Study on Sealevel Fluctuation Geodynamics of Carbonate Depositional Cycles in the North China Platform
——the Cambrian Milankovitch Geological Events

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Abstract Sealevel change, which is an important contents of sedimentary background dynamic field, is recognized by the features and messages of the direct dynamic field. This paper describes the meter—scale cycles and the stacking patterns in detail, and the synthetic research on the sealevel change with different frequencies (orders) are stated. The numerous variations of sealevel change with high—frequency indicate the driving mechanics of Milankovitch event. The features of cyclic thickness, frequency and cyclic interval of high —frequency sealevel change are also discussed. Finally, a composite sealevel change model of the North China Carbonate Platform is given.

Key Words: Sealevel fluctuation Cyclic sequences Milankovitch Rvent North China

1 Introduction

The authors (1993,1995) define the depositional geo—dynamic field in geological history as two types, i.e., the direct and background ones (Table 1). The sealevel change geo—dynamic field (including tectonic subsidence and eustacy) is able to be recognized in terms of the direct characteristics of geodynamic field and its variations, and even the recent sealevel change events in Quaternary (thousnds of years), can also be reconstructed through the recognition of sedimentary palaeoclimatic and palaeogeographic changes. The research on the evolution of the palaeo—eustacy in the North China Platform during the Early Palaeozoic, partly, depends on the synthetic approaches in sequence stratigraphy, cyclostratigraphy, petrology, sedimentary environment, and etc..

2 Cyclic sequence stratigraphy and composite sealevel changes on carbonate platform

The North China Platform, recording a complex interplays of numerous geo—dynamic variables, is sensitive to eustatic sealevel fluctuations as same as other cratonic carbonate platforms, which is one of the most ideal areas to study geodynamic system in terms of deposition. A variety of meter—scale cyclic sequences, which are characterized by superimposed sealevel fluctuations with different frequencies (defined as orders) and different amplitudes cycles, are represented in Cambrian and Ordovician.

Table 1 The schematic division of dynamic fields of sedimentary basin

Settings	Processing—fields		Change of coupling field—rhythms	
Syngenetic settings	Chemistry	Chemical f.	Calendar band+solar band; Sun—spot cycle; ENSO cycles; Gleisberg cycles	Directly coupling field; Mini—rhythms
		Precipitation f.		
		Evaporate f.		
	Biology	Biochemstry f.		
		Biophysical f.		
		Microbiol f.		
	Physics	Wave—tidal f.		
		Sea flow f.		
		Gravity flow f.		
Diagenetic settings	Un—burial diagenesis field			
	Burial diagenesis field		Milankovitch band; Extinction and Wilson cycle	Backgroundly complicated coupling field. medium—mega—rhythm
Basin forming and evolution	Global sealevel changes f.			
	Tectonical field			
	Prevananvce and rate of supply field			

2.1 The composite sealevel change, driving mechanics and deposition

The composite euatacy refers to superimposed sealevel fluctuations with different frequencies and different amplitudes. The ancient sedimentary records shows there exists a hierarchy of stratigraphic forcing driven by composite eustacy which results in organized stacking patterns. A hierarchy of cyclic forcing is in accordance with the stacking patterns of different order sequences or depositional associations. The composite cyclic stacking patterns of relative sealevel change are called as "cycle within cycle" by Mial(1984). The driving mechanics are related to the two genesis. The first one is the universe—earth system, including Milankovitch events, earth orbit, obliquity and global climate changes, the secondone is the fluctuations driven by the interior earth tectonic event.

The composite stacking patterns of stable cratonic carbonate cycles or cycle within cycle of the Early Palaeozoic in North China are mainly controlled by the eustatic changing rate among the universe—earth system, the tectonic subsidence rate of platform and the depositional productivity itself (Fig. 1).

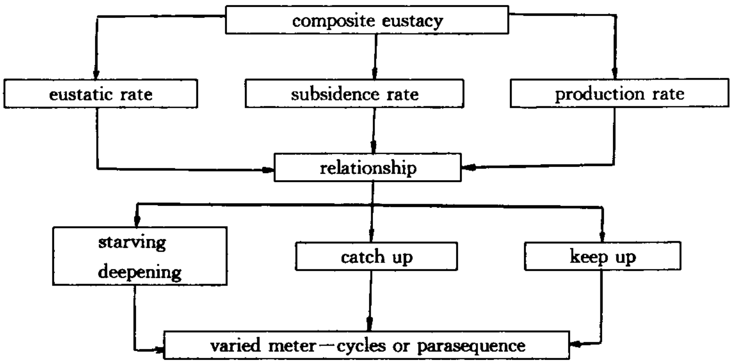
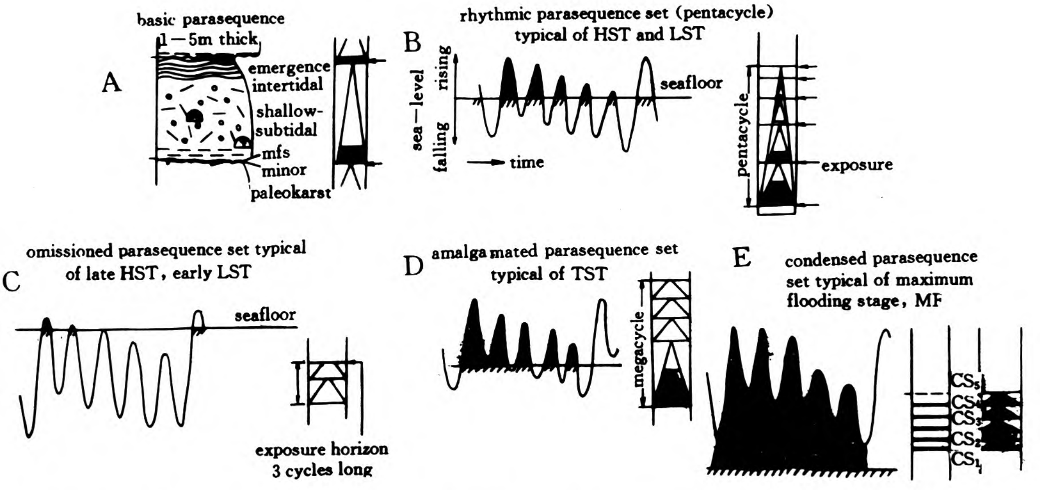


Fig. 1 The composite eustatic sequence types of cycle whithin cycle stacking patterns and the controlling factors in the North China platform

On a general note, the longer period($>10^6$ y) subsidence rate of cratonic basin or passive continental margin, i. e. , the thermal subsidence, is up to 1—25 cm/ky (Schlager, 1981), while the carbonate productivity (shallow water platform) is about 10^2—10^3 μm/y in average, that is, 0. 1—1 cm/ky. As the tectonic subsidence rate is over that rate, however, the rapid sealevel changes in high frequences (10^4—10^5/ y) and high depositional rate (10 cm/ky.) occur repeatly. The cyclic sedimentation in the rate mentioned above represents typical variations in vertical stacking sequence, that is, each individual cycles (including meter— scale cycles) begins with a short— interval nondeposition and, towards the top of cyclic sequence, is characterized by the rapid deposition, shallowing—upwards and (or) terminated with exposed surface. Fig. 2 summarizes the general features of a typical meter— scale cycle of carbonate platform in North China.

The high frequency sealevel osicillations, both the eccentricity (100,000 y. and 400,000 y. period) or the obiquity (20,000 y. and 40,000 y. period), are asymmetric, which caused the enhanced asymmetry of the meter—scale cycles and corresponding parasequence sets. Each individual composite eustacy would generate three effections on the deposition of shallow water carbonate.

①As the sealevel start up rising rapidly (start up stage), platform is wholely submerged, resulting in occuring of punctuated nondeposition intervals, and covered by deeper—water sediments of hardground and the thin starved laminations below the photic zone (Fig. 2 A, a unit).



A—basical parasequences (meter—scale cycles); B—rhythmic parasequence sets in highstand and lowstand; C—not completely developed parasequence sets (LHST, ELST); D—submerged parasequences of shallowing and thinning—upwards parasequence sets formed in transgression; E—CS—type parasequence sets

Fig. 2 The carbonate cycles, meter—scale cylces and their stacking patterns in the North China Platform

②From continuing rise of sealevel to slow rise (catch up stage), carbonate productivity is developed quickly and sealevel become lower, generating shallowing — upwards sequences (Fig. 2, b unit).

③With the sealevel begining to fall (keep up stage), carbonate deposition keeps up the sea level changes (equilibrating), which causes depositional surface to be exposed, and a series of exposed structure marks of supratidal bank islands, reef islands etc. are developed and, fresh water seepage zone and karst weathering crust appeared (Fig. 2 A, b unit).

2.2 The parasequences stacked by meter— scale cycles and dynamics of sealevel change

The basic meter—scale cycle characteristics discribed above, including lithology or lithofacies, sedimentary indicators and the vertical successions etc. , vary with the different palaeogeographic settings in the North China Platform, such as inner—shelf, mid—shelf and outer—shelf, and a variety of corresponding meter—scale cycles are generated. It is the basic work for us to recognize those carbonate meter—scale cycles formed during different geological period in studying on sequence stratigraphy and cyclic stratigrgaphy in the early Palaeozoic in the North China Platform.

Due to the complex interplay of various order high frequency and low frequency sealevel change and composite eustatic fluctuations, numerous parasequences or parasequence sets with assorted stacking patterns and orders are generated. Fig. 2 B, C, D, E exhibit the four types of parasequences and parasequence sets which are common in carbonate stratigraphy in the Early Palaeozoic, North China.

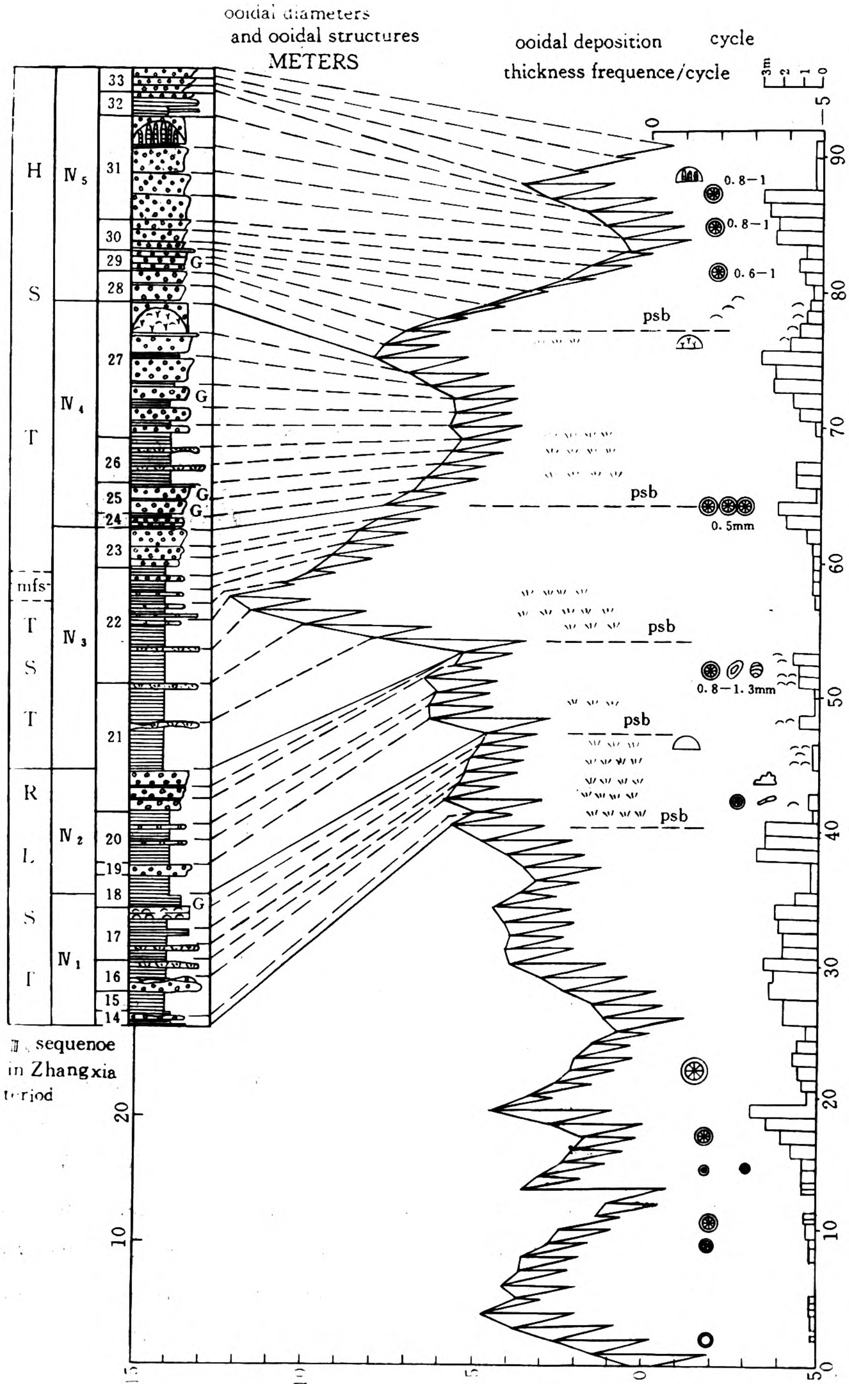
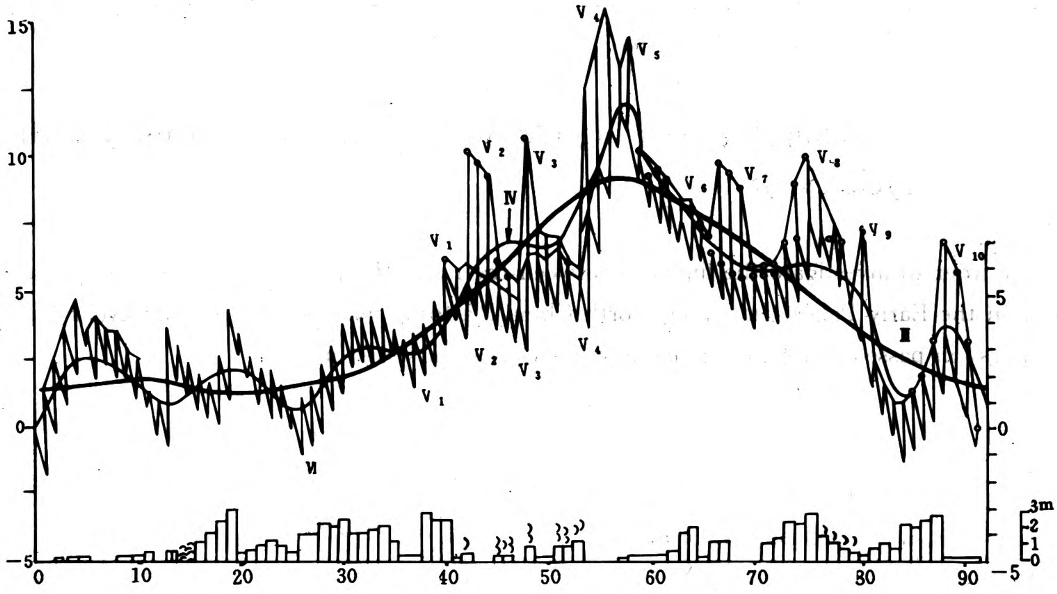


Fig. 3 The meter—Scale cycle plots in Ⅲ5 sequence (Zhangxia period of Mid—Cambrian) in the North China Platform (Plotted by Fischer Plot)

Type—B parasequence sets, a cycle consists of five parasequences, developed mainly in still—highstand and lowstand periods and characterized by shallowing and exposing—upwards meter—scale cycles formed in mid—inner shelf environments.

Type—C parasequence sets, or thinning—upward parasequence sets, is dominantly generated in the late highstand and in the early lowstand during sealevel fall and, meter—scale cycles are characterized by uncontinuing depositions or "missed beats" and long interval exposed layer.



(Plotted on the basis of meter scales mesured along the sections and Fischer Plot, and corrected in terms of compaction and water depth. The level axis represents the distributions of ooilitic and bio—limestone).

Fig. 4 The synthetic sealevel changes in Ⅲ, Ⅳ, Ⅴ, Ⅵ—order cycles in the Mid—Cambrian in the North China Platform

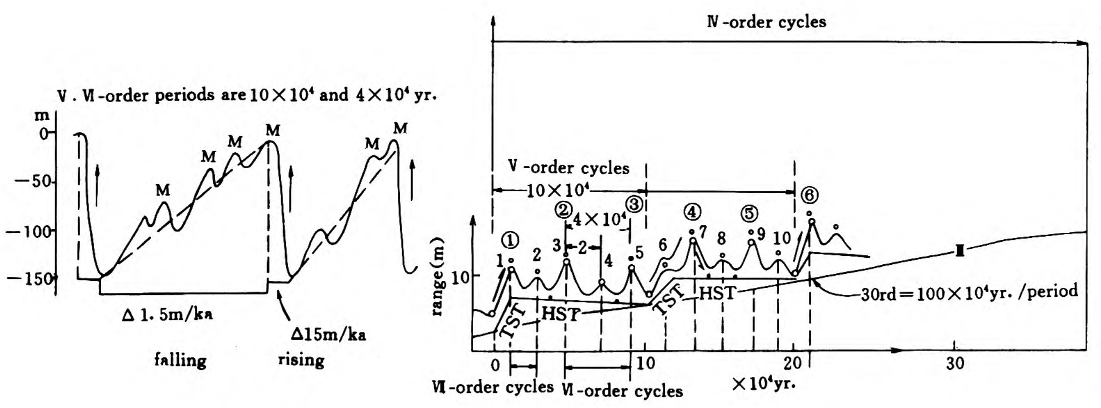
Type—D parasequence sets, or integrated super—cyclic sequence, is dominantly in transgression during sealevel rise and constitued by the meter—scale cycles of thinning and deepening—upwards with no hiatus deposition, and more terrigenous within the bottom cycles and, towards the up, rarely tidal flat and exposed units and commonly drowned cycles of mid—shelf or its upper facies.

Type—E parasequence sets, or starved (condensed) depositional parasequence sets, mainly occur during the maximum flooding period. Caused by the lower depositional rate rather than eustatic rate, the depositional sequences is mostly composed of the thin—bedded starved sediments which is characterized by hardgrounds and glauconite. The sets dominate the mid—shelf, lower shelf gentle slope as well as the lower part of inner shelf.

It is the key approach to recognize meter—scale cycle in detail within the continuing outcrop sections in investigating depositional cycles and its organized stacking patterns. On the basis of recognition of meter—scale cycles and measured thickness in the section, Fischer plot (Fischer, A. G. , 1964) are helpful to define long—term sealevel cycles. Fischer plots, however, only represent the stochastic time — accommodation series analyses of average cyclic thickness, that is, time—accommodation variations, which is not in accordance with the truely eustatic fluctuations, so in other works, they have to be corrected in terms of compaction and water depth in order to reflect the ancient changes directly. Fig. 3 and Fig. 4 show an example we have verified by the correction of compaction and water — depth in studying sequence stratigraphy of Early Paleozoic in the North China Platform.

3 The relationship between high frequency carbonate cycles and Milankovitch cycle events

In order to investigate the linkages between the high—frequency attributes of carbonate cycles in the Early Palaeozoic in the North China Platform and the Milankovitch event cycle dynamics, in passed studying, following researches are involved in:



The upper diagram is the rate of fifth and sixth—order sea level oscillation and the variations of $\delta^{18}O$ in the Late Pleistocene (after Williams, 1982), M representing the proble location of melted—snow within sea—basin as Mexico Gulf.

Fig. 5 The sea level fluctuations of varied orders astronomical periodicities (reviewed from Williams, 1982; Van Wangoner, 1988; Goldhammer,R. K. , 1990)

3. 1 Synthetically analysis on universe—earth system of depositional sphere on the basis of the available information

An obvious composite cyclic periods, is superimposed cycles with different high—frequencies astronomical periods (20,000; 40,000; 100,000 y. short eccentricity period and 400,000

y. long eccentricity period), and two 20,000 rhythms are in accordance with one 40, 000 y. rhythm, five 20,000 y. cycles consititutes one 100,000 y. cycle and ten 40,000 y. osicillations are equivalent to one of 400,000 y.. The sea level variations of 20,000; 40,000; 100, 000 and 400,000 y. rhythms total appear asymmetric, and each individual rhythms is characterized by the rapidly rising and slowly and gradually falling. This composite sea level fluctuaticns are all superimposed within the third—order sea level cycle of symmetric and long term period.

The correlation between the eustatic variations describeded above and the sea level change of carbonate cyclic sequences in the Early Palaeozoic in the North China Platform (Fig. 3) indicate that there exists, from No. 40 cycle to No. 92 cycle, a complete third—order eustacy, containing ten fourth —order cycles (1,2,3,4,5,6,7,8,9,10) and, each individual cycles is superimposed by 4—5 basic meter—scale cycles. The eustacy of the fifth—order cycles are characterized by the initial quick rising in the begining subcycle and then the gradually falling.

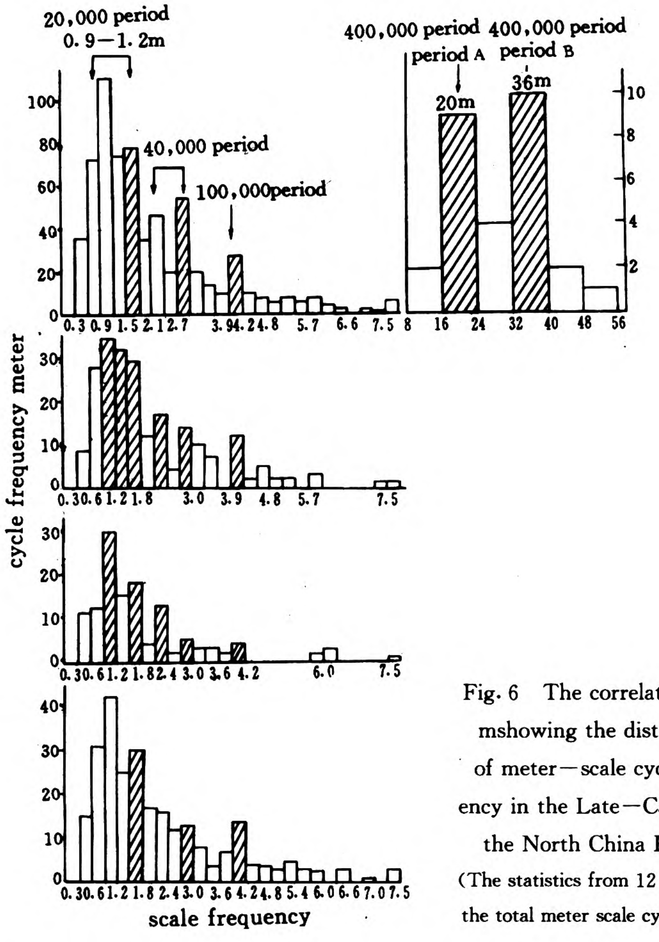


Fig. 6 The correlation diagra mshowing the distributions of meter—scale cycle frequency in the Late—Cambrian in the North China Platform

(The statistics from 12 sections and the total meter scale cycles 10008)

3. 2 Statistical summary of a variety of frequencies

In terms of the link between high—frequency sea level change and carbonate productivity, the cycle thickness and frequencies developed in different intervals appear a relative distribution range (Fig. 6 and Fig. 7). The statistical summary of cycle frenquencies on the basis of measured sections of Mid—Upper Cambrian in the North China Platform show that the cycle thicknesses are arrayed with the four ranges of 0. 9—1. 2 m; 2. 4—3. 0 m; 3. 9—4. 2 m and 20—36 m, which are in accordance with the four astronomical cycles of Milankovitch event.

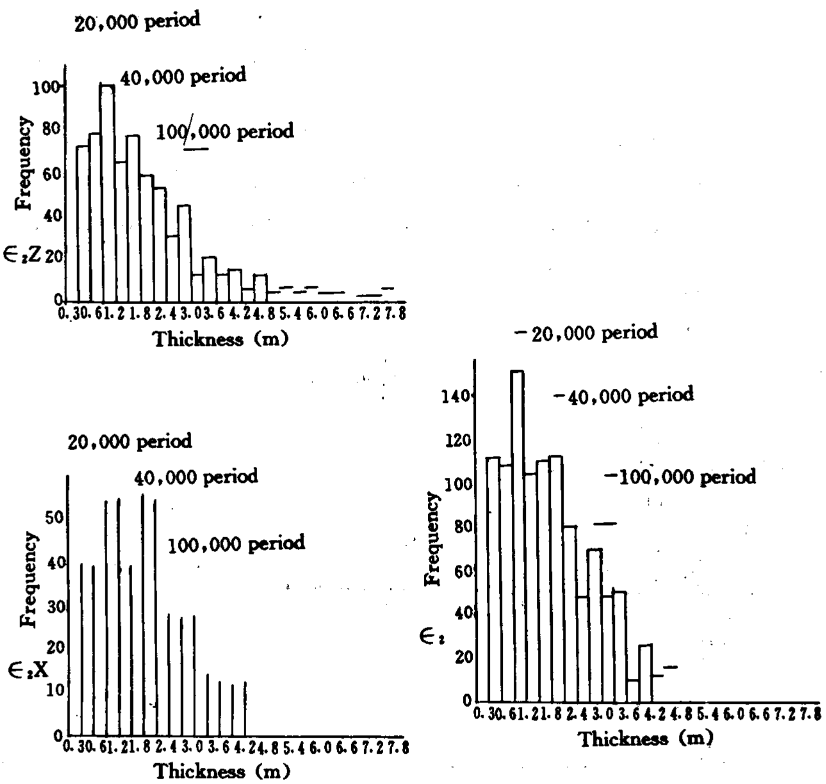


Fig. 7 The correlation diagram showing the distributions of meter—scale cycle frequency in the Mid—Cambrian in the North China Platform

(The statistics from 12 sections and total meter—scale cycles 594 of Zhangxia Fm, and the total meter—scale cycles 414 and 12 sections of Xuzhuang Fm.)

3. 3 Isochronous correlation in terms of sequence stratigraphy and cyclosequence in cabronate platform settings

The third—order (Ⅲ) sequences, fourth, fifth or sixth—order (Ⅳ, Ⅴ, Ⅵ) parasequences, recognized in the measured sections of Mid—Late Cambrian, have been well correlated both in the central —northern parts of platform and the south parts of North China, which suggest that the different cycles, such as fourth, fifth—order sequences be isochronous sedimentary units around the platform and, originally driven by the global universe—earth system geodynamic field.

Despite the evolution of the cratonic basin of the North China Platform in the Early Palaeozoic, i. e. , the initial south subsidence and then the south uplift and north subsidence during the Mid—Cambrian and from the Mid—Cambrian to the Early Ordovician, based on an axis of the present geographical latitude, the geodynamical field of universe—earth system, generating Ⅳ and Ⅴ —order sea level variations, is only slightly affected with the regional tectonic movement.

3. 4 The cycle intervals of high—frequency sea level fluctuations

The intervals of numerous varied orders cycles within carbonate sequences in the Mid—Late Cambrian have been evaluated based on the authors' research. The durations of Ⅳ , Ⅴ , Ⅵ —order cycles are calculated based on the typical section boundary of the international geological chart, the results suggest the average cyclic durations of Xuzhuang and Zhangxia Stage in Mid—Cambrian be 400,000 y. for fifth—order, 100,000 y. for sixth—order and 20,000 y. for senventh—order.

At least 5 third—order cyclic sequences from $Ⅲ_6$ to $Ⅲ_{10}$ and 25 fifth —order cyclic sequences, in the Late Cambrian, which can be well correlated across the carbonate platform, are recognized. Caused by the influence of the maximum sea—flooding event of megacycles developed from the Early Cambrian to Early Ordovician, the third—order cyclic sequence oppeared in the Upper Cambrian, that is, the top of Gushanian, developed limitedly. Taking into consideration of this cycle, in other words, 6 third—order sequences and 30 fourth—order sequences are actually included within the Upper Cambrian. Considering the duration of the Late Cambrian on the basis of international geological chart, 517 Ma—505 Ma=12 Ma, thus the individual fourth—order cyclic interval is as 12/30=0. 4 Ma and each individual third—order cycles, therefore, is 12/6=2 Ma appoximately. All those individual cyclic intervals suggest that the fifth and sixth—order cycles of high—frequency carbonate described above, in the Mid—Upper Cambrian, are in accordance with Milankovitch event cycle.

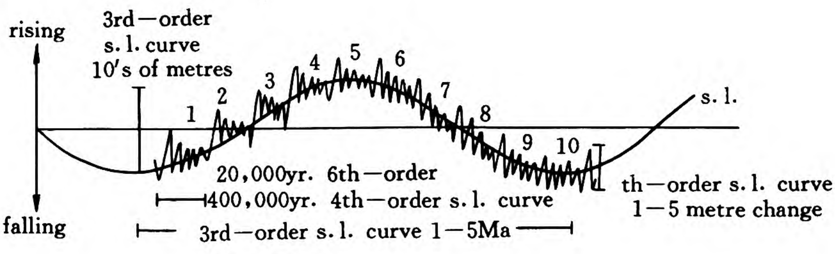


Fig. 8 A third—order cycle model showing the composite eustatic fluctuations related to the asymmetric carbonate cyclic rhythm in Cambrian in the North China Platform. (symmetric 3rd—order sealevel cycle with higher amplitude)

(5) On the basis of the achievements of geodynamic research, the model showing the sea level fluctuations related to the carbonate cyclic sequences in Cambrian in the North China

Platform is summaried as Fig. 8.

(Accempted in revised form January 2, 1996)

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