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Misao Hirayama's achievement as a pioneer in magnetotellurics

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Magnetotellurics is a field of geomagnetism in which conductivity of the earth's interior is estimated from combined analysis of magnetic and electric field variations. It has been accepted that L. Cagniard(1953) paved the way for the study of this kind. Recently, M.S. Zhdanov(2010) pointed out that M. Hirayama followed this line of approach as early as 1934. Hirayama finished the technician training course of the Central Meteorological Observatory in 1932 and he started in service at the Toyohara Magnetic Observatory. Japan actively participated in the Second Polar Year(1932-1933). The Toyohara Observatory, located in Sakhalin, was established as a part of this project. At Toyohara, telluric current observations were also conducted. Study of electrical properties of the earth's interior based on temporal variations of magnetic field was first made by H. Lamb(1883). However, an approach applying analysis of variations both in magnetic and electric fields was not taken until Hirayama's work. Hirayama noted the relationship between variations in these two kinds of fields. He supposed that externally applied magnetic disturbances would induce electric field variations within the conducting earth. He used a plane earth model. He set up Maxwell's equations in a rectangular coordinate system with its origin on the earth's surface. The x-axis is taken northwards, the y-axis eastwards, and the z-axis vertically downwards. The expression of Maxwell's equations in this coordinate system was employed by T. Terada(1917). Terada made an analysis of magentic field variations recorded at the Aburatsubo observation site which was under the Imperial Earthquake Investigation Committee. Terada was interested in short period magnetic variations, which were considered to be attributed to the magnetic effects of electric currents flowing in the ionosphere. Terada investigated the behaviour of this supposed overhead current on the basis of a model satisying Maxwell's equations. Hirayama followed Terada's way of setting up the equations, still he treated them in accordance with his own interest. He obtained the follwing formula expressing the ratio of the amplitude of electric field variation E(y) to that of magnetic field variation H{x}.

$$E_y/H_x=\{(uq)/(4*3.14*k)\}^{1/2}$$

where u is permieability, q denotes angular frequency of a specified variation, and k is subsurface electerical conductivity. The ratio E_y/H_x is obtained from observations for a particular frequency, then conductivity k is determined. M. Hirayama(1934) was the first paper in the world in which the above formula was derived. This is indeed an honorable achievement. The formula is usually called Cagniard's MT formula after Cagniard who gained eminence as a pioneer of magnetotellurics. But Hirayama was nearly twenty years ahead of Cagniard. Hirayama obtained the ratio E_y/H_x for lots of events with periods from several minutes to many tens of minutes. The result showed that the ratio was approximately proportional to the square root of the frequency. The theoretical model was supported by the observations. Contributions by anyone who pursued and developed a system of a specific field in more detail should be highly evaluated. At the same time, significance of the accomplishments which have revealed quite a new aspect of nature should not be diminished at all, even when they are only beginning to take shape. Hirayama buckled himself to the research work while he was occupied in routine observations on duty. Working conditions were disadvantageous to conducting research. Attention should also be directed toward a somewhat flexible atmosphere perhaps settled over the Central Meteorological Observatory. Though it was a technical office, there was some scope allowed for conducting purely academic research. This is of utmost importance in consideration of the recent Japanese research system which suffers from decades of bureaucracy driven by centralized structures.

Keywords: Geomagnetism, Magnetotellurics, Telluric current, Electrical conductivity, Toyohara Magnetic Observatory, Electromagnetic induction