REMOTE SENSING AND GIS FOR SEISMIC RISK ASSESSMENT IN HOA BINH HYDROPOWER DAM

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ABSTRACT

Basing on remove sensing, geological data, geomorphologic analysis and field observations, we determine fault systems which are potential to generate earthquake and could cause damages to Hoa Binh hydropower dam. They are sub-meridian fault system what consists of fault segments locating on in the central part of the east and the west flanks of the Quaternary Hoa Binh – Bat Bat graben: Hoa Binh 1 fault is east-dipping, N-S trending, 4 km long western of Hoa Binh and dip angle 75-80^o and Hoa Binh 2 is west-dipping, N-S trending eastern Hoa Binh graben, 8.4 km long, dip angle 70-75^o. Thereafter, we assessed the Maximum credible earthquake (MCE) and Peak ground acceleration (PGA) at Hoa Binh hydropower dam. Estimated MEC of HB 1, HB2 is 5.6 and 6.1, and maximum PGA at Hoa Binh dam is 0.30g and 0 .40 g, respectively.

1. INTRODUTION

Hoa Binh (HB) hydropower dam more than 120 m high is a highest dam in SE Asia. The plant contributes importantly to economic Vietnam development. In the Hoa binh area, two active normal faults locate not far from the dam to the east. In 1970s, in preparing for the construction of HB dam, Vietnamese-Russian workers carried out a series of geological and geophysical investigations. However, they did not pay attention on active faults. For seismic risk assessment, they used only old experimental law and seismic attenuation for far source. So, the implicit seismic risk of destruction of the dam threats directly not only to Hanoi but also all Red river delta with more than 20 millions inhabitants.To ensure absolute safety of HB dam, we have to realize analyzing active tectonics and series of measurement in details of geology, geomorphology and espcially analysis of remote sensing in HB zone to make seismic hazards assessment and proposal of most sensible operation of HB reservoir. The probabilistic is less effective where recording time is too short and with long recurrence interval of earthquake. In this case, it is necessary to assess seismic hazard by using simultaneously seismotectonic methods and probabilistic analysis for each site or for certain area. The seismogenic capability of the active faults is identified through satellite images, topographical and geological maps, and field survey and earthquake catalogue. The capability at one site is showed by MCE and PGA.

2. TECTONIC SETTING

The process of collision between the India and Asia that took place 50 million years ago had changed basically the tectonic framework of Asia. Systematic studies along the Red river fault zone (RRFZ) from Yunnan to Vietnam (Leloup et al., 1993, 1995) proved that almost gneiss structures along the Red river metamorphic zone were formed in Cenozoi. The RRFZ proves an important tectonic role for the formation and development of a series of Cenozoic structures at all scales in the northwest region and a part of the northeast of Vietnam. Many features of neotectonic deformation and topographical development HB zone in particular have been clarified thanks to analyses of deformational history of the RRFZ. Neotectonic activity in the northwest is expressed not only by the left lateral strike-slip displacement of the RRFZ, but it also happened along a series of fault zones in the same NW - SE direction. One can observe a series of structures of the northwest of Vietnam being formed in Cenozoi. Overthrusting phenomena were widely developed in the northwest as well as northeast of Vietnam, such as Hoabinh arc and Sapa marble. HB dam zone is regional boundary between RRFZ and Da river zone. Uplifting of the N-S fault system is expressed clearly by high and average topographical elevation more than 200 m in comparation with the southwest wing. This fault expresses clearly an active normal fault. The clearest manifestion is along east segments. Triangular facets are expressed clearly with dipping toward western. The height of triangular reaches 100 -120 m. Typical hung valleys prove the fast uplift of NE wing that goes beyond erosion speed of gravel, sand, soil. HoaBinh N-S system faults does not extend continuously but it is divided into small segments. Strongly separating and extensive activity of fault are manifested in this segment, the system is divided into 2 discontinuous segments that we called segments HB1 and HB2.

3. ACTIVE TECTONIC IN HOA BINH AND ADJACENT AREA

From Landsat, Spot image and DEM, we defined three N-S-trending segments next to HB dam root which generates a nearly vertical-flank graben (fig.2, fig.3). In some sites, the graben is 2.5 km wide filled with alluvial-proluvial deposits up to 70 m thick. The fault

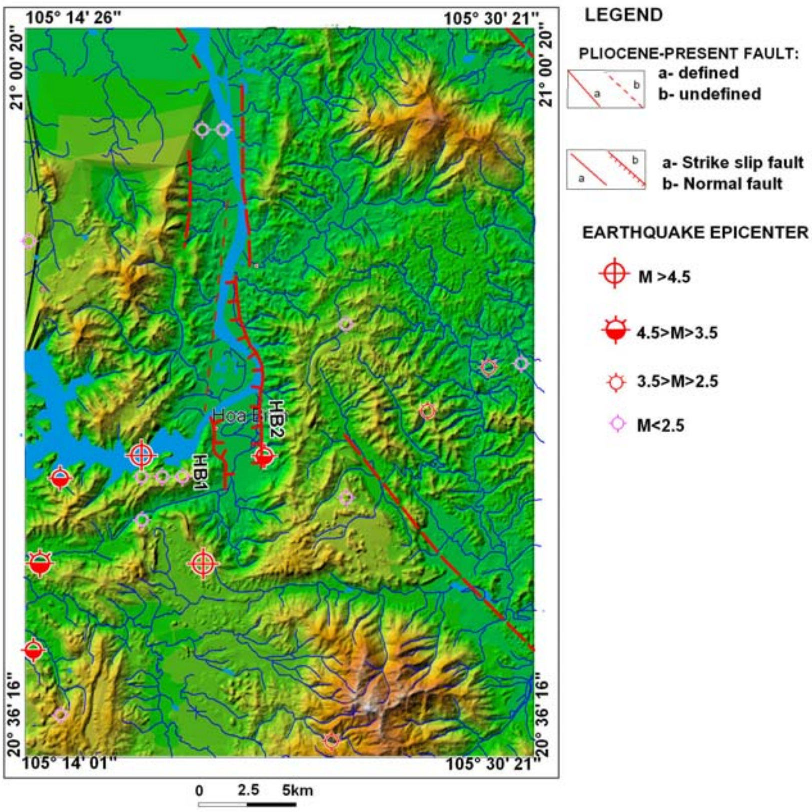

Figure 1. Active fault system in Hoa Binh and adjacent area based on DEM made from topographic map scale 1/50.000

segment at the east flank is 8.4 km long and the one segment is 4km long at the west. Distance between the latter and the dam is only 0.3 –2.5 km (fig.1). Diverging movement of the segments can clearly observe on Spot, Landsat image, DEM and in field. This movement is characterized by triangular facets. Results from tectonophysical methods are completely consistent with the representation above: If stress field is predominantly compressive in pre-Pliocene, stress field is predominated by normal extense trend in Pliocene – Quaternary.

We identified fault systems which are potential to generate earthquake and could cause directly damages to HB dam, that is sub-meridian fault system which broadly well developed. They also consist of segments focusing on in the central part of the east and west flanks of Hoa Binh–Bat Bat graben, on Kim Boi dome and and on Tu Ly arc-uplifting massif. Excepting faults controlling Hoa Binh – Bat Bat have length more than 10 km, other faults often are less than 10 km long (fig 2 and fig 3). In modern tectonic framework, this is the youngest fault cutting and varying all older structures and former framework. On each flank of Hoa Binh- Bat Bat graben, the normal fault surfaces are nearly vertical, dipped to the graben center and each fault coincides with some landforms and controls distribution of river terraces and alluvial flat (fig 3). In general view, all of the regions belong to the SW part of the RRFZ and Quaternary graben and tectonic breccia zones developing next to the RRF with acute angle exhibits right lateral movement. The sub-meridian fault system is distributed along two flank and controls structure of HB graben. The western branch running across Ong Tuong hill is more than 4 km long, its fault surface dips to the east. Along this segment, it can be recognized some normal active shear zone which could cause surface crack in this area. The eastern fault branch consists of one segment whose length is about 8.4 km. Along this segment, it is strongly developed triangular facets. The fault controles flow of river and stream system according to different base level. They are represented clearly on satelite images, actual topography through scrap and facets. Remarkably, along some segments at the eastern HB depression, we identify a series of triangular facets in Lang Ngoi, Lang Su. These facets have a height of 70-120m and a foot-side wide of more than 500

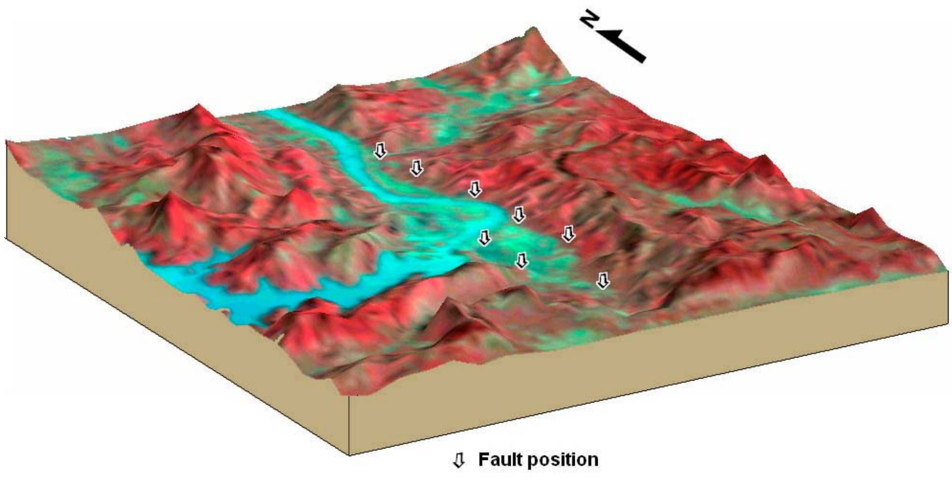

Figure 2: Stereo model of Landsat image showing active fault system near Hoa Binh hydropower dam and adjacent area

m. Age of facets must be in range of Pliocene – Quaternary that is formed by destructing Miocene peneplain earlier. Along some segments at the western HB depression such as in Ong Tuong, in mafic extrusive formation western of HB dam or Doc Cun area, the shear zones are normal slip form, its shear surfaces are concordant with the zone trend. Rolled materials are clay, debris of ferro-gel in fine-soft-porous state, some sites it can be recognized slickensides. Clearest in Ong Tuong hill, active shear zones cut across 20-50m-wide bedding plane system filled with black grey clay material. In addition, in Doc Cun or in low hill range at the eastern HB dam also appear similar normal shear zones, scale of the zones so are up to 60-80 cm.

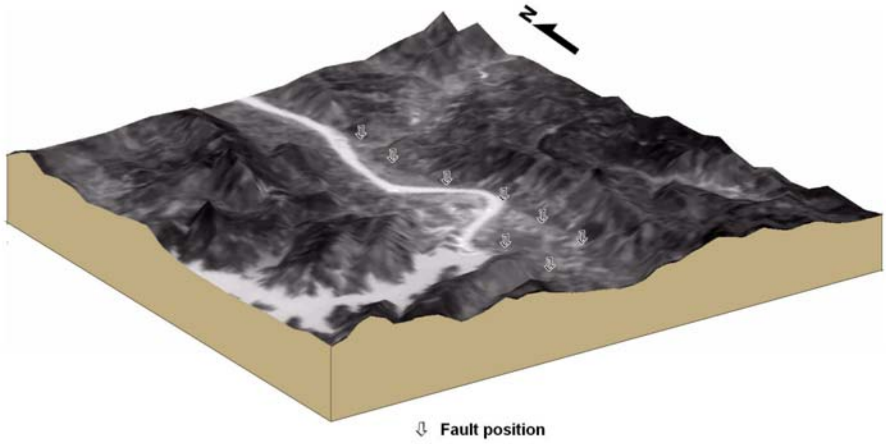

Figure 3: Stereo model of Spot panchromatic image showing active fault system near Hoa Binh hydropower dam and adjacent area.

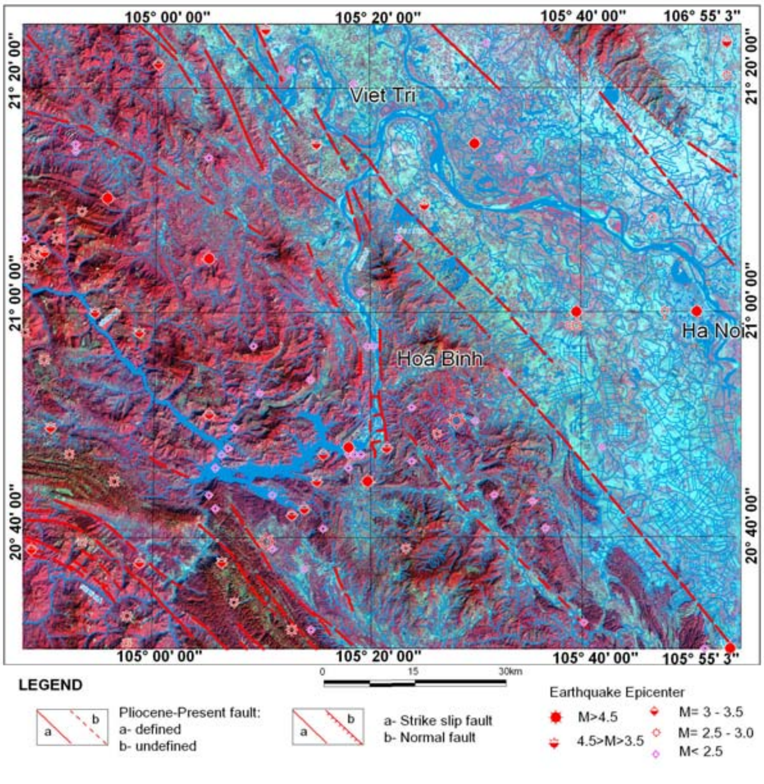

Figure 4. Active fault systems in Hoa Binh and adjacent area on Landsat satellite image.

Radon and mercury investigation show that these gas anomalies are relatively high characterizing for activity of the active sub-meridian fault system. HB graben cuts across HB town stretching from HB to Bat Bat. This structure could generate seismic risk for the two and the hydropower plan. The graben is widened 2.5 km and extended 40 km, according to sub meridian trend from HB to Bat Bat (fig .6). HB graben is filled up with formations of alluvial – colluvial pebble, gravel, sand and a little of marsh facies at south of HB. Thickness of this sedimetal layers vary according to each location, especially 50-60 m in HB.

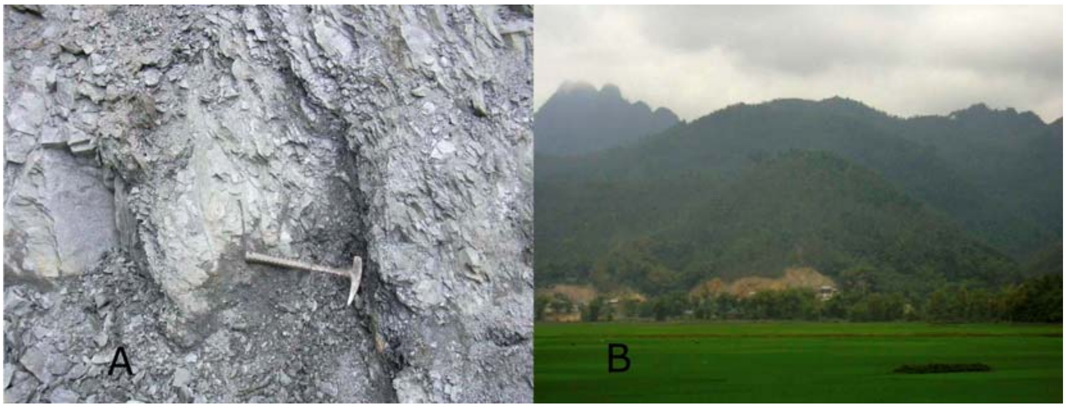

Figure 5. A- Active shear surface system cut across bedding plane system in Triassic siltstones in Ong Tuong hill area – Hoa Binh (shear surface, slickensides and bedding plane trending E-W and nearly vertical slope angles); **B- Triangular facets of a normal fault in east Bai Yen – Hoa Binh**

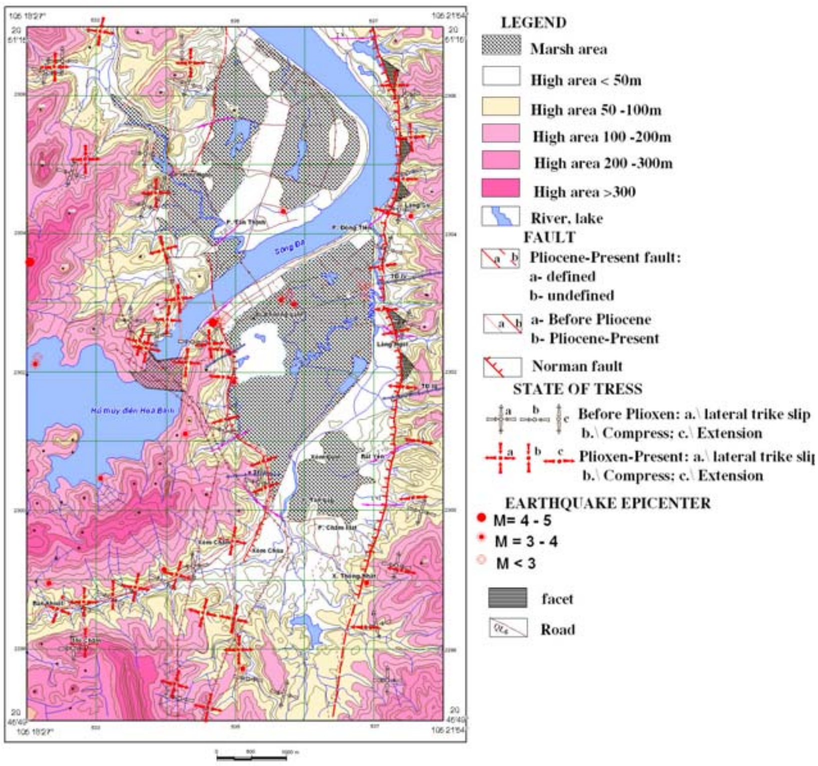

Figure 6: Sketch map of Neotectonics –Acitve geodynamic in Hoa Binh scale 1/25 000.

4. SEISMOTECTONIC ASSESSMENT IN HOA BINH AND ADJACENT AREA

In order to assess seismic hazard for HB hydropower dam area, we focus on the fault systems with significant size. Sub-meridian fault system is distributed along two flanks. The western fault branch is more than 4 km long, its nearly vertical fault surface dips to the east. The shortest distance from section HB1 to HB dam is of 0,3 km, the fault dip is determined of 75^0. The eastern fault branch is one segment with 8.4 km length. The shortest distance from section HB 2 to HB dam is of 2,5 km, the fault dip is determined of 70^0. For seismic assessment, we estimate firstly the MCE) From MCE and distance from the fault to the dam, we estimate the PGA. We use different methods to estimate MCE based on fault length, fault area and seismic moment. We take coefficient 1 for fault length approach, coefficient 2 for rupture area approach, and coefficient 3 for earthquake moment approach. For estimating PGA, we use attenuation models 1, 2, 3, 4 of Campbell and formulas of Idriss, Xiang and Gao, Woodward - Clyde, Ambraseys, Cornell, Mc Guire, Estena & Rosenblueth. Formula of Cornell, Mc Guire, Estena & Rosenblueth has value for reference only. Taking weight average to summarize PGA by different methods, 3 methods above cannot be used. Models 4 of Campbell based on global data of strong ground motion near the source, so it has high reliability in case of assessing earthquakes with in 50 km or less. The above formulas can use coefficient 3 for calculating weight average. Xiang-Gao's formula can also use coefficient 2, because it is set up from earthquake data in Yunnan close to geological condition.

Table 1: MCE and Maximum PGA at Hoa Binh dam provoked by segments Hoa Binh1, Hoa Binh 2.

No	Fault Segment	Length (km)	Depth (km)	Dip	Characteries	Magnitude (MCE)	Maximum PGA(g)
1	HB1	4.0	6.0	75^o	Normal	5.6	0.30
3	HB2	8.4	6.0	70^o	Normal	6.1	0.40

4. CONCLUSION

Basing on the satellite interpretation and geomorphologic observation, we regconise N-S active fault systems that are potential to generate earthquakes and could cause damages to HB hydropower dam. Fault system consist of two fault segments: the first segment is east-dipping, 4 km long, dip angle of $75\text{-}80^o$ and second is 8,4 km long, dipping to west with angle of $70\text{-}75^o$. Fault segment HB1 could produce MCE of 5.6 and PGA at HB hydropower dam of 0.3g. Fault segment HB2 could produce MCE of 6.1 and PGA at HB dam of 0.40g. For more detail, we need realise geophysical investigations and do trenching along fault segments for having geological evidence. Stress modeling of Coulomb stress change is necessary to forecast displacement and stress distribution in deep and on the surface. This work is financed by Prevention Consortium proj. 2058VNM /05-06 and Basic research program of Ministry of Science and Technology.

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