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ELECTRICAL RESISTIVITY BASED SHALLOW CRUSTAL DEFORMATION ANALYSIS IN AN ACTIVE SEISMIC ZONE

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ABSTRACT

This paper aims to assess the shallow crustal deformation in a highly seismic-prone zone of northeast India. For that purpose, Tripura University campus has been selected which is nearly 8 km away from Agartala city. The field work was conducted by using electrical resistivity meter. Vertical Electrical Sounding or VES method of resistivity survey was adopted for measuring the electrical resistivity and structural analysis of the study area. Total four VES points were recorded namely near the Department of Physics, Department of Geography and Disaster Management, Teachers' Residential area and Girls' Hostel. The recorded data was measured and two different electrical profiles were drawn i.e. (a) Physics building to Geography buildings and (b) teachers' quarters to Girls' Hostel. From the electrical resistivity profiles, a clear break in resistivity characters has been observed in the western part which is located near the Tripura University Girls' Hostel. This clearly proves that a deformation occurred in this area below 4 m depth and it can be very dangerous if a high magnitude seismic slip takes place. From this observation, this hostel is detected as the most risk prone building. Apart from that, the teachers' quarters near the Girls' hostel have also been detected as equally risk prone. From this point of view it can be recommended that construction of heavy buildings should be restricted in Tripura University campus as the subsurface deformation zone can create faulting during high magnitude earthquake.

Key words: structure, vertical electrical sounding, resistivity, deformation, seismic risk

ABSTRAK

Makalah ini bertujuan untuk mengukur deformasi kerak dangkal di zona seismik timur laut India yang sangat rawan. Karena alasan itulah, Universitas Tripura yang terletak hampir 8 km dari kota Agartala telah dipilih. Studi lapangan dilakukan dengan pengukur resistivitas listrik. Vertical Electrical Sounding (VES) atau metode survei resistivitas diadopsi untuk mengukur resistivitas listrik dan analisis struktural dari daerah studi. Sejumlah empat titik

VES dicatat yaitu J, ./urusan Fisika, Jurusan Geografi dan Manajemen Bencana, Daerah Hunian Pengajar, dan Asrama Mahasiswi. Data yang tercatat diukur dan dua profil listrik yang berbeda ditemukan yaitu (a) dari gedung Jurusan Fisika ke gedung Jurusan Geografi dan (b) dari daerah hunian pengajar ke asrama mahasiswi. Dari profil resistivitas listrik, telah diamati adanya pemutusan yang jelas terlihat dalam karakter resistivitas di bagian barat, yang terletak di dekat Asrama Mahasiswi Universitas Tripura. Hal ini jelas membuktikan bahwa deformasi terjadi di daerah ini pada kedalaman di bawah 4 m dan bisa menjadi sangat berbahaya jika pergeseran seismik berkekuatan tinggi berlangsung. Dari pengamatan ini, Asrama Mahasiswi terdeteksi sebagai bangunan yang paling rentan risiko. Selain itu, daerah hunian pengajar yang berada dekat Asrama Mahasiswi juga telah terdeteksi rawan risiko. Dari sudut pandang ini dapat direkomendasikan bahwa pembangunan bangunan berat harus dibatasi dalam kampus Universitas Tripura karena zona deformasi di bawah permukaan dapat menimbulkan terbentuknya patahan selama gempa berkekuatan tinggi terjadi.

Kata kunci: struktur, vertical electrical sounding, resistivitas, deformasi, resiko seismik

INTRODUCTION

Electrical resistivity of rocks is a significant physical character which helps to assess the geology structure and its spatial variation. Among the solid objects in the nature soil is considered as one of the most important environmental components in lithosphere which interacts with other environmental components. Early works by *Doran and Parkin,* [1994]. *Bernstone et al.* [1997] proved that functions of environmental components like vegetation, water, atmospheric compositions etc, are very important para-meters to measure the quality of soils. For ground water measurement, electrical conductivity of soil is used as a very common geophysical technique. Many investigations have been done on electric/ electromagnetic conductivity of various soils by [*McNeill*, 1980; *Palacky,* 1987; *Dahlin*, 1993. *Alfano et al*. 1993; *Dahlin*, 1996; *Christensen and Sørensen* 1996; *Dahlin and Lok* 1997; *Yoshida et al.* 1997; *Gorge et al*. 2008 and *Akpan et al*. 2009] which strongly support the efficiency of this technique. In a very recent published work, a research team of Tripura University, in which the present author belongs as a research scholar, successfully allied electrical resistivity characters of rock for detecting a fault line in Baromura hill [*Dey et al.* 2011]. Considering the scientific importance of this geophysical method, the present authors decided to perform an experimental study on near surface electrical conductivity and its physical significances. The basic objectives of this study are to prepare structural profiles and to assess the risk condition of Tripura University campus.

Geological evidences support that landform development in this part was started by sediment deposition during the mid Miocene epoch [*Mitra et al*. 1968; *Sinha and Sastri*, 1973; *Akram et al*. 2004 and *Dey* 2005]. Roughly Agartala and its surroundings can be distinguished into two geomorphic groups namely, dissected highlands and adjacent flat land of Haora river basin. This is remarkable that all the geomorphic units of this area are formed by the depositions of different geological periods. These depositions are not only different by their depositional periods but also different by their characteristics like origin, texture, structure and colour. Table 1 and Figure 2 are showing the different geological formations.

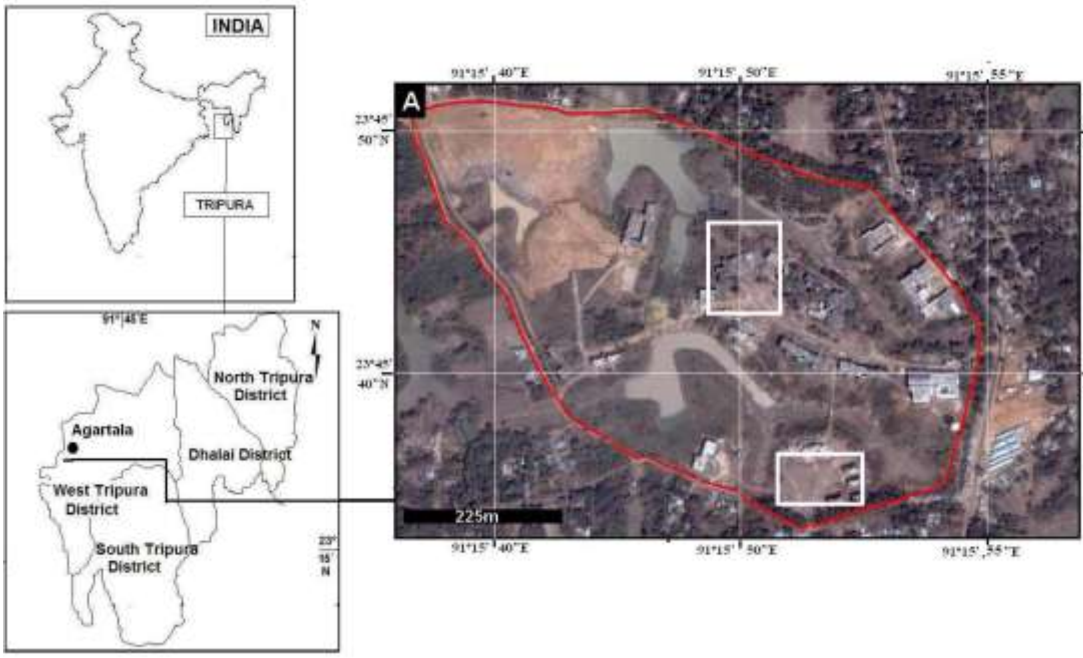

Figure 1. Location and environs of Tripura University campus (Google Earth View), white boxes are the surveyed areas

Recent works on rock microstructure and microarchitecture of Tripura by the research team of Tripura university like [*Dey et al.* 2009; *Debbarma et al*. 2010; *Dey et al.* 2011b and *Dey et al.* 2011c] strongly support that the geological evolution of this area remained very dynamic and early researches by [*Gupta and Singh*, 1982; *Guha and Bhattacharya*, 1984; *Agarwal*, 1986. *Kayal,* 1987; *Gupta and Singh*, 1989; *Gupta,* 1993; *Kayal* 1996, 1998 and *Bhattacharjee*, 1998] strongly support that geophysically northeastern part of India is one of the most active tectonic zones in the world and experiences frequent catastrophic earthquakes. In a quantitative study *Das-gupta et al.* [1998] systematically assessed the level of spatial scale seismo-tectonic hazards in northeastern and eastern parts of India.

According to the seismic map prepared by [*Thingbaijam et al.* 2008] the present study area falls within EBZ or Eastern Boundary Zone which is mainly of medium magnitude. Some recent earthquake experiences of EBZ and adjoining areas are shown in Table. 3.

In a very recent work [*Dey et al.* 2009] identified that prominent morphological signatures are the evidences of seismic activity in west and southern parts of Tripura.

Table 1. Geology of Agartala and surroundings

Form	Periods of depositions			Types of depositions
	Period	Epoch	Duration	
Younger alluvium	Quaternary	Holocene Pleistocene	10000 years 1.6 million years	Clayey silt, clay with silt, sands etc.
Tipam and Post-Tipam	Tertiary	Pliocene	5.3 million years	Brown clay sand, silty clay, white to gray sand rock with silt band, white clay

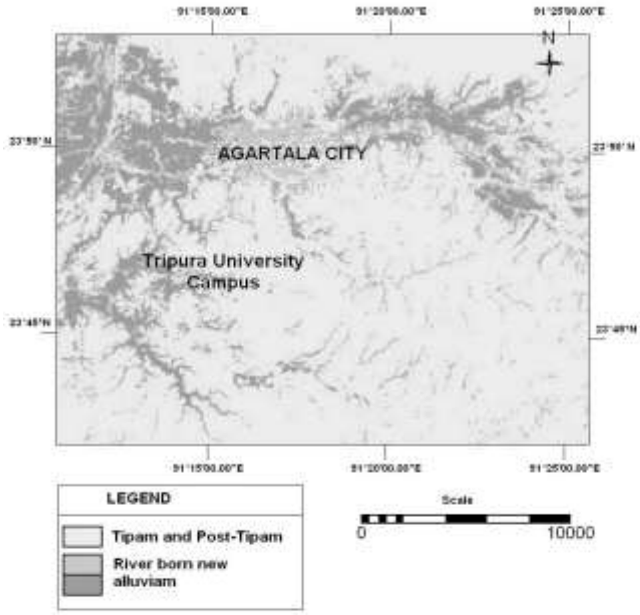

Figure 2. Geology of Agartala and its surroundings (prepared on Landsat TM Shortwave Infrared Band or Band 7)

Table 2. Earthquakes in Eastern Boundary Zone and its adjoining areas after 1965

Year	Place	Geographical locations	Magnitude	Severity
1968	NE of Agartala (Indo-Bangladesh Border region) Tripura	24.10N, 91.60E	5.2	Moderate
1971	East of Agartala (Tripura)	23.80N, 91.80E	5.4	Moderate
1984	SE of Agartala (Tripura)	23.6573N, 91.5078E	5.3	Moderate
1984	South of Silchar (Assam-Mizoram border region)	24.64N, 92.89E	6.0	High
1989	Tripura-Mizoram-Assam border region	24.4041N, 92.4312E	5.1	Moderate
1997	Southern Mizoram	22.212N, 92.702E	6.1	High

THE METHODS

Pre-field study

Prior to field investigation, some early reports and cartographic materials like Geological map (prepared by Geological Survey of India, 2003, scale: 1:500000), *SOI* toposheet (scale: 1:50000) etc were consulted for determining the geological condition of Tripura University campus and its surroundings. Google Earth image and Landsat *TM* were also studied for assessing the morphological condition of the study area. A geological map was prepared on Landsat *TM* Band 7 (Short-wave Infrared) on the basis of early maps and field work.

Field Instrumentation

One basis of primary survey in the university campus is that a total of four points were selected for vertical electrical sounding (*VES*) data generation. The four *VES* points are: (a) in front of Geography building, (b) in front of Physics building, (c) on the open ground in front of Girls' Hostel and (d) Teachers' quarters. Electrical Resistivity Meter was used for *VES* data generation. Wenner's configuration was adopted for vertical electrical sounding (Figure 3) and instrumental reading was taken up to 12m depth (interval 2m). The instrument was calibrated carefully. Range of the instrument was fixed X10 (current 100mA).

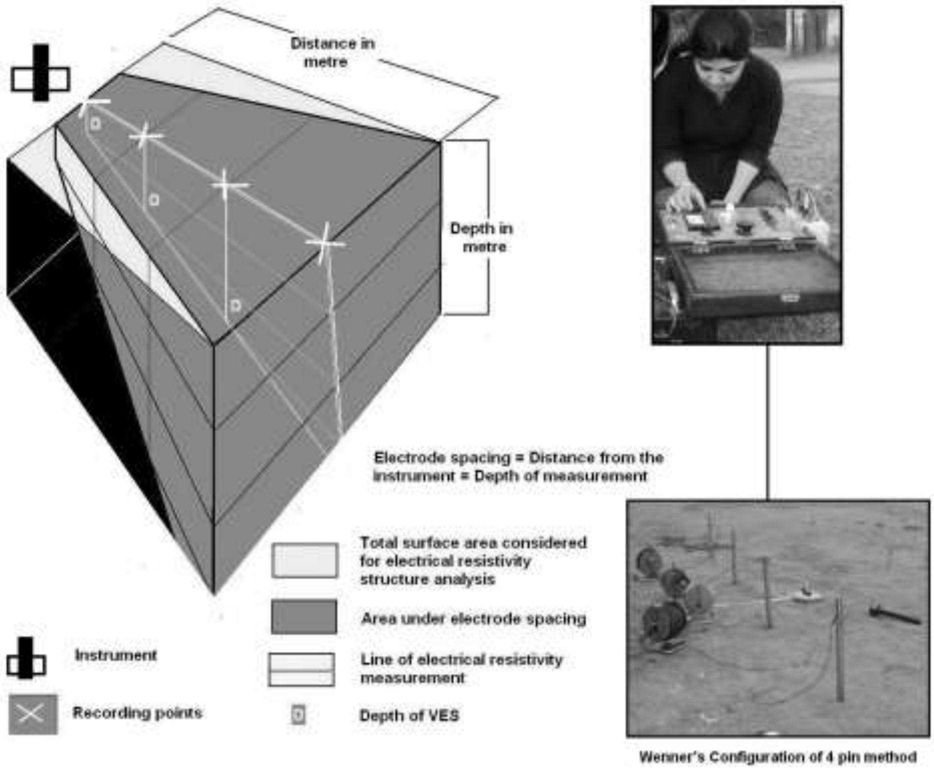

Figure 3. Theoretical plotting and field setting instrument and electrodes for *VES* data generation by Wenner's configuration of 4 pin method.

Table 3. Measuring electrical resistivity from field data

Depths	Open ground (GH)		Teachers' quarters		Geography building		Physics building	
	Instrument reading	ρ=2ЛAR in Ωm	Instrument reading	ρ=2ЛAR in Ωm	Instrument reading	ρ=2ЛAR in Ωm	Instrument reading	ρ=2ЛAR in Ωm
2 m	0.228	28.651	0.42	52.778	91.734	23.373	0.73	91.734
4 m	0.304	76.403	0.515	129.433	220.162	44.484	0.876	220.162
6 m	0.174	65.596	0.011	4.146	220.539	111.966	0.586	220.539
8 m	0.093	46.746	0.75	376.991	214.633	93.493	0.427	214.633
10 m	0.179	112.469	0.011	6.911	21.362	108.699	0.034	21.362
12 m	0.046	34.683	0.099	74.644	9.047	159.090	0.012	9.047

R=Range of the instrument X instrumental reading, electrical resistivity in Ωm

Data analysis

The recorded electrical data was measured by using simple formula and based on the calculated electrical resistivity of different *VES* points, and some graphs were prepared (Table. 3). The formula is as follows:

ρ=2ЛAR…………………………........(1)

Where,

ρ= Resistivity of rocks in Ωm

A= Spacing of electrodes

R= range of the instrument X instrumental reading

On the basis of the recorded resistivity characters, the soil / rocks of this area were divided into four classes namely top soil layer (resistivity up to 30 Ωm), soft rocks (resistivity below 80 Ωm), medium rocks (resistivity below 100 Ωm) and hard rocks (resistivity 200 Ωm and above).

RESULTS AND DISCUSSION

General resistivity characters

The first VES point is located near the PG Girls' Hostel. On this *VES* point minimum restivity of 28.651 Ωm was recorded at the top soil layer (2m depth). At 4m depth, the resistiviy is 76.403 Ωm and below 4m depth, a gradual decrease has been observed. At 5m and 6m depths, the recorded resistivities were 65.596 Ωm and 46.746 Ωm consecutively. The maximum resistivity of 112.469 Ωm was recorded at 10m depth. Below 10m depth, a sharp decrease of resistivity has been found and at 12m, it is only 34.683 Ωm. The second *VES* point is located near the teachers' quarters. In this part, the top soil is marked by comparatively greater resistivity than the first *VES* point. In this area, at 2m depth the electrical resistivity has been measured at 52.778 Ωm. Existence of hard rock has been detected at 4m depth where the resistivity is 129.433 Ωm. A sharp negative change has been observed at 6m depth (4.146 Ωm). Maximum resistivity found in this area at 8m depth is recorded at 376.991 Ωm. Another very low resistivity found at 10m depth is recorded at 6.911 Ωm, after which the resistivity increases up to 74.644 Ωm at 12m depth. The third *VES* point is the Geography building. In this area, up to 4m depth the resistivity is very low (<50 Ωm) At 6m depth, the resistivity increases to 111.966 Ωm and the maximum resistivity found at 12m depth is 159.090 Ωm. The fourth *VES* point is the Physics building. The top soil layer of this area is 91.734 Ωm which indicates a very hard soil type. Below 2 m, this area is characterised by very hard rocks and up to 8m depth, the resistivity is not less than 210 Ωm. Below 8m, the resistivity increases and at 10 m it is recorded at 21.362 Ωm and at 12m depth, it is recorded at 9.047 Ωm.

Ground water and other geological significances

The graphs of the *VES* data show that there are some sharp negative changes of electrical resistivity which prove that water bearing strata or very wet soil exists in those areas (Figure 4). In the first water *VES*, the negative change was found at 8m depth. However, in the second *VES* point, 2 negative changes were found at 6m and 8m depths. This variation of the level of water bearing strata indicates some geological complex character in this residential area. Near the Geography building, the negative change was found at 8m, while near physics building, the water bearing strata was observed at 10m depth.

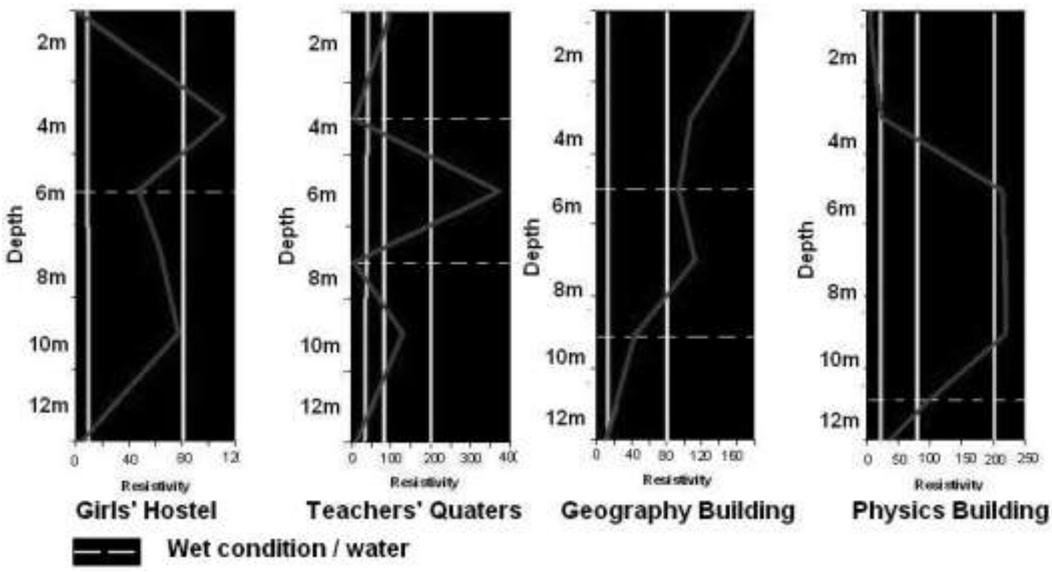

Figure 4. Line graphs showing the electrical resistvity structure at different depths of the VES points

Structural significance

On the basis of the electrical resistivity data, two resistivity profiles were prepared, i.e. (a) west to east profile by *VES* I and *VES* II and (b) north to south profile by *VES* III and *VES* IV (Figure 5). The first profile was prepared in the residential area in which one *VES* point is the open ground near the Girls' hostel and another *VES* point is the teachers' quarters. In this profile, a general east to west dip of the upper layers has been observed. Below 4 meter the dip becomes very low and towards the west, a clear break in resistivity profile has been detected which indicates a sub-surface deformation. A natural depression has been found in the surface of this deformed zone. The second profile consists of the *VES* points of Geography and Physics buildings. This area has a south to north dip direction and the structure is very simple. No break in electrical resistivity has been observed in this area. In the northern part, near Geography building, the top soil is very soft and towards the Physics building the soil becomes comparatively harder. This area has no geological complex character and thus this is attributed as a less risk zone.

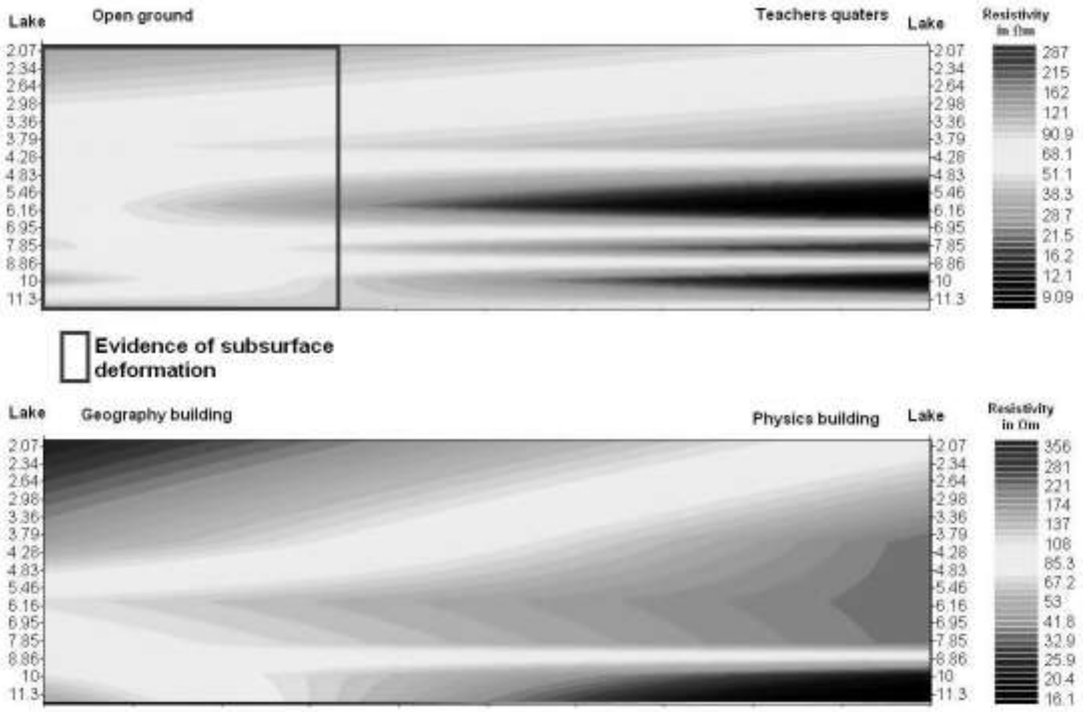

Figure 5. Electrical resistivity profiles showing the structural significances

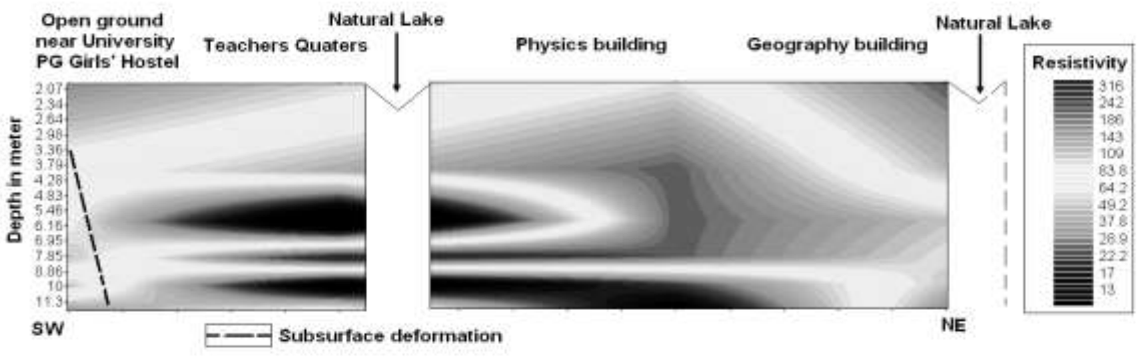

Figure 6a.Combined south-west to north-east electrical resistivity profile in the university campus

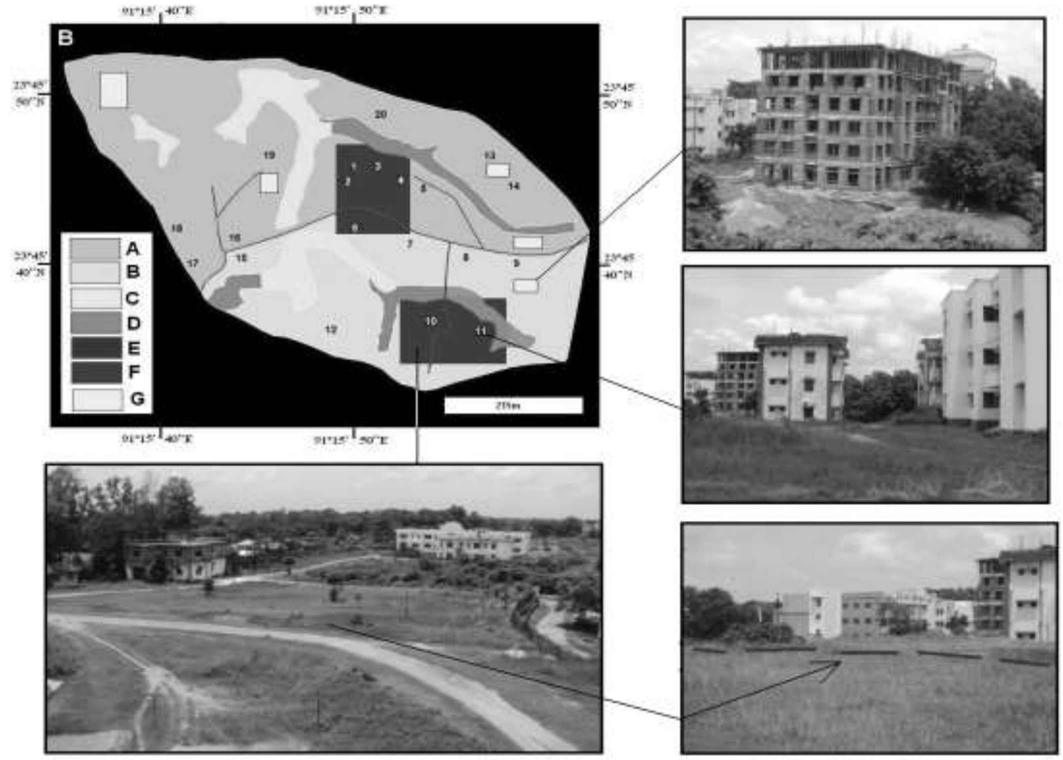

Figure 6b. Landuse map of Tripura University campus and risk prone zones (marked in the lower right and left photographs): A. Academic and administrative area, B. Residential area, C. Water body, D. Dry lake area, E. Roads, F. Electrical survey zones, G. Newly constructed buildings; 1. Geography building, 2. Old IT building, 3. Physics building, 4. Life Science, 5. Chemistry building, Economics, 7. Arts building-I, 8. Arts building-II, 9. Central Library, 10. Girls' Hostel, 11. Teachers' quarters, 12. PG Guest House and VC's residence, 13. Maharaja Bir Brikram Auditorium, 14. Main administrative building, 15. Non-teaching employ quarters, 16. New Technology building, 17. Non-teaching employ quarters, 18. Management building, 19. PG Boys' Hostel

Discussion

As a subsurface deformation has been detected in the residential area by the electrical resistivity profiling, the present author concentrates on risk assessment of this area (Figure 6a and 6b). The observation says that the present condition of the building of this risk prone area (teachers' quarters and hostel) is not much affected even after four strong seismic shakings during 2011 as these were very properly leveled during the foundation. This construction is not far away from the detected subsurface deformed zone.

Thus, if a large earthquake occurs, the whole area can be affected by faulting and the heavy buildings will be collapsed. However, this area is marked by many heavy buildings like the hostel and the teachers' quarters. Apart from those, other important buildings are the Tripura University Guest House, Vice-Chancellor's Residence and Health Centre which are located in the west of the deformed zone. Recently, a huge construction has been started just behind the library building which can increase the pressure on soil.

CONCLUSION

The study of disaster management in Geography curriculum is becoming popular and many geographers are working in this field. The present study attempts to assess the seismic risk probability by electrical resistivity measurement which is a very common method in the disciple of Geophysics. Origin of a devastating earthquake depends on many geophysical factors but the proximity of the fault line in the present study area may render high level hazard anytime. From that standpoint, electrical resistivity analysis strongly suggests that there remains a certain possibility of faulting in Tripura University campus during seismic activity. Although the result worked out through the above mentioned process of data simulation is satisfactory, some further addition of data from different sources for geo-processing is needed for a future version of advancement. Hence, regular seismic data generation and change detection mapping by establishing permanent monitoring stations equipped by satellite technologies like Geodetic *GPS* and remote sensing in some selected places are needed for more efficient earthquake disaster planning.

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