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Time Changes of Transfer Functions at Kakioka Related to Earthquake Occurrences (III)

—Periodic Changes of Transfer Functions and Other Related Phenomena—

by

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Abstract

Some periodic changes of transfer functions at Kakioka have been examined by the Fourier analysis and the superposed epoch method with relation to those of neighbouring earthquake occurrences and the geomagnetic activity. The data analyzed are the same as used in the previous papers.

The most outstanding results in the present study is that both transfer functions for longer periods than 60 min and earthquake occurrences near Kakioka during the epoch from Mar. 1977 to Dec. 1978 show significant 27-day periodic changes, while the geomagnetic activity does a predominant 29-day one. Most of remarkable periodic changes of transfer functions seem to be closely related to those of earthquake occurrences, but a little to those of the geomagnetic activity.

However, the mean 27-day periodic change of transfer functions for the long periods is exceptionally larger than the other for the short periods and that expected from the effect of the corresponding change of earthquake occurrences. It will be strongly suggested that such a 27-day periodic change of transfer functions is possibly intensified by some origins other than the earthquake precursor effect and the geomagnetic activity dependence.

1. Introduction

The author has investigated various behaviours in the time change of transfer functions at Kakioka since July 1976. (Hereafter, the term of transfer function is denoted by *T*-function). The existence of earthquake precursor changes in *T*-functions at Kakioka has been confirmed in many individual events and in statistical features for many remarkable earthquakes as reported in the previous papers; Part I and Part II of this series (Sano, 1980 and 1982). In addition to these results some other kinds of time changes of *T*-functions due to other origins such as the geomagnetic activity dependence have been also found, and some periodic changes with an about 27-day periodicity due to some origins different from the earthquake precursor or the geomagnetic activity dependence have been further suggested in Part II. Shiraki (1980) pointed out that there were some possible dependences of power or spectral slope of geomagnetic disturbances in *T*-functions obtained with a different method of the spectral analysis from the present author's. Of course, as introduced in Part I, the earthquake precursor changes in *T*-functions at Kakioka were already reported by Yanagihara (1972) and by Yanagihara and Nagano (1976).

As for the periodic change of *T*-functions at Kakioka, a six-year periodic secular change was reported by Yanagihara and Nagano (1976) and the seasonal variations were reported by Shiraki (1980) and by Sano and Nakajima (1982). But no short-periodic changes such as the aforementioned 27-day periodic change have been studied until the present study which is carried out as the first attempt of such the *T*-function study. This paper; Part III of this series, reports some analyzed results of the short-periodic changes of *T*-functions with relation to similar changes of the geomagnetic activity and the earthquake occurrence frequency (seismic activity).

The data of *T*-functions, earthquakes and the geomagnetic activity analyzed in this paper are the same as those used in Part I and Part II, being for the epoch from Mar. 1977 to Dec. 1978. The *T*-functions were obtained for seven periods of 10, 20, 30, 60, 60, 120 and 180 min. The calculation method of *T*-functions was the least square method of complex function for a number of sets of Fourier transforms of the geomagnetic disturbances. Each individual *T*-function was estimated together with the error factor, standard deviation. The earthquakes are of the magnitude larger than 3.4 and within various earthquake areas surrounding Kakioka such as Land area, Off Ibaraki area, Off Chiba area and so on as classified in Part II (see Fig. 6 in section 4). The geomagnetic activity is the mean daily sum of *K*-index at Kakioka (mean $\sum K$) during the epoch from which about ten geomagnetic disturbances were selected to determine a set of *T*-functions, such epoch being usually one or a few days.

In this paper, periodic changes (periodicities) of *T*-functions and related two phenomena have been investigated with two ways. One way is an application of the usual Fourier analysis and the other is the statistical analysis by the superposed epoch method which is the same as that used for the analysis of earthquake precursor changes in Part II. With the former, periodic changes of *T*-functions and the geomagnetic activity were examined for the periods from 15- to 45-days, and with the latter, all the phenomena were analyzed for the especially interesting periods from 26- to 30-days. The respective periodic changes thus obtained were compared with one another and their correlations, in particular, between the *T*-functions and the earthquake occurrences were analyzed. Before the description of the present results, one of some facts suggesting periodic changes of *T*-functions obtained in Part II will be reviewed in the next section.

2. Some facts suggesting periodic changes of transfer functions at Kakioka

It was suggested in Part II that there existed certain kinds of short-periodic time changes in *T*-functions at Kakioka which were not closely related to earthquake occurrences and the geomagnetic activity. Such two examples are reproduced in Fig. 1. These are the respective mean earthquake time changes obtained for two groups of remarkable selected earthquakes. One group is 16 earthquakes whose magnitudes are larger than 4.1 and epicenters are located within Circle area I, and the other is 12 ones larger than the magnitude of 4.4 within Region B (Circle area I and Circle area II). These earthquake time changes were obtained by the superposed epoch method. The lower two plots in Fig. 1 are the corresponding mean time changes of the earthquake occurrence frequency within various earthquake areas noted in the figure and that of the geomagnetic activity. The vertical lines indicate a few maximum peaks of general earthquake occurrence frequency. As for the earthquake areas, see Fig.6 in section 4.

As discussed in Part II, the time changes of *T*-functions presented in Fig. 1 shows such a typical feature as to be characterized by the earthquake precursor change. In particular, those for the S.P. band have been surely regarded as a typical earthquake

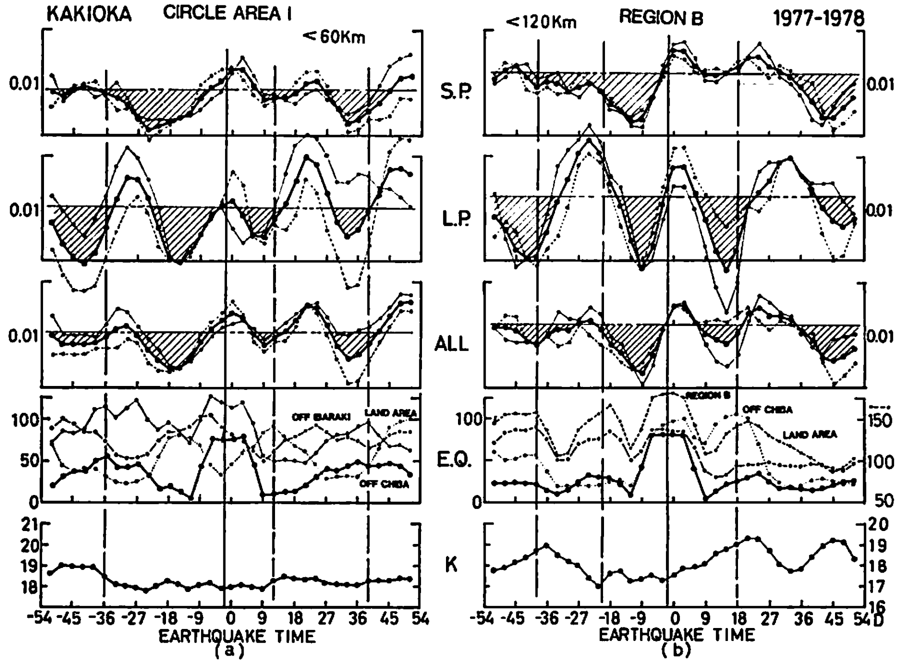

Fig. 1. Statistical earthquake time changes of transfer functions at Kakioka suggesting some periodic changes in addition to earthquake precursor changes (Reproduction from the previous paper, Part II).

precursor change. Those for the L.P. band, however, have three or four conspicuous decreasing changes whose all main parts are hardly regarded as earthquake precursor changes like those in the S.P. band. (Here, the S.P. and L.P. bands consist of 10, 20, 30, 60 min and of 90, 120, 180 min, respectively.) It is suggested from the above fact that the changes in the L.P. band seem to be some kinds of time changes in *T*-functions caused by origins other than the earthquake precursor effect. Of course, these have no close relation to the geomagnetic activity changes shown at the bottom of Fig. 1.

After all, these changes suggest that there is a possibility of the existence of some periodic changes in the L.P. band. As the magnitudes of change exceed the 95% confidence interval, it is hardly considered that the changes were produced by some accidental origins. Hence, such the periodic change will be regarded as a natural phenomenon, but its origin is quite unknown at present. In addition, it should be noted that no remarkable periodic changes were found in the S.P. band.

3. Fourier amplitudes of periodic changes of transfer functions and the geomagnetic activity

Since an existence of periodic changes in the *T*-functions of L.P. band has been

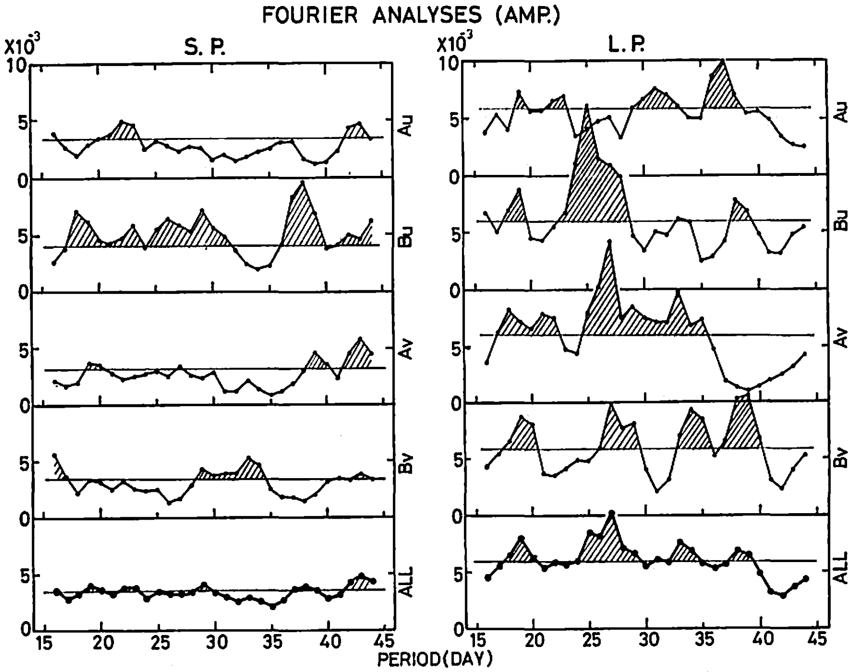

Fig. 2. Three-term running mean Fourier amplitudes of various groups of transfer functions for periods from 16-days to 44-days.

suggested, the *T*-functions and the geomagnetic activity have been investigated in more detail by the technique of usual Fourier analysis. Fourier amplitudes of *Au, Bu, Av* and *Bv* were calculated for periods from 15-days to 45-days. And mean Fourier amplitudes for the S.P. and L.P. bands were also calculated. These Fourier amplitudes were occasionally smoothed with the three-term weighted (1:3:1) running mean.

Fig. 2 shows spectral features of various kinds of Fourier amplitudes thus obtained. The respective plots are for *Au, Bu, Av, Bv* and *ALL* (all mean) from the top of each panel. The horizontal lines in the middle of each plot represent respective general noise levels or mean levels (by eye-estimation). Some significant Fourier amplitudes are hatched. In Fig. 3 are reproduced the spectral curves for the all means of two bands together with that of the geomagnetic activity to compare with one another. These spectral curves in Figs. 2 and 3 are what the respective original Fourier amplitudes were smoothed with the three-term running mean.

As can be seen in the figure, the spectral features for most of *T*-functions are quite complicated, and there are some clear differences in spectral structure from *T*-function to *T*-function and/or from period band to period band. The mean level

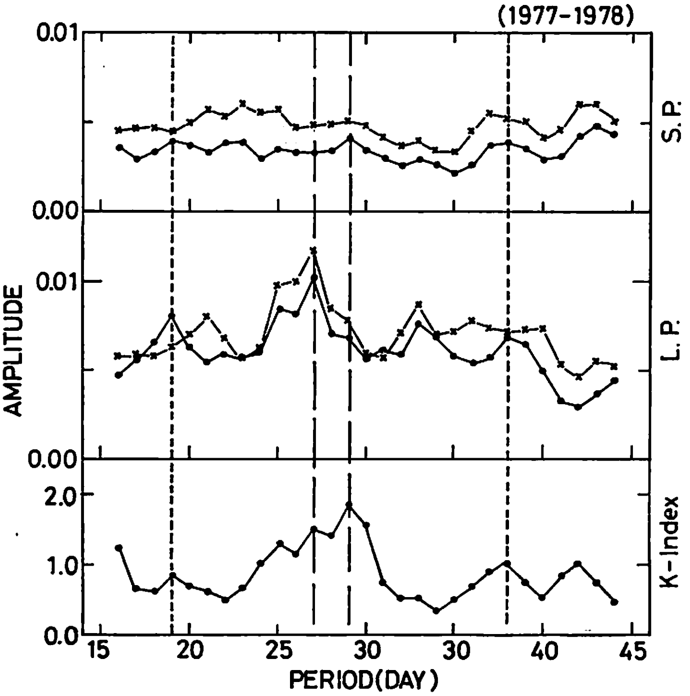

Fig. 3. Three-term running mean Fourier amplitudes of all mean of the short-period (S.P.) and long-period (L.P.) bands, and that of the geomagnetic activity (mean ΣK at Kakioka) for the same periods as in Fig. 2. ●=weighted, ×=simple means.

and the maximum value of Fourier amplitudes are in general larger in the L.P. band than in the S.P. band. At present it is not well understood whether or not the above differences are meaningful. However, following general features can be derived from the all mean spectra with fairly high confidence. There is no remarkable periodicity in the all mean of S.P. band (*ALL*), though the periodicity of *Bu* is rather predominant around the periods of 18-, 29- and 38-days. In the L.P. band, significant spectral structures are clearly seen. There are the most predominant periodicity around the 27-day period and three secondary ones around the 19-, 33- nad 38-day periods. At least, the most predominant one will be considerably reliable. While, the geomagnetic activity shows a fairly similar spectral appearance to that of *T*-function of L.P. band, but its detailed structure seems to be essentially different as will be discussed below.

In order to see fine spectral structures, original Fourier amplitudes (not smoothed) of all means for the S.P. and L.P. bands are shown in Fig. 4 together with that of the geomagnetic activity. In this figure it will be clear that the periodicity around the 27-day period in the L.P. band has a fine structure which consists of three components of 25-, 27- and 29-day periods. Of course, the 27-day periodicity is the most

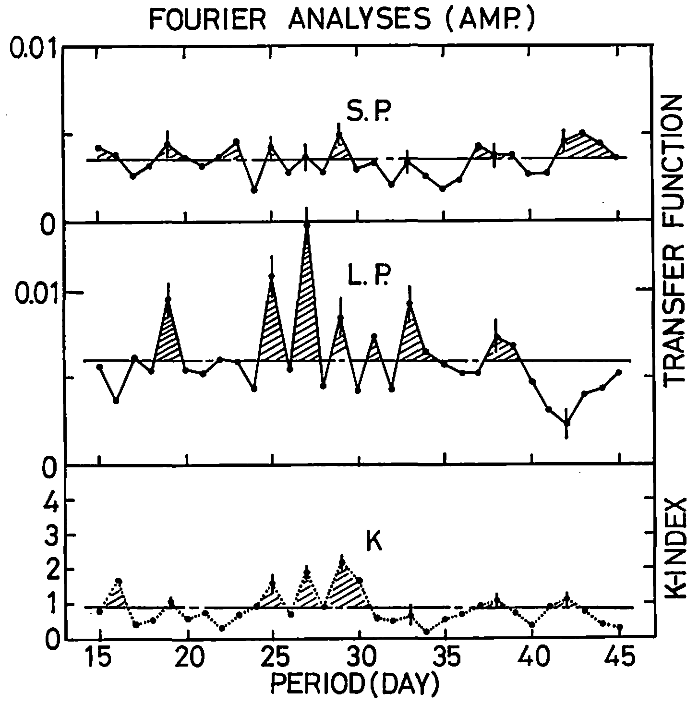

Fig. 4. Original Fourier amplitudes (not smoothed) of all mean of the S.P. and L.P. bands, and that of the geomagnetic activity for periods from 15-days to 45-days.

predominant, its Fourier amplitude amounting to 0.015. Corresponding to these features, a similar fine structure can be seen in the periodicity of the geomagnetic activity. However, its most predominant periodicity is not the 27-day period but the 29-day one. This may mean that the aforementioned periodicity of *T*-functions in the L.P. band is not closely related to the geomagnetic activity. This matter will be discussed again in section 6. The spectral feature of the S.P. band is rather irregular and shows much less periodicity than that of the L.P. band. It is not well known at present whether or not these fine spectral structures of *T*-functions are an essential feature.

4. Periodic changes of transfer functions and the related phenomena

As a result of the Fourier analyses presented in section 3, it has been made clear that there are some significant periodic changes in *T*-functions at Kakioka around the 27-day period. In order to develop this study, periodic changes of *T*-functions and the related phenomena (earthquake occurrences and geomagnetic activity) have been in detail examined by the same superposed epoch method as that used in Part II. In the present case, the superposed epoch method was applied taking the days of

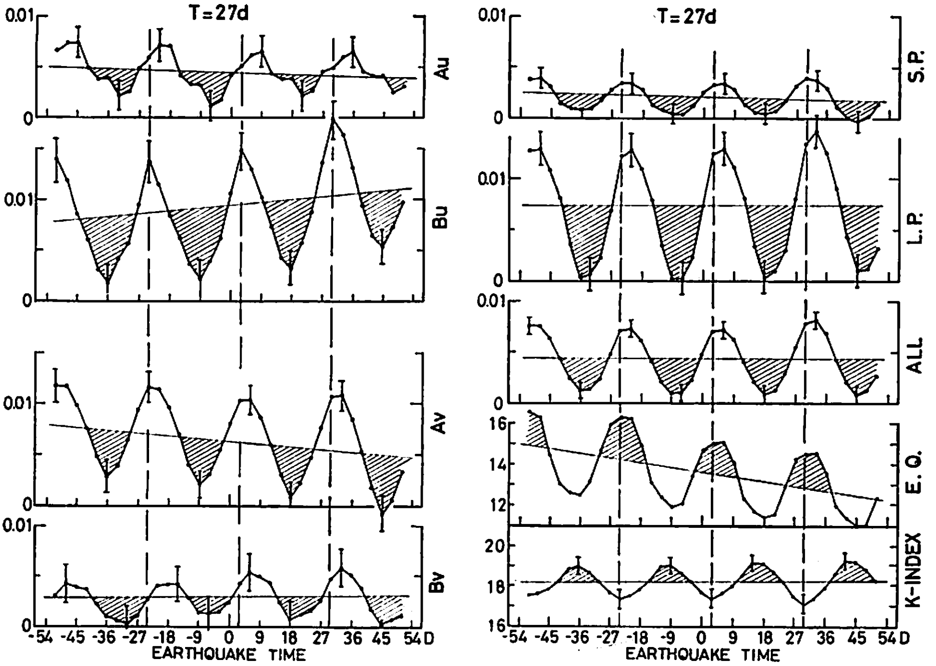

Fig. 5. 27-day periodic changes of transfer functions and corresponding similar periodic changes of earthquake occurrences and the geomagnetic activity obtained by the superposed epoch method. The error bars indicate the 68% confidence interval.

nPi as central days of respective superposed epochs, where n is 2, 3,. . .j, $j+1$ (j=the number of superposed epochs) and Pi is the period to be analyzed, such as 26-, 27-days and so on. The day of *nPi* was reckoned from the first day of the whole epoch from Mar. 1977 to Dec. 1978; Mar. 1st 1977 is 1-day.

4.1 27-day periodic changes of transfer functions and the related phenomena

In Fig. 5 are presented the most significant periodic changes with the 27-day period for various groups of T-functions. The left and right panels show all means of *Au*, *Bu*, *Av* and *Bv*, and those of three bands, S.P., L.P. and ALL, respectively, together with corresponding periodic changes of the earthquake occurrence frequency and geomagnetic activity in the right panel. The error bars are based on the standard error, 68% confidence interval. The earthquake occurrence frequency is a mean of weighted one superposed for earthquakes with the magnitude larger than 3.4 and within the earthquake area of Region A. Such earthquake areas are illustrated in Fig. 6. As noted in the figure, the Region A consists of the Land and the Ocean area. The epicenters of earthquakes larger than the magnitude 3.9 are plotted in Fig. 6. The weighted occurrence frequency of an earthquake was defined by $e^{(M-3.8)}$, (M=

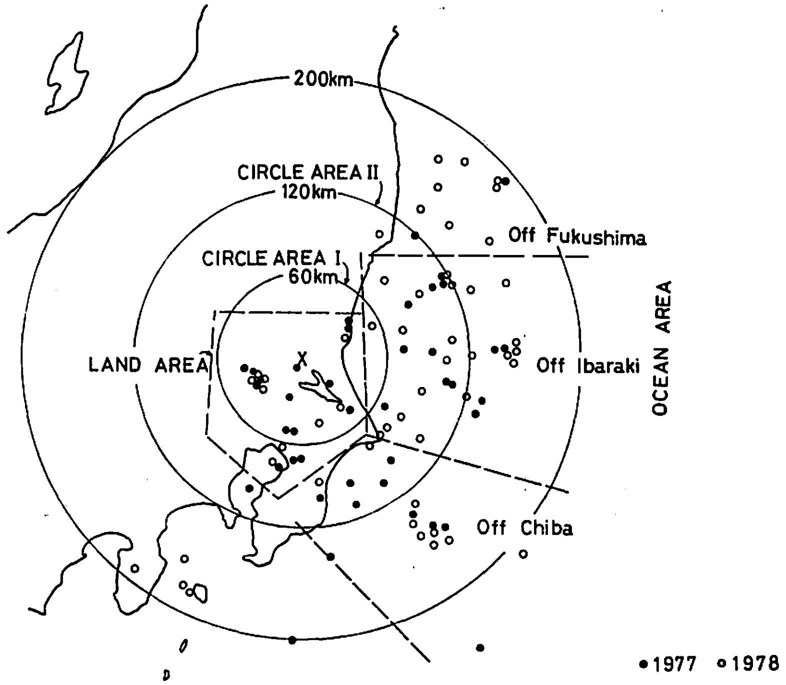

Fig. 6. Earthquake areas treated in the present study and the epicenters of earthquakes larger than the magnitude of 3.9.

magnitude of earthquake) as well as in Part II. These weighted occurrence frequencies were calculated with the superposed epoch method and their five-term running sums were taken. Furthermore, the superposed and five-term running sums were normalized by dividing them by the number of superposed epochs, (*j*). Thus normalized earthquake occurrence frequencies are shown in Fig. 5.

As can be seen in Fig. 5, all the superposed mean changes of *T*-functions have a significant periodic character, though that of *Au* is rather small and irregular. In particular, those for the L.P. band and/or *Bu* and *Av* are quite large, amounting to about 0.015 in double amplitude. These conspicuous changes will be accepted with the 95% confidence. And it is notable that the periodic changes in the L.P. band are larger than those previously suggested in the earthquake time changes in Fig. 1.

On the other hand, it is very interesting that the earthquake occurrence shows also a predominant 27-day periodic change whose phase coincides with that of *T*-function with a little phase difference. The above phase relation is quite similar to that in the case of the earthquake precursor change reported in Part II. The geomagnetic activity shows a weak periodic change which has nearly inverse-phase against that of *T*-function. This phase relation corresponds approximately to what is expected from the geomagnetic activity dependence of *T*-functions reported in Part I and Part II. From these facts it will be inferred that the 27-day periodic changes of *T*-functions are resulted from the earthquake precursor and geomagnetic activity effects, in particular, from the former. However, there is an important question whether or not the above effects are main origins especially in the L.P. band. Although this important matter will be discussed in detail in section 6, there will be strongly suggested that the periodic changes in *T*-functions of L.P. band are due to some origins other than the aforementioned two effects.

4.2 Other examples of periodic changes for the periods of 28- and 29.5-days

Other periodic changes of *T*-functions and the related phenomena for the periods of 26-, 28-, 29.5- and 30-days have been investigated. Two results for the periods of 28- and 29.5-days are shown in Figs. 7 and 8 in the same manner as Fig. 5. The period of 29.5-day corresponds to the lunar month, then it was adopted instead of the period of 29-day. As can be expected from the Fourier analyses, the changes of *T*-functions in these cases must be much smaller than those for the period of 27-day. Actually, all the changes in Figs. 7 and 8 are very small, the largest amplitude being only about 0.005.

As for the geomagnetic activity, the change for the period of 29.5-day is the largest and that for the period of 28-day is the smallest. While, as for the earthquake occurrence frequency, amplitudes of the periodic changes for the aforementioned four

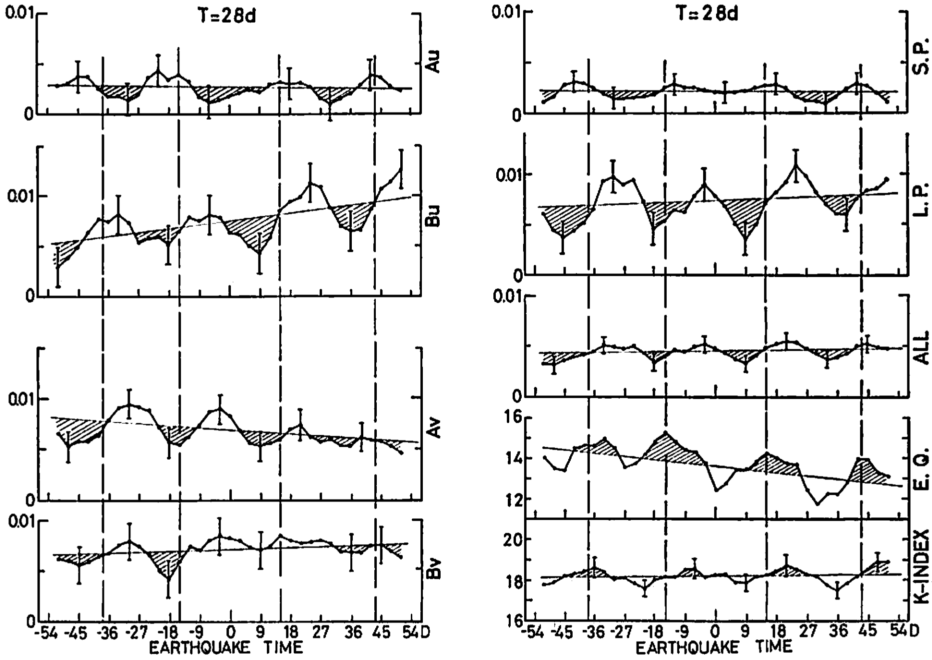

Fig. 7. Same as Fig. 5 except for the 28-day periodic changes.

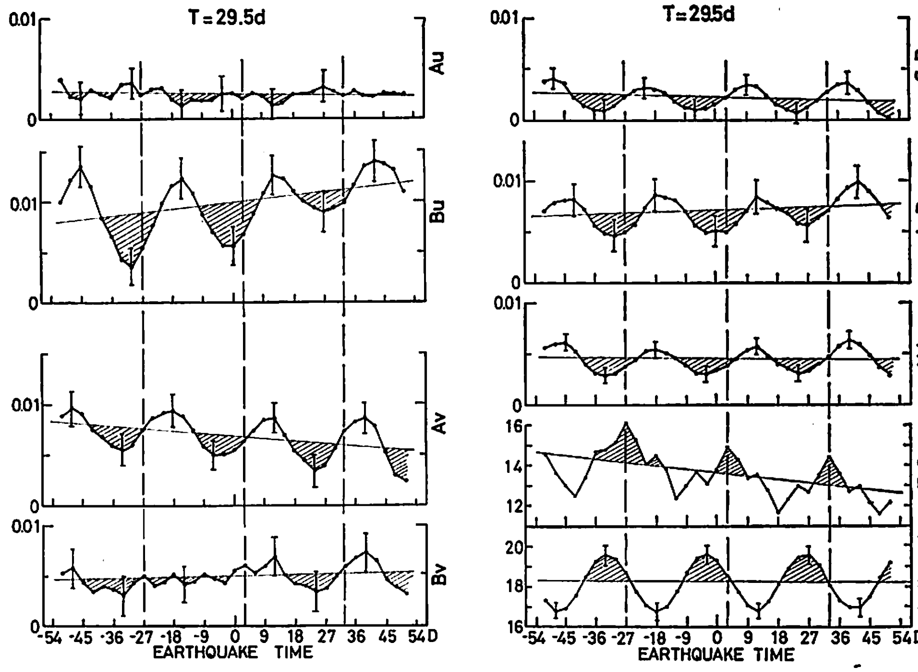

Fig. 8. Same as Fig. 5 except for the 29.5-day periodic changes.

periods are approximately proportional to those of T-functions. Phase relations between the T-function and the earthquake occurrence in all cases are roughly similar to that (in-phase) described in the case of 27-day period. The phase relations between

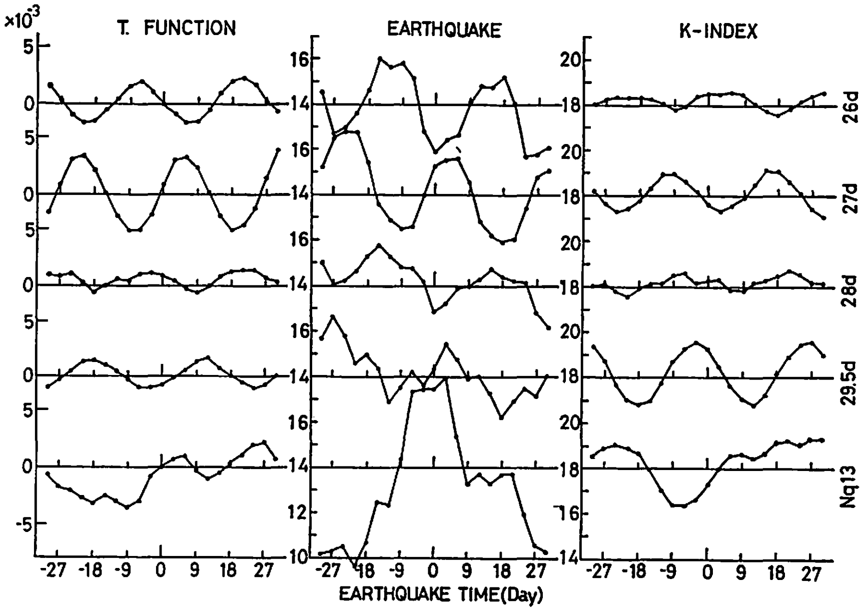

Fig. 9. Summary of the periodic changes of transfer functions and the related phenomena.

Table 1. Summary of the periodic changes of transfer functions and the other related phenomena. The values are amplitudes of the respective periodic changes. Transfer function $=10^{-3}$ unit.

PERIOD	Au		Bu		Av		Bv		MEAN				ALL MEAN	K	E.Q.
	S	L	S	L	S	L	S	L	S	L	R	I			
26d	32	47	82	82	37	101	15	45	31	53	43	38	39	1.0	3.1
	30		80		61		20								
27d	28	112	79	225	51	187	17	143	33	131	64	72	64	1.9	4.0
	48		125		97		43								
28d	37	37	?	162	23	82	?	?	13	55	20	27	17	1.0	1.4
	25		46		33		?								
29.5d	31	46	100	53	50	100	52	62	26	35	20	37	28	2.8	2.1
	15		67		45		20								
30d	16	70	77	59	39	57	40	40	32	38	34	31	33	2.4	1.8
	38		59		36		25								

S= S.P., L= L.P., R= Real part, I= Imaginary part, K= K-index and E.Q.= Earthquake the periodic changes of T-functions and geomagnetic activity are nearly inverse-phase except for the period of 28-day (in this case is rather in-phase).

4.3 Summary of the periodic changes around the period of 27-days

The periodic change examined in the present study are summarized in Fig. 9 and Table 1. The lowest three plots are replaced by an earthquake precursor change of T-functions and others reported in Part II instead of those for the period of 30-day. The values in Table 1 are respective amplitudes of the periodic changes. For some irregular changes, their amplitudes were measured by eye-smoothing. Main characteristics of these periodic changes are summarized as follows:

(1) The 27-day periodic change is most predominant in both cases of the T-function and the earthquake occurrence, while the 29- or 29.5-day periodic one is most predominant in the case of the geomagnetic activity.

(2) The periodic changes of T-functions for the L.P. band are much larger than those for the other band. In particular, the 27-day one for the L.P. band is exceptionally large.

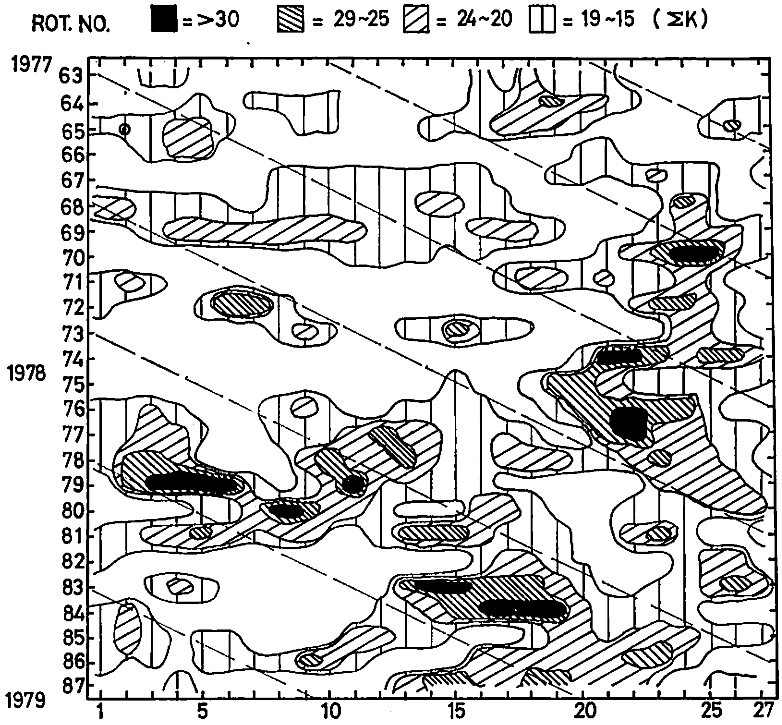

Fig. 10. Recurrence pattern of the geomagnetic activity (mean ΣK) at Kakioka during the epoch from 1977 to 1978. The mean ΣK is defined by the three-day running mean of daily ΣK's.

(3) The amplitudes of periodic changes of T-functions are well proportional to those of earthquake occurrences, but little to those of the geomagnetic activity (refer to Fig. 13 in section 6, too).

Although these facts will be discussed in section 6, the periodicity (recurrence) of the geomagnetic activity will be understood from another evidence shown in Fig. 10. Fig. 10 shows a recurrence pattern (contour map) of three-day running mean of $\sum K$ at Kakioka according to the 27-day solar rotation epoch. The contour lines are drawn with an increment of 5 from 15 to 30 of $\sum K$. The geomagnetic activity is indicated with four degrees as noted in the figure. As can be seen in the figure, many active patterns along the oblique lines which correspond to the 29-day periodicity (recurrence) are most predominant.

5. Detailed features of earthquake occurrences

It is very interesting to examine in detail the periodicity of earthquake occurrences within various areas as shown in Fig. 6. The earthquake areas have been partly explained already. The divisions of the area are the same as the two ways in Part II, being as follows:

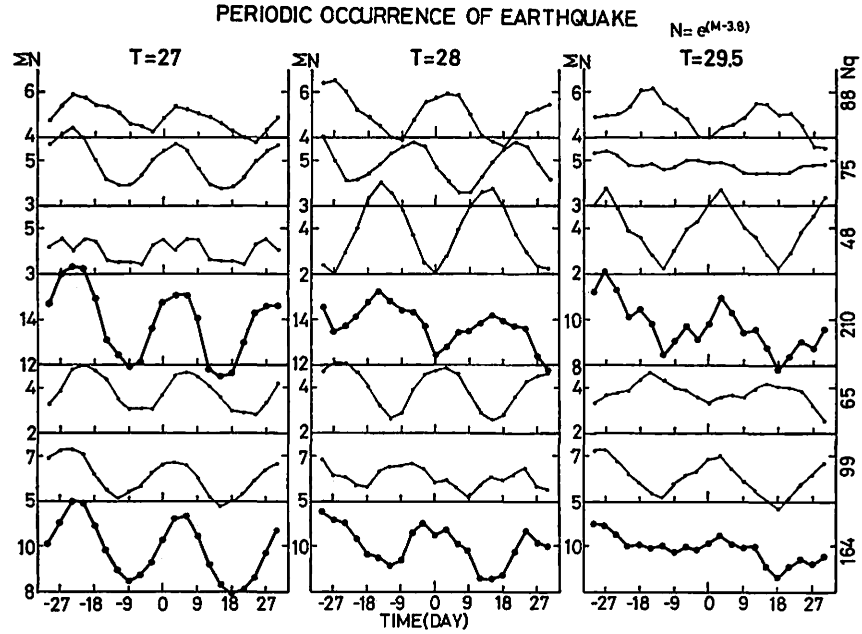

Fig. 11. Periodic occurrence features of earthquakes for the 27-, 28- and 29.5-day periods in various earthquake areas as illustrated in Fig. 6.

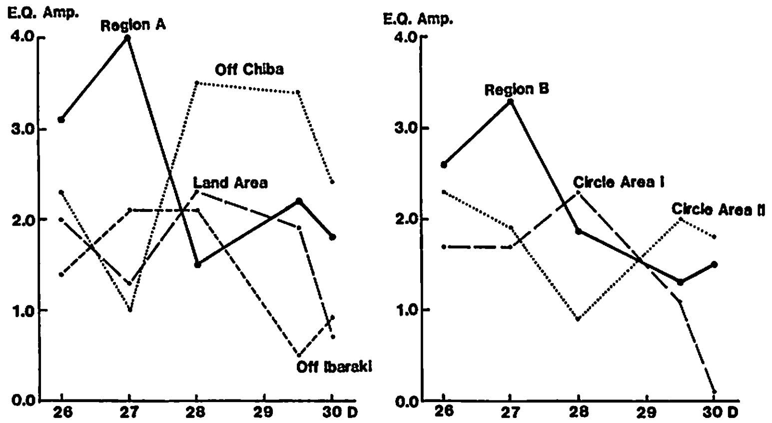

Fig. 12. Amplitudes of periodic changes of earthquake occurrences in the respective earthquake areas based on two divisions of the area neighbouring Kakioka.

One division is

Land area, Off Ibaraki area, Off Chiba area and partial Off Fukushima, and Region A, the total area of the above four sub-areas.

The other division is

Circle area I and Circle area II, and Region B, the total area of the above sub-areas.

In each area, various periodic changes of earthquake occurrences were obtained by the superposed epoch method. Three examples for the periods of 27-, 28- and 29.5-day are shown in Fig. 11. The respective plots are of the Land, Off Ibaraki (including the partial Off Fukushima), Off Chiba areas, Region A, Circle area I, Circle area II and Region B from the top in turn. Those for the Regions A and B are indicated by the thick lines. The numerals (*Nq*) at the right side are the numbers of the earthquakes treated in each area. In Fig. 12 are summarized the amplitudes of periodic changes for the respective areas as noted in the figure.

The most outstanding feature derived from these figures is that the amplitude of the 27-day periodic change in each region is largest, although those in the individual small areas, i.e. sub-areas, are rather smaller than those for the 28-day period. This means that the phases of the 27-day periodic changes in all the areas well coincide with one another, while those for the 28-day period are so largely different from one another as to be occasionally inverse-phase. In this way, the earthquake occurrences within the relatively large area neighbouring Kakioka seem to be well synchronized with the 27-day periodicity. This fact is interested as a close relation between the periodicities of earthquake occurrences and of *T*-functions. But it is uncertain whether this fact is a general feature or a mere accidental one peculiar to the epoch of present concern. Besides, the earthquake occurrence frequencies shown in Figs. 5, 7 and 8 are the same as the present ones of Region A.

6. Concluding remarks

In this paper the periodic changes of *T*-functions, earthquake occurrences and the geomagnetic activity at Kakioka have been investigated by the Fourier analysis and the statistical analysis with the superposed epoch method. In this section several important results are remarked and some interpretations or speculations are briefly discussed.

In Fig. 13 are summarized the amplitudes (T.F. Amp.) of periodic changes of *T*-functions for all the periods. It is one of the most outstanding results in this study that the 27-day periodicity is most predominant in the *T*-functions of the L.P. band. While, the periodicity of the S.P. band is not so predominant. Another outstanding result is that the earthquake occurrences in the Region A or in the Region B also

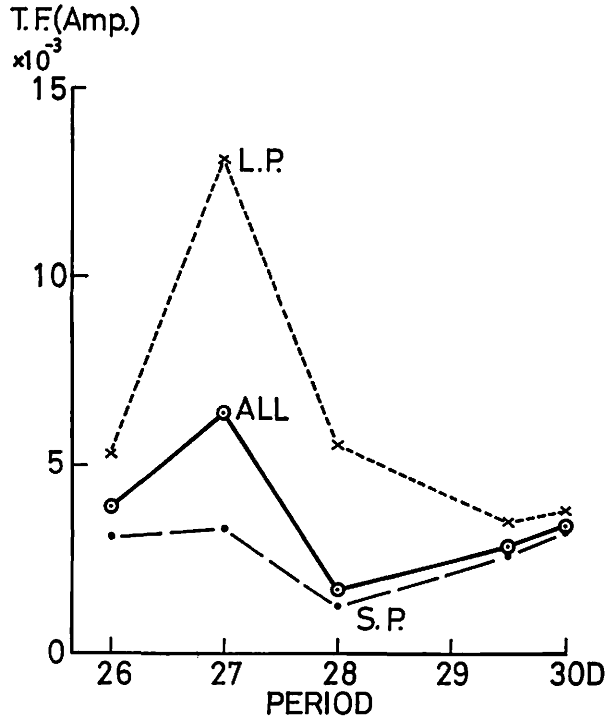

Fig. 13. Summary of the amplitudes of periodic changes of transfer functions.

show a 27-day predominant periodicity as well as in the case of *T*-functions. Furthermore, almost all of the periodic changes of *T*-functions seem to be so closely related to those of earthquake occurrences that the formers are the earthquake precursors as discussed in Part I and Part II.

Then, in Fig. 14 are shown three kinds of correlations (scatter diagrams) between the periodic changes of *T*-functions including the precursor changes obtained in Part II and the corresponding changes of earthquake occurrence frequency within the Region A. The plots indicated by the dotted circles are for the present periodic changes and the others by the open circles are for the earthquake precursor changes such as two examples presented in Fig. 1 in section 2. The oblique full lines in each scatter diagram is each regression line and the two broken lines indicate the width of two standard deviations. The coefficients of correlation and regression are given in Table 2.

As can be seen in this figure, all plots somewhat spread, but each of them has a good positive correlation. From this feature it can be first considered that in general not only the changes of *T*-functions obtained in Part II but also the other ones ob-

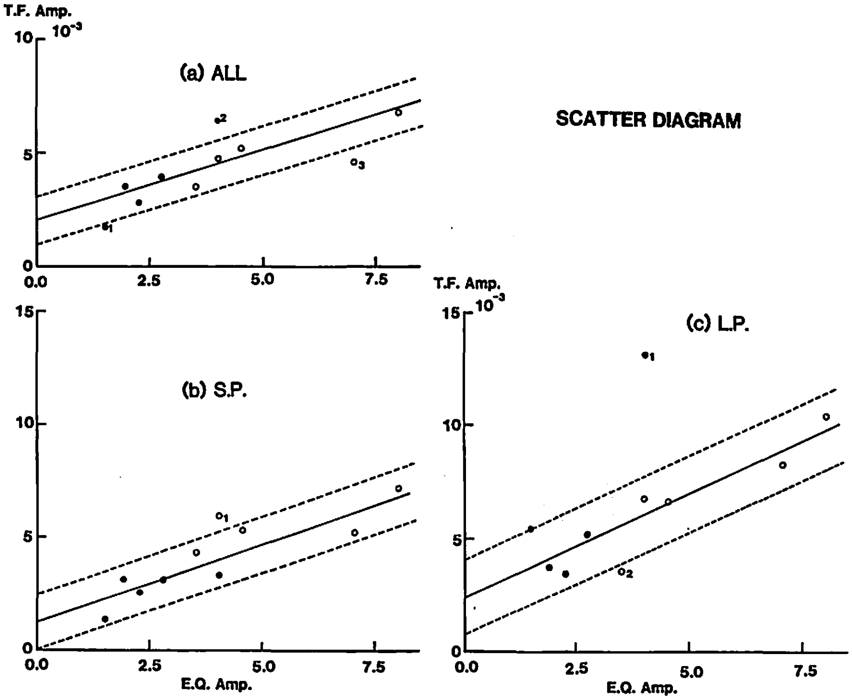

Fig. 14. Correlations between the amplitudes of various time changes of transfer functions and of the earthquake occurrence frequency in Region A. The plot indicated by the dotted circles and by the open circles are of the periodic changes obtained in this study and of the earthquake precursor changes obtained in Part II, respectively.

Table 2. Coefficients of correlation and regression between the amplitudes of transfer functions and of earthquake occurrences. The values in "Selected" are for what one or three data marked by the numerals in Fig. 14 are omitted.

	All			Selected		
	r	a	a_0	r	a	a_0
S.P.	0.86	0.35	1.4	0.92	0.35	1.2
L.P.	0.63	0.47	3.0	0.89	0.46	2.4
ALL	0.77	0.28	2.1	0.94	0.31	2.0

r = Coeff. of correlation, a = Coeff. of regression,
a_0 = Constant term.

tained in this study are the phenomena which were mainly related to earthquake precursors. In this way, it should be noted that the existence of earthquake precursor changes in *T*-functions can be also confirmed as well as in Part I and Part II, this being one of the most important results in this study.

Meanwhile, if Fig. 14 is seen in detail, it is found that there are one or three plots deviating from the general relation indicated by the regression line in each panel. Such plots are marked by the numerals, 1, 2 and 3. Especially the one marked by the numeral 1 in the panel (c), which is the 27-day periodic change of the L.P. band, is largely deviated upwards. This change is about two times larger than that expected from the general earthquake precursor, so that its large amplitude cannot be explained by only the earthquake precursor change. And this fact surely leads to the conclusion that there are some origins of the *T*-function change other than both the earthquake precursor effect and the geomagnetic activity dependence, being also an important result in this study. Such a feature cannot be clearly seen for the S.P. band in the panel (b). As a reasonable result, the 27-day change of the ALL band indicated by the numeral 2 in the panel (a) has a similar feature to the above of the L.P. band, though it is not so predominant.

It should be taken into consideration that the deviating feature of each plot depends somewhat upon the geomagnetic activity. Fig. 15 shows the geomagnetic activity dependences for various *T*-functions reported in Part II. The dependences are much complicated and are different for different *T*-functions and for the different bands. However, for example, a rather clear negative correlation will be seen in the all mean at the bottom. Its coefficient of linear regression is about $-0.0005/\Sigma K$ which is rather small, but cannot be ignored. Accordingly, it is considered in the scatter diagram of the panel (a) that the respective changes of *T*-functions are more or less

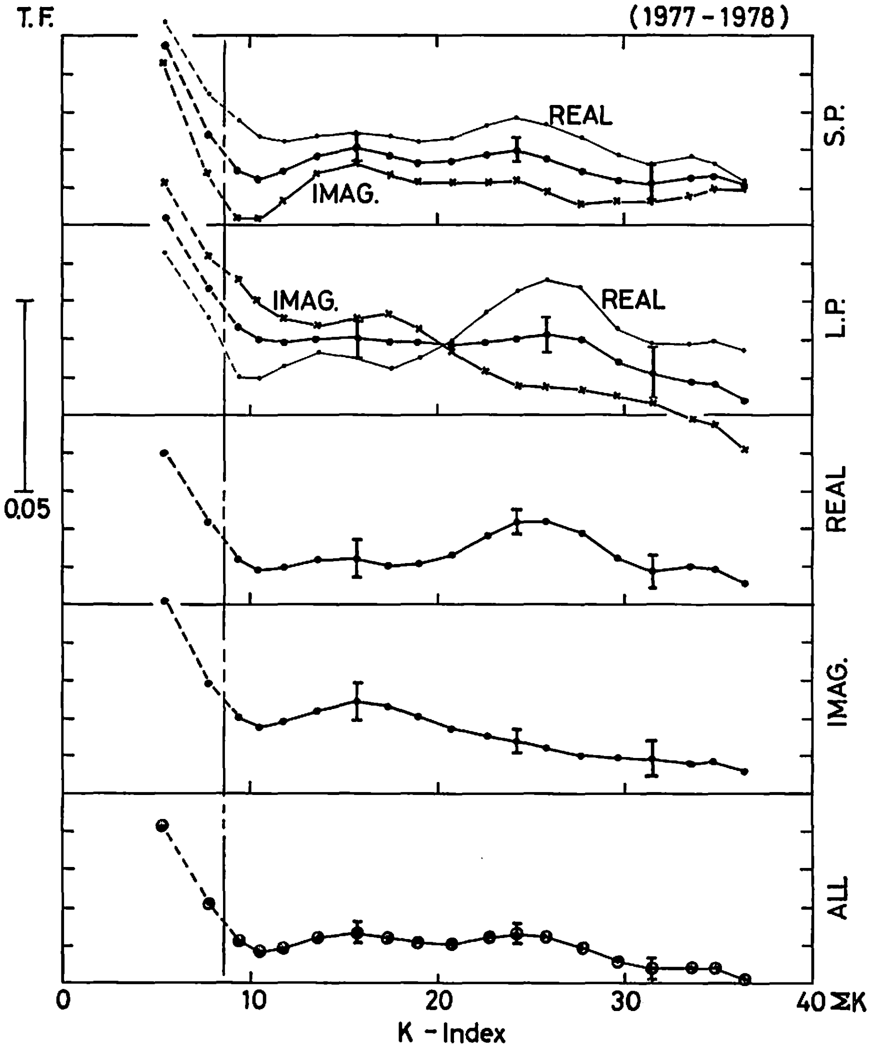

Fig. 15. Geomagnetic activity dependences in the time change of various groups of transfer functions. The error bars indicate the 95% confidence interval.

affected by the geomagnetic activity. In order to make further sure the relation between the *T*-function change and the earthquake occurrences, some corrections due to the geomagnetic activity dependence should be taken into consideration.

These corrections are qualitatively applied to the three deviating plots in the panel (a) for the ALL band. The plots marked by the numerals 1, 2 and 3 are of the 28-day, of the 27-day periodic change and of the earthquake precursor change with a relatively large change of the geomagnetic activity shown in Fig. 9, respectively.

The correlations are like that the plot of the 27-day periodic change is slightly shifted downwards and the others upwards. And these will somewhat approach to the regression line. Thus a better correlation between the changes of T-functions and earthquake occurrence will be attained. In spite of such correction, the 27-day plot seem to be still located above apart from the uppermost regression line, though its departure may be within an error. This may be mainly due to the 27-day periodic change in the L.P. band which is a component of the ALL band.

In the case of the L.P. band, of course, the large departure of the 27-day plot is little corrected by the geomagnetic activity dependence. This fact surely means that the 27-day periodic change in the L.P. band was originated by only the earthquake precursor effect (including a weak geomagnetic activity effect) but also by some unknown origins as already often mentioned.

In this way, the existence of the 27-day periodic change in the T-functions at Kakioka has been confirmed in the L.P. band. The origin cannot be well explained in the present study. However, if it is in the earth's interior, it must be located a deeper layer than at least the earthquake occurrence layer (about 20-80 km under the ground), so that the electrical conductivity change there affects little on short-period geomagnetic disturbances. Nevertheless, it seems that the above inferred origin has some relations to earthquake occurrences in the upper layer. Because the T-function change in the L.P. band and the earthquake occurrences within the large earthquake area such as the Region A show the common predominant periodicity of 27-day, though this coincidence may be by mere chance. The detailed relation or the physical mechanism is quite unknown at present.

What origins are imagined for the 27-day periodic change of T-functions and/or the earthquake occurrences? The period of the lunar revolution around the earth and the 27-day recurrence of the geomagnetic activity are intuitively considered as the 27-day periodicity of some related phenomena. The lunar revolution, one of the origins of the earth-tide, may be somewhat related to the 27-day periodic change of T-functions and earthquake occurrences. But, supposing the earth-tide has some relation to them, the 29.5-day periodic change must be expected to take place more predominantly than the 27-day's. But the fact is quite inversive. Consequently, the lunar revolution or the earth-tide can be hardly regarded as main origins of the 27-day periodic changes. While, the 27-day recurrence of the geomagnetic activity can be also hardly considered as the main origin. Because the 29.5- or 29-day recurrence was more predominant than the 27-day's and the periodic changes of the geomagnetic activity were not well or little correlated with those of T-functions as already frequently mentioned.

In conclusion, most of the present interpretations or speculations are still in question. It is unknown even whether the origin of the periodic change of T-functions is in the earth's interior or in the upper atmosphere such as the ionosphere or the magnetosphere. Their details should be investigated in the future.

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地震発生に関連した変換関数の時間的変化 (III)

—変換関数および他の関連現象の周期的変化—

佐野幸三

概要

柿岡における変換関数の各種の周期的変化を，周辺の地震発生および地磁気活動度のそれらと関連させて，フーリエ解析法および重ね合せ統計法により解析した。今回の解析での主な結果は次のとおりである。

1977年3月より1978年12月までの期間の資料を解析する限り，周期60分より長い周期の変換関数と柿岡周辺の地震発生に，比較的顕著な27日周期変化が見出された。一方，これよりも短周期の変換関数にはあまり顕著な周期的変化はなく，また地磁気活動度は29日周期変化が顕著であった。この長周期変換関数の27日周期変化の振幅は例外的に大きく，また後述の地震発生との相関から期待される変換関数の変化より約2倍大きいことより，これは地震前兆現象的効果以外の何かの原因により変化振幅が増大されているものと考えられる。むろん，地磁気活動度依存効果でも全く説明できない。このように，柿岡の長周期変換関数には現在のところ原因はよくわからないが，地球のかなり深部にソースを持つと考えられる27日周期変化が存在するらしいことがわかった。それらはまた地震発生とにも何らかの関係があるかも知れない。

ところで，今回解析した変換関数および地震発生の26日～30日周期変化の各振幅，さらに前論文 (Part II) で統計的に求められた変換関数の地震前兆現象的変化に対するそれらとを総合して，両者の振幅にはかなりの相関がある（但し，前述の27日周期変化は除く）。地磁気活動度変化の振幅とこれらとにはほとんど相関はない。これらの事実より，前述の27日周期変化を除き，今回求められた変換関数の周期的変化は主に地震前兆現象的変化であると思われる（変換関数の地震前兆現象的変化の再検出および再確認）。