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RESISTIVITY STEPS AS A PRECURSOR AND IMPENDING EARTHQUAKES OF AFTERSHOCKS OF GREAT EARTHQUAKE OF 26TH DECEMBER 2004 RECORDED AT IDUKKI OBSERVATARY, KERALA, INDIA

Antony Ravindran A.[1] and Ramanujam N.[2]
[1]Department of Geology, V.O. Chidambaram College, Thoothukudi, Tamil Nadu, India
[2]Coastal Disaster Management, Pondicherry, University, Port Blair, Andaman, India
E-Mail: antonicogeo@gmail.com

ABSTARCT

The study of resistivity relaxation before the impending earthquake events occurred during January-February 2005 in the Andaman-Sumatra subduction zone have proven the existence of the long range effects of strain related precursors, fortuitously recorded by the Variometer designed to reflect the premonitory rupture in Kottayam, Kerala, India at epicentral distances greater than 2000km. The swarms of the aftershock of Great earthquake of 2004 supplied sources of seismic waves that have been subsequently scattered, polarized and lead to the process of birefringence through the anisotropic rocks. The average values of earthquake magnitudes (M5.3), epicentral distances (1941km), radius of preparation zones (281km) and focal depths (23km) are calculated from the regression equations evolved from the bivariate plots. The abnormal increase of crustal strain even for a lower earthquake of M5.3 which has definitive radius of the preparation zone of 240km to an ultimate radius of more than 5400km from epicenters to observatory is discussed.

Keyword: earthquake, precursor, resistivity, magnitude, Idukki.

INTRODUCTION

The rock deformation allows the accumulation of stress energy, before the large earthquake and continued until stress energy was released by faulting at the time of earthquake [1]. The increase of stress energy due to swarm of earthquake with magnitude greater than M 5.0 induce large scale stress pattern and that can be recognized at substantial distances from eventual earthquake epicenter [2]. Electrical resistivity studies used for teri sediments and landslide prone zone and earthquake study [3, 4, 5]. As the strain rate in the focal zone increases by the order of magnitude, the zone of preparation also increases. The processes of rock deformation in the hypocenter can be: one with focal zone, where elastic strain developing (creep); and another is subjected to quasi- elastic deformation (preparation zone). The rocks in the preparation zone are capable of transmitting the orders of the magnitude of elastic strain developed in the focal zone. The elastic strain accumulated in the preparation zone is manifested in the form of EM emission, geochemical anomalies and resistivity changes.

The stress energy accumulated is released within the short span of time before the main shocks could be useful as precursor signals of an impending earthquake [6] Morgounovo, 2001. The sudden decrease of resistivity changes in the form of resistivity steps suggests that the stress begins to relax before the earthquake. The stress based forecasting depends upon the availability of the earthquake generated seismic waves such as compressional (P) and shear waves (S); whose coupling in anisotropic rocks leads scattering, birefringence and with hybrid polarization [7]. To predict the earthquake events the supply of sources of shear wave energy from sui. swarms of small earthquake is very uncommon.

Fortuito usly, the resistivity experimental design to reflect the premonitory rupture in the focal region in Idukki-Kottayam districts, Kerala, India, has recorded the aftershock events of Great Earthquake of 26th December 2004 in Andaman- Sumatra, from 1st January, 2005 onwards (Figure-1).

MATERIALS AND METHODS

Aim of the study is to retrieve the precursory duration between the onsets of the resistivity step before the main shocks, through the analysis of resistivity variogram.

Figure-1. Location map of the resistivity variometer observatory at kottayam and epicenters located along Andaman -Sumatra subduction zone.

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Deployment of Resistivity Variometer in the observatory at Erattupetta, Kerala (Latitude: 09o42'29.8" N - Longitude: 76o47'20.5" E) is close proximity to NW-SE trending Achankovil - Idukki shear zones. Current electrodes for the lengths of 600m, 450m, and 300m and the potential electrode separation with 100m are permanently fixed at 2m depth pits in E-W orientation with Schlumberger configuration (Figure-2). Multi core cable connects the electrodes with resistivity Variometer manufactured by IGIS Hyderabad. Resistivity data are recorded at an interval of one hour time from three depths of 100m, 150m, and 200m and stored in data logger attached with Variometer. The resistivity data stored in the data logger are transferred from the field station to the computer in the Seismological Research laboratory in the P.G. Department of Geology at V.O. Chidambaram College, Tuticorin.

RESULT AND DISCUSSIONS

Depth wise apparent resistivity values (Rn) are calculated for the resistivity value obtained from the field for every hour.

The apparent resistivity values calculated for three depths are summed up (ΔRn), and normalized (Rn x 100/ ΔRn) and plotted against time interval in a single plot as variogram.

The precursor duration in hours T, the time between the onset of the resistivity change and main shock is measured in all variogram. Along with the precursory duration, the percentages of variation of the apparent resistivity values obtained at the time of onset before the main shock are calculated the precursory duration.

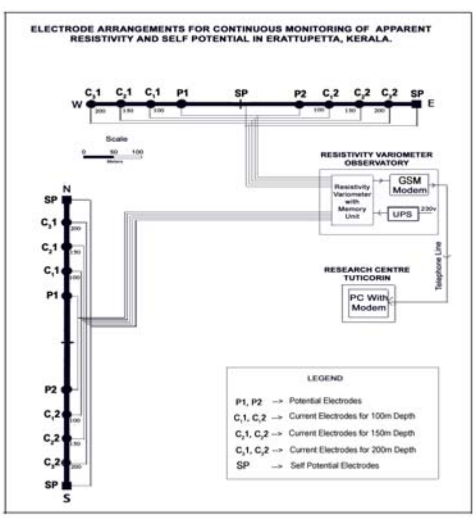
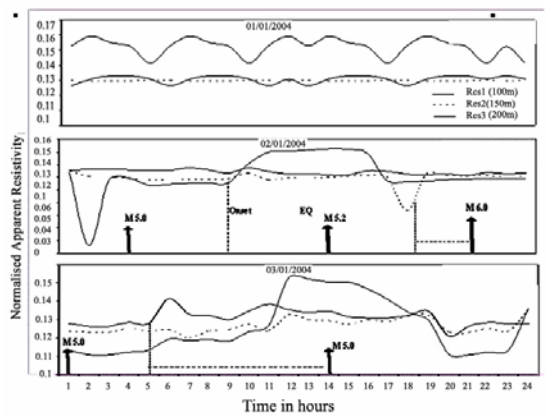


Figure-2. Electrode configuration for continuous monitoring of resistivity.

The sudden drop of the apparent resistivity value indicates the onset of the stress relaxation before the impending earthquake. Then, there is a rise of apparent resistivity values and extended for some periods say few hours to few days, and once again the drop of the apparent resistivity values is followed by earthquake. Similarly, the Chinese group [8] (Zongjin *et al*., 1990) classified the resistivity anomaly into three phases: 1) beginning stage (resistivity begins to drop, 2) lasting stage (s. drop in resistivity) and 3) accelerating stage (resistivity drops drastically).

From the variogram, the precursory duration and resistivity drop in the form of resistivity steps of the imminent earthquake is determined by studying the variations in the amplitudes of the apparent resistivity curves. (Figures 3 to 13 represent the month of January and Figures 14 to 23 for the month of February 2005). Figures 3 to 13 Depicts the Onset of Resistivity drops prior to impending earthquakes in the month of January, 2005.



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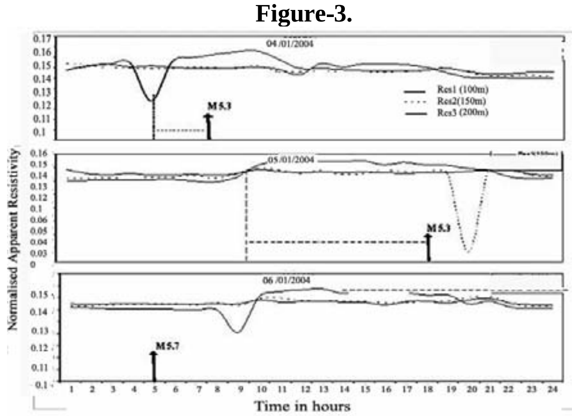

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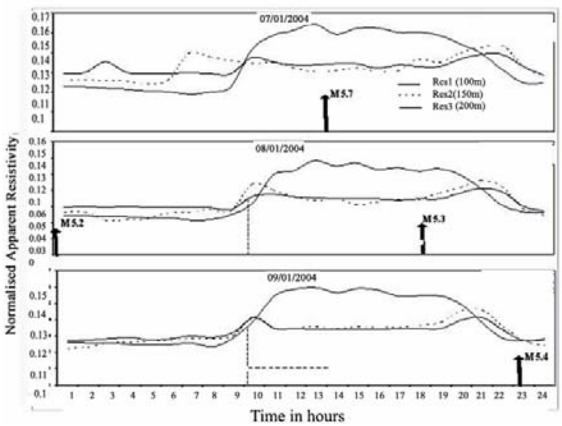

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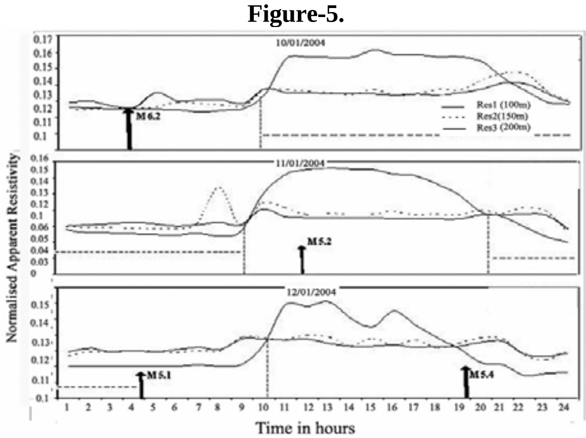

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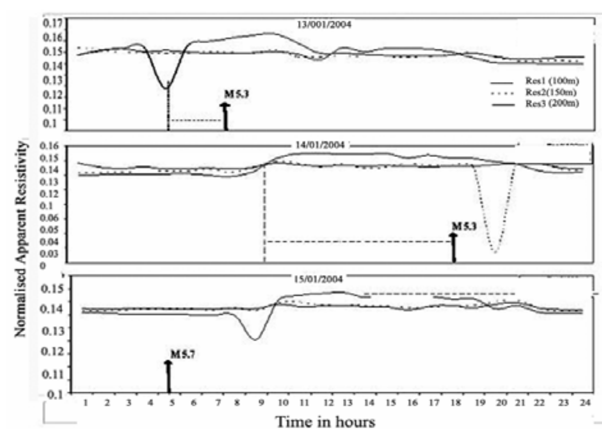

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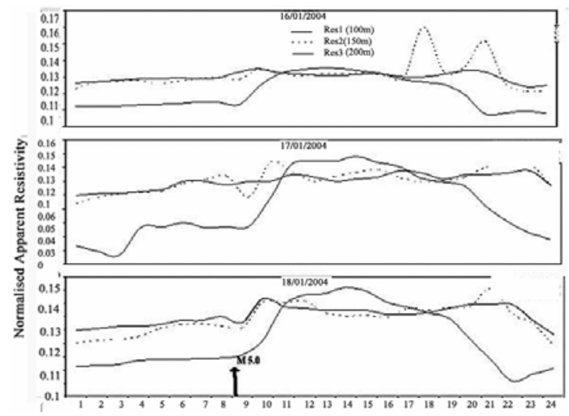

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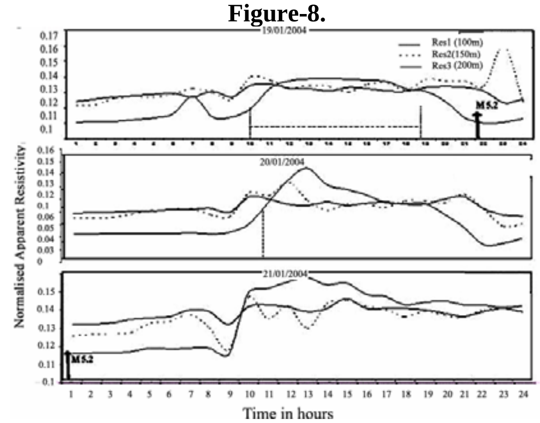

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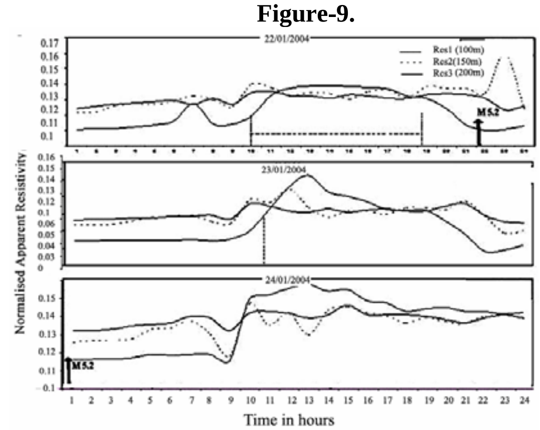

Figure-10.

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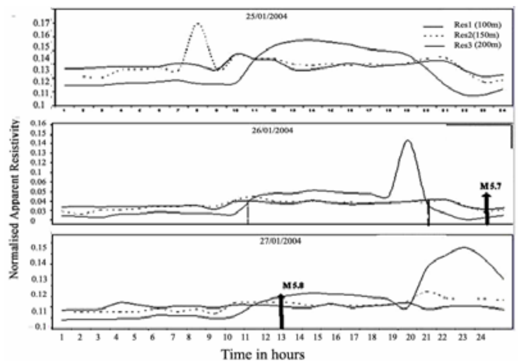

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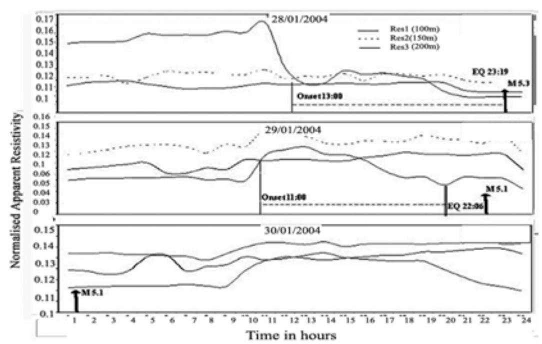

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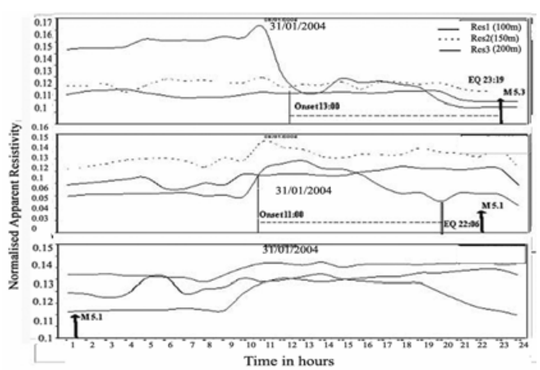

Figure-13.

The earthquake predictability is formulated on the basis of the orders of the magnitude, sensitiveness of the preparation zone, depth of the hypocenters and epicentral distance, with the precursory duration and apparent resistivity variation during the onset of the earthquake events. Bivariate plot of magnitude M versus the preparation zone shows very high positive correlation (R^2 = 0.9194). Other bivariate plots of Magnitude versus Precursory duration

a) Magnitude versus apparent resistivity
b) Focal depth versus precursory duration
c) Focal depth versus apparent resistivity
d) Preparation zone versus precursory duration
e) Preparation zone versus apparent resistivity
f) Epicentral distance versus precursory duration
g) Epicentral distance versus apparent resistivity

shows very low positive and negative correlations (Figures 24 to 30). Similarly, positive correlations are also observed for i) precursory durations with the focal depths of the earthquakes, and ii) precursory duration and with the size of the preparation zones (R*).

The negative trends are perceptible for apparent resistivity versus depth of hypocenters; and apparent resistivity versus epicentral distances. But, the bivariate plots for the apparent resistivity and size of the preparation zone observed for 100m depth exhibits negative trend, whereas data of the apparent resistivity recorded at 150 and 200 m display positive trends with the size of the preparation zone R*. Although, 153 aftershocks recorded with magnitude greater than M 5 during January and February 2005, only 29 out of 119 aftershocks in January and 33 out of 34 aftershocks in February have been successfully forecasted, with the dependent variables such as precursory duration in hours and apparent resistivity steps in Ohm m with other independent variables such as magnitude, focal depth, radius of preparation zone and epicentral distances. The low prediction rate in the month of January was due to swarm of after shocks without any seismic gap. These continuous sequences of the seismic events have masked progression of strain developments over a period of time. As a consequence of that, the manifestation of resistivity changes in the form of resistivity steps could not be detected with the discrete events. During the month of February 2005, earthquake events occurred with sufficient seismic gaps have paved the way for the successful prediction of 33 seismic events out of 34 aftershocks. The sensitivity of the preparation zone R* depends upon the orders of the magnitude. The larger the size of the preparation zone the increase the duration of precursory time; imply that strain developed would have been enveloped the entire preparation zone. The strain sensitive zone has extended over considerable distance from the epicenter. As a result of that Geoelectrical resistivity and precursory duration are also increased. The equations developed from bivariate plots of dependent and independent variables are utilized to calculate the average values of magnitude (M5.37), focal depths (23.27km), radius of preparation zones (281.34 km), and epicentral distances (1941.04km). The calculated and observed values of magnitudes, focal depths, radius of preparation zone and epicentral distances have the consistency with each other.

CONCLUSIONS

Earthquake precursors recorded in the observatory are an indirect response of strain evolution in the focal zone. The anisotropy in the rock dependent the travel time anomalies, shear wave birefringence, surface wave scattering, and direction dependence. The estimation of ultimate radius of strain sensitivity of preparation zone based on R* = 10 0.5 M - 0.27 in km; the radius of preparation zone calculated for the range of magnitude are as R* = 955 km for M 6.5; R* = 5370 km for M 8.0; R* = 16982 km for M 9.0 [9], [10]. The strain sensitivity zone has extended over considerable distances from the epicenter after the great earthquake, 2004. This approach explains in particular the long range effects of strain related precursors including "Strange" precursors in rocks recorded at the epicentral distances longer than 1000 km [11]. Correspondingly, the preparation zone for the Great Chilean earthquake of 1960 with M 8.5 was estimated as R* = 9550 km. Warwick *et al*., [12] have recorded EM emissions at five U.S. Stations before the Great Chilean earthquake of 1960 at a distance of 10,000km away from epicenter. It meets assumption of Benioff (1954) [13] that elastic stress can have a planetary scale. The successive jolting of strongest earthquakes in different parts of the world supports this assumption (Taiwan, Turkey, Greece in 1999; Algeria, Philippines, Taiwan and Japan, in 2003; Great earthquake at Andaman - Sumatra subduction zone in 2004) the increase of precursory duration of 3.30 to 5 hours with the magnitudes 5 to 6.5. The rocks in the preparation zone are shattered, cracked and became so weak and could not able to shear the stress accumulation over hundreds of millions to billions of cubic kilometers from epicenters to observatory. In consequent to that the stress accumulated within the preparation zone has shown the explicit of increase of precursory duration and percentage of resistivity drops before the impending earthquakes [14]. The considerable increase of crustal strain in the preparation zone to a radius of R* = 16.982 km at the time of great earthquake of M 9, 2004 has propelled the lower magnitude of M 5 with radius of 150 km to a ultimate radius of R * 5400 km of equivalent the strong earthquake with M 8 [15], [16], [17]. The increase of the crustal strain to a larger extension has helped to identify the short lived precursors observed in the form of resistivity steps 15 to 20 Ohm m and 3.50 to 5.0 hours prior the after shocks with M 5 to 6.5. Thus the phenomena observed as a short term precursors in the resistivity steps recorded by resistivity Variometer in January and February 2005, doesn't seems to be abnormal and were virtually measured in the observatory 2000 km away from the epicenters.

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