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STUDIES ON CHARACTERISTICS OF THE GEOMAGNETIC PULSATIONS

(PART I)

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CONTENTS

Introduction

Geomagnetic pulsations are small regular fluctuations of the geomagnetic field, the oscillations lasting for an hour or more. The period varies from a few seconds to about three minutes and the amplitude is usually several gammas. They occur not only during storms but also on otherwise quiet days.

Observations at middle latitude stations are all coincidental in the occurrence of two distinct types of pulsations: a continuous flux of quasi-periodic fluctuation during the daylight hours and a succession of pulses at night. But, in the period of magnetic disturbance, the former type of pulsations appear even in the night time and latter even in the day time.

The 10th Committee of IAGA determined to tentatively take up the names 'Pc' and 'Pt' for two types of pulsations. The following definitions suggested by the chairman of the Committee, to picturize general aspects of geomagnetic pulsations.

Pc(continuous pulsations)

A series of pulsations lasting for many hours with periods usually in the range of from 10 to 60 seconds and amplitudes of the order of 1/10 γ. The maximum occurrence frequency is in the daylight hemisphere.

Pt(trains of pulsations)

These appear as several series of oscillations, each series usually lasting from 10 to 20 minutes, the whole phenomenon lasting for periods of not more than about 1 hour. They are well damped with longer period than Pc pulsation and usually of greater amplitude, i.e. of the order 0.5 γ. The maximum occurrence frequency is at midnight. Series of oscillations of different amplitude and period are often superposed and may be caused by different sources and different excitation processes.

In order to investigate the morphology of micropulsations it is desirable not only to obtain information on their statistical characteristics at a station, but also some knowledge of their world wide behaviour.

It is said that the first discovery of geomagnetic pulsations was made by B. Stewart (1861).(1) M. Eschenhagen (1896),(2) one of the researchers in this field, constructed a variometer of high sensitivity, which was called the Eschenhagen type variometer with rapid-run recorder.

Afterward, Pulsation phenomena attract attention of many researchers: J. Coulomb, G. Grenet, E. R. R. Holmberg, V. A. Troyickaya, J. W. Dungey, M. Schlumberger and N. F. Astbury: in Japan Y. Kato and his colleagues, viz., S. Utashiro, J. Ossaka, A. Sakurai, M. Okuda, S. Akasofu, T. Tamao and T. Watanabe. Then, many interesting characters of geomagnetic pulsation were studied.

On the theoretical works, several authors proposed new theories. Dungey (1954)[3] proposed that the geomagnetic pulsations would be caused by the hydromagnetic oscillation of the ionized outer atmosphere expanding outwards beyond the ionosphere. Y. Kato and his colleagues (1956)[4] proposed that the giant pulsations are to be caused by the hydromagnetic oscillation of the outer atmosphere, and they have found that the spectral distribution of periods can be explained fairly well by their theory.

In this paper, characteristics of geomagnetic micropulsations, Pt and Pc, were studied analyzing observation results in middle latitude and lower latitude. Magnetic stations used in this analysis are Memanbetsu, Onagawa, Simosato and Kanoya in Japan: and Honolulu, Apia, Guam and Koror operating by the Coast and Geodetic Survey of U S A.

At first, the author observed geomagnetic micropulsations by the induction magnetometers on three components of earth's magnetic field at Simosato lies in the southern part of the Kii Peninsula during the International geophysical Year from 1957 to 1958. The induction magnetometers have a core consists of Sendust, and they were designed by Professor Y. Kato of Tohoku University. Analyzing the results of observations, it was shown that occurrence freqency of micropulsation Pc and Pt depends on local time. Also it was discovered that the type of micropulsation accompanying SSC differ in the night hemisphere and sunlite hemisphere. Also, a remarkable micropulsations accompanying SSC frequently occur in summer and equinox.

Now, it is well known that Pc type pulsation occurs simultaneously over the world. The auther studied records of induction magnetometers at four magnetic observatories in Japan (Memanbetsu, Onagawa, Simosato and Kanoya) and got the results as follows.

1) The local Pc occurs frequently during daytime. 2) The maximum of occurrence frequency of local Pc lies in equinox, and the minimum lies in winter. 3) The frequency of occurrence of local Pc depends on local mean time, and the maximum frequency of it's occurrence lies around 13 h (L. T.).

In order to examine the simultaneity of occurrence of Pc in the lower latitude and equator, the author compared magnetograms by high sensitivity magnetometers with rapid run recorders at several stations in lower latitude, and the simultaneity of waves of Pc was confirmed over a wide region in lower latitude and equator.

The possibility of the occurrence of local Pc in middle latitude and synchronous Pc in lower latitude was discussed. Now, if it is assumed that such characteristic phenomena caused by means of the hydromagnetic oscillations in the region between the inner Van Allen Belt and ionosphere, two modes of oscillations exist in this region, one is the toroidal and the other is the poloidal oscillation. The toroidal wave is propagated along the magnetic line of force and the poloidal wave at right angle to it. A superpose of the poloidal and toroidal oscillations can be observed at the four observatories as local Pc pulsation. Then, on the toroidal oscillation, its period varies with increasing latitude and the period of the poloidal oscillation is invariable on latitude. If it is assumed that the hydromagnetic waves are produced by means of a corpuscular stream coming from the sun at outer surface of the inner Van Allen Belt, as a magnetic line of force through a station in lower latitude is not reach to the inner Van Allen Belt, the toroidal oscillation is unable to be observed at lower latitude stations.

Therefore, local Pc occurs in the middle latitude and synchronous Pc in lower latitude and equator occurs over the world.

Chapter 1 Observation of Geomagnetic Micropulsation at the Simosato Magnetic Observatory

§1 Position

The Simosato Magnetic Observatory lies in the southern part of the Kii Peninsula, about 130 km south of Osaka, of approximate position:

Geographic	Latitude :	33° 34.5′ N
〃	Longitude :	135 56.4 E
Geomagnetic	Latitude :	23.0° N
〃	Longitude :	202.4° E

The elevation is about 56 meters above the sea level. The site of the Magnetic Observatory is quite free from any electric disturbance, the nearest traffic with direct electric current, the Wakayama Electric Railway, runs at a distance of about 90 km. The situation of the Simosato Magnetic Observatory is shown in Fig. 1 and 2.

The Simosato Magnetic Observatory is regularly operated by the Hydrographic Office of Maritime Safety Board in Japan.

§2 Instruments

During IGY, rapid-run registration of geomagnetic variation was carried out by equipment of induction type magnetometer. The induction magnetometer consists of an induction coil which is wound around a high permeable rode, made of Sendust, and galvanometer, its natural period is 4 sec. The induction current in the coil due to the variation of the earth's magnetic field is recorded photographically. Sendust is one of the high permeable alloy which consists of Fe, Al and Si. The length of the rode of Sendust is 240 cm and its diameter is 2.5 cm having apparent permeability about 1000 e.m.u.

The observation are carried out on three component $\frac{dH}{dt}$, $\frac{dD}{dt}$ and $\frac{dZ}{dt}$, and the records is registered in speed 6 mm/min.

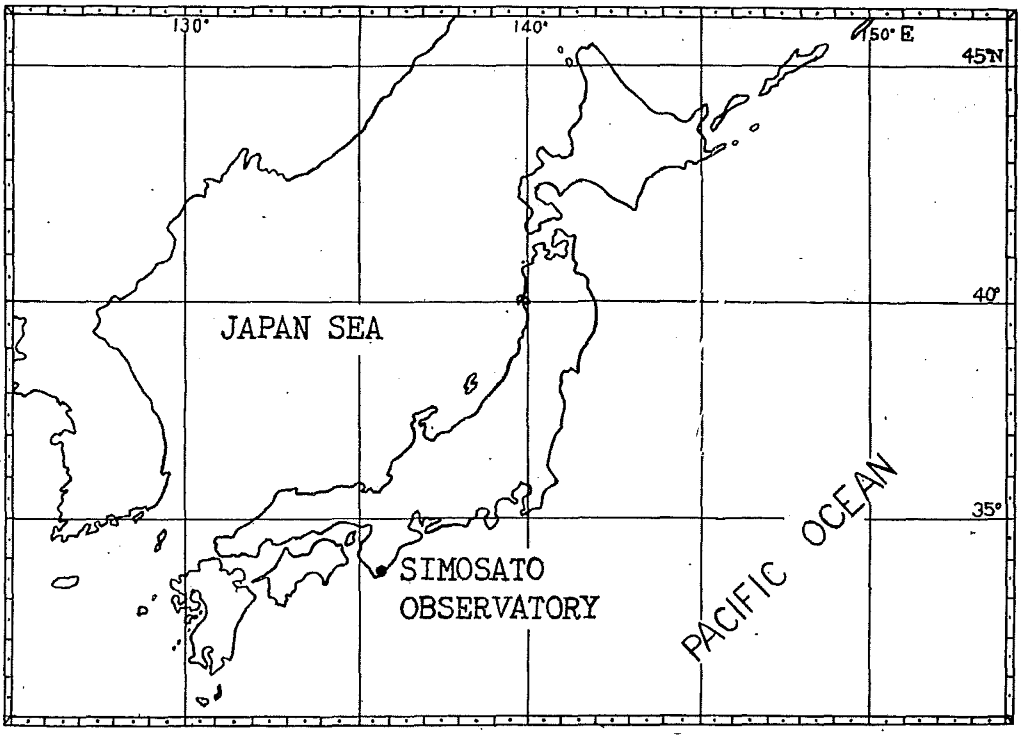


Fig. 1 The Situation of the Simosato Magnetic Observatory

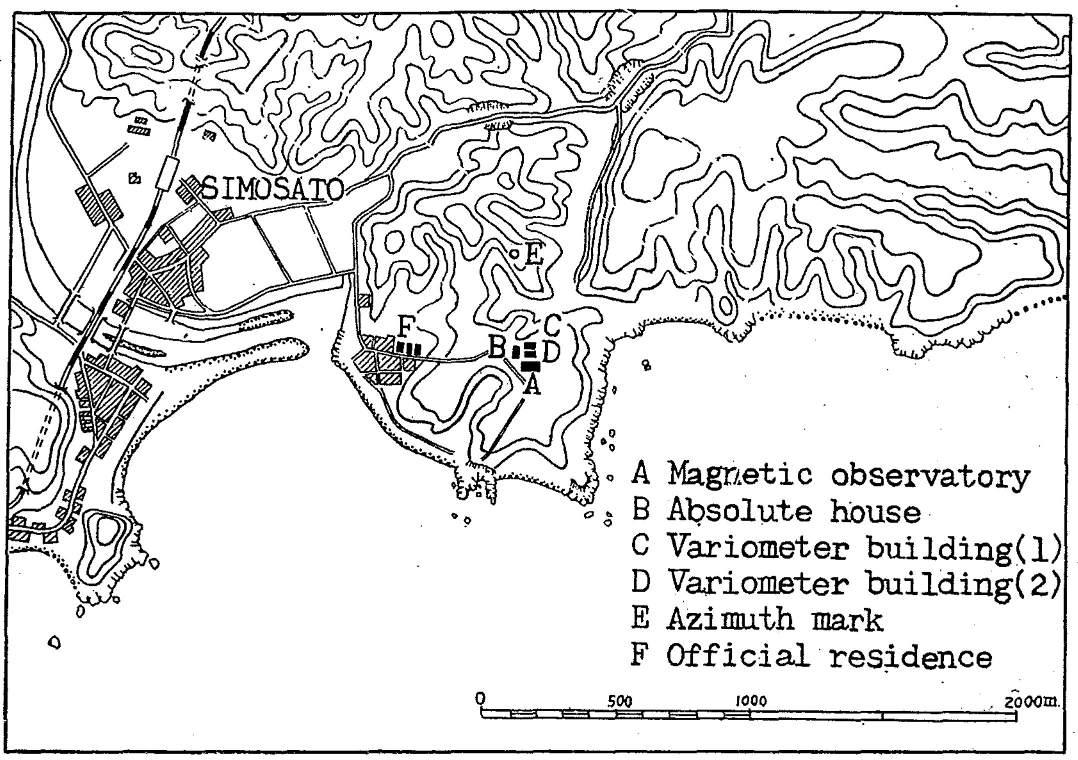


Fig. 2 Simosato and it's Vicinity

The sensitivities of the induction magnetogram is shown in the following

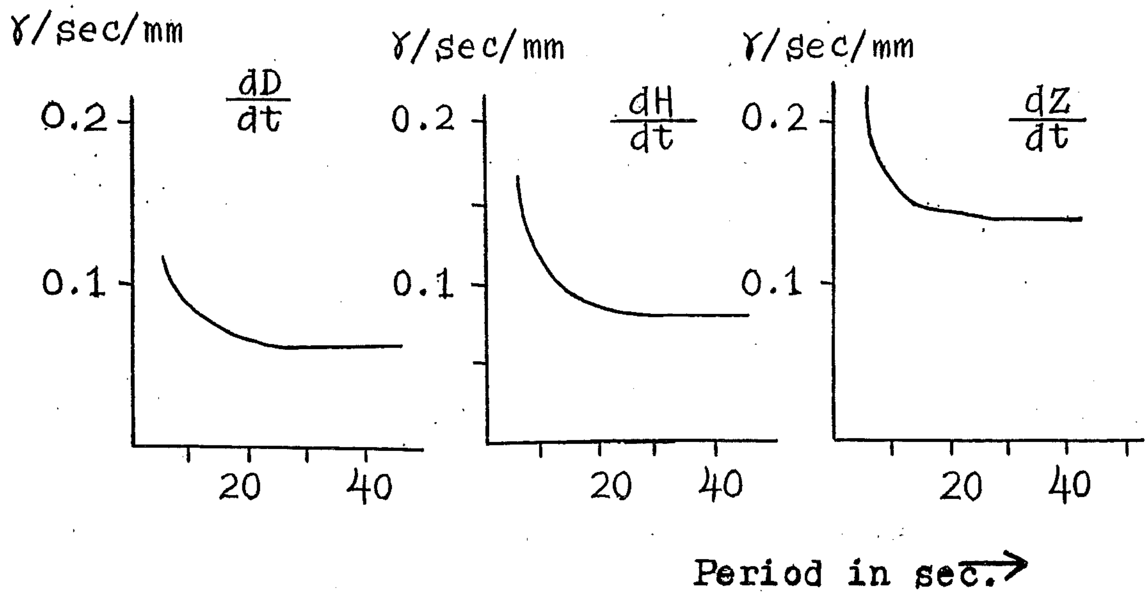


Fig. 3 Sensitivities of Induction Magnetogram

figure 3. The sensitivity of these induction magnetometer were obtained by supplying an artificial alternating magnetic field which is producted in the solenoidal coil, wound around the core, by the alternating current supplied by Tohoku University type super low frequency oscillator. This instruments is shown in Fig. 4, and its dimension are shown as follows:

Permeability of Sendust	$\mu=1000$ emu
Turns of Coil	N=6230
Resistance of Coil	R=34 Ω
Self-inductance	L=28.7 H
Sensitibity	0.10~0.40 γ/sec/cm

He calculated the error of amplitude and time lag caused by the inductance of the coil. The relation between the amplitude and the periods, and the phase difference and the periods are shown in Fig. 5. When the period of the micropulsation observed is larger than 20 sec, the error of the amplitude is not larger than 10 % and the phase difference is smaller than 20°. As initial field is larger than 0.05 γ, there are no influence of the temperature effect on the susceptibility of Sendust. The records were taken in critical damping state and the influence caused by the inertia of the moving part of the galvanometer is corrected.

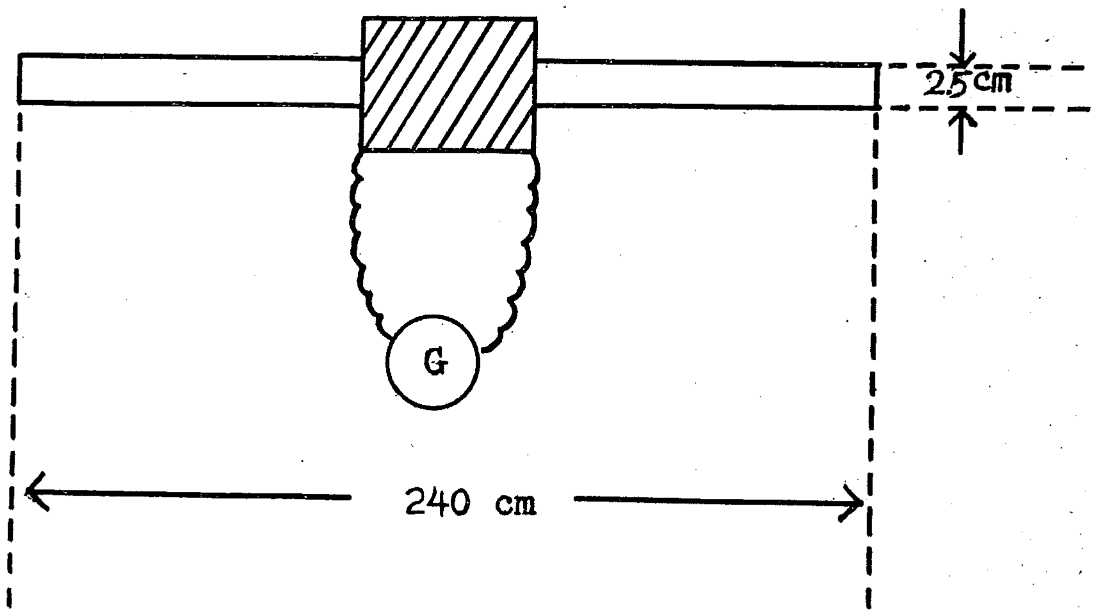


Fig. 4 Induction Magnetometer

Fig. 5-1 Time Lag caused by the Inductance of Instrument

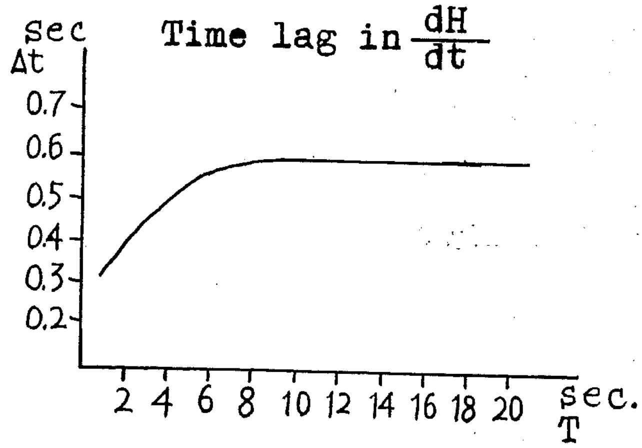
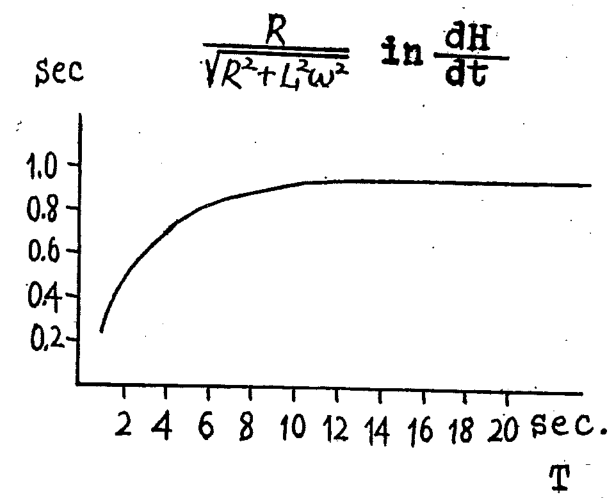


Fig. 5-2 Influence of the Amplitude caused by the Inductance of Instrument



§3 Results of Observations

Observations of geomagnetic micropulsation were carried out by the induction magnetometer with Sendust core at the Simosato Magnetic Observatory during IGY from 1957 to 1958. Geomagnetic micropulsations are generally observed by one of the following three recording,

(1) Recording by high sensitivity variometers and quick-run recorder.

(2) Recording by induction magnetometers: in this case time derivative of magnetic fields is observed.

Their frequency responses are different each other and the amplitude ratio in observation of sinusoidal oscillation having period T is about 1:1/T. Then, it is very difficult to compare the observed results by high sensitivity variometers and induction magnetometers each other with careful consideration. It is often experienced that the oscillation form of pulsations on induction magnetograms is quite different with that on magnetograms of high sensitivity variometers. It is desirable to directly measure the three components of the magnetic field, but studies of short period pulsations are rather difficult by direct record of magnetic elements because of overlapping large amplitude fluctuations with longer period. Therefore, induction magnetometer supply most useful date for study of geomagnetic micropulsations.

In this paper, results of observation by the induction magnetometer is reported. Some typical examples of micropulsation observed by the induction magnetometers at Simosato during IGY from 1957 to 1958 are shown on full-size in Fig. 6.

Chapter 2 Characteristics of Micropulsation at Simosato

§1 Micropulsations accompanying SSC

It is well known that the magnetic storm occurs simultaneously over the whole area of the earth and the sudden commencement occurs nearly at the same time and the amplitude of the main phase and the sudden commencement is greater in the night hemisphere than in the day hemisphere. The author observed micropulsations during magnetic storms by the induction magnetometer at Simosato in the southern part of the Kii Peninsula during IGY and found the following results.

1) The type of micropulsation at sudden commencement varies respectivily, according as it occurs in the night hemisphere or day hemisphere: that is, the oscillation of micropulsation is very remarkable at daytime, while it is weak at night. In the day hemisphere the amplitude of the oscillation of micropulsation is greater than that which occurs in the night hemisphere.

Fig. 7 shows only some examples: the above stated characteristic is very remarkable and occurs almost without exception. This fact is reverse of the statistical results obtained from the records of the ordinary magnetograms of H, D and Z.

2) A remarkable micropulsation at the sudden commencement frequently took places during the summer and equinox, while it is weak during the winter. From these results it is considered that the sudden commencement is attributable to the electric current system in the ionosphere due to the ionization by the sudden increase of the solar radiation.

§2 Daily Variation of Occurrence Frequency on Pt and Pc

This problem was discussed by H. Hatakeyama,[5] S. Imamichi,[6] M. Hirayama[7] and T. Yoshimatsu.[8] The author investigated following results from the data observed at Simosato during IGY. The frequency of the occurrence of Pc type micropulsation and Pt type micropulsation in different hours of local time was counted, and it is shown in Fig. 8. As the figure shows, the Pc type micropulsation occurs most frequently in the daytime. These results coincide with the tendency shown by H. Hatakeyama and S. Imamichi. Frome these results the writer considered that the Pc type micropulsation occurred due to the electrohydromagnetic oscillation in the outer atmosphere, which occurred when the corpuscle coming from the sun penetrated into the outer atmosphere.

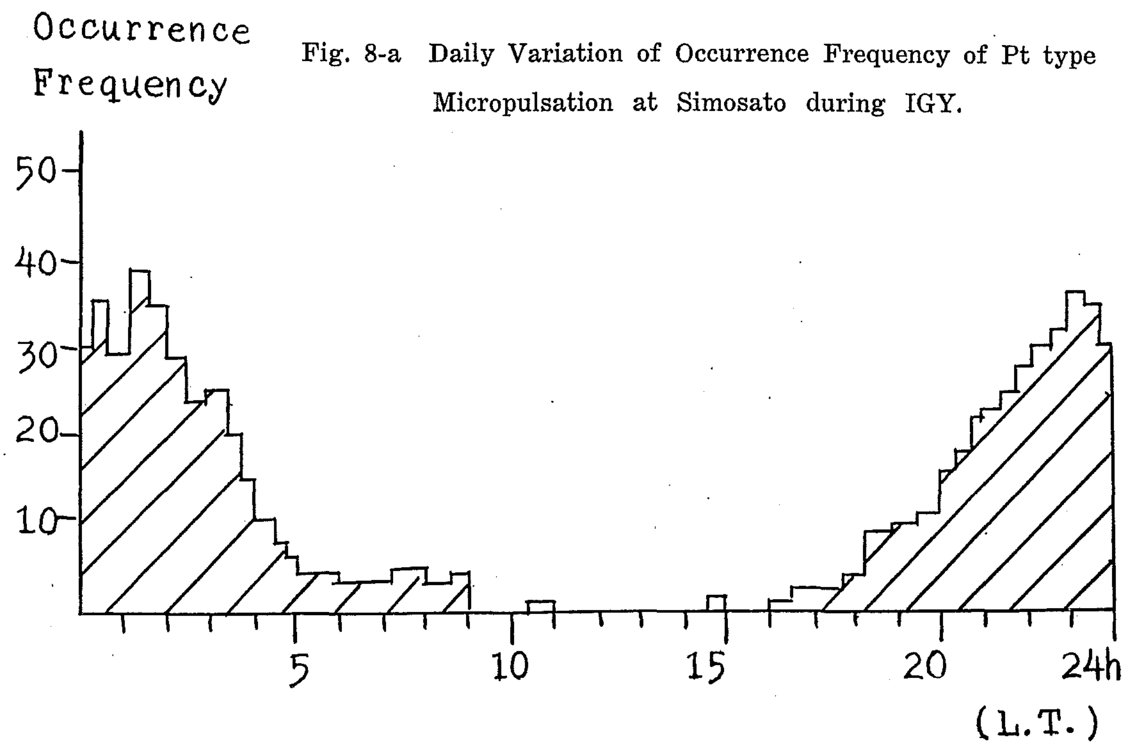


Fig. 8-a Daily Variation of Occurrence Frequency of Pt type Micropulsation at Simosato during IGY.

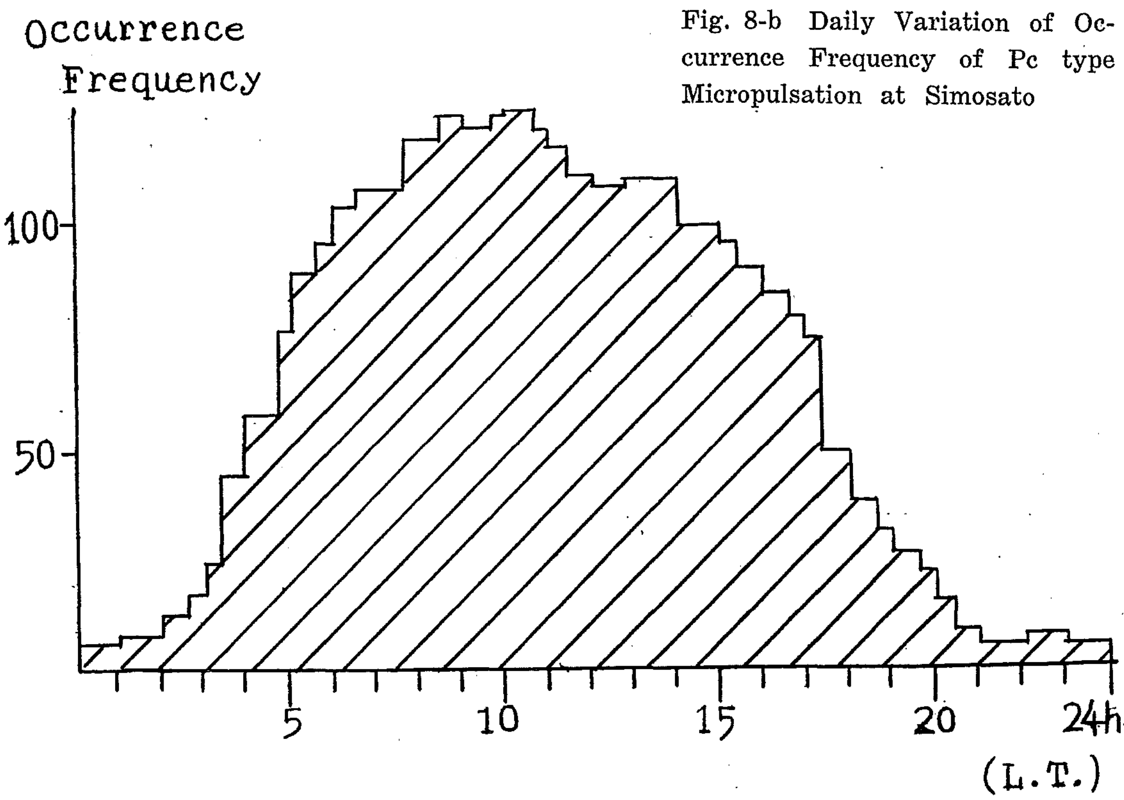


Fig. 8-b Daily Variation of Occurrence Frequency of Pc type Micropulsation at Simosato

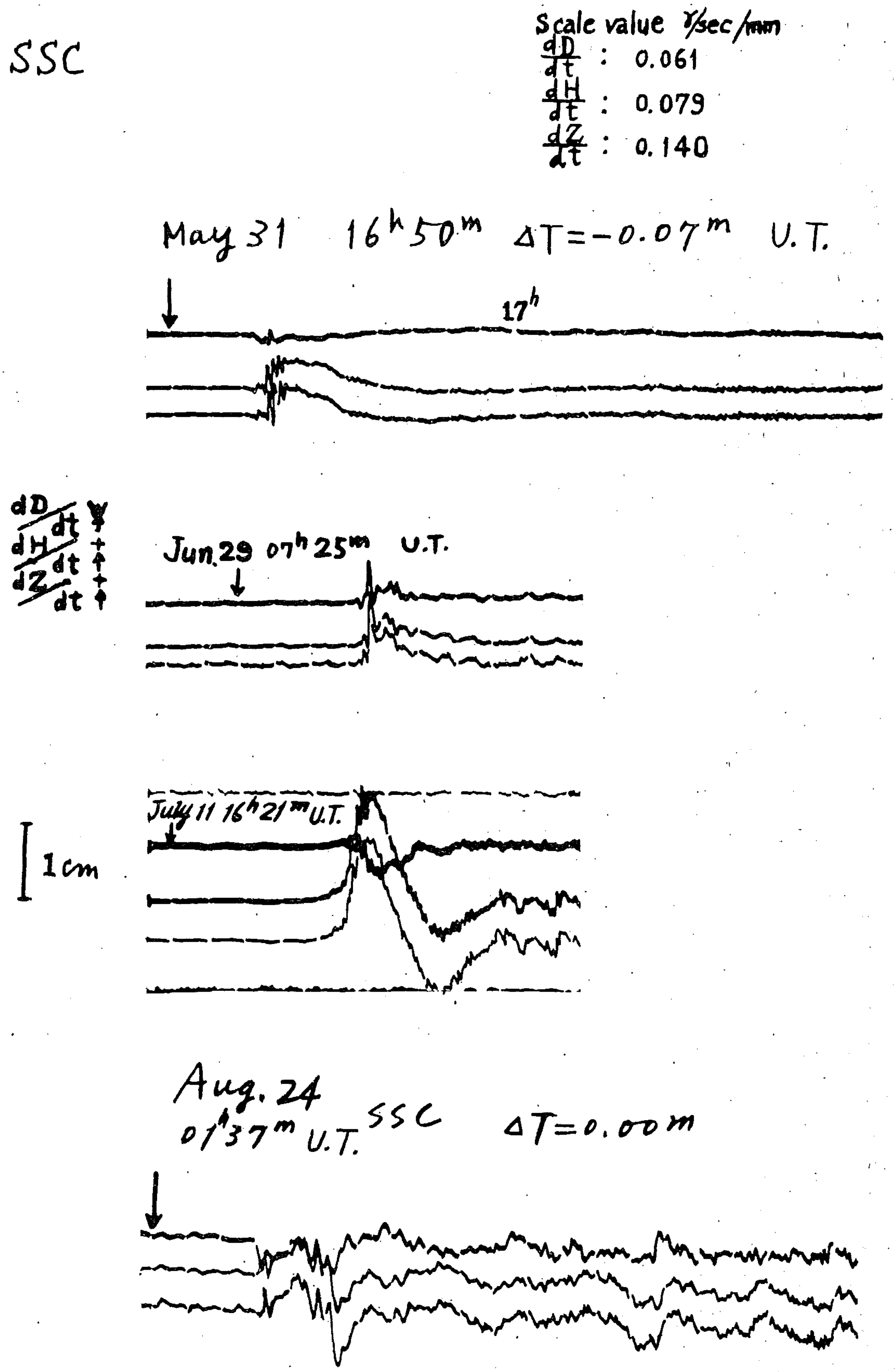


Fig. 6 Some Typical Examples of Micropulsation

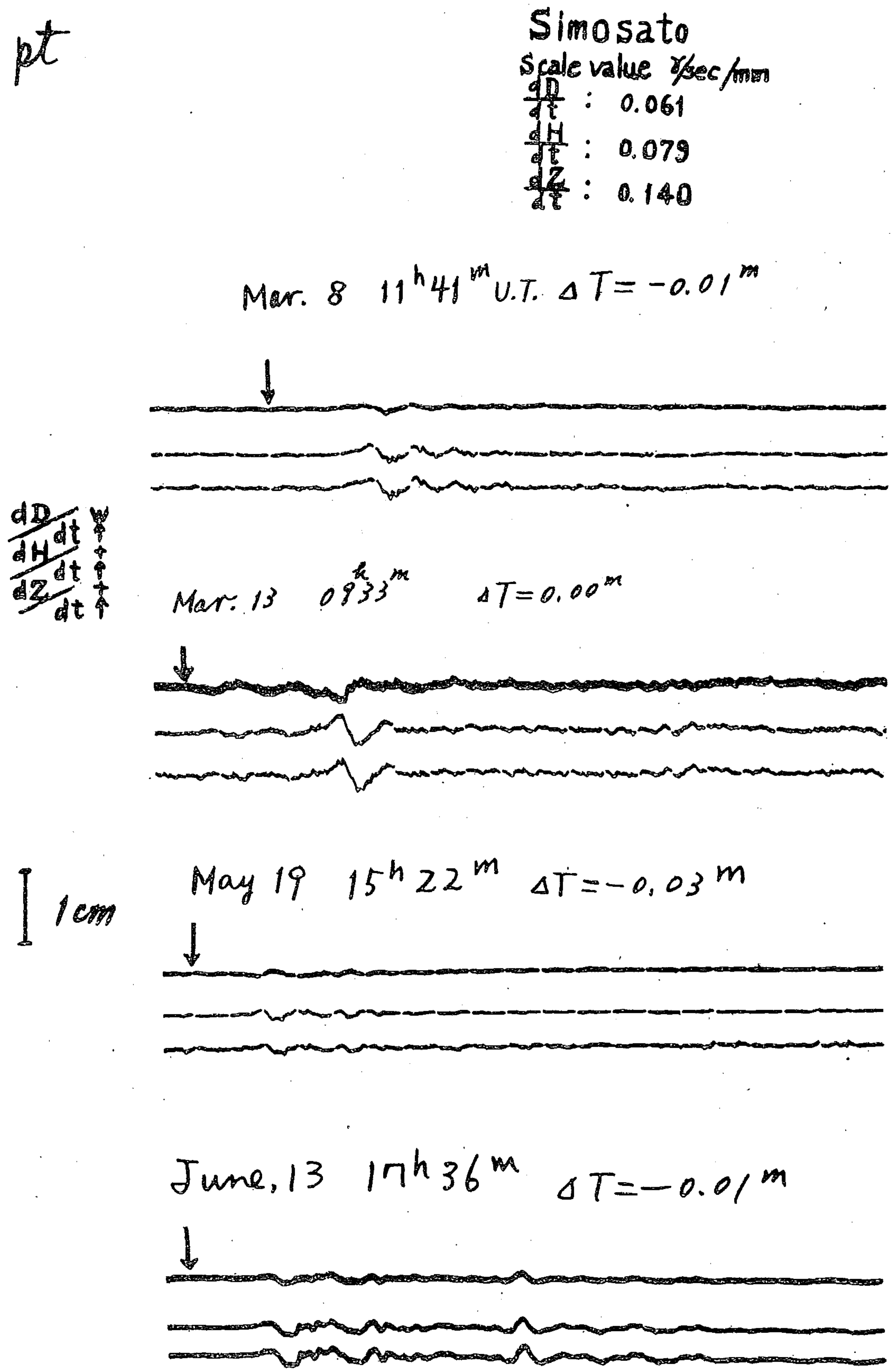


Fig. 6 Some Typical Examples of Micropulsation

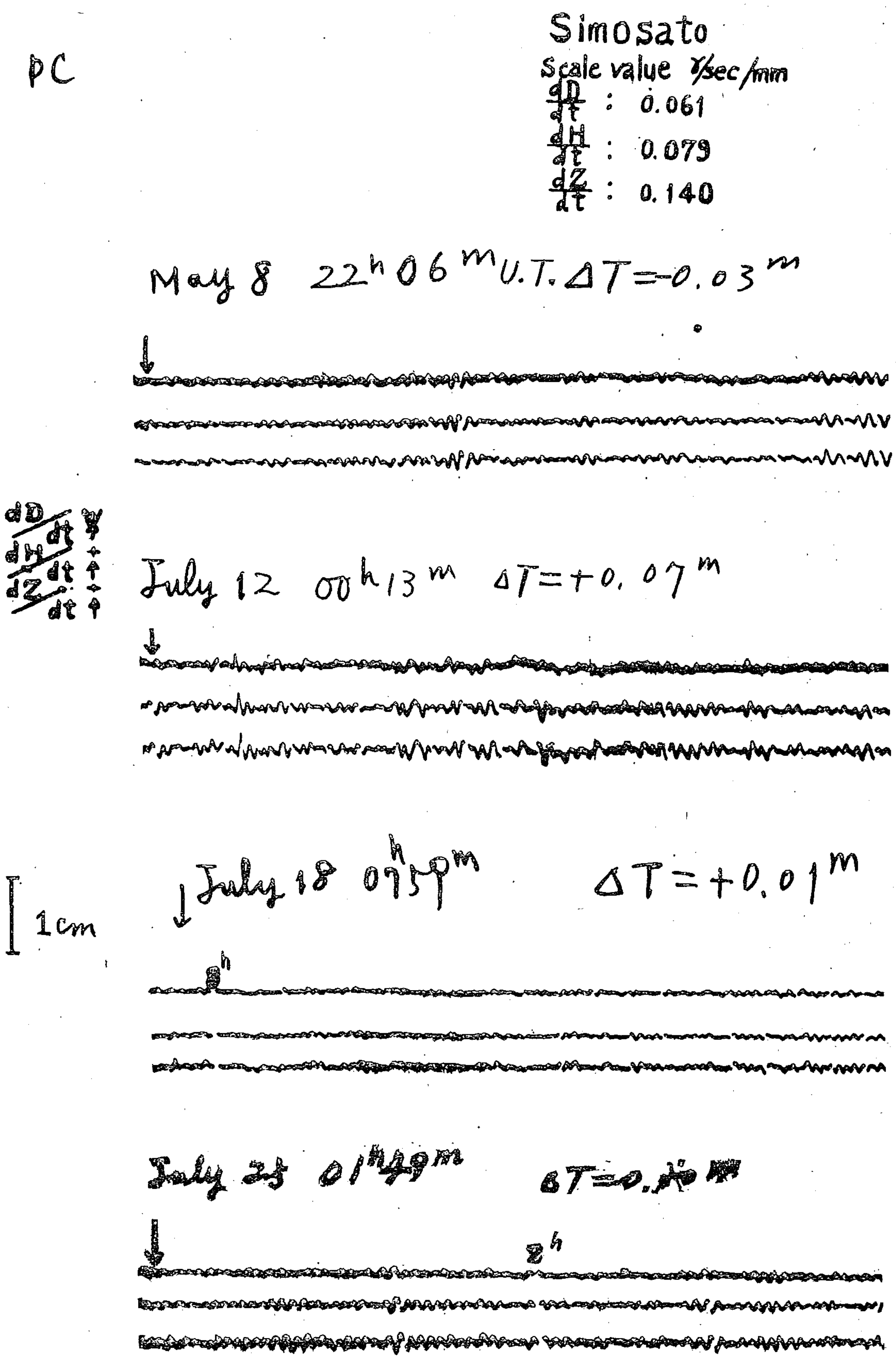


Fig. 6 Some Typical Examples of Micropulsation

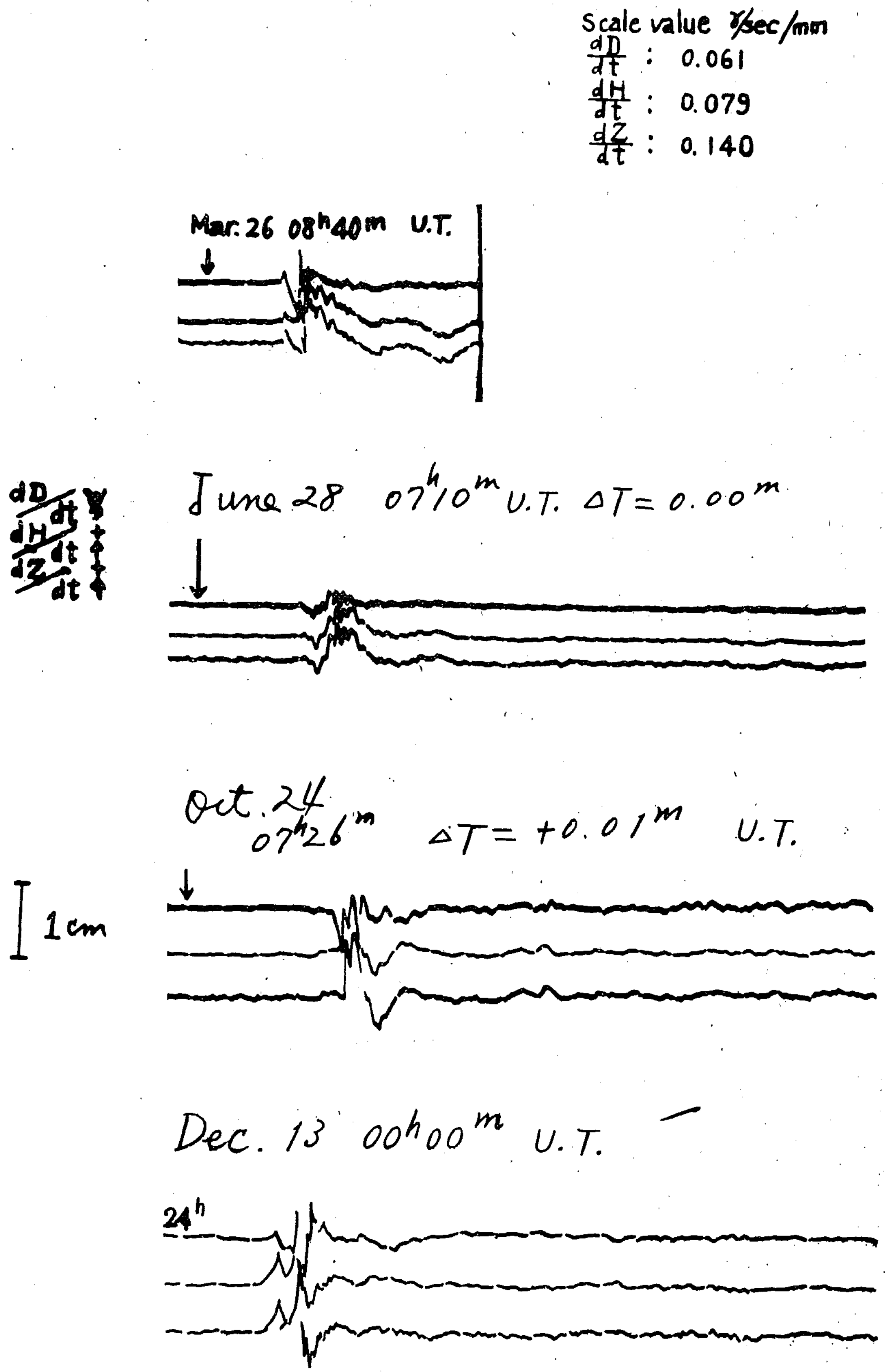


Fig. 7 Micropulsations accompanying SSC
in the Sunlite Hemisphere

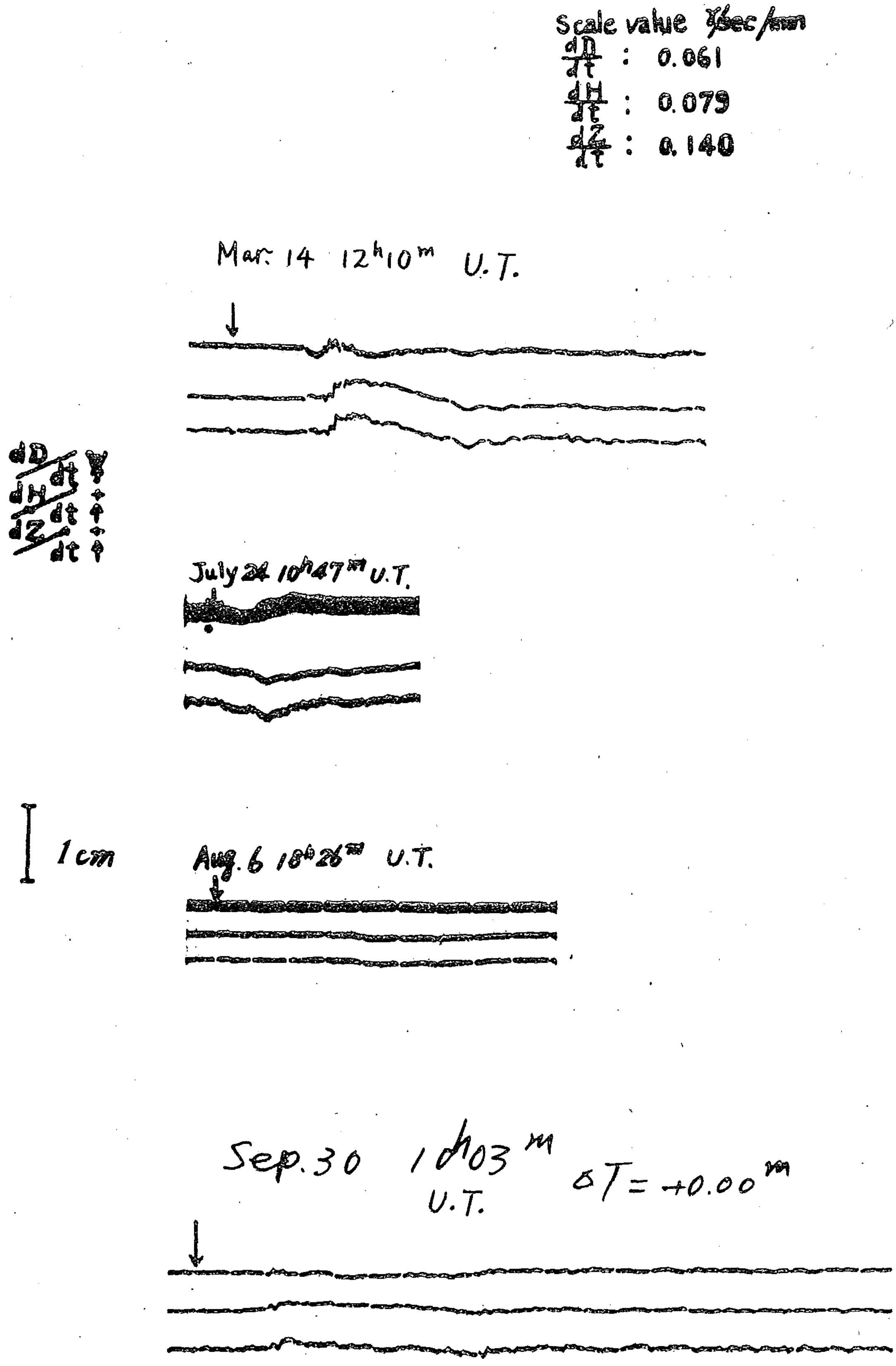


Fig. 7 Micropulsations accompanying SSC
in the Night Hemisphere