# Sequence stratigraphy of the Cambrian Terreneuvian Dalinzi Formation in southern Liaoning

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**Abstract.** As one of the only Cambrian Terreneuvian rock stratas in southern Liaoning, the Dalinzi Formation is of great significance for studying the evolution of the Early Cambrian sedimentary basin and the global sea level change in North China. Taking the Zhaokanzi section as an example, the sedimentary facies of the Dalinzi Formation in southern Liaoning were identified, and then the sequence stratigraphy was studied. The study suggests that the Dalinzi Formation is formed in the lagoon and tidal flat sedimentary environment, and a three-level sequence and several parasequences and parasequence sets can be divided. The relative sea level changes and sedimentary basin evolution are discussed.

## 1 Introduction

The southern Liaoning is located in the southern part of the Liaodong Peninsula. It is a typical developmental area of the Paleozoic Cambrian strata in Liaoning. It is widely exposed and developed. The Dalinzi Formation is one of the only 2 rock stratas in the Cambrian Terreneuvian system in the region. It is only exposed in the Jinzhou and Wafangdian areas of Dalian. Therefore, the Dalinzi Formation in southern Liaoning has important significance for studying the evolution of the Early Cambrian sedimentary basins and global sea level changes in North China, but its research results are relatively few, only in genesis [1], sedimentary facies [2], age [3] and other aspects have been discussed. In the paper of 2018, the author studied the sequence stratigraphy of the Dalinzi Formation in Fuzhou [4]. This paper adds and corrects some of the contents of the Dalinzi Formation based on the Zhaokanzi section in the literature [4]. The environment, sequence stratigraphy and its internal structure are discussed.

## 2 Petrological characteristics

The Dalinzi Formation stratotype section is located in the Dalinzi, Manjiatan, Jinzhou, Dalian. It is a set of sedimentary rocks with magenta dolomite as the main sand and conglomerate. No fossils are found. In the Jinzhou, its parallel unconformity is above the Terreneuvian Getun Formation. It is parallel to the Sinian Majiatun Formation in the Wafangdian area, and its top is covered by the Cambrian Series2 Jianchang Formation parallel unconformity. It can be divided into 3 lithologic members.

The lower lithologic member consists of gray-white sandstone, purple shale and gray-white dolomitic marl. The bottom is developed with a bottom structure, and upward development of sedimentary bedding, wave marks, symmetrical wave marks, small flushing surface, horizontal bedding and other sedimentary structures. Salt pseudocrystals.

Middle lithologic member: It consists of purple dolomite and gray sandstone. It develops deposits such as iron nodules and parallel bedding. See a large number of salt pseudocrystals.

Upper lithologic member: consists of gray sandstone, pebbly sandstone, and dolomitic limestone and a small amount of dolomite. It develops flushing surface, lenticular layering and horizontal bedding.

## 3 Sedimentary facies analysis

Combined with the field survey and the measured section of Zhaokanzi, it is believed that the Dalinzi Formation is a subfacies of the tidal flat and the lagoon of the barrier-type coastal bank. The tidal flat subfacies can further identify the 3 microfacies of the subtidal, intertidal and supratidal, lagoon divided into 2 kinds of microfacies of desalination lagoon and brackish lagoon.

### 3.1 Tidal flat

The tidal flat develops in a gentle coastal zone with obvious periodic tidal action, distributed around the

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lagoon, behind the bay, barrier island or sand dam, and the tidal flat deposits are parallel to the coastline. 3 microfacies of subtidal, intertidal and supratidal are identified in the subphase.

#### *3.1.1 Subtidal*

Below the average low tide line, it is the subtidal part of the tidal flat. The lithology is grayish white thick layer of pebbly sandstone, which develops a small scouring surface, and the vertical stacking method is not obvious.

#### *3.1.2 Intertidal*

Located between the average low tide line and the average high tide line, is the middle part of the tidal flat. The lithology is gray-white middle sandstone and gray-white-purple shale. It has obvious upward purple increase, fine grain size and thin layer thickness in the vertical direction. It has developed sedimentary structures such as oblique bedding and wave marks.

#### *3.1.3 Supratidal*

Above the average high tide line, it is the upper part of the tide. The lithology is dolomite, dolomitic limestone and shale, and there are salt pseudocrystals in the area, which develop symmetric wave marks and parallel layering. The vertical direction is characterized by fine grain size and thin layer thickness.

### 3.2 Lagoon

The lagoon subphase is a shallow water basin that is restricted by the coast and blocked by the barrier island. According to the change of salinity, it can be divided into 2 kinds of microfacies: desalination lagoon and brackish lagoon.

#### *3.2.1 Desalination lagoon*

When the lagoon is in a warm and humid environment, the rainfall is greater than the evaporation of the water, and the salinity of the lagoon becomes low to form a desalinated lagoon. Purple iron-bearing pebbly dolomite and purple silty shale, developing iron tuberculosis and parallel bedding.

#### *3.2.2 Brackish lagoon*

When the lagoon is in arid and hot environment, a large amount of water evaporates, and the salinity of the lagoon increases to form a salty lagoon. The main lithology of the desalinated lagoon microfacies is brick red dolomite and gray sandstone, and the vertical direction is characterized by the increase of upward dolomite and the increase of thick sandstone, and the development of a large number of salt pseudocrystals.

## 4 Sequence stratigraphic features

In this paper, the Dalinzi Formation is divided into 1 sequence. And it consists of transgressive system (TST) and highstand system (HST). TST consists of 4 parasequence sets (PSS). HST consists of 5 parasequence sets (PSS), and each PSS is internally composed of several parasequences (PS). The sequence division features are shown in Figure 1. The bottom boundary of the sequence is SB1 type, which belongs to the I type sequence.

### 4.1 Transgressive System (TST)

Located in the lower part of the sequence, it is mainly composed of lithology such as conglomerate, sandstone, shale and dolomitic marl. A total of 4 degenerate parasequence sets (PSS1-PSS4) were identified.

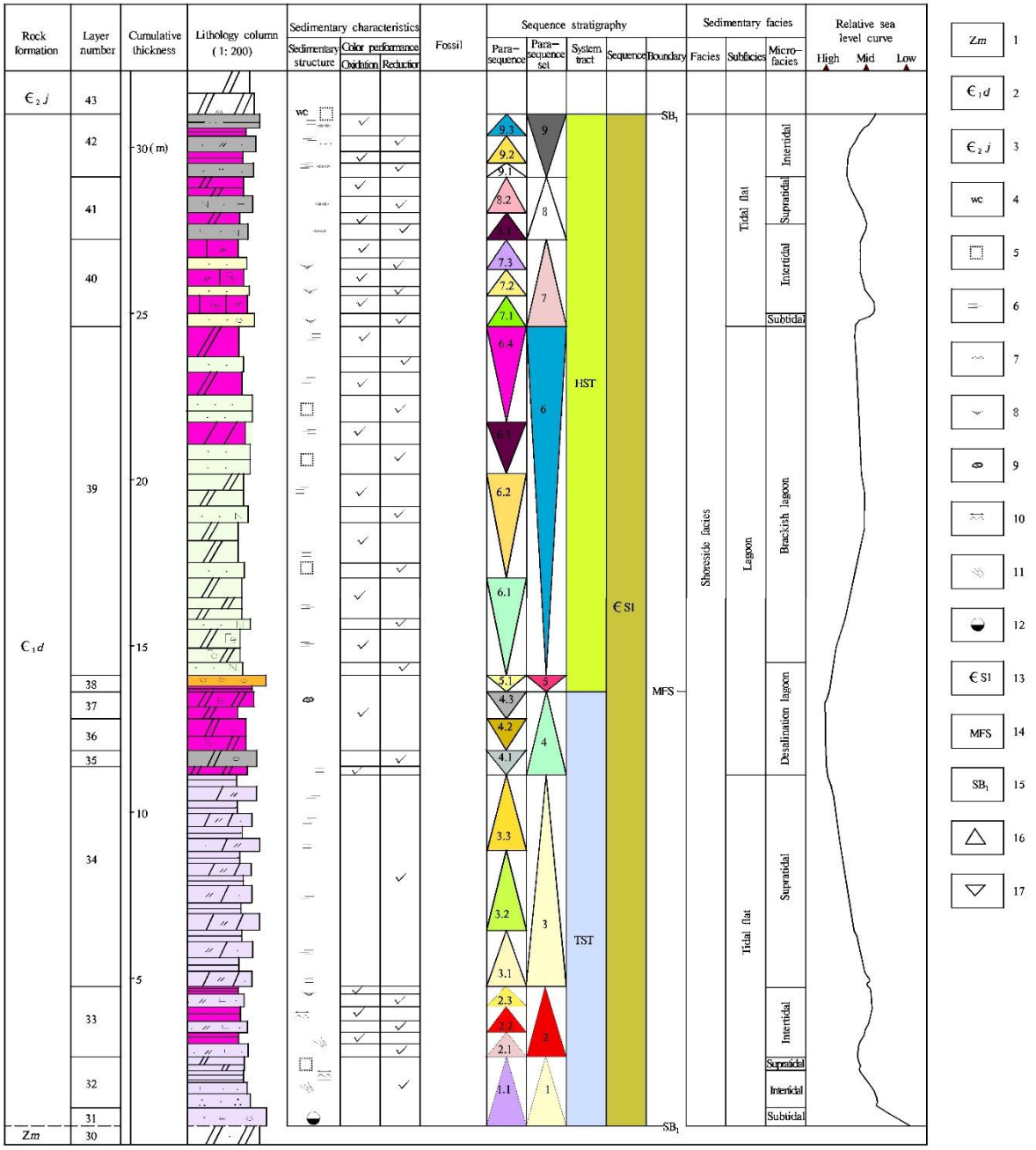


**Fig. 1.** Sequence diagram of the sequence of Dalinzi Formation in southern Liaoning:1-Majiiatun Formation, 2-Dalinzi Formation, 3-Jianchang Formation, 4-Ancient weathering crust, 5-Salt pseudocrystal, 6-Parallel layering, 7-Lenticular layering, 8-Scour surface, 9-Iron tuberculosis, 10-Symmetrical wave mark, 11-Oblique layering, 12-Bottom structure, 13-The first sequence of the Cambrian, 14-Maximum flooding surface, 15-Type I sequence interface boundary, 16- Thinning up, 17- Thicken up

Among them, PSS1 recognizes 1 parasequence, and the overall performance is characterized by the upward thinning and thinning degenerate parasequence set structure. It represents the initial sedimentary stage of the Dalinzi Formation. Due to the crustal uplift and rapid intrusion of seawater, the sediment supply rate is greater than the basin sedimentation rate. The gravel coarse conglomerate is deposited at the bottom of the sequence, which has obvious characteristics of bottom structure. As the seawater continues to deepen, the sedimentary facies change from the subtidal to intertidal, and the basin begins to accept sandstone deposits. The seawater gradually became stable and the sandstone and shale alternately deposited. Symmetrical wave marks appear in the sandstone, which is the result of alternating low tide and high tide flats in the intertidal subfacies. After that, the seawater continued to deepen, and the phase sequence gradually changed from intertidal to the supratidal. At this time, the salt pseudocrystals and dolomites reflected the arid and hot climatic conditions.

PSS2 recognizes 3 parasequences (PS2.1-PS2.3), and the overall performance is characterized by the upward thinning and thinning degenerate parasequence set structure, which represents the rapid intrusion of seawater after the PSS1 period. Although the sea level as a whole shows an upward trend, the sedimentary environment gradually tends to stabilize in the intertidal state. Taking PS2.1 as an example, it consists of 2 layers of dolomitic

calcareous sandstone and purple shale in gray, and then 4 such pairs of layers constitute the parasequence of the increase of sandstone in the upper shale, and the sandstone development is inclined. The bedding and symmetrical wave marks are the intertidal of the reducing environment. Lithology gradually turned into purple shale, and the sedimentary facies was turned into a climatic sloping facies. The PS2.1 is formed by the alternating appearance of the intertidal and the climax mud flat.

PSS3 can be identified by 3 parasequences (PS3.1-PS3.3), and the overall performance is characterized by an upward thinning and thinning degenerate parasequence set structure. The grayish white dolomitic sandstone marl and yellow-green shale are the main lithologies. During this period, the seawater is deeper than PSS2, but the sediment supply is sufficient and the sediment thickness is large. The overall performance is characterized by the deposition of the supratidal. Taking PS3.1 as an example, although it has been in the supratidal, due to the seasonal climate, the water environment alternates between cold and warm, forming gray-white dolomitic sand-grain marl in arid environment and yellow-green shale layer in humid environment. Yes, then the 4-6 layer pairs constitute a parasequence in which the upshale shale increases and the marl becomes less.

PSS4 identified 3 parasequences (PS4.1-PS4.3), and the overall performance is characterized by upward thinning and thinning. The purple thin layer contains iron dolomite, pebbly limestone and purple silty sand. The shale dominates the lagoon sedimentary environment. In the original arid and hot climatic conditions, the unconsolidated terrigenous clastics are oxidized into purple-red or purple. With the fresh water carrying a large amount of terrestrial debris, the evaporation is less than the injection volume, the water body gradually deepens, and the iron nodules and parallel are developed. The bedding is the maximum sea flooding period from the purple silty shale at the top of the parasequence set to the micro-thin ferrous silice-mud dolomite.

### 4.2 Highstand System (HST)

Located in the upper-middle part of the sequence, mainly composed of dolomite and sandstone, it is a set of barrier-type coastal lagoon deposits. A total of 5 parasequence sets (PSS5-PSS9) were identified.

Among them, PSS5 can identify a parasequence, which consists of gray-yellow thin layer of calcareous complex fine conglomerate and gray-purple shale interbed, and it consists of 3 overall upward shale reductions and an increase in conglomerate cycles. At this time, the fresh water injection amount is gradually reduced, the evaporation amount is larger than the fresh water injection amount, the lagoon is changed from desalination to salinization, and the formation structure as a whole is an accumulation type.

PSS6 identified 4 parasequences (PS6.1-PS6.4), which consist of a pair of brick red dolomite and gray sandstone, and then several such pairs of layers constitute the total upward dolomite increase and thickening. Taking PS6.1 as an example, the internal parasequence is composed of dolomite and sandstone. Each parasequence shows the characteristics that the dolomite gradually increases and becomes thicker and the sandstone decreases, and the gray and brick red alternately appear. The development has parallel bedding, which is characterized by a rapid intrusion of seawater and a slow decline in a short-term cycle of high sea level.

PSS7 was identified as 3 parasequences (PS7.1-PS7.3) consisting of gray sandstone and brick red iron-bearing dolomitic limestone. The parasequence is taken as an example of PS7.1. Each parasequence consists of 2 lithologies: gray calcareous feldspar sandstone and brick red iron dolomitic limestone. The 2 rhythmic interbeds are composed of upward thinning cycle. The scouring surface of the sandstone is developed as a high-energy tidal channel sedimentary environment. With the increase of water volume, the phase sequence gradually changes from the subtidal to intertidal, and the early oxidized intertidal gray matter begins to deposit. Each parasequence consists of 3 or more subtidal-intertidal cycles, which are characterized by an increase in upward limestone and a decrease in sandstone. Then, the 3 parasequences form an overall upward limestone and increase the number of cycles of sandstone reduction, which shows the structural characteristics of the transgressive-type parasequence set.

PSS8 was identified as 2 parasequences (PS8.1-PS8.2), which consisted of gray micro-thin layer of calcareous feldspar quartz sandstone and purple dolomite interbed, which was an intertidal-tidal sedimentary environment. Taking PS8.1 as an example, each parasequence consists of gray micro-thin layer of calcareous feldspar quartz sandstone and purple dolomite interbed, and the rhythmic interbeds of the 2 layers form an upward thinning and thinning cycle, and the dolomite is more see lenticular structure. Sandstone reflects the intertidal sedimentary environment, and dolomite is reflected as arid tidal sedimentary environment. With the repeated intrusion of seawater, 3 or more alternating intertidal-subtidal subfacies, the parasequence are formed. Along with 2 higher-level transgressions, the 2 parasequences constitute a parasequence set with upward limestone and sandstone reduction.

PSS9 identified 3 parasequences (PS9.1-PS9.2). After 2 transgressions of PSS7 and PSS8, the sea level began to rapidly become shallow after a short period of steady, and the phase sequence was also from the tide. The belt gradually becomes intertidal, and with the rapid decline of sea level, a large amount of terrestrial detrital matter is brought in, forming a relatively pure land-source clastic sedimentary sequence of PSS9, which is composed of gray-white siliceous sandstone and purple pages. The rock is composed of 2 lithologies. Taking PS9.1 as an example, it consists of 4 sandstone-shale layers that form an upward shale-increasing cycle. In the sandstone, a wave-like, lens-like lens formed by the wavy deposit formed during the high tide period and the tidal period formed during the tidal period is developed. Parallel, veined bedding, parallel stratification in shale, 4 pairs of pairs reflect the alternating process of 4 mid-tidal flats and high tide mud flats, and the upward overall water level has risen. Then, 3 such parasequences form a parasequence set. The parasequence set as a whole exhibits the characteristics of

the progressive stratigraphic structure with coarse grain size and thick layer thickness.

## 5 Conclusion

The Dalinzi Formation in southern Liaoning identified 2 subphases of tidal flat and lagoon, and further divided the tidal flat subfacies into 3 sub-facies of subtidal, intertidal and supratidal. The lagoon subphase is divided into desalination lagoon and brackish lagoon.

The Dalinzi Formation is divided into 1 three-level sequence, which is determined to belong to the I-type sequence. The sequence includes the transgressive system and the highstand system, and further internalizes the system into several parasequences and parasequence sets.

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