EARTHQUAKE CLOUDS AND SHORT TERM PREDICTION

Article

Chinese People Struggle Against Earthquake Disaster

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Earthquakes have been the source of countless natural disasters throughout Chinese history. Ancient Chinese people observed these phenomena with great curiosity. Despite the fact that they did not understand the forces responsible for earthquakes, they left behind detailed records which are valuable even today. So, let's talk about their great contributions at first, then introduce how modern Chinese people have struggled against disaster before, during, and after a big earthquake. As an example, this article will focus on the 7.8 Tangshan earthquake in 1976.

Four Great Contributions of Ancient Chinese on Earthquake Work

At least 3,600 years ago, ancient Chinese people began keeping records of when, where, and how strong were the earthquakes in China[1]. Record-keeping must have been very difficult, because many of the records predate the invention of paper. These data are extremely important for scientists, not only to draw an earthquake frequency map, but also to understand earthquake mechanisms. In addition to recording the physical parameters of earthquakes, many different earthquake related phenomena were recorded, such as anomalous weather, changes in groundwater level and composition, earth- sound, earth- flash, foreshocks, anomalous animal behavior, and so on. The great extent of this work indicates that Chinese sought to correlate earthquakes with other physical phenomena. In other words, they looked for precursors, with the goal of making predictions.

Another great contribution is that Scholar Chang Heng invented the first earthquake recorder in the world around 132 A.D. (Fig. 1 of [2]). The recorder has 8 dragons and 8 frogs facing 8 directions evenly. "Balls were held in the dragons' mouths by lever devices connected to an internal pendulum. The direction of the first main impulse of the ground shaking was reputed to be detected by the particular ball that was released" [2].

The third great contribution is that Chinese made the first successful earthquake prediction by an earthquake cloud in 1622. The method was discussed in detail in the previous issue of this journal [3].

The fourth great contribution is in construction technique. For many centuries, bridges in China were built with an earthquake-resistant design. A good example is An Ji bridge, located in Zhao county (about 37.75N, 114.8E), Hebei province, and built with rock plates at the beginning of Sui Dynasty (590-608 A.D.) by Li Chun. It has a single span of 37.02 meters, a height of 7.23 meters, a total length of 50.82 meters, and a width of about 10 meters. Above the main arch, there are 4 small arches for saving material, draining floods, and promoting aesthetic value [4]. The bridge is not only very beautiful, but also extremely strong. It resisted four big earthquakes successfully [see Table], while in contrast, modern construction fell down. Moreover, neither Chinese nor foreign experts can solve the puzzle.

Table An Ji Bridge, Zhao county, Hebei, China and Four Big Earthquakes *

No.	Date	Time	Latitude(N)	Longitude(E)	Magnitude (ML)	Distance (km)
1	777		37.8	115.2	8 **	35.5
2	3/07/1966	21:29	37.3	114.9	6.8	50.7
3	3/22/1966	8:19	37.5	115.1	7.6	38.3
4	3/22/1966	8:19	37.6	115.2	6.9	38.9

* Dunbar, P.K., Lockridge, P.A. & Whiteside, L.S. World Data Center A for Solid Earth Geophysics, 144-151 (National Geophysical Data Center, Colorado, 1992).

** Chinese Scale, for example the epicenters of the 7.8 Thanshan earthquake and the 7.6 Xingtai earthquake have 11 and 10 intensity respectively.

Modern Chinese People Struggle Against Earthquake Disaster

Ancient Chinese also had many other achievements in earthquake research, but to compress them into a short paper is impossible. The depth of this ancient knowledge was sufficient to guide developments well into the 20th century. After the founding of the PRC in 1949, there was an uncharacteristic lack of major earthquakes for 17 years, leading to the widely-held belief that earthquakes were a product of Japan. In 1966, two earthquakes struck Xingtai, Hebei province and caught the populace by surprise, killing 8,064 people. This triggered a dramatic revival of Chinese earthquake research. Premier Zhou Enlai gathered a group of China's leading earth scientists and asked them to help people immediately [5]. Following Chairman Mao's instruction, Chinese combined "professional and mass efforts", and "indigenous and foreign methods". There were about 10,000 experts, relying on more than 100,000 amateurs and volunteers then [6]. They worked on different branches, such as geodetic, geothermal, geophysical, geochemical, hydrological, seismic, constructive, animal behavior, and so on. They published a number of meaningful articles about what happens before, during, and after a big earthquake.

As an example, I would like to discuss the 7.8 Tangshan (39.6 N, 118.2 E) earthquake on July 28, 1976. It is the most devastating one in China during the past 400 years [9]. It destroyed almost all of the city, and killed 242,000 and injured 164,000 at 3:42 LT (Local time) [7-9]. The direct economic loss was up to 9.6 billion RMB. The 7.1 Luanxian (39.8 N, 118.6 E) earthquake on the same day, and 5 other 6~6.9 earthquakes added to the damage [9].

1. Warnings of the Impending Disaster.

Relying on geodetic measurement, the Chinese scientists found an average uplift of 19 mm southeast of and close to Tangshan between 1967~1968, and 24.1 mm northwest of and close to Tangshan between 1968~1969. They gave an official warning in 1970 that there would be a big earthquake in the Beijing- Tianjin- Tangshan area [10]. Yet, the prediction did not have a time window. In fact, no short-term prediction for this earthquake was ever made. But this certainly does not mean that there was no short-term precursor. Following are four examples.

Zhang and Zhao reported that the oil-well pressure sharply increased 20~ 50 atm. about one month before the quake, and oil erupted three times from Well No. 4 (150 km away from Tangshan) between June 16 and July 28, 1976 [11].

Shi et al. reported that a dry well, 7.8 meter depth, at Wan- Quan- Zhuang, Beijing (150 km away from Tangshan), was sounding like a steam whistle, and a lot of gas was erupting from it from July 26 until five hours before the Tangshan earthquake. After the quake, it began whistling again since 9 a.m. The plume of gas reached 2.5 meters high, and the velocity of the gas was 38 m/s. The sound reached 94 dB, and could be heard 200 meters away. Nine hours later, the 7.1 Luanxian quake happened near the 7.8 quake. The gas plume appeared again before each of two 6 ML aftershocks on August 8, and 9. The gas was analyzed as 12.9% carbon- dioxide [12-13].

Cai et al. reported, the vertical wall of the earthquake investigative well of No. 10 Tangshan high school became sloped 4 days before the quake [14].

Tang[1] reported that one minute before the quake, two drivers, Zhang and Liu, of the No. 129 express train of Beijing - Dalian suddenly saw "three belts of glittering flashes appearing in the night sky", and thought this must be the precursor of an imminent earthquake, and stopped the train immediately, a mere 24 km from the epicenter. Due to the drivers' knowledge of the ancient earthquake lore, and their courage to make a short-term prediction, the lives of all the passengers were saved. The residents of Tangshan were not so fortunate. It is clear that many anomalies were observed before the quake, and there was ample time to warn the populace, but not enough understanding of the precursor mechanisms to make a confident prediction.

2. Tangshan people struggled against the disaster during the earthquake.

The disaster struck at 3:42 AM local time, when most residents of Tangshan were asleep in bed. The first locals to respond were four officials from the local headquarters of the Coal Mine Bureau. Thirty minutes after the quake, they searched for a way to contact the central government in Beijing. They found that the government buildings were destroyed, and there was no telephone connection. They drove to Beijing to report the catastrophe, but were interrupted several times by crowds of confused people, some of whom even threw bricks at the car. Midway to Beijing, they met several seismologists from the geological team of the State Seismological Bureau (SSB) who were looking for the epicenter. They reported to the State Council about four hours after the quake, and requested mine rescue teams for 10,000 coal miners trapped 1,000 m underground, and troops and medical teams for the city [7].

At about 10 a.m., 6 hours after the quake, heavy rain began to fall. The Dou Hu reservoir, 15 km northeast of Tangshan, was in danger because its dam had 1,700-m- long longitudinal cracks and 50 smaller transverse cracks, some of which were about 1- m-wide and 10-m-long. It contained 36,000,000 cubic meters of water, and its bottom was 10 m higher than Tangshan. To open the flood gates, four strong soldiers together wound 100 times the windlass to lift 1 cm of a 100- ton gate [7].

The mine rescue teams were the first to arrive at the ruined city, in the evening by plane. Next were 100,000 soldiers, followed by 200 medical teams with about 10,000 experts[7].

Miraculously, the quake only devastated surface buildings. Underground, most of the construction was undamaged. In fact, not a single miner was injured. Almost all the miners were able to leave the mine about 10 hours after the quake. Only 17 miners died because they could not find the exit in the darkness. Five others were trapped in hunger, darkness and dampness for 15 days, but survived [7].

For the first four days after the quake, rescue efforts were hampered by the absence of heavy equipment. The soldiers used their bare hands for digging through the rubble. Nine workers unburied a hand-generator to light a street light in the second night that gave the panicked populace new hope. Two days after the quake, 30 trucks carried water to the thirsty people. On the third day, Shanghai sent a 12,000 m fire-hose to convey water from nearby reservoirs. Nearly every residence in the city had been destroyed, so the condition of the survivors worsened rapidly. Without bathrooms, excrement was piled everywhere, attracting flies and mosquitoes. Rotting corpses of people and animals produced an unbearable stench. Pestilence began to attack the survivors, against which 21 expert teams came with various medicines and 176 tons of insecticide [7]. Despite the tremendous difficulties, remarkably there was no request for foreign assistance [7,8].

In total, there were 160,000 seriously injured people. More than 100,000 victims were transferred to 11 provinces by 159 trains and 470 airplanes. An operation of this scale had never been attempted in China before, so there were numerous problems, including the lack of equipment to transport the victims, blood for transfusion, and water for doctors to wash their hands. The longest record for a survivor was 13 days. A well-known story is that of a nurse who was trapped under a strong table, and had nothing but a bottle of glucose to survive. When soldiers cleared the rubble 8 days after the quake, she jumped out like nothing had happened to her [7].

3. Chinese Scientists Observe the Quake's Aftermath

Chinese scientists investigated the destroyed area, and drew a damage intensity distribution based on the Chinese Standard. Intensity 11 (almost all constructions collapsed), 10, 9, 8 and 7 areas were 47, 320; 1,433; 5,470 and 26,030 km^2 respectively. The sum of the above areas was 33,300 km^2 [8, 9].

They photographed and measured the damage along with many unusual phenomena. The main broken band was 30 m wide, and 8 km long [15], with many crevasses. The largest was measured 1.5 m horizontally, and 0.8 m vertically [8, 15]. Many pools emerged, for example, an 8 m hole filled with water in the middle of a highway (Fig. 168 of [15]) and another diameter 3 m and depth 3 m was in front of a shop (Fig. 169 of [15]). Water, soil and stones spouted from the pools (Fig. 162-165 etc. of [15]). There were many sand blows, or sand boils like volcanic mouths (Fig. 7 of [8], Fig. 1-29 of [9]). Uncountable bridges were broken. The highways were cracked open and railways were severely warped. Many trains were overturned. Almost all the tops of the chimneys of smelter of Steel and Iron Works of Tangshan fell off [8, 9, 15]. Even some buildings in Beijing (about 150 km away) were seriously damaged[9, 15].

There were four unusual sights. 1. Some free-standing brick-wood buildings near the epicenter were left standing, apparently untouched. (Fig. 111, 112 of [15], Fig. 7-4 of [9]); 2. An one-story brick-wood building was moved 1.2 m from its origin, but suffered no damage, as though it were a chair sliding on the floor (Fig. 87 of [15]); 3. In the region of Intensity 10, the quake did not collapse a one-story building, but spouting groundwater made a large hole in its ceiling (Fig. 7-17 of [9]); 4. During the period, hot erupting material burned a man [13].

4. Tangshan people rebuilt their hometown after the earthquake

Having suffered through the devastation, the indomitable Tangshan people rebuilt their hometown. After 10 years of struggle with the help of both the government and people from all over the country, a new Tangshan stood near the ruin on the vast plain of Northern China. It consisted of 17.7 million m^2 buildings, including 11.27 million m^2 apartment buildings, and 95% families had moved into new homes[9]. The city's also industries made rapid progress. By 1985, Tangshan had achieved a 70% of increase in annual economic output, 3,780 million Yuan RMB, relative to 1975, the year before the quake.

The surviving buildings have become important cultural relics to be preserved [15]. They not only teach new generations to remember the lessons, but also motivate them to predict earthquakes, improve building design, and unite in preparation for future disasters.

5. Chinese scientists learn from the earthquake

Chinese scientists carefully studied the Tangshan earthquake and others, and have since published more than 800 relevant articles. The articles cover the full range of traditional earthquake topics such as geodetic [10, 11, 16, 17], geothermal [13, 14, 18], geophysical[11, 19-22], geochemical[12, 13, 23, 24], hydrological[12, 13, 19, 25], seismic[26, 27], constructive [9, 15], animal behavior[28], meteorological [29], earthquake mechanism [14, 30, 31], and prediction [31- 33]. The scientists also explored unconventional ideas, such as those of C. Kagida, who proposed that a special type of cloud may be a precursor for earthquakes[3, 34].

I will briefly discuss some of the questions raised and lessons learned by the Tangshan quake. The quake was quite different from others because of the long period of creep preceding it, without any foreshock [35]. This revelation had serious implications for prediction, because it had previously been thought that all major earthquakes have associated foreshocks. Without dependable foreshocks, measurement of seismic activity alone is clearly insufficient for making short-term predictions.

The Tangshan earthquake also stimulated debate relating to aftershocks. Yang and Zhao propose a special view: there were not one or two, but three main earthquakes during the earthquake [26]. This view is different from the predominant opinion that all earthquakes are aftershocks if they occur after and are smaller than and within the same region as a big one. The current opinion is confusing. For example, seven years after a big earthquake, a new earthquake near the big one is still announced as an aftershock. No one knows why it is not a new earthquake, but an aftershock, and how long a big earthquake can make an aftershock, and what the scientific definition of "aftershock" is. Therefore, Yang and Zhao's view is meaningful.

In an experiment by Cai et al.[14], the rapid increase in ground temperature prior to the Tangshan earthquake was directly related to the observed creep. The authors collected material to make a model system which mimiced the layer structure of the ground near the fault. They applied forces to it to simulate the temperature increase, and found that the actual temperature increase was well-described by their model system. The motion in their model system was compared to the observed ground motion, with the goal of using increasing ground temperature as a short-term precursor.

Motivated by ground-based observations of erupting gases prior to earthquakes, Giang et al.[31] found the same phenomena in infrared satellite images. A pressure-electricity model was used to explain how a rock releases gases. They also claimed to have used this precursor to predict more than 40 medium and strong earthquakes. Unfortunately, the accuracy of their predictions has not been verified[36].

Jiang and Du [28] proposed a precursor based on animal behaviour. They reviewed the cases of hibernating snakes leaving their holes during the winter, and found that every case in which the snakes died was followed by an earthquake within a few months, while the only case in which they returned alive was not followed by an earthquake. The authors propose that gas erupting through cracks in the ground stimulated this suicidal behaviour.

Chinese scientists uncovered yet another precursor by applying advanced mathematical tools to mundane observations. Zheng and Feng [25] used a mathematical method known as "fuzzy recognition" to analyze recorded groundwater levels in 33 wells near Tangshan before and after the earthquake. They found previously unknown anomalies in the correlations between water levels in different wells beginning three hours before the quake. The anomalies were distinct from typical fluctuations during the 5 day period analyzed, and increased in strength as the earthquake approached.

Chinese scientists do not use some of the advanced equipment and techniques that are available in modern laboratories in the west. However, they have made up for this lack of infrastructure by energetically pursuing almost every possible approach to earthquake prediction. Chinese research demonstrates the most thorough search for earthquake precursors in existence. Although these efforts have not yet borne fruit, much progress has been made. The State Seismological Bureau claimed an accuracy rate of 25% for medium- to short- range forecasts. Its success relies on financial support, to the extent of $45 million in 1996 [5]. To develop short-term prediction, Li [32], a senior Chinese research professor, proposed a target, "the magnitude being +/-1, the time span <1 year, the coverage area <50,000 km^2 , and the rate of accuracy >= 50%". His target shows both the aim for the future, and the current standard. I believe that Chinese will follow their great ancestors to chase the elusive target of earthquake prediction, and will ultimately make a great contribution to the world.

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