ROHIT SINHA,ONGC, NIKOS MARTAKIS, LandTech Enterprises SA, Athens,Greece, AKIS TSELENTIS, and PARIS PARASKEVOPOULOS, Dept of Seismology, University of Patras, Greece.

Results of a Preliminary Test Investigation on the Applicability of Passive Seismic Tomography in VC Block -Assam, India

The purpose of this investigation was to undertake a 1st Phase passive seismic survey in Assam area in order to examine if the natural seismicity in the area is sufficient enough to provide a 3D V_p and V_p/V_s subsurface model via passive tomography (PST) and provide a course velocity and V_p/V_s model after 3 months of recording. These velocity models will serve as a test for the potential of PST methodology and not for the detailed structural and lithologic assessment of the area to be used for Hydrocarbon exploration. This will be the purpose of the 2nd phase. It is assumed that based on the regional seismicity of the area (Fig.1b), local seismicity can be high enough to sustain a passive survey.

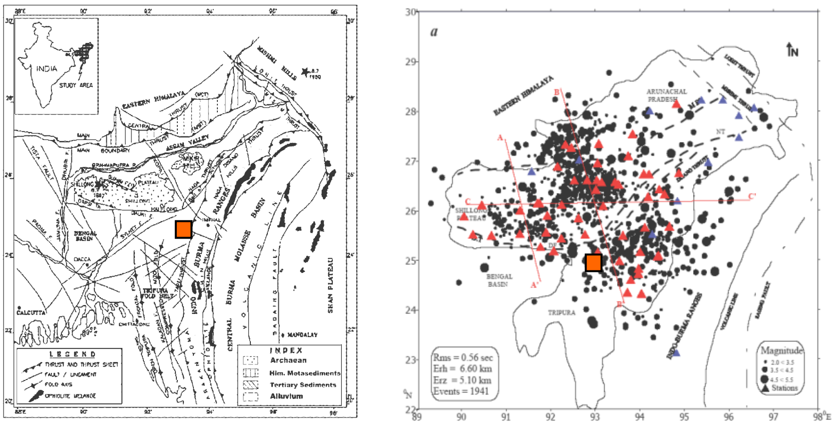


Fig. 1. (a) Geotectonic map of Assam Region (b) Earthquake activity in Assam region from 1993-1999 (Bhatacharya et al, 2005).

It is important to mention that the VC Block area is located in the most intense seismic zone of India (zone V) where 2 major earthquakes with magnitudes M>8.0R (Shillong 1897, M=8.7 and Assam 1950, M=8.7R) and numerous strong earthquakes with magnitudes M>6.0R have been occurred the last 120 years (Fig.1b). In figure 2a, the very complicated geotectonic regime is obvious, mainly dominated by major thrust faults like MBT and MCT to the north and Naga and Yapu thrusts to the east but also with numerous transfer faults.

Seismological Network

The designed network spanned an area of $1900km^2$ although the VC block has an area of about $850km^2$. The reasons that dictated this particular network design are: a) The published seismicity information that shows seismic activity in the area with many earthquakes in depths from 20-50km. b) The micro seismic network should cover a larger area than the block in order to avoid "border smearing" (Martakis et al., 2006). c) The earthquakes focal depth has a very important role in designing of a PST network because in the case where dimensions of the network are smaller than the focal depth can, lead to significant focal depth calculation errors and consequently will affect the velocity model during the inversion procedure (Lee and Stewart, 1981).

Thus, it is always recommended that at least in the first phase (or feasibility) of a PST survey the seismic network has to be extended in order to accurately locate hypocentral parameters and calculate a reasonable starting velocity model. In the second phase the network can be densified over the area of interest based on velocity and seismicity estimations of the first phase.

A microearthquake network which was installed in the area of investigation consisted of 36 LandTech SR24 digitizers supplemented with 30 LandTech S100 and 6 Nanometrics BB Trillium 40, three component sensors. The network spans an area of approximately 1900 km^2 covering the most of VC block area in order to ensure complete subsurface coverage (Fig.2). Recording began on 19th of November 2009 and completed on the 23rd of February 2010.

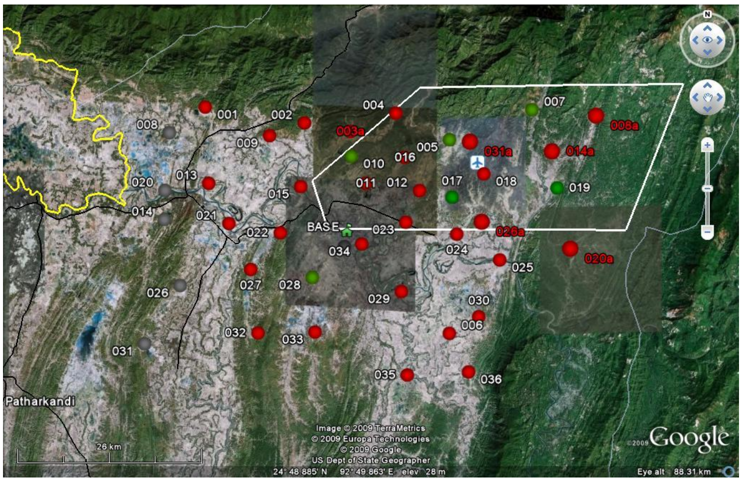
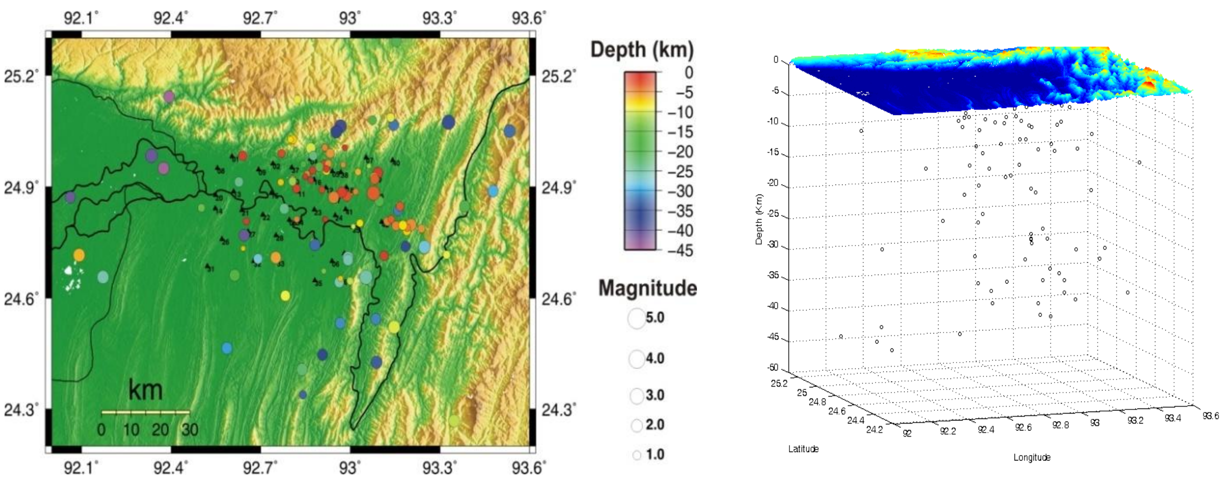


Fig.2. Assam (Block VC) microseismic network (Red circles: short period stations, Green circles: BB stations and Grey circles: stations moved according to ONGC recommendations. The white line represents the boundaries of ONGC VC Block)

Data Analysis

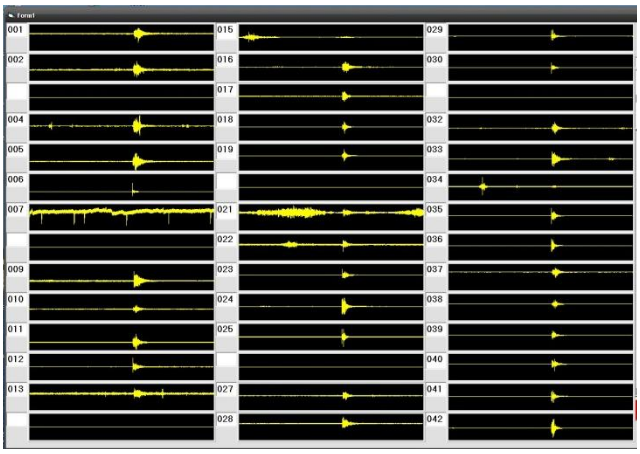
One of the most important steps of a PST survey is the identification and initial location of seismic events. It is a hard and time-consuming procedure because it is necessary to separate seismic events from noise within the whole recording without loosing significant earthquake

Fig. 3. Areal and 3D distribution of 116 located events within the 90 days recording period.



information. In order to achieve this result, we used manual and automatic event detection.

The automatic event detection procedure was performed using the in-house developed software package Sismwin. In parallel to automatic detection we checked all 10min files recorded for all stations and days in order to minimize the possibility to loose data corresponding to very weak events.



During the 90 days of continuous recording significant earthquake activity was observed in the area of interest. Many teleseismic or distant events have been recorder during the 1st phase recording period (Fig.3). In this paper we present only the events that are close or within the seismic network and are useful for seismicity level assessment in the area of interest and construction of a preliminary 3D velocity and V_p/V_s models.

Fig.4. Example of an event recorded in most of the stations of the seismological network.

Figure 4 depicts a seismic event (28-12-2009 at 19.55 GMT with Magnitude 2.5R) recorded at most of the stations of the network.

Data Processing

For the VC Block-PST survey, a reliable initial 1D velocity model provided by a Regional PST survey in NE India was used. After several trial & error 1D inversions we found out that it is preferable to use a uniform 1.72 V_p/Vs value (especially in this early inversion stage with limited amount of data) and leave the model to identify the variations of V_p/V_s which is more ambiguous and sensitive rather than biasing the result using a layered model.

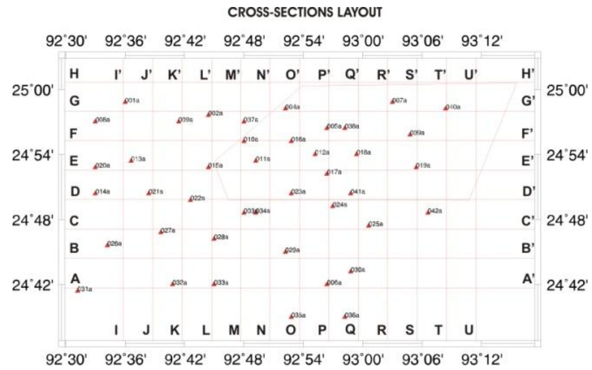
Using the joint hypocenter-velocity inversion, we reached to the conclusion that the minimum 1D velocity model for P-wave velocity and V_p/V_s is the one presented in Table 1. The above mentioned 1D velocity model is the one that minimizes the total RMS misfit and will be used as initial for the 3D inversion procedure.

Depth (km)	Vp (km/sec) Average velocity at corresponding depth)	Vp/Vs
0	5.37	1.72
2	5.41	
4	5.58	
6	5.68	
8	5.81	
10	5.88	
15	6.13	
20	6.37	
30	6.82	
40	7.29	
50 (Moho)	8.00	
>50	8.40	

Table 1: 1D P-wave velocity model and V_p/V_s ratio derived form joint velocity-hypocentral inversion.

The 105 seismic events used for the tomographic inversion provided 1930 P& S-wave arrivals (1078 P and 852 S-wave arrivals) that were used for the tomographic inversion. The final total RMS for seismic events hypocentral estimation was reduced to 0.063sec, in comparison to 0.080 after the 1D inversion procedure.

During the above calculations we used a V_p and V_p/V_s damping factor of 10 (Martakis et al., 2006).



The visualization of Passive Seismic results is presented in the form of a)horizontal, b) vertical and c) 3D distribution of the V_p and V_p/V_s parameters. The horizontal sections have been constructed every 1000m starting from the mean sea level and the vertical sections every 5 km along the lines shown in Fig.5.

Fig.5. Cross-section positions.

Figures 6,7 depict horizontal V_p and vertical V_p/V_s sections below VC Block.

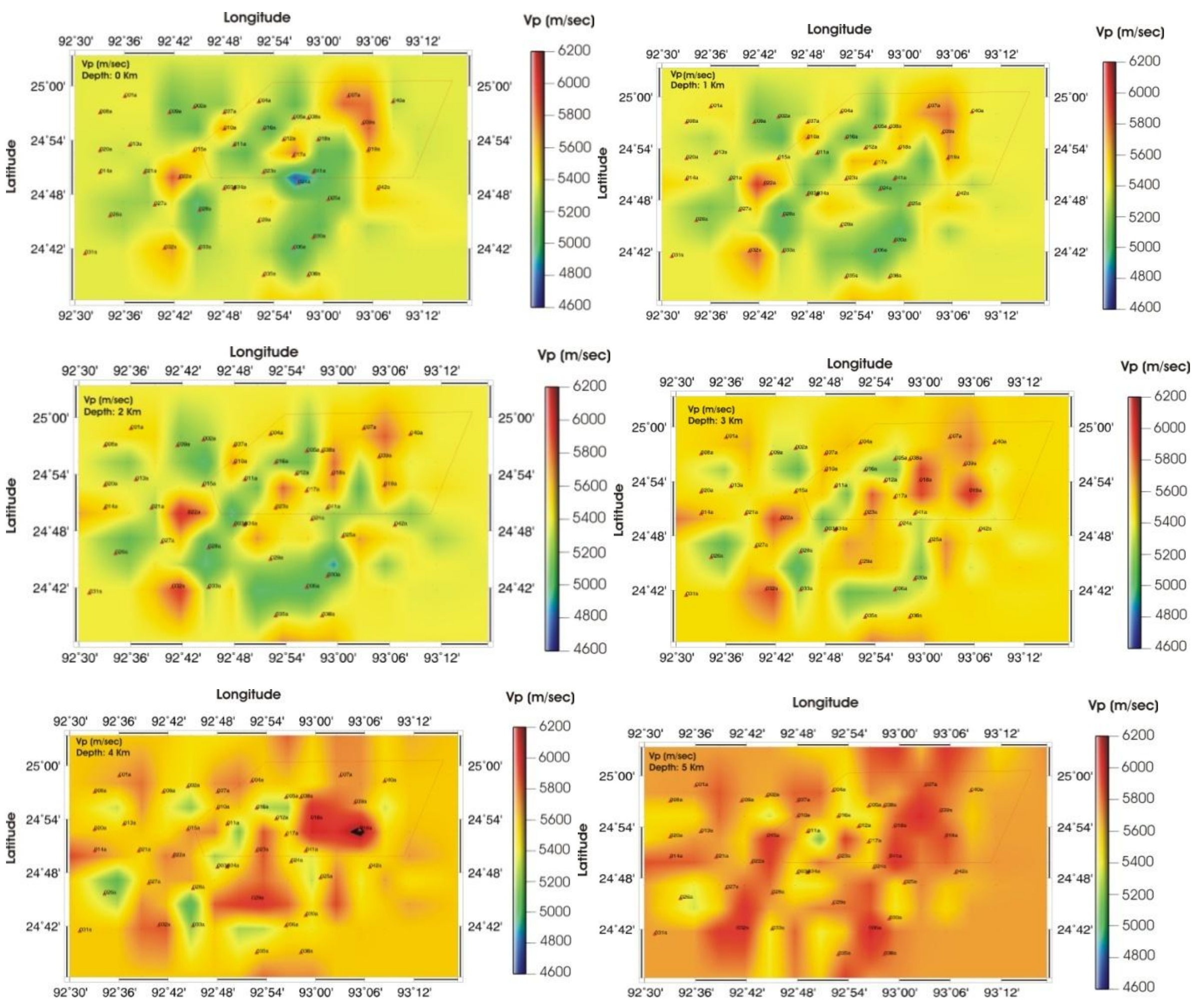


Fig.6. Horizontal V_p sections at 1Km depth interval.

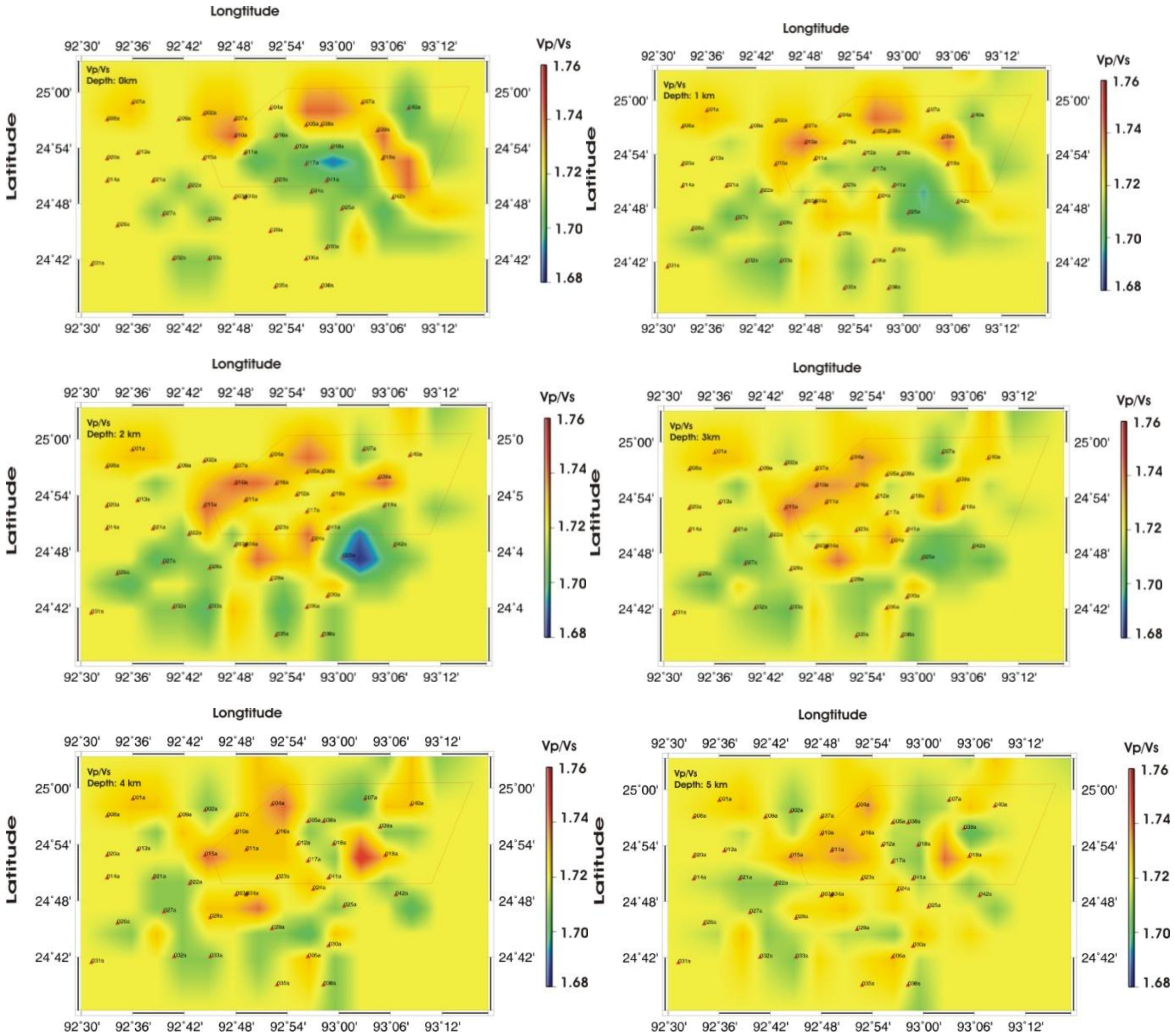


Fig.7. Horizontal V_p /V_s sections at 1Km depth interval.

Some representative V_p and V_p/V_s vertical sections along the directions shown in Fig.5 are depicted in Fig. 8a,b respectively.

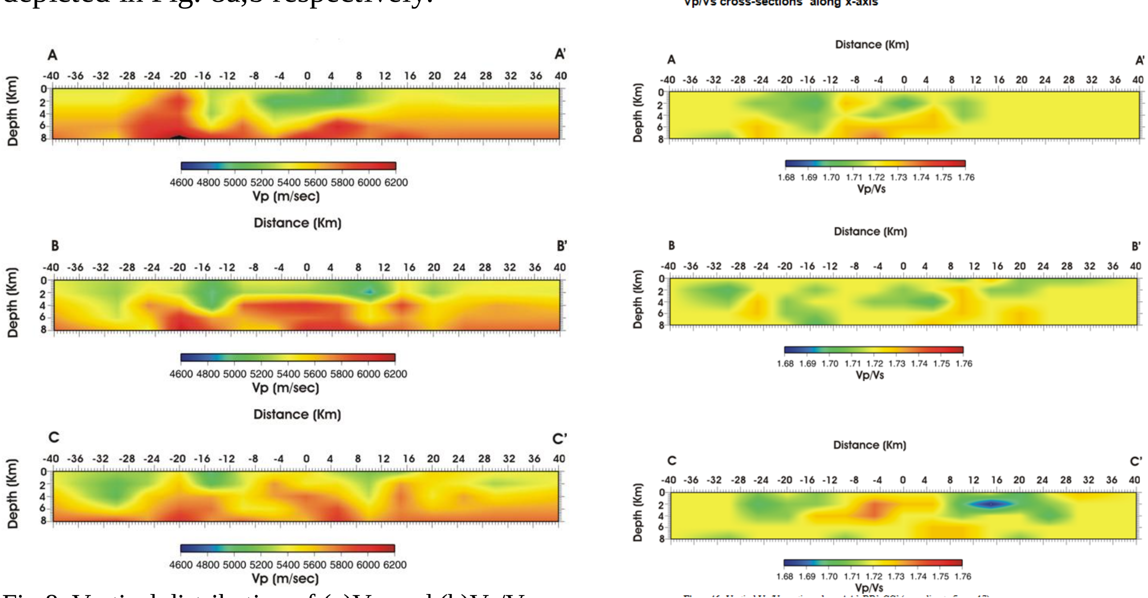


Fig.8. Vertical distribution of (a)V_p and (b)V_p/V_s.

In the figures below (Fig.9,10) we also present selectively 3D images of the calculated V_p and V_p/V_s models.

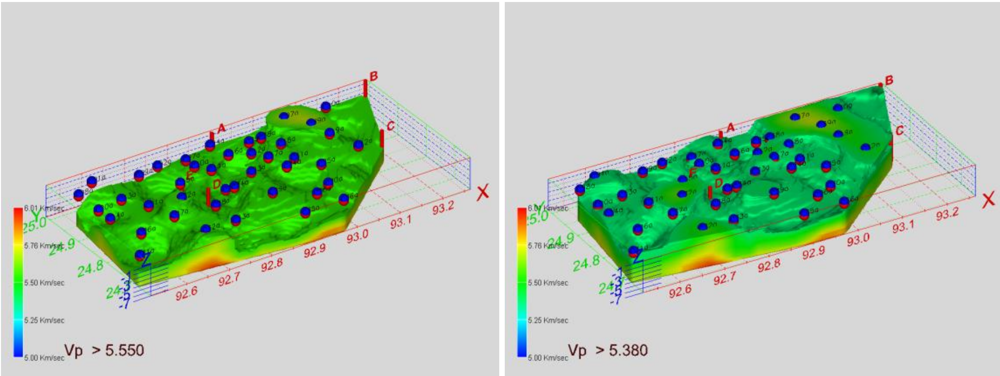


Fig.9. 3D representation of V_p eliminating all velocities below (a)5.550Km/s and (b) 5.380Km/s.

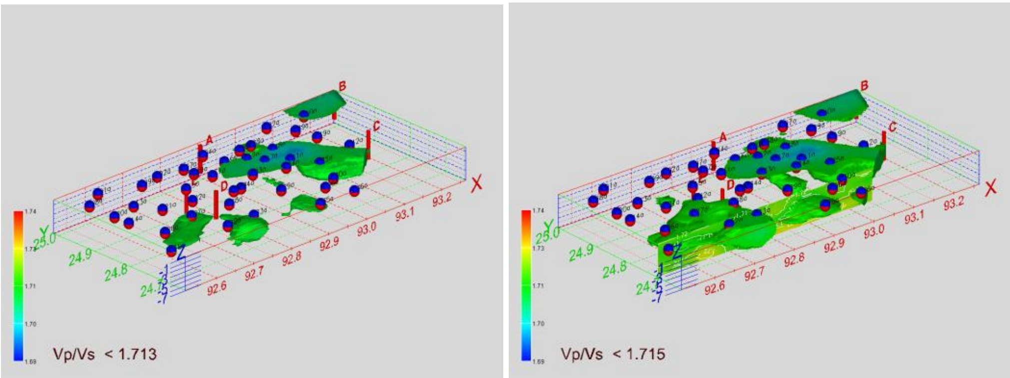


Fig.10. 3D representation of V_p /Vs eliminating all values above (a)1.713 and (b) 1.715.

Conclusions

Based on the observed seismicity rate and having in mind by our experience that with a denser network we are able to locate about 20% more events (due to the increase of P and S-wave arrivals for very weak events) we expect to locate about 500-700 microearthquakes during the 2nd phase. To achieve this we plan to install another 40 stations thus having a total of 76, resulting in a drastic increase of the resolution and assessment of the correct velocities, which in the present preliminary survey are overestimated due to the low ray coverage and the high 1D initial P-wave velocity model. Despite this, there is a satisfactory correlation between the structural models derived during this preliminary survey with known information in the region, which has not been released to us, thus the present investigation can be considered as a blind test. Based on well information, within the Silchar VC block area, provided by ONGC, an updated 3D velocity model will be constructed.

N. Martakis, S. Kapotas And G-Akis Tselentis., 2006, *Integrated Passive Seismic Acquisition And Methodology. Case Studies*. Geophysical Prospecting, 54, 829–847.

Bhatacharya, P.M., Pujol, J., Mahumdar R.K. and Kayal J.R 2005, *Relocation of Earthquakes NorthEast India Using Joint Hypocenter Determination Method.* Current Science, Vol.89, No. 8

Lee, W.H.K. and Stewart, S.W. 1981, Principals and applications of microearthquake networks, *Academic Press*, New York