

CONCLUSIONS

The Cretaceous Bagh Group sequence of the Western Lower Narmada Valley attains a thickness of more than 300 meters and is exposed as detached outcrops. A detailed investigation was done on sedimentological and ichnological aspects by the author to analyze the sequence stratigraphy, which leads to the following conclusions:

- The lithostratigraphy of Cretaceous succession of WLNV is amended and assigned the Bagh Group according to ISSC ranging in age from Berriasian? (Neocomian) to Coniacian.
- Bagh Group is divided into five formations, namely Songir, Vajepur, Bilthana, Nodular Limestone, and Uchad formations in ascending order. The old names such as Songir Bilthana and Nodular Limestone are retained; Vajepur and Uchad formations are the new units introduced. The Uchad Formation is further subdivided into the Narmada Sandstone and Men Nadi Limestone members.
- The stratigraphic succession of the Bagh Group comprises siliciclastics, mixed siliciclastic-carbonates, shales, and carbonates rocks which are further classified into fourteen facies, conglomerate, planar and trough cross-stratified sandstone, horizontal-thinly bedded sandstone, massive sandstone, bedded quartz arenite, shale, calcareous sandstone, micritic sandstone, sandstone- siltstone-shale, sandy/silty allochemic limestone, fossiliferous limestone, sandy/silty micrite, mudstone, and muddy micrite.
- The Songir Formation at the base of the Bagh Group succession is composed of non-marine sediments and deposited in a fluvial-braided and alluvial-fan environment. It lies unconformably above the Precambrian basement and corresponds to the initial rift phase.

- The overlying Vajepur Formation marks the onset of base-level rise during the Albian. It is represented by the cross-stratified sandstone-shale in the lower part and the laminated and rippled calcareous sandstones (marine fossils) in the upper part.
- The Bilthana Formation constitutes oyster beds intercalated with the shale and shows the presence of well-preserved body and trace fossils. The succeeding Nodular Limestone is widely traceable in the LNV containing abundant ammonites of the Turonian age. The sedimentological and ichnological evidence suggests deposition of Bilthana Formation in lower shoreface/offshore transition and Nodular Limestone in the offshore environment.
- Uchad Formation differs from the underlying Nodular Limestone in having a distinct lithological assemblage and bed geometry. The Narmada Sandstone Member represents the high-energy shoreface environment, whereas the overlying Men Nadi Limestone Member consists of distal shoreface deposits.
- Sandy allochemic limestone, micritic sandstone, sandstone-siltstone-shale, fossiliferous limestone, mudstone, bedded quartz arenite, planar cross stratified sandstone, and calcareous sandstone facies are low-to moderately bioturbated and show the presence of twenty-six ichnospecies belonging to seventeen ichnogenera, including *Apectoichnus*, *Archaeonassa*, *?Arenicolites*, *Bergaueria*, *Conichnus*, *Conostichus*, *Didymaulichnus*, *Gordia*, *Helminthoidichnites*, *Lockeia*, *Oniscoidichnus*, *Paleophycus*, *Planolites*, *Ptychoplasma*, *Skolithos*, *Taenidium*, and *Thalassinoides*.
- Overall density of the trace fossils is low and represents five ethological categories, including cubichnia, pascichnia, domichnia, repichnia and fodinichnia.
- Nine trace fossil assemblages, namely *Apectoichnus*, *Archaeonassa*, *Bergaueria*, *Conichnus-Conostichus*, *Helminthoidichnites-Gordia*, *Lockeia-Planolites*, *Skolithos*, *Taenidium*, and *Thalassinoides* represent three ichnofacies namely, *Skolithos*, *Cruziana*, and *Glossifungites* which reflect the environmental conditions (bathymetry, salinity, oxygenation, energy conditions, sedimentation rate, substrate characteristics)

- Occurrence of abundant plug-shaped burrows- *Bergaueria hemispherica*, *Conichnus conicus*, *Conostichus stouti*, and *Conostichus broadheadi* recorded from the Cenomanian-Turonian Bilthana Formation is limited to the fine-grained, soft, unconsolidated, non-fluidized clastic sediments, which appears to be favorable for sea anemone colonization.
- Uniform fill, prominent relief, and lack of slump structures suggest that all the sea anemones simultaneously vacated the burrow, which was subsequently filled by the overlying sandy allochemic limestone indicating an increase in energy conditions in the shoreface environment.
- The presence of densely packed, unaltered, least abraded, disarticulated, unoriented oyster shells with faint growth lines and the presence of *Thalassinoides* and plug-shaped burrows at the sole of the oyster limestone bed suggests surface exhumation followed by storm events in the offshore-transition environment.
- The increase in ichnodiversity observed in the upper part of the Vajepur Formation suggests a low-energy, nutrient-rich, shoreface environment. In contrast, the ichnofauna of the Bilthana Formation is dominated by comparatively deeper feeding burrows of *Thalassinoides* followed by plug-shaped burrows.
- The high ichnodiversity and ichnodensity of deposit-feeding burrows in the sandy allochemic limestone and fossiliferous limestone facies of the Bilthana Formation suggest concentration of nutrients in a well-oxygenated substrate, while the occurrence of plug-shaped burrows of suspension feeders suggests ample supply of nutrients from the water column.
- An abrupt decline of body fossils and trace fossils in the Nodular Limestone and the presence of pyrite suggest reduced oxygen or dysoxic conditions.

- Overall, the Cretaceous Bagh Group is characterized by low-moderate ichnodiversity, dominated by large *Thalassinoides* burrows suggesting flourishing of decapod crustaceans followed by sea anemones, gastropods, polyphyletic vermiform, and arthropods.
- The *Cruziana* ichnofacies is characterized by moderate diversity of horizontal structures made by mobile organisms, suggesting low to moderate-energy conditions, and abundant nutrients and oxygenation in the sediments in the shoreface environment.
- The *Glossifungites* ichnofacies are characteristics of the Bilthana Formation suggesting unlithified, stable, cohesive substrate such as dewatered muds produced due to burial and later made available to the organisms due to erosion.
- The *Skolithos* ichnofacies observed in the Narmada Sandstone Member suggest changes in the substrate consistency, well-oxygenated bottom water conditions, and abundant suspension food supply in the shoreface environment.
- Sedimentological and ichnological data of the Bagh Group revealed first-order genetic sequence characterized by various System Tracts, Sequence Stratigraphic Surface, Systems Tract Boundary, and Sequence Boundary.
- HAST is characterized by the alluvial fan and braided channel deposits in Songir Formation represented by conglomerates facies, planar and trough cross-stratified sandstone facies, horizontal-thinly bedded sandstone facies, and massive sandstone facies.
- LST is characterized by prograding and aggrading deposits, which filled the accommodation space created by the rising base-level. LST is poorly bioturbated and consists of *Helminthoidichnites-Gordia* and *Taenidium* assemblage. The low ichnotaxonomic diversity and density of trace fossils suggest deposition in a stressed foreshore environment.

- The TST-I comprises rippled quartz arenite/calcareous sandstone and micritic sandstone facies of the Cenomanian Vajepur Formation; fossiliferous limestone-shale, shale, sandy allochemic limestone facies belonging to Bilthana Formation of Cenomanian-Turonian age, and the mudstone and sandy micrite facies of the Turonian Nodular Limestone. The lower part of the TST-I comprises abundant plug-shaped burrows of sea anemones with *Archaeonassa*, *Oniscoidichnus*, *Lockeia*, *Ptychoplasma*, and *Thalassinoides*, while the upper part comprises abundant marine body fossils and trace fossils of shoreface to the offshore environment.
- TST-I is characterized by the Maximum Flooding Surface (Sequence Boundary), two minor Flooding Surfaces (FS-I and FS-II), and Transgressive Ravinement Surface (TRS); it shows a retrogradational stacking pattern and a fining-upward succession characterized by an increase in the carbonate content towards the top suggesting the rate of base-level rise outpaced the sedimentation during the Turonian.
- The transgressive phase shows an abrupt change in lithofacies and ichnofacies (*Skolithos*) in Narmada Sandstone Member represented by the Highstand Systems Tract-I (HST-I) where progradation and aggradation took place during the highstand of base-level and high rate of sedimentation has outpaced the accommodation space resulting in normal regressive deposits.
- TST-II marks the second transgressive event during the Coniacian characterized by muddy micrite, shale, and mudstone facies of the Men Nadi Limestone Member. The facies variation across the minor within trend surface (Flooding Surface-III) shows a retrogradational stacking pattern due to base-level rise.
- The sedimentological and ichnological data of the WLVN reveal the stratigraphic succession is correlatable with pervasive Cretaceous Tethyan basins like ELNV, Eastern Desert, and Saurashtra while differs from the Carnarvon, Mahajanga, Cauvery, and Kachchh.

- The (Berriasian?-Aptian) Songir Formation is correlatable with the Early Cretaceous fluvial Himmatnagar Sandstones of Cambay basin, fluvial Nimar Formation of the ELNV, the fluvio-deltaic Bhuj Formation of the Kachchh Basin, and the fluvial Dhrangadhra Group of the Saurashtra Basin.
- Albian-Cenomanian calcareous sandstone of Vajepur Formation (WLNV) is correlatable Surendranagar Sandstone Member (of the Saurashtra Basin); the Turonian Nodular Limestone of WLNV and ELNV are correlatable with the Navanaia Limestone of the Saurashtra Basin, and Coniacian Uchad Formation is correlatable with Bryozoan/Coralline Limestone of the ELNV and the Bhaduka Limestone Member of the Saurashtra Basin.
- The age of the youngest unit of the Bagh Group, Coralline Limestone of the ELNV and Men Nadi Limestone Member of the WLNV, coincide with the rift event of India from Madagascar and outpour of flood basalts in the Mahajanga Basin.

The WLNV basin preserves a complete Cretaceous geological record and witnessed regional and global events. Sedimentological and ichnological evidence document the intracratonic rift events with the major marine transgression of the Cretaceous, which have facilitated correlation with the pervasive Tethyan Basins.