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# Tide-factor anomalies from observations of well level in the Sichuan Province prior to the great Wenchuan earthquake of 2008

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ABSTRACT

We systematically calculated the tide-factors of $M_2$ and $O_1$ waves of the earth tide using water level data from 16 wells in the Sichuan Province acquired 2 years prior to the great Wenchuan earthquake of 2008. Our purpose was to extract anomalies in the tide-factors and analyze their variations in time and space. The results indicate that these anomalies are related to the Wenchuan quake of 2008. The numbers of wells that exhibited anomalies of the $O_1$ wave tide-factor increased gradually as time approached the occurrence of the quake. These anomalies were distributed in space in a discontinuous manner. In terms of such signals, it is possible to exclude the interferences from other factors such as rainfall and exploitation to some extent when we attempt to use anomalous well level variations to predict future earthquakes.


## 1. Introduction

Anomalous variations of groundwater level have been reported to appear prior to earthquakes (e.g., Chia et al., 2008; King et al., 2006). Such anomalies are, however, usually very complicated because of the effects of rainfall, atmosphere, solid tide and artificial interference (Kümpel, 1991; Matsumoto et al., 2003; Woith et al., 2011). Some researchers regard solid tide as contributing to noise in water level data and make corrections to it (Cutillo and Ge, 2006; Reoloffs et al., 2003). Several studies analyzed the relationship between tidal changes derived from well water levels and earthquakes and found that anomalies of tidal variations seemed to occur in the well levels prior to some quakes (Igarashi and Wakita, 1991; Zhu et al., 1997). The tidal effects in the well water level are primarily the responses to the volumetric strain of the aquifer in the subsurface, which are usually not subjected to interference by rainfall, discharge and other factors. Therefore, to some extent, we can study tide anomalies from well level observations prior to earthquakes without the influence of these sources of noise (Akita and Matsumoto, 2004; Li and Jiao, 2001; Riedel et al., 2010; Taniguchi, 2002).

There are several studies on the coseismic responses to the great Wenchuan earthquake of 2008 using well water level data from mainland China (Yan, 2009a; Yang et al., 2008). A number of researchers have suggested that water level anomalies occurred before this event at the following wells in the Sichuan Province: Beichuan, Pujiang 11, Xiaojin Chuan 07, Deyang Chuan 08, Luzhou Chuan 13 and Qionglai Chuan 22 (Cheng et al., 2011; Lan and Chi, 2010; Liu et al., 2011; Yan, 2009b). Most of these studies focused on dynamic changes in water level. Because of the interference from rainfall, water exploitation and other factors, the correct method for the evaluation of these anomalies is controversial.

This work attempts to study the tidal effects of micro dynamic variations in the water level. We systemically analyzed the variations of tidal-factors of $M_2$ and $O_1$ waves in the water levels of 16 wells in the Sichuan Province in the 2 years prior to the 2008 Wenchuan event. Our purpose is to extract anomalies of the tidal-factors and analyze their variations in time and space, migration in space and its relation to the fault. The major goal is to examine whether observable tidal anomalies, represented by minute changes in the well water level, exist prior to large earthquakes.

## 2. Seismotectonic setting

On 12 May 2008, the M8.0 Wenchuan earthquake (with epicenter geographic coordinates of 30.986°N, 103.364°E) struck Wenchuan, Beichuan, and Qingchuan Counties, Sichuan Province, China. The earthquake event took place beneath the steep eastern margin of the Tibetan plateau, a tectonically active region with frequent major quakes that occur on active faults. The earthquake generated 240 km rupture zones along the Longmenshan fault, with a maximum displacement of 6.5 ± 0.5 m (Xu et al., 2009). The event

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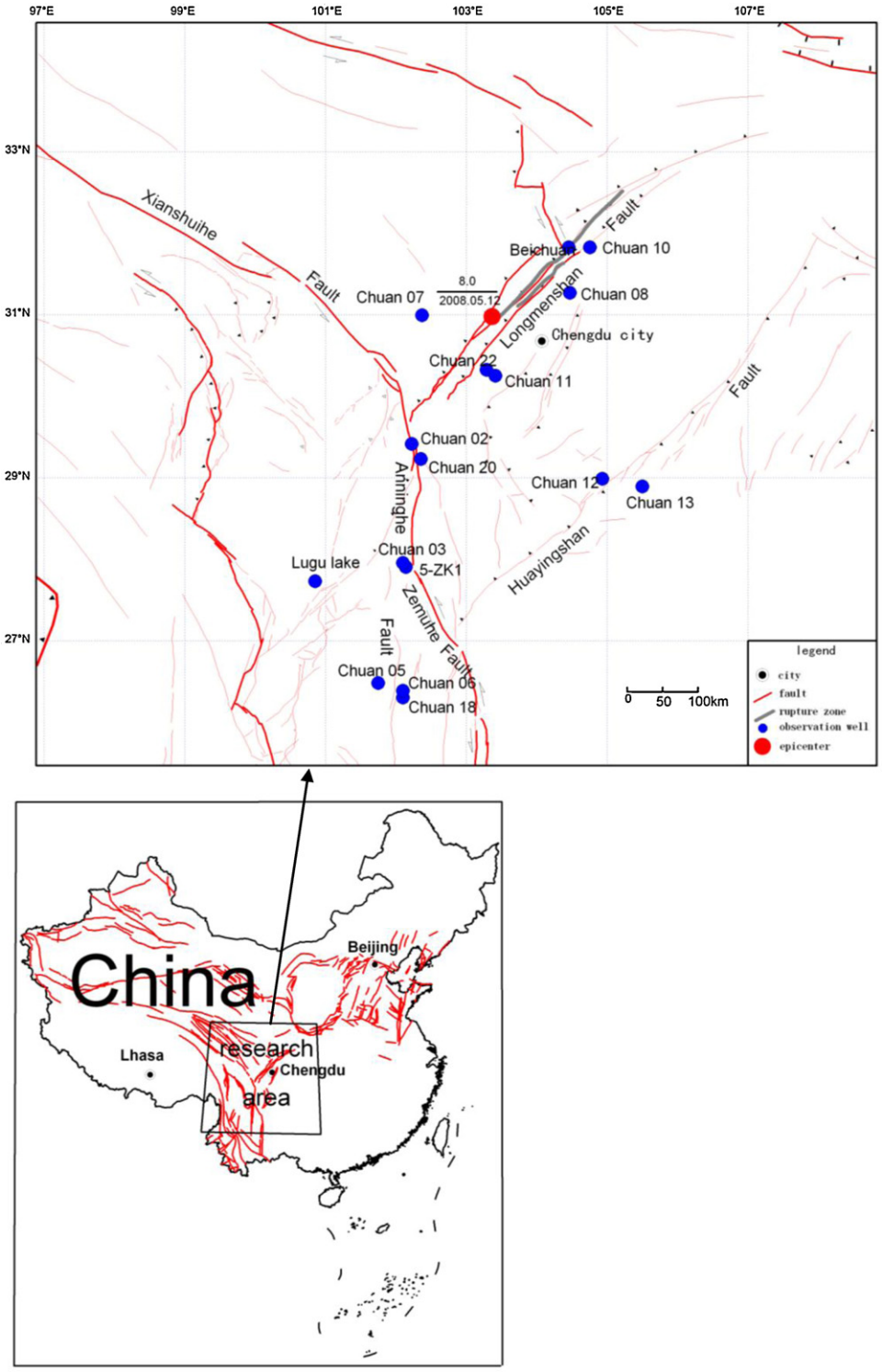


**Fig. 1.** Map showing the locations of the wells for water level observations in the Sichuan Province.

ruptured the Longmenshan. Reverse and right-slip components were of comparable magnitude along the southwestern portion of the rupture, but right-slips dominated the northeastern portion. This event occurred within the context of a long-term uplift and eastward enlargement of the Tibetan plateau, which is hampered by the rigid Sichuan Basin in the east. Such a context in geodynamics is associated with the far-field effect of the India–Asia collision (Burchfiel et al., 2008; Zhang et al., 2008).

The study area is located in the Sichuan Province of China, which has a geographic coordinate of 97–109°E, 25–35°N. The study area includes the Sichuan Basin and the eastern Tibetan plateau. Rocks exposed in the Sichuan Basin are mainly of Cretaceous and, locally, of Jurassic age. Eocene rocks are folded and exposed in active anticlines that form ridges in the southwestern part of the basin and are unconformably overlain by Pleistocene conglomerates and sandstone. Between the folds, Eocene and