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II-1B-5. Morphological Study of Geomagnetic Pulsations

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Using the rapid-run and the ordinary magnetograms obtained during IGY, at the observatories distributed fairly well over the world, continuous pulsations of tpye I (range in period from 10 to 50 seconds), II (50-150 sec) and III (150-900 sec) are analyzed with *pt*-type pulsation. Type II *pc* shows remarkable enhancement in the daytime as type I *pc*, while type III *pc* has two vague maxima in the morning and the evening. The geomagnetic latitude is higher, the range of all three types of pulsations is larger, especially for type III *pc*, there is a sharp maximum in the auroral zone.

For *pt*-type pulsation, its latitudinal dependence is compared with that of bay disturbance. The detail mode of world-wide synchronous oscillation according as the progress of *pt* shows that the direction of each oscillation is apt to point towards the midnight meridian in the northern or southern auroral zone.

§ 1. Introduction

Many investigators have been striving to find a connection between geomagnetic pulsations and the hydromagnetic oscillations in the earth's exosphere[1),2),3)]. However, it was difficult to imagine world-wide behaviour of the pulsations from the morphological standpoint, because we have had to get their information from the magnetograms obtained at only a few localized observatories. Recently, some investigations were made from the broader aspects analyzing the data during IGY[4),5),6)].

In order to piling up more knowledge about geomagnetic pulsations over the large scale region, the present paper deals with the world-wide characteristics of both continuous pulsations with various periods and *pt*-type pulsation using the rapid-run and ordinary magnetograms obtained at the 20 and 27 observatories respectively during IGY.

§ 2. Analyses

1. Continuous pulsations.

In this paper, continuous regular pulsations are divided in three types which are conveniently named according to the next obvious period bands.

Type I *pc*: 10—50 sec (so-called "*pc*")
Type II *pc*: 50—150 sec
Type III *pc*: 150—900 sec

One of the following four indices is given according to the duration of *pc* within each hour interval.

1 : 10—15 min
2 : 15—30 〃
3 : 30—45 〃
4 : 45—60 〃

We also employed the next value;

activity = (index for duration) × (maximum range during one hour interval)

(1) *The diurnal variation of each type.*

The diurnal frequency distribution of occurrence in each period band at, for example, Fredericksburg during whole days of October, 1957 is given in Fig. 1, where one dott shows the occurrence of *pc*, index for duration of which is larger than one, regardless of its value. The figure shows that the above stated classification is reasonable and that the period of type II *pc* is shorter in the daytime than in the night-time, which is also seen in the cases of other observatories[7)]. The reason why such inverted-U type diurnal variation of the period in type I *pc* as analyzed from the induction magnetogram at Onagawa[8),9)] is not clear in the figure, may result from the less responsibility of the rapid-run magnetometer for the short period, but such a tendency is possible to be endorsed by some observational facts[10),11)]. The monthly average of activity in each hour interval is obtained in Fig. 2. In Figs. 1 and 2, types I and II *pc*'s are considered to be the remarkable daytime pulsations while type III *pc* is seemed to increase its activity slightly in the morning and the evening.

(2) *The latitudinal dependence*

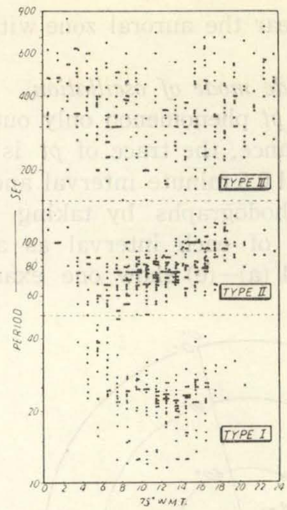


Fig. 1

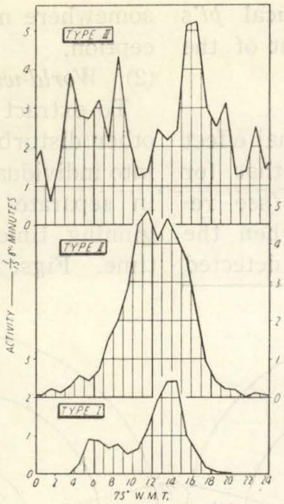


Fig. 2

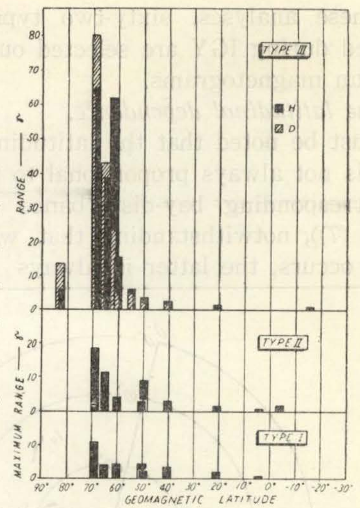


Fig. 3

Fig. 1. Frequency distribution of continuous pulsations.

Fig. 2. Diurnal variation of activity of continuous pulsations.

Fig. 3. Latitudinal dependence for each type of pulsation in the following time or time interval.

Type I: during 40 hours biginning from 06^h00^mU. T., October 29, 1957.

Type II: ibid.

Type III: 23^h55^m U. T., October 1, 1957.

It is rather easy to get a latitudinal dependence of the type III *pc* at a simultaneous moment because, first, the vague diurnal variation prevents to confuse a longitudinal effect caused by the longitudinal scattering of the observatories, next, many data can be supplied even from the stations observing with the ordinary magnetometer only. On the other hand, the latitudinal dependences of the types I and II *pc*'s must be obtained not by their amplitudes at the simultaneous universal time but by the maximum ranges during a whole day because of their strong local time effects. Fig. 3 obtained from such a point of view shows that the ranges of all three types in the high latitude are larger than those in the middle or low latitude, though the gradient of increase near the auroral zone is steeper in type III *pc* than in types I and II *pc*'s. Type III *pc* has a remarkable maximum in its range at the auroral region, which was also seen in the other analyzed examples, whereas such characters are not able to be confirmed in types I and II *pc*'s because of lacking of the stations operating the rapid-run magnetometer in the polar region. In the lower latitude the range of *H*-component of type III *pc* is larger than that of declination while *vice versa* in the high latitude.

(3) *Longitudinal effect in type I pc.*

Obviating short periodic disturbances accompanying with the bay or bay-like phenomena, the interval of 40 hours beginning from 06^h00^m U.T., October 29, 1957 is selected and read their activities. The maximum time of diurnal activity variation is observed in the afternoon at Fredericksburg and Chambon-la-Forêt, in the forenoon at Big Delta, Honolulu and Onagawa, and near noon at Point Barrow, Sitka and Tucson. At Guam and Koror, equatorial stations, the diurnal behaviours are much complicated[7] as Hutton's results[12]. Taking into consideration of the possible relation between the *foF*2 and the hydromagnetic barrier controlling the occurrence of type I *pc*, it is worthwhile to notice an observational fact that the variation of the *foF*2 has some close connection not only with the above-mentioned longitudinal effect, but also with the seasonal variation of type I *pc* that the diurnal occurrence probability curve for type I *pc* at Onagawa has maximum at $7-8^h$ L.T. in winter, while it swells up towards the noon in summer[6].

2. *pt*-type pulsation[13]

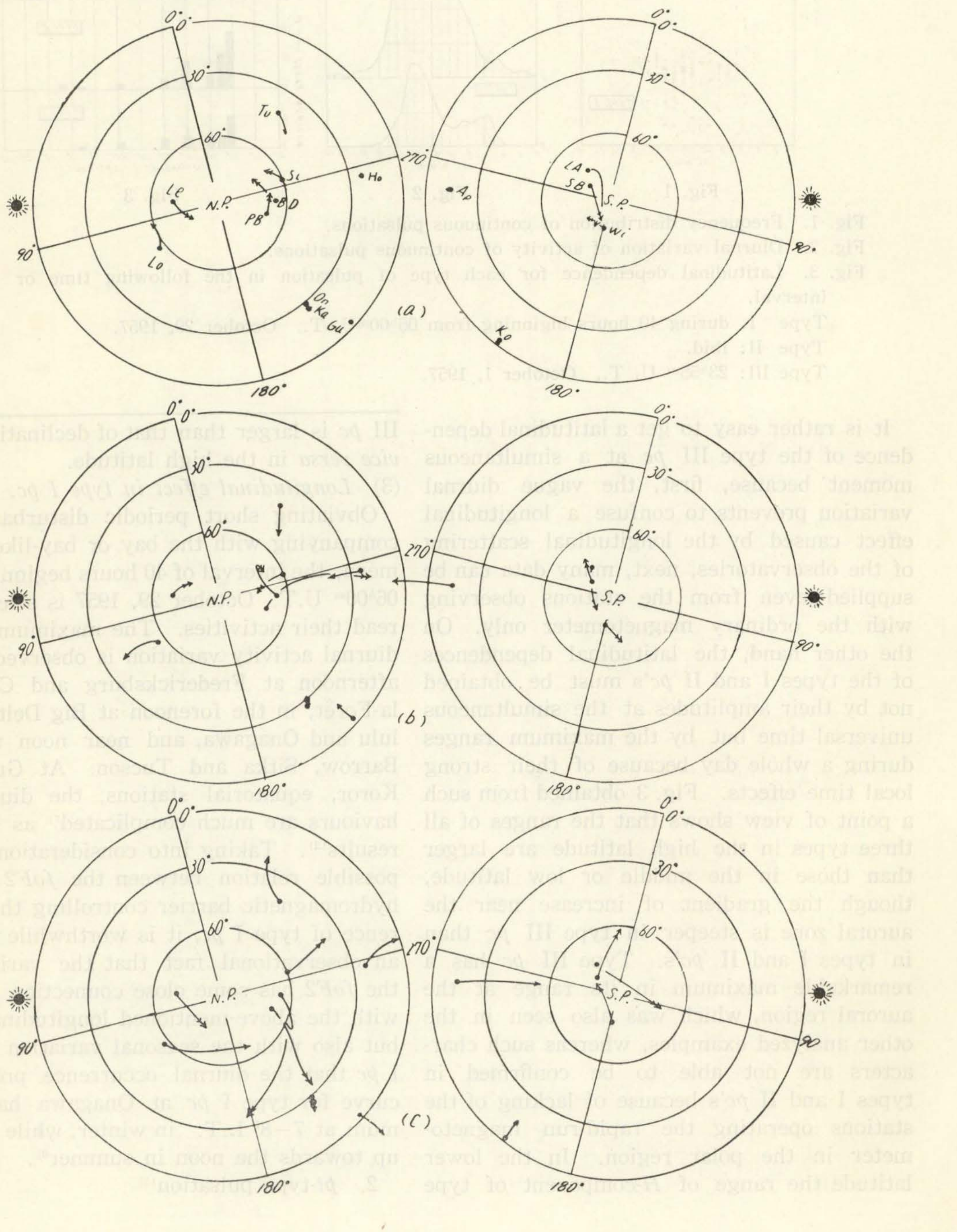
In these analyses, sixty-two typical *pt*'s observed during IGY are selected out of the rapid-run magnetograms.

(1) *The latitudinal dependence.*

It must be noted that the latitudinal effect for *pt* is not always proportional to that for the corresponding bay-disturbance (see reference (7)), notwithstanding that when the former occurs, the latter is always detected somewhere near the auroral zone without exception.

(2) *World-wide mode of oscillation.*

To extract *pt* phenomenon only out of the other disturbance, the trace of *pt* is divided into individual 0.5 minute interval and drawn in separate hodographs by taking the beginning time of each interval as a datum time. Figs. 4 (a)—(e) show one example of



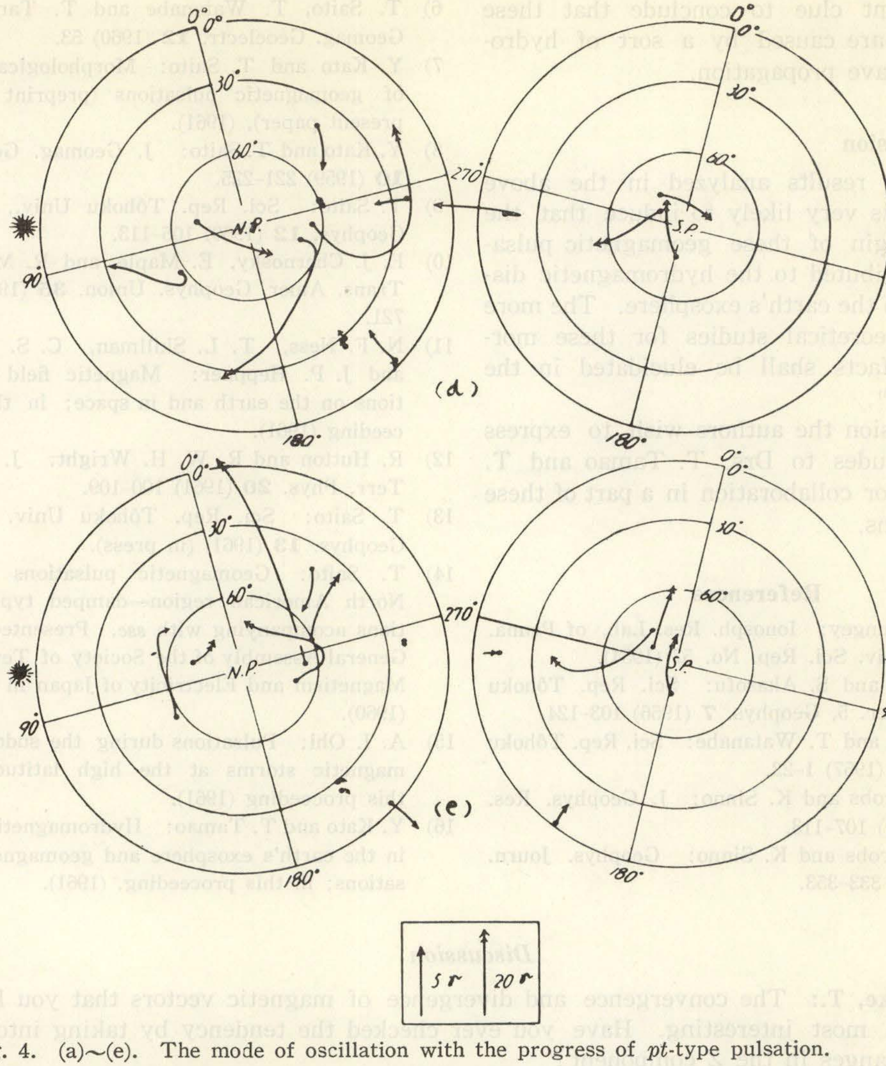


Fig. 4. (a)~(e). The mode of oscillation with the progress of *pt*-type pulsation.

(a) 11ʰ35.5ᵐ—11ʰ36.0ᵐ U. T., August 29, 1957

(b) 11ʰ36.0ᵐ—11ʰ36.5ᵐ

(c) 11ʰ36.5ᵐ—11ʰ37.0ᵐ

(d) 11ʰ37.0ᵐ—11ʰ37.5ᵐ

(e) 11ʰ37.5ᵐ—11ʰ38.0ᵐ.

the momentary hodographs drawn on the world maps by such a method. As seen in Fig. 4 (a), *pt* starts at $11^h35.5^m$ U. T., when disturbing hodographs of the geomagnetic field in the northern hemisphere converge to near north-western Canada, then diverge from there during the next 0.5 minutes (Fig. 4(b)), thus alternating with con- and divergence (Figs. 4(c)—(e)). On the contrary, hodographs in the southern hemisphere seem to start with divergence from the region south-eastward of New Zealand during the first 0.5 minute (Fig. 4 (a)), then oscillate radially with respect to there (Figs. 4 (b)—(e)). Statistically speaking, the center of their radial oscillations situates on the region near local midnight meridian in the auroral zone, though its location differs considerablly according as individual *pt*'s.

The character that the oscillation of hodograph is apt to be delayed after those in the middle or low latitude is generally seen in the other analyzed examples. The observational fact that such a delay phenomenon is also seen in the case of the damped type type III *pc* accompanying with *ssc*[14),15)] should be an important clue to conclude that these oscillations are caused by a sort of hydromagnetic wave propagation.

§ 3. Conclusion

From the results analyzed in the above chapter, it is very likely to induce that the primary origin of these geomagnetic pulsations is attributed to the hydromagnetic disturbances in the earth's exosphere. The more thorough theoretical studies for these morphological facts shall be elucidated in the next paper[16].

In conclusion the authors wish to express their gratitudes to Drs. T. Tamao and T. Watanabe for collaboration in a part of these investigations.

References

1) J. W. Dungey: Ionosph. Res. Lab. of Penna. State Univ. Sci. Rep. No. 57 (1954).
2) Y. Kato and S. Akasofu: Sci. Rep. Tôhoku Univ., Ser. 5, Geophys. **7** (1956) 103-124.
3) Y. Kato and T. Watanabe: Sci. Rep. Tôhoku Univ. **8** (1957) 1-22.
4) J. A. Jacobs and K. Sinno: J. Geophys. Res. **65** (1960) 107-113.
5) J. A. Jacobs and K. Sinno: Geophys. Journ. **3** (1960) 333-353.
6) T. Saito, T. Watanabe and T. Tamao: J. Geomag. Geoelectr. **12** (1960) 53.
7) Y. Kato and T. Saito: Morphological study of geomagnetic pulsations (preprint of the present paper), (1961).
8) Y. Kato and T. Saito: J. Geomag. Geoelectr. **10** (1959) 221-225.
9) T. Saito: Sci. Rep. Tôhoku Univ., Ser. 5, Geophys. **12** (1960) 105-113.
10) E. J. Chernosky, E. Maple and R. M. Coon: Trans. Amer. Geophys. Union. **35** (1954) 711-721.
11) N. F. Ness, T. L. Skillman, C. S. Scearce and J. P. Heppner: Magnetic field fluctuations on the earth and in space; in this proceeding (1961).
12) R. Hutton and R. W. H. Wright: J. Atmos. Terr. Phys. **20** (1961) 100-109.
13) T. Saito: Sci. Rep. Tôhoku Univ. Ser. 5, Geophys. **13** (1961) (in press).
14) T. Saito: Geomagnetic pulsations in the North American region—damped type pulsations acompanying with *ssc*. Presented at the General Assembly of the Society of Terrestrial Magnetism and Electricity of Japan in October (1960).
15) A. I. Ohl: Pulsations during the sudden geomagnetic storms at the high latitudes; in this proceeding (1961).
16) Y. Kato and T. Tamao: Hydromagnetic waves in the earth's exosphere and geomagnetic pulsations; in this proceeding, (1961).

Discussion

Rikitake, T.: The convergence and divergence of magnetic vectors that you have found is most interesting. Have you ever checked the tendency by taking into account changes in the *Z* component?

Kato, Y.: As you kindly adviced me, it is important to check the tendency using the changes of *Z* component, and of course I analysed it but I can not yet obtain good information because the variation of *Z* component is much affected by the induced current in the earth's ground.

Dessler, A. J.: Is not there some difficulty in using variations in the vertical intensity since eddy currents in the earth will affect the results?

Kato, Y.: Yes, the variations in the vertical intensity is much affected by the induction currents in the earth's crust, but the variations in the horizontal intensity (*X* component or *Y* component) is not so much affected. Therefore we carefully used only the variations of horizontal component in this paper.

Vestine E. H.: A thesis by Mustapha El Wakil (deceased) 1937, on earth currents induced by micropulsations was presented to the University of London, and this unpublished work supervised by Prof. Chapman and Prof. Price may interest students of the subject.

Kato, Y.: The investigation on the earth currents induced by the micropulsations is one of the most interesting and important problems in geophysics.

Sir Charles Wright: To Prof. Kato, the *pc*'s referred to follow the strict definition as lasting for several hours?

Kato, Y.: Usually in lower or middle latitude the *pc* pulsations last several hours in the most active stage, but I think it needs not so strict definition as lasting for several hours. Actually I defined the activity of the pulsation as follows.

Activity=(the period of duration)×(the maximum range of the oscillations) and the period of duration is divided into four ranks, that is

if it lasts 10—15 minutes	......	put it rank 1
〃 15—30 〃	......	〃 2
〃 30—45 〃	......	〃 3
〃 45—60 〃	......	〃 4

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II-1B-6. Hydromagnetic Waves in the Earth's Exosphere and Geomagnetic Pulsations

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In the first place the qualitative discussion on the physical characters in the exosphere are given. Using the propagation equation of hydromagnetic waves (HM-waves) in the particular coordinates and assuming Johnson's model of the exosphere, refractive indices for downward propagation of external HM-waves with specified period and wave length in the lower latitudes are obtained as a function of altitudes. It is shown that HM-waves propagating to the perpendicular direction to lines of force will be reflected at the particular level corresponding to their period, and a part of their energy will be transported into the lower region (higher latitudes) by means of transverse waves propagating parallel to the line of force through this level. It is suggested that primary sources of daytime continuous pulsations are attributed to large amplitude HM-disturbances in the outermost exosphere as found by Sonett *et al.* Since these disturbances may have considerable wide band width of spectrum, $T \simeq 1$ sec$\sim 3\times 10^2$ sec, observed characteristics of daytime pulsations at the surface will be explained in terms of the filtering effect of the dispersive inner exosphere. It is also suggested that damped type pulsation, *pt*'s, may be caused by the hydromagnetic compression of the local hot gas in the outer exosphere near the equatorial plane in the dark hemisphere, and this compression will occur as a result of the precipitation of trapped energetic electrons from this local region to the auroral zone.

§ 1. Physical State in the Exosphere

After Sonett *et al.*[1)–3)], we may have the following configuration of the magnetic field in the space surrounding the earth during the relatively undisturbed period, remembering that geocentric distances between the respective subregion will vary with rise and fall of the solar stream.

(I) $r/r_0 \leqq 5$; the magnetic cavity with the dipole field.

(II) $5 \leqq r/r_0 \leqq 7$; the gross deviation of the field from the dipolar form, solar energetic particle trapped, and there is the diamagnetic ring current.

(III) $7 \leqq r/r_0 \leqq 10$; the weak disturbed region, the ordered field exists.

(IV) $10 \leqq r/r_0 \leqq 14$; the intense disturbed region (the outermost exosphere), there are