TECTONOMAGNETIC OBSERVATIONS AND EARTHQUAKE PREDICTION RESEARCH BY GEOMAGNETIC APPROACH

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Abstract

In order to research seismomagnetic precursor, we carried out the tectonomagnetic observations. We obtained that there is 2—3 nT of geomagnetic changes before and after the underground nuclear explosion and at the explosion time. The tectonomagnetic observation around the Miyun reservoir shows the relation coefficient between geomagnetic changes and the variations of water level in the Miyun reservoir is −0. 28 nT/m. We measure the geomagnetic total intensity and geodetic distance across the Babaoshan fault for tectonomagnetic investigation. It is a significant experiment to research earthquake prediction. In China, there are about 100 stations and 800 sites to observe seismomagnetic precursor and monitor seismic activity. A lot of seismomagnetic anomalies was observed. According to the relationship between seismomagnetic precursor and earthquake, and the practical experiences of earthquake prediction research by geomagnetic approach, the practical methods have been preliminarily worked out for the application in earthquake prediction research by geomagnetic approach. We experimentally study earthquake prediction by geomagnetic approach in the Beijing and its western area. At present, earthquake prediction by geomagnetic approach is still a very difficult problem; and it is necessary to strengthen the comprehentive observation and research.

I. Introduction

Tectonomagnetism is one of the important subjects in solid earth geomagnetism. The tectonomagnetic investigations have drawn great attention, not only because of its geophysical significance, but also because of the prospects of its potential application in predicting natural hazards, such as earthquakes and volcanic eruptions. Some significant results, therefore, have been obtained (Rikitake and Honkura, 1985;

Johnston, 1987; Zhan, 1989; Sasai and Ishikawa, 1991).

Seismomagnetic precursor is one of important earthquake precursors. Therefore, seismomagnetic investigations have been intensively done in the experimental sites for earthquake prediction research (Shapiro et al., 1978; Rikitake et al., 1980; Abdullabekov, 1989; Johnston, 1989). In China, there has been much investigation of seismomagnetic precursor since Xingtai earthquake ($M=7.2$, 1966, Hebei Province) (Qi, 1978; Zhan, 1988). In the same time, the earthquake prediction research by geomagnetic approach has been conducted and some practical experiences have been obtained. This paper briefly reports our tectonomagnetic observations and earthquake prediction research by geomagnetic approach.

II. Tectonomagnetic observations

1. Geomagnetic effect of the underground nuclear explosion

To investigate the geomagnetic effect of the underground nuclear explosion, we set up 17 geomagnetic sites in the underground nuclear test field in West China (Figure 1). Site 1 is the nearest to the explosion point, about 3.8 km apart. Site 17 is the furthest, about 140 km apart. The distance between adjacent sites of the sites 3 — 12 is 3 — 5 km, and that of the sites 12 — 17 is about 20 km. During September - October, 1983, we observed the total intensity of geomagnetic field at sample rate of once every minute, using model G—816 and G—826 proton precession magnetometers made by Geometrics of USA. In order to search for geomagnetic changes in detail, synchronous observations were made every 10 seconds during the several hours before and after the explosion. The mean standard deviation of the observational data is 0.46 nT (Zhan *et al.*, 1992).

Table 1 shows changes f in the geomagnetic total intensity at various sites before and after the underground nuclear explosion. It is seen that the changes f in mean differences of geomagnetic total intensity increases uniformly from —0.8 nT at site 3 to 1.1 nT at site 17, with some exceptions (sites 8 and 16). Site 2 was chosen as a reference one because there was no distant station at which geomagnetic total intensity was synchronously recorded. Site 2 was only about 30 km from the explosion point, and perhaps was affected by the explosion. On the whole, however, Table 1 shows that the maximum change generated by the explosion is about 1.9 nT and the mean one is about 1.0 nT. Using the least square method, the fitting formula is obtained:

$$f = 0.504 \log_e d - 1.85$$

where f is in nT and d in km, and the fitting residual deviation is 0.30 nT.

Table 1 Changes *f* in geomagnetic differences at various sites before and after the underground nuclear explosion

Site number	1	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
f (nT)	−0. 6	−0. 8	−0. 4	−0. 4	−0. 2	−0. 2	0. 0	−0. 3	−0. 2	0. 2	0. 4	0. 5	0. 4	0. 5	−0. 3	1. 1

Figure 2 shows the changes in the synchronous differences of geomagnetic total intensity with 10 second sample (a) and with 5 min sample (b) at sites 1, 12 and 14 relative to site 2. It is seen that there is a jump anomalous change of about 2 — 3 nT at the time of the underground nuclear exposion.

An underground nuclear explosion is equivalent to an artificial earthquake. Therefore, the experiment is a good simulation of seimomagnetic effect. According to the experimental result, the seismomagnetic precursor can be observed.

2. Tectonomagnetic experiment around the Miyun reservoir

To study the possible tectonomagnetic effect around reservoir, we set up 21 sites near the Miyun reservoir, which is in the northern part in Beijing (Fig. 3). The distance between adjacent sites is 2 — 5 km. The distances between the sites and the reservoir bank are in the range of tens meters and 15 km. Using G—816 and G—826 magnetometers, the total intensity of geomagnetic field was measured once each season during 1983 — 1987. The standard deviation of the survey data is 0. 81 nT (Zhan *et al.*, 1991).

The analytical results show that there is the relationship between the geomagnetic changes *f* and the variations of the water level h and water volume v in the Miyun reservoir during March-July of 1984, June-September of 1985, Augest of 1986-January of 1987, which variations of the water storage during the three periods were greater (Table 2). The mean values of the relation coefficients from Table 2 are obtained: $fh=f/h=-0.28$ nT/m, $fv=f/v=-0.35\times10^{-8}$ nT/m^3. These results show that there is a stronger negative relationship between the geomagnetic changes and the variations of the water storage in the Miyun reservoir.

We collected the rock samples near the geomagnetic sites around the Miyun reservoir. The measurement of the rock magnetism showed that the rock magnetism was stronger. The stronger negative relationship between geomagnetic changes and variations of water storage in the Miyun reservoir, therefore, is probably a reflection of the piezomagnetic effect of the stronger magnetic rock beneath the vicinity of the reservoir. According to the result of tectonomagnetic experiment in the reservoir, it is better to set up some stations and sites, which are located in the place with stronger magnetic rock, for observing the seismomagnetic precursor.

Table 2 Relationship between geomagnetic changes and variations of the water storage in the Miyun reservoir

Time	March—July, 1984	June—Sept., 1985	Aug., 1986—Jan., 1987
f (nT)	−1.3	1.1	0.5
h (m)	3.72	−5.30	−2.59
v ($10^8 m^3$)	3.02	−3.62	−2.43
fh (nT/m)	−0.35	−0.20	−0.28
fv (10^{-8} nT/m^3)	−0.44	−0.30	−0.30

3. Geomagnetic and geodetic measurements across the Babaoshan fault

The Babaoshan fault is an active one in Beijing area. We set up 4 stations for geomagnetic observation and 3 sites for geodetic measurement across the Babaoshan fault (Fig. 4). Analyzing the geomagnetic and geodetic data, there is no obvious relationship between geomagnetic changes and distance variations across the fault because there was no obvious tectonic event near the fault during the period 1987—1989 (Fig. 5). For investigation of tectonomagnetic effect and earthquake prediction study, it is a significant experiment to do the combinative observation of geomagnetic field and geodetic measurement across the fault in the same time. This work, therefore, should be conducted in the future.

III. Earthquake prediction research by geomagnetic approach

1. Seismomagnetic observations and earthquake prediction research in China

In order to observe seismomagnetic precursor and research earthquake prediction, a lot of seismomagnetic observations have been carried out since Xingtai earthquake ($M=7.2$, 1966, Hebei Province). There are about 100 stations and 800 sites for seismomagnetic observations in China. They mainly distribute in North China, Yunnan-Sichuan area and region along the Tian-Lun fault, which are seismoactive areas. During the present 20 years, a lot of seismomagnetic anomalies was observed.

Table 3 Main seismomagnetic information of the Tangshan earthquake ($M=7.8$, 1976)

Parameter	T	d (km)	Anomaly range or feature
Z	about 1 year	5	12 nT
		70	10 nT
F	about 1 year	35	8 nT
Z	July 5—26, 1976	100	10 nT (Difference in range of daily variations)
Z/H, A			Short-period seismomagnetic information
Wiese vector	about 6 months	70	
Smj, Bsn	about 1 year	100	Statistical information of seismomagnetic effect

Table 3 (Continued)

Parameter	*T*	*d* (km)	Anomaly range or feature
Tmin	July 4, 1976	100—300	Special phenomenon of daily variation in Z component as "Low-point displacement"

A severe earthquake ($M=7.8$) occurred in Tangshan city, Hebei Province, on July 28, 1976. Table 3 shows the main seismomagnetic information of the Tangshan earthquake (Zhan, 1990), where T is precursor time, d is epicenter distance. It is seen in Table 3 that the seismomagnetic changes occurred before the Tangshan earthquake in the total intensity and vertical component of geomagnetic field, in long-term, short-term and short-period variations of geomagnetic field in the vicinity of the Tangshan earthquake. It suggests that there probably exists more seismomagnetic information for a severe earthquake.

Table 4 Main results of seismomagnetic phenomena observed in China

Time	Place	Magnitude	Geomagnetic component	Epicentral distance(km)	Precursor time(day)	Anomalous range(nT)
1967—1969	Xingtai, Hebei	4.6—6.1	Z, D	<50	80	5—10
July, 1973	Ganzhi, Sichuan	7.9	H	80	365	24
June, 1974	Xingtai, Hebei	5.0	Z	15	60	5
July, 1974	Xingtai, Hebei	4.3	Z	15	30	4
Feb., 1975	Haicheng, Liaoning	7.3	Z	246	450	20
			F	<100	730	20
July, 1976	Tangshan, Hebei	7.8	Z	5	365	12
			Z	70	730	10
			F	35	365	8
July, 1979	Liyang, Jiangsu	6.0	Z	18	20	16
			Z	60	60	12
Aug., 1981	Fengzhen, Neimeng	5.8	F	78	150	9
Nov. 1981	Longyao, Hebei	5.8	Z	20	480	6
			F	20	480	7
July, 1982	Jianchuang, Yunnan	5.4	F	<30	360	9
Nov., 1983	Heze, Shandong	5.9	F	160	360	9
			Z	12	180	7
Dec., 1982	Madaoyu, Beijing	4.9	F	30—50	60	2—3
May, 1984	Huanghai, Jiangsu	6.2	Z	110	60	9
Nov., 1985	Renxian, Hebei	5.3	F	25	360	6
Feb., 1987	Sheyang, Jiangsu	5.1	Z	80	10	9
Aug., 1987	Chenwu, Jiangxi	5.6	F	10	730	13

Table 4 (Continued)

Time	Place	Magnitude	Geomagnetic component	Epicentral distance(km)	Precursor time(day)	Anomalous range(nT)
Nov., 1988	Lanchang—Gengma Yunnan	7.6	H	210	60	50
			Z	240	60	100
			D	270	60	100—200
Apr., 1989	Shimian, Sichuan	5.3	F	100	480	7
Apr., 1989	Batang, Sichuan	6.7	F	350	480	9
Oct., 1989	Datong—Yanggao Shanxi	6.1	F	45	180	12
Sep., 1989	Xiaojin, Sichuan	6.6	F	120	480	8
May, 1990	Xiaotangshan, Beijing	3.7	F	2	7	3

Table 4 shows the main results of seismomagnetic phenomena observed in China. It is seen that the range of the earthquake magnitude is 3.7 — 7.9. The distances between the geomagnetic stations or sites and the epicenters are in the range of 2 — 350 km, and the most ones are within 100 km. The seismomagnetic effects are in the range of a few nT to 200 nT and the most ones are within 20 nT, and can be observed in various components of geomagnetic field. The range of the seismomagnetic precursor time is a few days to a few years. Using the data in Table 4, the relationship between geomagnetic precursor and earthquake is preliminarily obtained:

$$f = 3.22M - 9.59, \ \lg T = 0.24M + 0.72 \text{ and } \lg d = 0.25M + 0.15$$

where f is in nT, T in day and d in km. The statistical test result shows that the relationships are significant at the significant level 0.05. It shows that geomagnetic approach is a hopeful tool for medium-term and short-term earthquake prediction research.

The research results show that the seismomagnetic precursor changes can be divided into long-term one and short-term one. Seismomagnetic anomalies have some regularity in the space distribution. According to the time-space distribution character of seismomagnetic anomalies and its relationship with earthquake, and the practical experiences of earthquake prediction research by geomagnetic approach, we preliminarily worked out the test methods for the application in earthquake prediction by geomagnetism. The main methods for extracting the information of seismomagnetic precursor are: the difference method, the correlation method, the statistical method, the method of the tranfer fuction and so on. The test methods are helpful for routine monitoring the seismic activity.

2. Investigation of seismomagnetic precursor in the Beijing and its western area

In order to investigate the seismomagnetic precursor as an earthquake prediction tool, we set up a dense geomagnetic survey network in the Beijing and its western area (Fig. 6). Altogether there are 16 temporary stations and about 150 sites. We observe the total intensity of geomagnetic field once every season with proton precession magnetometers. At the stations, the G—826 magnetometers are recording at 2 min sample rate for about a week during each survey period . At the sites, the G—816 magnetometers are used for geomagnetic survey. The mean standard deviation of the survey data is 1. 2 nT.

In order to search for the information of seismomagnetic precursor, we analyze the time-space changes of geomagnetic total intensity and the amplitude ratio of the FFT (the Fast Fourior Transfer) for the same period at various stations relative to the Beijing station (BJ) during the same time period of each survey (Zhan *et al.*, 1990a and 1990b). According to the analytical results of the geomagnetic data and the practical experiences in the earthquake prediction research, we attend the workshop about the earthquake prediction research.

Figure 7 shows that the mean changes of geomagnetic total intensity in the various profiles relative to the station BJ in the Beijing array (a) and relative to the station YC in the western Beijing array (b). It is seen in Fig. 7 that there are greater changes in the following profiles: E1: 2. 7 nT; W2: 2. 6 nT; W5: 2. 4 nT; H1: 3. 0 nT; H2: 3. 3 nT; H3: 2. 8 nT. Figure 8 shows that the space distribution (a) and the changes with time (b) of FFT amplitude ratio of geomagnetic total intensity at various stations relative to the station BJ for the period $T=17.1^h, 8.5^h$ and 5.7^h. It is seen that the changes at 3 stations in the western Beijing area are remarkable. According to the piezomagnetic theory and the seismomagnetic induction effect (Qi *et al.*, 1981), the changes are worth to notice for earthquake prediction research in the future.

IV. Conclusion and discussion

Sum up all the above, a severe earthquake may be accompanied by quite plenty of seismomagnetic information. According to the results of the tectonomagnetic experiments, the information of seismomagnetic precursor can be observed. The geomagnetic approach has a good perspective of its application in medium-term and short-term earthquake prediction research.

The results of the field observations and the data analysis show that seismomagnetic precursor is complicated, and its relationship with earthquake is still uncertain. Besides the earthquake happened when the seismomagnetic precursor occurred, there was no correspending earthquake when the geomagnetic anomaly was observed; an earthquake happened, but there was no correspending seismomagnetic precursor. Although there are some successful cases and practical experiences in earthquake prediction research by geomagnetic approach, we could not predict most of the earthquake and we suffered failure. At present, the earthquake prediction by geomagnetic approach is still a very difficult scientific problem,and is still in the trial and test state with accumulation of practical experiences. To improve the earthquake prediction research by geomagnetic approach, it is neccessary to set up the dense geomagnetic network in the seismoactive area and to use magnetometer with high accuracy and good stability. We should strengthen comprehensive study on seismomagnetic precursor: analysis of extracting seismomagnetic information, experimental and theoretical research of the physical mechanism of seismomagnetic precursor, and the combination of seismomagnetic precursor research and the practical test of earthquake prediction by geomagnetic approach. For comprehensive earthquake prediction research, it is better to set up the combination observations of seismomagnetic precursor with others, such as seismology, deformation, geodetics, groundwater, resistivity, gravity, stress and so on.

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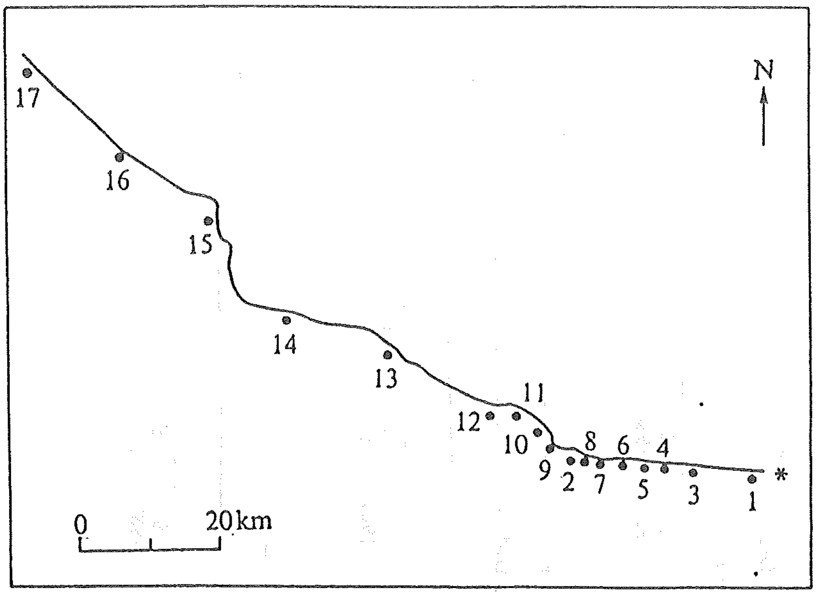


Fig. 1 Locations of the point of the underground nuclear explosion and geomagnetic sites.

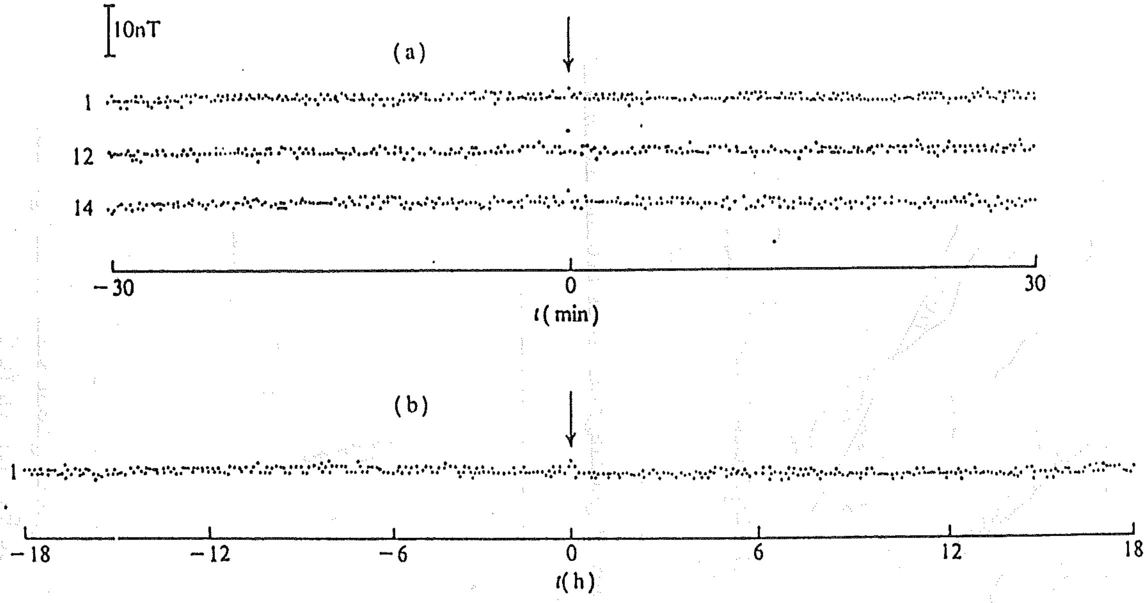


Fig. 2 Changes in synchronous differences of geomagnetic total intensity for a 10 second sample (a) and a 5 minute sample (b) at various sites before and after the underground nuclear explosion.

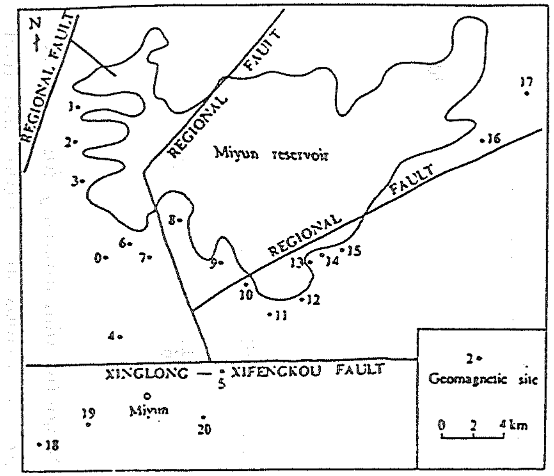


Fig. 3 Locations of geomagnetic sites around the Miyun reservoir.

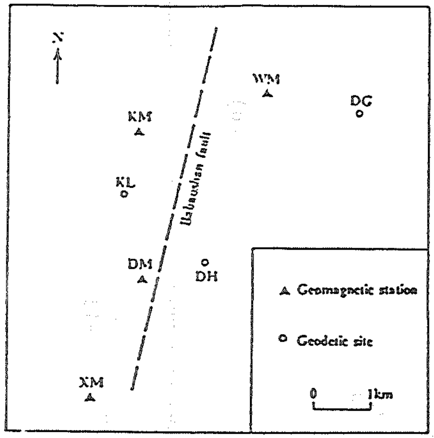


Fig. 4 Locations of geomagnetic stations and geodetic sites across the Babaoshan fault.

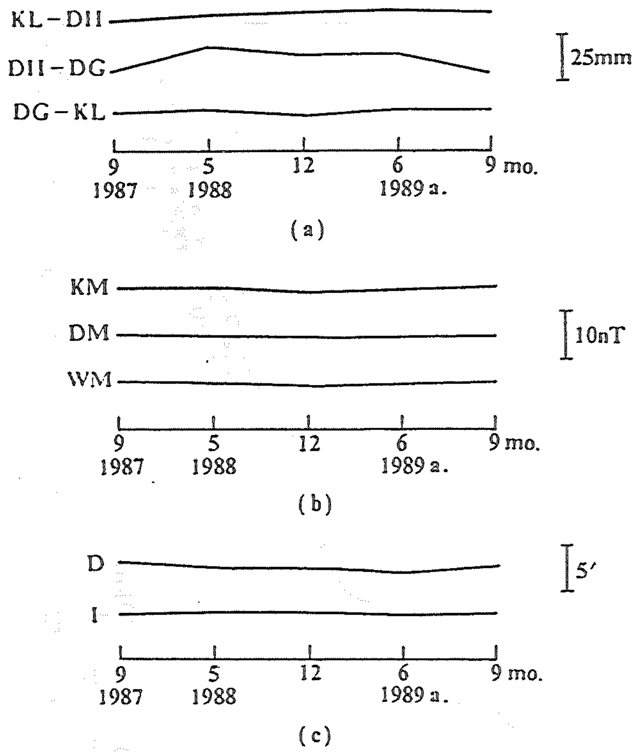
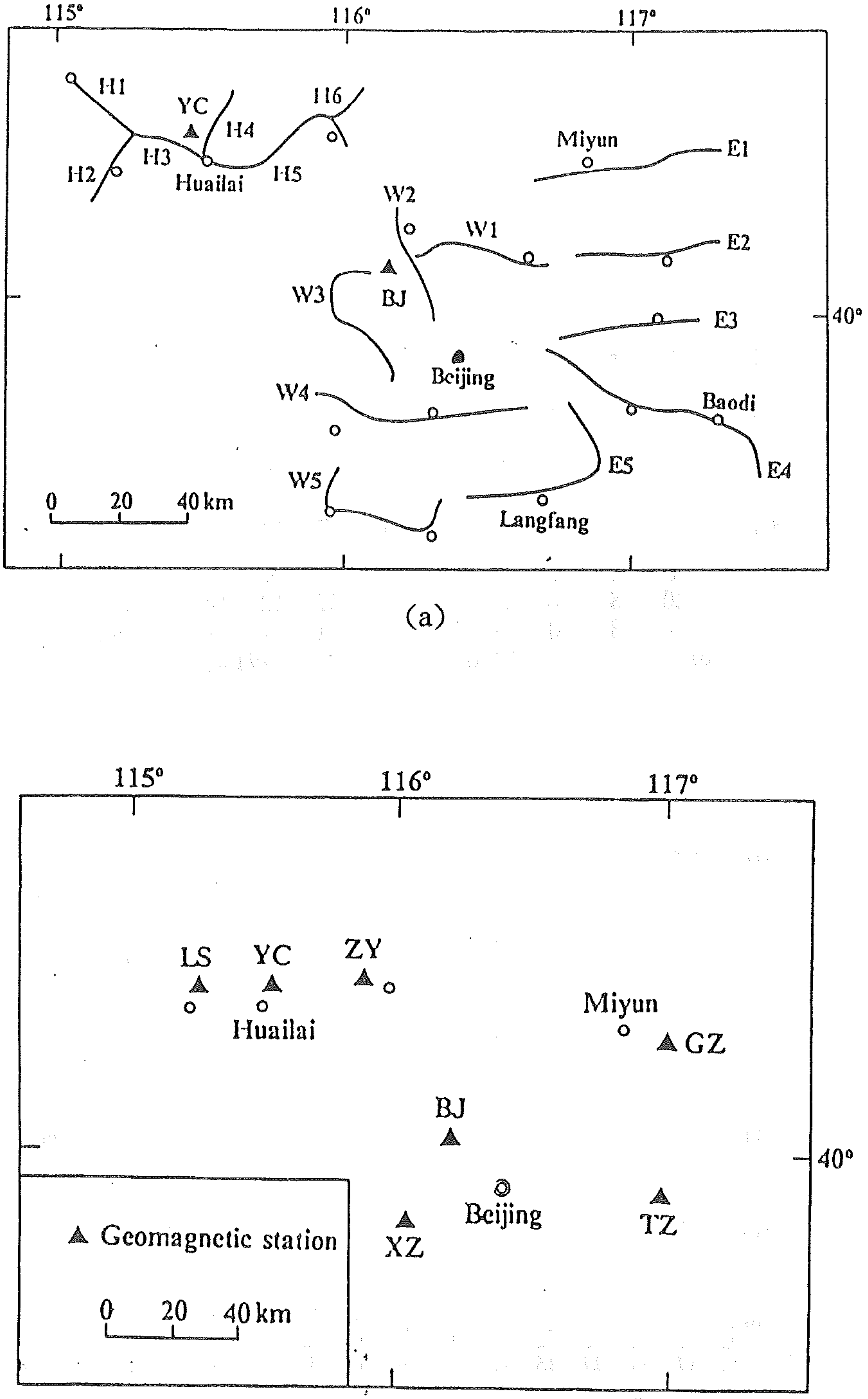


Fig. 5 Comparison of geomagnetic and geodetic data during 1987-1989. (a) Geodetic data; (b) Geomagnetic total intensity; (c) Geomagnetic declination D and inclination I.



(a)

(b)

Fig. 6 Distribution of the geomagnetic profiles (a) and locations of geomagnetic stations (b) in the Beijing and its western area.

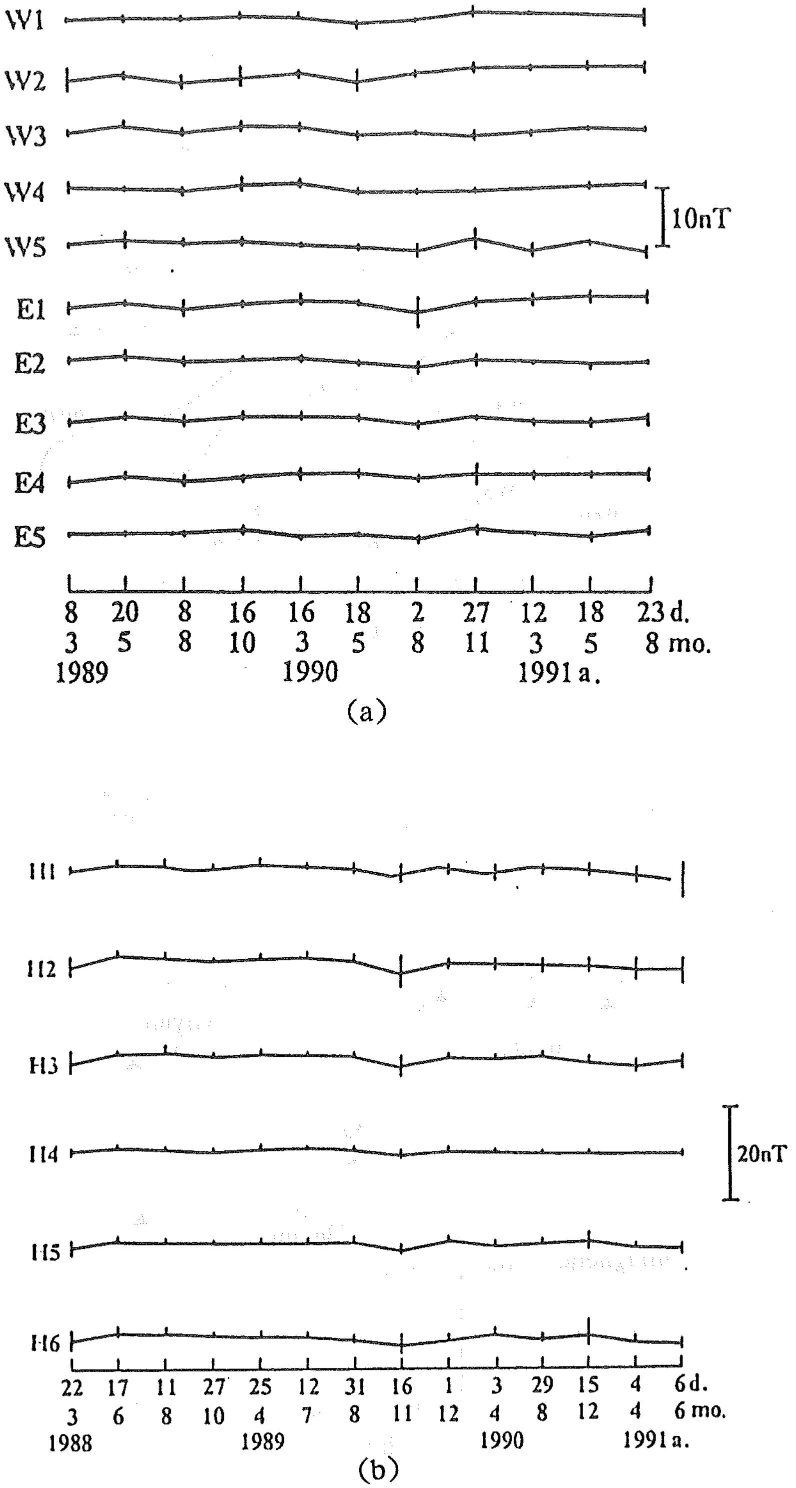
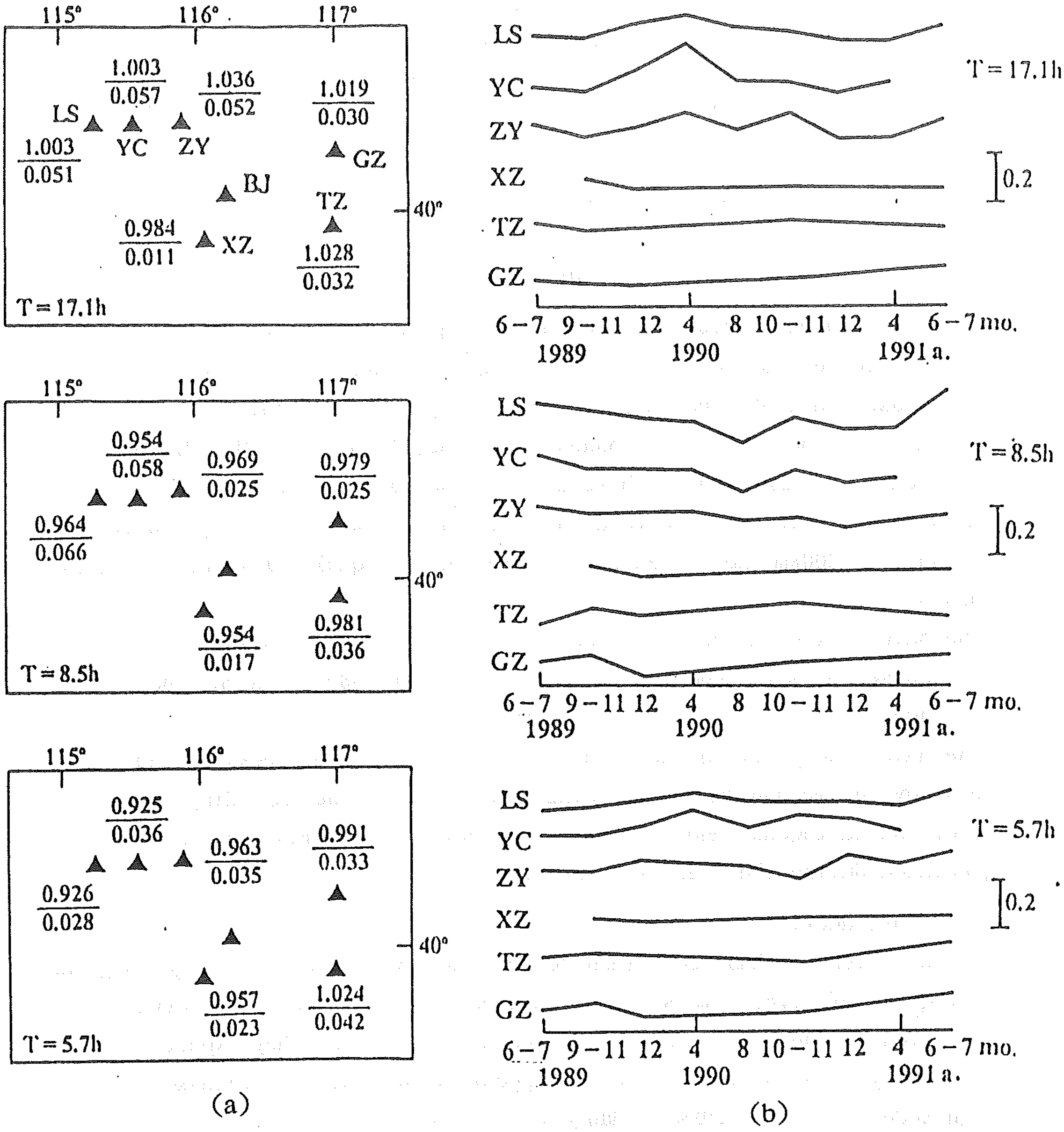


Fig. 7 Mean changes of geomagnetic total intensity in the various profiles in the Beijing array (a) and its western array (b).



(a)

(b)

Fig. 8 Space distribution (a) and the changes with time (b) of FFT amplitude ratio of geomagnetic total intensity at various stations relative to the station BJ for the period $T=17.1^{h}$, 8.5^{h} and 5.7^{h}. In Fig. 8 (a), the values above and under the line denote the FFT amplitude ratio and their standard deviations respectively.