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Hydrogeology of Brahmaputra Basin, India

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ABSTRACT

The Ganga-Brahmaputra river system together forms one of the largest deltas in the world comprising some 59570 sq km. The waterpower resources of the Brahmaputra have been presumed to be the fourth biggest in the world being 19.83 x 10^3 m^3 s^1. The entire lower portion of the Brahmaputra consists of a vast network of distributary channels, which are dry in the cold season but are inundated during monsoon. The catchment area of the entire river is about 580,000 sq km, out of which 195,000 sq km lies in India. The maximum discharge as measured at Pandu in 1962 was of the order of 72800 m^3 s^{-1} while the minimum was 1750 m^3 s^{-1} in 1968. The drainage pattern in the valley is of antecedent type while the yazoo drainage pattern is most significant over the composite flood plain to the south of the Brahmaputra.

The Brahmaputra valley is covered by Recent alluvium throughout its stretch except a few isolated sedimentary hills in the upper Assam, inselbergs/bornhardt of gneissic hills in the Darrang, Kamrup and Goalpara districts and a few inlying patches of Older Alluvium in the Darrang and Goalpara districts.

The basin is very unstable. The present configuration of the basin is the result of uplift and subsidence of the Precambrian crystalline landmasses. Four geotectonic provinces can be delineated in the N-E India through which the Brahmaputra flows. These are bounded by major tectonic lineaments such as the basement E-W trending Dauki fault, a NE-SW trending structural feature of imbricate thrusts known as 'belt of Schuppen' and the NW-SE trending Mishmi thrust.

Hydrogeologically, the Brahmaputra basin can be divided into two distinct categories, viz (a) dissected alluvial plain and (b) the inselberg zone. The first category is represented in the flood plain extending from the south of Sub-Himalayan piedmont fan zone in the north to right upto the main rock promontory of Garo Hills and Shillong Plateau. The inselberg zone is characterized by fractured, jointed and weathered ancient crystalline rocks with interhill narrow valley plains, consisting of thin to occasionally thick piles of assorted sediments.

From the subsurface lithological data, two broad groups of aquifers are identified. These are i) shallow water table and ii) deeper water table or confined ones, separated by a system of aquicludes. The shallow aquifer materials, in general, consist of white to greyish white, fine grained micaceous sand and the thickness ranges from 1.2 to 10.3 m. The sand and clay ratio varies from 1: 2.5 to 1: 26. The bedrock occurs at depth ranges of 30.4 to 39.5 m. The materials of the deeper aquifers comprise grey to greyish white, fine to medium grained sand. The sand and clay ratio varies from 1: 2 to 1: 7. The effective size of the aquifer materials varies from 0.125 to 0.062 mm with uniformity co-efficient around 4.00, porosity 38 to 42 %, co-efficient of permeability 304 to 390 galls per day/ 0.3 m^2. The ground water is mildly alkaline with P^H value 6.5 to 8.5, chloride 10 to 40 ppm, bi-carbonate 50 to 350 ppm, iron content ranges from a fraction of a ppm to 50 ppm. Total dissolved solids are low, hardness as $CaCo_3$ 50 to 300 ppm, specific conductance at 25 ^{0} C 150 to 650 mhos/cm. The yield from shallow aquifers is 1440 litres to 33750 litres/hour and for deeper aquifers ~ 1700 litres/hour at a draw down of 13.41 m, specific capacity 21 litres/minute. The temperatures of ground water are 23^0-25^0 C during winter, 24^0-26^0 C during pre-monsoon and 27^0- 28^0 C during peak monsoon. The general hydraulic gradient in the north bank is 1:800 whereas in the south bank it is 1: 300-400 The Tertiary sediments yield a range of water from 200 to 300 l.p.m whereas the yield from the Older Alluvium is 500 to 700 l.p.m. The estimated transmissibility and co-efficient of storage is of the order of ~ 800 l.p.m/ m and 8.2 x 10^{-3} respectively. Depths to water levels range from 5.3 to 10m below land surface (b.l.s). In the Younger or Newer Alluvium, ground water occurs both under water table and confined conditions. Depths to water levels vary from ground level to 10 m b.l.s. Depth to water ranges from 6 m b.l.s. to 2 m above land surface. The yield of the deep tubewells ranges from 2 to 4 kl/minute for a draw down of 3 m to 6 m. The transmissibility of the aquifers varies from 69 to 1600 l.p.m/ m and the storage co-efficient is of the order of 3.52 x 10^{-2}.

INTRODUCTION

The Ganga-Brahmaputra river system together forms the largest tide dominated deltas in the world comprising some 59,570 sq km. The Brahmaputra River originates from the Chemayundung glaciers at an elevation of about 5,000 m (m.s.l) near Manasaravar-Rakhas lakes between Kailash and Kanglung ranges, east of Manasaravar (Fig. 1). Between Namcha Barwa and its confluence with Dihang, the river has a descent of about 2,200 m and its water power resources (average discharge at mouth) have been presumed to be the fourth biggest in the world coming after the Amazon (99.15

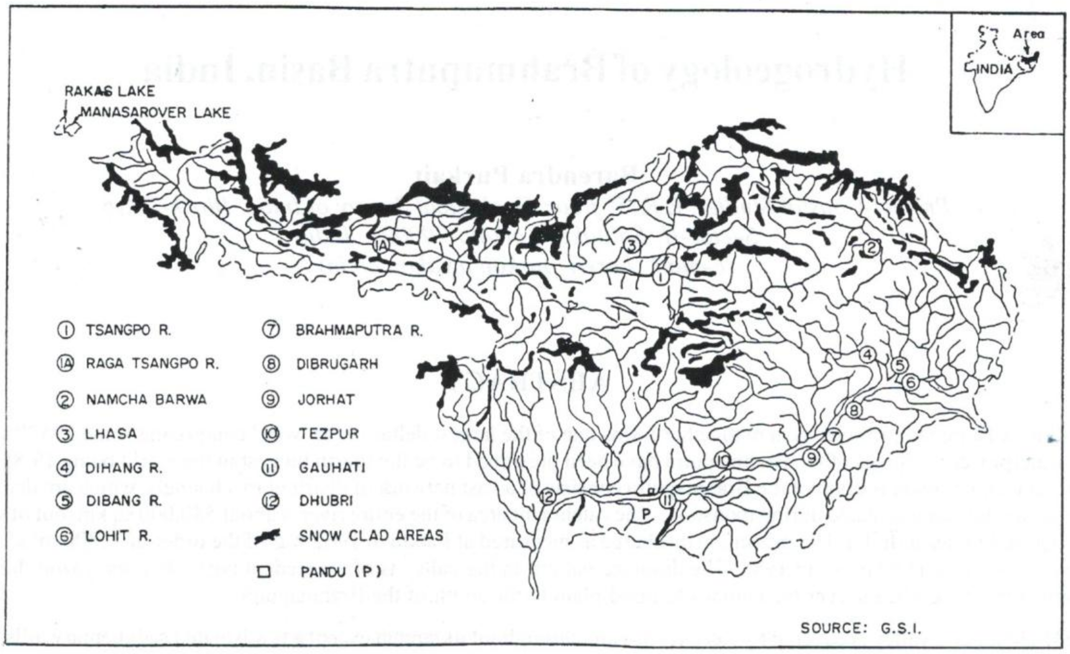


Fig. 1: Location map of the Brahmaputra Drainage Basin

x 10^3 m^3 s^{-1}), Congo (39.66 x 10^3 m^3 s^{-1}), Yangtze (21.80 x 10^3 m^3 s^{-1}) and Brahmaputra (19.83 x 10^3 m^3 s^{-1}). The entire lower portion of Brahmaputra consists of a vast network of distributary channels, which are dry in the cold season but are inundated during monsoon.

GEOMORPHOLOGY

Physiography

The Brahmaputra basin can be divided into 3 parts (Fig. 2):

i) The vast alluvial plain of the Brahmaputra valley in the north, comprising the districts of Goalpara, Kamrup, Darrang. Nowgong, Sibsagar, Lakhimpur and Dibrugarh.

ii) The central Assam hills comprising the united Mikir and north Cachar Hills districts.

iii) The hilly and alluvial terrain in the south covering the Cachar district in the upper Surma (Barak) valley.

Ranging in average elevation from 50 m to 120 m (above m.s.l), the Brahmaputra valley represents a unique landscape, 800 km long and 130 km wide valley, separated from the comparatively low lying Surma (Barak) valley in the south by the Mikir Hills and Barail range (North Cachar Hills) in the central part. A few granitoid inselbergs and bornhardts occur south and south-west of the Brahmaputra basin (Fig. 3). There are number of channel cut-offs or bils, oxbows and marshy tracts which occupy part of the flood plain deposits. The general elevation of the alluvial plain varies from 60-110 m above m.s.l with a general northerly gradient.

Drainage

The catchment area of the entire river is about 580,000 sq km, out of which 195,000 sq km lies in India. The maximum discharge of the Brahmaputra as measured at Pandu (Fig. 1) in 1962 was of the order of 72794m^3 s^{-1}, while the minimum discharge was 1757 m^3 s^{-1} as measured in 1968 (Goswami 1998).

The river is joined by as many as 30 tributaries from the north and 20 tributaries from the south. The catchments of the north bank tributaries lie in the Himalayan range having very steep slope. The drainage pattern of the Brahmaputra network (within India), in general, is dendritic in the N-E and N-W, subparallel in the south and reticulate or anastomosing in the main course.The drainage pattern in the valley is of antecedent type. The yazoo drainage pattern is also most significant and predominately seen over the composite flood plain to the south of the Brahmaputra.

GEOLOGY

The Brahmaputra valley excepting a few isolated sedimentary hills in upper Assam, inselbergs/bornhardt of gneissic hills in the Darrang, Kamrup and Goalpara districts and a few inlying patches of Older Alluvium in the Darrang and Goalpara districts, is covered by Recent Alluvium throughout its stretch.

Situated south of Assam, the Bengal basin is primarily of Quaternary alluvial deposits laid down by the Ganges, Brahmaputra and Meghana rivers (Fig. 3). The Lower Jurassic Trap rocks border on the west and north-west of the Bengal basin and the Shillong Hills predominately composed of Eocene Sandstones and Numulitic Limestones occur on its north-east. The Tripura and Chittagong Hills border its

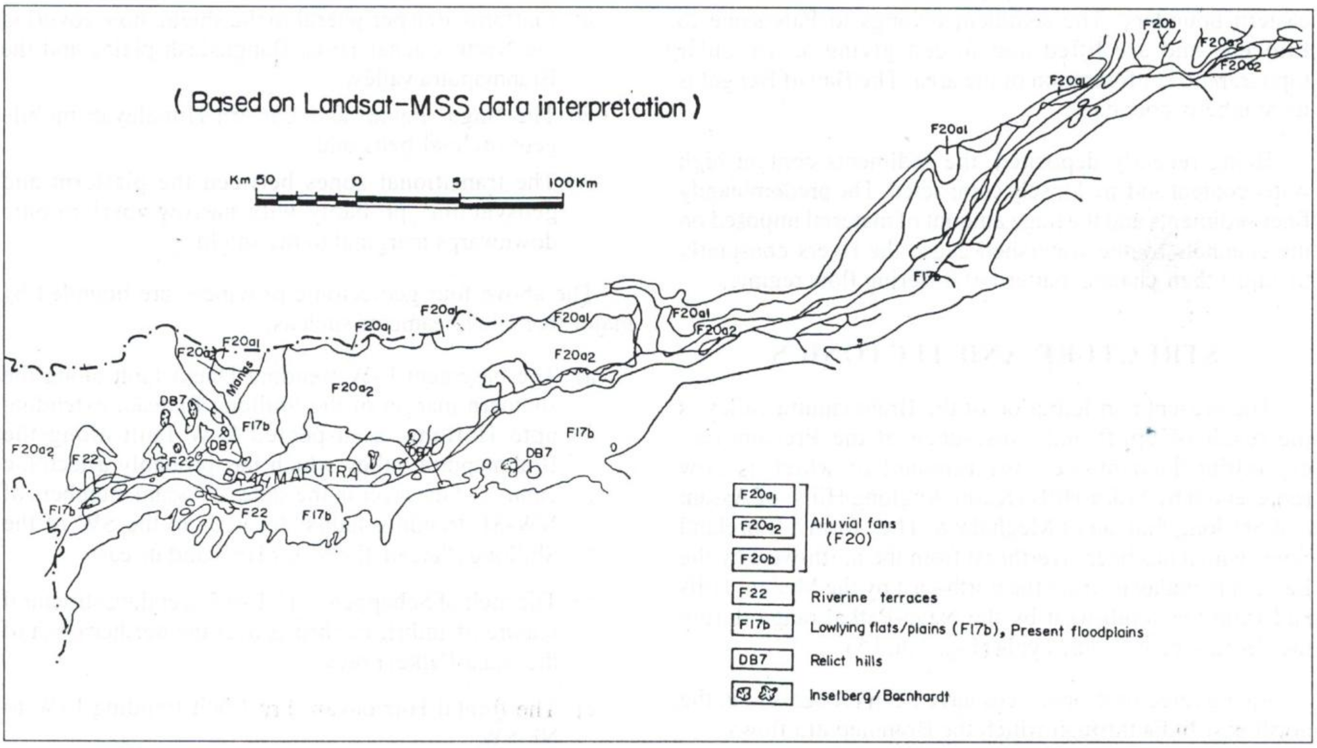


Fig. 2: Geomorphological map of the Brahmaputra valley

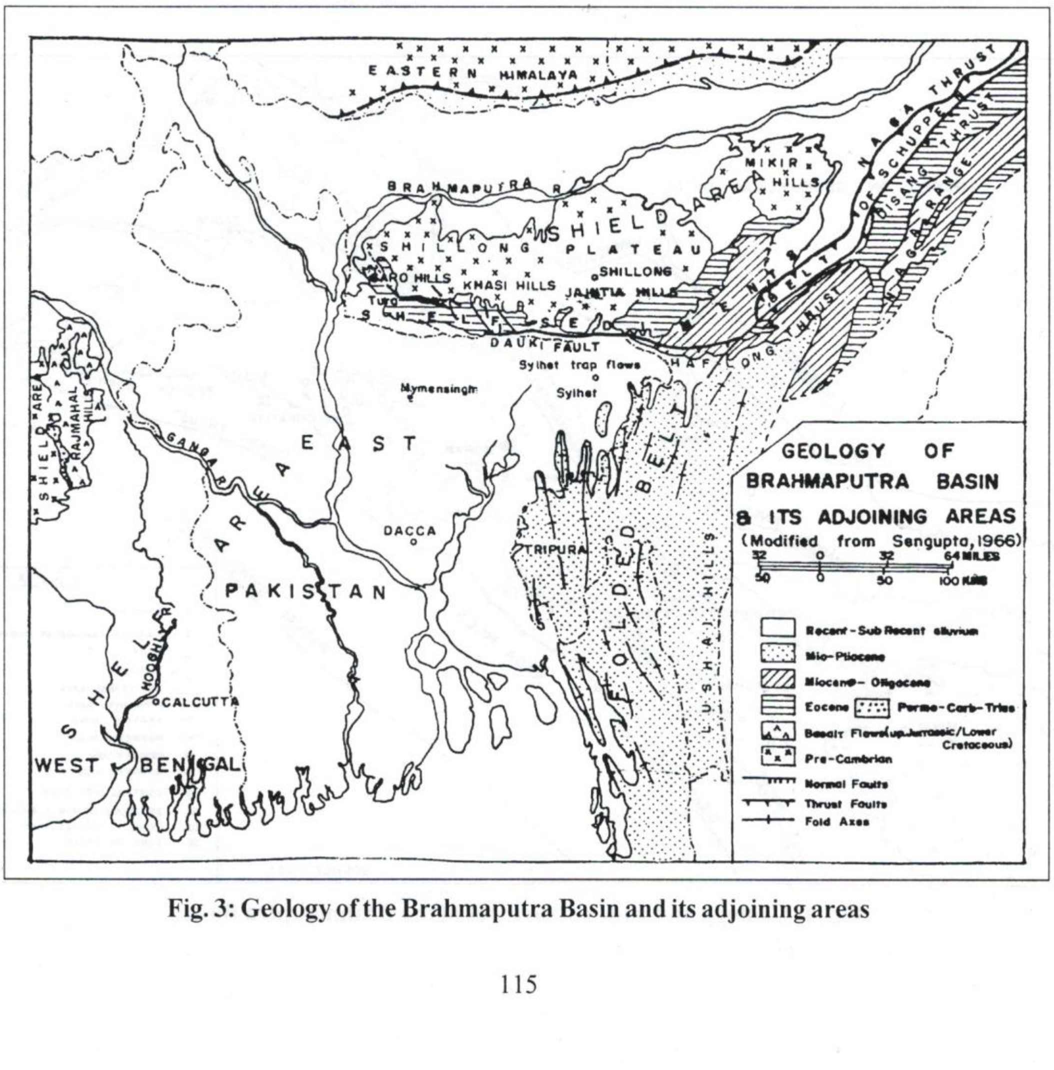


Fig. 3: Geology of the Brahmaputra Basin and its adjoining areas

eastern boundary. The sediment belongs to Paleocene to Pliocene and are lifted and folded giving an irregular topographic configuration of the area. The Bay of Bengal is its southern boundary.

Being recently deposited, the sediments contain high water content and are loosely compacted. The predominantly finer sediments and the huge amount of material imposed on the channels by the watershed cause the rivers constantly to adjust their channel pattern of differing flow regimes.

STRUCTURE AND TECTONICS

The present configuration of the Brahmaputra valley is the result of uplift and subsidence of the Precambrian crystalline land masses, the remnant of which is now represented by Mikir Hills (Karbi-Anglong Hills) of Assam and Shillong Plateau of Meghalaya. They form a 'Foreland Spur' which has been overthrust from the north-west by the Eastern Himalayas, from the north-east by the Mishmi Hills and from the south-west by the Naga-Patkai range during the Tertiary geotectonic cycle (Fig. 4 and 5).

Four geotectonic provinces have been recognized in the north-east India through which the Brahmaputra flows:

i) The stable shield area of Shillong Plateau and Mikir Hills.

ii) Platform area peripheral to the shield, now covering the North Cachar Hills, Bangladesh plains and the Brahmaputra valley.

iii) The Naga- Patkai and Eastern Himalayan mobile geosynclinal belts and

iv) The transitional zones between the platform and geosyncline, probably with narrow pericratonic downwarps marginal to the shield.

The above four geotectonic provinces are bounded by major tectonic lineaments such as:

a) The basement E-W trending Dauki fault along the southern margin of the Shillong Plateau, extending upto Haflong, a suspected E-W fault along the Brahmaputra valley which has probably a tectonic control of the river in the state of Assam, numbers of NW-SE trending faults located in the SW of the Shillong Plateau, the Mikir Hills and its east

b) The 'belt of Schuppen' - a NE-SW trending structural feature of imbricate thrusts over the northern part of the Naga-Patkai range

c) The frontal Himalayan thrust belt trending E-W to NE-SW,

d) The NW-SE trending Mishmi thrust along the Lohit foothills,

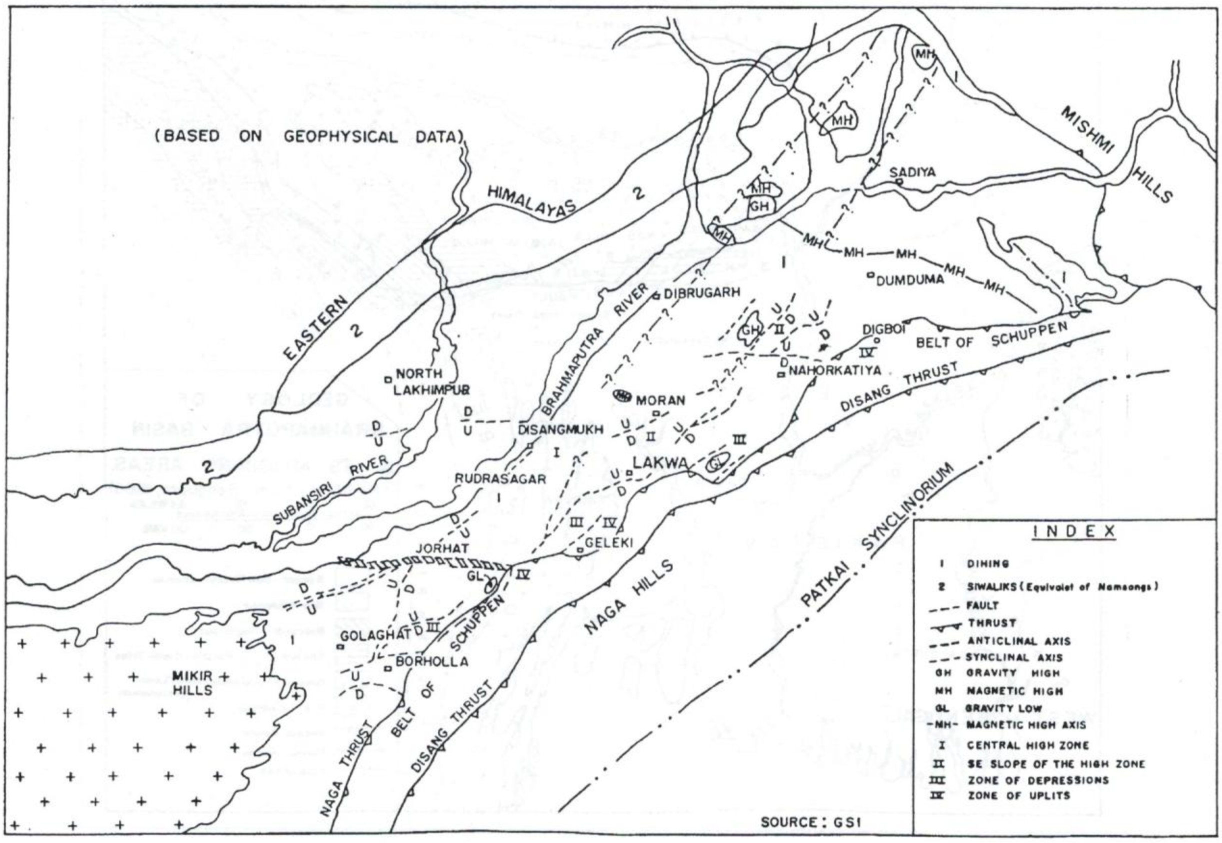
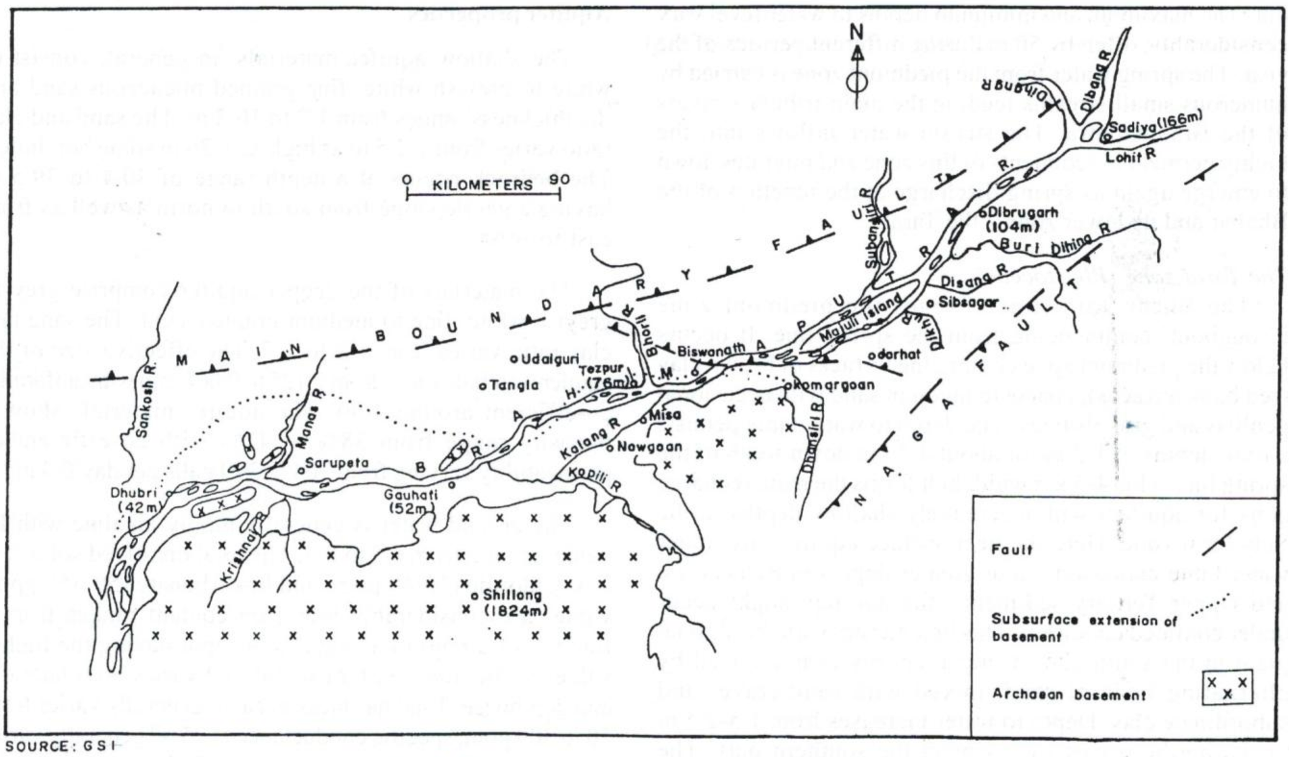


Fig. 4: Geology and major structures of the Brahmauptra Basin



SOURCE: GSI

Fig. 5: Tectonic map of the Brahmaputra valley

e) Probable northeasterly extension of NE-SW Calcutta-Mymensing gravity high to the south of the North Cachar Hills through Cachar district.

HYDROGEOLOGY

The Brahmaputra basin can be divided into two distinct categories, viz. a) dissected alluvial plain and b) the inselberg zone. The first category is represented in the flood plain extending from south of Sub-Himalayan piedmont fan zone in the north to right upto the main rock promontory of Garo Hills and Shillong Plateau. The sediments of this vast alluvial plain have been brought down by the past and present Himalayan rivers. There are a large number of buried channels consisting of gravel and sands, natural levees of sands and silts, back swamps/bils and clays. Borehole data reveal a general coarsening of sediments at depth with two to three zones of cyclothemic gravels within depth of 90-100 m indicating a cyclic nature of sedimentation. There is also a coarsening of grain size noted on the present surface away from the main channel towards the higher altitudes.

The inselberg zone is characterised by fractured, jointed and weathered ancient crystalline rocks with inter hill narrow valley plains, consisting of thin to occasionally thick piles of assorted sediments.

Aquifers

Subsurface lithological data suggest two broad groups of aquifers e.g. (i) shallow water table and (ii) deeper water table or confined ones, separated by a system of aquicludes.

The sediments in the lower Assam plain of the Brahmaputra can be grouped into belts from north to south as detailed below:

Piedmont zone (Bhabar belt- Pleistocene)

It consists of talus fans having all the general characteristics of foothill terraces all along the Sub-Himalayan belt and is called as Bhabar belt in Assam. The terraces comprise rock fragments, boulders, pebbles and ill sorted sand and minor clay. These fans hardly retain any percolating water and the ground intake from precipitation and run-off migrates rapidly down to the terraces below. Adequate ground water exists in the area under water table as well as confined conditions. The average depth to water is 3-3.5 m during March-April. The piezometric surface generally occurs slightly higher than that of the water table. Flowing conditions in some areas in the case of a few tubewells indicate water at depths from 26-38 m with thickness of water column ranging from 3 to 14 m. With the gradual thinning out of the terrace southward, depth to water also gets reduced correspondingly. The southern extremity of the Bhabar belt is characterized by water table at shallow depth of 1 to 2.5 m. Due to considerable rise of the water table in the Bhabar belt, following monsoon precipitation, water oozes out at various places in the form of spring. The spring line follows a sinuous tract. The position and mode of the occurrence of water at deeper horizons is not known. However, presence of water bearing granular horizons at greater depths, presuming the extension of Sub-Himalayan Tertiary and Pleistocene formations beneath the terrace deposits, cannot be ruled out. The maximum and minimum depths to water level vary considerably, often by 50 m during different periods of the year. The spring water from the piedmont zone is carried by numerous small streams feeding the main tributary rivers of the Brahmaputra. The stream water inflows into the highly permeable sediments of this zone and migrates down to emerge again as spring discharge at the junction of the Bhabar and its lower zone – the Tarai.

The Tarai zone (Pleistocene)

The linear Tarai tract fringes the piedmont zone throughout, commencing from the spring line. It occurs below the piedmont zone comprising terraces of brown clay (red bank terraces), coarse to medium sand with occasional pebbles and gravels beds. The depth to water table persists within depths of 1-2 m for about 4-5 km down south of the spring line. This 4-5 km width belt forms the main recharge zone for aquifers within relatively shallow depths in the Sub-Tarai zone. Here the near surface aquifers are under water table condition but at greater depths in Pleistocene and Upper Tertiary sediments, the aquifers might occur under confined condition. This belt merges with the alluvial plain in the south almost imperceptibly characterized by alternating beds of sand, mixed with sand/gravel and subordinate clay. Depth to water increases from 1.5-2.5 m in the northern part to 2-4 m in the southern part. The parallelism between the water table slope and the topographic gradient from north to south is observed in this belt.

The present day flood plain deposits

They occur between the Tarai belt and the Brahmaputra river. The sediments are mainly gravel, sand, silt and clay. The near surface sand and gravel beds constitute the aquifers which contain ground water under water table condition. Deeper aquifers are often under confined conditon. The water table slopes about 2 m/km and has a centripetal gradient. The gradient flattens out where the flood plain is broader. In the central part of the plain, the water table stands at depth of 3-4 m below land surface during the months of March and April.

In the central part of the area where alternating sand and clay beds occur below the topmost clayey horizon upto 18 m thick, at least 3-4 significant confined aquifers have been tapped from 20-53 m depths. In the southern part of the alluvial plain, where sandy sediments predominate, small diameter tubewells tap water from the aquifers between 10-26 m depth. The aquifers are under semi-confined to free condition. Deeper aquifers down to 60 m depth are also under semi-confined condition as no impervious horizon of any importance exists within this depth. Piezometric level varies in the alluvial plain from 1.4 to 5.9 m below land surface. In most cases, the level is 0.3 m above the prevalent level of the water table. The average piezometric level for the area is 3.2 m as against the average depth to water table of 3.5 m. A number of tubewells in the sedimentary plain have shown artesian flow.

Aquifer properties

The shallow aquifer materials, in general, consist of white to greyish white, fine grained micaceous sand and the thickness ranges from 1.2 to 10.3 m. The sand and clay ratio varies from 1:2.5 to as high as 1:26 in some boreholes. The bedrock occurs at a depth range of 30.4 to 39.5 m having a gentle slope from south to north as well as from east to west.

The materials of the deeper aquifer comprise grey to greyish white, fine to medium grained sand. The sand and clay ratio varies from 1:2 to 1:7. The effective size of the aquifer materials varies from 0.125 to 0.062 mm with uniformity co-efficient around 4.00. The aquifer materials show a porosity range from 38% to 42% with co-efficient of permeability varying from 304 to 390 galls per day/0.3 m^2

The ground water is generally mildly alkaline with P^H value ranging from 6.5 to 8.5. The total dissolved solids are low. Chloride (10-40 ppm) and bi-carbonate (50-350 ppm) values are considerably low. Iron content ranges from a fraction of a ppm to as high as 50 ppm having the higher values in the north-eastern sector and varies both laterally and depthwise. Total hardness as $caco_3$ generally varies from 50 to 300 ppm, specific conductance at 25 °C generally varies from 150 to 650 mhos/cm. A general flushing movement is indicated from the chemical properties.

GROUND WATER POTENTIAL

The Brahmaputra basin has adequate surface and ground water resources. Besides, a few mineral water occurrences are also recorded. Ground water though available in plenty, its quality affects the potable nature because of high iron content. Moreover, at greater depth of 30 m i.e beyond the zone of oxidation it is free from much of iron.

The shallow water table is recharged by rainfall almost upto the ground level by mid-monsoon period after which the rainfall is mostly rejected as run-off. In general, the yield of the tube wells of shallow aquifers varies from 1,440 litres to 33,750 litres/hour whereas the yield from the tubewells of deeper aquifers is 1,700 litres/hour at a draw down of 13.41 m, specific capacity 21 litres/minute.

The temperature of the ground water is, in general, in the range of 23-25 °C during winter, 24-26 ° C during pre-monsoon and 27-28 °C during peak monsoon when the water table rises within 2 to 2.5 m of surface where ambient temperatures operate. The temperature data indicate an overall normal state of ground water motion. Due to stagnation condition, the ground water of the back swamp lakes shows a higher temperature range of upto 31-34 °C. Number of bils show the temperatures proximal to ground water temperature indicating ground water feed back whereas the river water normally shows a lower temperature range of 18-20 °C

The general hydraulic gradient in the north bank is 1:800 whereas in the south bank it is 1:300-400.

A few shallow tubewells in Tertiary sediments yield a range of water from 200 to 300 l.p.m. The ground water yield from the Older Alluvium varied from 500 to 700 l.p.m for a draw down of about 3 m. The estimated transmissibility and co-efficient of storage is of the order of 793 l.p.m/m and 8.2 x 10^{-3} respectively. Depths to water levels in the wells range from 5.3 m to 10 m below land surface. In the Younger or Newer Alluvium, ground water occurs both under water table and confined conditions. Depths to water levels vary from ground level to 10 m below land surface. Depth to the tubewells ranges from 30 to 200 m and depth to water ranges from 6 m below land surface to 2 m above land surface. The yield of the deep tubewells ranges from 2 to 4 kl/minute for a draw down of 3 m to 6 m. The transmissibility of the aquifers varies from 69 to 1,600 l.p.m/m and the storage co-efficient is of the order of 3.52 x 10^{-2} (Raju 1981).

CONCLUSIONS

The vast alluvial plain of the Brahmaputra basin has adequate surface as well as ground water resources. Its water power resources presumed to be the fourth biggest in the world. The catchment area of the entire river is about 580,000 km^2, out of which 195,000 km^2 lies in India. The maximum and minimum discharges are of the order of 72800m^3s^{-1} and 1750m^3s^{-1} respectively. The major part of the Brahmaputra basin is covered by Recent alluvium sediments except a few isolated inselbergs/bornhardt of gneissic hills.

Structurally, the Brahmaputra basin is very unstable. The present configuration of the basin is the result of uplift and subsidence of the Precambrian crystalline landmasses. The area can be divided into 4 geotectonic provinces bounded by major tectonic lineaments such as E-W trending Dauki fault along the southern margin of the Shillong Plateau, a NE-SW trending structural feature like 'belt of schuppen' and the NW-SE trending Mishmi thrust along the Lohit foot hills.

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The effective size of the aquifer materials varies from 0.125 to 0.062 mm with uniformity co-efficient around 4.00, porosity 38 to 42 %, co-efficient of permeability 304 to 390 galls per day/ft^2 Ground water is mildly alkaline with pH value ranging from 6.5 to 8.5, chloride 10 to 40 ppm and bi-carbonate 50-350 ppm, iron content from a fraction of a ppm to 50 ppm. Total dissolved solids are low, total hardness as $CaCo_3$ varies from 50 to 300 ppm, specific conductance at 25 ^{0}C varies from 150 to 650 mhos/cm.

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