Locating Earthquakes Occurring in Sri Lanka

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1. ABSTRACT

Sri Lanka has been recognized as aseismic or Stable Continental Region (SCR) because of its location well away from boundary of the Indus Australian Tectonic plate. Due to this, risk due to collision between inter-tectonic plates can be neglected safely. The historical background of active seismicity has been revealed that the North-East and some Southern parts of the country have evidence to prove the seismogenic nature of the territory. This paper help to locate the epicentres of earthquakes that occurred in onshore of Sri Lanka. Sri Lanka has three seismic meters which is located in Pallekelle, Mahakandarawa and in Hakkmana region. This paper focuses on the seismic activities within the period from September 2008 to March 2019. Within this period selected 23 events were considered from the 30 events identified. Primary waves(P) and Secondary waves (S) of the seismic activities are picked using the SeisGram2K seismic waveform analysis tool and the epicentres were located according to the circular method with the use of travel time curve and Generic Mapping Tools (GMT). According to the results of this study, the eastern part of the country around the boundary between Highland complex and Vijayan complex may consist of some consideration, because the greatest number of events have been generated around this area. Especially, six events have concentrated in the Wadinagala area in Ampara district and two events in Maduru Oya national park region. Also, several other events occurred in the central part of the country. Therefore, these results can be used to interpret the geological settings and tectonic features of the region and to determine an exact reason for these kinds of earth tremors occurring in Sri Lanka.

***Keywords*:** Seismic activity, epicentre, circular method, tectonic, earth tremors

2. INTRODUCTION

Seismology is the study of seismic sources, structure of the earth, links between earthquakes and tectonic processes. The study of earthquakes helps to identify the internal structure of the earth and tectonic plates [1]. When an earthquake occurs, generated seismic waves at the hypocentre travel through the earth surface and interior by indoctrinating each wave characteristics. According to the way of propagating, seismic waves are considered as surface waves and body waves. Surface waves are the waves that travel near to the earth surface and body waves are that travel either interior or surface of the earth. To investigate the interior of the earth seismic waves play a major role[5]. When an earthquake occur some part of the released energy takes the form of elastic waves and is transmitted into the interior of the earth[12]. A special instrument was invented to detect there waves is called seismometer. This measure and record the ground motion of the surface and wave velocity, basically depending on the density and elastic moduli of the rock through the ray path. Identification of P wave and

S wave of the recorded seismogram helps to identify hypocentre origin time locating the epicentre. To locate epicenter of an earthquake several methods are used. Seismological nature within the country mainly based on the shear zones and geological classification of Wanni complex, Vijayan complex, highland complex and Kadugannawa complex. (Figure 1)[17] .

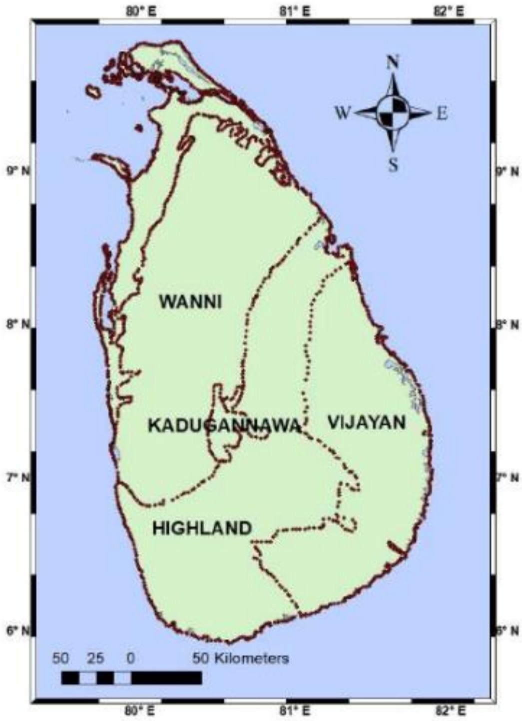


Figure 1: Geological settings of Sri Lanka

Triangulation method is used to determine the distance from the seismic station to uniquely locate the epicentre. Here circles are drawn and the intersection of them depicts the epicentre. To determine the epicentre firstly, the arrival time of the P-wave and S-wave was determined. Then time difference between the two waves are found. Next, find the corresponding distance are found using the Travel time graph. The corresponding X axis provides the epicentre distance and this will be the radius of the circle. The circle is drawn with the epicentre distance where the centre is the location of the seismic station. This will be the basic procedure to locate the epicentre.

3. METHODOLOGY

The area of consideration is the region of Sri Lanka in the latitude range 5.50N – 10.50N and longitude range 78.50E – 82.50E and all the micro seismic activities recorded in three main permanent seismic stations inside the country from 2008 to 2019 were analyzed using the relevant waveforms. For the Pallekele Station Seismic waveform data were accessed as the first step of the study from PALK station browser and for that task Jweed v4.1r3 software package by IRIS DMC was installed[14][13]. Under the query for stations, PALK station was selected and the channel of the seismometer should be selected as BHZ**.** And relevant waveform is selected and downloaded as MINISEED format. To obtain the waveform from Mahakanadarwa and Hakmana seismic stations, waveforms can be downloaded through GFZ – Potsdam web browser (http://eida.gfzpotsdam.de/webdc3/)supported by GEOFON programme [7]. To analyse the obtained data SeisGram2K seismogram viewer v7.0.0 seismic waveform analysis software package could be used. This software package was developed with the support of the following European seismological collaborative, EduSeis - European Educational Seismological Project. Identifying P and S phases of a seismic waveform and fit these phases in to a reliable travel time curve is more efficient to calculate the travel time of the generated seismic wave inside the earth and calculate the distance from seismic station to earthquake epicentre. Further manipulated signals could be obtained by removing the composition of noises by applying a suitable filter method. Butterworth filter was applied for this frequency range and very smooth and non- noisy waveforms were generated.

Some of the waveforms are shown in Figure 2 and Figure 3.In the top Figure represents waveforms, here white colour waveform is PALK station record (only vertical component) and other two sets of records are from HALK and MALK stations (three components).

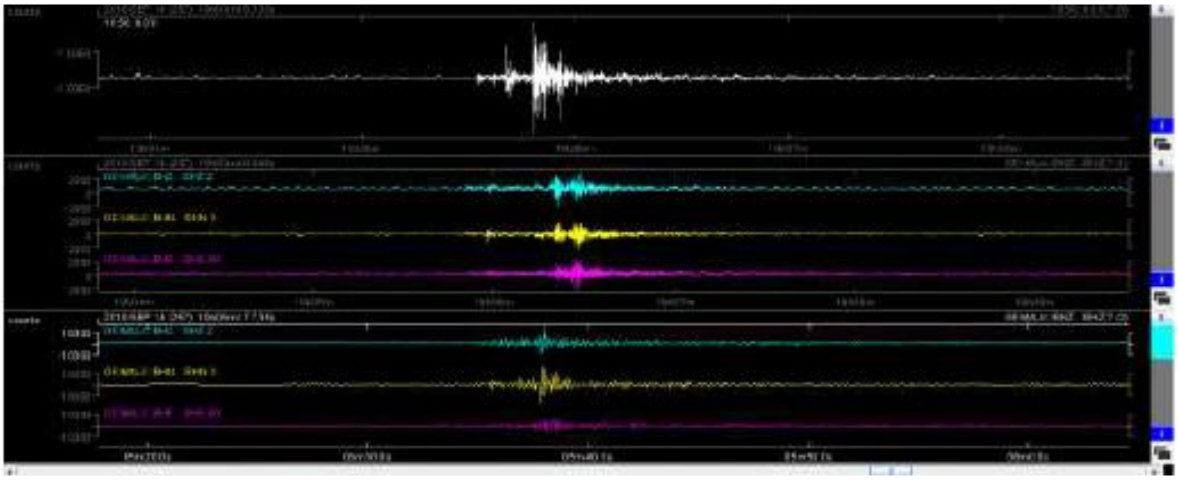


Figure 2: SeisGram2K software interface. Here, White colour waveform is PALK station

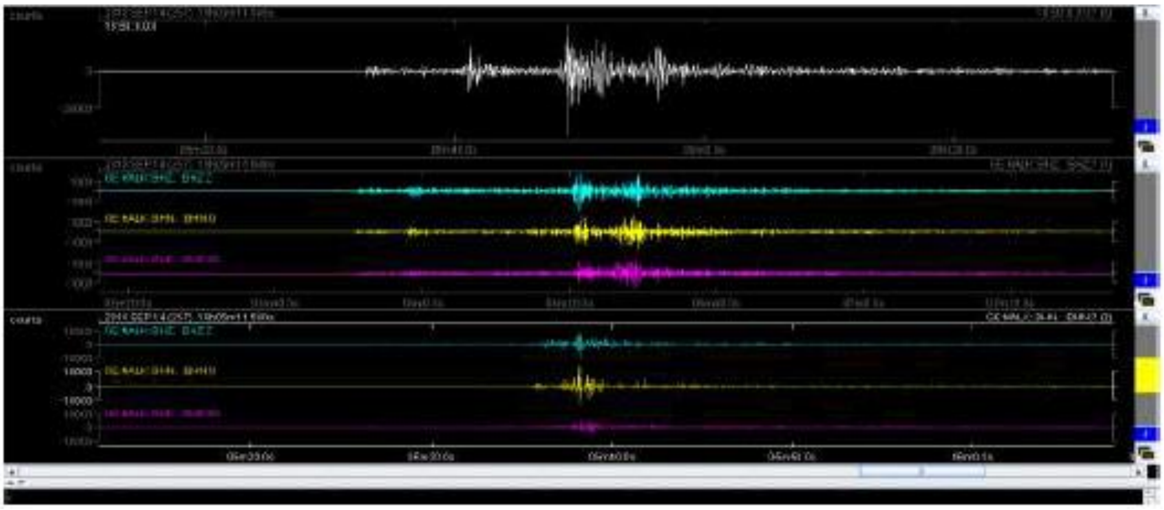


Figure 3: Seismic waveforms after applying Butterworth filter

The Spectrogram is a method of fast identification of frequency content of continuous waveforms recorded by seismometers to help distinguish and characterize the different types of earthquakes or phases by analysing their frequency variations. Arriving of P, S and Surface waves could be identified by observing fire colour variation. Arriving of P, S and Surface waves could be identified by observing fire colour variation.(Figure 4)

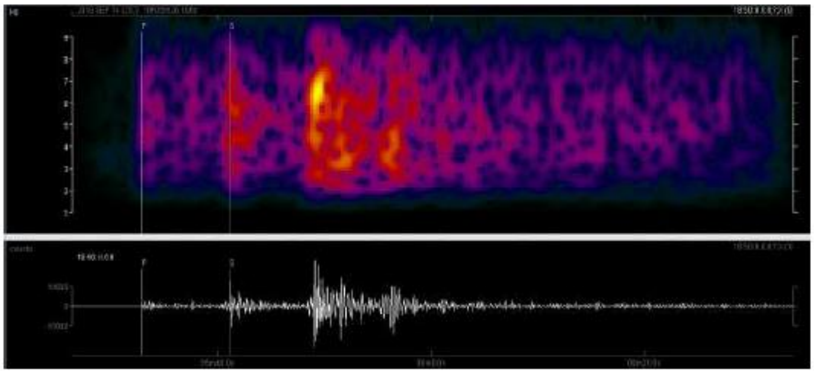


Figure 4: Spectrogram of a recorded seismic wave and corresponding P and S phases.

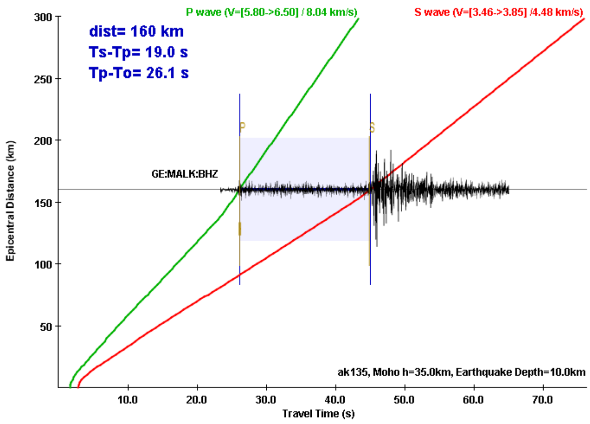


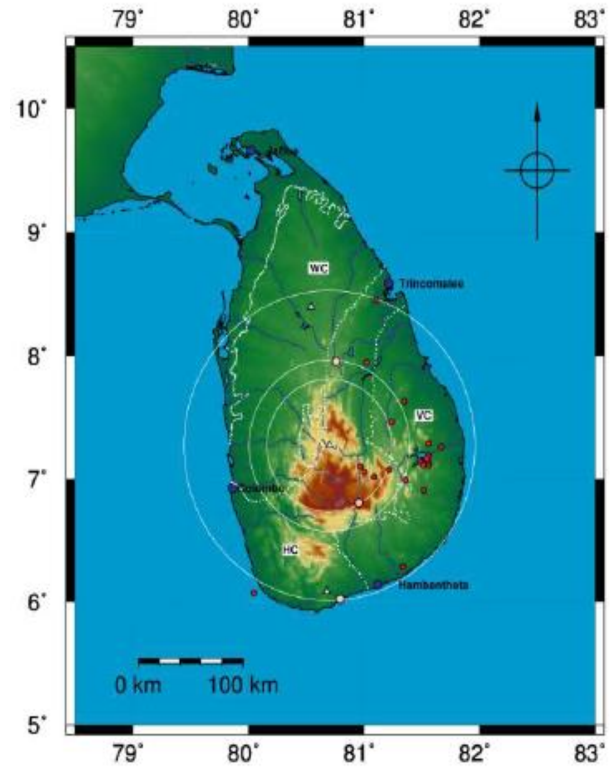
Figure 5: P and S waves fit on to a travel time curve.

The P and S waves were correctly picked by the software and matched with the relevant travel time curve and local travel time curve this can be seen in the Figure 5. Then the P S time interval are calculated according to the S P time graph.

The same procedure should be followed for waveforms recorded by MALK and HALK stations. Then, these available distances were graphically represented in Google earth pro. So that length was represented as the radius of the circle. Three circles from three stations were reduced these two points into one exact point as an epicentre of the event was selected. The found epicentre for each event and latitude, longitude coordinates were also noted down Finally, all the coordinates were represented in one map using GMT tool.

4. RESULTS

Calculated epicentre coordinates were marked on the map of Sri Lanka as in the figure 6. And fig 7 shows the epicentres, the hot water springs, and seismic stations.



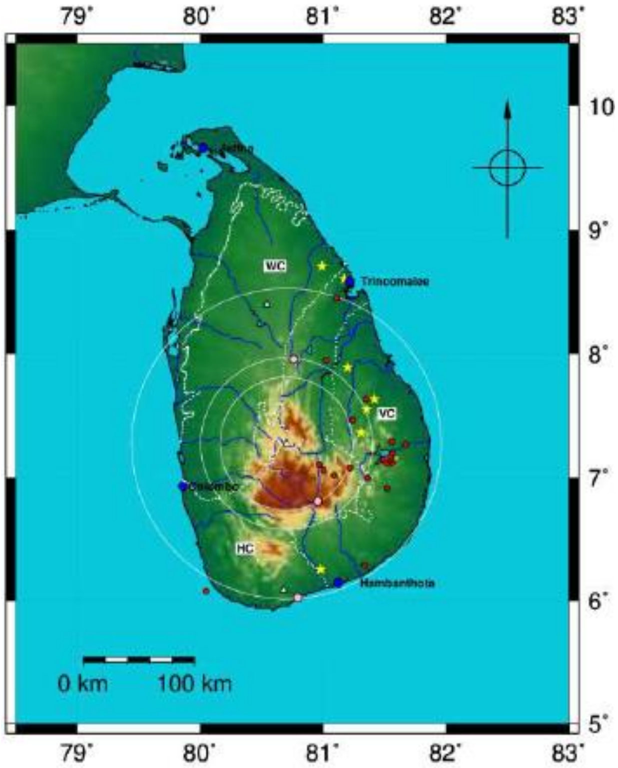


Figure 6: Seismicity Map of Sri Lanka from 2008 -2019, White colour triangles indicate three main seismic stations (MALK, PALK, and HALK) in Sri Lanka. Geological boundaries of Highland, Vijayan and Wanni units mark in white colour line. Pink colour points represent the events experienced area in year 2008 corresponding to three white colour circles.

Figure 7: Modified seismicity Map of Sri Lanka with the geothermal potential of the country Modified seismicity Map of Sri Lanka with the geothermal potential of the country from 2008 -2018.White colour triangles indicate three main seismic stations (MALK, PALK, HALK) in Sri Lanka, yellow colour stars are the hot spring distribution and red colour dots are denoted the locations of the events. White colour circles are denoted the possible epicentre locations for 42 the events occurred 2008 – 2010. Jayanthi wewa hot springs are very close to the Wadinagala area.

5. DISCUSSION

Approximately 30 events caused to shakings and experienced by the civilians were confirmed as the micro seismic events in the north, east and some southern part of the country between October 2008 to March 2019. Other than some events were skipped because of the lack of details contained such as exact points of primary and secondary wave arrivals could not be identified (e.g.; 18th Sep 2018 in Hali Ela and 12th June 2010). A suitable band pass filter was applied between 2 Hz – 16 Hz and 2 Hz – 32 Hz to identify the special characteristics of the waveforms. SeisGram2K seismic waveform analysis software, Google Earth Pro and Generic Mapping Tool (GMT) were mainly used to analyse the selected seismic waveform data in this study. P and S phases were picked for 23 events and the travel time difference for each P and S phase pair was also calculated. The time difference was matched with ak135 travel time curve. On the next step distance from the seismic station to epicentre was calculated for each waveform recorded by three stations and circular method was used to graphically represent the epicentres using the GMT tool. Therefore in this study events occurred from 2008 to 2010 were analysed using only one seismic waveform recorded in PALK for each. According to this study all the seismic activities have concentrated into the NorthEast, East, Southern and Central hills of the country. Most of the mentioned events had taken place at the central part of Sri Lanka near Maduru Oya, Highland - Vijayan boundary and Wadinagala area of Ampara district. Two events were reported in Maduru Oya national park area. Earthquakes occurring in the new plate zone of offshore eastern part of Sri Lanka may have impact on these faults, weak zones and small movements of the basement. As a result of that tremors may occur in this region. most of the events have occurred after the middle of the year 2012. The rate of occurring earthquakes has increased within the region after the 11th of April 2012 Sumatran strike slip earthquake[8].

6. CONCLUSION

A study in generic terms has been undertaken to identify the locations of past seismic activity during the last decade in Sri Lanka considering the country in the local context and in the regional context at tele-seismic distances in the northern Indian Ocean[16]. The Correlation of historical seismic activities reported within the country with the local geotectonic setup is the main way of studying the reason for this kind of activities and possible seismic sources caused to the observations [6]. The geological boundary between the HC and VC can be a potential tectonic boundary of convergence, where the HC thrusts over the VC in south and SouthEastern directions. Most of the past seismic events that occurred around this region have almost proven this statement. Some hot springs distribution over the country have also matched with the locations of epicentres (e.g. Wadinagala, Trincomalee, Maduru oya) revealed that weak zone of earth crust may also dominate for these activities add to the minor faulting. It is evident that geology and tectonic setting of the region should be investigated using these results will be essential in the future.

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