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RESPONSE OF TRIASSIC SEQUENCE STRATIGRAPHY OF LOWER YANGTZE TO THE COLLISION BETWEEN THE YANGTZE PLATE AND THE NORTH CHINA PLATE

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Abstract

The characteristics of the Triassic sequences developed in the Lower Yangtze area display some great changes in both environment and climate. The change of environment was a transition from marine to continent via alternating environments. The change of climate was a transition from tropic (torrid) to warm and wet climate via subtropic dry climate. The type variations of the sequences were from the marine sequences to the continental sequences, corresponding to the changes of environments and climates. Sequence 1 is a type II of sequence of mixed clastic and carbonate sediments; sequence 2 is a type I of sequence of carbonate platform; sequence 3 is a type I of sequence of carbonate tidal flat-salt lagoon, sequence 4 is a type II of sequence of lacustrine within marine layers, and sequence 5 is a sequence of lacustrine-swamp. The development, distribution and preservation of those sequences reveal the tectonic controls and their changes in the background. The collision between the Yangtze plate and the North China plate was a great geological event in the geological history, but the timing of the collision is still disputed. However, the characteristics of Triassic sequence stratigraphy and sea level changes in the Lower Yangtze area responded to this collision. The collision started at the beginning of middle Triassic and the great regression in the Lower Yangtze area started 22Ma earlier than those in the world. The tectonic conditions occurred before and during the collision controlled the development of sequences and type changes.

Keywords: Yangtze plate; North China plate; Lower Yangtze area; Triassic; sequence; response

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Introduction

The collision between the Yangtze Plate and the North China Plate was a great tectonic event in the geological history of the continent of East Asia, which not only led to the forming of Dabie-Sulu orogenic belt, but also influenced the formation, development and evolution of the

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periphery basins. One of the focused problems is the time of the collision. Some results are from the studies of the ages about the formation of Ultra-high pressure metamorphic belt and the studies about the curves of the moving paleo-magnetic poles, as well as from the integrated analyses of the regional geology and related sedimentations. There are still some different ideas about the time and the style of the collision between the Yangtze Plate and the North China Plate owing to the data and the directions of the studies and analyses.

Lower Yangtze area is located to the south of the Dabie-Sulu orogenic belt, and had undergone complicated tectonics since Triassic. The Triassic tectonics changed the stable marine environments and paleogeography into the continental background. The stratigraphic record can arguably be considered to provide the only complete record of the effects of external forcing on basin evolution (Gupta *et al.*, 2000), and this forcing was related to the regional orogeny and the deep processes. The changes of sequences, from marine types to continental types in Lower Yangtze area during Triassic, reflected the changes of controls of sequence stratigraphy, such as relative sea level changes, climate variations, changes of sediment supply rates, and subsidence etc. Those changes may reveal the great tectonics of the background and the eustacy. In this paper we will discuss the characteristics of Triassic sequence stratigraphy and their controls of Lower Yangtze area, and the relationship to the collision between the Yangtze Plate and the North China Plate.

1 Development of sequence stratigraphy and type

1.1 Succession of lithography and facies

The sequences of Triassic started to develop under the background of regression, which occurred at late Permian in the Lower Yangtze area. Succession of Triassic strata are composed of early Triassic Qinglong Fm.(including Hushan Member and Changbomen Member), middle Triassic Zhouchongchun Fm., late Triassic Huangmaqing Fm. and Fanjiatang Fm. from bottom to top (Fig. 1) according to the data from the regional geological surveys*, *Lithostratigraphy of Jiangsu Province* (Xu, 1997) and our field study.

Hushan Member is mainly made of gray-yellow, gray mudstone and mud-limestone. The lower part of this member is of mudstone with some layers of mud-limestone; the middle is of interbedded mudstone and mud-limestone; the upper is of limestone and mud-limestone with some layers of mudstone, showing increasing in mudstone and decreasing in limestone vertically. This rock succession developed in Nanjing-Zhengjiang, while the lithography changed in Yixing-Liyang, decreasing in mudstone and bearing massive micrite calcirudite formed by the storm (Qian *et al.*,1995). The lithography in Suzhou-Wuxi changed further, not only decreasing in mudstone, but also developing intraclastic limestone, oolite limestone, oncolite limestone, stromatolite limestone and dolomitic calcarenite. Some burrows and bird-eye structures developed in upper part of this succession. Hushan Member is slop (ramp) facies with mixed fine clastic and carbonate sediments,

* Geological Survey of Jiangsu Province, 1965, The exponent of geological map of Changzhou (1:200000); Geological Survey of Jiangsu Province, 1976, The report of the survey of regional geology of Changzhou and Suzhou (1:200000)

contacted with Dalong Fm. or Changxing Fm. in conformity.

Cangbomen Member is composed of two sub-members. The nodular limestone sub-member is the lower part of Cangbomen Member, which is an association of gray micrite limestone interbedded with gray-yellow micrite nodular limestone. The vermiform limestone sub-member is the upper part of Cangbomen Member, which is an association of gray vermiform limestone interbedded with gray micrite limestone and dolomitic rock, and gypsum and halite increase on the top of the sub-member. This rock succession developed in Nanjing – Zhenjiang. In Yixing- Liyang, the nodular limestone decrease in the lower part of Cangbomen Member and the vermiform limestone is interbedded with micrite calcirudite and burrow limestone in its upper part, and on its top is the sparite oolite limestone. In Suzhou-Wuxi, the lower part of Cangbomen Member is micrite calcarenite interbedded with sparite oolite limestone. Its upper part is micrite limestone and sparite oolite limestone. The Cangbomen Member is carbonate platform facies.

Zhouchongcun Formation is made of two Members in Nanjing - Zhengjiang. The lower Member mainly is an association of gypsum breccia, micrite limestone and dolomite with some gypsum layers. The upper Member mainly is an association of micrite limestone, micrite dolomite, gypsum breccia and silt mudstone, and there is wire chicken structure developed. In Yixing -Liyang, Zhouchongcun Formation mainly is of micrite limestone, dolomitic limestone and calcirudite, and some bird-eye structures and gypsum pseudocrystals developed there. In Suzhou- Wuxi, Zhongchongcun Formation mainly is of fine and coarse crystal limestone, and some gypsum developed locally (e. g., Zhengluqiao, Wujin). The exposure structures often occur on the top of the formation. Zhongchongcun Formation is carbonate tidal flat-salt lagoon facies.

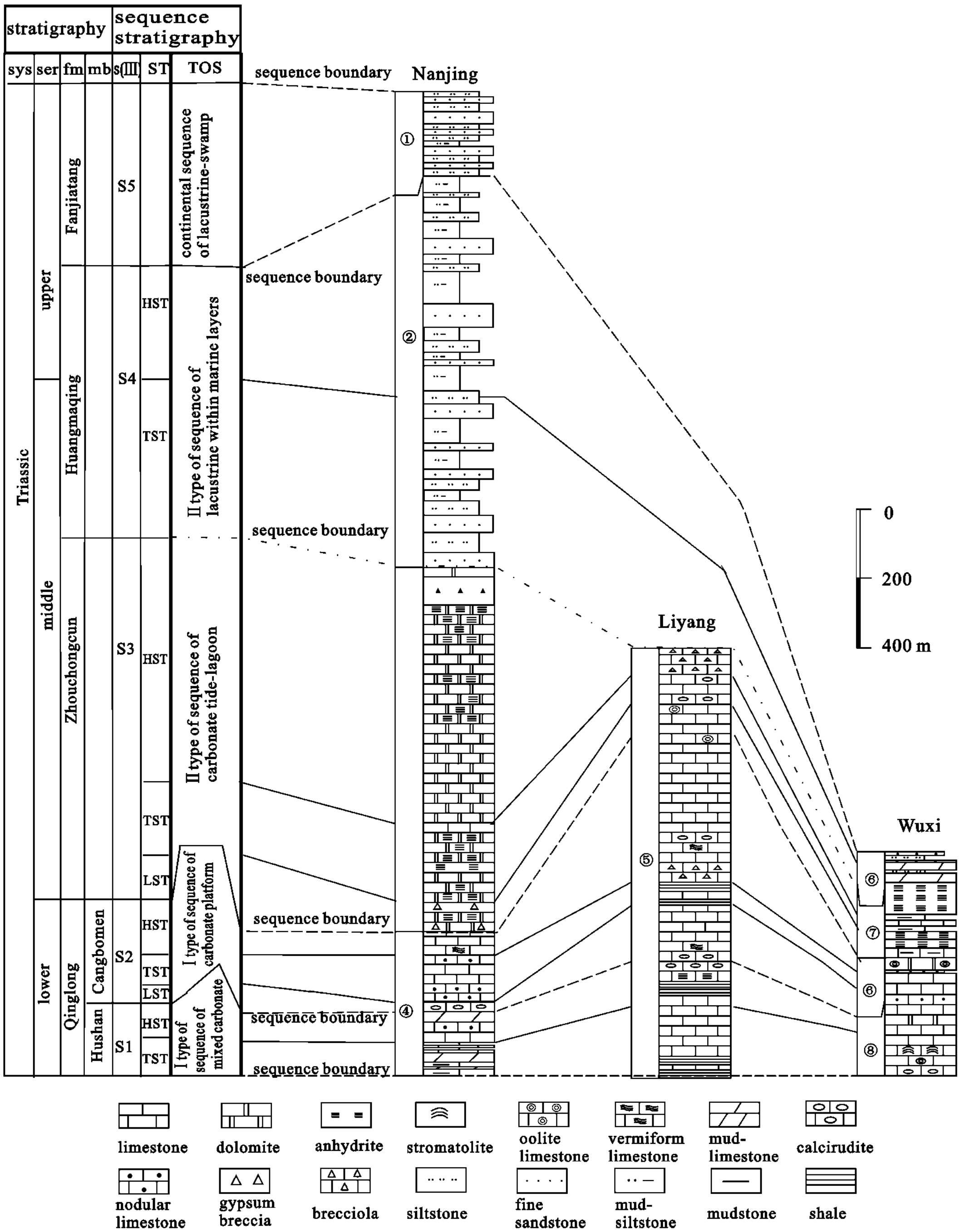
Huangmaqing Formation is made of two parts. The lower part is of thick gray-yellow, gray-green fine feldspar sandstone interbedded with siltstone. The upper part is of thin-thick purple-amaranth greywacke interbedded with silt mudstone, and the conglomerates and crossbeddings developed locally. Huanmaqing Formation is lacustrine facies influenced by sea.

Fanjiatang Formation mainly is of middle- thick dark gray fine feldspar quartz sandstone, siltstone interbedded with middle- thin black mudstone and coal bearing pyrite nodule. Fanjiatang formation is lacustrine –swamp facies.

1.2 Sequences and their types

The Triassic strata of Lower Yangtze area can be divided into 5 Ⅲ rank of sequences and 2 II rank of sequences by lithography and facies of this succession, surfaces' features, durations and paleontology (Fig. 2).

Sequence 1is Hushan Member of Qinglong Formation, whose bottom boundary is a surface of a parallel unconformity or conformity occurred between Hushan member and upper Permian, and whose top surface is the bottom of Cangbomen Member. This sequence is composed of transgressive systems tract (TST) and highstand systems tract (HST). TST is represented by mudstone interbedded with mud-limestone, reflecting extending of transgression and some varied environments in shallow sea background. The decreasing of mud sediments was related to the sea



LST-Lowstand Systems Ttract; TST-Transgressive Systems Tract; HST-Highstand Systems Tract

sys-system; ser- series; fm - formatiom; mb-member; S(Ⅲ)- Ⅲ rank of sequence; ST- Systems Tract; TOS - Types of Sequences

① profile 15 of Fanjiachang,Baohua,Jurong County; ② Zhongshan profile, Nanjing; ③ Drilling Zk105, Nanjing; ④ Longtan profile, Nanjng; ⑤ Shanghuang profile, Liyang; ⑥ Drilling 2, Nanmen, Wuxi; ⑦ Zhengluqiao profile, Wujin County; ⑧ Songshan profile, Wuxi County

Fig. 1 Correlation of Triassic sequence stratigraphy of Lower Yangtze area

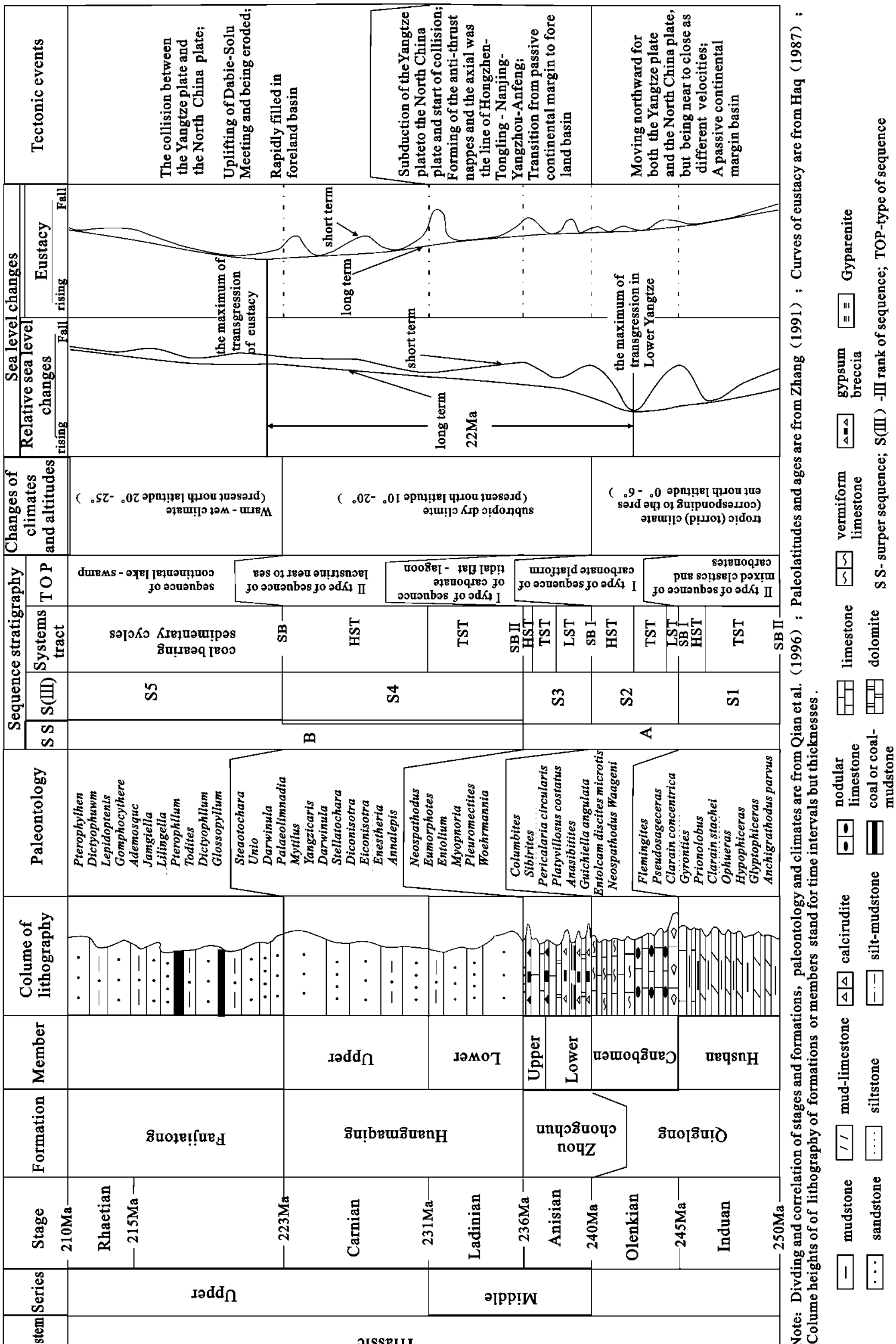


Fig. 2 Triassic Sequence Stratigraphy and Sequence controls of Lower Yangtze area

extension and far from source area. The west Zhejiang and the northeast Jiangxi belonged to the same Triassic sea basin with Lower Yangtze area, where the calc-siltstones and sandy shales developed, as shore-shallow sea sediments (Qian et al., 1995), showing that the sources were from the south ancient land. The laminar mud limestone and shale, the sediments of condensed section, developed there, presenting the maximum of transgression's coming. HST is represented by the limestone and mud limestone, reflecting well-developed carbonate slope which was related to decreasing of the terrigenous clastics, clean water, sunshine and prosperity of livings. The development of carbonate began at the transgressive stage in some place, such as Songshan Wuxi where a carbonate shoal formed instead of mud sediments, as a high land existed under water. In other places such as Suzhou, Yixing, Guangde and Nanling, the developments of carbonates were earlier than that of in Nanjing and Chaohu, reflecting the deep water developed there. The early Triassic Yangtze sea basin was that the south was shallow and the north was deep in geography based on the direction of clastic supplies and variation of water depths. In a suitable condition, carbonates grew rapidly, which made sea water shallow and sea level dropped relatively, leading to the occurrence of the exposure structures, such as the bird-eye structures developed in Suzhou-Wuxi. The development of sequence 1 ended when the slope carbonate system changed into carbonate platform system. The sequence 1 is a II type of sequence of mixed clastics and carbonates.

Sequence 2 is Changbomen Member of Qinglong Formation, whose bottom boundary is a conformity surface of erosion at bottom of this Member. The sequence is composed of lowstand systems tract (LST), transgressive systems tract and highstand systems tract. LST is represented by a set of the micrite calcirudite occurred on the erosion surface. The forming of the erosion surface was related to landslip- gravity flow happened on the ramp of carbonate platform, showing the sea level dropped down below the margin of the platform and the platform might expose and be eroded. TST is represented by micrite nodular limestone interbedded with limestone. Increasing of the nodular limestone reflects that the water depth was near to CCD, developing solution facies (Meng et al., 1993), and implying the coming of the maximum flooding. Decreasing or thinning of the nodular limestone in Yixing- Liyang and Suzhou-Wuxi reflects that the water depth was shallow due to the high basement landform there. It is a local feature to develop sparite oolite limestone and micrite calcarenite in Suzhou-Wuxi. HST is represented by the vermiform limestone and dolomite. It is a feature that sparite oolite limestone and dolomite developed widely in the east to Nanjing-Zhenjiang. Occurrence of dolomite implied the formation supatidal salt environments, reflecting falling of sea level. The development of sequence 2 ended when carbonate platform system changed into carbonate tide- salt lagoon system. Sequence 2 is a I type of sequence of carbonate platform.

Sequence 3 is Zhouchongcun Formation, whose bottom boundary located at the bottom of this formation, marked as the thick massive solution breccia, contacted the under rocks with a conformity or erosion which was related to the exposure resulted from falling of sea level. The sequence is composed of LST, TST and HST, formed within a tidal flat – Lagoon basin. LST is represented the thick solution breccia, micrite dolomites and anhydrocks, reflecting the exposure, salty and fresh water leach, while the sea level may be lower than that of the lagoon basin. TST is represented by the thick solution breccia interbedded with middle-thin micrite limestone, formed during a turbulent transgression. The transgression got its maximum when the thin micrite limestone was distributed stably. HST is represented by the micrite limestone, micrite dolomite, solution breccia and silt-mudstone. The features are of : 1) evident exposure structures, such as the wire chicken structure and the gypsum pseudocrystals; 2) higher content of dolomite ; and 3) the imputing of the terrigenous clastic materials. The development of sequence 3 ended when the carbonate tidal flat- lagoon system changed into the lacustrine system near to sea. Sequence 3 is a I type of sequence of carbonate tidal flat- lagoon.

Sequence 4 is Huanghuanqing Formation, whose bottom boundary is located at the bottom of this formation, marked as the gray feldspar quartz sandstone, contacted the under rocks with a conformity. This sequence is composed of transgressive systems tract and highstand systems tract. TST is represented by the gray fine quartz feldspar sandstone interbedded with calc-siltstone and silt-mudstone of shore –shallow lake facies. The silt-mudstone bearing marine fossils was formed during the maximum flooding (Xu, 1999). HST is represented by the sediments of shore – shallow lake facies with purple-amaranth color, showing the ending of direct control of sea level. The development of sequence 4 ended when the lacustrine system near to sea changed into the continental lake-swamp system. Sequence 4 is a II type of sequence of lacustrine near to sea.

Sequence 5 is Fanjiatang Formation, whose bottom boundary is located at the bottom of this formation. This is a sequence of continental lake-swamp basin, which is not easy to describe in the terms of “systems tract”. It is composed of some coal bearing cycles forming the lake –swamp sedimentary rhythms. The maximum coal accumulation occurred in the middle of sequence evolution, which may correlate with the maximum flooding of lacustrine basin. Sequence 5 ended due to the coal accumulation and the inputting of clastics. Sequence 5 is a sequence of continental lake-swamp.

Supper sequence A is made of sequence 1, sequence 2 and sequence 3, and Supper sequence B is made of Sequence 4 and sequence 5 (Fig. 2).

2 Changes of sedimentary environment, climate and sea level

Sedimentary environments changed greatly from sequence 1to sequence 5 in the Lower Yangtze area. The change of environments was a transition from marine to continent via a marine -continent alternating environment. The sequence types also changed. The important change was that the marine environment was vanished.

The climates of the Lower Yangtze area were changed with the great variations of environments (Fig. 2), proved from the rocks and the fossils in the conserved strata. Qian et al. (1996) studied the climate changes, showing that the change of climate was a transition from tropic (torrid) climate of early Triassic (corresponding to the present north latitude 0 ° -6 °) and subtropic dry climate of middle Triassic (present north latitude 10 ° -20 °) to warm - wet climate of late Triassic (present north latitude 20 ° -25 °) (Fig. 1). The great changes of climates in the same area might be related to the long distance migration of the climate zone.

Development of sequence is not only related to sedimentary environment, sedimentation, and changes of relative sea level and climate, but also controlled by eustacy. There was a long term of eustacy in Triassic (Fig. 2), according to the curve of sea level changes (Haq et al., 1987). Its duration was 255-211Ma, in which 255-250Ma was late Permian, a stage of great sea level fall. The transgression of Triassic started at 250Ma, the beginning of Induan. The maximum flooding was at middle- late Carian, 225.5Ma. The sea level got its lowest at the end of Rheatian. Under the long term setting there were some short term fluctuations of sea level- Ⅲ cycles. In general, There were 10 Ⅲ cycles including 1 cycle from 250Ma to 245Ma; 3 cycles from 245Ma to 239Ma; 1cycle from 239Ma to 237Ma; 1 cycle from 237Ma to 232Ma; 2 cycles from 232 Ma to224Ma; 1 cycle from 224Ma to 215Ma; and 1 cycle from 215Ma to 211Ma. Comparatively, the stage of maximum transgression was at Ladinian, Carnian and Norian, and the height of sea level was lower at Iduan, Olenkian and Rheatian. The other feature was that fluctuations of sea levels of Olenkian were frequent, with 3 short terms.

The sea level changes, reflected from Triassic sequence development of the Lower Yangtze area may be correlated with the long terms of eustacy, but the differences are clear. Not all the Ⅲ cycles of the Lower Yangtze are correlated with the global standards of Haq's, 1vs 3 at Olenkian; 1vs3 at Ladinian - Carnian; 1vs 3 at Norian- Rheatian; only 1vs 1 at Induan. Those differences may be related to the precision of the study. Tong et al. (1996) divided Qinglong Formation of Songshan, Wuxi (Griesbachian and Dienerian of Induan – Smithian of Olenkian) into 24 parasequences and 3 sequences. However, more important thing is the difference of the types of sequences developed under the setting of the transition from marine to continent in Lower Yangtze area, and the most important control of the sequences after Olenkian was not the global sea level changes. During the long term of sea level change of the Lower Yangtze, the great regression stared at the middle of Olenkian, but the global regression stared at the middle of Norian, being a time span about 22Ma. Is it related to the transition of marine to continent? After Ladinian there were sequences of marine –continental alternating type and continental type developed, and the sequences of Norian-Rhaetian were not controlled by sea level changes directly, although the global transgression happened, which showed that the Lower Yangtze was away from sea.

3 Age of the collision between the Yangtze Plate and the North China Plate

The following facts can be gained from the development of Triassic sequences in the Lower Yangtze area:

1) The great sedimentary environment changes were happened from marine carbonate environment to the continental lake-swamp environment. The transitional face was the bottom boundary of sequence 4, occurred between Zhouchongchun Formation and Huangmaqing Formation at early Ladinian.

2) The great climate background changes were happened from tropic (torrid) to warm and wet climate via a subtropic dry climate.

3) The type variations of sequences were from type II of sequence of mixed clastic and carbonate rocks, type I of sequence of carbonate platform and type I of sequence of carbonate tidal flat- salt lagoon to type II of sequence of lacustrine within marine layers and sequence of

lacustrine- swamp. The main control of the sequences turned from the sea level changes into the tectonics under the background of climate changes.

4) The great regression stared at middle Olenkian made Lower Yangtze area away from sea.

Those facts reveal that a great geological event had happened since the middle of Triassic, which is related to the problems about the collision between the Yangtze plate and the North China plate and the closure of the ancient Qinling ocean. There exists a disputed problem on the timing of the collision between the Yangtze plate and the North China plate, including Neo-Proterozoic (Zhang et al., 1989), early Paleozoic (Xu et al., 1988), and Triassic (Li et al., 1989; Xu et al., 1992; Ames et al., 1993; Cong et al., 1994). The ancient latitude moving tracks of the Lower Yangtze plate and the North China plate from the data of paleomagnetism (Nanjing and Shijiazhuang as the reference points)(Zhang, 1991), show the latitude changes of both plates from Sinian to Quaternary. The distance between the two plates was very great during Sinian- Permian, especially at Sinian it was more than 3000km, enough to exist an ancient Qinling ocean. After Sinian the two plates were moving close up slowly. They began to move close rapidly at Triassic, and began to move with the same step at Jurassic. The latitude changes of the Lower Yangtze plate were from about North latitude 4 ° to about North latitude 20 ° during Triassic. The study of paleomagnetism not only interprets the great climate changes of Triassic in Lower Yangtze area, but also reveal that the time of the collision and melting of two plates and the closure of ancient Qinling ocean was Triassic not before. The study of Sm/Nd age of eclogite and ultrabasic rock occurred in Dabie suture zone (230-240Ma)(Li et al., 1989), and the study of Wulian complex rocks of Sulu orogenic zone (Zhou et al., 2003), also prove that the time was middle- late Triassic.

4 Discussion

The styles of sequence stratigraphy was a response to the collision between the Yangtze plate and the North China plate during Triassic in the Lower Yangtze area, which gives the stratigraphic proves about timing of the collision. Those stratigraphic features not only validate the time studies from the curves of moving paleomagnetic poles and the formation of the ultrahigh pressure belt of Dabie-Sulu, but also reveal the processes of the interaction of two plates through the sequence types and their controls.

Lower Yangtze basin developed on the passive continental margin under the extensional background at early Triassic (Li, 2001), succeed to the paleogeography of late Permian. In general, the basin was deep in north and shallow in south, and the transgressive direction was from north toward south as that of Permian (Chen et al., 1999). The II type of sequence of carbonate mixed with clastics developed with the sea level changes. The terrigenous clastic materials came from the south craton land. The sequence developed on a gentle slope and the deep water area was Nanjing-Chaohu. Under the humid –hot climate condition, fast growth of carbonates had the slope turned to be the platform where I type of carbonate sequence developed. The eustacy of early Triassic still controlled the development of the sequence although the Yangtze plate was near to the North China plate. The Yangtze plate began to subduction to the North China plate at middle Triassic. Closing of the two continents had carbonate tide- salt lagoon developed in the Lower

Yangtze area, being a remained sea basin between the continents at that time (Li, 2001). The basin was turned to be a foreland basin and the climate changed into dry hot. Under this situation, the I type of sequence of carbonate tide- lagoon developed while the supply of terrigenous clastics added. Closing and collision of the two plates led to starting a great long term of transgression in the Lower Yangtze area at middle of Olenkian, earlier 22Ma than that of eustacy of Triassic. The II type of sequence of lacustrine within marine layers developed in the tectonic setting of intensive collision of the two plates during late of middle Triassic (Ladinian)- early of late Triassic (Carnian). This II type of sequence developed well contacted with the sequence below in a conformity in the area where was the central zone of the anti-thrust nappes with a lower topography, whose axial was the line of Hongzhen – Tongling – Nanjing – Yangzhou – Anfeng (Yang, 1997). The tectonics had been the main control to the sequence, although it was still influenced by the changes of sea level. The supply of terrigenous clastics was also an important control factor of sequence development. The sediments with feldspar and metamorphic clastics indicted that they came from the Dabie – Sulu orogenic belt. Sea water had been withdrawn from the Lower Yangtze area and the climate had turned to be dry hot during highstand stage of the sequence development, which led to form the mauve sediments, different from the underlain dark color sediments. Tectonics, lake level changes, climate and rate of supply of clastics were the controlling factors, of which the tectonics is first, other than sea level changes. When Yangtze plate and North China plate joined together, the II type of sequence of lacustrine within marine layers turned into a continental lake-swamp sequence under the warm and wet climate. Although the sea level was still rising at that time, it did not influenced the sequence development directly.

5 Conclusions

Although the other studies, such as the ultrahigh pressure metamorphism of Dabie – Sulu, the paleo- magnetism of the Yangtze plate and the North China plate, the source of sediments and the evolution of environments, may gain the ideas about the collision between the two plates and timing, it is necessary to have the proves from sequence stratigraphy, because the development of sequences can reflect better than the sediments themselves in the controls and changes. Sequence stratigraphy can put controlling factors, such as eustacy, tectonics, relative sea (lake) level changes, climate changes and rate of sediment supply and sources, together with types of sequences. The transition of sequences of Triassic in the Lower Yangtze area and the advent of the long term regression 22 Ma earlier were the stratigraphic responses to the collision between the Yangtze plate and the North China plate. The time of subduction, collision and joining of the two plates is middle- late Triassic. With the interaction between the two plates, the ancient Qingling ocean was closed and the Dabie-Sulu mountain was uplifted, while the sedimentary records related to the collision of the two plates were conserved in the Triassic strata in the Lower Yangtze basin.

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References

Ames L, Tilton G R and Zhou G Z. 1993. Timing of collision of the Sino- Korean and Yangtze craton: U/Pb zircon dating of coesite bearing eclogites. *Geology*, 21:339-342

Cheng Shiyue and Liu Huanjie. 1999. Sequence stratigraphic framework and its characteristics of the Carboniferous-Permian in North China. *Acta Sedimentologica Sinica*, 17(1):63-70 (in Chinese with English abstract).

Cong B, Wang Q, Zhai M et al. 1994. Ultrahigh pressure metamorphic rocks in Dabie-Sulu region, China: their formation and exhumation. *The Island Arc*, 3:135-150.

Gupta S and Cowie P. 2000. Processes and controls in the stratigraphy development of extensional basins. *Basin Research*, 20(3/4): 185-194.

Haq B U, Hardenbol Jan and Vail P R. 1987. Chronology of fluctuating sea levels since the Triassic. *Science*, 235: 1136-1167.

Li Jinyi. 2001. Pattern and time of collision between the Sino-Korean and Yangtze blocks: Evolution of the Sinian-Jurassic sedimentary settings in the middle-Lower reaches of the Yangtze River. *Acta Geologica Sinica*, 75(1): 25-34 (in Chinese with English abstract).

Li Shuguang, Hart S, Zheng Shuanggeng et al. 1989. Sm-Nd isotopic evidences of collision between North China plate and South China plate. *Science in China (D)*, (3): 312-319 (in Chinese).

Meng Xianghua and Ge Ming. 1993. Study of intrabasin sediments. Petroleum Industry Publishing House, Beijing (in Chinese).

Qian Maiping and Guo Peixia. 1995. Paleogeographic evolution and marine storm deposits presented in Triassic strata in the lower Yangtze Valley. *Geology of Jiangsu Province*, 19(2):77-82 (in Chinese with English abstract).

Qian Maiping and Guo Peixia. 1996. The evolution of paleonotologic and paleogeographic faces in Triassic period in the lower Yangtze valley and its essential cause. *Geology of Jiangsu Province*, 20(3): 156-165 (in Chinese with English abstract).

Tong Jinnan and Li Hongli. 1996. Lower Triassic sequence stratigraphy of Songshan, Wuxi, Jiangsu. *Journal of Stratigraphy*, 20(4):257-261 (in Chinese with English abstract).

Xu shutong, Jiang Laili, Liu Yican et al. 1991. Tectonic framework and evolution of the Dabie mountains in Anhui, eastern China. *Acta Geologica Sinica*, 66(1):1-14 (in Chinese with English abstract).

Xu Xueqiu. 1999. The stratigraphic framework of Triassic period in south Jiangsu. *Geology of Jiangsu Province*, 23(3):141-147 (in Chinese with English abstract)

Xu Xuetian. 1997. Lithostratigraphy of Jiangsu Province. China University of Geosciences Press, Wuhan (in Chinese).

Xu Zhiqin, Zhang Jianxian, Xu Huifen et al. 1997. Ductile shear zones in the main continental mountain chains and their dynamics. Geological Publishing House, Beijing (in Chinese).

Yang Shengliang. 1997. Structural features and oil and gas potential of the Mesozoic in Xiayangzi region of China. *Petroleum Exploration and Development*, 24(3):10-14 (in Chinese with English abstract).

Zhang Shuye, Hu Ke, Liu Xiaochun et al. 1989. The characteristics of Proterozoic blueschist – white schist - eclogite in central China: A trinity of ancient intercontinental collapse-collision zone. *Journal of Changchun University of Earth Science*, Sup: 152-157 (in Chinese with English abstract).

Zhang Yonghong. 1991. Huangqiao transform event in tectonic evolution of lower Yangtze region and the Meso-Paleozoic hydrocarbon exploration target. *Oil & Gas Geology*, 12(4):439-448 (in Chinese with English abstract).

Zhou Jianbo, Zheng Yongfei and Wu Yuanbao. 2003. Zircon U-Pb ages for Wulian granites in northwest Sulu and their tectonic implications. *Chinese Science Bulletin*, 48(4):379-384.