P 373

# Tectonic Analysis of Damoh and Jabera Structures in Son Valley Vindhyans: A Structural Modeling Approach

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***Summary***

*Exploratory efforts in the Vindhyan Basin in Central India, especially in the Son Valley part, have received a major boost with recent gas discovery in Nohta area which has once again proved the potentiality of the basin to produce hydrocarbons. As all out efforts are being carried out to re-interpret and refine the geological models on the basis of new datasets, peripheral studies are also being taken up simultaneously to gather supporting evidences for the geological models conceptualized. One such compelling evidence comes from systematic modeling exercises using state of art interpretation software available in the market today. In the present work, structural modeling and tectonic analysis was carried out along a seismic profile across the most important structures in Son valley – Damoh and Jabera structures – using the MOVE™ software. Results show that initial rifting in pre- and syn-Kajrahat times involved the basement in normal faulting that gave rise to highs and half-grabens in addition to other structures. The subsequent basin filling stage was punctuated with transgressive cycles related to latter compressive pulses during the Lower Vindhyan which inverted some of the structures present, thus heralding very shallow marine to even fluvatile conditions in phases. Upper Vindhyan sedimentation on the eroded Lower Vindhyan unconformity surface was thus fed by older sediments. Compressive events have affected even the Upper Vindhyan sediments hinting probably at the role of neotectonics in sculpting the present day geomorphic architecture of the basin.*

***Keywords:*** *Vindhyan Basin, Son Valley, Damoh structure, Jabera structure*

## Introduction

Vindhyan Basin (**Figure-1**) is a large intracratonic basin (Ray, 2006) in central India which covers an area of about 1,62,000 sq.km, a sizeable part of which is concealed under Deccan Traps. The Narmada-Son Geofracture or the Son-Narmada Lineament (SNL) forms the southern boundary while its western margin is marked by the Great Boundary Fault (GBF).The Bundelkhand Massif nestles in the north-central part of the basin separating it into two geographical sectors: Chambal Valley to the west and Son Valley to the east. Basin geometry in the Son Valley is characterized by a ENE-WSW trending synclinal depression (Chakraborty, 2006) that is deeper towards south in the proximity of the SNL and becomes shallower northward towards the Bundelkhand Massif. The unmetamorphosed Proterozoic sediment fill (Ray, 2006) comprises alternating siliciclastic and carbonate units depicting the fluctuating depositional set-up under an overall shallow marine regime (**Figure-2**). The sediments show variable thickness along strike and attain a maximum thickness of about $5500^{+}$ m close to the SNL which is traditionally considered to have been the depositional limit for Vindhyan sediments to the south (Lakshmanan, 1966). The SNL is considered to have initiated during the Archean and remained active throughout the evolutionary history of the Vindhyan Basin. The SNL is characterized by intense structural deformation of the Lower Vindhyan sediments in its northern vicinity and exhibits tight folds, both normal and reverse faults, mylonitization and strike-slip movements concomitant to Vindhyan sedimentation and even during post Vindhyan times (Pandey, 1971). The northern and eastern margins of the basin have a comparatively gentler gradient.

Son Valley has been in focus ever since the first well J-1 produced thermogenic gas from the Lower Vindhyan sequence (**Figure-3**). With the recent discovery of gas through wells N-1 and N-2 from the Lower Vindhyan Rohtas Limestone Formation, exploratory interest in this area has multiplied.

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Structural modeling and analysis constitutes an interpretation tool that provides important inputs for better understanding of the evolutionary history of structures and their relative timings. Although the solutions are non-unique in nature, the outputs of such studies can go a long way in optimizing inputs for studies like basin modeling and sequence stratigraphy. With this in mind, structural modeling has been attempted using the 2012.1 version of MOVE™ software developed by Midland Valley Exploration Ltd. across a carefully chosen seismic profile (A-A', **Figure-3**) so that some insight into the Son Valley structures (in terms of generation timings, sequence of structurization and variation of structural geometries through time) is obtained.

The seismic profile was selected primarily due to the following reasons –

i) It approximates the tectonic transport direction in the Son Valley Sector.
ii) It contains wells J-1, J-2 and D-1 and lies close to well N-1.
iii) An interpreted Pre Stack Depth Migrated (PSDM) section (**Figure-4**) is available across this seismic profile. Depth sections are a pre-requisite for meaningful structural interpretations.

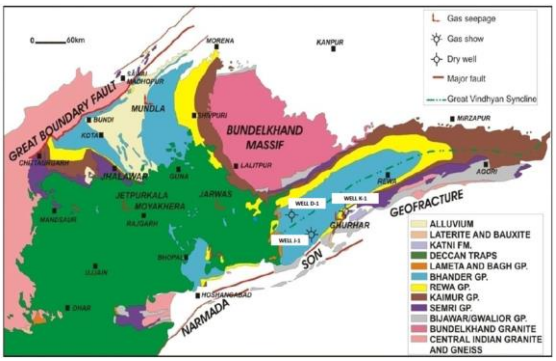


Figure 1: Geological Map of the Vindhyan Basin

| SUPERGROUP | GROUP | SUBGROUP | WEST VINDHYAN BASIN (CHAMBAL VALLEY) | | | EAST VINDHYAN BASIN (SON VALLEY) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | CHITTOR-BUNDI AREA (After Prasad, 1976) | GWALIOR-KARAULI AREA After Prasad, 1984) | | DAMOH-REWA AREA (After Srivastava et al. 1983) | | | | MIRZAPUR-ROBERTGANJ AREA (After Sastri & Moitra 1984) | |
| | | | STRATIGRAPHY | STRATIGRAPHY | | STRATIGRAPHY | | | Mt. | STRATIGRAPHY | |
| | | | | DECCAN TRAP | | LAMETA FM. | | | | SUB-RECENT LATERITE | |
| VINDHYAN SUPERGROUP | UPPER VINDHYAN GROUP | BHANDER GROUP | DHOLPURA SHALE | BHANDER GROUP | UPPER BHANDER SST. | BHANDER SUBGROUP | HAVELI FM. | MAIHER SST | 87 | | |
| | | | BALWAN LIMESTONE | | SIRBU SHALE | | | SIRBU SHALE | 80 | | |
| | | | MAIHER SANDSTONE | | LOWER BHANDER SST | | BETWA FM. | NAGOD LST | 112 | | |
| | | | SIRBU SHALE | | SAMARIA SHALE | | | GANURGARH SHALE | 45 | | |
| | | | BUNDI HILL SST | | | | | | | | |
| | | | SAMARIA SHALE | | | | | | | | |
| | | | LAKHERI LIMESTONE | | | | | | | | |
| | | | GANURGARH SHALE | | | | | | | | |
| | | REWA | GOVINDGARH SST | REWA SUB-GROUP | UPPER REWA SST | REWA SUBGROUP | ADHESAR FM. | GOVINDGARH SST | 55 | | |
| | | | JHIRI SHALE | | JHIRI SHALE | | | JHIRI SHALE | 34 | | |
| | | | INDARGARH SST | | LOWER REWA SST | | ADWA FM. | ASAN SST | 64 | KAIMUR GROUP | DHANDRAUL SANDSTONE |
| | | | PANNA SHALE | | PANNA SHALE | | | PANNA SHALE | 34 | | MANGESAR FORMATION |
| | | KAIMUR | AKODA MAHADEV SST | KAIMUR SUB-GROUP | AKODA MAHADEV SST | KAIMUR SUBGROUP | CHURK FM. | DHANDRAUL QRTZ. | 185 | | BIJAIGARH SHALE |
| | | | CHITTAUR FORT SST | | | | | SOMAN SCARP SST. | 140 | | GHAGHAR SANDSTONE |
| | | | | | | | RAMPUR FM. | BIJAIGARH SHALE | 34 | | SUSNAI BRECCIA |
| | | | | | | | | DOMARKHOKA QRTZ. | 95 | | SASARAM SANDSTONE |
| | LOWER VINDHYAN GROUP | SUKET SHALE | TIROHAN GROUP | TIROHAN BRECCIA | SEMRI GROUP | ROHTAS FM. | BHAGAWAR SHALE | 420 | ROHTAS SUBGR. | BHAGAWAR SHALE |
| | | NIMBAHERA LST | | | | | ROHTAS LST | | | ROHTASGARH LST |
| | | BARI SHALE | | | | KHEINJUA FM. | BASUHARI (GLAUCONITIC) SST. | 320 | KHEINJUA SUBGR. | RAMPUR GLAUCONITE |
| | | JIRAN SST WITH CONGL. | | CONGLOMERATE | | | | | | |
| | | BINOTA SHALE | | TIROHAN LST. | | | MOHANA (FAWN) LST | 207 | | SALKHAN LST |
| | | KALMIA (GLAUC.) SST | | GLAUCONITIC BEDS | | | CHARKARIA (OLIVE) SHALE | 561 | | KOLDAHA SHALE |
| | | PALRI SHALE WITH PORCL. | | | | CHOPAN FM. | JARDEPAHAR PORCILLINITE | 555 | PROCEL SUBGR | DEONAR PORCELLINITE |
| | | SAWA SST WITH CONGL. | | SST WITH CONGLOMERT. | | | | | | |
| | | BHAGWANPURA LST. | | | | | KAJARAHAT LST | 335 | MIRZAPUR SUBGROUP | KAJARAHAT LST |
| | | | | | | | | | | ARANGI FORMATION |
| | | KHARDEOLA SST. | | | | | BASAL CONGLOMERATE | | | DEOLAND FORMATION |
| | | KHAIRMALIA ANDESITE | | | | | | | | |
| ARAVALI GROUP | | | | GWALIOR GROUP | | BIJAWAR GROUP | | | | BIJAWAR / MAHAKOSHAL GROUP | |
| BUNDELKHAND GNIESS | | | | BUNDELKHAND GNIESS/ GRANITE | | BUNDELKHAND GNIESS | | | | BUNDELKHAND GNIESS | |

Figure 2: Stratigraphy of the Vindhyan Basin (Chambal Valley and Son Valley Sectors)

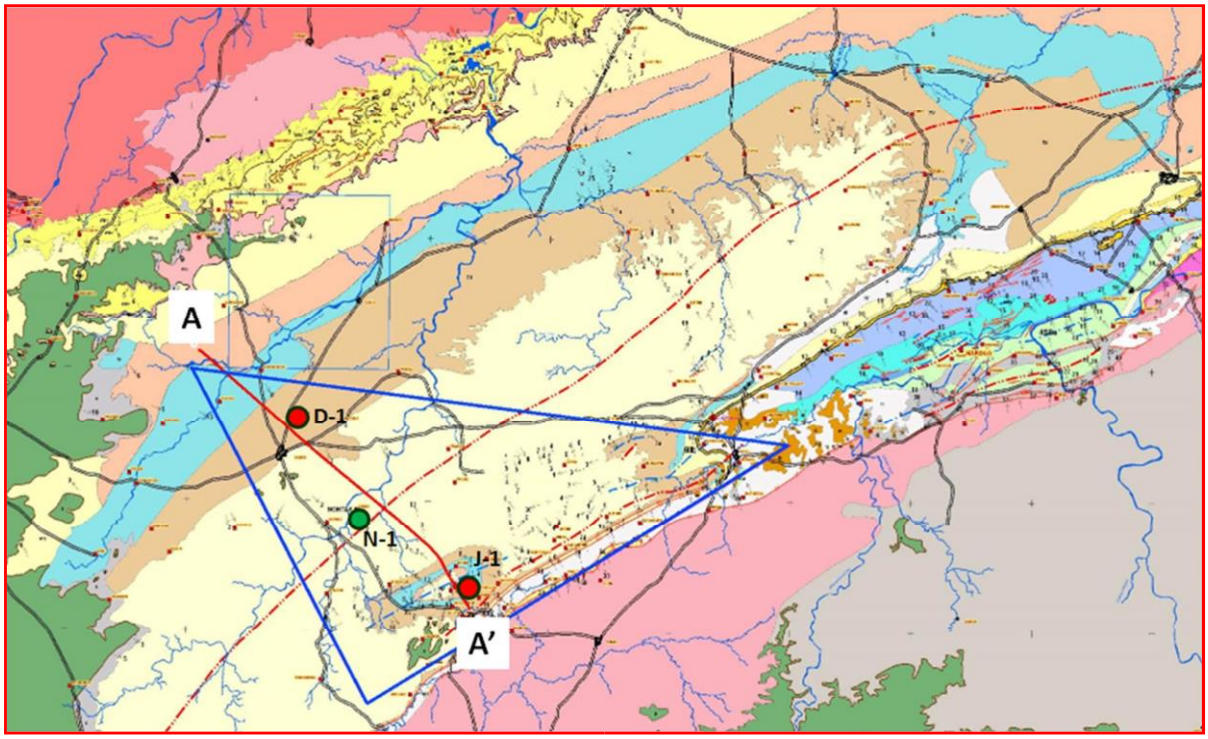


Figure 3: Geological Map of Son Valley Vindhyans showing seismic profile A-A' and the drilled wells

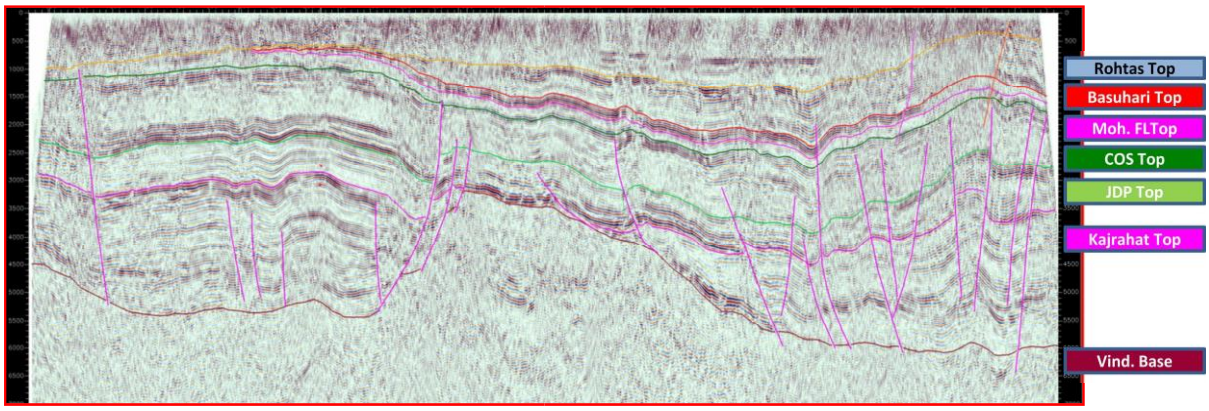


Figure 4: Interpreted seismic profile A-A' (PSDM); profile orientation is NW-SE from Left to Right

## Methodology

Structural modeling can be carried out in either of two ways – forward modeling or restoration. In the former case, an undeformed stratigraphic succession is gradually deformed to approximate the present day deformed state. On the contrary, the restoration technique sequentially removes deformation from an interpreted present day structural configuration to achieve the structural geometry at some earlier stage of deformation or to the earliest pre-deformation geometry. Both these modeling techniques provide valuable insights into the evolution of the structures under study by demonstrating the intermediate stage(s) between the fully deformed interpretation and fully restored section In the present work, the sequential restoration technique has been applied to analyze the interpretation along seismic profile A-A' and to arrive at

inferences regarding the evolution of the Damoh and the Jabera structures that have formed along it. For modeling purpose, the condition of plane strain has been assumed, i.e., it is assumed that no material has moved in and out of the plane of the section during deformation at any stage. It is also assumed that flattening at any particular horizon top replicates the basinal geometry of that particular point in time. In the absence of actual site specific data, the parameters for decompaction of underlying strata as the overlying strata is 'eroded-off' or 'backstripped' has been accepted as is available in the software default database (Initial Porosity: 0.56 and Depth Coefficient: 0.39 per km).

## Results

The intermediary stages of tectonic evolution of the Damoh and Jabera structures are shown from **Figure-5.1 to 5.7**.

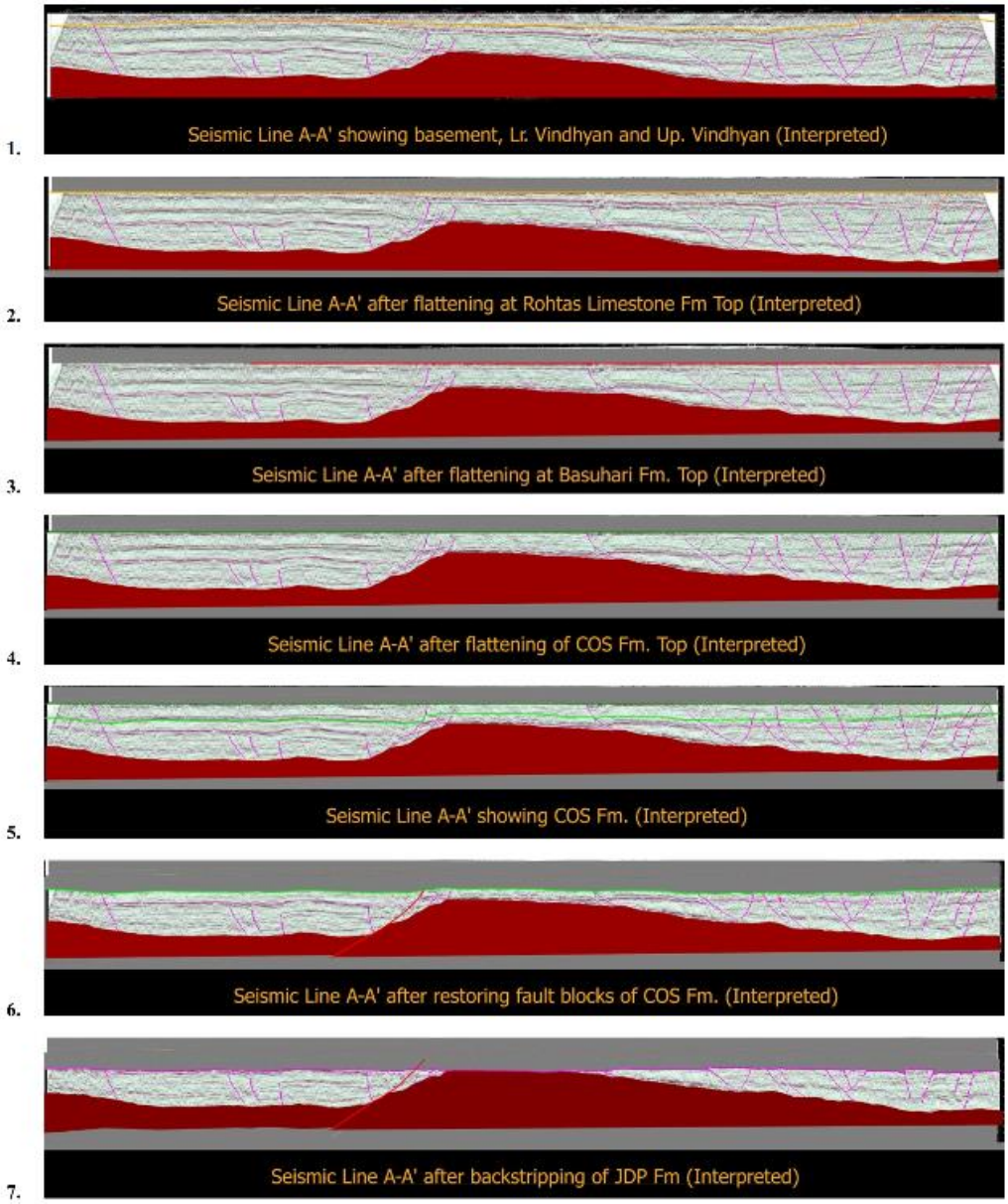


Figure 5.1 to 5.7: Sequential restoration of the interpreted seismic profile A-A' showing intermediary stages of evolution of the Damoh and Jabera structures (Sections oriented NW-SE from Left to Right)

## Inferences and conclusions

a. From a detailed analysis of the intermediate deformation stages reconstructed during the sequential restoration, following inferences and conclusions are drawn:

b. The Son Valley sector of the Vindhyan Basin appears to have been tectonically disturbed throughout its sedimentation history (**Figures 5.1 to 5.7**). There have been tectonic disturbances even in post Upper Vindhyan times probably upto the present day. As such effect of neotectonic activities on the ultimate geomorphology of the basin cannot be ruled out.

c. Between the Damoh and the Jabera depressions, the latter seem to have remained tectonically more active throughout (**Figures 5.1 to 5.7**). This observation is consistent with the general understanding of the basin that its southern margin has been tectonically more active (Gupta et al, 2003). Also this is most probably related to tectonic movements along the SNL. Thus the SNL appears to have initiated before Lower Vindhyan sedimentation.

d. Jabera Structure could not be flattened even at the base of Jardepahar Formation (**Figure 5.7**). In fact, block faulting towards the end of Kajrahat times appears to have created the high over which the Jabera Dome now occurs.

e. The normal fault in the SE margin of the Damoh structure came into existence during the deposition of Charkaria Olive Shale (COS) and is confined to this unit only (**Figure 5.5**). Thus extensional regime prevailed in this sector of the Vindhyan Basin at least till the end of deposition of the COS.

f. Sometime after the deposition of COS, tectonic inversion appears to have initiated in the basin leading to shallowing of parts of the basin and deposition of Mohana Limestones probably in a carbonate tidal flat of a shallow open sea. Mohana Limestone Formation may therefore be patchy in its spatial occurrence. Most reverse faults appear to have initiated after COS and might have grown with subsequent tectonic pulses, thus affecting the subsequently deposited formations.

g. Normally glauconite is considered to be a mineral diagnostic of depositional environments with slow rates of accumulation. Therefore the Basuhari Glauconitic sandstones appear to be products of erosion of the positive landmasses of a slowly inverting shallow marine basin, parts of which may even have converted to fluvatile environments.

h. A fresh pulse of compression in the basin appears to have resulted in basin deepening (**Figure 5.1 and 5.2**), with the consequent transgressive phase being widespread and spread over the entire Son Valley. Widespread carbonate deposition was thus facilitated during Rohtas times. Deposition with accompanying subsidence at similar rates might have presented an environment that was suitable for deposition of huge volumes of carbonates.

i. The hiatus at the top of Rohtas Formation provides evidences of large scale compressive tectonism during the close of Rohtas time followed by erosion and leveling of the geomorphic surface. On this unconformity surface (Chakraborty, 2006; Schieber et al, 2007)) the Upper Vindhyans were deposited (**Figures 5.1 and 5.2**).

j. Even after sequential restoration upto the Jardepahar unit, the Damoh and Jabera depressions remain as lows of considerable dimensions (**Figure 5.7**) thus providing evidence of basement involvement during rifting during pre- and syn-Kajrahat deposition. The rifts appear to have resulted due to continental scale movements that may perhaps be related to movements along the SNL. These depressions provided the accommodation spaces for quick filling of sediments in the Jabera and Damoh 'half-grabens', with fan deposits in the proximal parts, shales in the deeper parts and carbonate associations in the shallower parts of the Vindhyan Basin.

## Acknowledgement

While the views expressed in this paper are solely the authors' own and by no means representing organizational perceptions, thanks are due to the ONGC management especially Director (Exploration) for permission to publish this paper. Guidance received from Dr. D.N. Singh, GM-Basin Manager, Dr. D.K. Srivastava, GM-Block Manager, Vindhyan Block, and Shri A.K. Arya, GM-Block Manager, HF Block and technical support from s/Shri T.K. Mistry, V. Raturi and A. Tripathi, all from Frontier Basin, ONGC, is gratefully acknowledged.

## References


Chakraborty, C., (2006): Proterozoic intracontinental basin: The Vindhyan example, J. Earth Syst. Sci., 115, No. 1, February 2006, pp. 3-22

Gupta, S., Jain, K.C., Srivastava, V.C. and Mehrotra, R.D., (2003): Depositional environment and tectonism during th sedimentation of the Semri and Kaimur groups of rocks, Vindhyan Basin, Jour. Palaeon. Soc. Ind., Vol. 48, 2003, pp. 181-190

Lakshmanan, S., (1966): On the nature of the basal conglomerate of the Semri Series in the Son Valley, Centre of Advanced Study in Geol., Univ. of Saugar, Vol. 34 A. No. 1

Pandey, S.N., (1971): Development of dome and basin structure due to interference of major folds of the southern margin of the Vindhyan Basin, Deptt. of App. Geol., Univ. of Saugar, Vol. 39 A, No. 1

Ray, Jyotiranjan S., (2006): Age of the Vindhyan Supergroup: A review of recent findings, J. Earth Syst. Sci., 115, No. 1, February 2006, pp. 149-160

Schieber, J., Sur, S. and Banerjee, S., (2007): Benthic microbial mats in black shale units from the Vindhyan Supergroup, Middle Proterozoic of India: the challenges of recognizing the genuine article, In: Atlas of microbial mat features preserved within the clastic rock record, Schieber, J. et al (Eds.), Elsevier, p. 189-197 (2007)