



## Three credible examples of major earthquakes' stress-strain precursors in China

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China started in late 1960s the campaign of investigating precursors of major earthquakes by establishing a network of observatories over the country, in order to forecast this kind of natural disasters. One of the campaign's components is stress-strain observation. Various kinds of borehole instruments have been tested during the past four decades, including piezomagnetic type of three-component stressmeter, electric-resistance type of soil strainmeter, string type of strainmeter, electric-capacitance type of 4-gage strainmeter and a Chinese version of Sacks-Evertson dilatometer.

Over one hundred seismological stations have been equipped with these instruments. Some stations recorded significant credible anomalous changes of stress-strain before the earthquakes of Tangshan M7.8 earthquake in 1976, Wuqia, Xinjiang, M7.4 earthquake in 1985 and Wenchuan, Sichuan, M8.0 earthquake in 2008.

Before the Tangshan earthquake, two stations, namely Douhe and Zhanggezhuang, which happened to be located on the seismic fault zone, recorded obvious abnormal changes of stress. While the 3-component piezomagnetic type borehole stressmeters used in these two sites had not very high resolution and the data were sampled only once everyday, the recordings of both sites are comparable. The anomaly was characterized by a series of tensile pulses in the graphs, especially for the recording of the sensor in the direction of N70W, nearly perpendicular to the strike of the seismic fault. The pulses had been seemingly getting larger and more frequent since over a year ago while the main shock was approaching.

The electric-resistance type strainmeters that recorded the precursory changes of the Wuqia earthquake were simple, low-resolution (about  $1E-6$ ), and installed in soil. The most credible anomaly comes from a site, Kashi, located on the seismic fault, 40km from the epicenter of the mainshock. Since the auxiliary observations such as atmospheric pressure, temperatures of air and soil, and rainfall were kept along with the stress observation, one can easily identify on the graph the anomaly that started a few months before the shock. A paper analog recording shows the details of the anomaly that are characterized by short-periods zigzags getting larger and more frequent as the shock was approaching, somehow similar to that of the Tangshan earthquake.

In the example of the 2008 Wenchuan earthquake, there was only one borehole strainmeter observatory, Guza, within 300km from the seismic fault zone. It is using an YRY-4 strainmeter and located at the south-west end of the Longmenshan fault, 150km from the epicenter of the mainshock. It recorded weak but credible precursory anomalous changes before, during and after the shock. The minute data were processed with a newly developed technique termed as Overrun Rate Analysis so that the anomaly, which also appears in a pattern of a series of short-period zigzags, can be more easily realized.