EMSEV 2012
Gotemba Kogen Resort, Gotemba, Japan
October 1–4, 2012
Abstract 1-03

The electromagnetic anomaly before earthquake observed by CSELF method

Zhao Guoze[1)], Tang Ji[1)], Zhan Yan[1)], Chen Xiaobin[1)], Wang Lifeng[1)], Xiao Qibin[1)], Wang Jijun[1)], Cai Juntao[1)]

1) *Institute of Geology, China Earthquake Administration, Beijing 100029, CHINA*

Introduction

Ever since the Xingtai earthquake Mw=7.2 in Hebei province in 1966 electromagnetic methods have been used in earthquake monitoring in China. However most of data come from observation using traditional electric and magnetic methods which only measure electrical or magnetic fields (Qian et al, 2009). These data are either only in frequency band of less 1Hz while they are used in monitoring the natural electromagnetic fields or only reflect the shallow resistivity by DC method which has not insight in deep crustal structure around the hypocenters. The culture noise becomes more and more strong and disturbance is increased on the observed electromagnetic data.

The artificial SLF (Super Low Frequency, 300-30Hz) electromagnetic signals transmitted by powered transmitter as a new method is proposed to apply in monitoring the electromagnetic anomaly (Saraev, et al, 1998). The experiments in Beijing capital area and active seismic regions in Sichuan and Yunnan provinces have been carried out. The electromagnetic anomalies were observed before the earthquakes occurred near the observation sites.

CSELF method

Control Source Extremely Low Frequency (CSELF) is an artificial powered electromagnetic method. The transmitter consists of antenna cable(s) and signal generator. The cable with several dozens km long is laid on the earth surface where the higher resistivity exists from earth surface down to a depth corresponding to the skin depth for signal frequency and is connected with earth through large sized electrodes at both ends of the cable where the low resistivity exists. The sinuate electrical current with the bigger amplitude than 100A is transmitted into cable by signal generator. The alternate current in the circuit induces the alternate electromagnetic field. The electromagnetic field distributes in the space and propagates in the conductance between earth surface and ionosphere. The frequency band of electromagnetic wave generated by transmitter is from 300Hz to 0.1Hz, which includes SLF (300-30Hz), ELF (30-3Hz) and part of ULF (<3Hz) and called as CSELF method simply. The algorithms for calculating electromagnetic waves generated by transmitter in near field, far field and conductance region (Yang, 2011), and the data processing method used in analysis of the observed CSELF data (Wang, 2008) are studied.

The 1st experiment for monitoring EM anomaly

The first experiment was done in 1999 at 5 sites in Beijing capital area to measure the signal generated by transmitter in Kola Peninsula in Russian with about 6500 km distant between observatories and the transmitter in Kola. The frequency of signal used in experiment was 80 Hz. One electric component and one magnetic component with perpendicular to each other were measured at each site. The culture noise level was quite different for different sites among 5 sites but all spectra of SLF signal at different sites are 20-30 time's spectra of natural signal.

The continuous measurement was done at one of sites, Baodi station, for 10 days to monitor the change of the electromagnetic field and resistivity. The electric component was in direction of N10ºW and magnetic component in N80ºE. The space between the both electrodes was 100 m. The time series recorded at Baodi station show that amplitude of the artificial signal is bigger than amplitude of the natural signal either for electric or for magnetic field.

During the continuous observation for 10 days (May 4 - 14) the data were measured in same time space for every day. It is found that the spectra of natural signals changed for some extent but those of SLF signals were rather stable indicating that the spectrum change of SLF signals is almost no relative to natural signal (Zhao et al, 2003).

The fluctuation of electric and magnetic spectra and apparent resistivity and phase during 10 days were characteristic for two time sections (Fig.1). For the first time section from May 4 to 9 the spectra are relatively stable with maximum fluctuation amounted to about 20% generally. The apparent resistivity kept for about 25Ωm. The electric and magnetic spectra and apparent resistivity changed much for the second time section from May 10 to 14. The variation amplitude of electric and magnetic spectra gradually increased from May 10 to 12 and reached about two time's average variation on May 12. The apparent resistivity increased by about 10%. All they decreased from May 13 to 14. In chance, Qianan earthquake (Mw=4.2) happened at 8:55 of May 12 with distance of about 120 km to Baodi station in the NEE direction. The focus was at a depth of about 33km (Fig.1). It is postulated that anomalous variations of electric and magnetic spectra and apparent resistivity for second time section are relative to the Qianan earthquake due to no other factors can be found for interpretation of these anomalies.

The 2nd experiment for monitoring EM anomaly

The second experiment was carried out from September 15-29 2005 in active seismic area in Yunnan province (at stations Qiaojia and Dongchuan) and in Beijing capital area (at stations Shisanling and

Huailai) using the industrial power line (31km long, along NW direction and in central China continent) as a transmitter antenna. The distance between the transmitter and both measurement areas are about 1100km respectively. The data are recorded in early morning and later afternoon for every day with lasting for about 2 hours for every recording.

An earthquake with magnitude Mw=3.6 occurred at 9:52:22 in September 21, 2005 in Taoyuan in Yunnan province. The epicenter is about 70 km distant to Qiaojia station and about 130 km to Dongchuan station. The magnetic spectra for frequencies 170Hz, 126Hz and 85Hz are shown in Fig.2 for stations Dongchuan and Shisanling respectively. It indicates that the magnetic spectra in September 20 and 21 are bigger by one order than other days either for morning measurement or for afternoon measurement. We considered that the anomalous increase in September 20 and 21 may be relative to the Taoyuan earthquake.

However the measurements at stations in Shisanling and Huailai in Beijing capital area indicated that there was no anomalous variation either for magnetic or for electric field during the same time periods of September 20 and 21 (Fig.2). This may be interpreted by too long distance (about 2000km) between epicenters and these observatories. It is also shown that the PSD variation for CSELF signal were much smooth than that for natural source from day to day.

The 3rd experiment using CSELF signal

The third experiment was done from July to August in 2009 using the industrial power lines (60km long, NS direction, in central China continent) as transmitter antenna. The recorded devises were laid at 12 earthquake monitoring stations distributed in different provinces. The observed data at stations from July 21 to August 20 in 2009 show that both magnetic and electric PSD obtained by CSELF signal varied about 10% or less during one month for recorded data. But the PSD obtained at same station by using natural source varied about one order or bigger. It is clear that the PSD for CSELF signal is much stable during one month than that for natural source, which is prone to monitoring the electromagnetic anomaly by use of CSELF data. The characterized decrease of the PSD with increased distance of the different stations is also found.

Electromagnetic Observatory Network

In order to develop CSELF method and apply it in the earthquake monitoring. New electromagnetic devices will be installed in 30 stations and it will reach 42 devices totally. The special transmitter will be also constructed using industrial power lines in central China continent. The frequency band of electromagnetic wave transmitted is from 300-0.1Hz. The maximum current generated by transmitter will be about 200A. The industrial power lines include NS cable of about 60km and EW cable of about 80km.

Discussion

The CSELF method not only can be used in the monitoring electromagnetic anomaly but also in the prospecting of the crustal structure (Zhuo, et al 2004). The advantages of it lies in that the signal can cover large distance like MT signals and the data with high S/N ratio can be obtained. The cost can be also reduced when it is used in resources prospecting due to only one signal source is used in a large area. Regarding to the effect of its use in the monitoring the earthquake electromagnetic anomaly it needs to do more observation.

Acknowledgment

The study is supported by the NSFC (41074047), Special Project (20080801) and NDRC. The collaborative measurements in 1999 were made with Prof. Saraev A K et al of St. Petersburg State University, Russia.

References

[1.] Qian Fuye, Zhao Biru, Qian Wei, et al, HRT wave precursor before Wenchuan Ms 8.0 earthquake and HRT wave predicting methods. Science in China(D) (in Chinese): 39(1):11-23,2009.

[2.] Saraev A， Kostkin P M， Ivochkin V, Polarization characteristics of the electromagnetic field from a VLF radio-wave transmitter, Izvestiya. Physics of the Solid Earth, 34(7):570-575, 1998.

[3.] Wang Xiao, Extraction of Artificial-source SLF/ELF Electromagnetic Signal and Data Processing. Master thesis, Institute of Geology, CEA, 2008

[4.] Yang Jing, Propagation characteristics of CSELF electromagnetic waves. Master thesis, Institute of Geology, CEA, 2011.

[5.] Zhao Guoze,Tang Ji, Deng Oianhui, et al,Artificial SLF method and the experimental study for earthquake monitoring in Beijing area.Earth Science Frontiers, (in Chinese), 10(Suppl): 248-257, 2003.

[6.] Zhuo Xianjun, Zhao Guoze, A new electromagnetic method for resource prospectimg. Oil Geophysical Prospecting, 39(suppl.):114-117, 2004

Figures and captions

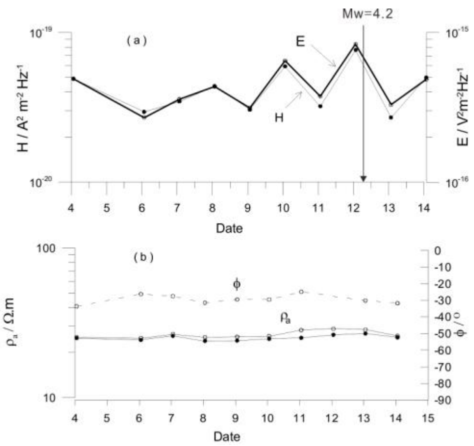

Fig.1 Powered spectrum density (PSD) of artificial electric (E, in top figure) and magnetic (H, in top figure) and apparent resistivity (ρ_a, Ωm, in bottom figure) and phase (φ, degree, in bottom figure) for 80Hz observed at Baodi station from May 4 to 14 1999. The left and right axis in top show the spectrum for magnetic and electric field respectively. The left and right axis in bottom show the resistivity (Ωm) and impedance phase (degree) respectively. The two lines for apparent resistivities show the minimum and maximum values of the resistivity.

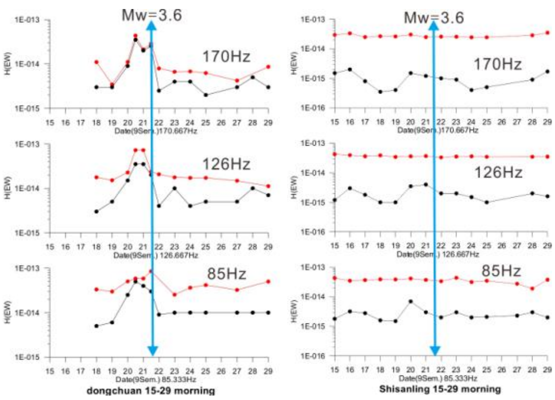

Fig.2 The PSD (unit: $(A/m)^2/Hz)$) of magnetic field for 170Hz, 126Hz and 85Hz are measured at station Dongchuan in Yunnan Province (left) and at station Shisanling in Beijing capital area (right). The recorded time in Beijing capital area is 3 days earlier than that in Yunnan province. An earthquake Mw=3.6 occurred at 9:55 in September 21. The red lines show the data using CSELF signal. The black lines show the data obtained using natural source.