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RESEARCH ARTICLE

A tectono-hydrogeologic investigation on the late medieval Ahom Era ponds of the Brahmaputra Valley, Northeast India

Farha Zaman*, **Uttam Goswami, Devojit Bezbaruah**

Department of Applied Geology, Dibrugarh University, Assam, India

The Brahmaputra valley was formed by stratified deposits of Palaeo-Proterozoic to Recent sediments that were drained from the Himalaya, Assam-Arakan, and Shillong-Mikir Hill ranges. The underlying hydrogeologic system was developed by alluvium (sand-silt-clay mixtures) layer. Several ancient kingdoms have thrived because of this hydrogeologic environment as a whole prior to the Ahom dynasty (1228-1826 AD). Ahoms were the final monarchs and they made a major impact on Assam's history, particularly about pond building methods. This study has investigated tectonic and hydrogeological aspects of the major pond series in the Sivasagar District, Assam, using satellite imageries, subsurface lithologic distribution (panel or fence diagram from boreholes data), water table, and surface water variation. The regional groundwater flow is parallel to the east-west linearly aligned major ponds. The moat, or jamuna, that is built around these large ponds plays a vital part in preserving the water level. The sandy clay layer is found on top of the aquifer creating confined aquifers that have kept the water pressure constant, with the foothills having the maximum water pressure. Majority of ponds close to the foothill, therefore, do not need Jamuna surrounding them. The area is controlled by the splaying of the Jorhat Fault, the Naga Thrust zone, and local tectonic features. Conversely, the water from the Jamuna, paleo-channels, and channels has fed the large ponds in the valley. The water level has been sustained by the hydrogeologic environment as well as the link between the Jamuna and the ponds' effluent-affluent groundwater.

Keywords: Brahmaputra, Ahom, Pond, Hydrology, Tectonics

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*For correspondence:
zaman.farha@outlook.com

Contact us:
mizoacadsci@gmail.com

Introduction

In the 18th century, the ruling Ahom dynasty (1228-1826 AD) of the plains of Brahmaputra Valley, Assam of northeast India (Fig. 1 and 2) had constructed many monuments like mounted domes- Moidam, cultural and royal palaces- Ghars, Temples and man-made ponds or the Pukhuri (Fig. 1). They constructed such architectural marvels with ancient myths based on futuristic approach and understanding of geology and engineering. Most fascinating among all these features are these ponds of varying sizes.[1,2,3,4,5] The Ahom's were advanced in matters of science and technology.[6,7] Their creativities, designs and the unorthodox approaches used for such construction is unparallel and is no less than any aesthetic design and architectural technologies of present times.[8] Their medium of construction was evolved with time, from perishable materials to brick and lime mortar.[9,10,11] In Sivasagar (earlier known as Sibsagar), there were more than 170 Pukhuris i.e., ponds or tanks, many of which now have been dried up, encroached, and filled up. The ponds were built at an elevated part from the surroundings and have thick boundaries. They also constructed temples on the bank, which might be one to four in number.[12] There is a historical

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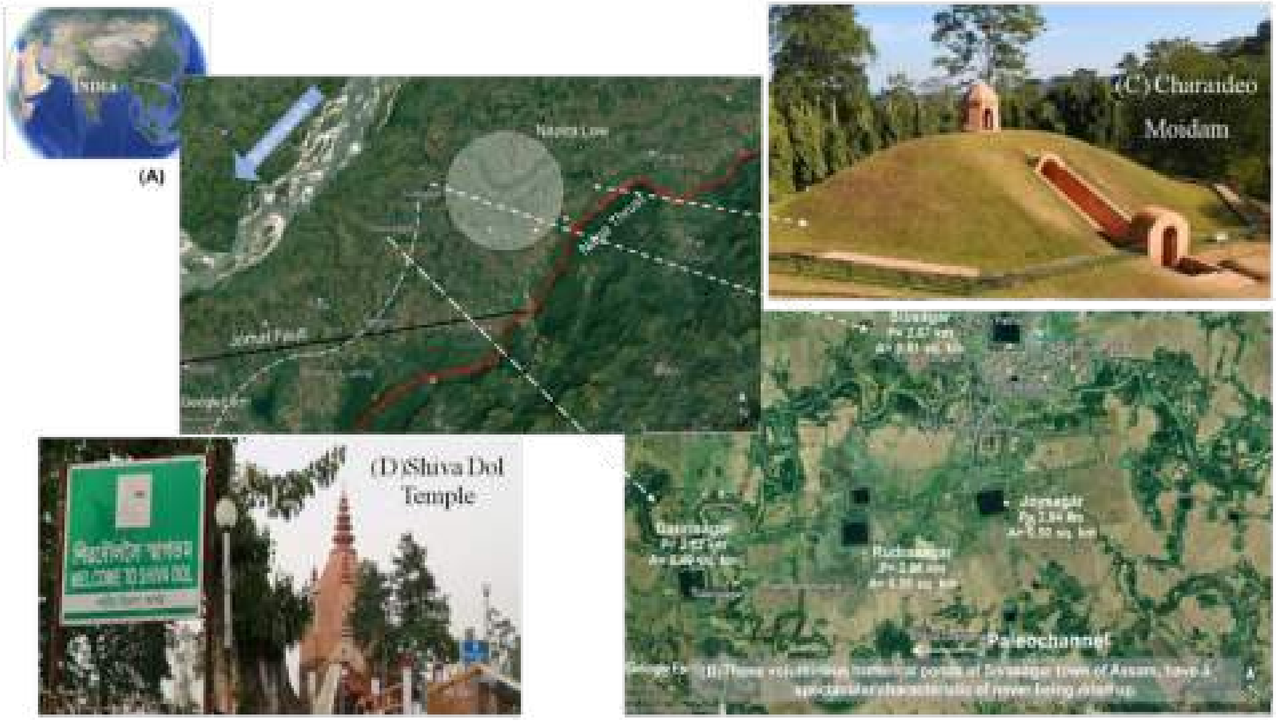

Figure 1. Location map of the study area representing (A) the tectonic factors associated with eastern part of the Brahmaputra Valley once ruled by the Ahom Kings. They constructed (B) Several big pond or Pukhuris, (C) Moidams and (D) Temples

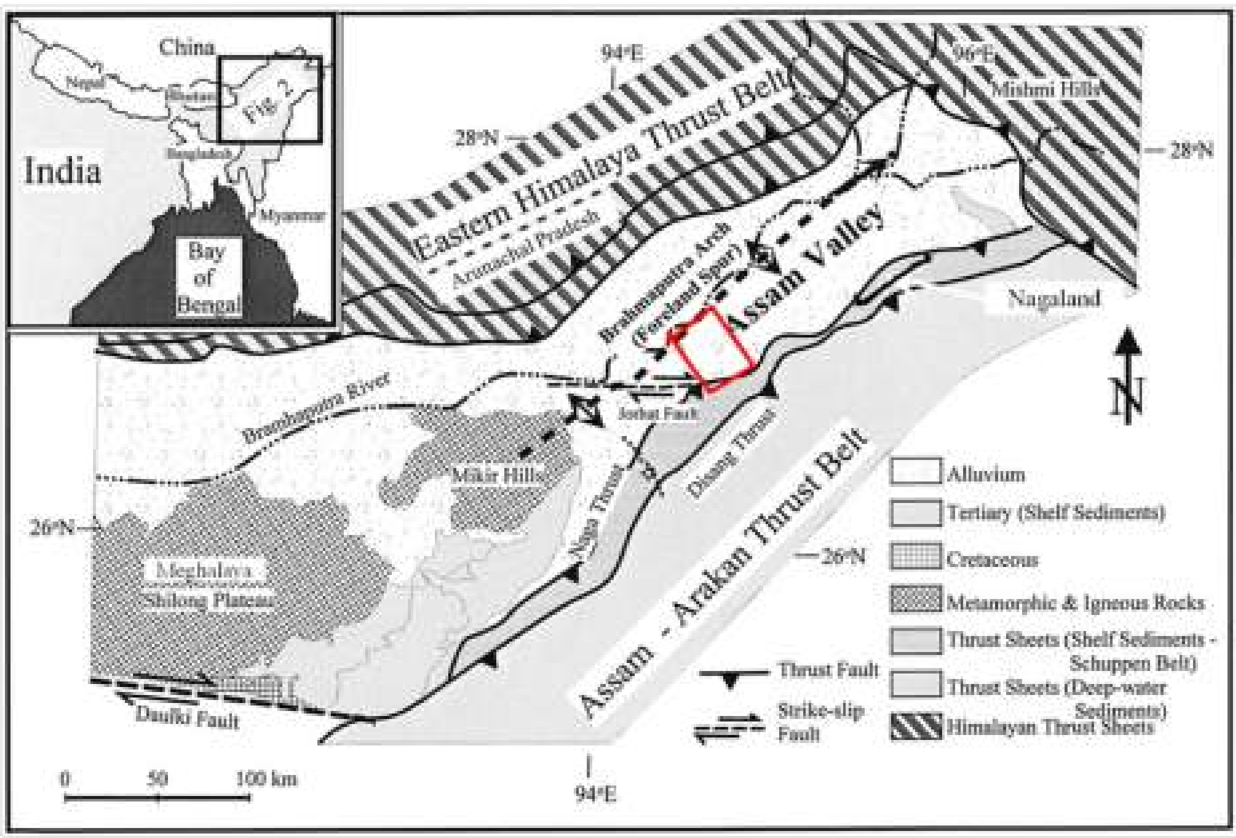

Figure 2. Regional Tectonic setup of the Brahmaputra Valley which is also known as Assam Valley, northeast India. The Red box indicating the study area (Map from Berger et al.[41]).

significance of ponds in Brahmaputra valley, both during pre- and post- Ahom times. Many kingdoms like Danov, Borman, Shalstambha, Pal etc. have ruled the historical Kamrup State across the Brahmaputra Valley during pre-Ahom era (Barpujari[12] and references within). There are many evidences indicating digging or construction of ponds during their respective regimes. Seventh century famous king Bhaskar Borman had constructed many reservoirs.[1] On the other hand, Pal kingdom also built many temples in the entire Brahmaputra Valley.[4] Jitari, Bhuyan-Samanta, Chutia, Kachari, and Koch people afterwards prioritized excavating and building ponds.[3,4,6] There are numerous Chutia Kingdom remains, including the ponds they built, in the modern Lakhimpur district of Assam (such as Gorkhiya Dol or the temple in Dhakuakhana) and Siang district of Arunachal Pradesh. Along the banks of the Dibong and Dikrong Rivers, British army commander Captain Hannay recorded the remains of old temples and ponds. Ponds were utilized by the Kachari tribe to define the border in the Gaurisagar area of the Sivasagar district. The Silpukhuri ponds, which are designated as the Kachari and Ahom kingdoms' border, are located in each of the Hatighuli, Mitong Naktani, and Khonakhokora localities.[4,7,9]

Several ponds were built during the Ahom dynasty, including the well-known Sivasagar, Joysagar, Rudrasagar, and Gaurisagar as well as other smaller ponds to show respect for the Kings, Queens, and other significant people.[1,5] Ponds were utilized to store water and used to produce fish, crops as well as in royal rites. Additionally, water sports were practiced here. Their building process largely hinges on the lunar tide cycle first, followed by locating an artesian aquifer or spring source. Pond construction is under Chang Rung Phukan's (a gazetted officer in the Royal assembly) supervision. The source is entered using a long, pointed stick or piece of hollow wood with a sharp bottom end. Later, large tree trunks with an outside surface spiraling inward are put in the center, known as Nagmaari. At the base of it, a Tamrapatra (special copper sheet) is positioned. The Tamrapatra is covered in specially made juice while also being topped with charcoal or stone fragments. The water is filtered using this process.[7] From high to low areas, fireclay and iron rods connect each of the ponds. Their construction strategies for the future, however, have never been examined in such depth previously. Ahom built the pond by digging only to some meters and then dug up the outer boundary as a closed water channel surrounding the main water body (Fig. 3). This was called as Jamuna or moat. It has very significant role in maintain the water level in the main pond, however exact process was not discovered which drives this research work. These water bodies might have important role in maintaining the ponds throughout. This worked as a system and somehow maintained the water level for ages. Though there are some hypotheses behind this but no one has ever proved how the water level is maintained throughout different centuries in all seasons. This also works as water reservoir which might be related to their preparation for any dry season or high heat conditions; though this area is subjected to high precipitation due to Indian Monsoon. Moreover, it might also work as flood water management system to uphold the excess water during the

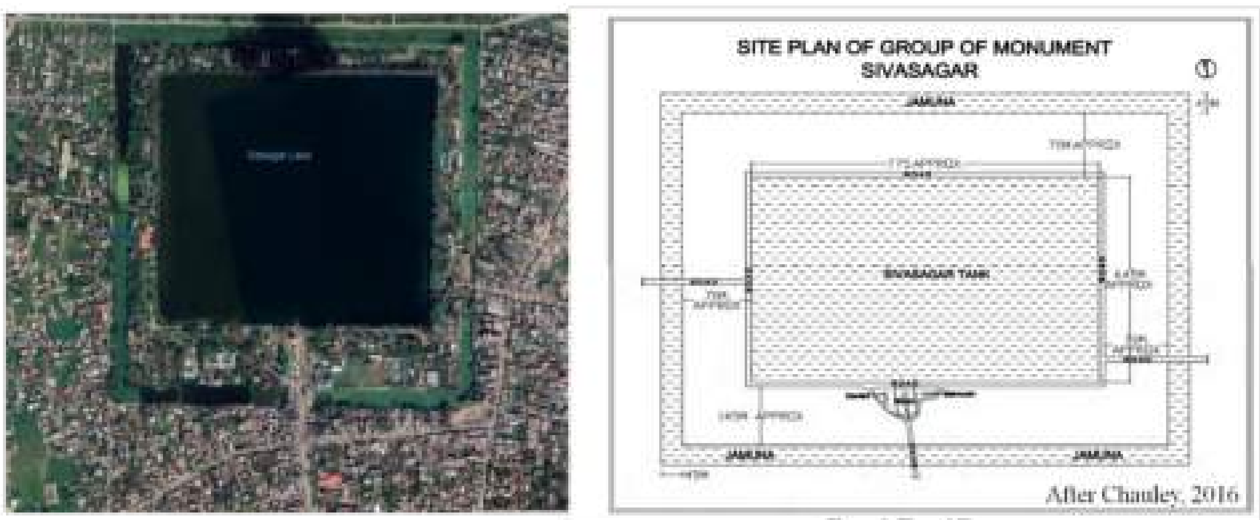

Figure 3. Ahoms' built moat, locally known as Jamuna which helps to maintain the water level in the ponds. The sketch after Chauley[10].

rainy season.

The proposed area under this study lies within the Ahom's capital region in Assam valley bounded by the Himalayas in the north and Naga Hills in the south. It comprises of alluviums with shelf (Mikir Hills) and geosynclinal facies-Naga Hills.[5] There are many tectonic features present in the region including some major faults such as Naga-Disang thrust zone in the south, Jorhat Fault in the west and geologic features like Nazira Low in the eastern side as shown in Fig. 1A.[13,14,15] The Naga-Disang fault zone is comprised of thrust splays that includes minor sub-Thrusts.[4,5,16] It has pronounced effect on the tectonics of the region. These thrusts are active and a number of local faults have generated due to ongoing deformation in the foothill area because of splaying from the Naga Thrust.[16,17,18,19] The study area falls under the direct influence of the Naga orogeny together with influences of climate that gave rise to present topography. Tectonic control and thereby the hydrogeologic factors on the formation of the Brahmaputra valley shape both the distribution of the natural water bodies as well as the civilization on the northeast India. The age of the geological formations of the Brahmaputra valley spans from the Palaeo-Proterozoic to the recent.[20,21,22,23] The older rocks consist of a complex of metamorphic gneiss to schist rocks. Quartzite and phyllite make up the Neo-Proterozoic group, which is overlain by continental shelf sediments from the lower Tertiary that date back to the Eocene, shelf sediments from the upper Tertiary to Oligo-Mio-Pliocene, and undifferentiated older and younger alluvium from the Quaternary.[24-32] In the Brahmaputra flood basins, significant rainfall of up to 400 cm per year enables adequate groundwater replenishment. According to Central Ground Water Board[33], the groundwater table typically sits 10 m or less below ground level. Additionally, the groundwater exists in both confined and unconfined settings. This also reflects in the various water bodies present in the valley.

In the present context, study of the human made water bodies i.e. the ponds were undertaken which seems to be aligned along the Naga thrust.[5] The recharge zone is located at a higher level in this region. As it is observed that south of Jorhat fault consists of highlands whereas north part comprises of lowlands. Both the Naga thrust and the Jorhat Fault have uplifted the region over the course of time. The recharge zone in this region has been uplifted too. The Naga thrust is active in the present times. The neotectonic activities in the region indicate activeness of the same. In the Assam valley, the bank stratigraphy of Dikhow River reflects the deformation of Quaternary sediments like changes in dip from north bearing to south in different places. This deformation of the soft older alluvium indicates that the area is undergoing deformation during post-Pliocene time.[5]

Regional Tectono-Hydrology

The Brahmaputra basin is a composite foreland basin positioned between the Assam-Arakan thrust region and the northeastern Himalayan foothills.[34,35,36,37] The Naga Thrust and the Himalayan Frontal Thrust have established a structural triangular zone that includes the basin.[38,39,40,41] The Himalayan orogeny to the north, the Mishmi thrust to the east, and the Assam Arakan mountains to the south have all had significant tectonic influences on the basin layout. (Fig. 2). It is distinguished by an asymmetrical slope that dips gradually in the direction of the Naga Hills in the south and the Himalayan foothills in the north.[36,37,42,43,44,45] The Shillong plateau uplift to the southwest partially disrupts the northeast side of the basin, which is terminated at the Mishmi Thrust to the northeast. The central basement of the basin has undergone intense flexure and structural arrangements because of the Indian Plate's convergence with the Eurasian plate and its collision with the Burmese Plate, producing a number of highs and lows.[40,46-51] The sediments were separated into various lithological groups and placed on top of the crystalline rocks. These deposits, which include limestone, shales-sandstone, coal-shale beds, significant sandstone, mottled and variegated clays, intercalated sands, and substantial alluvium cover, were created in a range of shallow marine, deltaic, and fluvial environments.[35,36,40,52-57] The basin currently receives sediment from all three sides, i.e., north, south, and east, due to the massive fold and thrust belts that surrounds it (Fig. 2).[36,40,45]

The Brahmaputra River basin covers 5,80,000 square kilometers, with China (50.5%), India (33.6%), Bangladesh (8.1%), and Bhutan (7.8%) sharing it. Although the river does not pass through Bhutan, 96% of the nation is within its catchment area. The catchment area in India spans 1,94,413 square kilometers and includes the states of Arunachal Pradesh, Assam, West Bengal, Meghalaya, Nagaland, and Sikkim. In Assam, the valley is primarily covered with more recent and older alluviums, with crystalline rock remnants mounting out in certain places. Most rivers flow down the Himalaya, Mishmi-Naga Hills, Karbi Hills, and Shillong Plateau during the monsoon. Most of the runoff water comes from this, which maintains the sediment flux from the incipient of the valley. The distribution of the sand and clay layers beneath the topsoil was shown to affect the ground water. The Brahmaputra flood plains receive enough groundwater recharge thanks to heavy rains of up to 400 cm each year. Groundwater table typically sits 10 m or less below the surface, though susceptible to the seasonal variability (Fig. 4).[33] The subsurface alluvium contains confined and unconfined groundwater. The aquifer is made up of sand, silt, clay, and gravel, with medium- to coarse-grained sand making up around 50% of the total aquifer material. The crystalline gneiss-schist complex and limestone are the subsurface materials in the center region of the Brahmaputra valley, which is partly mountainous.[57] The horizon contains groundwater that travels through joints, cracks, and fissures. In the southern portion of the Brahmaputra valley, semi-consolidated sediments are revealed, together with mudstone and sporadic patches of sandstone. These result in the formation of regional groundwater conditions from 130m to 40m distributing west to east of the Brahmaputra Valley.

Methodology

For proper tectono-hydrological analysis, geological field-based investigations have been conducted in all of Assam's Sivasagar and Charaideo districts as well as those that bordering Nagaland. Pond elevation and in relation to the Jamuna and other neighboring areas were recorded during the field visit. First, a remote sensing approach was used with Google Earth and ArcGIS, Global Mapper to analyze satellite images. The identification of changes in the channel morphology and water bodies was made much easier by these imageries. Additionally, the connection between rivers and ponds may be seen. In addition to direct geological research, water table contour maps and fence diagrams were produced using subsurface drilling data from the Public Health Engineering Departments (PHED). This is followed by preparation of geologic maps and sections. Detail studies of the geologic attributes would be recorded during the field visits. Later, the features were plotted in the geologic map by using GIS software. Application of Geospatial technology for understanding the water level with respect to the surrounding conditions are collected and corrected with the field data. Correlation of the litho-logs, generated from the borehole data, with hydro-geologic studies to understand the reason behind constant water level. The borehole data have been acquired from the PHED of Sonari, Nazira and Sivasagar under Government of Assam. Moreover, topographic maps and satellite imageries were evaluated for identifying major active faults.

Figure 4. Regional hydrogeologic map of Brahmaputra valley (source CGWB[33])

Results

The first outcome appeared from the historical literature which suggests the Ahom people possess the expertise for the pond construction. The indigenous knowledge system that they used in the identification and construction of the ponds became obsolete in the course of history. Satellite imageries and Google earth images inferred that the area is comprised of many small to medium paleochannels which became route for the overflow water during the floods (Fig. 1B). The ponds are found to be associated with these paleochannels either directly or indirectly. The three major ponds of the Sivasagar districts are Sibsagar, Joysagar, Rudrasagar and Gaurisagar. These ponds were built around the Dikhow River. There are three ponds on the western bank of the river and one on the eastern part. The perimeter (P) and the area (A) of these ponds are Sibsagar P = 2.87 km, A= 0.51 sq. km; Joysagar P= 2.84 km, A= 0.50 sq. km; Rudrasagar P= 2.98 km, A= 0.55 sq. km; and Gaurisagar P= 2.82 km, A= 0.49 sq. km respectively. These ponds never dried up and therefore study of such ancient techniques might be the solution to water crisis. Their construction method of putting hollow wood and then the Nagmaari is very systematic way to pierce the aquifer in such a way that most of the groundwater pressure remains in the same region.

In present day context, the using of borehole data helps us to create the subsurface lithological distribution as panel or fence diagram (Fig. 5) and water table contour map (Fig. 6). These illustrations indicate that the sandy clay layer mostly present in the top part of the entire study area, however, its thickness is more near the foothills and less towards the northern part in the valley. On contrary this also reflects that the thickness of the water rich sand layers are more in the valley than near the foothills, below the clay part. This also reflects on the regional water table contour map which infers that the overall natural flow of the groundwater is towards north-west meeting at the Brahmaputra. The ponds near the foothills or Naga Thrust do not contain any additional moat around it, which reflects shallower confined aquifer (Pond number 1-20, in Fig. 6). When we consider Gaurisagar, Rudrasagar and Joysagar ponds, it has been observed that the Rudrasagar present in lower than the other two, maintain the overall regional aspects of the groundwater flow. The ponds and Jamunas built around the ponds have a great significance. Jamuna maintains water level in the ponds as stated by many authors but how they do that was not clear. The graphical representations for each of the site indicate that water level in Jamuna is lower than the ponds.

Discussion

The Naga-Schuppen belt cause bending and flexural deformation the entire Cenozoic sediments including the alluvial which results into the neotectonic and active tectonic deformation. The major subsurface thrusting followed by oblique faulting of the lithostragraphic units have shaped the entire valley, it is the upper more recent sediments that cause formation of hydro-geologic setting of the Brahmaputra Valley. Presence of Naga thrust, Jorhat fault, Nazira low and other small local active tectonic features have control over the subsurface and surficial landforms and lithological distribution and thereby the groundwater system. These tectonic forces, however, does not formed in few years and therefore the long scale tectonic factors have remained same. The forces have caused rise of the sand and clay layers in some places and subsides in some other, though very rarely in the valley (Fig. 4). The groundwater has regional west-southwest trend which follows sharp change in the groundwater contour in the upper Assam area, specially around the study area.

The construction of the ponds in the ancient Assam, especially during Ahom regime was remarkable and the geo-engineering aspects were quite ahead from their time. It is quite interesting that the major ponds around Sivasagar were built in a straight line, near east-west direction. Moreover, their shape is quite similar though they are little bit rectangular rather than exactly square, as mentioned by many authors.[4] This infers their understanding of the ancient vedic knowledge which indicate that the such water structures are less susceptible to evaporation. Their entire pond construction method starting from exploration to dedication or opening for use completely based on ancient scientific knowledge. Exploration of the best site reflects either identification of water seepage or near surface water table. The clay mixed sand works well for the capillary action from the water table to the surface which put offs the diyas. Digging up of the soil layers to some extent lowers the ground level and in the same time increase the bank heights of the ponds. This helps to accommodate more water. Inserting a hollow wood works as exploratory well which would confirm the presence of the artesian aquifer below which mostly available around the sandy part of the alluvial. This part is thicker near the Sivasagar region, away from the hill fronts. When the Nagmaari is inserted with proper rituals and the entire materials one above the other, this reflects their understanding of the purification of the

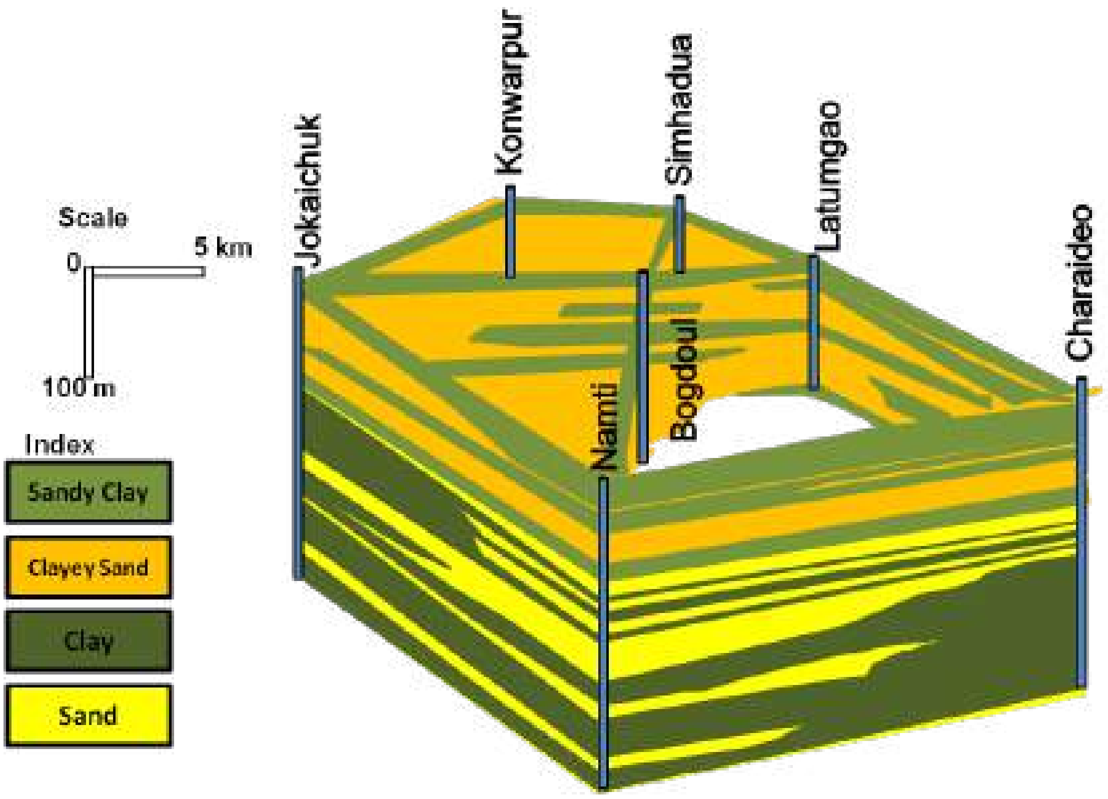

Figure 5. The Panel or fence diagram from the borehole data indicates presence of sandy aquifer and clayey impermeable layer, making a confined ground water system, which is thicker towards the valley.

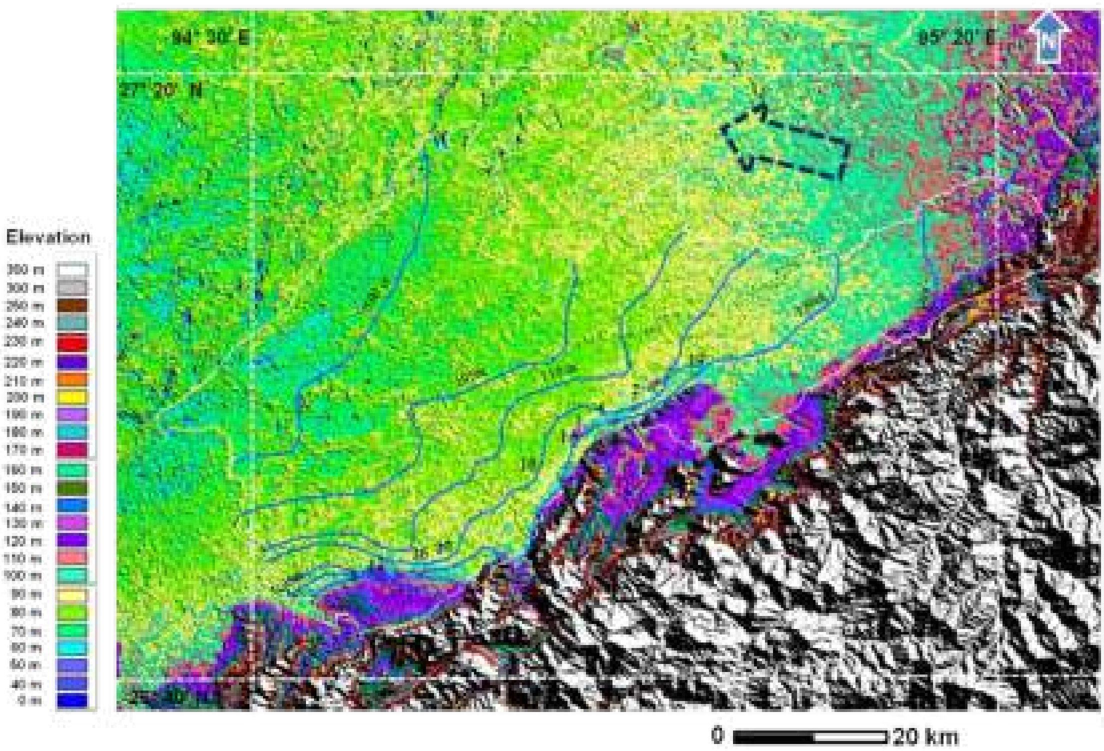

Figure 6. The regional water table contour (Blue lines) map reflecting west-northwest ward flow of the groundwater (blue dotted arrow) towards the valley.

groundwater.

However, majority of the people are unaware of the fact that they not only understand the local hydrology, rather also have regional tectono-hydrologic perspective. The regional water table contour map, which reflects the overall groundwater flow towards west-northwest direction, follows the same east-west line near the three ponds (Fig. 5).[58] The middle pond is situated in lower elevated region than the other two while maintaining a regional flow. The major role of the Jamuna which levels below the ponds works as local equalizer for the groundwater table. It works both as Effluent during monsoon (when water flows pond to Jamuna and then to nearby small channels or paleo-channels) and affluent/influent during winter or less rainfall time (Jamuna to Pond).

There are some ponds which do not pose any Jamuna in it, majority of which present near the foothills. These localities have been investigated in the field to explore the cause behind their sustainability. They mostly have thicker sandy clay top, above the confined aquifer and the presence of recharge zone adjacent to it provide enough water pressure from the subsurface. Moreover, tectonic uplift of the aquifer resulted in the shallow aquifer zone, along with the presence of both confined and semi-confined aquifer all along the foothills. The confined and/or semi-confined aquifers are present near the surface, which lies above the major confined aquifers below. Therefore, these ponds receive water from both the hydrologic setting which is controlled by the tectonic features associated with the orogeny.

Presence of confined aquifers in the near subsurface zone draws attention for detailed study to regarding the liquefaction potential of the region. More detailed interpretation of the tectonics of the region could be generated from the local lithological and structural data together with the neotectonic signatures. Geologic studies facilitate understanding of such landscape evolution with respect to time and space. Research on the past and present conditions of the landscape around these monuments would advance the relevant information regarding the future of this region. The methodology of pond construction if researched properly could also be employed in regions of similar geological setup to prevent drought or water crisis.

Conflict of interests

Authors declare no conflicts of interest.

References

1. Gait, E.A. (1906). A History of Assam, Orig. Calcutta. (Delhi: Surjeet Publications) pp.20–30
2. Baruah S.L. (2003). A Comprehensive History of Assam, Munshiram Manoharlal Publishers Pvt. Ltd, New Delhi. pp. 25–96
3. Bhuyan, S. (2014). Satsori Asom Buranji (ed.), Second Edition, Bani Mandir, Guwahati.
4. Buragohain, N. (2019). Ahom JugarGarh, Ali aru Hilahanku, First edition, Kunhipat Prakash, Sivasagar.
5. Zaman, F., Bezbaruah, D. (2019). Morphotectonic aspects in a part of Naga-Schuppen belt, Assam Nagaland region, Northeast India. *Science Vision*, **19**, 6–11. https://doi.org/10.33493/scivis.19.01.02
6. Gogoi, P. (1976). Tai Ahom Religion and Customs, First Edition, Publication Board of Assam, Guwahati.
7. Handique, B.C. (1959). Chang-Rung Phukanar Buranji(ed.), It is an Old Engineering records of Ahom, Second Edition, Dibrugarh.
8. Konwar P. (2014). Town Planning and Architectural Study of The Medieval Ahom Royal Palaces at Che-Hong (Gargāon) and Che-Muan (Rangpur). *Tai Culture*, **21**, 119–136.
9. Hazarika, B.B et.al (Ed). (1990). Assam District Gazetteers (Kamrup District). Guwahati: Govt. of Assam, Assam.
10. Chauley, M.K. (2016). Ahom Monuments - An Architectural Marvel (New Perspective), Heritage. *Journal of Multidisciplinary Studies in Archaeology*, **4**, 228–23.
11. Saikia, R.R., Amin, N. (2019). A Study on the Salt Production of Ancient Assam. Indian *Journal of History of Science*, **54**, 485–496.
12. Barpujari, H.K. (1994). Comprehensive History of Assam, Vol.- III(ed.), Publication Board Assam, Guwahati. pp. 56–88.
13. Chakradhar, M., Gaur, M.P. (1985). Systematic Geological Mapping around Jaluke, Kohima district, Nagaland. Unpublished Progress Report, GSI.
14. Evans, P. (1932). Explanatory notes to accompany a table showing the Tertiary succession in Assam. *Transactions of the Mining, Geological and Metallurgical Institute of India*, **27**, 168–248.
15. Evans, P., Mathur, L.P. (1964). 'Oil in India'. International Geological Cong. 22 Session, India,

1964.

16. Hayden, H.H. (1910). Some coalfields in the Northeastern Assam. *Records of the Geological Survey of India*, **40(4)**, 283–319.
17. Cooper, H.H., Bredehoeft, J.D., Papadopulos, I.S. (1965). The Response of Well-Aquifer Systems to Seismic Waves. *Journal of Geophysical Research*, **70 (16)**, 3915–3926.
18. Debadhikari, B. (1968). Detailed investigation of coal and geological mapping in the Changkikong and Japukong ranges of Nagaland. GSI Progress Report for F.S. 1967–68. (unpublished).
19. Jena, S.K., Devdas, V. (1984). Systematic Geological mapping in (I) Didiua-New Yachang area, Wokha district, Nagaland. GSI Progress Report for F.S. 1983–84.
20. Madhav, C. (1989). Quaternary geology and geomorphology in parts of Kohima, Wokha, Mokokchung and Mong district, Nagaland. GSI, Unpublished Progress Report, 1988–89.
21. Sen, K.K., Jha, V.K. (1974). Geological mapping of the Sanis Lakhanti-Merapani area, Mokokchung Dt., Nagaland. GSI Progress Report for F.S. 1972–73.
22. Sengupta, S.R., Bhattachrya, S. (1983). Systematic Geological mapping around Reguri and Akhen villages, Phek district, Nagaland. Geol. Surv. of India Progress Report for F.S. 1981–82.
23. Shukla, R. C (1988). A report on Geoenvironmetnal studies in Dimapur its surroundings, Kohima district, Nagaland GSI, Unpub. Progress Report 1986-87 & 1987-88.
24. Mahanta, C., Enmark, G., Nordborg, D., Sracek, O., Nath, B., Nickson, R. T., Bhattacharya, P. (2015). Hydrogeochemical controls on mobilization of arsenic in groundwater of a part of Brahmaputra River floodplain, India. *Journal of Hydrology: Regional Studies*, **4**, 154–171.
25. Bharali, B. (2017). A geological study on upper Bhuban Formation in parts of Surma basin, Aizawl, Mizoram. *Science Vision*, **17(3)**, 128–147. https://doi.org/10.33493/scivis.17.03.02.
26. Bharali, B., Hussain, M.F., Borgohain, P., Bezbaruah, D., Vanthangliana, V., Rakshit, R., Phukan, P.P. (2021). Reconstruction of middle Miocene Surma Basin as two arcs derived sedimentary model: evidence from provenance, source rock weathering and paleo-environmental conditions. *Geochemistry International*, **59(3)**, 264–289. https://doi.org/10.1134/S0016702921030022.
27. Bharali, B., Rakshit, R., Dinpuia, L., Saikia, S., Baruah, S. (2021). The 2020 Mw 5.5 Mizoram earthquake and associated swarm activity in the junction of the Surma Basin and Indo-Myanmar Subduction Region. *Natural Hazards*, **109(3)**, 2381 –2398. https://doi.org/10.1007/s11069-021-04924-1
28. Rakshit, R., Lalhmingsangi, D.B., Bharali, B. (2017). Morphotectonic and sedimentological aspects in describing the relationship with ancient failure surfaces in southern part of Aizawl anticline, Mizoram, India. *Science Vision*, **17**, 204–216. https://doi.org/10.33493/scivis.17.04.04
29. Rakshit, R., Bharali, B. (2018). Rockfall Hazard and risk assessment along Aizawl-Durtlang road section, Mizoram, India. *Senhri Journal of Multidiscpinary Studies*, **3(1)**, 19–31.
30. Rakshit, R., Bezbaruah, D., Zaman, F., Bharali, B. (2020). Variability of orographic architecture of Indo-Burmese Ranges (NE India): constraints from morphotectonic and lineament analysis. *Geological Quarterly*, **64(1)**, 130–140. DOI: http://dx.doi.org/10.7306/gq.1522
31. Rakshit, R., Bezbaruah, D., Bharali, B., Borgohain, P., Rakshit, K. (2021). Macro-Mechanical Characteristics and Their Control on The Strength Of Sandstones Of Western Indo-Burmese Ranges, Ne India. *Acta Geodynamica et Geomaterialia*, **18(2)**, 19–31.
32. Rakshit, R., Bezbaruah, D., Zaman, F., Bharali, B., Saikia, S. (2022). Locked crustal faults associated with the subducting Indian Lithosphere and its implications in seismotectonic activity in the Central Indo-Burmese Ranges, Northeast India. *Geofizika*, **39(1)**, 163–178. https://doi.org/10.15233/gfz.2022.39.5
33. CGWB, (2013). Master plan for artificial recharge to ground water in India. Central ground water board, Ministry of Water Resources (CGWB, MoWR). Government of India.
34. Nandy, D.R. (2001). Seismogenesis of Northeastern India and the Adjacent Areas. Earthquake Risk Mitigation. pp. 25–69.
35. Sahoo, M., Gogoi, K.D. (2009). Depositional history, processes and mechanism of early Miocene sediments of Upper Assam Basin. *Journal of the Geological Society of India*, **73 (4)**, 575–585.
36. Mandal, K., Dasgupta, R. (2013). Upper Assam basin and its basinal depositional history. In SPG

10th Biennial international conference and exposition, Kochi, India.

37. Hossain, M.S., Khan, M.S.H., Abdullah, R., Mukherjee, S. (2021). Late Cenozoic transpression at the plate boundary: Kinematics of the eastern segment of the Dauki Fault Zone (Bangladesh) and tectonic evolution of the petroliferous NE Bengal Basin. *Marine and Petroleum Geology*, **131**, 105133.
38. Oldham, T. (1883). Report on Geology of Manipur state and Naga Hills. *Memoirs of the Geological Survey of India*, **19(4)**, 217–242.
39. Pascoe, E.H. (1912). Traverse across Naga Hills of Assam from Dimapur to the neighbourhood of Saramati peak. *Records of Geological Survey of India*, **42(4)**, 312–330.
40. Kumar, A., Kotoky, N., Shekhar, S. (2024). Spatial variation of seismicity parameters in Meghalaya, North-East India. *Acta Geophysica*, **72 (6)**, 3811–3829.
41. Berger, P., Cerny, P., Hook, J.V., Jaffex, Kabir, C.S., Kumar, R., Minne, J.C., Pinningtou, D.J., Serra, O., Shukla, S.N., and Sibbit AnVisvanath, S.N., (1983) Petroleum Geology of India in Schlumberger, Well Evaluation Conference. pp. 1−36.
42. Rockwell, T.K., Keller, E.A., Johnson, D.L. (1985). Tectonic geomorphology of alluvial fans and mountain fronts near Ventura, California. In Tectonic Geomorphology. Proceedings of the 15th Annual Geomorphology Symposium. Allen and Unwin Publishers, Boston, MA. pp. 183–207.
43. Silva, P.G., Goy, J.L., Zazo, C., Bardaji, T. (2003). Fault-generated mountains fronts in southwest Spain: geomorphic assessment of tectonic and seismic activity. *Geomorphology*, **50**, 203–225.
44. Reddy, D.V., Nagabhushanam, P., Kumar, D., Sukhija, B.S., Thomas, P.J., Pandey, A.K., Sahoo, R.N., Prasad, G.V.R., Datta, K. (2009). The great 1950 Assam Earthquake revisited: Field evidences of liquefaction and search for paleoseismic events. *Tectonophysics*, **474(3-4)**, 463 –472.
45. Mandal, S.K., Scherler, D., Wittmann, H. (2021). Tectonic accretion controls erosional cyclicity in the Himalaya. *AGU Advances*, **2(3)**, e2021AV000487.
46. Srivastava, R.K. (1983). Systematic Geological mapping around Phokpur-Aipunger-Penkim-Fakimile areas, Tuensang district, Nagaland. GSI Progress Report for F.S.1982–83.
47. Verma R.G. (1988-89). Photogeological mapping in parts of Phekdistrict, Nagaland TS. No. 83K/2, 5 & 6. GSI Progress Report.
48. Sarma, H. (1985). Systematic Geological Mapping around Pukha-Lungwa-Chenwent-Hyou-Champang areas of Mon district. GSI Progress Report for F.S. 1984–85.
49. Mallet, F.R. (1876). On the coal field of Naga hills, bordering the Sivasagar and Lakhimpur districts. *Memoirs of the Geological Survey of India,* **12(2)**, 1–95.
50. Verma, M., Bansal, B.K. (2013). Seismic hazard assessment and mitigation in India: an overview. International *Journal of Earth Sciences*, **102(5)**, 1203–1218.
51. Borgohain, S., Das, J., Saraf, A.K., Singh, G., Baral, S.S. (2017). Structural controls on topography and river morphodynamics in Upper Assam Valley, India. *Geodinamica Acta*, **29 (1)**, 62–69.
52. Bhandari, L.L., Fuloria, R.C., Sastri, V.V. (1973). Stratigraphy of Assam Valley, India. *AAPG Bulletin*, **57(4)**, 642–654.
53. Raju, S.V., Mathur, N. (1995). Petroleum geochemistry of a part of Upper Assam Basin, India: a brief overview. *Organic Geochemistry*, **23 (1)**, 55–70.
54. Goswami, B., Bhattacharyya, C. (2014). Petrogenesis of shoshonitic granitoids, eastern India: implications for the late Grenvillian post-collisional magmatism. *Geoscience Frontiers*, **5(6)**, 821–843.
55. Deb, S.S., Barua, I. (2010). Depositional environment, reservoir characteristics and extent of sediments of langpar & lakadong + therria in Chabua area of Upper Assam Basin. In 8th Biennial International Conference & Exposition on Petroleum Geophysics, Vol. 177.
56. Seed, H.B. (1979). Soil liquefaction and cyclic mobility for level ground during earthquakes: *Journal of Geotechnical Engineering, American Society of Civil Engineers*, **105**, 201–255.
57. Seed, H.B., Idriss, I.M. (1982). A simplified procedure for evaluating soil liquefaction potential: *Journal of Soil Mechanics and Foundation Engineering Division, American Society of Civil Engineers*, **97**, 1249–1274.
58. Bhawan, S., Puram, R.K. (2014). Watershed atlas of India. New Delhi Center Water Commision.