].

The purpose of the present paper is to provide triggering mechanism of the syn-depositional deformational features associated with gluconitic sandstone member of the Kheinjua Formation of the Sonbhadra district, Uttar Pradesh, India and to present their structural analysis.

2. GEOLOGICAL AND TECTONIC SETTING

Vindhyan Supergroup has been divided into the Lower Vindhyan, known as the Semri Group and the Upper Vindhyan comprising three groups namely Kaimur, Rewa and Bhander on the basis of basin-wide unconformity and its associative conformity [2]. The Semri Group contains Basal Conglomerate Formation, Kajarahat Limestone Formation, Porcellanite Formation, Kheinjua Formation and Rohtash Limestone Formation in ascending stratigraphic order (Table **1**). Furthermore, Kheinjua Formation contains Olive shale, Fawn limestone and Glauconitic sandstone (Table **1**). A conglomerate bed occurs at the contact between the Fawn limestone and the Glauconitic sandstone. This conglomerate contains mainly pebbles of jasper. Currently, age of the Vindhyan Supergroup is a controversial issue. Ray *et al*. [6,7] and Rasmunssen *et al.* [8] considered the age of the Semri Group as about 1600 Ma, while Azmi [9] reported small shelly fauna of Cambrian age from the Semri Group. However, the glauconite of the glauconitic sandstone has been dated using the K-Ar method as1100 ± 60 Ma by Vinogradov and Tugarinov [10], which has been recalculated to 1080 ± 40Ma by Kreuzer *et al.* [11].

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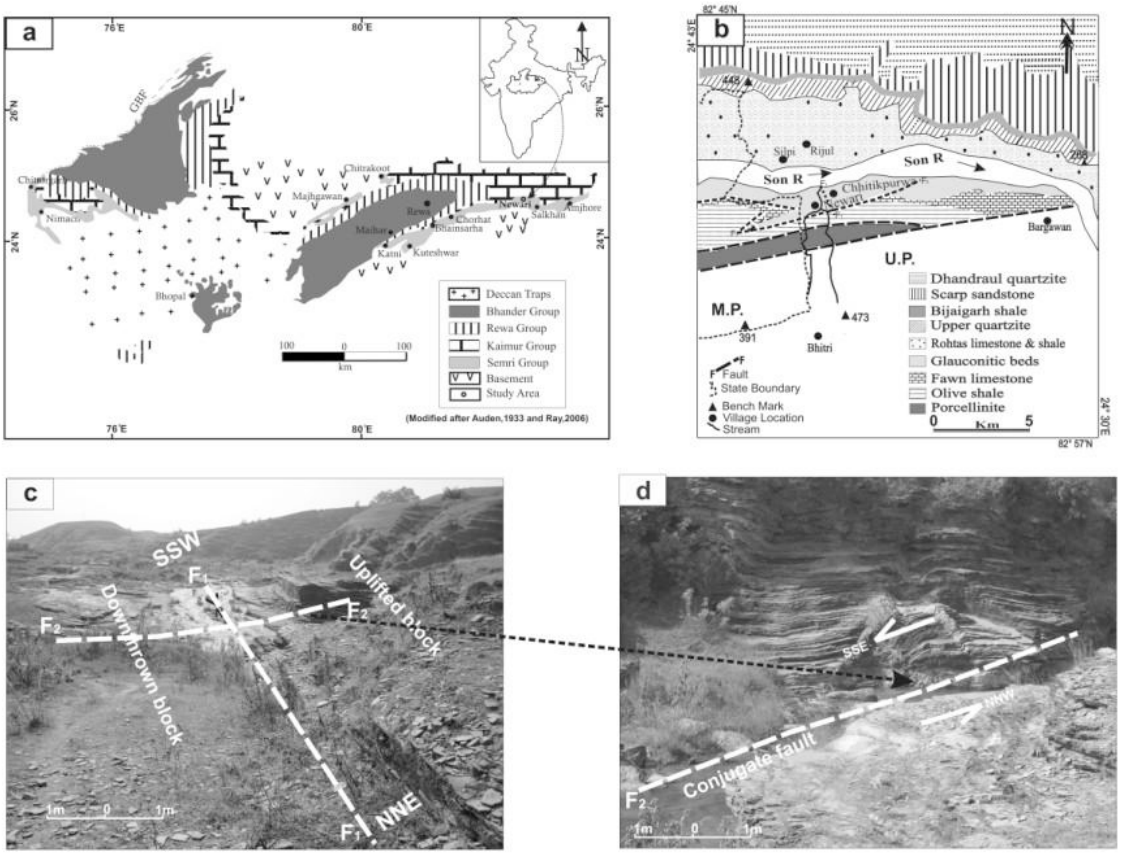

Figure 1: (**a**) Location and geological map of the study area (modified after Auden, 1933 and Ray, 2006). (**b**) Geological map of the area around Newari (modified after Auden, 1933) (**c**) Field photograph showing synoptic view along the tributary of river Son near Newari village. Reverse fault F_1 and its oblique fault F_2 is marked on the photograph. (**d**) Field photograph showing chevron folds (along the F_2 fault).

Table 1: Lithostratigraphic Succession of Vindhyan Supergroup of Son Valley (Modified after Auden, 1933 and Kumar, 1978)

V		Dhandraul Quartzite Formation	
I		Scarp Sandstone Formation	
N		Bijaigarh Shale Formation	
D	Kaimur Group	Upper Quartzite Formation	
H		Susnai Breccia Formation	
Y		Lower Quartzite Formation	
A			
N	----------Unconformity ----------		
S			
U		Rohtas Limestone Formation	
P			
E		Kheinjua Formation	Glauconitic sandstone
R	Semri Group		Fawn Limestone
G			Olive Shale
R		Porcellanite Formation	
O		Kajrahat Limestone Formation	
U		Basal Conglomerate Formation	
P			

The basement of the Vindhyan basin is the Bundelkhand Granitoid complex in the north and the Pre-Vindhyan Sidhi/ Mahakoshal Group along with the granitoids-batholith associations towards south [12]. The Son-Narmada and Amsi-Jiawan lineaments provided the basal structures for the sedimentation within the Vindhyan basin. These lineaments have been considered as ancient suture zones those have witnessed repeated rejuvenations in the geological past and show continued reactivation till present [13, 14]. Evidences favoring reactivation and vertical movement along these lineaments and those generated subsequently have been recorded south of the Vindhyan margins [14]. Both Semri and Kaimur Group of cyclic sequences developed as a result of rifting and sagging during Mesoproterozoic in central India [1].

3. SYN-DEPOSITIONAL DEFORMATIONAL STRUCTURES AND ANALYSIS

Glauconitic sandstones contain cross-bedded, thin-bedded and laminated sandstone facies. The laminated sandstone shows syn-depositional deformational features such as kink bands and chevron folds roughly half km west of the Newari village near the southern bank of the river Son along a tributary [15]. This tributary of river Son flows in roughly SSW-NNE directions (Figure **1a** and **1b**). Conjugate pairs of kink bands are present in about 1 sq. km area along the stream course (tributary of river Son) which is flowing through a fault plane (F_1 in Figure **1c** and **1d**) lies west of Newari village. Here, thin lamellae of 1-3 cm thickness are present in exposures of kinked fine-grained sandstone. At places, some thick lamellae of 5-8 cm are also present in between thin lamellae (Figures **2** and **3**). On moving downward the intensity of deformation increases which led to the formation of kink bands (Figure **3**).

In order to analyze data from kink planes, poles to the kink planes were plotted on the lower hemisphere of equal area net and β-axis has been inferred. The plot suggests that the kink bands evolved in a conjugate set as a result of coupler forces developed due to the compressional stress regime, which might have been active from NE-SW direction and resulted penecontemporaneous deformation during sedimentation. The inferred average trend of kink axis of kink bands shows the plunge in SE direction (Figure **4**). The Vindhyan basin is marked by two major lineament systems viz. Son-Narmada and Amsi-Jiawan lineament systems, which suggest periodically pulsating tectonism throughout the entire period of sedimentation [12]. The present day trend of the Son Narmada lineament is roughly E-W with minor changes at some places. The NE-SW trend of stress direction determined in the present study may be related to local variation in the tectonism associated with the Son lineament. This also suggests that the regional trend of the Son lineament was oblique to the present day trend

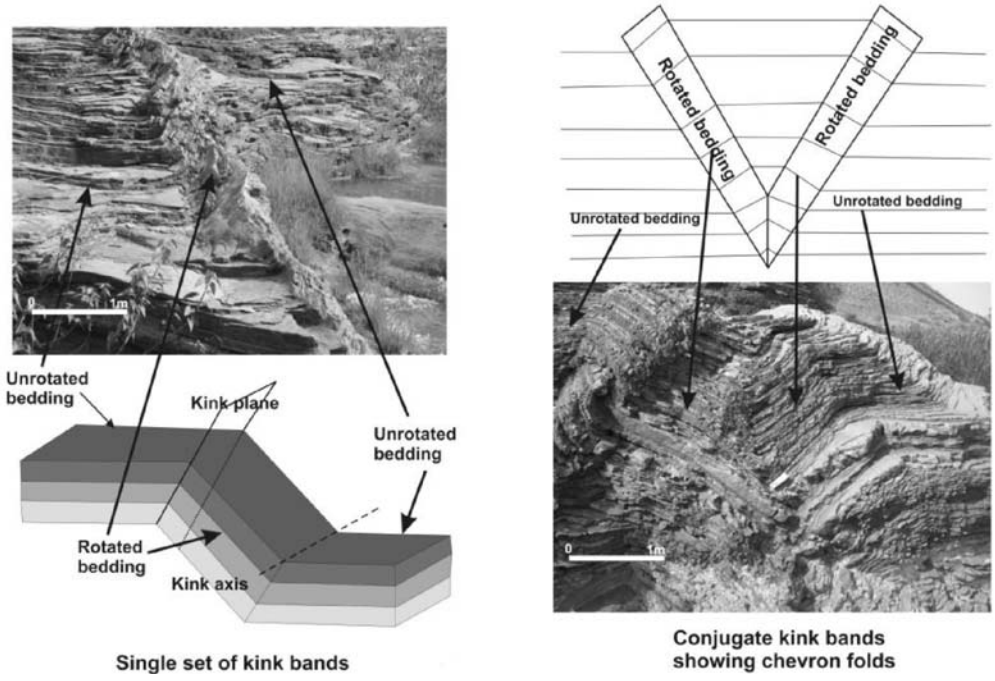

Figure 2: Field photographs showing closure view of kink bands and chevron folds along the tributary of river Son near Newari village. Descriptive terminologies has been marked on the photographs.

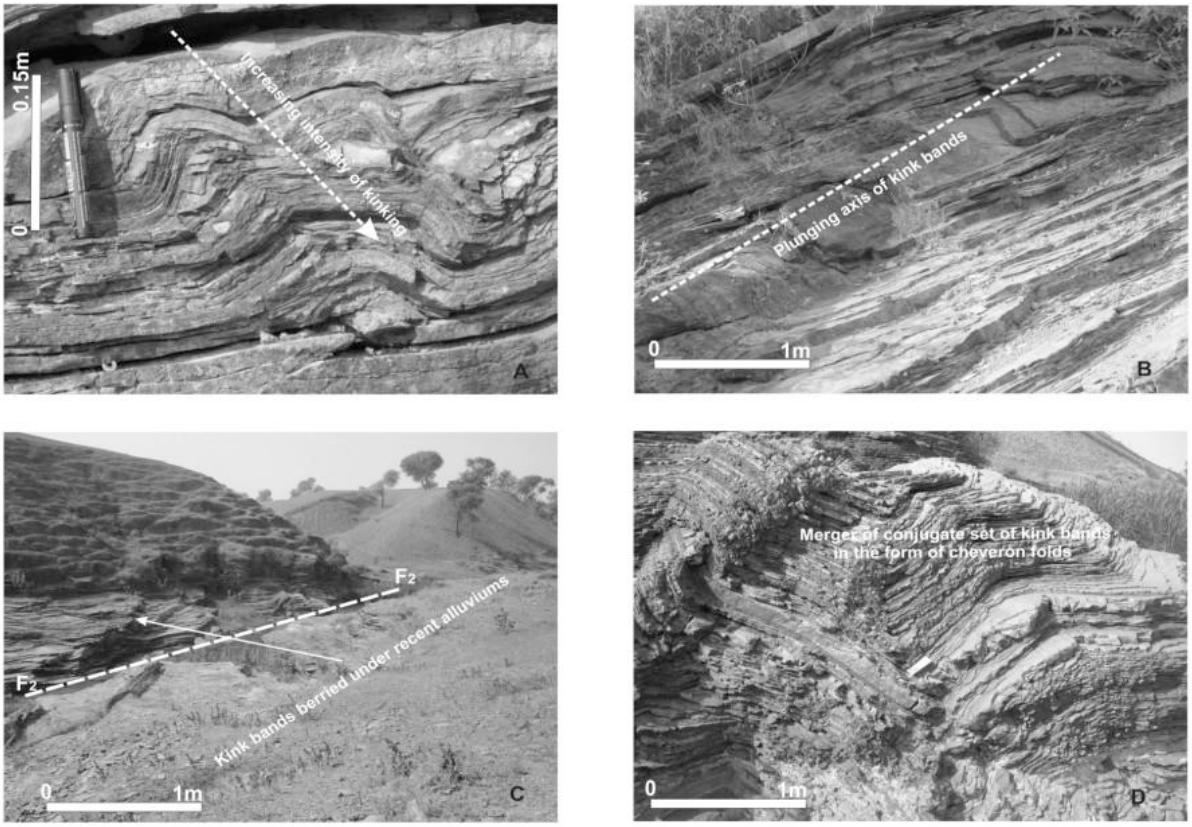

Figure 3: Field photographs showing (**A**) Downward increasing intensity of kinking; (**B**) Plunging axis of kink bands; (**C**) Buried kink bands under recent alluvium; (**D**) Chevron folds developed due to merger of conjugate set of kink bands.

during the sedimentation of the glauconitic sandstone in the Newari area.

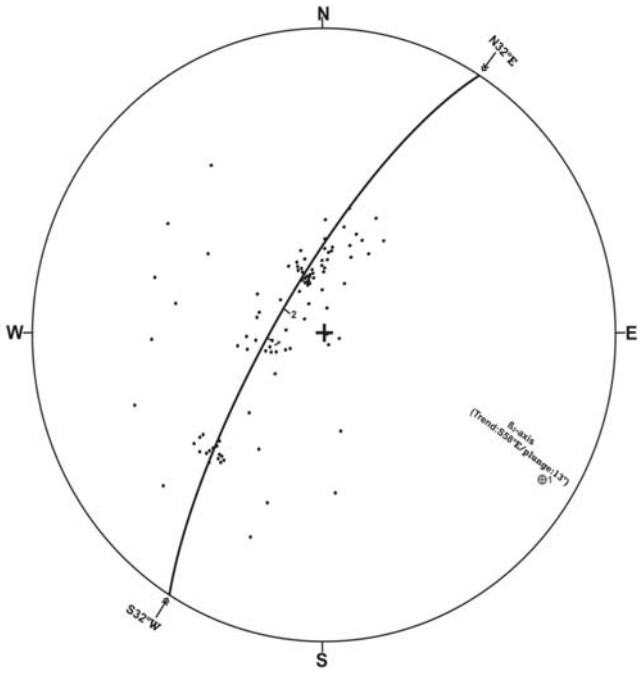

Figure 4: Lower hemisphere of equal area projection of poles (N=50) to kink planes. Inferred β-axis of conjugate set of kink bands corresponds to the observed fold axis.

Course of the tributary of Son is dominantly linear but near the confluence it shows some meanders. During field investigation, it has been found that this stream is flowing through the fault plane, which is a reverse fault dipping 40˚ NE and striking N 25˚ W to S 25˚ E (F_1 in Figure **1c**). Another fault plane is oblique to the F_1 (F_2 in Figure **1d**), dipping 70˚ SE and striking N 70˚ E to S 70˚ W. Auden [4] has reported fault plane of regional extent passing through Newari striking roughly in WSW-ENE and further in SW-NE direction (about 8 km west of Bargwan) that marks the boundary between olive shale and glauconitic sandstone south west of Newari and continues further east in glauconitic sandstone horizons. It is found in the present investigation that the F_1 fault near Newari may be sympathetic fault or an extension (as per strike trend) of the fault reported by Auden [4]. Since the above mentioned small tributary is flowing through this fault plane in roughly linear pattern and on the basis of existing geomorphology, it appears that the extension of fault plane (terminating 2-3 km south of southern bank of river Son in accordance with Auden [4]) is continued up to the southern bank of river Son.

Fault F_2, which is a local fault striking oblique to the F_1 is responsible for abrupt turn in the course of stream

towards north-east at the intersection of F_1 and F_2 (Figure **1c** and **1d**).

4. DISCUSSION AND CONCLUSIONS

Kink bands are small-scale structures, usually of the order of few millimeters to few centimeters in spacing, and are defined by sharp boundaries where the orientation of the pre-existing laminar structure varies abruptly. They are a special type of shear zone, occurring in rocks that already possess a strongly layered or laminated structure before the development of the kink band [16]. The occurrence of the kink bands and chevron folds within the laminated sandstones and their confinement within the undeformed beds from both the sides suggests that they may be soft-sediment deformational structures (SSD) [17]. The SSD structures are invariably bounded by undeformed beds and their dimensions depend on the thickness of bed affected by liquefaction in tectonically active basins [18, 19]. Also, under certain conditions, stress acting parallel and normal to the fault plane during strike-slip faulting will induce an ephemeral stress system compatible with kink-band development [20]. The main trigger mechanisms are firstly earthquakes, secondly overloading from volcanic rocks and thirdly, to a lesser extent, subaqueous currents [17]. Singh *et al*. [15] has postulated that the lithofacies of the glauconitic sandstone deposited in shoreface to foreshore zone of a shelf. Continental slopes are the best locations for the gravity sliding and formation of related SSD structures. Since the Glauconitic sandstone deposited on the shelf which has a low angle of slope, the development of SSD structures as a result of gravity slides looks a weak possibility. Also, the absence of volcanic rocks associated with the glauconitic sandstone makes possibility of this as a trigger mechanism less likely.

Further in the downstream part, it is noticed that chevron folds and kink bands are buried under the capping of recent alluvium (can be seen in eroded sections along the course of stream) (Figure **3c**). Conspicuously, the north eastern block at the intersection zone of fault F_1 and F_2 is showing 10-15 m high exposure along the course of the stream. In view of the fact that glauconitic sandstone suggests an age bracket 1080 ± 40Ma, it can be concluded that the SSD structures formed around this time and a major seismic activity occurred as a result of the tectonic movements of the Son and associated faults. As Vindhyan basin is a rifted basin the tectonic activities were governed by the movements of the faults during its development, which also generated seismic activity. Thus, it is concluded that the kink bands and chevron folds developed within the laminated sandstones are the penecontemporaneous deformational structures formed as a result of the seismic activities along the faults present in the Newari area of the Sonbhadra district of Uttar Pradesh, India.

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