Tipaimukh Dam: A geo-tectonic blunder of international dimensions
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THE proposed Tipaimukh dam is to be located 500 metres downstream from the confluence of Barak and Tuivai rivers, and lies on the south-western corner of Manipur state. It is a huge earth dam (rock-fill with central impervious core) having an altitude of about 180m above the sea level with a maximum reservoir level of 178m and 136m as the minimum draw down level. The dam was originally conceived to only contain the floodwater in the Cachar plains of Assam but later on, emphasis has been placed on hydroelectric power generation, having an installation capacity of 1,500MW with only a firm generation of 412MW (less than 30 per cent of installed capacity). In order to appease the people of Manipur state, the project proponent, NEEPCO, has been building up a list of benefits that include high-class tourism, free power sharing, resettlement and rehabilitation package and an all round rosy picture of development.

Over the past decade and half, the issue of Tipaimukh dam has created a lot of disenchantment in regard to scientific, technical, economic and environmental feasibility of the dam, especially concerning with the state of Manipur. An attempt is, therefore, made here to provide a brief geological, structural and tectonic account of Tipaimukh and its adjoining region in terms of tectonic framework of Indo-Myanmar [Burma] Ranges in general and that of Manipur in particular and possible socio-economic impacts of the dam. Such a consideration would reveal the nature and extent of the geo-tectonic risk being taken by constructing a mega-dam at Tipaimukh.

Some basic geological information

TIPAIMUKH and its adjoining areas are basically made up of Surma Group of rocks. The rocks of Surma Group are mainly light grey to brownish grey generally medium to coarse grained sandstones having occasional shale and silt/sand intervening bands between massive to thickly bedded sandstones. Conglomeratic (loosely cemented pebbles and gravel)) horizon at the base of Bhuban Formation, though, can be observed in the field easily due to its wide areal extent; other conglomeratic horizons are generally often missing which is probably due to their localised nature. In general, this group of rocks are predominantly arenaceous with subordinate shales. Usually shales are less sandy and sandstones are less argillaceous. Some typical natures of bedding similar to turbidite character are also found at places. Like Barails, Surma Group of rocks is also marked by primary structures such as cross bedding, ripple marks, etc.

All these geologic features, lithocharacters as well as primary structures suggest a different depositional environment from that of the Disangs and Barails. So, these groups of rocks as well as the younger Tipams are treated as molasse sediments.

The rocks of Surma Group are well characterised by folds and faults having regional strike similar to that of the Barails, i.e. NNE-SSW. Fractures are also well developed which have close relationship with the topographic features and drainage patterns. The

geometry of folds found in the region is quite typical as in other parts of the Surma Basin and Western Manipur. Antiforms are generally sharp and angular forming ridges while synforms are broad and rounded representing valleys and river beds. Such geometry of the folds might have been controlled by hidden faults called blind thrusts. And these thrusts could be potential earthquake foci any time in future.

Geomorphic and topographic features around Tipaimukh and its adjoining region is also quite interesting not only because of thickly vegetated low-lying hill ranges but also due to the intimate relationship between the topography, especially the drainage system, and the structural and tectonic lineaments of the region. The drainage pattern of the Barak river and its tributary system around Tipaimukh displays how delicately Barak river takes a turn of about 360 degrees at Tipaimukh giving rise to what is called, barbed pattern. Such a drainage pattern is always resulted from the structural control of the river. And practically the main Barak River opposite to Tuivai River itself is also controlled by the Barak-Makru thrust fault. Further it is also observed that main Barak river course and its tributary system are all controlled by faults and fractures as they all show rectangular to sub-rectangular drainage patterns. All these faults and fractures cause localised shifting or deflection of the main river course, and even at the confluence of Barak River and Tuivai River. Such faults are potentially active and may be focal and/or epicentres of any future earthquake.

Northeast region among six major seismically active zones of the world tectonic setting of Northeast India is one of the most interesting aspects in the tectonic framework of Southeast Asia. In this region, two typical tectonic settings are found resulting from the convergence between Indian and Eurasian plates. The Eastern Himalayas represent a continent to continent collision mechanism while the Indo-Myanmar Range is an island arc type of subduction mechanism. The Indo-Myanmar Range, therefore, evolved as an accretionary prism where major structural and tectonic features spread out in the form of an imbricate thrust system. The Tipaimukh area, about which the dam is proposed to construct, lies in the Barak-Makru Thrust zone of the imbricate thrust system.

The structural and tectonic pattern of Manipur is transitional between the NE-SW trending pattern of Naga-Patkai Hills and N-S trend of Mizoram and Chin Hills. The general structural and lithological trend of the rock formations of the state is NNE-SSW. It frequently varies between N-S and NE-SW although sometimes NNW-SSE trends are locally common. Almost all the major structural elements such as folds, thrust and reverse faults follow this regional strike. Majority of the extensional structures, e.g. normal faults, have WNW-ESE trend. While the structures having neither compress ional nor extensional affinities strike in the NW-SE and NE-SW quadrants. Dip of the lithounits varies between moderate to steep angles towards east or west. The geological and structural settings suggest a very interesting tectonic evolutionary history of the state.

The state, forming an integral part of the Indo-Myanmar Range, lies in the boundary region of the Indian, Eurasian and Myanmar plates having typical interaction nature. As a result, the region is also one of the most seismically active zones in the world (Zone V, earthquake zones of India).

The northeast region of India is one of the six major seismically active zones of the world that includes California, North-East India, Japan, Mexico, Taiwan and Turkey. So, it is essential to have a brief discussion on these aspects also.

Plate kinematics

THE root cause of earthquakes in a particular region is more or less exclusively a function of the tectonic setting of that region and its proximity to plate boundary. Therefore, the tectonic setting, plate movements and palaeo- and neo-stress analyses of the region are very important aspects in order to know about the seismic activity of that region. It not only will reveal the deformation mechanism of the region but also will provide knowledge about the structures that may be easily reactivated as a function of the plate kinematics in that region.

Analysis conducted by the author about the plate kinematics in and around Manipur reveals that the structural and tectonic features of the IMR in general and that of Manipur in particular evolved through the interaction between the Indian and Myanmar plates rather than Indian and Eurasian (China) plates under a simple shear deformation mechanism. From the analysis it is found that the region has compression in the WNW-ESE direction while extension lies in the NNE-SSW direction. As a result, structures such as folds, reverse and thrust faults oriented parallel to NNE-SSW direction will suffer maximum compression and shortening while structures such as normal faults, tension fractures and joints running parallel to the WNW-ESE direction will undergo maximum extension.

And structures lying in the NW-SE and NE-SW quadrants will have strike-slip movement. The faults and fractures around Tipaimukh dam axis belong to the category that may undergo strike-slip and extensional movements. So, these structures can be easily reactivated causing small to considerable displacement along them by any tectonic phenomena e.g. moderate and large earthquakes. By such a process, if the dam axis is displaced by a few centimetres a serious damage may occur causing a dam disaster leading to huge loss of lives and property.

Seismicity

Northeast India is one of the highest earthquake-potential area in the world due to its tectonic setting, i.e. subduction, as well as collision plate convergence. Analysis of earthquake epicentres and magnitudes of 5M and above within 100-200km radii of Tipaimukh dam site reveals hundreds of earthquakes in the last 100-200 years. It is found that within 100km radius of Tipaimukh, 2 earthquakes of +7M magnitude have taken place in the last 150 years and the last one being in 1957 at an aerial distance of about 75km from the dam site in the ENE direction.

Beside the frequency of such large earthquakes within 100km radius, it is also further observed that a number of epicentral points align in the form of a linear array parallel to

regional strike NNE-SSW or N-S revealing how this Barak-Makru thrust zone is seismically active. Another important aspect of seismic activity is that shallow earthquakes are far more disastrous than the deeper ones even if magnitude is relatively low since destructive surface waves can be quickly and easily propagated from the focus/epicentre. And majority of the earthquakes that takes place on the western side of Manipur are shallow (50km focal depth or less) which is due to the tectonic setting of the Indo-Myanmar Range.

Under these circumstances whether it will be a wise policy to construct a huge dam or not need to be thoroughly discussed and investigated. The trend of earthquakes shows that the regions which have experienced earthquakes in the past are more prone to it; the magnitude of future earthquakes may be uniform to the past ones; and the earthquake occurrence, geological data and tectonic history all have close correlation (Mollick). The Tipaimukh Dam site has been chosen at the highest risk seismically hazardous zone.

The dam proponent, NEEPCO, claims that seismic hazards are being taken care of through consultations with Rourkee University (However, the government of India has requested NEEPCO to also consult with the Geological Survey of India). Here it is pertinent to state that extreme seismic hazards cannot be addressed adequately or satisfactorily through consultations with seismologists, as the risk inducing and impact factors are mechanical, geophysical, tectonic and socio-economic in nature.

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