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# TEMPORAL EVOLUTION OF THE SHEAR-WAVE SPLITTING AND THE GEO-ELECTRICAL ANISOTROPY IN TIANZHU—GULANG EARTHQUAKE

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**Abstract**: Adopting the same method used in the study on Yongdeng earthquake[1], the temporal evolution characteristics of shear-wave splitting and the geo-electrical anisotropy of crust media during the preparation and occurrence of Tianzhu—Gulang $M_S$5.4 earthquake on June first, 1996 are studied. The results show that before the earthquake both the geo-electrical axis of $\rho_{xy}$ and the polarization of fast S-wave rotated from northwest to northeast until occurrence of the earthquake, its source mechanism solution indicats that the P axis direction is in N 50°E. So the three directions are generally the same. On the other hand, the geo—electrical station is coincidently on the seismogenic fault, the variations of apparent resistivity of various frequencies are all evident while the variation of $\rho_{xy}$ component is greater than $\rho_{xy}$ component contrary to that of Yongdeng earthquake. But due to scarce of collected seismic data the accumulation process of stress is not demonstrated by the time delay between the two split S waves. The other reason for the analyzed result of time delay maybe is the influence of stress adjustment after Yongdeng earthquake on the stress preparation of Tianzhu—Gulang earthquake (the distance between two events is about 120 km).

**Key words**: **Shear-wave splitting; Geo-electrical anisotropy; Earthquake**

## 0 Introduction

In the previous paper [1] we have studied the characteristics of anisotropy evolution of seismic wave and geo-electrical precursors during the preparation of Yongdeng $M_S$5.8 earthquake on July 22, 1995, using S wave splitting method and magnetic telluric approach together. The result shows, in general, that the directional variation of fast S-wave polarization was in agreement with the principal axis( $\rho_{xy}$ )of geo-electricity during the earthquake preparation. Moreover, they were identical to the directional evolution of the maximum stress field during Yongdeng earthquake. Before Yongdeng earthquake the direction of maximum stress was in northeast and gradually changed to northwest with stress accumulation (P axis was in N15°W).

As a new discovery, it is necessary to study various earthquake cases to confirm the consistent variations of the two different anisotropy precursors, their relations with stress evolution and the reliability of the adopted research method. Fortunately, in the small area another earthquake with enough magnitude, Tianzhu—Gulang $M_S$5.4 event occurred on June 1, 1996, and the P axis was in N50°E[2] contrary to that of Yongdeng earthquake. So it is significant to study this event and compare it with the result of Yongdeng earthquake. On the other hand, as we known, the two earthquakes mentioned above are the only two cases that during its preparation there are distributed small magnitude earthquakes, seismography stations satisfying the observation condition of split S wave and continuous observation stations of geo-electrical magnetic field at the same time.

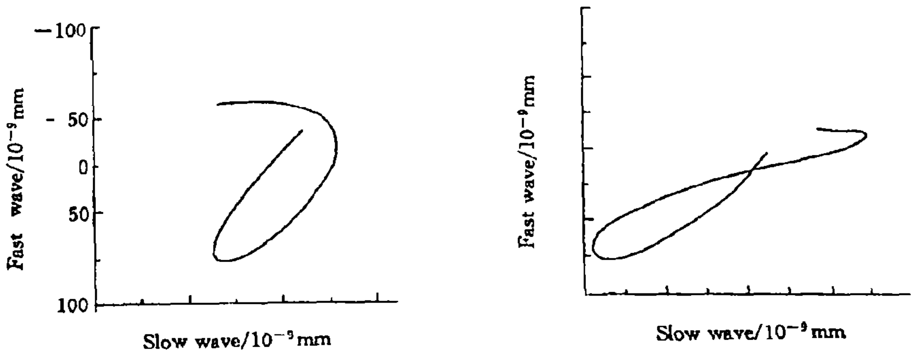
## 1 The characteristics of split S waves of Tianzhu—Gulang earthquake

The epicenter of Tianzhu—Gulang earthquake is located at 37°18′N, 102°45′E. In the research we collect eight small seismic events since November of 1995 satisfying the window condition of S wave splitting. All of the three components records are from Langsuo seismography station in Sino—France cooperation program. The epicenter distance of the earthquake is about 98 km. The catalogue of the eight small seismic events and their parameters are listed in table 1. The parameters are estimated by assuming the focal depth is 5 km, because there is no focal depth information in formal earthquake catalogue. In present paper the rotated correlation approach[3] and the maximum eigenvalue method[4] are used together to estimate the parameters of split S waves.

**Table 1 Parameters of small seismic events from Langsuo station before Tianzhu—Gulang earthquake**

| Event | Time | Epicenter | | Magnitude | Distance | Incident of | Travel time of | Travel time of |
|---|---|---|---|---|---|---|---|---|
| | | Lat(N) | Long(E) | / $M_L$ | /km | S wave/° | P wave/s | S wave/s |
| A4 | 1995-11-07 16:03 | 37°18′ | 103°06′ | 2.7 | 61.29 | 40.48 | 10.57 | 18.18 |
| B5 | 1996-04-03 07:40 | 37°34′ | 102°43′ | 3.1 | 111.69 | 40.57 | 19.18 | 32.98 |
| C6 | 1996-04-17 02:52 | 37°37′ | 102°45′ | 1.1 | 111.49 | 40.58 | 19.15 | 32.92 |
| D7 | 1996-05-11 06:05 | 37°37′ | 102°45′ | 1.4 | 111.49 | 40.58 | 19.15 | 32.92 |
| E9 | 1996-06-01 21:29 | 37°16′ | 102°46′ | 3.3 | 95.35 | 40.56 | 16.38 | 28.17 |
| F10 | 1996-06-01 21:54 | 37°16′ | 102°45′ | 1.9 | 97.51 | 40.57 | 16.89 | 29.05 |
| G11 | 1996-06-01 22:03 | 37°14′ | 102°40′ | 2.2 | 105.47 | 40.57 | 18.24 | 31.36 |
| H12 | 1991-06-01 22:32 | 37°18′ | 102°45′ | 2.9 | 98.20 | 40.57 | 17.03 | 29.27 |

The resultant velocity trace of fast and slow S waves of event B5 is plotted in figure 1: figure 1(a) is the trace in fast and slow polarization coordinates; figure 1(b) is the trace after the time delay being corrected. The calculated split parameters are listed in table 2.




(a) Polarization coordinates (b) Time delay corrected

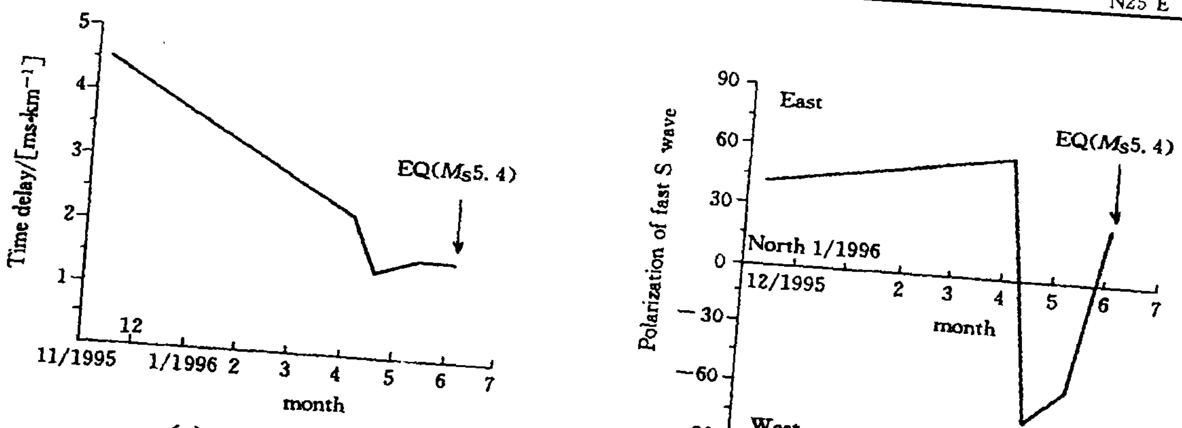
Fig. 1 Calculated velocity trace of split S waves of event B5.

To clearly demonstrate the evolution of split S wave with development of the earthquake, Figure 2 gives the temporal variation of the time delay and polarization of fast S wave.

The time delay did not increase before the earthquake as shown in figure 2(a). According to table 2, the time delay of most events but the first one are small and increase little after the main shock. There are maybe two reasons: the first, the number of collected small events is too little and time is too short; the second, the earthquake is influenced by the stress adjustment of the preceding Yongdeng earthquake. The polarization of fast S wave varied from northeast to northwest, but just before the occurrence of main shock it had returned to northeast again (Fig. 2(b)). In contrary, the polarization of fast S wave was in northwest before and during Yongdeng earthquake and turned to northeast after main shock. In both cases the polarizations of fast S wave are in agreement with the corresponding directions of P axis of focal mechanism solution. The P axis of Yongdeng earthquake is in N15°W, while the P axis of Tianzhu—Gulang earthquake is in N50°E. It is obviously that in present paper the temporal evolution of stress field is not so clear, because the time between Tianzhu—Gulang earthquake and Yongdeng earthquake is less than one year and few seismic data were collected.

**Table 2 Calculated parameters of split S waves for 8 seismic events**

| Event | Time | distance /km | Time delay /s | Time delay/distance /[ms · km$^{-1}$] | Polarization of fast S wave |
|---|---|---|---|---|---|
| A4 | 1995-11-07 16:03 | 61.29 | 0.275 | 4.49 | N41°E |
| B5 | 1996-04-03 07:40 | 111.69 | 0.25 | 2.24 | N60°E |
| C6 | 1996-04-17 02:52 | 111.49 | 0.15 | 1.35 | N72°W |
| D7 | 1996-05- 11 06:05 | 111.49 | 0.175 | 1.57 | N55°W |
| E9 | 1996-06-01 21:29 | 95.35 | 0.15 | 1.57 | N32°E |
| F10 | 1996-06-01 21:541 | 97.51 | 0.05 | 0.51 | N8°E |
| G11 | 1996-06-01 22:03 | 105.47 | 0.325 | 3.08 | N63°E |
| H12 | 1996-06-01 22:32 | 98.20 | 0.20 | 2.04 | N25°E |



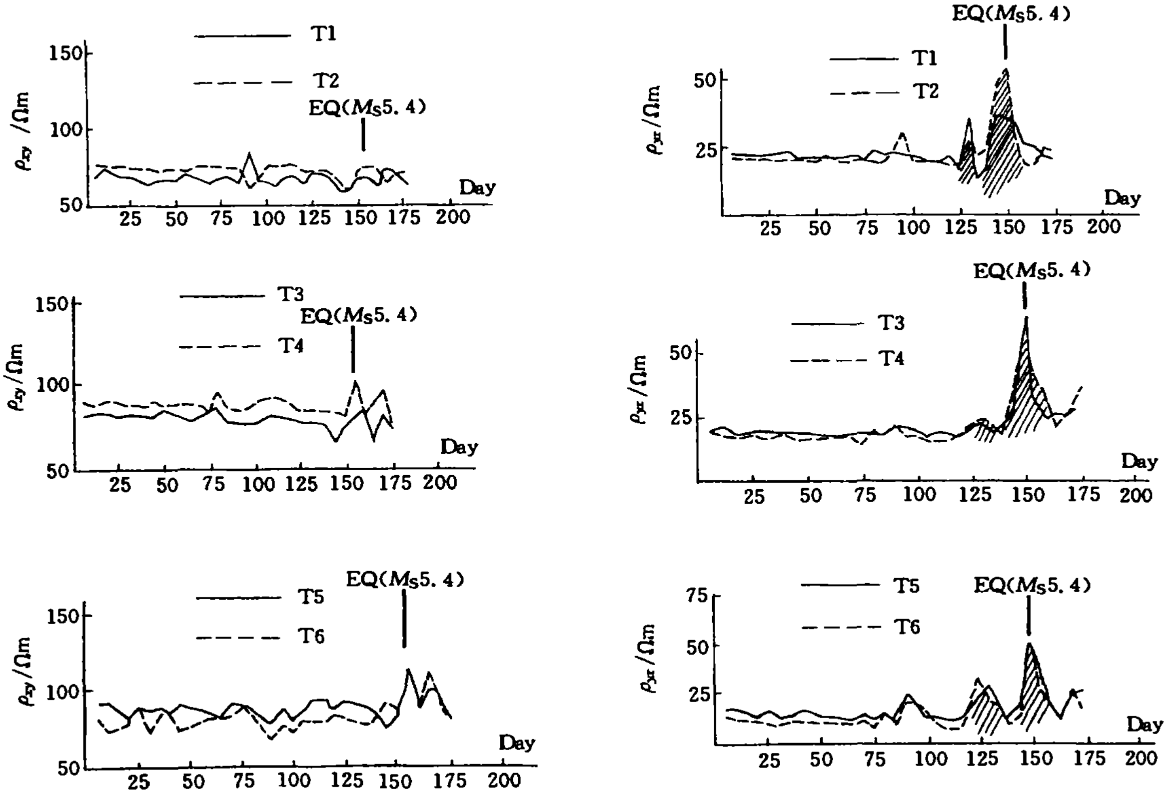

(a) Temporal evolution

(b) Polarization

Fig. 2 Temporal evolution of S wave splitting of Tianzhu—Gulang earthquake.

## 2 The MT calculated results of Tianzhu—Gulang earthquake

Because the focus of Tianzhu—Gulang earthquake and songshan geo-electrical magnetic station are ocated on the same fault and the distance between the focus and the station is only 71 km, therefore the nomalous variations of observed telluric field and apparent resistivity are strongly controlled by the rike of seismogenic fault. Figure 3 shows the variation of apparent resistivity of various frequencies be-re and after the earthquake [5]. It is easy to see that the anomalous variation of apparent resistivity of . is much more evident than that of $\rho_{xy}$, in all of frequency which is contrary to Yongdeng earthquake d reflects the control effect of geological structure on the intensity and the anisotropic characteristics precursors.




(a) $\rho_{xy}$　　　(b) $\rho_{xy}$

$T_1=160$ s, $T_2=226$ s, $T_3=320$ s, $T_4=453$ s, $T_5=640$ s, $T_6=905$ s

Fig. 3　Temporal variation of apparent resistivity in various periods of Tianzhu—Gulang earthquake process.

The directional variations of principal axis ( $\rho_{xy}$ ) with frequency in several periods are given in figure 4. The start time of calculation is from January 1, 1996.

Before the earthquake the principal axis of $\rho_{xy}$ varied from northeast to northwest, then turned to northeast again until earthquake occurred, after the earthquake its direction was recovered but still in northeast. Such directional variations are almost the same for different frequencies in Yongdeng earthquake process. For demonstrating the temporal evolution of geo-electrical principal axis, directional variation of $\rho_{xy}$ at period 200 s is given in figure 5,including Yongdeng earthquake as well.

It shows that the principal axis of geo-electricity ( $\rho_{xy}$ ) changed from northwest to northeast in Tianzhu—Gulang earthquake process,which is identical to the P axis of focal mechanism solution(N50° E). The comparison of temporal evolutions of geo-electrical principal axis ( $\rho_{xy}$ ) and polarization of fast S wave show that the results from two different methods are almost the same, although the variation value in geo-electricity is smaller but more obvious.

## 3　Conclusions

(1) The calculated results in present paper further confirms the dynamic variations of the polarization of fast S wave and the direction of one of the geo-electrical principal axes indeed reflect the variation of stress field, during earthquake they are roughly in agreement with P axis of focus mechanism solution. It also indicates that the dynamic anisotropy theories about seismic wave and geo-electricity based on EDA model[6,7] are correct, EDA model or APE theory[8,9] maybe are the bases in future study of the

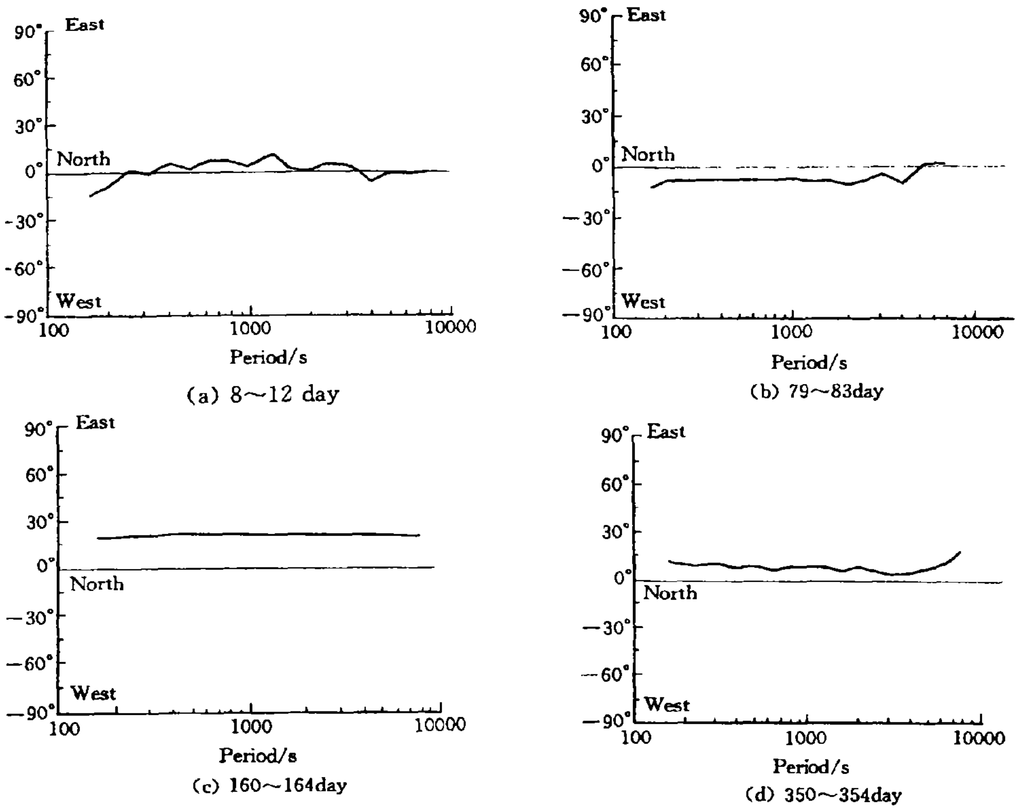



Fig. 4 Directional variations of principal axis ( $\rho_{xy}$ ) with frequency in several periods of Tianzhu—Gulang $M_S5.4$ earthquake process.

model of comprehensive physical precursory field of earthquake.

(2) The precursory anisotropy in Tianzhu — Gulang earthquake has its own characteristics different from that of Yongdeng earthquake. First, the geo-electrical magnetic station is on the same fault with the focus of Tianzhu—Gulang earthquake, so the fault shows strong controlling influence on the variation of apparent resistivity that obviously varied at all frequencies. While in Yongdeng earthquake only at special frequency the variation of apparent resistivity was obvious. Second, the variation of $\rho_{xy}$ that identical with P axis is smaller than that of $\rho_{yx}$ that parallel to fault, reflecting the control of fault is stronger than stress field. While in Yongdeng earthquake the variation of $\rho_{xy}$ was greater than that of $\rho_{xy}$ , completely controlled by stress, because there is no direct relation between fault and station.

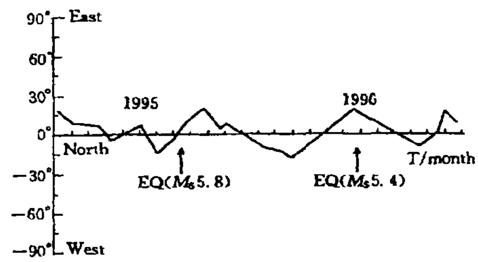



Fig. 5 Directional variation of principal axis ( $\rho_{xy}$ ) in period 200 s of the earthquakes.

(3) Since the time interval between the two earthquakes is only 11 months, spatial distance is about 120 km and the collected data of Tianzhu—Gulang earthquake is few, so the calculated parameters of split S waves especially the time delay are not very satisfying.

(4) According to the calculated results of the two earthquakes, it seems that one of the geo-electrical principal axes matching P axis of earthquake is better than the polarization of fast S wave, which maybe is due to the fact that the perpendicularity between fast and slow waves is not as good as that of

geo-electrical two principal axes. Another advantage of MT method is that its frequency features for different frequencies can reflect precursory variation with depth. From geo-electricity point of view the analysis of the two earthquakes further confirms that the dynamic variation of EDA cracks induced by stress extensively exist in the crust in some ranges.

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# 天祝—古浪地震剪切波分裂及电性各向异性变化特征

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**摘要**:采用与永登地震相同的方法，研究了1996年6月1日天祝—古浪5.4级地震前后地壳介质剪切波分裂、电性各向异性随时间的变化特征. 结果表明临震前电性主轴、快S偏振方向都是从北偏西方向转为北偏东，而该次地震的P轴为北偏东50°，三者总体上是一致的. 由于该次地震与松山电磁台同处一个断层构造上，因此视电阻率变化在各频段均较强，但$\rho_{yx}$比$\rho_{xy}$变化大，这一点与永登地震不同. 另外，由于收集的小震资料较少，快慢S波时间延迟的分析结果没能反映出应力强度的积累，另一个原因可能是该次地震孕育与永登地震后应力调整纠缠在一起的结果(两者距离120多公里).

**关键词**:剪切波分裂; 地电各向异性; 地震

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