Vindhyan Supergroup

Presentation By

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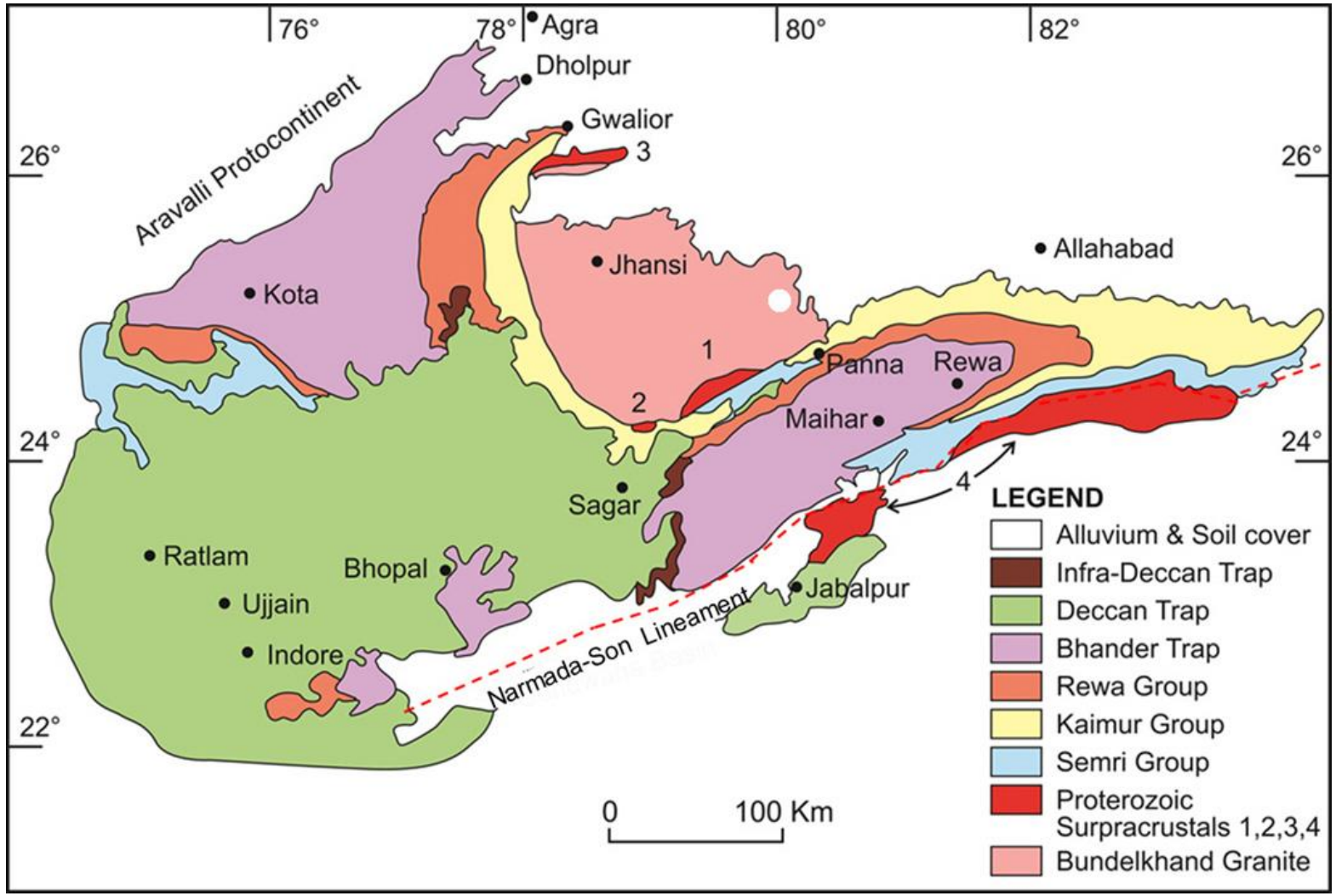
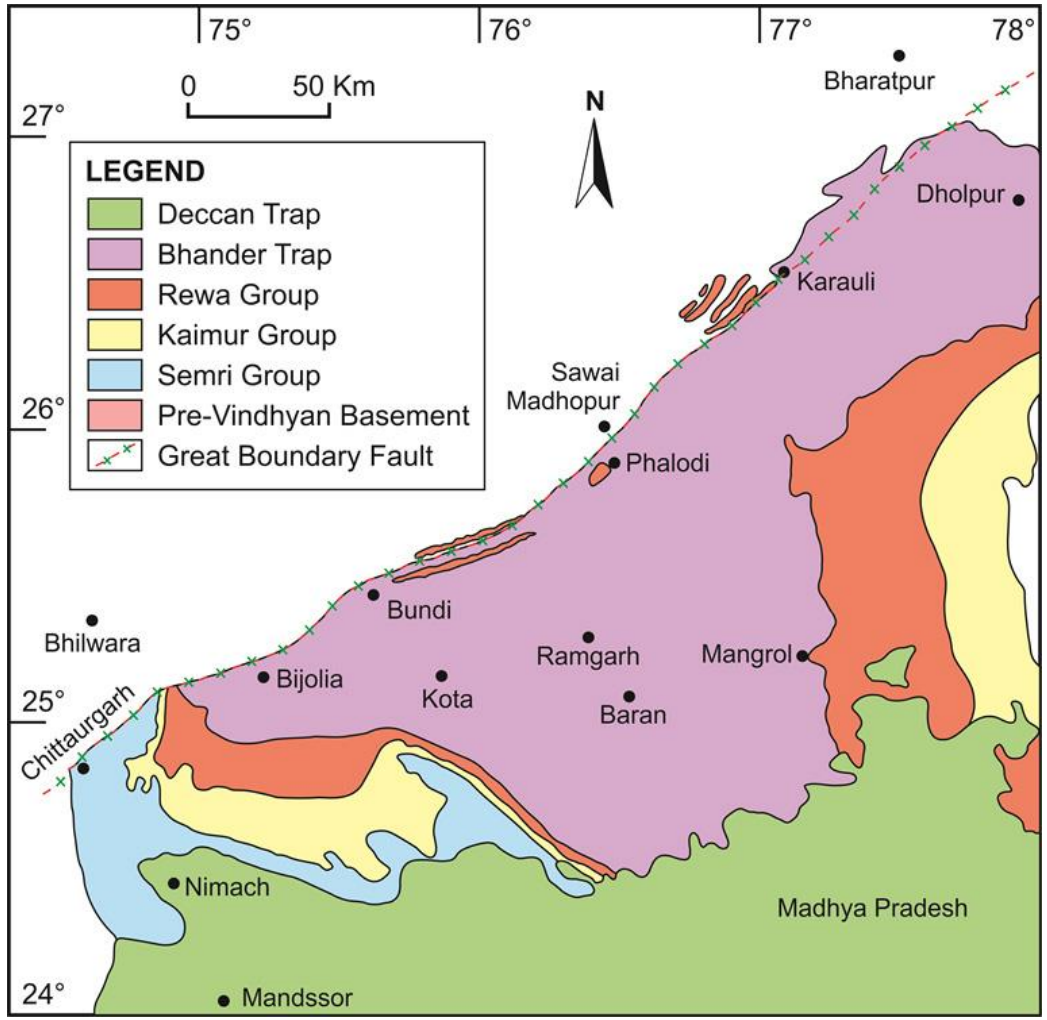
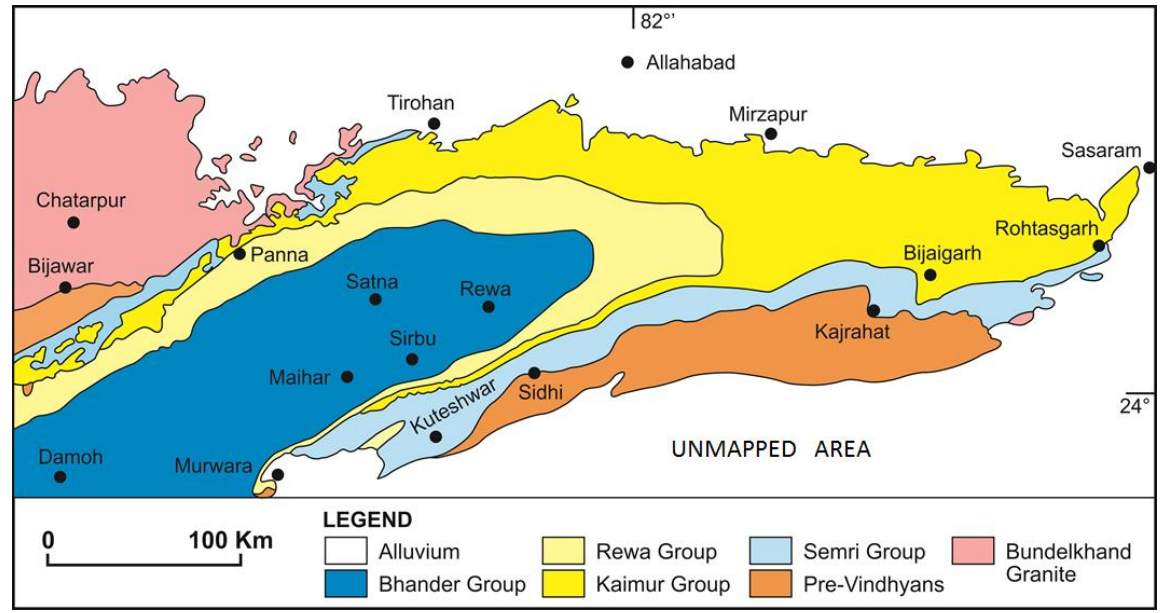

76°
78°
80°
82°
26°
24°
22°
Agra
Dholpur
Gwalior
3
Aravalli Protocontinent
Kota
Jhansi
1
2
Allahabad
Panna
Rewa
Maihar
4
Sagar
Ratlam
Bhopal
Ujjain
Indore
Jabalpur
Narmada-Son Lineament
0
100 Km
LEGEND
Alluvium & Soil cover
Infra-Deccan Trap
Deccan Trap
Bhander Trap
Rewa Group
Kaimur Group
Semri Group
Proterozoic Surpracrustals 1,2,3,4
Bundelkhand Granite

Vindhyan Basin

- Known as the largest Proterozoic (Purana in older terminology) cratonic basin in the Indian Shield, the Vindhyan Basin is exposed over about 60, 000 sq. km area.
- More than the double of the area is under the cover of sediments of the Indo-Gangetic Alluvial Plain in the north and the volcanics and the associated rock types of the Deccan Trap in the SW.
- The broadly U-shaped outcrops of the Vindhyan sediments, in spite of the huge cover of Deccan Trap in the southwestern part, is traditionally referred to as the Great Vindhyan Basin mainly because of the huge area it covers.
- The half-moon shaped Bundelkhand Craton occurs as an inlier occupying the core region of the Vindhyan Basin.
- The exposed area of the Vindhyan Basin have been into divided into two geographical parts: (i) the Son Valley Vindhyans in the SE side between Sasaram and Hosangabad; and (ii) the Chambal Valley Vindhyans where exposures occur from N of Dholpur to Neemach and Jhalwar in the south .
- The outcrops of Vindhyans in the eastern part do not end at Sasaram as normally inferred. The study of satellite Imagery indicates that the outcrops of the Son Valley Vindhyans extend beyond Rajgir up to Jamalpur in the NE.

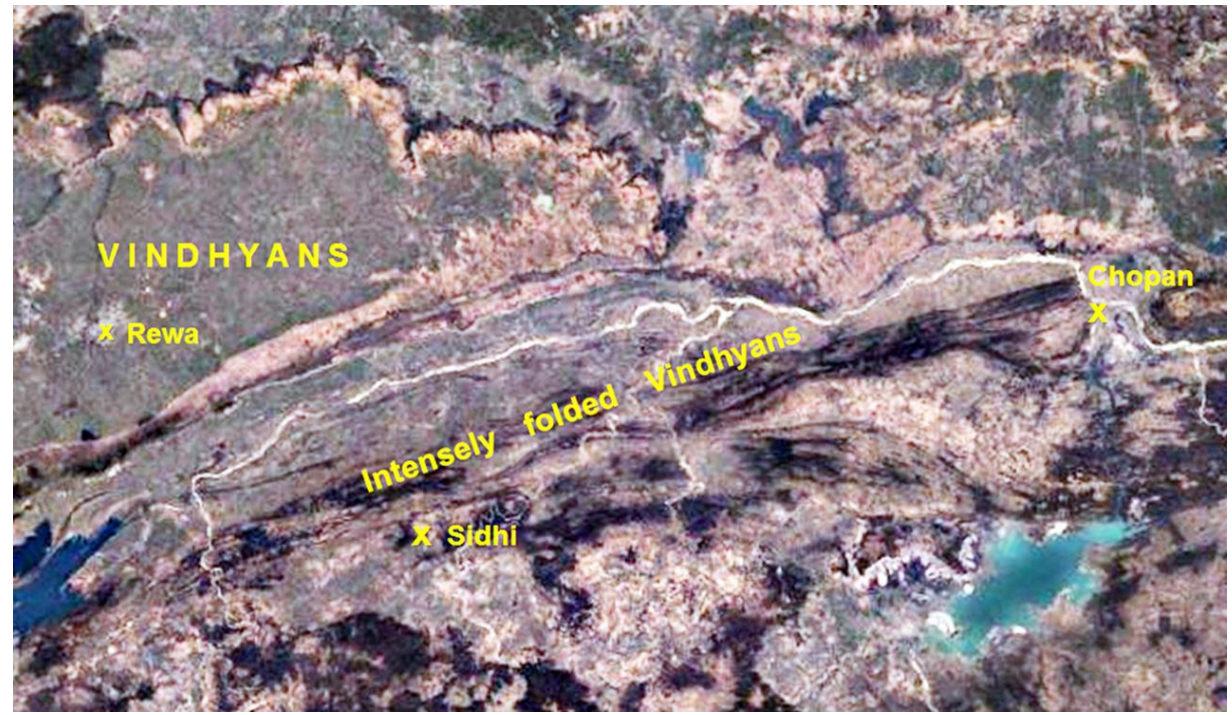

75°
76°
77°
78°
0
50 Km
N
27°
26°
25°
24°
LEGEND
Deccan Trap
Bhander Trap
Rewa Group
Kaimur Group
Semri Group
Pre-Vindhyan Basement
Great Boundary Fault
Bharatpur
Dholpur
Karauli
Sawai Madhopur
Phalodi
Bundi
Bhilwara
Bijolia
Kota
Ramgarh
Mangrol
Baran
Chittaurgarh
Nimach
Madhya Pradesh
Mandssor


82°
Allahabad
Tirohan
Mirzapur
Sasaram
Chatarpur
Rohtasgarh
Bijaigarh
Bijawar
Panna
Satna
Rewa
Sirbu
Kajrahat
Maihar
Sidhi
Kuteshwar
24°
Damoh
Murwara
UNMAPPED AREA
0
100 Km
LEGEND
Alluvium
Bhander Group
Rewa Group
Kaimur Group
Semri Group
Pre-Vindhyans
Bundelkhand Granite

Deformation in Vindhyans

- The Vindhyan rocks are broadly undeformed and unmetamorphosed. However, some deformation structures occur in the western part, east of Chittaurgarh and in the southeastern and southern part of the Bundelkhand Protocontinent. In the western part, a series of north-south trending alternate aniforms and synforms are present in the Vindhyan rocks, which gradually die out in the easterly direction from the east of Dhaneshwar.
- Strongly deformed Vindhyan rocks are also observed in the eastern side close to the Narmada-Son Lineament zone in the Son Valley region. A series of parallel folds having ENE-WSW trend has developed close to the eastern margin between Sasaram and Hosangabad. The zone of folding is also traversed by a number of faults, some of which represent high angle overthrusts.
- The overturned folds having tight to isoclinal geometry are also quite common. The intensely folded belt is marked by steepening of beds as noted near the SE margin of the Vindhyan Basin between Chopan, Sidhi & further South.


Great Boundary Fault
Chittorgarh
xDhareshwar


VINDHYANS
x Rewa
Chopan
x
Intensely folded Vindhyans
x Sidhi

Lithostratigraphy

- The earliest study of the Vindhyan Basin was by Thomas Oldham (1856) who worked on these rocks about one-and-half century ago. Significant contributions have been made by Mallet (1869) and Auden (1933) during later period, which formed the basis for all the latter works.
- Oldham (1856) was the first to propose a lithostratigraphic succession subdividing the Vindhyan rocks into three ‘series’, namely the Kaimur, Rewa and Bhander; presuming the Semri as a part of the pre-Vindhyan basement. Medlicott (1859) modified the Vindhyan succession by including the Semri as the basal part of the Vindhyan.
- Conventionally, the stratigraphic scheme adopted for the rocks developed in the Son Valley region (Mallet, 1869; Auden, 1933) is used for the entire Vindhyan Basin. Following the “Code of the Stratigraphic Nomenclature” the term Group has been introduced in place of ‘series’; while elevating the stratigraphic status of the Vindhyans to the level of Supergroup.

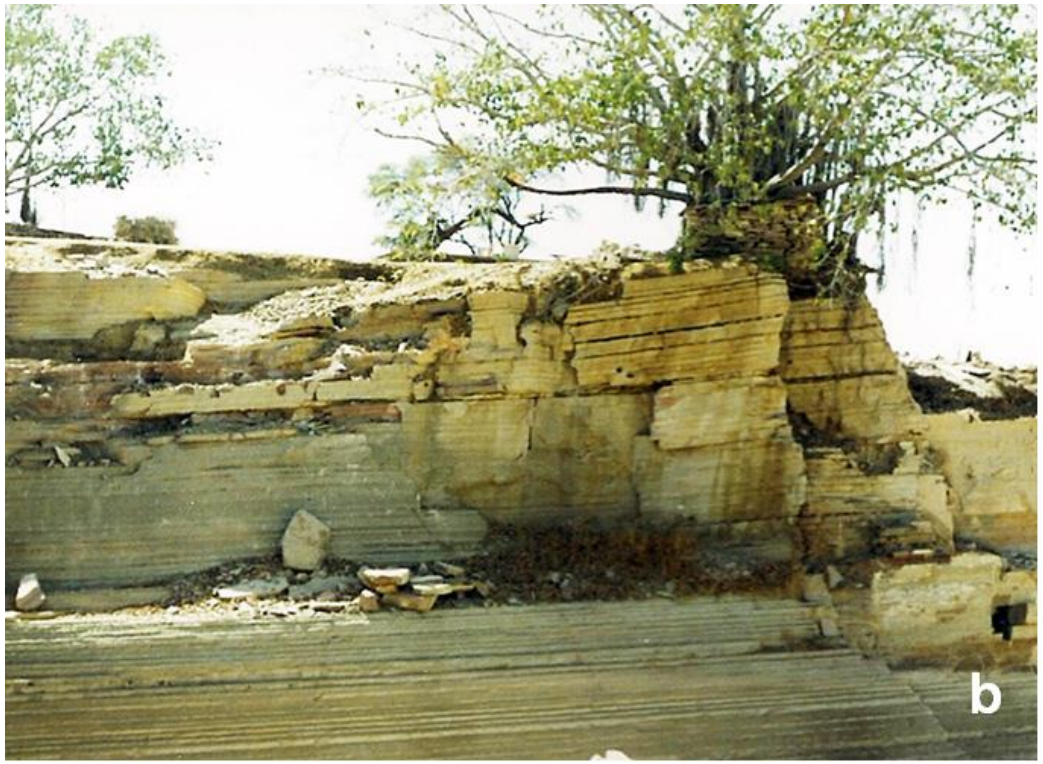
Generalised lithostratigraphic succession of the Vindhyan Supergroup (After Prasad, 1984; Soni et al. 1987; Ramakrishnan and Vaidhyanadhan, 2008)

	Son 3Valley	Chambal Valley
Bhander Group	Bhavpura Formation Balwan Limestone Salkaoda Formation Sirbu Shale Bundi Hill Sandstone Lower Bhander Limestone Ganurgarh Shale	 Upper Bhander Sandstone Sirbu Shale Bundi Hill Sandstone Lower Bhander Limestone Ganurgarh Shale
Rewa Group	Upper Rewa Sandstone Jhiri Shale Lower Rewa Sandstone Panna Shale	Govindgarh Sandstone Jhiri Shale Lower Rewa Sandstone Panna Shale
Kaimur Group	Bijaigarh Shale Markundi Quartzite Gurma Shale Ghagar Quartzite	Upper Kaimur Sandstone Ghaghar Sandstone Susnai Breccia Lower Kaimur Snadstone
Semri Group	Rotash Limestone Basuhar Sandstone Bargawan Limestone Kheinjua Shale Chopan Porcellanite Kajrahat Limestone Arangi Conglomerate	 Suket Shale Nimbahera Limestone Bari Shale Jiran Sandstone Cohri Malan Conglomerate Binota Shales Parli Shale Porcellanite Sawa Sandstone Bhagwanpura Limestone Khardeola Sandstone

Semri Group

- The Semri Group in the Son Valley developed over the pre-Vindhyan rocks like laterite–capped Bijawar Group at places over the granite gneisses of the Bundelkhand Granite.
- The basal beds include patches of conglomerate which at places appear as mass of debris flow type oriented clasts. A diamictite type conglomerate is reported from the Gangau region which has been described as ‘glacial tilloids’ formed by debris flow type deposits.
- The Semri Group is dominantly calc-argillaceous in nature, intercalated with shale and porcellanite beds. The carbonate formations are the more dominant component compared to the other lithologies which have been deposited below the wave base in the marine environment.
- Towards the later part of carbonate succession, extensive development of dolomitic bioherms like stromatolites, other microbial structures have developed in the shallow shelf region of the basin.

(a) Finely laminated Kajrahat Limestone (basal beds) from Maihar area, Son Valley. Kumar and Sharma (2010);
(b) Nimbahera Limestone (upper section) characteristically showing development of thin, uniformly planar beds.



Depositional Conditions

- The carbonate depositional condition was interrupted by the volcanic formations when the porcellanite beds were deposited.
- In the Son Valley, volcanism occurred after the deposition of the Kajrahat Limestone. It was an explosive volcanism, penecontemporaneous with the sedimentation on land and in water in tidal flats.
- The acidic volcanism in the Chopan area consists of rhyolitic tuff, vesiculated and accretionary lapilli, ignimbrite and agglomerate with fragments of pumice and volcanic bombs.
- The Semri Group shows variable stratigraphic thickness in different parts of the Vindhyan Basin. It is much thicker in the Son Valley compared to that in the Chambal Valley region. The estimated thickness of the Semri sediments ranges between 20 m near Chandola to nearly 4345 m near Deoland . This suggests that the depositional floor depths of the Vindhyan Basin was uneven at least during the initial stages.

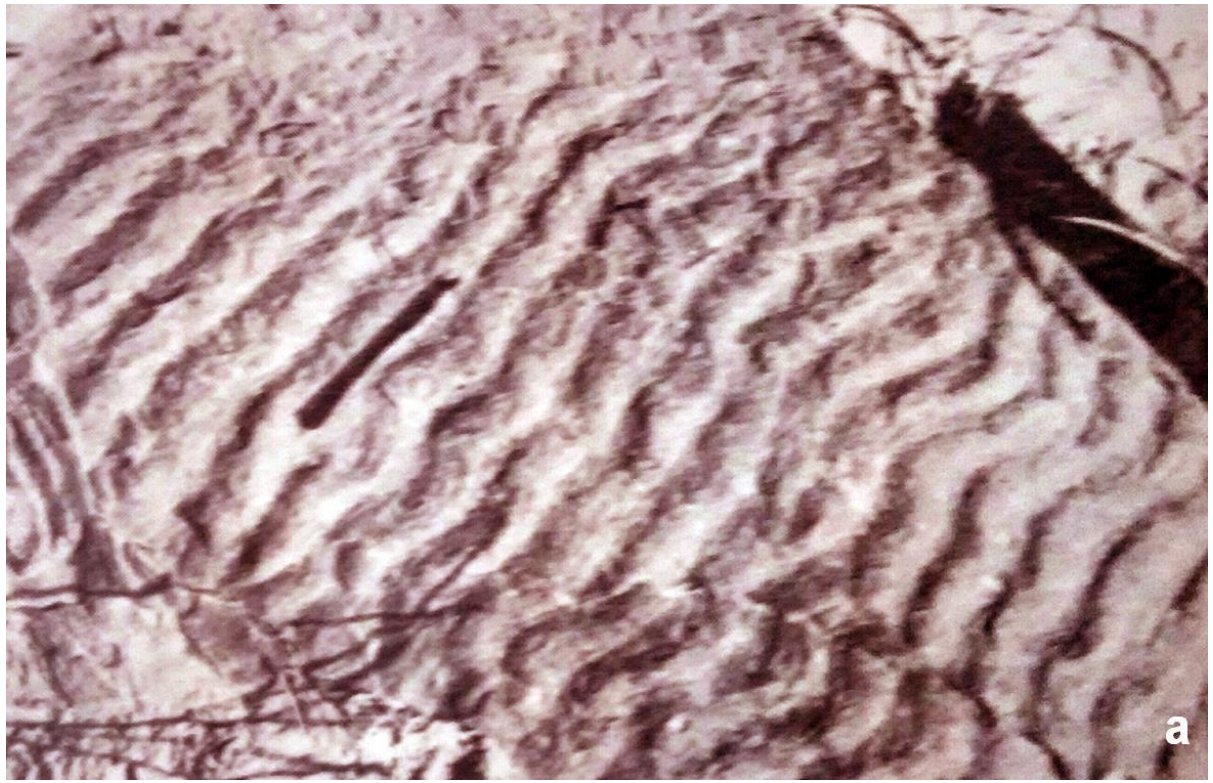
Kaimur Group

- The Kaimur Group overlies the carbonate dominated Semri Group with an unconformity in between. A conformable relationship between the two is observed in the Chambal Valley outcrops in Rajasthan, especially near Chittaurgarh. At Bundi, lenses of conglomerate occur at the base of the Kaimur Group overlying the Semri.
- In the eastern belts, the conformable relationship is observed in the Chitrakoot-Kohari-Panna area in Madhya Pradesh. However, an angular unconformity is reported near the Kalinjar Fort where the subhorizontal Kaimur sediments lie on mildly folded Semri Group.
- The Kaimur is dominantly arenitic in composition with some shale beds. The sequence locally shows interbeds of the porcellanite and silty shales. The sandstones are thick bedded, grey and pink coloured. These are commonly cross-bedded and ripple marked. Mud cracks are noted in the fine-grained rocks.
- The Bijaigarh Shale containing pyrite is interpreted as a quiet water swamp or lagoonal deposit. The Kaimur Group of sandstones are spread almost all over the Vindhyan Basin at places transgressing into the boundaries of the Semri Group. The rocks have their maximum thickness (about 400 m) near Rotashgarh. The Kaimur sandstones are extensively used as building stones from the historical times.

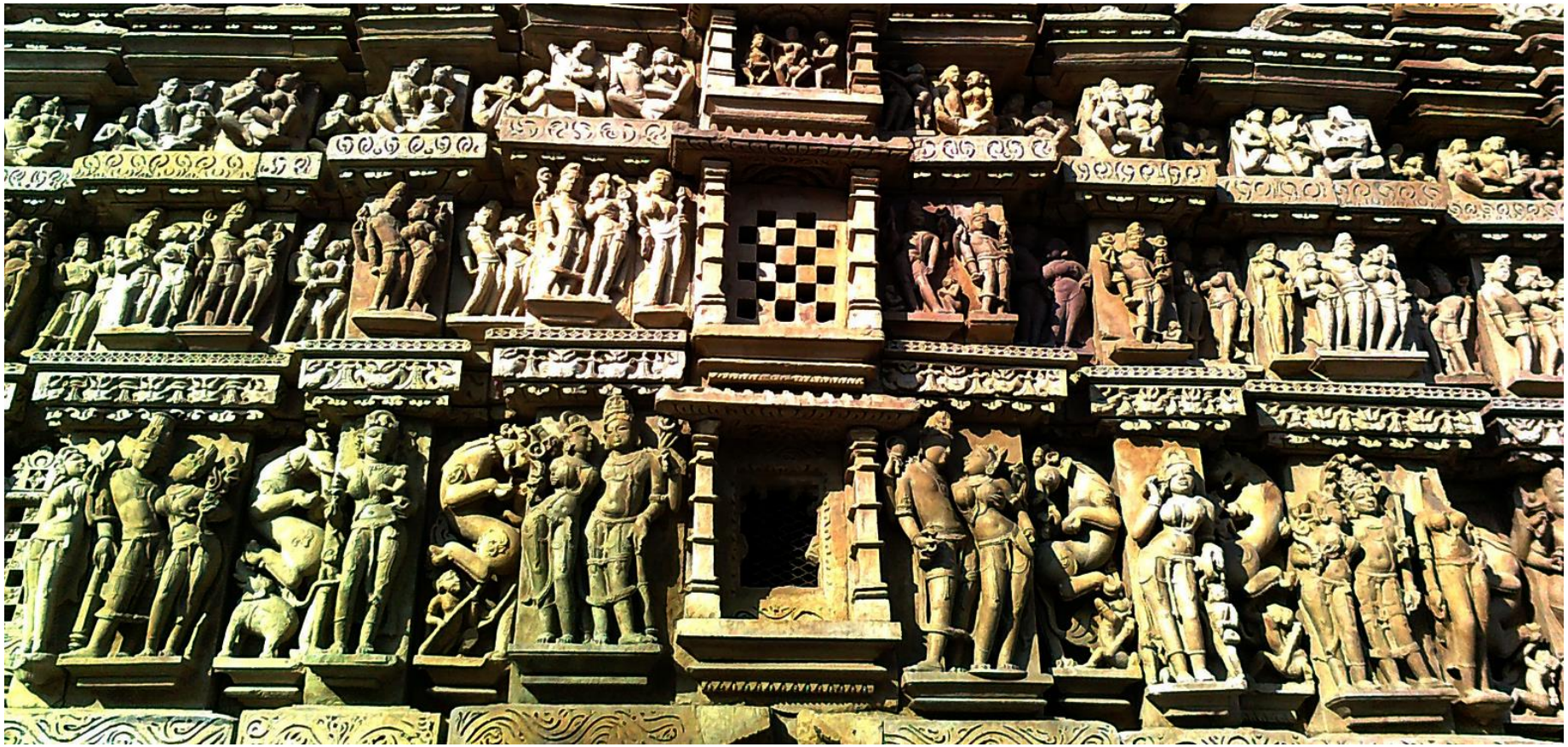
Rewa Group

- The Rewa Group is characterised by lateral Facies variations and is best developed along the northern part of the Vindhyan Basin, particularly in the Panna (109m thick) and Satna districts in Madhya Pradesh.
- In the western part of the Son Valley, the thickness of the Rewa Group varies from about 180m-300 m.
- The Rewa is well known for having some diamond bearing conglomerate horizons in the Panna area. The Panna shales and the Lower Rewa sandstones occurring in the lower part of the Rewa Group have developed as a regressional sequence on the sloping floor of the Kaimur.
- One of the most fascinating aspect of this group of the Vindhyans Basin is the fact that the exquisite statues, figures and panels that decorate the Khajuraho temples near Panna was carved out from greyish to cream coloured Rewa sandstones.

(a) Ripple marks in Rewa sandstones. (b) Deformed cross laminations in Govindgarh Sandstone, Rewa group. From Kumar and Sharma (2010).

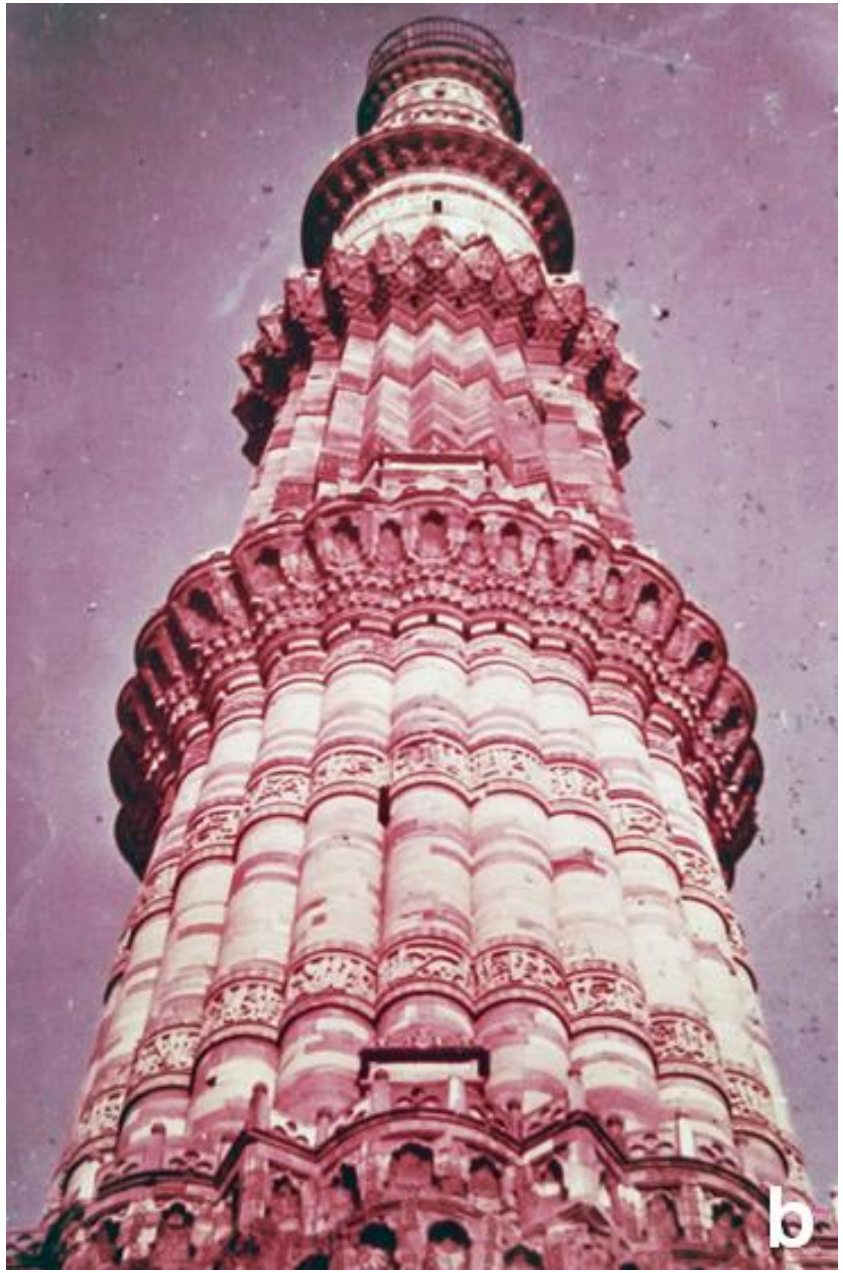


The exquisitely carved statues and murals in the Khajuraho temples near Panna are made of Rewa sandstones



Bhander Group

- The Bhander Group represents the youngest lithostratigraphic unit in the Vindhyan succession.
- Lithologically, it forms the typical shale-sand-carbonate succession deposited in stable continental shelf zone under a shallow water depositional condition in basins like lagoons, tidal flats with channels, and beaches.
- The sand-shale dominated Bhander rocks show alternate thicker sandstone alternating with shale layers, preserving hosts of primary depositional features.
- Finely laminated algal mats and cyanobacterial stromatolites formed bioherms in the supratidal to subtidal environments, especially in the western Chambal Valley sector.
- The Bhander limestones are grey coloured stromatolitic type having high concentration of CaO and low Mg. The chemical character of the carbonates makes it useful for development of cement factory.
- The red coloured variety of sandstones is being widely used as building stones from historical times like the Qutub Minar at Delhi, and the Red Forts at Delhi and Agra.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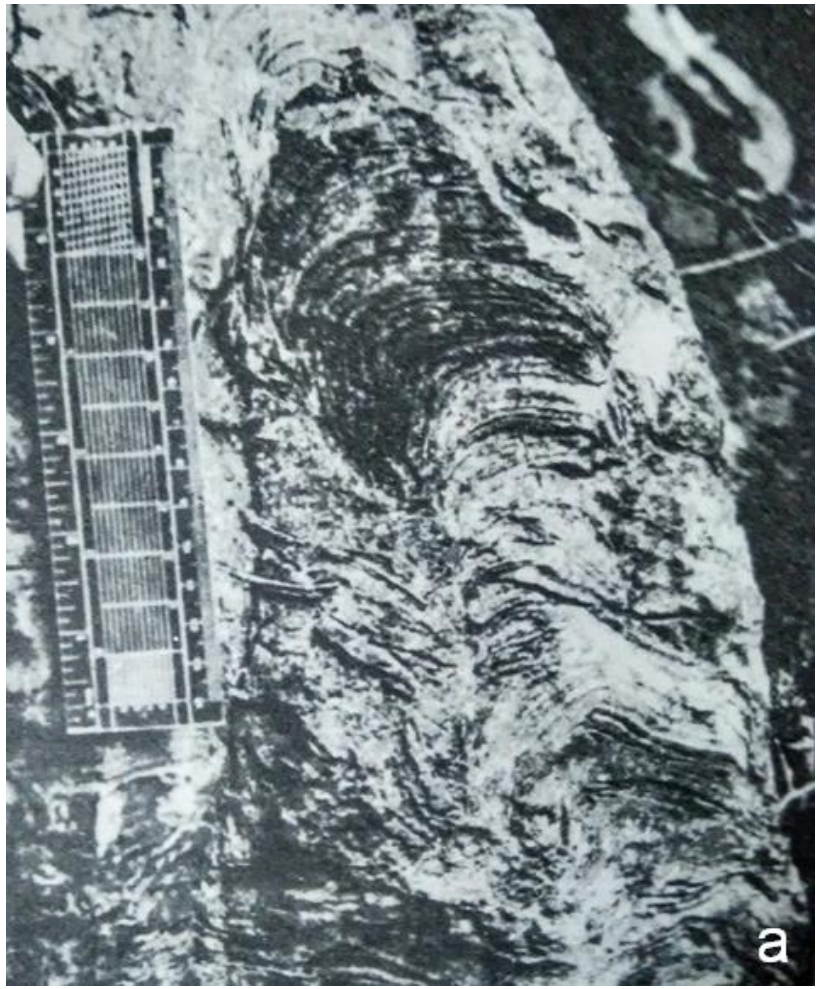
Depositional Environment and Sedimentation Pattern in Vindhyans

- The Vindhyan sedimentation is traditionally attributed to near-shore marine depositional environment.
- Recent studies, however, indicated highly varied depositional environments ranging from fluvial to deep marine environment during the Vindhyan sedimentation (Bhattachyarya and Morad, 1993; Bose and Chakraborty, 1994; Akhtar 1996; Chakraborty, C. et al. 1996).
- The basal succession (Semri Group) consists dominantly of carbonate association, which shows profuse development of stromatolitic structures and laminated algal mat indicating deposition under subtidal to supratidal conditions. The rare presence of gypsum layers indicated conditions favourable for the formation of evaporates (Akhtar, 1996).

Images of different forms of stromatolites in the Semri Group.

(a) Columnar Stromatolite in Kajrahat Limestone, Semri Group. Photo reproduced from Soni et al. (1987).

(b) Algal laminites in the Shalkhan Limestone of Semri Group, Maihar. Reproduced from Kumar and Sharma (2010)



Upper Vindhyan palaeoenvironment

- The Kaimur Group, consisting dominantly of siliciclastic rocks (shale, siltstone and sandstone) show a depositional setting that included tidal-flat lagoons, barrier island complex shoal-sand bar complex, and other tidally influenced environments. Intermittent emergent basin condition is indicated by the occurrence of desiccation cracks, raindrop imprints and rill marks (Akhtar, 1996).
- The main sandstone facies of Rewa group has been described as the deltaic facies (Bhardwaj, 1977). On the other hand, the shale-sandstone association show a coarsening upward regressive sequence generated by rapid build-up of a series of deltas along the coastal plains.
- The Bhander Group includes an important limestone formation (the Lakheri Limestone) which represents a transgressive sequence deposited in a protected, low-energy marine to marginal intermittently exposed tidal flats and shallow sub-tidal lagoons (Akhtar , 1996).

- Apart from the microbialites, there are references of micro- and macrofossils in the Vindhyan Supergroup. A number of planktonic as well as benthic microfossil assemblages have been recorded from the chemogenic as well as argillaceous sediments of the Vindhyan Supergroup.
- Azmi (1998) reported occurrences of small shelly fossils and brachiopods from the Rotashgarh Limestone (Semri Group). There are also several reports of enigmatic forms supposed to represent macrofossil from the Vindhyan rocks.
- Seminal studies made by Bose et al. (2015) indicated occurrences of distinctive facies assemblages and diverse palaeocurrents in different exposures of the Semri Group which play a pivotal role in the interpretation.
- Analysis of outcrop and subsurface data from under the Gangetic alluvium in the north of the Vindhyan outcrops supports the hypothesis that an east–west-elongated basement ridge initially separated the ‘master’ Vindhyan Basin from smaller contemporary basins to the north.
- According to Bose et al. (2015), the deposition took place in isolated lacustrine and fluvial basins north of the divide while a marine realm was in South.
- The uniform character of the Upper Vindhyans (the Kaimur, Rewa and Bhander Groups) throughout the Vindhyan Basin is because of the subsequent drowning of the divide ridge causing unification of all of the smaller sub-basins, primarily as the consequence of regional northward tilt of the basin (Bose et al. 2015).

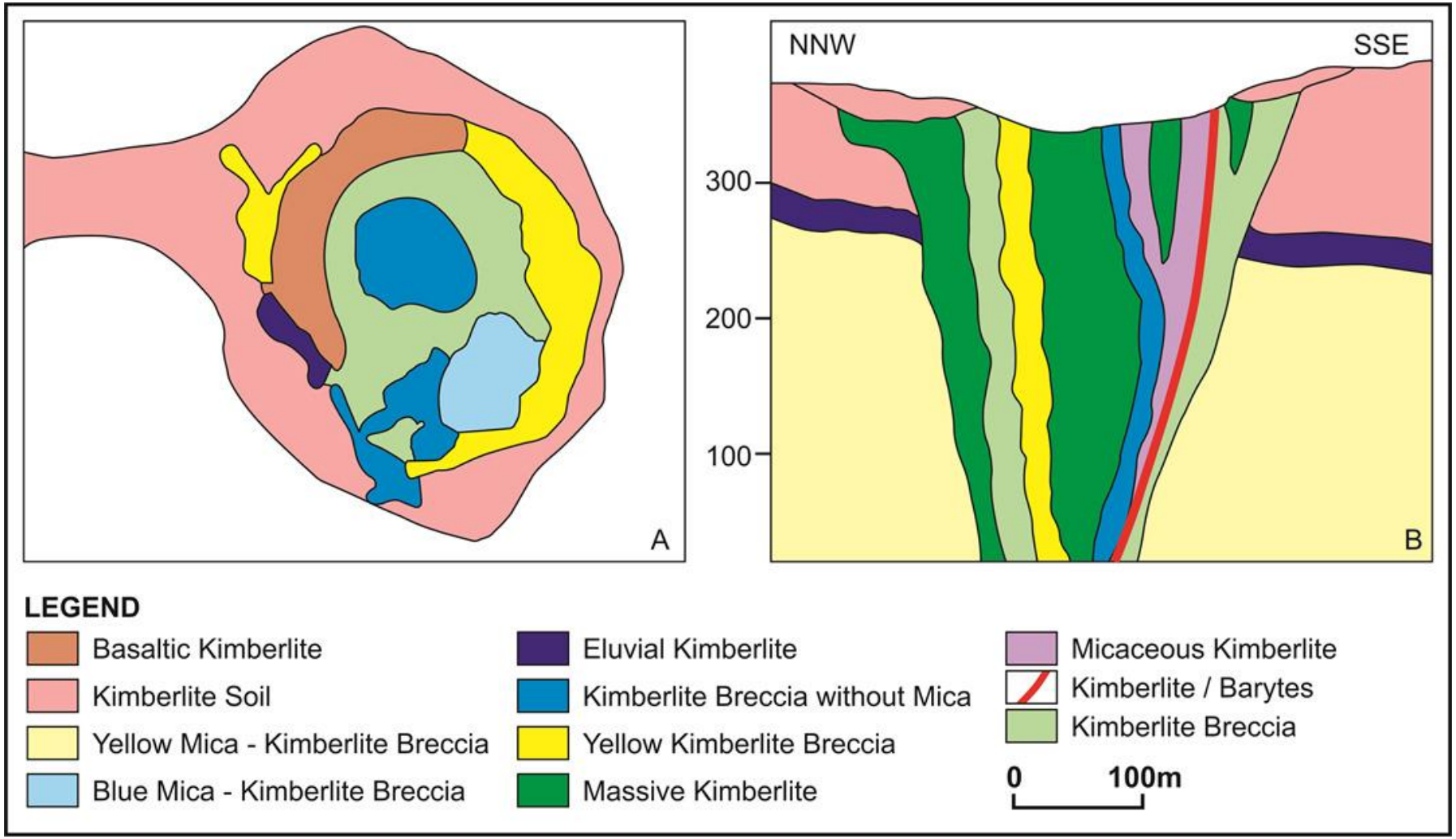
Volcanic activity

- Occurrences of porcellanite beds have been described from the basal Semri Group rocks in different parts of the Vindhyan deposits as the effusive-enriched bodies. Apart from that little is known about the volcanics in other lithostratigraphic formations.
- Three distinct volcanic eruptions have been detected in the Son Valley porcellanite bearing formation at Chopan (Srivastav et al. 2003) in the form of
- (i) ash-fall (volcanic ash/dust), (ii) pyroclastic breccia and ignimbrite, and (iii) finer pyroclastics, and silicified tuff (often described as chert).
- Studies indicate occurrences of pyroclastic deposits from the dominantly arenitic Kaimur and Rewa Groups (Chakraboty P.P. et al. 1996).
- In the Kaimur Group, lenses of pyroclastic layers have been recorded which occur as discontinuous layers varying from about 50 m to a few millimetres in thickness.
- Microscopic studies revealed occurrences of flow banding and stretched pumice fragments and locally concentric and radial tensional cracks with development of peripheral devitrification.
- SEM studies indicated occurrence of frozen droplets of viscous fluid with wrinkle marks and such other features. Volcano-clastics are reported in different forms in the shale units of the Rewa Group. Petrologically three different types are noted: (i) pyroclastic falls, (ii) flow breccia and (iii) epiclastics (Chakraborty, P.P. 1996).

Tectonics and intrusions

- An important feature reported by Chakraborty,P.P. et al. (1996) is that all the volcano-sedimentary deposits occurring at different stratigraphic levels are succeeded by major events of regression indicating regional uplift of the source area followed by erosion. The information greatly helps in the understanding the basin evolution and sedimentation tectonics of the Vindhyan rocks.
- Though smaller in dimension, the kimberlite and lamproite pipe-shaped plugs which occur at two places, Hinota and Majhgawan near Panna deserve special mention.
- The Majhgawan pipe in particular is characterized by diamond and phlogopite. Covering about 500 m ground surface, the cone–shaped Majhgawan plug is made of olivine lamproite type lapilli tuffs of the crater face. The diamond distribution is concentric within the body. The eroded materials from the plugs occur in the conglomerate horizons of the Rewa succession.

Surface outcrop (a) and a section through the Majhgawan Plug (b) showing structure and compositional characteristics of the Majhgawan ‘Pipe’. After Chatterjee and Rao 1995).



Basin tectonics

- Different aspects of basin evolution, inversion related tectonics and post-depositional tectonics of the Vindhyan Basin are studied mainly because of the accumulation of data on remote sensing, gravity, magnetic, magneto-telluric, and seismic reflection studies.
- All these data suggest a rift model for the Vindhyan sedimentation. Vindhyan Basin is constrained by two major fault-lineaments, the Great Boundary Fault virtually marking the northwestern, and the Narmada–Son Lineament bounding the southern and the southeastern margins.
- Evidences suggest that these two basin margin faults-lineaments actually acted as rift shoulders during different periods of deposition of the Vindhyan sediments. Available regional gravity and magnetic data coupled with the analysis of the seismic reflection data coupled with the analysis of the seismic reflection profiles indicate southward deepening of the basin, the deepest part occurring close to the southern basin margin.

- The Narmada-Son Lineament constitute the southern basin margin fault during the Vindhyan sedimentation. Although no detailed subsurface data are available from the western Vindhyan Basin, it has been argued that the Great Boundary Fault, representing northwestern margin of the western Vindhyan Basin, also behaved in a similar fashion (Verma, 1996).
- Although the nature of movements observed along the intrabasinal as well as the major basin margin faults is dominantly of the strike-slip type, the interpretation of thickness variation and the abrupt changes in lithofacies across the faults indicate that these are post-depositional faults.
- The opening of the Vindhyan Basin was due to trans-tensional rifting (Jokhan Ram et al., 1996) during the extension of the stabilised parts of the surrounding Crust.
- The north-south trending open folds east of Chittaurgarh resulted due to the easterly push of the Aravalli Protocontinental block. On the other hand, the tight to isoclinal folds along the southeastern margin were formed due to the transpressional movement of southeastern crustal block. It is possible that the differential movements of the different crustal blocks had also resulted during the late Quaternary. The present seismicity along the Narmada-Son Lineament is a proof of such pattern of the Quaternary and the Recent crustal movements

Age of Vindhyans

- Based on the study of the multicellular palaeobiological evidence, Venkatachala et al. (1996) suggested that the 'Purana' sediments of the Vindhyan antiquity range in age from the Lower Riphean to Upper Riphean (i.e., between ~1650 and ~600 Ma).These authors also inferred Crygenian age (850 to 650 Ma) of the Vindhyans.
- There is, however, no record of any incontrovertible evidence to mark the Precambrian-Cambrian boundary in the Vindhyan sediments.
- The Rb-Sr study of glauconites from the basal Semri Group yielded ages of 1449 ± 15 , 1461 ± 15,1504 ± 15 and 1531 ± 15 Ma (Anil Kumar et al. 2001).
- Ray et al. (2002) reported 1631±5 Ma zircon ages using U-Pb zircon dates and Sr isotope systematics from the procellanite beds in the Semri Group.
- Further, 1628±8 and 1599±8 Ma U-Pb zircon ages are reported by Rasmussen et al. (2002) from the Chorhat Sandstone bearing evidence of burrows of the triploblastic animals in the Lower Vindhyan sequence.
- Records of much older ages come from 1729±110 Ma Pb-Pb age from the Kajarhat Limestone in the Semri Group (Sarangi et al., 2004).
- Similar older age of ~1721 Ma comes from the study of trace element and Nd isotope data by Chakrabarty et al. (2007), who indicated that these older ages are from the source rocks of the Vindhyan sediments.

- The K-Ar age of the phlogopite of the Majhgawan pipe is 1140±112 Ma (Paul et al., 1975). The Rb-Sr isochron age of lamproite body is 1067±31Ma (Anil Kumar et al. 1993). Since the kimberlite pipes are intrusive in the Kaimur Group rocks, it may be assumed that the depositional age of the Kaimur rocks must be older.
- Collating the available geochronological data, it may be suggested that the Vindhyans sedimentation was initiated with the deposition of Semri Group at around 1600 ± 50 Ma.
- The kimberlite ages on the other hand suggest that the deposition of the arenite dominant Kaimur Group must have taken place before the intrusion of the diamond bearing plugs around 1050 Ma.
- There is no reliable isotope data to fix the age of deposition of the youngest units, the Rewa and the Bhander. Inferences have been made about the Crygenian age (850 to 650Ma) of the younger Vindhyan sequences based on the occurrence of multicellular palaeobiological evidence.
- In short, it may be suggested that the geological evolutionary history of the Vindhyans spanned over about 1000 million years during the Meso- and Neoproterozoic.
-