Chapter 6. Conclusions

1. Summarized sedimentary evolution of the southern Doushantuo Yangtze platform

Figure 58, synthesis of the four previous chapters, shows the sedimentary evolution of the southern margin of Edicaran Yangtze platform during the two and a half parasequences represented by the Doushantuo Formation. Because the lack of detailed facies description in the sections from regional literature, only data from visited sections are used in this figure.

1. The first transgressive event of the Doushantuo Formation is due to the rise of sea level following the melting of ice after the Marinoan glaciation (635 Ma, Condon et al., 2005). This transgression deposited the black shales, which overlie the “cap carbonate”. An erosional surface due to emergence in the proximal (landward) Zhancumping section, Hubei province, marks a fall in relative sea level. The formation of isolated, shallow-water intrashelf basins at the platform margin (Chapter 5) indicates that a rim (sand shoals or paleorelief) emerged during sea level fall and blocked the wave energy. Phosphorite associated with evaporites (and cherts) (Chapters 3, 4 and 5) in the middle Doushantuo Formation were deposited during the regressive period of parasequence I.
2. The second transgression induced marine currents, which reworked the shelf sediments and deposited sand banks. Thus, high-energy coarse-grained sediments correspond to this transgressive interval, which crops out in Zhancumping and Xiaofenghe sections, Hubei province, and Yanwutan section, Hunan province. The absence of black shales corresponding to sea level highstand may indicate that this second transgression is less intense than the first transgression.
3. During the sea level fall of parasequence II, rims (paleoreliefs or sand shoals) emerged at the platform margin and isolated the shelf from the open sea. Thus, suspension settling dominated the back-rim shelf sedimentation. The large-scale slide sheets in Hunan province (Chapter 4) were deposited during this regression (Chapter 5).
4. Oolith sand banks, infered from the debrites in Zhongling and Yangjiaping sections, Hunan province, represent the transgressive interval of the parasequence III. Deposition of debrites with oversized mud clasts, however, remains problematic. The idea of debrite sedimentation due to active tectonics (such as sketched in Fig. 58) is highly speculative.

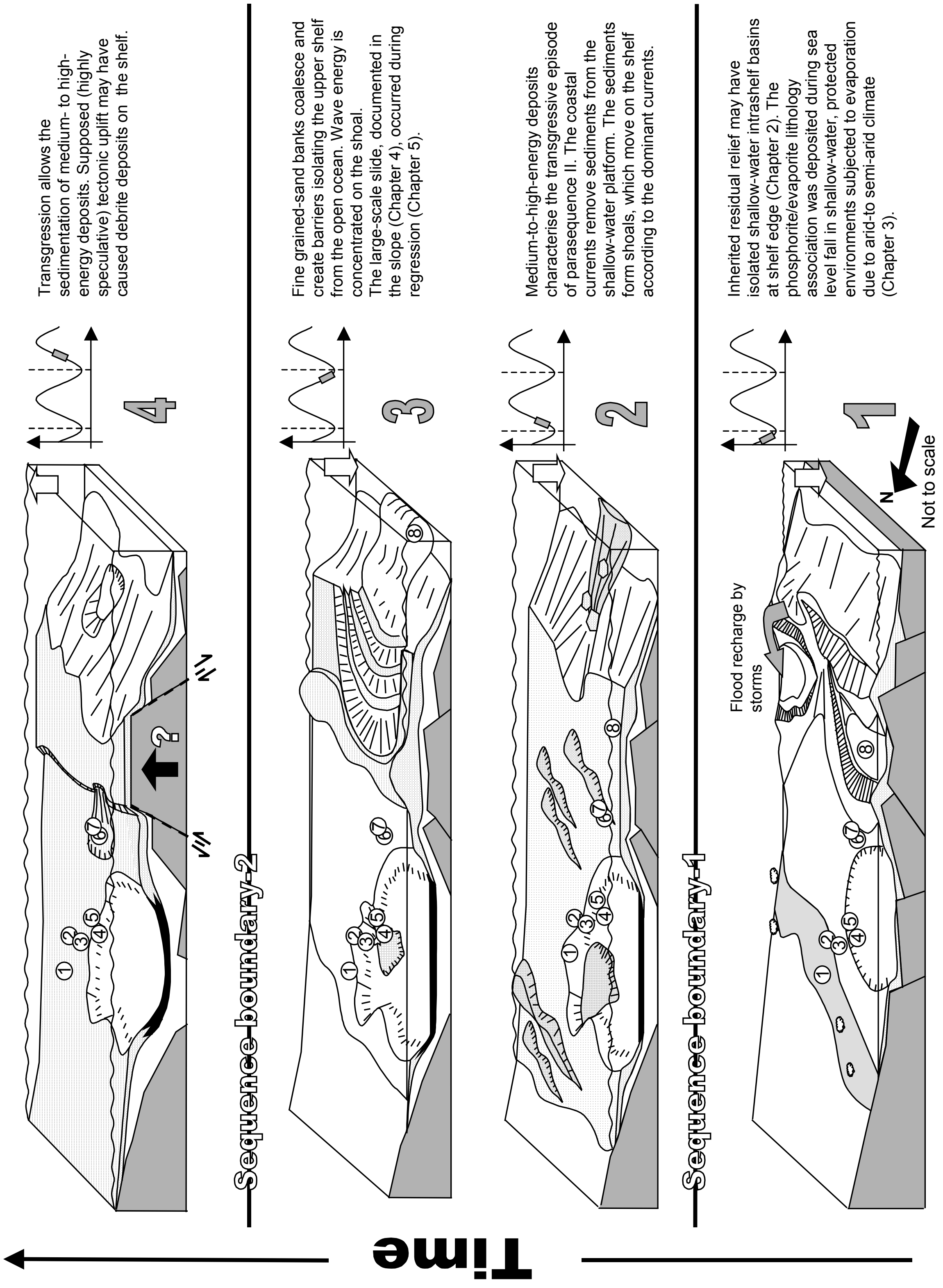

Fig. 58. Sedimentary evolution of the Yangtze platform during Doushantuo time. This sketch integrates data of chapters 2 to 5. (1) Zhancumping section, (2) Xiaofenghe section, (3) Neo-Tianjiayuanzi, (4) Maoping section, (5) Wuhe section, (6) Zhongling section, (7) Yangjiaping section, (8) Luoyixi, Xixi, and Yanwutan sections (slide sheet). The curve shows the variation in sea level and the cursor shows the relative sea level during deposition.

2. SUMMARY OF SCIENTIFIC CONTRIBUTIONS

Compilation of literature and field data (Chapter 2) allows to reconstruct an Ediacaran Yangtze platform with an irregular sea floor bathymetry. Facies and thickness isopachs maps of three provinces (Hunan, Hubei, and Guizhou) allow to estimate the location and geometry of intra-shelf basins and highs. These maps sketch the contours of a deep intrashelf basin, centered near Liuping section, Hubei province, and the presence of shallow-water, restricted basins near the platform margin (Figs. 14 and 22). A paleobathymetric high is suggested in Weng'an section, Guizhou province. Rapid unexpected lateral facies changes characterize shelf sedimentation and argue for fault-bounded basins and highs. Faults may have been inherited from rifting, which, according to Wang and Li (2003), ended during Nantuo time. This dissertation partially modifies the paleoenvironmental reconstructions suggested in previous studies (Steiner, 2001; Zhu et al., 2003), by proposing an interpretation of the "facies patchwork" on the shelf. Two depositional environment models, epeiric rimmed platform and wave-dominated open shelf, correspond to the sedimentary record of the Doushantuo Formation. Sequence-stratigraphic analysis of the shelf sections divided the Doushantuo Formation in two-and-a-half parasequences recording 2^{nd}-order sea level variations. Sequence analysis may facilitate the correlation between sections and regions.

In the slope environment of the southern margin of the Yangtze platform, shallow-water limestone intervals are correlatable between sections. Slump folds in the limestones and in the over- and underlying black shales suggest an allochthonous origin. Four shelf-edge-originated slide sheets were identified. The documentation of oversized slide sheets invalidates the previous eustasy-related interpretation (Zhu, pers. comm.). Detailed facies interpretation of the lithologies of slide sheet No. 3 allows to reconstruct the paleoenvironment, which may have been shallow-water, protected basins, oversaturated with respect to sulfates and recording emergence periods. These basins, located on the shelf edge, implicate the presence of a rim protecting a back-rim shelf region from wave energy. A subsequent sea level rise deposited packstone/grainstone facies on top of the protected basin deposits. Thus, the rimmed platform evolved to a wave-dominated open shelf. Correlation of the sedimentary record of slide sheet No.3 with a standard shelf section indicates that the displacement probably occurred at the end of parasequence II, during the regressive period.

Except for the sequence stratigraphic approach of Wang et al. (1998), local geologists used to divide the stratigraphy of the Doushantuo Formation in four lithologically defined members ("cap carbonate", shales, dolomites, shales) and correlated lithostratigraphically. This dissertation has shown that (1) variations in shelf bathymetry caused facies variation; (2) facies and depositional environments change according to 2^{nd}-order eustatic variations; (3) limestone intervals in the slope are allochthonous. Therefore, the lithostratigraphic correlation used by Zhu et al. (2003) and many others is limited in its usefulness.

In contrast to Wang et al. (1998), I interpreted the black shales to have been deposited during sea level minimum, when the platform margin rim blocked wave energy and favored suspension-settling in the back-rim region. Wackestones/packstones with medium-energy current-related sedimentary structures represent maximum flooding deposits. Coarse-grained packstones/grainstones with large-scale crossbedding or conglomerates were deposited during early transgression. The sedimentary analysis presented in this work assists in the calibration and interpretation of curves showing the sulfur (Goldberg, 2005), carbon and oxygen isotopic variations (Guo et al., submitted). Identification of allochthonous deposits avoided a misinterpretation of isotope anomalies.

3. Perspectives

This work represents a first attempt at sedimentary research on the Ediacaran Yangtze platform and gives a general idea about its evolution. Several interesting and problematic aspects result from this study.

The Ediacaran and Cambrian phosphorites on the Yangtze platform appear to be important for understanding the hydrodynamic and chemical evolution of the platform. The presence of Precambrian phosphorites appears related to global events and sea level fluctuations (Appendix 1). Additional investigations should evaluate phosphorites as time markers and correlation tools. At present, phosmicrite is an uncommon facies. A detailed study of phosphorite microfacies would yield interesting information about Ediacaran conditions of phosphorite precipitation. Moreover, phosphorites require partially anoxic conditions. It may be instructive to study conditions of the anoxia, its impact on the fauna, and on fossil preservation. Phosphorites in Xixi section, Hunan province, appear to have recorded cycles. Further investigation should determine the type of cyclicity and could provide valuable information about the sedimentary dynamics of intra-shelf basins.

Adding more stratigraphic sections would refine the proposed correlation, help to better understand the platform geometry, and would facilitate correlation between sections and biota. Moreover, new studies should investigate the northern margin of the Yangtze platform (south of the Qin-Lin fault) to obtain a complete view of the platform.

The numerous tuffaceous beds identified during my study can provide absolute ages, allowing the calibration of sections on the Yangtze platform. This would require a petrological approach in order to characterize the origin of those beds and give (if possible) criteria for their field identification and differentiation, the geochronological dating method, and for constructing an age framework over the entire Doushantuo platform. A sedimentological approach could use the ages in reconstructing the sedimentary evolution of the Ediacaran Yangtze platform and in estimating sedimentation rate, compaction, and subsidence history. This, in turn, would allow to calculate evolutionary rates of Ediacara fauna.

Another aspect of the Ediacaran Yangtze platform is the abundance of black shales. Geochemical analysis of these shales may give the information necessary to differentiate shallow from deep-water shales, which are difficult to recognize in the field.

The Yangtze platform “cap carbonate” facies remains poorly known and may yield relevant information about the depositional conditions of this peculiar interval.

Concerning the Dengying/Liuchapo Formation, numerous points remain unexplored. Despite the apparent facies monotony shown by these two formations, their sedimentary analysis is fundamental to understand the Cambrian bioradiation, because the Precambrian/Cambrian transition is located in these formations.

Facies analysis of the Dengying Formation, coupled with stable isotope analysis may determine the sedimentary and chemical conditions of the depositional environment. Associated with a study of stromatolite morphological variations, such a study may give an interesting view on the interaction between stromatolite growth and depositional conditions. This work may complete the observations of Weber (pers. comm.), who noted a relationship between trace fossils and the presence of biomats.

A chemical study of dolomitization may contribute to the understanding of Ediacaran diagenetic processes.

In the Liuchapo Formation, the challenge may be to find a way to differentiate shales. To this purpose, a systematic geochemical analysis may help. Another problematic aspect is to understand the mechanisms of black shale silicification and the local presence of “pure” chert. It may be interesting to look for the origin of silica, to understand if the Liuchapo Formation is not a diagenetically silicified facies of Doushantuo Formation black shales, and, in this case, if the extent of silicification in outcrop is time-equivalent in all sections.

Moreover, several episodes of mass movement marked by major slide sheets, slumps, and debrites have been identified in the Liuchapo Formation. Their sedimentary analysis and mapping remains to be studied.

Finally, it would be meaningful to place the sedimentary evolution of the Ediacaran Yangtze platform in a worldwide context. For example, Jiang et al. (2003c) proposed a correlation between the evolution of the Yangtze platform and the Lesser Himalaya deposits in India. It appears that the Ediacara-fauna specimens occur, in general, on shallow-water, more-or-less agitated platform or tidal flats with siliciclastic inputs (Knoll et al., 1995; Vidal and Moczydlowska, 1995; Shanker et al., 2004). More similarities need to be found between Ediacara-fauna localities worldwide in order to highlight common factors, which may have favored the Ediacaran bioradiation.