Source properties of 17 June 2019 Changning earthquake (M_S 6.2) , China and its aftershocks

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1. Introduction

A M_S 6.2 earthquake hits Changning County of Yibin City in southwest China's Sichuan Province, at 14:55 UTC time (22:55 local time), on 17 June 2019, resulting in 13 causalities. The earthquake occurs in a region where no earthquake larger than M_S 6.0 was reported and is followed by thousands of aftershocks with 4 of them achieving a magnitude of 5. Besides, it is very close to a salt mine. For convenience, we name the earthquake (M_S 6.2) as the mainshock (M) and the others as the nth aftershock with respect for their occurrence time. Employing both the seismic data and InSAR observation, We relocate these events and deduce their rupture property. The result shows complex rupture modes (Fig. 1).

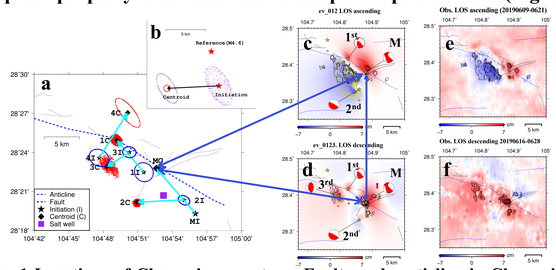


Fig. 1 Locations of Changning events. a, Faults and anticline in Changning area as well as the locations and ruptures of Changning events. The centroids and hypocenters of the aftershocks are relatively relocated taking the centroid of mainshock as a reference. b, the rupture of 2nd aftershock, on which the initiation of 2nd aftershock is determined; c & d, the centroid of mainshock constrained by InSAR observation (black traces); e & f, static placement from InSAR observation.

2. Source inversion method

The focal mechanism is constrained based on the fitting of three types of seismic data: 1) the long-period waveforms of regional Pnl waves, Rayleigh waves and Love waves and 2) the polarity of P wave. The error function is defined as:

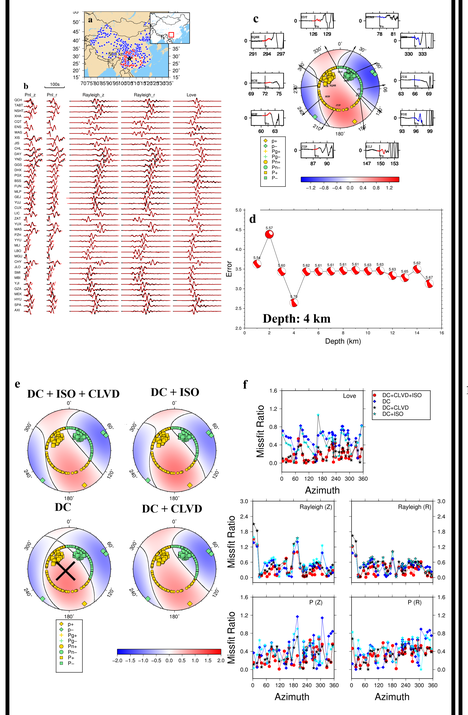
$$e = \sum_{j=1}^{j=nst} \frac{k_1 e_j^{Pnl}}{nst1} + \frac{k_2 e_j^{Ray}}{nst2} + \frac{k_3 e_j^{Love}}{nst3} + k_4 e_{polarity}$$

$$e_j = \sqrt{\| [d_j(t) - u_j(t-\delta t)] \| / \| [d_j(t)] \|}, \qquad e_{polarity} = (N_p - n_p)/N_p$$

d_j is the data records at the j[th] station; u_j is the synthetics; δt is the delay time between the synthetics and data; $\| \ \|$ stands for L2 norm. N_p is the number of stations marked with polarity; n_p is the number of stations where the synthetic polarity is correctly predicted. $nst1$, $nst2$, $nst3$ is the number of Pnl, Rayleigh, Love waves used in the waveform inversion; $k_1 - k_3$ is weight for misfits of local Pnl waves, local Rayleigh waves, local Love waves, k_4 is weight for misfit of polarity.

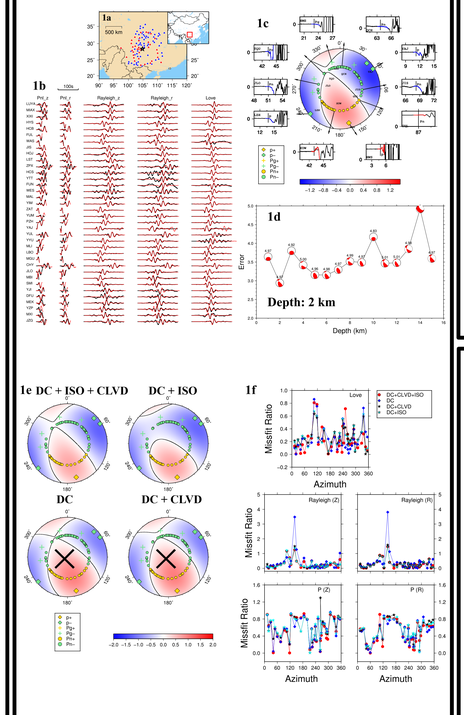
3. Source inversion results: multiple mechanisms of Changning events

Mainshock



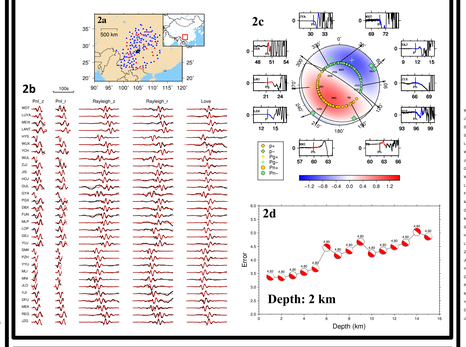
The DC (59%) + ISO (2%) + CLVD (39%) solution does best on fitting the data.

1st aftershock

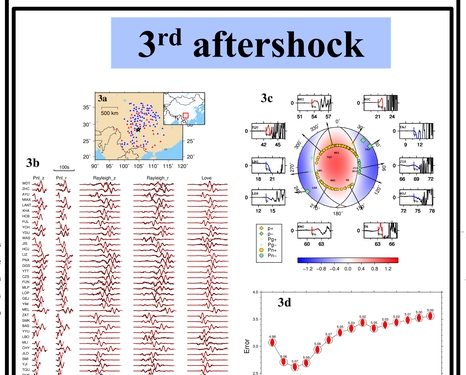


The DC (56%) + ISO (15%) + CLVD (29%) solution does best on fitting the data.

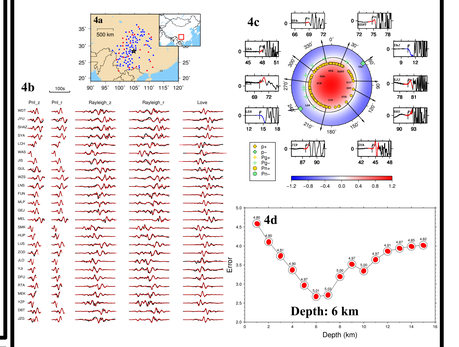
2nd aftershock

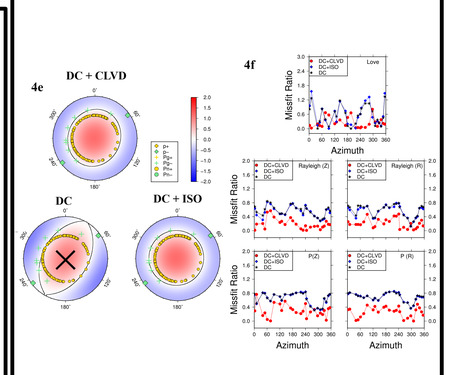


3rd aftershock



4th aftershock





The DC (23%) + CLVD (77%) solution predicts the data best.

Fig. 2 Mechanisms of the Changning earthquakes. a (same for 1a, 2a, 3a, 4a), Map showing location of the earthquake (black star) and distribution of stations (triangles) used in the inversion, in which polarity of P-waves (red and blue triangles), local velocity waveforms (red and green triangles) are included. b (same for 1b, 2b, 3b, 4b), Local velocity waveforms with black traces as the observation and red traces as the synthetics. c (same for 1c, 2c, 3c, 4c), Radiation pattern of the solution along with the polarity of P waves. The black line is the boundary of positive and negative values; d (same for 1d, 2d, 3d, 4d), The residuals with respect to the best focal mechanism along with the magnitude at different depths. e (same for 1e, 4e), fitting of observed polarity for different solutions (DC: double couple; ISO: isotropic; CLVD: compensated-linear-vector- dipole). f (same for 1f, 4f), Misfit of amplitude between synthetics and data calculated with the formula of $\left|\frac{A\_syn - A\_data}{A\_data}\right|$, A_syn (A_data) stands for the maximum amplitude of synthetics (data).

4. Summary of seismic results

1. The Changning earthquakes show complex source mechanisms and ruptures. Although sharing the same strike with Mainshock, the 2nd aftershock ruptures along a more flat dip.
2. The Mainshock, 1st aftershock and 4th aftershock show large part of CLVD component in their source mechanism. Especially, the 4th aftershock, is an interesting earthquake with its source contains about 80% vertical CLVD component.
3. The source of Mainshock and 1st aftershock shares the same DC and CLVD component and contains the implosion component.
4. 4 earthquakes（Mainshock, 1st aftershock，2nd aftershock and 3rd aftershock）occur at shallow depths about 2 - 3 km, close to the depth of fluid injection of salt mining about 2.7 - 3.0 km. While the 4th aftershock, far away from the salt wells, occurs at depth of 6 km.

5. Interpretations & Implications

1. The complex ruptures of Changning earthquakes suggest a complicated fault system in local area.
2. The fluid injection of salt mining may contribute to the occurrence of Changning events occurred at depth of 2 - 3 km.
3. The 4th aftershock, far away from the salt wells, may have something to do with the flowing fluid.
4. The CLVD may be an important component for source of fluid induced earthquake that has not been found before.