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Tectonic sequence framework and sedimentary basin evolution of upper triassic in the sichuan basin, China

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ABSTRACT

The Late Triassic is an important geologic age for the evolution of the Sichuan Basin. Based on data from field outcrops, drilling, and seismic acquisition, a detailed study on the sequence boundaries, division, and characteristics of the Upper Triassic in the Sichuan Basin was conducted using tectonic sequence stratigraphy to establish a sequence stratigraphic framework. The research indicates that four sequence boundaries were distinguishable in the Upper Triassic: 1) regionally structural unconformity between the Upper Triassic and Middle and Lower Triassic; 2) the boundary between the second member of the Xujiahe Formation and the Xiaotangzi Formation; 3) the secondary structural unconformity between the third and fourth members of the Xujiahe Formation; and 4) regionally structural unconformity between the Triassic and Jurassic. Based on the occurrence of sequence boundaries, three tectonic sequences could be divided in the study area, each of which was bound by the maximum flooding surface and subdivided into basin extension (BE) and basin wither (BW) system tracts. The evolution of the Western Sichuan Foreland Basin was the main evolution in the Late Triassic, in which TS1 represents the evolution stage of the marginal foreland basin, TS2 represents the formation of the Western Sichuan Foreland Basin with the advent of the Longmen Mountain thrusting and napping body, and TS3 represents the development of the Western Sichuan Foreland Basin. In TS3, the Longmen Mountain was thrust and folded to form the mountain, which was affected by the An County Movement, such that the entire Sichuan Basin transferred into a continental depositional environment. This provided a large amount of carbonate fragments for western Sichuan Basin and became the principal provenance in this area. Tectonic movement is a major controlling factor of the Sichuan Basin evolution in the Late Triassic.

KEYWORDS

Tectonic sequence; Basin evolution; Upper Triassic; Western sichuan foreland basin; Sichuan basin.

INTRODUCTION

The Sichuan Basin is situated in the western Yangtze Paraplatform, bound by the Qinling Mountain Folding Zone to the north and the Songpan-Ganzi Folding Zone to the west. It is a rhombic structural-depositional basin formed by deep intersecting NE- and NW-trending faulting in the Upper Yangtze Paraplatform (Figure 1). The Sichuan Basin, a sedimentary basin superimposed by Mesozoic, Cenozoic, and Paleozoic strata, experienced multiple-phase tectonic movements from the Sinian to Quaternary. The main body of depression was located in the western region in the Late Triassic, referred to as the “Western Sichuan Foreland Basin” (WSFB)[3,4,5,7,11,14,15,17,18,24]. Outcrops of the Upper Triassic are widespread but generally incomplete, with the strata formed in the early Late Triassic mostly absent in this area. Moreover, lateral and vertical variation in the thickness, lithology, and lithofacies of the Upper Triassic are extremely large, making the study on this series very difficult. Previous research indicates that evolution of the Sichuan Basin in the Late Triassic was mainly controlled by tectonic evolution, with the paleogeographic environment transiting from marine to transitional to continental environments[12,13]. This basin has the characteristics of multiple provenances and rapid facies changes.

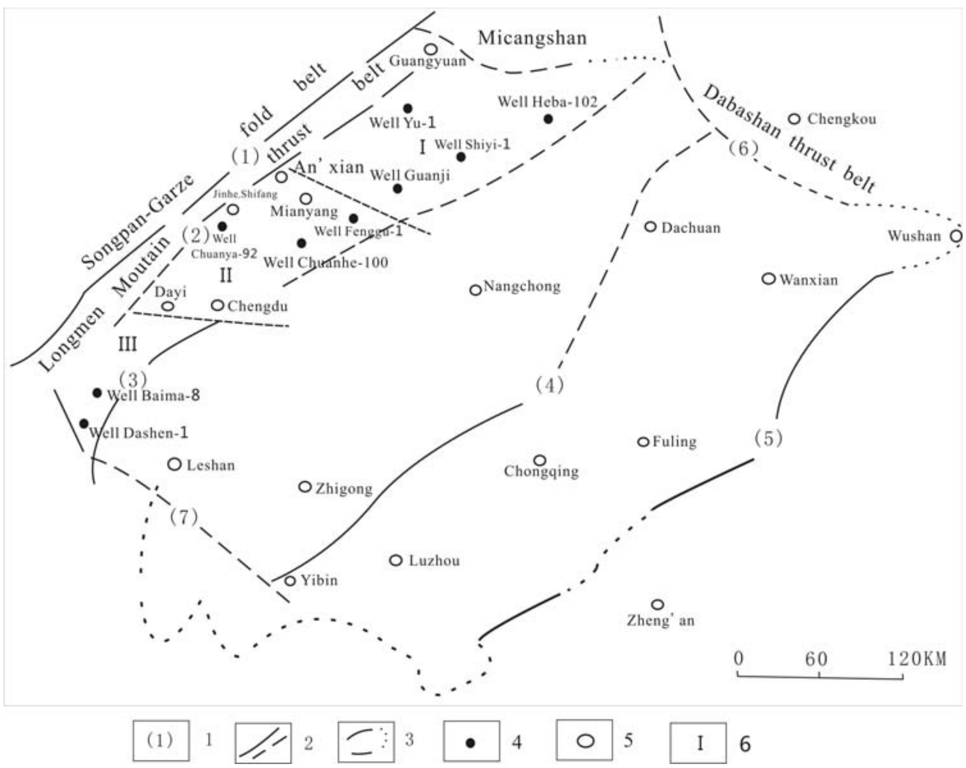


Figure 1 : A sketch tectonic map of Sichuan Basin (modified from Tong-chongguang, 1985); 1.Fault: (1) Longmen Moutain fault; (2) Pengguan fault; (3) Xiongpo fault; (4) Huayingshan fault; (5) Qiyueshan fault; (6) Wuxi-Tiexi fault; (7) Emei Washan fault. 2.Contemporaneous faults(including basement faults). 3. Basin range. 4. Well names. 5. Place names. 6. Zone: I—The northern of Longmen Moutain; II—The middle of Longmen Moutain; III—The southern of Longmen Moutain.

The tectonic sequences were formed in the background of tectonism, bound by unconformities or corresponding conformities. The basin exhibits depositional basin-type tectonic evolution[19], with its stages consistent with episodic tectonic cycles[8]. The tectonic sequence method has the scientific, quantitative, predictive, and comprehensive advantages that could make up for deficiencies of lithostratigraphic studies on the basin. Moreover, it provides a single composite method for more accurate geochronologic correlation, paleogeographic reconstruction, basin generation and evolution, and the prediction of sedimentary mineral commodities. In addition, this method is important for the analysis of basin tectonic movements. Some geologists have successfully applied tectonic sequence stratigraphy theories to the analysis of depositional basins[1,4,21,22,25,27,28]. Detailed studies, division, and correlation has been conducted on sequence boundaries and characteristics of the Upper Triassic Sichuan Basin on the basis of such previous research outcomes with regard to field outcrops, drilling cores, logging, and seismic data. This has enabled the establishment of the sequence framework using tectonic sequence stratigraphy to solve isochronous correlation in the Upper Triassic and to analyze basin evolution.

SEQUENCE BOUNDARIES

The sequence boundary is the key for sequence division. It separates not only new and old strata across this boundary, giving the sequence chronostratigraphic meaning (in other words, the sequence constrained by boundaries is an isochronic unit), but also divides sequences and defines genetic types. Furthermore, it provides important landmarks for regional isochronic correlation and sequence stratigraphic framework construction. With regard to terrestrial infill basins, cyclic napping tectonic movements of basin marginal mountains are the principal controlling factors dictating sequence development and boundary formation. With respect to thrusting and napping of adjacent tectonic mountains, structural unconformities and large erosion scours (depositional break) occur cyclically in basin margins, with thick alluvial fan depositional wedges, represented by conglomerate, prograded into the basin center. Widespread maximum flooding surface, represented by black shale and muddy limestone in the basin cycles, corresponds with the weakening and cession of thrusting and napping of adjacent tectonic mountains, and is retrograded from the inner basin to the basin margin. In the Mesozoic and Cenozoic continental basins in the same tectonic regime, the above two boundaries exhibit strong isochroneity, widespread and consistent extension extent, and clear recognizable marks, making reliable sequence boundaries.

As mentioned above, several sequence boundaries are identifiable in the Upper Triassic, Sichuan Basin:

1. One regional tectonic unconformity occurs between the Upper Triassic and Middle and Lower Triassic and exhibits accordant unconformity over the majority of this region. The strata was absent to varying degrees in the underlying Middle and Lower Triassic. The boundary is rough with paleokarsts in which residual clay, oxidized caps, and breccias filled in the underlying beds, and debris and coal fragments filled dissolution caverns in the overlying beds. The boundary in the front range of the Longmen Mountain zone sometimes displays angular unconformity in which the underlying strata were folded in differing intensities. The intersecting angle of the upper and lower strata is clear, and a paleoweathering surface is common.
2. The boundary between the second member of the Xujiahe Formation and the Xiaotangzi Formation is a lithologic and lithofacies transform surface.
3. A secondary unconformity by tectonic movement occurs between the third and fourth members of the Xujiahe Formation. It has a significant seismic reflection profile, with consistent lateral extension and distinct truncation with microangular unconformity. This secondary unconformity is a product of the An County Movement, as confirmed by drilling data[20]. On surface outcrops in Haiwozi-Weizidong, Peng County, this boundary is found as a microangular unconformity with underlying strata of the third member and overlying strata of the fourth member. The intersecting angle of these members is 10°–16° with a rough boundary. The cutting depth reaches 1 m with root clay[4]. A bauxite bed consisting of diaspore has been found in the upper third member in the Heba 102 well, NE Sichuan (between the third and fourth members) (Figures. 2 and 3).
4. A regional tectonic unconformity occurs between the Triassic and Jurassic, with distinct lateral continuity. On surface outcrops, the Middle and Lower Jurassic strata in the northern section of the Longmen Mountains overlapped on different horizons of the Xujiahe Formation with angular unconformity. The underlying strata were folded and deformed. The Middle Jurassic Qianfoya Formation in the central section of the Longmen Mountains has a high-angular unconformity on the Xujiahe Formation with an intersecting angle of 40°–50° and fluctuating boundaries, above which a 20–30-cm-thick grayish white clay bed occurs[10].

Besides the four sequence boundaries stated above, almost all tectonic sequences have one significant flooding surface, which is also an important landmark for large-scale sequence tracing and correlation.

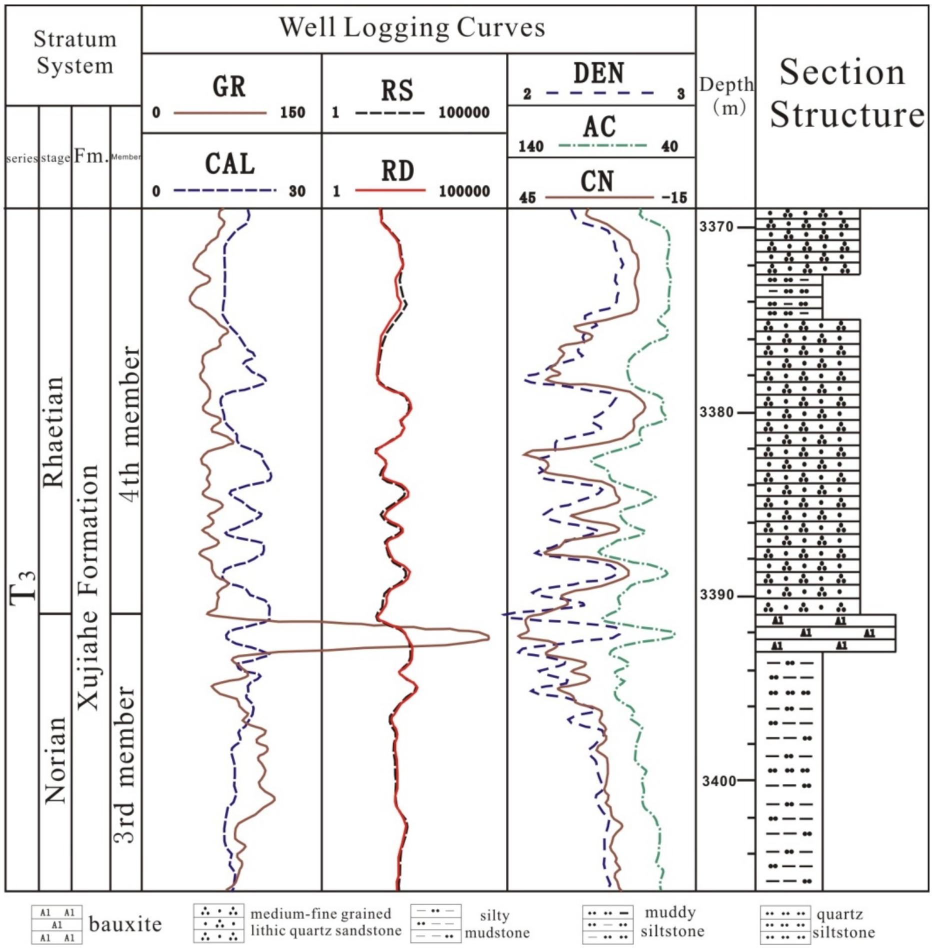
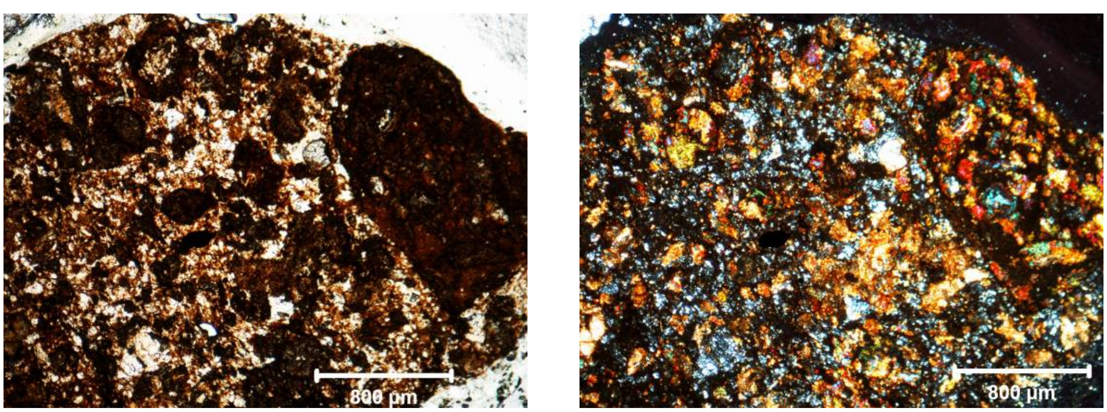


Figure 2 : The vertical development characteristic of bauxite in Well Heba 102.



polarized light (-) **perpendicular polarized light (+)**

Figure 3 : Pisolitic bauxite from 3391 m to 3392 m in Well Heba 102.

SEQUENCE DIVISION

Based on the unconformity levels, other sequence boundaries in the outcrops, and drilling (logging) profiles, the Upper Triassic in the Sichuan Basin was divided into three tectonic sequences.

Each tectonic sequence was subdivided by the maximum flooding surface into two system tracts, namely the Basin Extention System Tract (BE) and the basin wither system tract (BW) (Figure 4).

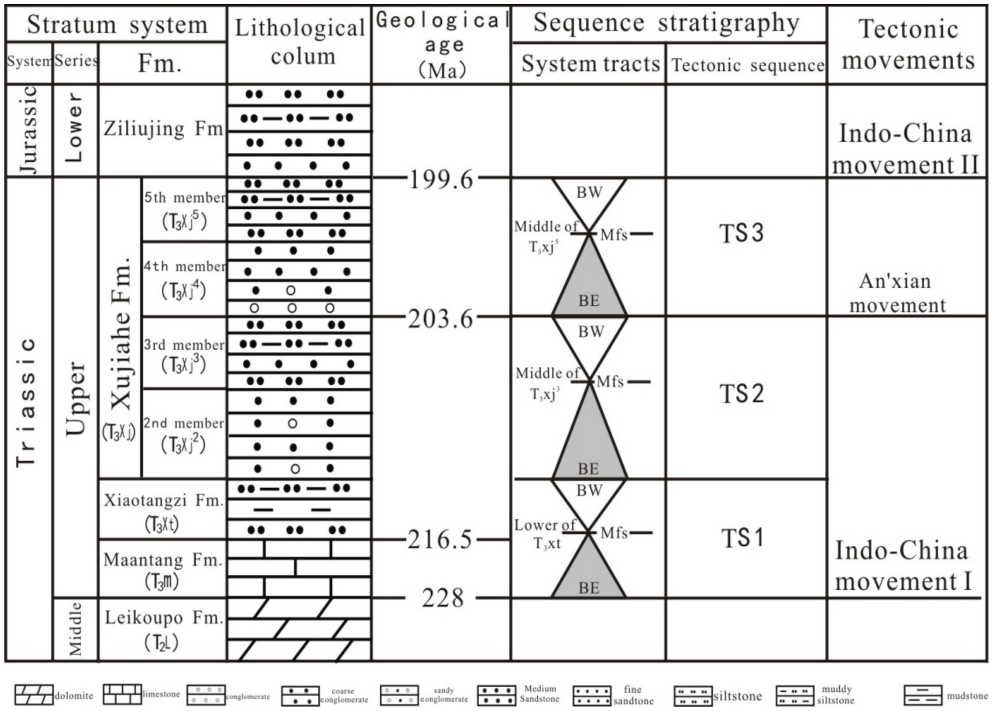


Figure 4 : The division of the upper Triassic tectonic sequence in Sichuan basin.

SEQUENCE CHARACTERISTICS

1. TS1 tectonic sequence

The TS1 sequence consists of the Maantang and Xiaotangzi Formations. It occurs predominantly in the western Sichuan area (the Longmen Mountain Front), whereas it is absent in other areas. This sequence has regional unconformity with an early episode of the IndoChina Movement forming the base, and alithologic and lithofacies transitional boundary between the Xiaotangzi Formation and the second member of the Xujiahe Formation as the upper layer. The sequence in the BE system tract generally consists of the Maantang Formation. From Mianzhu to Hanwang, the lithology of this formation is muddy limestone and oolitic limestone with sponge bioherms, which is the product of normal marine deposits. Conversely, the sequence in the BW system tract consists mainly of the Xiaotangzi Formation. In the profile for the Guangyuan-Gongnong Town, the lithology of the Xiaotangzi Formation is yellowish green calcareous argillutite, light gray, thin–intermediate–thick, heterogranular, lithic quartzsiltite, which is the product of transitional deposition[13]. The maximum flooding surface is located on the bottom of the Xiaotangzi Formation.

2. TS2 tectonic sequence

TS2 consists of the second and third members of the Xujiahe Formation. The top is composed of a regional unconformity formed by the An County Movement. In this sequence, the BE system tract predominantly consists of the second member. The lithology is mainly light gray, grayish white, fine–intermediate-granular lithic arkose and feldspathic lithic quartz sandstone with common scour bottom produced from transitional deposition. The BW system tract consists mainly of the third member, with the lithology consisting of mainly dark gray, grayish black shale and mudstone intercalated with siltstone, fine sandstone, charcoal lineation, and coal seam products of continental deposits[12]. The maximum flooding surface of this sequence is the base of the third member.

3. TS3 tectonic sequence

TS3 consists of the fourth and fifth members of the Xujiahe Formation. The top is a regional unconformity between the Triassic and Jurassic. In this sequence, the BE system tract consists predominantly of the fourth member, with a lithology composed primarily of conglomerates, conglomeratic sandstone, lithic sandstone intercalated with sandy mudstone and muddy limestone, and occasional charcoal lineation as the products of alluvial fan and fluvial deposition. The BW system tract generally consists of the fifth member, the lithology of which is mainly gray-dark-gray, fine-granular lithic sandstone, siltstone, and grayish black shale with common plant fossils, resulting from lacustrine and deltaic deposition[12]. The maximum flooding surface of this sequence is the base of the fifth member.

BASIN EVOLUTION

In the Late Triassic, the evolution of WSFB was the major occurrence in the Sichuan Basin. Besides the confinement from deep geologic-geophysical processes, its formation, development, and evolution were intensively controlled by the thrusting and napping of the Longmen Mountains. Based on previous research, tectonic evolution of the WSFB in the Late Triassic was divided into three stages: the marginal foreland basin stage ($T_{3\ m} \rightarrow T_3xt$), the formation of the foreland basin ($T_3x^2 \rightarrow T_3x^3$), and the development of the foreland basin ($T_3x^4 \rightarrow T_3x^5$)[2,3,4,5,14,15,17,18,23]. Their evolution characteristics are as follows:

1. Marginal foreland basin stage–1st tectonic sequence ($T_{3\ m} \rightarrow T_3xt$, TS1)

The first tectonic sequence was developed in the marginal foreland basin stage and primarily consists of the Upper Triassic Carnian (Maantang or Kuahongdong Formation) and Lower Norian (Xiaotangzi Formation).

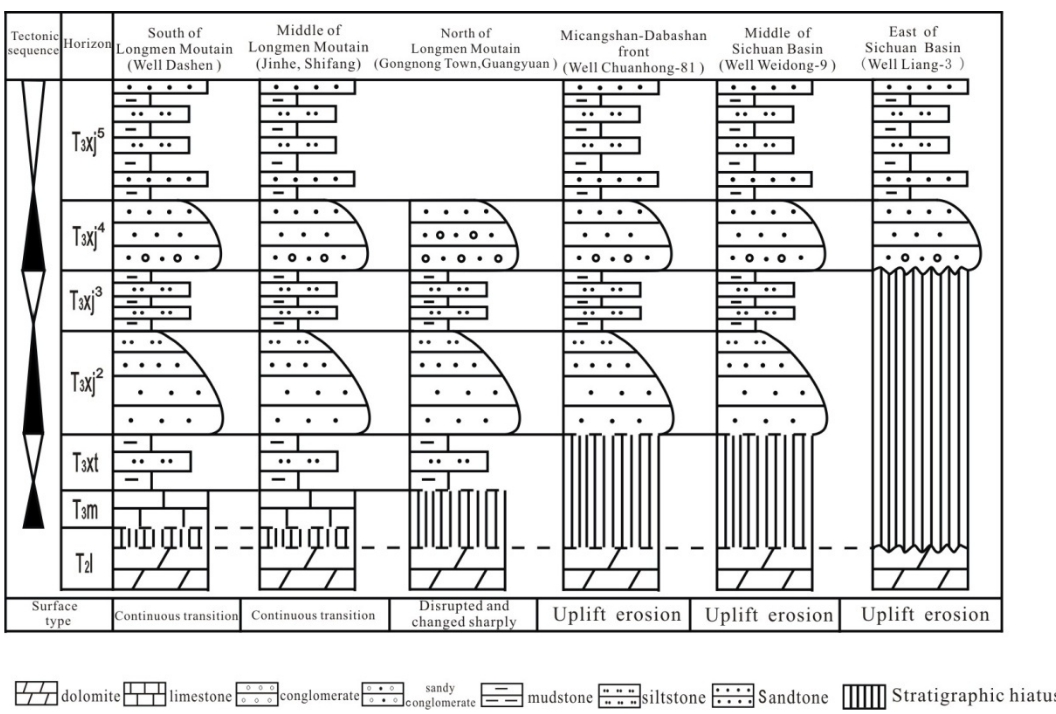


Figure 5 : The boundary style and profile characteristic of the upper Triassic in Sichuan basin

The lower boundary is a regional unconformity between the Upper Triassic and the Middle and Lower Triassic (the product of the IndoChina Movement). In other words, the structural unconformity at the base of the Maantang Formation (Carnian) acts as the bottom boundary of the first tectonic sequence (TS1), the configuration of which differs because of diverse intensities in regional tectonic movements in this basin (Figures. 5 and 6). The bottom sequence boundary occurs between the Maantang Formation (or Kuahongdong Formation) and the underlying Leikoupo Formation in the southern and middle sections of the Longmen Mountain Front. The strata are basically consistent with insignificant depositional variation, with a continuous transition surface, and transitional type. In the northern section of the Longmen Mountains, the bottom sequence boundary occurs between the Xiaotangzi Formation and the underlying Leikoupo Formation with the hiatus. The depositional environment transited from a marine carbonate platform to a terrestrial clastic one, and the transition surface was disrupted and changed sharply. In front of the Micang Mountain-Daba Mountain, in the central and eastern Sichuan areas, transition boundaries occur between the second and fourth members of the Xujiahe Formation and the underlying Leikoupo Formation. The earlier strata were eroded because of a sharp change in the depositional environment and uplifting in the Luzhou-Kaijiang area. The transition boundary is, therefore, the uplift–erosion type, and the first structural sequence was not developed.

In the early stages of the Late Triassic (Carnian), in the back-Longmen Mountain zone and the Songpan-Ganzi area to the west, the large-scale extensional faulted depression became the Songpan-Ganzi sag trough. In this trough, a huge thick marine flysch formation and continental slope turbidite were deposited with numerous patterns of Bouma sequences, generally over 3,000 m and about 10,000 m at the maximum, along with ammonite, radiolaria, and other plankton. However, organic limestone in a shallow-marine organic banks and bounds was deposited in the front range of the Longmen Mountain zone and the current western Sichuan Basin. Common shallow-marine organisms, like sponges, crinoids, and corals, in the Maantang Formation along Jiangyou, An County, and Mianzhu indicate that no large islands between the Sichuan and Aba Sea Basins existed without the barrier of seawater circulation.

At the end of the Carnian, after the deposition of the Triassic Xikang Group, the Songpan-Ganzi area was folded and deformed[16]. However, it remained below the water level, with the western Songpan-Ganzi area retaining a seawater connection with the water body in western Sichuan, maintaining a shore–deltaic depositional environment. The study of rock fragment composition[13] indicates that the Longmen Mountain thrusting and napping zone was yet to be formed at that time.

2. Formation stage of WSFB-the second tectonic sequence ($T_3x^2 \rightarrow T_3x^3$, TS2)

This tectonic sequence corresponds to the formation of the WSFB with the bottom of the boundary of the Xiaotangzi Formation and the second member and the top of the boundary of the third and fourth members (the product of the An County Movement). In this stage, due to the initiation of thrusting and napping of the Longmen Mountains, the miniature orogenic belt was formed. Part of the area uplifted in a large range that began to crest the water, generating a NE-trending island arc. A large area of residual withering multi-island sea basin occurred to the west of this island arc, and the WSFB, mainly compression, depression, and subsidence to the east, began to evolve. On the aspect of stratigraphic distribution, the second and third members of the Xujiahe Formation pinched out towards the central basin and show the half-graben basin framework, which is thicker westwards, faulting in the west and overlapping in the east (Figure 6).

Changing the tectonic setup must cause variation in the depositional environment and sediments. Along with the formation of the western island arc in the study area and the particular uplifting of the Jiuding Mountain and Motian Ranges to partially separate the Aba Sea and form bays in the BE stage, the deltaic sediments were widely developed to form huge thick sand bodies, which thinned from west to east. In the Shifangjin River profile, trace element analysis in argillaceous rocks (the second member of the Xujiahe Formation) indicated a similar Sr/Ba trend as that in the lower first member, both of which were higher than 1. In the upper third member, the value was lower than 1, which shows that in the second member of the Xujiahe Formation, the Shifangjin River was in a marine environment and that the study area was connected with the Aba Sea[12].

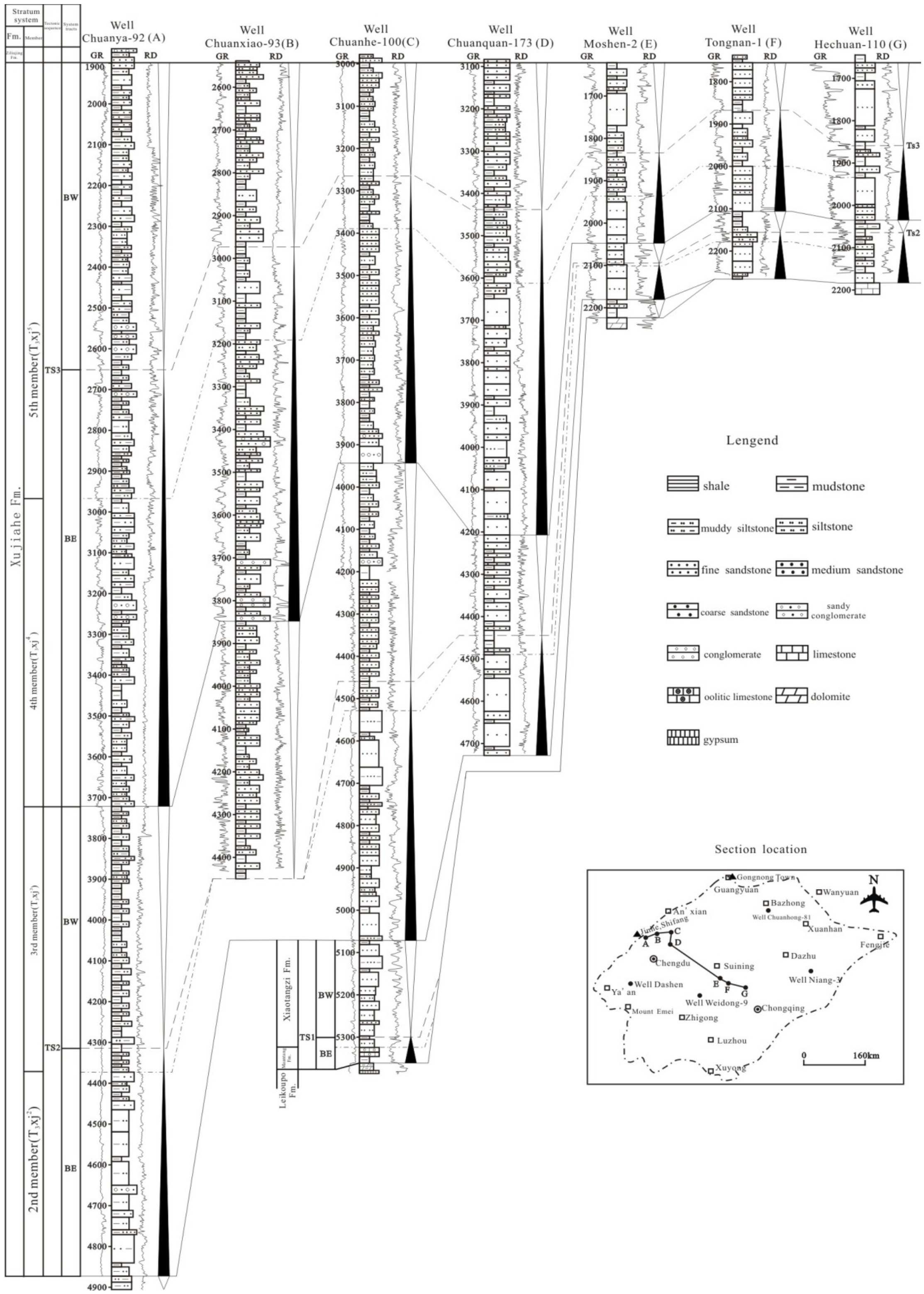


Figure 6 : The Stratigraphy and tectonic sequence correlation of the upper Triassic from Well Chuanya 92 to Well Hechuan110 in Sichuan basin.

Along with intensive activity of the Longmen Mountain thrusting and napping body, the islands in the west were further uplifted and expanded, and the composition of light and heavy sandstone minerals in the front range of the Longmen Mountain varied significantly (TABLE 1). A large amount of sedimentary rock occurs in certain areas, namely in the northern section of the Longmen Mountain, with a lithology of predominantly carbonate sedimentary rock fragments. The content of the rock fragments in sandstone (Well Siyi-1) increases from 14.30% in the second member to 76.00% in the third member and from 11.57% to 74.00% in the second member (Well Guanji). In the central section, where the lithology is mainly carbonate rocks, siltstone, and muddy shale, the content increases from 8.29% in the second member to 33.00% in the third member for Well Chuanya-92 and from 12.50% to 48.00% in Well Fenggu-1. Whereas in the southern section, in which the lithology is primarily siltstone and muddy shale, the content increases from 8.04% in the second member to 60.00% in the third member for Well Baima-8 and from 2.57% to 35.00% for Well Dashen-1. They could explain that it had become the principal provenance of western Sichuan along with continuous uplifting of the Longmen Mountain thrusting and napping body and could provide a large amount of rock fragments with poor wear resistance for this area.

Marine deposition generally ended in the BW stage in the Sichuan Basin. Aside from a few brackish-water bivalve fossils in the local strata, which indicate the connection with the Ganzi-Aba Sea by channels (Li et al., 1999), almost the entire study area entered into evolution of a continental environment. In the BW stage, the depositional environment was lacustrine–deltaic–front in the west, shore–shallow–lacustrine in the central region, and mostly deltaic plains in the east. The subsidence center was located in the Longfengchang area (Well Longfeng-1), the thickness of which reached over 1,000 m.

3. Development stage of WSFB-the third tectonic sequence ($T_3x^4 \rightarrow T_3x^5$, TS3)

This tectonic sequence corresponds with the development stage of WSFB, in which the boundary of the third and fourth members of the Xujiahe Formation are the bottom (the product of the An County Movement) and the boundary of the Xujiahe Formation and Jurassic are the top (the product of late episode of IndoChina Movement). The infill depositional sequence has an overlapping and thinning trend from west to east (Figure 6).

The Longmen Mountain Thrusting Zone was intensively folded and formed mountains by the influence of the An County Movement. The entire Sichuan Basin subsequently entered into a continental environment, with alluvial fans in the northwest and northeast, deltaic front–shore–shallow-lacustrine in the central and western regions, and deltaic plains in the east and south.

In addition, the light and heavy minerals of sandstone in the front range of the Longmen Mountain vary significantly (TABLE 1). In the northern section of the Longmen Mountain, the rock fragments of sandstone in the fourth member are primarily depositional, particularly carbonate with a content of over 95%. The content of rock fragments in Well Yu-1 increased from 18% in the third member to 66.06% in the fourth member. A large suite of conglomerates, predominantly limestone and dolomite, occurred at the base of the fourth member. The profile of the Gongnong Town, Guangyuan, indicates a similar conglomeratic bed. Our analysis indicates that the geologic age of these conglomerates is mainly D-T_2. No conglomeratic bed occurred in the southern section of the Longmen Mountain.

The rock fragments in the fourth member was also depositional, however, they are the association of siltstone and muddy shale. The content decreased from 60.00% to 27.91% in the third member (Well Baima-8) and is 34.54% in the fourth member, equivalent to the 35.00% recorded for the third member in Well Dashen-1. In the central section of Longmen Mountain, the rock fragments in the fourth member were mainly depositional, an association of carbonate rocks, siltstone, and muddy shale, reflecting its role as the “transitional zone” of the northern and southern sections. The content increased from 33.00% in the third member to 38.40% in the fourth member in Well Chuanya-92 and from 21.00% to 48.93% in Well Chuanhe-100.

After the An County Movement, this study area was in the BW stage deposition episode, with a relative “quiet” tectonic background. The sandstone composition had the inheritance and continuity of the fourth member. The depositional environment in the SW basin was mainly deltaic front–shore–shallow lacustrine, it was deltaic plain in eastern and southern parts, and alluvial fan in the northeast corner. The widespread area to the north of the An County-Zhongba Structure-Jiulong

Mountain Structure was denuded without the fifth member because of the influence of the late episode of the IndoChina Movement.

TABLE 1 : The sandstone composition analysis of typical well the frontal region of Longmen Moutain.

Area	Well	Horizon	Quartz (%)	Feldspar (%)	Debris (%)	The number of samples
North of Longmen Moutain	Well Shiyi- 1	T_3xj^5	50.30	2.10	47.60	30
		T_3xj^4	22.52	0.78	76.70	20
		T_3xj^3	24.00	0	76.00	20
		T_3xj^2	78.20	7.50	14.30	60
		T_3xj^1	84.00	4.00	12.00	17
	Well Yu-1	T_3xj^5	Denuded			
		T_3xj^4	33.90	0.04	66.06	31
		T_3xj^3	79.00	3.00	18.00	25
		T_3xj^2	82.77	7.70	9.53	45
		T_3xj^1	81.00	6.00	13.00	30
	Well Guanji	T_3xj^5	44.30	0.80	54.90	15
		T_3xj^4	28.23	1.24	70.53	35
		T_3xj^3	25.00	1.00	74.00	20
		T_3xj^2	82.49	5.94	11.57	69
		T_3xj^1	87.00	4.00	9.00	24
Middle of Longmen Moutain	Well Chuanhe-100	T_3xj^5	67.40	1.30	31.30	7
		T_3xj^4	49.29	1.78	48.93	14
		T_3xj^3	76.00	3.00	21.00	21
		T_3xj^2	57.78	7.09	35.13	23
		T_3xj^1	82.00	6.00	12.00	5
	Well Chuanya-92	T_3xj^5	41.40	3.00	55.60	20
		T_3xj^4	60.50	1.10	38.40	39
		T_3xj^3	65.00	2.00	33.00	16
		T_3xj^2	75.13	16.58	8.29	12
		T_3xj^1	74.00	2.00	24.00	1
	Well Fenggu-1	T_3xj^5	46.50	1.00	52.50	25
		T_3xj^4	12.79	0	87.21	51
		T_3xj^3	51.00	1.00	48.00	50
		T_3xj^2	82.48	5.02	12.50	65
		T_3xj^1	Missing data			
Sorth of Longmen Moutain	Well Baima-8	T_3xj^5	75.30	13.60	11.10	20
		T_3xj^4	63.81	8.28	27.91	20
		T_3xj^3	34.00	6.00	60.00	10
		T_3xj^2	72.00	19.96	8.04	47
		T_3xj^1	83.00	13.00	4.00	20
	Well Dashen-1	T_3xj^5	81.20	3.00	15.80	15
		T_3xj^4	61.34	4.12	34.54	20
		T_3xj^3	62.00	3.00	35.00	10
		T_3xj^2	91.81	5.62	2.57	44
		T_3xj^1	86.00	8.00	6.00	10

CONCLUSIONS

This study on the Sichuan Basin in the Late Triassic was conducted by a tectonic sequence, and the following conclusions were obtained:

1. Four tectonic sequence boundaries were identified: the regional structural unconformity between the Upper Triassic and the Middle and Lower Triassic, the lithologic and lithofacies transition surface between the second member of the Xujiahe Formation, the secondary tectonic unconformity between the third and fourth members of the Xujiahe Formation, and the regional structural unconformity between the Triassic and Jurassic.
2. Three structural sequences were divided in the Upper Triassic, Sichuan Basin. Each structural sequence was subdivided into two system tracts by the maximum flooding surface, these being the basin extension (BE) and basin wither (BW) system tracts.
3. In the third member of the Xujiahe Formation, the light and heavy sandstone minerals varied significantly in the study area. A large amount of depositional debris occurred in some areas, indicating that it had become a major provenance along with continuous uplifting of the Longmen Mountain thrusting and napping body, generating numerous rock fragments with poor wear resistance. In the fourth member, conglomeratic beds of carbonate occurred in the northern interval of the Longmen Mountain, which demonstrated it had been affected by the An County Movement. The Longmen Mountain thrusting and napping body was folded and formed as a mountain and provided a large amount of deposits for the study area.
4. The evolution of the Sichuan Basin in the Late Triassic is predominantly the evolution of WSFB, which is divided into three stages as follows: TS1 is the stage of marginal foreland basin; TS2 is the formation stage of WSFB, in which the miniature of Longmen Mountain orogenic zone was formed by the initiation of its thrusting and napping; by largely uplifting, the area emerged and constituted an island chain extending in a northeast direction; a large scale of contracted residual multi-island marine basins occurred to the west of this island chain; and the WSFB, mainly compression, depressing, and subsidence, to the east. TS3 was the development stage of the WSFB, which was affected by the An County Movement. The Longmen Mountain thrusting zone was intensively folded and formed as mountains, transforming the entire Sichuan Basin into a continental environment.

REFERENCES

[1] Chen Jie; Tectonic sequence of Tertiary in Jiyang Depression and its evolution. Progress in Geophysics, **18(4)**, 700~706 **(2003)**.

[2] Chen Yang, Liu Shugen, Li Zhiwu,et al., LA-ICP-MS Detrital Zircon U-Pb geochronology approaches to the sediment provenance of the Western Sichuan foreland basin and limited uplift of the Longmen Mountains during the early stage of Late Triassic. Geotectonica Et Metallogenia, **35(2)**, 315-323 **(2011)**.

[3] Deng Kangling; Formation and evolution of Sichuan Basin and domains for oil and gas exploration. Natural Gas Industry, **12(5)**, 7-12 **(1992)**.

[4] Dou Lirong, Li Jianzhong; Syn-rift tectonic-sequence stratigraphic characteristics of the Lower Cretaceous Formations in Northeastern China. Petroleum Exploration and Development, **22(3)**, 7-13 **(1995)**.

[5] Guo Zhengwu, Deng Kangling, Han Yonghui;. The formation and evolution of Sichuan Basin. Beijing: Geological Publishing House, 1-200 **(1996)**.

[6] He Li; Seismic-stratigraphic division and correlation project of the Upper Triassic system in Sichuan Basin. Oil and Gas Geology, **10(4)**, 439-445 **(1989)**.

[7] Jia Dong, Chen Zhu xin, Jia Chengzao et al.; Structural features of the Longmenshan fold and trust belt and development of the Western Sichuan foreland basin, Central China. Geological Journal of China Universities, **9(3)**, 402~410 **(2003)**.

[8] Xie Xinong, Ren Jianye, Jiao Yangquan et al.; Tectonism and sequence patterns of down-faulted basins. Geological Review, **42(3)**, 239-244 **(1996)**.

[9] Li Shubing, He li, Liu Meiqing; Continental basin evolution history of Sichuan Basin since Late Triassic. Natural Gas Industry, **19(Suppl.)**, 18-23 **(1999)**.

[10] Li Yong, Zeng Yunfu, Yi Haisen et al.; Sedimentary and tectonic evolution of the Longmenshan foreland basin. Chengdu: Chengdu University of Science and Technology press, 1-92 **(1995)**.

[11] Lian Lixia, Yin Taiju, Wang Lei et al.; Formation and sedimentary filling of Late Triassic Western Sichuan foreland basin. Journal of Oil and Gas Technology, **33(3)**, 2-18 **(2011)**.

[12] Lin Loangbiao, Chen Hongde, Jiang Ping et al.; Sedimentary facies and lithopaleogeographic evolution of the Upper Triassic Xujiahe Formation in West Sichuan foreland basin. Journal of Chengdu University of Technology(Science and Technology Edition), **33(4)**, 376-383 **(2006a)**.
[13] Lin Liangbiao, Chen Hongde, Zhai Changbo et al.; Sandstone compositions and paleogeographic evolution of the Upper Triassic Xujiahe formation in the Western Sichuan Basin,China. Petroleum Geology and Experiment, **28(6)**, 511-517 **(2006b)**.
[14] Liu Shugeng, Luo Zhili, Zhao Xikui et al.; Study in the dynamic mode and its simulation in the formation of Longmen Mountain-West Sichuan foreland basin system, China. Petroleum Geology and Experiment, **25(5)**, 432-438 **(2003)**.
[15] Liu Shugen, Tong Chongguang, Luo Zhili et al.; The formation and evolution of late Triassic foreland basin in Sichuan. Natural Gas Industry, **15(2)**, 11-15 **(1995)**.
[16] Liu Shugen, Zhao Xikui, Luo Zhili et al.; Study on the tectonic events in the system of the Longmen Mountain-West Sichuan foreland basin, China. Journal of Chengdu University of Technology, **28(3)**, 221-230 **(2001)**.
[17] Liu Shugen; The formation and evolution of the Longmenshan thrust belt and Western Sichuan foreland basin. Chengdu: Chengdu University of Science and Technology press, 1-167 **(1993)**.
[18] Luo Zhili; The dynamical model of the lithospheric evolution of Longmenshan orogenic belt. Journal of Chengdu College Geology, **18(1)**, 1-7 **(1991)**.
[19] Wang Zecheng, Zhao Wenzhi, Zhang Lin et al.; Tectonic sequence and natural gas exploration of Sichuan Basin. Beijing: Geological Publishing House, 1-287 **(2002)**.
[20] Wang Jinqi; An'xian tectonic movement. Oil and Gas Geology, **11(3)**, 223-234 **(1990)**.
[21] Xia Wenchen, Zhang Ning, Yuan Xiaoping et al.;Jurassic tectonic sequences of Qaidam and foreland basin evolution. Oil and Gas Geology, **19(3)**, 173-180 **(1998)**.
[22] Xu Shenglin, Hou Mingcai, Lin Liangbiao et al.; Depositional characteristics within tectonic sequence of Jurassic， western Sichuan foreland basin. Acta Petrologica Sinica, **27(8)**, 2327-2338 **(2011)**.
[23] Xu Xiaosong, Liu Baojun, Xu Qiang et al.; Basin analysis and earth dynamics of Chinese large West Basins. Beijing: Petroleum Industry Press, 1-168 **(1997)**.
[24] Yan Yangji, Wu Yinglin; Evolution of the Bayan Har-West Sichuan peripheral foreland basin in Southwestern Chian. Sedimentary Facies and Palaeogeography, **16(3)**, 16-29 **(1996)**.
[25] Yang Xiaoping, Li Yangchun, Liu Zhen,et al.; Classification of tectonic sequence and dynamic evolution of Jixi Basin, Eastern Heilongjiang province. Journal of Jilin University (Earth Science Edition), **35(5)**, 616-621 **(2005)**.
[26] Zhai Guangming; Petroleum geology of China (Vol.10 Oil and gas region of Sichuan). Beijing: Petroleum Industry Press, 1-516 **(1989)**.
[27] Zhao Zongju, Zhang Yunbo, Pan Mao et al.; Cambrian sequence stratigraphic framework in Tariam Basin. Geological Review, **56(5)**, 609-620 **(2010)**.
[28] Zheng Shunde, Wu Zhiping, Li Wei et al.; The Mesozoic tectonic features in Jiyang depression. Journal of Oil and Gas Technology, **27(2)**, 285-287 **(2005)**.