The theory of drought-earthquake relationship revisited

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Abstract. Geng Qingguo summarized the drought-earthquake relationship data from 1956 to 1972 to derive a theoretical formula for drought-earthquake. In this paper, the area of the drought area and the duration of drought before the 8½ magnitude earthquake in Tancheng in 1668 were substituted into this formula to invert the future earthquake magnitude. At the same time, the magnitude 7 earthquakes that occurred since 1972 that were related to drought were also inverted for future magnitudes. The analysis suggests that there may be a relationship between drought and earthquakes, and that the drought-earthquake relationship can also be used as one of the medium-term forecasting methods for large earthquakes when earthquake forecasting has not yet been overcome, and the possible future earthquake magnitudes in drought areas are calculated by Geng Qingguo's empirical formula for drought-earthquakes.

1. Introduction
Since entering the 21st century, major earthquakes of magnitude 8 have occurred frequently around the world, with 25 earthquakes of magnitude 8.0, the largest being the 9.0 magnitude earthquake in Japan on March 11, 2011, among which the 8.1 magnitude earthquake that occurred in mainland China on November 14, 2011 at the junction of Xinjiang and Qinghai (the western mouth of the Kunlun Mountains) and the 8.0 Wenchuan earthquake in Sichuan Province on May 12, 2008. In addition, 8 earthquakes of magnitude 7 or higher have occurred in mainland China since 2000.

The heavy loss of life and property caused by strong earthquakes makes the work of earthquake forecasting all the more urgent. However, earthquake forecasting is still a world problem, except for some earthquakes such as the Haicheng earthquake, which were successfully forecasted through experience, but no earthquake has been successfully forecasted from the real seismogenic mechanism. Geng Qingguo examined 69 major earthquakes of magnitude 6.0 or higher in North China and Bohai Sea during the 2202 years from 231 B.C. (the 16th year of Qin Shihuang) to 1971 A.D. Among them, there were 27 major droughts in the year before the earthquake, 15 major droughts in the two years before the earthquake, 16 major droughts in the three years before the earthquake, and 9 major droughts in the three and a half years before the earthquake, which is summarized as 67 major droughts in the three and a half years before the earthquake. The total number of earthquakes was 67, accounting for 97.1% of the total number of earthquakes. “A great drought followed by an earthquake”. The “drought-earthquake relationship” has caused some repercussions in the seismic community, and the proponents and opponents are all in agreement. In this paper, we continue to explore this issue by compiling data on drought-earthquake relationships from 1956 to 1972 from Geng Qingguo and subsequent examples of earthquakes of magnitude 7 or greater that are related to drought.

Geng Qingguo, through the statistics of many earthquakes of magnitude 6 or above, there is a drought weather phenomenon before the occurrence of earthquakes, and came up with the theory of...
“big drought will lead to big earthquake”: Under the action of the universal friction between the moon and the sun on the earth, the underground magma is flowing, and the flowing magma will sometimes form a spinning up magma spiral spring, which will form a high temperature magma hole under the area. This makes the ground temperature in this area high for a long time. The increase in ground temperature will evaporate the groundwater, and will make the temperature in this area rise, and the air will rise, which will prevent the convergence of cold and warm air in the high altitude, and cause the drought in this area, and also make the crust of this area thinner and less able to bear the force, and easy to break. At the bottom of the high-temperature magma cave, the flowing magma tends to form a magma spiral spring again, when the formed magma spiral spring has little resistance and great power, it can topple the earth's crust and trigger earthquakes, so earthquakes tend to occur after drought. [1-2]

According to Geng Qingguo, from 1956 to 1972, there were 44 drought areas in mainland China, among which 36 drought areas with earthquakes of magnitude 6 or higher occurred, accounting for 81.8% (36/44) of the total number of drought areas. There were 58 earthquakes of magnitude 6 or higher (including 4 earthquakes of magnitude 7 or higher) during this period, of which 56 occurred 1 to 3.5 years after the emergence of the drought zone, and the minimum area of the drought zone before the magnitude 6 earthquake was 252,000 km², and the minimum area of the dry zone before the magnitude 7 earthquake was 432,000 km². This represents 41.4% of the statistical sample; 18 earthquakes occurred after 2 years in the drought zone, accounting for 31.0% of the statistical sample; 12 earthquakes occurred after 3 years, accounting for 20.7% of the statistical sample; and 2 earthquakes occurred after 3.5 years in the drought zone, accounting for 3.4% of the statistical sample. Therefore, Geng Qingguo concluded that, in general, the epicenter area of large earthquakes of magnitude 6 or higher tends to be a drought zone 1 to 3.5 years before the earthquake, and the probability of an earthquake occurring within 1 to 3.5 years after the appearance of drought is about 96.5%. Meanwhile, the area of the drought zone increases and decreases with the magnitude of the earthquake, the larger the magnitude, the longer the drought, and the magnitude of the earthquake in the third year of occurrence is 0.5 magnitudes greater than that of the earthquake within the first year after the drought. [1]

2. Empirical formula for the drought-earthquake relationship [1]
From the statistical results of the analysis of drought-earthquake cases between the major domestic drought (drought area S≥252,000 km²) from 1956 to 1972 and the occurrence of strong earthquakes with M≥6.0 in the drought area within a period of 1 to 3.5 years. In September 1972, Geng Qingguo gave the empirical formula about the drought-earthquake relationship between the duration of a drought before the earthquake and the drought area and the earthquake magnitude:

\[ M = 1.5 \log T + 3.5 \log S + 0.5 \pm 0.5 \]  

(1)

where T is the duration of drought anomaly (in days) and S is the area of drought anomaly area in 105 km².

3. Inverse earthquake magnitude based on the drought area and duration before the 1668 Tancheng 8½ magnitude earthquake
Historical records show that four years before the Tancheng earthquake, in the fall and winter of 1664, there was a widespread drought in a large area in the western part of the epicenter area, including the western part of Shandong, Henan, Hebei, Jiangsu and Anhui provinces. The following year, the drought continued to develop throughout Shandong Province and spread to Henan, Hebei, Anhui and Jiangsu provinces. This year, in addition to the Jiaodong Peninsula wheat harvest two tenths, other places in the summer, autumn yield, it is “a thousand miles of red land” grass are withered. In some counties, there was a tragic scene of “people eating each other”. The drought history of Shandong Province for nearly 300 years from 1640 to 1900, before the earthquake, the scope of the drought is large. The drought period is long, the severity of the disaster is rare, can be described as "very large drought". Three years after the drought, the Great Tancheng Earthquake of 8½ magnitude occurred in 1668. [3]
According to this description, the drought area at that time included the western part of Shandong, Henan, Hebei, Jiangsu and Anhui provinces, and two tenths of the harvest of Jiaodong Peninsula, which means that Jiaodong was also in the drought area, so the area should be calculated for the whole Shandong province. According to the current inter-provincial division, the land area of Shandong Province is 157,000 km², the land area of Henan Province is 167,000 km², the land area of Hebei Province is 187,000 km², the land area of Jiangsu Province is 102,600 km², the land area of Anhui Province is 139,600 km², then the area of drought area before Tancheng earthquake \( S = (157,000 + 167,000 + 187,000 + 102,600 + 139,600) = 753,200 \text{ (km}^2\text{)} \), the duration is 3 years, calculated according to Geng Qingguo's empirical relationship formula for drought earthquakes, that is, \( T = 365 \times 3 = 1095 \) (days), \( S = 7.532, \) substituting Substitute into equation (1), to get:

\[
M = 1.5 \log S + 3.5 \log 7.532 + 0.5 \pm 0.5 = 8.0 \pm 0.5
\]

According to Geng Qingguo's empirical conclusion, the earthquake occurs after the third year of drought, so the magnitude should be added 0.5 to the original one. Therefore, according to the area of the drought area and the duration of the drought, the future earthquake magnitude \( M = 8.0 + 0.5 = 8.5 \), in the drought area calculated with the drought earthquake formula, which is consistent with the magnitude of the 8½ magnitude Tancheng earthquake that occurred in 1668.

4. Comparison of magnitude backpropagation and actual occurrence of some earthquake cases for the drought-earthquake relations

4.1. Partial earthquake examples of drought-earthquake relations

After 1972, there are some other earthquake examples of drought-earthquake theoretical relationships.

1) In 1972, there was a severe drought in North China and the Bohai Sea region that was unprecedented for decades, with a large drought area of 1.13 million km², which is a drought area large enough for two sets of large magnitude 7 earthquakes and even a possible set of strong magnitude 8 earthquakes to occur. Among them, the area around Jinzhou-Suiyan in Liaoning, Tangshan area in Hebei and the area around Shijiazhuang, Xingtai, Taiyuan and Xinzian at the intersection of Shanxi and Hebei were the special drought areas. As a result, on February 4, 1975, two years and one month after the 1972 drought in North China and the Bohai region, a strong earthquake of magnitude 7.3 occurred in Haicheng in the Jinzhou-Suiyan special drought area of Liaoning [4]; on July 28, 1976, 3.5 years after the 1972 drought in North China and the Bohai region, a large earthquake of magnitude 7.8 occurred in Tangshan in the Tangshan special drought area of Hebei and a strong earthquake of magnitude 7.1 occurred in Luanxian. strong earthquake of magnitude 7.1 in Luanxian [5].

2) In 1972, a large drought area of 1.29 million km² occurred in southwestern China (northwestern and southern Sichuan Province, northeastern and western Yunnan Province, and eastern and central Tibet Autonomous Region). This is the result of a drought area that large enough for a set of 8 magnitude earthquakes or two sets of strong earthquakes of magnitude 7 or more. 7.9 magnitude earthquakes occurred on February 6, 1973 in the area of Furho-Ganzi within the special drought zone of northwestern Sichuan[6] and 6.0 magnitude earthquakes in Furho on February 8, 1973; 6.5 magnitude earthquakes occurred on August 11, 1973 in the area of Nanping and Songpan in northwestern Sichuan; then On August 16, a magnitude 6.3 earthquake occurred in the area of Simao and Pu'er within the special drought zone of southwestern Yunnan Province; and on May 11, 1974, a magnitude 7.1 earthquake occurred in the area of Leibo and Zhaotong within the special drought zone of southern Sichuan Province and northeastern Yunnan Province.

3) In 1974, a drought zone with an area of 567,000 km² appeared in northwestern Sichuan, southern Gansu and northwestern Qinghai and its southeastern part of China. As a result, a 6.2 magnitude earthquake occurred on January 15, 1975, near Jiulong, between Kangding and Shimian in Sichuan.

4) In 1975, a large drought zone with an area of 923,000 km² appeared in western and northern Yunnan Province, southwestern Sichuan Province, and eastern Tibet Autonomous Region, China. This
is a drought zone area large enough for two sets of strong earthquakes of magnitude 7 or higher, or even a set of large earthquakes of magnitude 8. As a result, a magnitude 7.5 earthquake occurred on May 29, 1976 in the area of Longling and Luxi in Yunnan within the Eryuan-Gengma special drought zone. Two strong earthquakes of magnitude 7.5 and 7.6 occurred in the area; on November 7, 1976, an earthquake of magnitude 6.7 occurred in the area of Lijiang and Ninglang, Yunnan within the Zhongdian-Jianchuan special drought zone, and another earthquake of magnitude 6.0 occurred in the area of Ninglang, Yunnan on December 13, 1976[6].

5) In 1986, Yunnan suffered a severe drought, which resulted in two major earthquakes with magnitudes of 7.6 (Lancang) and 7.2 (Gengma) at 21:03 and 21:16 on November 6, 1988, in Lancang and Gengma, Yunnan Province.

6) From the summer of 2006 to the spring of 2007, Sichuan and Chongqing were hit by a huge drought unprecedented in 100 years, which resulted in a major earthquake of magnitude 8 in Wenchuan, Sichuan on May 12, 2008.

7) In the 20th century, there was no major earthquake during the 18 years of drought in Africa, and once the drought ended, two major earthquakes of magnitude 7 or higher occurred in Sudan in 1990.

8) Villagers holding empty buckets of water for their livestock walk across a dried-up dam in Ramon Bank, East Java province, Indonesia, August 20, 2008. On September 2, 2009, an earthquake measuring 7.3 on the Richter scale struck in the Indian Ocean off West Java, Indonesia.

9) On May 10, 2004, Peru was hit by the worst drought in a decade, and water supply restrictions were introduced in the capital Lima. The lack of rainfall in northern and central Peru led to drought, which seriously affected agricultural production and the lives of residents. In the central region, the provinces of Junin and Huancavelica are also in a serious situation, with 24,900 hectares of crops affected. It is estimated that the production of crops such as rice, corn, potatoes, cotton and sugar cane will drop significantly in Peru this year. on August 15, 2007, an 8.0 magnitude earthquake struck the central coast of Peru, killing more than 500 people, injuring 1,366 and destroying more than 50,000 houses.

10) In June 2007, northern and central Italy suffered from a rare drought. The experts concerned pointed out that the precipitation in the said areas decreased by 20-50% compared to the same period last year. The water level of the longest river in Italy, the river Po (675 km), has fallen to a historical low for the same period, with the average water level in late April being 6.53 m below sea level. as a result, a major earthquake of 6.3 magnitude struck the L'Aquila region in central Italy in the early hours of April 6, 2009, killing 294 people.

11) In February 2008, the South American country of Chile, suffered the worst drought in 80 years, with more than a quarter of the country facing water shortages and at least 120,000 people affected by the drought. Reservoirs bottomed out, wells dried up, land dried up and cracked, and drinking water became a problem for residents in many areas. The Chilean government has had to send water convoys to regularly deliver drinking water to areas where the drought is severe. The drought has left crops in the south-central region of Chile unproductive and many farmers have watched their livestock die of thirst. As a result, a massive 8.8 magnitude earthquake occurred in Chile on February 27, 2010.

4.2. Comparison of seismic magnitude backpropagation with actual occurrence
From the above 11 earthquake examples of drought-earthquake relationship, the five earthquakes that explicitly had drought area and drought duration were used to invert the future drought-earthquake generation magnitude, and the drought duration and drought area in the earthquake examples were substituted into the equation (1) for calculation, respectively. Meanwhile, because according to Geng Qingguo's statistics, the probability of earthquakes occurring in the drought-earthquake relationship theory from 1 to 3.5 years reaches 96%, earthquakes occurring after the drought appearance time $T \geq 3.5$ years are calculated with $\pm 0.5$ by adding 0.5, and vice versa, subtracting 0.5. Then the calculation results are shown in Table 1.
Table 1. Comparison of inverse seismic magnitude and actual seismic magnitude based on the theoretical formula for dry seismicity

| Earthquake Date (yyyy.mm.dd) | Epicenter Location | Drought Duration (days) | Drought Area (105km²) | ±0.5 | Calculation Magnitude (M) | Actual Magnitude (M) |
|-----------------------------|-------------------|-------------------------|-----------------------|------|--------------------------|---------------------|
| 1975.02.04 Liaoning Haicheng | 760               | 11.3                    | -0.5                  | 8.0  | 7.3                      |
| 1976.07.28 Tangshan, Hebei   | 1277              | 11.3                    | +0.5                  | 9.4  | 7.8, 7.1                 |
| 1973.02.06 Furho, Sichuan    | 365               | 12.9                    | -0.5                  | 8.2  | 7.7                      |
| 1974.05.11 Zhaotong, Yunnan  | 730               | 12.9                    | -0.5                  | 8.2  | 7.9                      |
| 1976.05.29 Longling, Yunnan  | 365               | 9.23                    | -0.5                  | 7.2  | 7.5, 7.6                 |

Among these 5 examples of drought-quake relations, 4 earthquakes occurred about 2 years after the appearance of the drought (the shortest was 1 year: the Longling and Luxi 7.5 and 7.6 magnitude earthquakes, which occurred 1 year after the duration of the drought), and only the Tangshan earthquake occurred 3.5 years after the appearance of the drought. The magnitude of the Tangshan earthquake was about 1.6 magnitudes larger than the actual magnitude of the earthquake, but the Haicheng earthquake occurred 1.5 years before the Tangshan earthquake, which may have an offloading effect on North China, and the Tangshan earthquake was a double earthquake. The magnitude calculation can also provide some reference for predicting the magnitude of future earthquakes.

5. Discussion and conclusion

1) From the results of the statistical earthquake cases, there is indeed a relationship between drought and earthquake, which explains the cause of large drought areas from another aspect. The number of drought areas with earthquakes after drought accounts for 81.8% of the total number of drought areas, i.e., there is generally a drought before an earthquake, but there is not necessarily an earthquake after a drought.

2) The magnitude of the earthquakes inversely derived from the time of drought appearance and the area of drought in the equation of drought-quake theory is larger than the actual occurrence of earthquakes, but this magnitude calculation can also provide some reference for the magnitude prediction of future occurrence of earthquakes.

3) In the statistical earthquake cases, the earthquakes generally occurred 1 to 3.5 years after the appearance of the drought. It indicates that there are meteorological anomalies as its precursors before the occurrence of large earthquakes, and capturing such precursors may play a role in predicting, forecasting and preventing large earthquakes. Therefore, the theory of drought-earthquake relationship can also be used as one of the medium-term forecasting methods for large earthquakes when earthquake forecasting has not been conquered yet.

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