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Electrical conductivity of sedimentary medium measured by electromagnetic pulses in the earth

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In order to confirm electromagnetic (EM) pulses which might be generated by strong stress impacts to the earth crust when the earthquakes occurred, we have been observing them by a sensor system inserted into a borehole of 100 m in depth.

One of observation sites is in the campus of Seto Marine Biological Laboratory of Kyoto University in Shirahama town, Wakayama prefecture, where is on a narrow peninsula. Since the sedimentary layer around the borehole at the site was composed of shells and sandstone, it was expected that sea water easily penetrate into the sedimentary layer and that EM waves from the sky would be rapidly decayed with the depth in the layer. However, we found that almost all of EM pulses detected at the bottom in the borehole were lightning generated ones which were counted to 10000 per day in the rainy season.

Under such the observation condition, we could clearly estimate the electrical conductivity of the sedimentary medium in the layer by using waveforms of the rapidly decayed EM pulses. It was, however, required that EM pulses used for the estimations of the conductivity should be linearly polarized in the both regions, above the ground and in the earth, because it was hard to compare amplitudes and phases between waveforms of ellipsoidal polarized pulses. Although, in general, if linearly polarized EM waves were obliquely incident to the ground their polarizations in the earth become ellipsoidal, when its incidence into the ground was vertically the penetrated waves in the earth represent linear polarization. Thus we have to select EM pulses with linear polarization at the both points for the estimation of electrical conductivity of the sedimentary medium.

For this purpose, we used tri-axial magnetic search coils at the depth of 95 m in the borehole and on the ground for checking polarizations of detected EM pulses. Waveforms of six analogue pulses of three directional components of a magnetic pulse detected at each detecting point were captured into a personal computer through a multi-channel AD convertor with a sampling period of 32 micro second. The timing of waveform capturing was triggered by a pulse of magnetic east-west component detected at the 95 m depth as pre-triggering AD conversions.

The measured results were as follows. A dominant frequency of detected EM pulses was about 5 kHz, the amplitude and the phase detected at the 95 m-depth were respectively depressed to 1/22 and had 83 micro-seconds delay against those detected on the ground. From these results, we obtained the conductivity of the sedimentary layer was 0.067 S/m. Using this value, the propagation velocity of the EM pulse in the sedimentary medium was 1/345 of the light velocity. Thus the travel time of the EM pulse from the ground surface to the depth of 95 m was coincident with the value of the delay time between waveforms. Therefore it has been proved that the obtained value of the electrical conductivity by this method was valid.

We are now conducting observations for detecting earth-origin EM pulses and to identify their source locations on real-time basis by a network with two or three observation sites. If we found an earth-origin EM pulse and determined its source location, we can obtain differential path lengths between path distances from the source location to each observation site. On the other hand, we can obtain time differences in detections of EM pulse at each observation site. Using the differences of path lengths and the time differences, we can obtain propagation velocity, and then we can obtain electrical conductivity in the medium near the depth of EM source location.

Keywords: electromagnetic (EM) pulses, measurement of electrical conductivity, detection of EM waves in a borehole