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Fibonacci Sequence Found in Parkfield Earthquake

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Abstract

USA scientists found a 22-year cycle in Parkfield earthquake sequence, and they predicted that the next quake would come in 1988 ± 5 with 95% possibility, while the quake happened in 2004, which is 11 years later than the prediction. Here, we reanalyze the Parkfield earthquake sequence, and find 11-year cycle; multiple 11-year cycle and Fibonacci sequence existed for earthquake. With these methods, the 2004 earthquake can be predicted well. We also predict that the next earthquake may occur in 2031-2032.

Keywords

Fibonacci Sequence, Parkfield Earthquake, 11-Year Cycle

1. Introduction

Parkfield earthquake prediction experiment is the world-famous experiment. In 1985 USA scientists found that some M6 earthquakes happened in Parkfield, California along the San Andreas Fault occurred repeatedly on January 9, 1857, February 2, 1881, March 3, 1901, March 10, 1922, June 8, 1934, June 28, 1966, and September 28, 2004 [1]. Bakun found that the earthquakes occurred regularly with a 22-year cycle, so they predicted that the next quake would come in 1988 ± 5 with 95% possibility on the San Andreas Fault near Parkfield [2]. Then they decided to launch a long-term experiment to understand the physics of earthquakes—what actually happens on the fault and in the surrounding region before, during and after an earthquake. About 100 researchers from USGS, universities and government laboratories of USA gathered in Parkfield. They constructed a dense network of instruments and tried to "capture" the anticipated earthquake and revealed the earthquake process in unprecedented detail. However, no such event occurred until September 28, 2004. Someone considered that

this earthquake prediction experiment was based on a small data set, which unavoidably poses a challenge [3]. Someone considered a reason that Bakun used a constant loading velocity and failure threshold, while the next quake did not follow it [4]. Someone considered that maybe it was due to the M6.5 quake that happened 25km northeast of Parkfield in 1983 [5]. Here we analyze the Parkfield earthquake and find an interesting Fibonacci sequence existed for occurrence of earthquake. With this sequence, the quake in 2004 can be predicted well.

2. The Parkfield Earthquake Prediction Experiment

Bakun performed a linear regression for the six earthquakes of Parkfield. He found that the average interval is about 22 years, from which the regression equation was obtained $T = 21.7I + 1836.2$ (see **Figure 1**) [2]. For $I = 1$ to 6, the predicted earthquake time was 1857.9, 1879.6, 1901.3, 1923, 1944.7 and 1966.4, and their error was 0.9, −1.4, 0.3, 1, 10.7, 0.4, respectively. We can see that five of six errors were within [−1.4, 1], except the 1934 earthquake, whose error was 10.7 years. This meant that the 1934 earthquake was an exception and this equation could not predict the 1934 earthquake accurately. But statistically speaking, 5 of total 6 earthquakes were predicted well with the linear regression equation, so people believed that it was very possible that this equation could also predicted the next one. So Bakun let $I = 7$ and got the year 1988. He gave a 10-year time window from 1983 to1993. Unfortunately, the actual earthquake happened in 2004, its error was about 11 years, which was very close to that of 1934. If let $I = 8$, then $T = 2010$ which has a big error of 6 years. Obviously, this equation failed to predict not only the 1934 earthquake but also the 2004 earthquake, though it fitted well with the other 5 earthquakes. So, we try to construct a new model to predict the 1934 and 2004 earthquake.

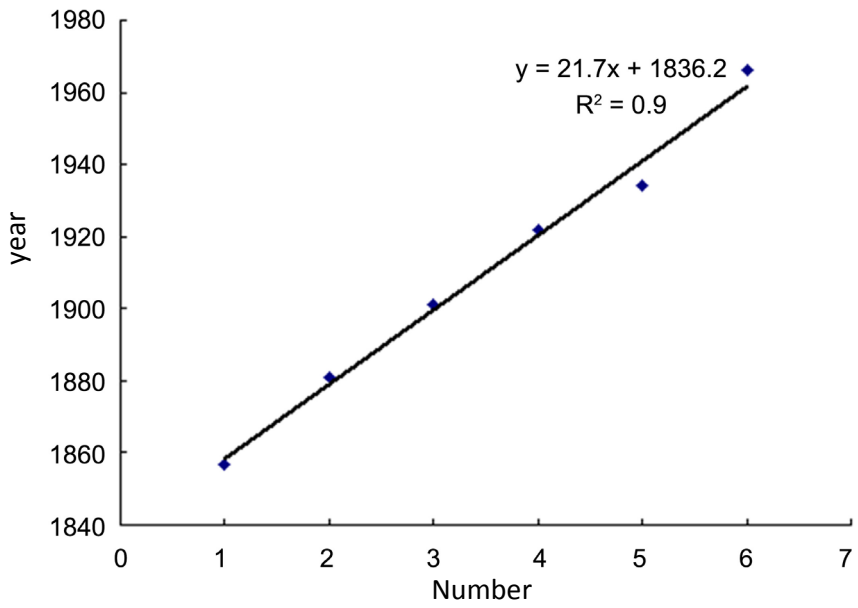

Figure 1. The linear regression equation made by Bakun.

3. For the 1934 Earthquake Prediction

To predict the 1934 earthquake, we subtract all earthquake years with each other and find that 1934 − 1922 = 12, 1922 − 1901 = 21, 1934 − 1901 = 33, 1966 − 1934 = 32, 1966 − 1922 = 44, 1901 − 1857 = 44, 1922 − 1857 = 65, 1966 − 1901 = 65, 1934 − 1857 = 77, 1966 − 1857 = 109. They are 1 time, 2 times, 3 times, 4 times, 6 times, 7 times and 10 times of 11 years, respectively (there may be 1-year error for some quakes), indicating that there is an 11-year cycle in this sequence. It is well known that 11-year cycle is the famous sunspot cycle, and the 22-year cycle discovered by Bakun is only a special case of multiple 11-year cycle. With the different starting year 1857, 1881, 1901, 1922 and the 11-year cycle, we get Table 1.

Table 1 shows the possible earthquake years with the 11-year cycle. We can see that all the results point to 1933-1936. The year 1934 appears twice and 1933 appears once, considering the 1-year error, they can be seen as the same earthquake. For the 1881 starting year, it gets 1936, which has 2 years error. The average of 1934, 1936, 1934 and 1933 is 1934.25, which is close to the fact. Therefore, with this method, the 1934 earthquake can be predicted and the error is smaller than 1-year, while the error is 10.7 years with Bakun's method.

For the starting year 1857, there are total 8 numbers and 4 shocked, the success rate is 50%; for the starting year 1901, there are total 4 numbers and 3 shocked, the success rate is 75%; for the starting year 1922, 2 numbers both shocked, so the success rate is 100%. That means this method can predict the future earthquakes with some accuracy, so we try to use this method to predict the 2004 earthquake. The result shows that the nearest year is 2002 when 1881 is considered as starting year, while all other results show a big error about 4-6 years, which means that this method cannot predict 2004 earthquake accurately.

4. For the 2004 Earthquake Prediction

For the Parkfield earthquake sequence 1857, 1881, 1901, 1922, 1934, 1966 and 2004, their interval was 24, 20, 21, 12, 32 and 38 years. We find an interesting point that 12/60 = 0.6, 21/32 = 0.656, 24/38 = 0.631. These three ratios are all close to 0.6, their average value is 0.629 which is close to the Golden ratio 0.618, and the difference is only 0.011. Therefore, we consider that maybe Fibonacci sequence could be used in this study. We construct a Fibonacci sequence 7, 12, 20, 32, 51, 83 (1-year error is allowed due to the Sun spot cycle is 11 - 12 years),

Table 1. Prediction about the 1934 earthquake with 11-year cycle, the bold number means the earthquake that has happened.

1857	1868	1879	1890	**1901**	1912	**1923**	**1934**
1881	1892	1903	1914	1925	1936		
1901	1912	**1923**	**1934**				
1922	**1933**						

and their ratio is 0.583, 0.6, 0.625, 0.627 and 0.614, respectively. We can see that with the number increase, their ratio is close to the Golden ration 0.618. We use this sequence to predict the 2004 earthquake and the result is listed in Table 2.

From Table 2 we can see that when six different starting year plus numbers from Fibonacci sequence, finally all the results point to the year 2003-2005. The average is 2004.3, which is close to the fact, while the error of Bakun's method is about 6 - 11 years. For the 1934 earthquake, if the interval 12 is used, 1922 + 12 = 1934, which means the 1934 earthquake can also be predicted with the Fibonacci sequence.

5. Prediction about the Next Earthquake

Based on the above method, we attempt to predict the next earthquake. We have known that no M6 earthquake happened in Parkfield from 2005-2019.

1) For the 11-year cycle method, we get Table 3. We can see that the former three of the four starting years point to 2032-2033, which means 2032-2033 will shock possibly.

2) For the multiple 11-year cycle, we find that 1857 + 65 = 1922, 1901 + 65 = 1966. We know that 65 was about 6 times of 11-year cycle, and 1966 + 65 = 2031. The 10 times of 11-year cycle is 109, 1857 + 109 = 1966, and 1922 + 109 = 2031. We plot the years in Figure 2 and then the regularity can be seen clearly.

3) For the Fibonacci sequence 7, 12, 20, 32, 51, 83, we get 20 + 7 = 27, and 2004 + 27 = 2031.

Table 2. Prediction about 2004 earthquake with Fibonacci sequence.

1857 + 83 + 51 + 12 = 2003
1881 + 83 + 20 + 20 = 2004
1901 + 83 + 20 = 2004
1922 + 83 = 2005
1934 + 20 + 51 = 2005
1966 + 32 + 7 = 2005

Table 3. Prediction about the next earthquake with 11-year cycle (bold means the earthquakes have happened).

1922	**1933**	1944	1955	**1966**	1977	1988	1999	2010	2021	2032
1934	1945	1956	**1967**	1978	1989	2000	2011	2022	2033	
1966	1977	1988	1999	2010	2021	2032				
2004	2015	2026	2037							

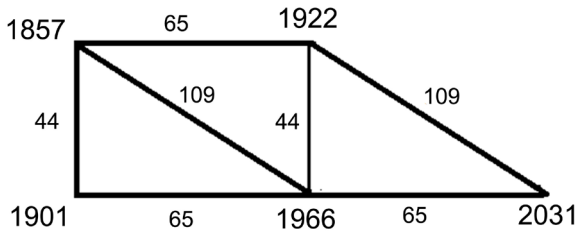

Figure 2. Earthquakes show a regular pattern in temporal domain.

4) For Bakun's linear regression equation $T = 21.7I + 1836.2$, when $I = 9$, $T = 2031.5$.

The above four results all point to the same year 2031-2032, therefore, we consider that Parkfield is most likely to have an earthquake in 2031-2032. Note that this result is just derived from the time series analysis, if combined with field survey data such as small earthquake activities, geophysical data etc, and then the result may be more reliable.

6. Conclusion

Here we reanalyze the Parkfield earthquake data and find an 11-year cycle and Fibonacci sequence existed for earthquake. Please note that 36 years passed since Bakun predicted Parkfield earthquake in 1984, and we are the first in the world to find Fibonacci sequence in Parkfield earthquake. Our method is simple but it performs well. With these cycles and sequence, the 1934 and 2004 earthquakes can be predicted well, while they cannot be predicted with Bakun's method [1]. This example suggests that the quakes in Parkfield do not follow the linear trend. For a linear regression method, even the correlation coefficient of the fit equation reaches 0.9; it only shows a good fit to the past laws. We do not know whether future events will still follow the old laws, or some new laws. In the case of Parkfield, the earthquake show a clear 11-year cycle and multiple 11-year cycle, while the 2004 earthquake does not follow these cycles, it follows a new Fibonacci sequence law, so the Parkfield earthquake prediction failed. Finally, in accordance with the 11-year cycle, multiple 11-year cycle and Fibonacci sequence, we predict that the next earthquake may occur in 2031-2032.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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