ABSTRACT

Systematic investigation of sedimentary and stratigraphic architecture and sediment geochemistry within modern continental foreland basins not only provides insight into the evolution in fluvial processes and environments in response to external controls but also contributes to our understanding of the nature of the subsurface. In this regard, the Quaternary alluvial system of Gangetic Foreland Basin which supports several densely populated cities containing more than ~500 million people, provides an excellent opportunity to assess the influence of modern sedimentary processes on the urban underground space resources. The motivation for this research is to investigate these processes in detail and consider how improved geological understanding can contribute to the sustainable management of the natural resources and socio-economic development of the city of Varanasi.

Utilising a network of 87 boreholes, this research presents a geological framework that utilises the capture and detailed description of lithological and gamma-ray borehole logs (up to 100 m depth) to identify lithofacies and their associations which reflect the variation in depositional architecture elements. The vertical stacking pattern of these lithofacies assemblages further permits for the first time the application of sequence stratigraphic principles to the Gangetic alluvium.

This study identifies the fluvial architecture to comprise three stratigraphic sequences, bounded by both conformable and unconformable surfaces. The oldest, Sequence 1 (~38–100 m depth) comprises in upwards succession, a series of degradational–transitional and aggradational systems tracts reflecting a change from proximal–distal braided channel networks and eventually evolving to anastomosing behaviour. The overlying Sequence 2 (~9–38 m depth) and the youngest, Sequence 3 (up to ~9 m depth) are both interpreted as aggradational tracts correlating with the present-day axial-tributary regime.

Recognising that allogenic controlled changes in sediment geochemistry may reflect the drainage modifications responsible for variation in accommodation spaces, this study utilises the major, trace and REE geochemistry of sediments to make a preliminary investigation of the evolution of the multi-sourced sediment-supply system into the Himalayan distal foredeep. The abrupt variation of elemental ratios across the sequence boundaries indicates the presence of geochemically distinct sediment packages that confirm the stratigraphic framework. The deeper degradational tract sediments of Sequence 1 are of cratonic origin (Central Bundelkhand Greenstone Complex) and are progressively overlain by Lesser Himalayan sediment as the river system transitioned to aggradational conditions. Sequence 2 and 3 sediments are mostly derived from Higher Himalayan Crystalline Sequences.

Based on this framework, a hydrostratigraphic model is proposed to identify and correlate the aquifer systems in each systems tract and separated them by the bounding surfaces. The model shows the degradational tract of Sequence 1 to have high connectivity and is likely to yield potable and economically sustainable groundwater. This hydrostratigraphic architecture is then correlated with aggradation-degradation induced lithological variations to provide an integrated 2D urban hazard zoning map and 3D lithotechnical (lithological & geotechnical) model relevant for preliminary assessment of the subsurface engineering conditions to inform underground infrastructure development.

In summary, this multi-disciplinary study highlights how fluvial processes within a foreland setting evolved with changing accommodation spaces and how their resulting architecture provides an initial foundation for future urban planning and city development.

Keywords: Continental foreland basins, Urban underground space, Varanasi, Gangetic alluvium, Stratigraphic sequences, Hydrostratigraphic architecture, 3D lithotechnical model