The Ordered Network Structure of $M \geq 6$ Strong Earthquakes and Its Prediction in the Jiangsu–South Yellow Sea Region

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The the Jiangsu–South Yellow Sea region is one of the key seismic monitoring defence areas in the eastern part of China. Since 1846, $M \geq 6$ strong earthquakes have showed an obvious commensurability and orderliness in this region. The main orderly values are 74 ∼ 75 a, 57 ∼ 58 a, 11 ∼ 12 a, and 5 ∼ 6 a, wherein 74 ∼ 75 a and 57 ∼ 58 a with an outstanding predictive role. According to the information prediction theory of Wen-Bo Weng, we conceived the $M \geq 6$ strong earthquake ordered network structure in the South Yellow Sea and the whole region. Based on this, we analyzed and discussed the variation of seismicity in detail and also made a trend prediction of $M \geq 6$ strong earthquakes in the future. The results showed that since 1998 it has entered into a new quiet episode which may continue until about 2042; and the first $M \geq 6$ strong earthquake in the next active episode will probably occur in 2053 pre and post, with the location likely in the sea area of the South Yellow Sea; also, the second and the third ones or strong earthquake swarm in the future will probably occur in 2058 and 2070 pre and post.

Key words: Jiangsu-South Yellow Sea Region; Division of Seismic Period; Strong Earthquake Chains; Informational Ordered Network Structure; Strong Earthquake Prediction.

1. Introduction

Earthquake prediction has been one of the difficult problems which science could not solve in the past hundred years around the world. In the 1980's, W.-B. Weng created the information forecasting theory and made outstanding achievements in prediction of earthquakes and other natural disasters such as drought and flood, opening up a brand-new path for the forecast of severe natural disasters [1 – 3]. Xu et al. [4 – 8] made a deep research on the time–space orderliness and characteristics of strong earthquake network in China and Asia, proposed the network hypothesis of earthquake occurrence and the concept of self-organized network, respectively, and further explored and developed the information forecasting theory [9 – 12]. A network hypothesis, which regards the earthquake as a multi-level, multi-factor, multi-dimensional network node, is helpful in the research of the complexity and the information orderliness of a major earthquake from the overall and dynamic perspective. In 2010, Xu, Men, and Deng firstly proposed the network structure of $M \geq 8$ earthquakes in China mainland [13], which is the important innovation and contribution to the research on $M \geq 8$ earthquake prediction. Since 1993, the author has concentrated on the earthquake prediction research, particularly devoting to studying the orderliness of seismic activity and its network structure, such as the $M \geq 7$ strong earthquakes in Xinjiang and the northern Tibetan Plateau region, the $M \geq 8$ great earthquakes in China mainland, as well as the $M \geq 6$ earthquakes in the Jiangsu–South Yellow Sea region, and made a number of research results [14 – 25].

The Jiangsu–South Yellow Sea region is located in the eastern part of East China, with the famous modern city Shanghai and the strong economic province Jiangsu in this region. Therefore, the trend of strong earthquake and its prediction research has great practical significance. Based on the above results, combining the information forecasting theory with complex network technology, this paper will make a thorough analysis and summary of middle and strong earthquake activities in time–space order from 1839 to 2011 in this region, revise and construct the ordered network structure of $M \geq 6$ earthquakes for mining and exploring its forecast function, and at the same time present a new prediction opinion about the next seismic active episode in order to provide an important basis for the work of earthquake preparedness and disaster reduction.

2. General Situation of Seismic Activity in the Research Area

In this paper, the research range is 31 – 35.5° N and 118 – 124.5° E, which is the main area of the middle and lower reaches of the Yangtze River–South Yellow Sea seismic belt (the Y-S belt). Its northern border is the 35.5 degree of north latitude, its western border is the famous Tancheng–Lujiang fault zone, and its southern border near by the South China active block. The Yellow Sea is located in its eastern part. In the research area, the faults are well-developed, the new tectonic movement and the modern tectonic movement are stronger. Since the territory is nearby to various groups of active fault intersection cutting in the NE, NNE and NW, NWW, the junction of depression and uplift are main places where earthquakes occur. The seismic activity level, both the intensity and frequency, are of medium level in the whole nation. Therefore, it has been listed as China's eastern key area for earthquake surveillance and protection over the years.

On one side, the research area belongs to the great North China seismic belt, which has the same tectonic stress field and both internally connect to each other; on the other side, they own different activity characteristics and activity stage episodes. In the distribution of time, the seismic activity in the research area is obviously inhomogeneous, and also presents a periodic characteristic which alternates from concentrated to calm. In the distribution of space, the most notable feature is the activity of earthquakes in the sea area which is far stronger than that in the land, as the majority of strong earthquakes occurred in the South Yellow Sea region, and the strain energy released by $M \geq 6$ earthquakes accounts for 92% of the whole research area. According to the characteristics of geological structure, four geological tectonics can be classified with apparent different earthquake activities: North depression area, Middle uplift area, South depression area, and Wunansha uplift area, which are from north to south in turn. The place of the greatest earthquake occurred in this area is in the South depression area, which was in 1846 with $M = 7$.

According to [23 – 27] and the seismic data [28 – 30], two seismic active periods could be divided in this research area from AD 1400 to now. The first one is from 1491 to 1838, which omitted most strong earthquakes; therefore, we will not discuss it. The second one is from 1839 to 2011, with three earthquake cycles in the research area. 45 earthquakes with $M \geq 5$ occurred in the total during of this period, among which are 16 strong earthquakes with $M \geq 6$ (see Tabs. 1 and 2). The first earthquake cycle lasted 66 a (1839 – 1904), which released $14.26 \cdot 10^7\ \mathrm{J}^{1/2}$ strain energy totally, including the first active episode lasting 17 a and releasing $12.04 \cdot 10^7\ \mathrm{J}^{1/2}$ energy. The second cycle lasted 69 a, releasing $12.76 \cdot 10^7\ \mathrm{J}^{1/2}$ energy, in which the second active episode lasted 28 a and released $12.11 \cdot 10^7\ \mathrm{J}^{1/2}$ energy. The third cycle has not finished from 1974 to 2011, which lasted 38 a. The third active episode during this cycle lasted 24 a from 1974 to 1997, and released $5.83 \cdot 10^7\ \mathrm{J}^{1/2}$ strain energy. Therefore, the seismic activity level of three earthquake cycles decreased in the order of time. The strain energy released by the third active episode is only 48% of the first and second one.

3. Analysis on Ordered Network Structure of $M \geq 6$ Strong Earthquakes in the Jiangsu–South Yellow Sea Region

3.1. Constructing Ordered Network of $M \geq 6$ Strong Earthquakes in the whole Research Area

According to the research by the author for many years [18 – 22], the strong earthquakes in the area present good orderliness and commensurability. By calculating, the main commensurable value (or commensurable element) of $M \geq 5$ earthquakes is about 2.9 a and that of $M \geq 6$ earthquakes is about 6.2 a. In particular, the orderliness of $M \geq 6$ earthquakes performs more significantly, with the major values of orderliness (or called order parameters) being 74 ∼ 75 a, 57 ∼ 58 a, 11 ∼ 12 a, and 5 ∼ 6 a. Figure 1 shows the ordered network structure of the $M \geq 6$ strong earthquake chain in the whole research area (including sea area and land). Based on the principle and approach for constructing network of [14], in order to prominent the rule of overall structure, the strong earthquake samples

Table 1. Catalogue of $M \geq 6$ strong earthquakes in the Jiangsu–South Yellow Sea Region (1846 – 2011).

No.	Dates Year-Month-Day	Epicentral location Latitude (°N)	Longitude(°E)	Magnitude (M)	Locality
1	1846-08-04	33.5	122.0	(7)	South Yellow Sea
2	1847-11-12	33.0	122.0	(6)	South Yellow Sea
3	1852-12-16	33.5	121.5	$(\geq 6\frac{1}{2})$	South Yellow Sea
4	1853-04-14	33.5	121.5	$(\geq 6\frac{1}{2})$	South Yellow Sea
5	1853-04-15	33.0	121.5	$(\geq 6\frac{1}{2})$	South Yellow Sea
6	1853-04-23	32.0	122.5	(6)	South Yellow Sea
7	1879-04-04	34.0	122.0	$(6\frac{1}{2})$	South Yellow Sea
8*	1905-09-29	33.8	121.5	$(6\frac{1}{2})$	South Yellow Sea
9	1910-01-08	35.0	122.0	$6\frac{3}{4}$	South Yellow Sea
10	1921-12-01	33.7	122.0	$6\frac{1}{2}$	South Yellow Sea
11	1927-02-03	33.5	121.0	$6\frac{1}{2}$	South Yellow Sea
12	1927-02-03	33.5	121.0	$6\frac{1}{2}$	South Yellow Sea
13	1979-07-09	31.45	119.25	6.0	Southwest Liyang, Jiangsu
14	1984-05-21	32.60	121.66	6.1	South Yellow Sea
15	1984-05-21	32.64	121.60	6.2	South Yellow Sea
16	1996-11-09	31.83	123.10	6.1	South Yellow Sea

Note No. 8*: in [28] the magnitude of this earthquake was $6\frac{1}{2}$, the magnitude was modified to 5.6 in [29].

Table 2. Division of seismic periods in the Jiangsu–South Yellow Sea Region (1839 – 2011).

Seismic episode	Experience of time: Stage	Years	Sum	Earthquake frequency: 5 – 5.9	6 – 6.9	≥ 7	Sum	Max magnitude (M)	Energy released $\sum\sqrt{E}\cdot 10^7 J^{1/2}$	Sum
1st active episode	1839 – 1855	17 a		6 (data miss.)	5	1	12	7	12.05	
1st quiet episode	1856 – 1904	49 a	66a	1	1	0	2	6.5	2.21	14.26
2nd active episode	1905 – 1932	28 a		10	5	0	15	6.75	12.11	
2nd quiet episode	1933 – 1973	41 a	69a	2	0	0	2	5.75	0.65	12.76
3rd active episode	1974 – 1997	24 a		9	4	0	13	6.2	5.83	
3rd quiet episode	1998 – 2042?	45 a?	69a?	1	0	0	?	5.0 (up to now)	(0.14)	(5.97)
4th active episode in the future	2043? –									

Note: Revised by Table 2 in [25].

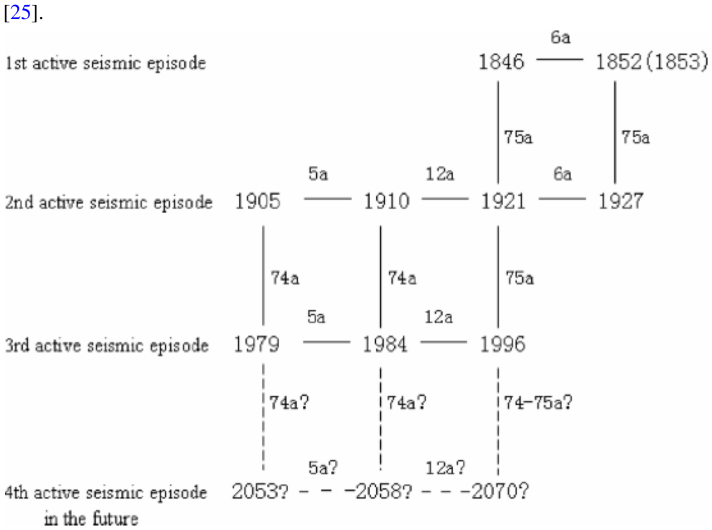

Fig. 1. Strong earthquake chains and their ordered network structure of $M \geq 6$ and prediction sketch map in the Jiangsu–South Yellow Sea region (dashed denotes prediction and followings are the same).

with great orderliness and commensurability are chosen as the network nodes. Here, sample 1879 was not chosed as a node of network in the orderliness analysis. In order to ensure the temporal association between the samples up and down, some individual samples can also be repeated in the network diagram. Sometimes it is difficult for a network diagram to give a comprehensive summary, therefore it can be described by a two-dimensional plane or a three-dimensional network diagram from different angles [13, 14]. In this paper, the sample 1847 and 1846 are combined, 1853 and 1852 are combined, with the left corner of the plane regarded as the coordinate origin, connected and expanded according to the time sequence from left to right, from up to down at the same time. The nodes are represented by the year of the strong earthquake occurrence, with the number in the line representing the time interval of the two earthquakes in the nodes. Also, individual situations are slightly adjusted. For example, the year difference between 1921 and 1910 is 11 a, however, the actual interval is 11.9 a, so it's calculated as 12 a; the year difference between 1910 and 1846 is 64 a, however, the actual interval is 63.4 a, so it's calculated as 63 a. The same in the following sample. The row shows the transitive relationship among the $M \geq 6$ strong earthquake chain in the same active episode. However, the column shows the connection relationship between $M \geq 6$ strong earthquakes in different active episodes.

Figure 1 depicts deeply the objective rule of $M \geq 6$ strong earthquakes in this area for the past 170 years, which is concise, accurate, and clear. Especially, the forecast feature of the orderliness value $74 \sim 75$ a is outstanding, which can transit between every active episode. However, $11 \sim 12$ a and $5 \sim 6$ a could only transit in the internal of an active episode. At the same time, Figure 1 reflects the classification of $M \geq 6$ strong earthquake active episodes brightly. Since the $M6.1$ earthquake in the South Yellow Sea in 1996, the activity of $M \geq 6$ strong earthquakes in this area has entered into a quiet episode. The author has well predicted the occurrence of the earthquake in 1996 based on the ordered structure net figure and the orderliness and commensurability in 1993 and 1995 [18, 19]. From Figure 1, we can predict that the next $M \geq 6$ strong earthquake will probably occur before or after 2053 by extending the first column to 74 a. This one will become the first $M \geq 6$ strong earthquake during the fourth active episode in the future. Also, the second

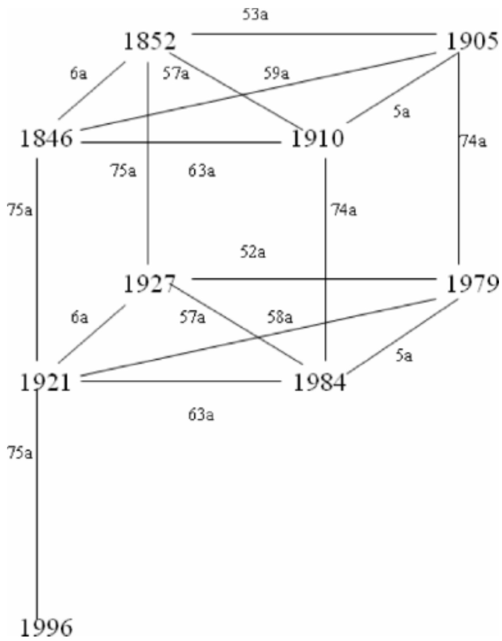

Fig. 2. Sketch of prediction for the 1996 South Yellow Sea $M6.1$ earthquake by using a 3D-ordered network structure.

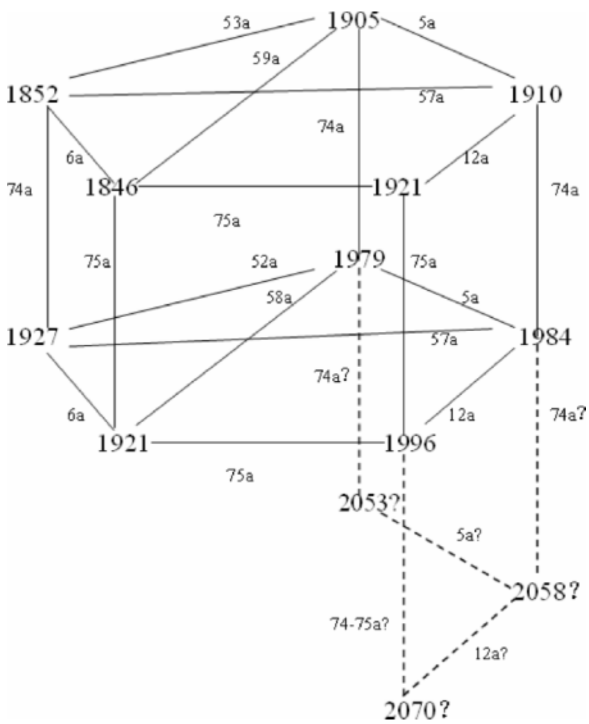

Fig. 3. 3D-ordered network structure and its prediction of $M \geq 6$ earthquakes in the Jiangsu–South Yellow Sea region.

and the third $M \geq 6$ strong earthquake or strong earthquake swarm in the future will probably occur in 2058, 2070 pre and post. (In this paper, each strong earthquake is named by its occurred year number, when the prediction error is ± 1 a, and followings are the same.)

If Figure 1 is regarded as three-dimension, then there will be the quadrangular shaped ordered network structure of $M \geq 6$ strong earthquakes in the whole research area as in Figure 2, extending from strong earthquake sample 1921 downward to 75 a, which is the $M = 6.1$ strong earthquake in the South Yellow Sea in 1996. And this result is consistent with the prediction result in Figure 1.

In the same way, if Figure 1 is regarded as three-dimension, we also find the five prism shaped 3D-ordered network structure showed as real line in Figure 3. Sample 1921 is repeated in order to connect the nodes in both sides up and down. Also, the figure generalizes and summarizes the activity rule of strong earthquakes relationship in this area since 1846 accurately. The strong earthquakes samples 1979, 1984, and 1996 in Figure 3 were extended downward to 74 a, respectively, which results in the strong earthquake prediction values 2053, 2058, and 2070 during the fourth active curtain. This is also consistent with the prediction results of Figures 1 and 2.

3.2. *Constructing Ordered Network of $M \geq 6$ Strong Earthquakes in the South Yellow Sea*

Figure 4 shows the ordered network structure plot of $M \geq 6$ strong earthquakes in the sea area of the South Yellow Sea. Since 1846, $M \geq 6$ strong earthquakes in the South Yellow Sea present clearly a feature of clusters: $M \geq 6$ strong earthquakes are distributed by three groups, with 57 a between each group and $11 \sim 12$ a or $5 \sim 6$ a between earthquakes in the same group. Firstly, the horizonal line in Figure 3 is regarded as the main chain, and each line shows a group of strong earthquakes in the same active episode (without aftershock). Secondly, the vertical bar plays the role of connecting and supporting, showing the relationship between two active episodes up and down and the procedure of the transition among the three groups by time sequence. Thirdly, the slash presents the leaping interval relationship.

For example, the leaping intervals are 63 a between the first (1846) and third (1910) sample, the fourth (1921) and sixth (1984) sample, which can be expressed by slash. Similarly, the leaping intervals are 69 a between the second (1852) and fourth (1921) sample, the fifth (1927) and seventh (1996) sample can be expressed by slash too. By analogy, among the three strong earthquake samples 1984 — 1996 --- the future event (defined as X), the leaping interval relationship between 1984 and X can be expressed by dotted slash (meaning prediction), whose time interval should also be 69 a. And the slash intersects with the vertical bar beginning from 1996 and extending 57 a at the point '2053' (which is No. 4 point in the parallelogram constituted by the solid and dotted lines (parallelogram), see Fig. 4).

Figure 4 presents clearly that the regularity is significant as followes: since 1846, the three strong earth-

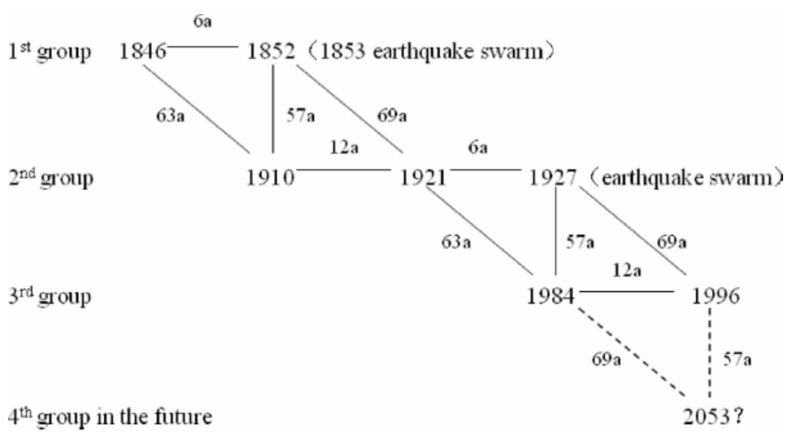

Fig. 4. Three groups of $M \geq 6$ strong earthquake chains and their ordered network structure in the South Yellow Sea since 1846.

quake and quiet earthquake episodes occured alternating with each other, however, the length of the quiet episodes almost remain 57 a. Based on the results in [23–25], since the $M5.1$ earthquake in 1997 in the South Yellow Sea, the whole research area has confirmed into a new cycle of quiet episode. Therefore, the position of $M6.1$ earthquake sample in the South Yellow Sea in 1996 is as same as that of strong earthquakes in 1927 and 1852, which shows a transition effect. The first $M \geq 6$ strong earthquake sample 2053 in the fourth group in future will come after a quiet episode with length of 57 a, which means the beginning of next active episode cycle in the South Yellow Sea area. If so, the four samples 1927 — 1984 — 1996 --- 2053 will form a very standard and stable quadrilateral in the future (see Fig. 4).

In Figure 4, there are seven samples in total expressing the three groups $M \geq 6$ strong earthquakes in the South Yellow Sea: 1846, 1852, 1910, 1921, 1927, 1984, and 1996. They almost form two congruent quadrilaterals: 1846 — 1852 — 1910 — 1921 and 1921 — 1927 — 1984 — 1996. This seems to indicate that the $M \geq 6$ strong earthquakes in the South Yellow Sea have self-reproduction characteristics (see Fig. 4). This paper used the approach which is like the genetic gene shear-bonding technology in biological engineering. Cut Figure 4 at the node 1921, parallel shelve the two quadrilaterals up and down, with the former one as the upper bottom, the later one as the lower bottom. Therefore, the above seven strong earthquake samples are another quadrangular-shaped 3D-ordered network (see Fig. 5). Here the sample 1921 is also repeated. Figure 5 summarized the active rule of $M \geq 6$ strong earthquakes since 1846 completely and deeply. From Figure 5, we can predict the occurrence of the $M6.1$ earthquake in the South Yellow Sea in 1996.

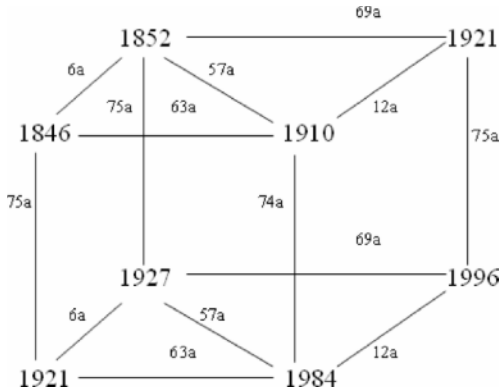

Fig. 5. 3D-ordered network structure of $M \geq 6$ strong earthquakes in the South Yellow Sea.

Vertically diagonal sectioned from the up to the bottom surface, Figure 5 can be decomposed into two ordered networks of triangular prism, as showned in Figure 6a,b. Figure 6a reflects that the $M = 6.2$ earthquake in 1984 coupling associated orderly with the samples 1846, 1852, 1910, 1921, and 1927; Figure 6b reflects that the $M = 6.1$ earthquake in 1996 coupling associated orderly with the samples 1852, 1910, 1921, 1927, and 1984. Figure 6 can be used to predict the strong earthquakes in 1984 and 1996.

3.3. *The Warp–Weft Strong Earthquake Chain in the whole Research Area*

These seven samples are the core ones not only in the South Yellow Sea area, but also in the whole

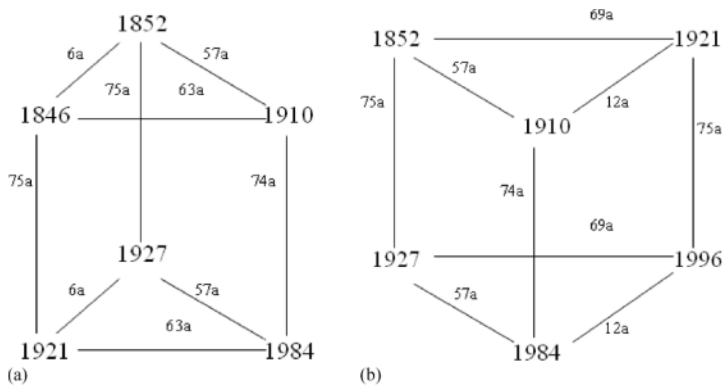

Fig. 6. Two triangular prisms by cutting the quadrangular.

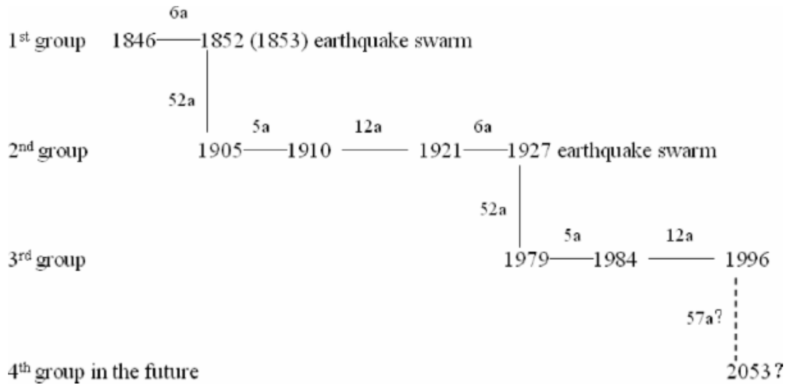

Fig. 7. Warp and weft chain of the $M \geq 6$ strong earthquake chain in the whole research area.

research area, which include the most important information of strong earthquakes. The three basic order parameters: 57 a (or 58 a), 11 a (or 12 a), 5 a (or 6 a), and their sum: 57 a + 12 a + 6 a = 75 a (or 74 a). Rearranging the samples in Figure 1 in the warp and weft strong earthquake chain according to time order as showed in Figure 7, it owns a feature of circulation by '6 a – 57 a (52 a + 5 a) – 12 a – ', which is interesting and attractive.

Figure 7 is the simplified structure of Figure 1, very clearly and accurately reflecting the connection relationship between the active episode and the quiet episode in the whole research area. Three wefts denote three active episodes, respectively, and two warps denote two quiet episodes, that is to say, the warp is the time interval between two active episodes. Three parallel wefts represent the three active curtains, respectively, and the two warps represent two calmly curtains. In other words, the warp representing a calm curtain is the time interval between the connected two active curtains before and after. According to the time order, the warp–weft strong earthquake chain in Figure 7 is decomposed into the following five earthquake chains with length being 75 a (or 74 a):

1. 1846 — 1852 — 1905 — 1910 — 1921, that is, 1846 (+75 a) → 1921;
2. 1852 — 1905 — 1910 — 1921 — 1927, that is, 1852 (+75 a) → 1927;
3. 1905 — 1910 — 1921 — 1927 — 1979, that is, 1905 (+74 a) → 1979;
4. 1910 — 1921 — 1927 — 1979 — 1984, that is, 1910 (+74 a) → 1984;
5. 1921 — 1927 — 1979 — 1984 — 1996, that is, 1921 (+75 a) → 1996.

So, we shall have a new earthquake chain with length being 74 a (or 75 a): 1979 — 1984 — 1996 → 2053?

From what has been discussed above, the strong earthquake activity is the main object in the research area. The first $M \geq 6$ strong earthquake in the fourth group in future will occur in 2053 pre and post, with the location in the sea area of South Yellow Sea.

4. Conclusion and Discussion

(i) The event in a strong earthquake chain is not isolated, but coupling intereacted with others before and after, and thus forming a network. That is called the emergence [31]. The strong earthquake chain network structure is a kind of implicit networks. In this paper, the proposed network structure of $M \geq 6$ strong earthquakes in the Jiangsu–South Yellow Sea region is a simple constrained generating process with different parameters or information. Since 1846, the seismic activity of $M \geq 6$ strong earthquakes has had an obvious self-organized orderliness, whose main ordered values are 74∼75 a, 69 a, 63 a, 57∼58 a, 11∼12 a, and 5∼6 a, wherein 74∼75 a and 57∼58 a are the most important parameters. They showed the relation between the three active episodes and the quiet episodes in this region, so they have a prominent predictor.

(ii) For over 170 years, the medium-strong earthquake activity in the Jiangsu–South Yellow Sea region has experienced three cycles. Since 1998, this region has entered into a new quiet episode, and it may be last to about 2042 pre and post. In this period, there still will be few earthquakes with magnitude 5 occurring, but generally no $M \geq 6$ earthquake or strong earthquake swarm. The first $M \geq 6$ strong earthquake of the next active episode may occur before or after 2053, and the location will be likely in the sea area of the South Yellow Sea; the second and the third $M \geq 6$ strong earthquake or strong earthquake swarm in the future will probably occur in 2058 and 2070 pre and post.

(iii) The prediction of strong earthquakes is a difficult topic in the world, but the development of promoting earthquake prediction should relied on innovation [32, 33]. This paper shows that strong earthquakes can be predicted. The ordered network characteristics presented by strong earthquake activity should be formed by a mechanism of strong earthquake. The structure is the base of function, and the function is the reflection of structure. Thus the structure is the rule. It is a kind of innovation that complex network technology is also applied to strong earthquake prediction research. The proposed network structure of $M \geq 6$ strong earthquakes in the Jiangsu–South Yellow Sea region covers highly of $M \geq 6$ strong earthquake activity in this region within more than 170 years and reveals the complex and ordered feature, showing its good prediction function. Also it will help us to deeply understand the rule of seismic activity, to effectively analyze and to solve the leaping prediction for moderate term and long term of strong earthquakes. So, it has very important practical significance to vigorously promote the earthquake prediction research and earthquake prevention and disaster reduction work.

(iv) It attracts people's attention that two earthquakes occurred recently: the $M5.0$ earthquake on Jan. 12, 2011, occurred in the South Yellow seismic belt (33.3° N, 123.9° E), which is the greatest earthquake for 14 years in the South Yellow Sea area; and the $M4.9$ earthquake on July 20, 2012, occurred in the junction of Gaoyou and Baoying (33.0° N, 119.6° E), with the focal depth being 5 km which made the whole province obviously felt. It is the greatest earthquake for the past 20 years in the land area of Jiangsu Province. The research in this paper shows that both of them are individual and isolated earthquakes in a quiet episode of this area, and the public don't need to worry as there will be no $M \geq 5.5$ destructive earthquake in the near future.

[1] W. B. Weng, Fundamentals of Forecasting Theory (in Chinese), Petroleum Industry Press, Beijing 1984.
[2] W. B. Weng, N. D. Lu, and Q. Zhang, Theory of Forecasting (in Chinese), Petroleum Industry Press, Beijing 1996.
[3] W. B. Weng, K. P. Men, and W. L. Qing, Primary Data Distribution (in Chinese), Petroleum Industry Press, Beijing 2004.
[4] D. Y. Xu, M. T. Wang, Q. G. Geng, and W. L. Wang, Prog. Geophys. **22**, 1375 (2007).
[5] D. Y. Xu and T. Ouchi, Chinese J. Geophys. **42**, 42 (1999).
[6] D. Y. Xu and T. Ouchi, Res. Rep. RCUSS **2**, 159 (1998).
[7] D. Y. Xu and T. Ouchi, Res. Rep. RCUSS **2**, 141 (1998).
[8] D. Y. Xu, G. Asteriadis, and D. Arabelos, Survey Review **35**, 204 (1999).
[9] D. Y. Xu and T. Ouchi, Prog. Abstr. Seism. Soc. Jap. **2**, 54 (1997).
[10] D. Y. Xu, Earth Sci. Front. **8**, 211 (2001).
[11] D. Y. Xu, Bull. Mineral. Petro. Geochem. **24**, 178 (2005).
[12] D. Y. Xu, in: Commentaries on the First Disaster Chains Seminar in China, China Meteorological Press, Beijing 2007, pp. 175.
[13] D. Y. Xu, K. P. Men, and Z. H. Deng, Eng. Sci. **8**, 13 (2010).
[14] K. P. Men and W. J. Liu, Z. Naturforsch. **66a**, 363 (2011).
[15] K. P. Men, Z. Naturforsch. **66a**, 681 (2011).
[16] K. P. Men, Z. Naturforsch. **67a**, 308 (2012).
[17] K. P. Men, Eng. Sci. **11**, 82 (2009).
[18] K. P. Men, Seism. Geomag. Observ. Res. **14**, 7 (1993).
[19] K. P. Men and B. Zhao, Seism. Geomag. Observ. Res. **18**, 65 (1997).
[20] K. P. Men and Y. X. Wang, Earthq. Res. Plat. **11**, 25 (1999).
[21] K. P. Men and D. Li, Northw. Seism. J. **22**, 134 (2000).
[22] K. P. Men, in: Review for the 20th Century: Academician Wen-Bo Weng and Natural Disaster Forecasting (in Chinese), Eds. M. T. Wang and Q. G. Geng, Petroleu Industry Press, Beijing 2001, pp. 121.
[23] K. P. Men, in: Progress Natural Disaster of Informational Forecasting in China (in Chinese), Eds. M. T. Wang and Q. G. Geng, Petroleu Industry Press, Beijing 2004, pp. 163.
[24] K. P. Men, Progr. Geophys. **21**, 1028 (2006).
[25] K. P. Men, Chin. J. Geophys. **52**, 2573 (2009).
[26] H. Z. Xie and J. M. Tian, J. Seismol. **3**, 1 (1998).
[27] J. M. Tian, X. Xu, H. Z. Xie, Y. Yang, and Z. Ding, Acta Seismol. Sinica **17**, 480 (2004).
[28] Earthquake Administration of Jiangsu Province, Historical Materials of Jiangsu Earthquake (in Chinese), Seismological Press, Beijing 1987.

[29] Department of Earthquake Disaster Prevention, State Seismological Bureau, Catalogue of Chinese Historical Strong Earthquakes (the 23rd Century B.C.–1911 A.D.) (in Chinese), Seismological Press, Beijing 1995.
[30] Department of Earthquake Disaster Prevention, China Earthquake Administration, Catalogue of Chinese Recent Earthquakes (1912 – 1990 A.D. Ms $\geq$ 4.7) (in Chinese), China Science and Technology Press, Beijing 1999.
[31] J. H. Holland, Emergence: From Chaos to Order, Oxford University Press, Oxford 1998, pp. 1.
[32] S. X. Xu, Rec. Dev. World Seismol. **2**, 1 (2003).
[33] S. X. Xu, Rec. Dev. World Seismol. **5**, 30 (2005).