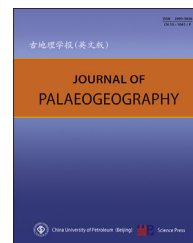




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Multi-origin of soft-sediment deformation structures and seismites

Researches of soft-sediment deformation structures and seismites in China — A brief review



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Abstract During the past 30 years (1987–2016), a great progress has been made in researches of soft-sediment deformation structures (SSDS), seismites and palaeoearthquakes in China. However, the research thought of this academic field is not open enough. It is almost with one viewpoint or one voice, *i.e.*, almost all the papers published in journals of China considered the layers with SSDS as seismites. On the other hand, the authors are very glad to learn that the professors and students of China University of Petroleum (East China) have proposed different academic viewpoints on the origin of SSDS in Lingshan Island, Qingdao, Shandong Province, China. It is a very active academic atmosphere. The authors' ideas are as follows: (1) The SSDS are sedimentary structures with multi-origin. The term “SSDS” is a good sedimentary and geological term and should be utilized continually. (2) The term “seismites” is a term which is definitely assigned to the layers with SSDS induced by earthquakes. It is one type of the layers with SSDS. It is not equal to SSDS. (3) Some geologists suggested obsoleting the term “seismites”. These suggestions are rational. However, since the term “seismites” has been utilized for a long time in China and worldwide, to obsolete this term should be discussed and agreement should be acquired from numerous geologists in China and worldwide. It may be suitable that let the geological practice decide whether to obsolete it or not. (4) Hopefully, further progress will be made in the researches of SSDS.

Keywords Soft-sediment deformation structures (SSDS), Multi-origin, Seismites, Palaeoearthquake, Lingshan Island, China

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1. Introduction

The “soft-sediment deformation structures (SSDS)” are sedimentary structures with multi-origin.

The term “seismites” was introduced by Seilacher (1969) to indicate the layers with SSDS that were induced by earthquake.

1.1. Great progress, but almost with one viewpoint

The earliest reports in Chinese journals are *Event deposits* (Gong, 1987) and *Tempestite, seismites and tsunamite: A discussion of several sedimentological terms* (Gong, 1988), both written by Prof. Yi-Ming Gong.

The first paper on the research results of seismites published in Chinese journals is *A possible seismic-tsunami succession in the Precambrian carbonate rocks in the Ming Tombs, Beijing* by Prof. Tian-Rui Song (Song, 1988).

Prof. Xiu-Fu Qiao and his scientific research team have published many papers and books about SSDS, seismites and palaeoearthquakes in China. *Seismic Records in strata (Ancient Earthquakes)* and *Seismites: Palaeoseismic records in sedimentary rocks*, are the representative works of Qiao et al. (2006, 2013). Prof. Qiao has made great contributions to the researches of seismites and palaeoearthquakes of China.

In order to promote the further development of researches of SSDS, seismites and palaeoearthquakes in China, in early 2011, the *Journal of Palaeogeography (Chinese Edition)* decided to organize a special issue of SSDS, seismites and palaeoearthquakes.

In August 2011, two manuscripts were submitted to the *Journal of Palaeogeography (Chinese Edition)*.

The first manuscript, *Discussion about studies of earthquake event deposit in China*, was written by Prof. Yuan-Sheng Du. He firstly summarized and reviewed 115 papers of SSDS and seismites published before 2011 in Chinese journals.

The second manuscript, *Soft-sediment deformation and occurrence frequency of palaeoearthquake in the Mesoproterozoic Wumishan Formation, Yongding River Valley, Beijing* was written by Prof. De-Chen Su and Prof. Ai-Ping Sun. The photos of SSDS in this manuscript are highly interesting. I suggested the authors of this paper to guide me, Prof. Xiu-Fu Qiao, Prof. Xiu-Juan Zheng and others to Yongding River Valley and to examine the outcrop of SSDS. They all agreed with my proposal.

On September 3, 2011, Prof. Su and Prof. Sun guided us (I, Profs. Xiu-Fu Qiao, Bi-Zhu He, You-Liang Ji, Xian-

Pu Guo, Xiu-Juan Zheng, Dr. Xin-Po Li and several students) to Yongding River Valley. The SSDS in the field outcrop are very clear and beautiful and the explanations of SSDS by Prof. Su are reasonable (cf., Su and Sun, 2011, 2012). About the characters and origin of the SSDS and the lithological characteristics of the host rocks of SSDS, we discussed and contended enthusiastically and basically got a common view in final. It was a successful investigation and review field trip.

In December 2011, a special issue of SSDS, seismites and palaeoearthquakes was published in Vol.13, No.6 of the *Journal of Palaeogeography (Chinese Edition)*. It includes 7 papers, i.e., Du, 2011; He et al., 2011; Jia et al., 2011; Su and Sun, 2011; Tian et al., 2011; Yang et al., 2011; Zhou et al., 2011; Zhu et al., 2011. It was the first special issue for seismites in journals of China.

As the Editor-in-Chief of *Journal of Palaeogeography (Chinese Edition)*, I wrote a preface, *Go ahead, researches on palaeoearthquake in China*, to congratulate on the special issue and palaeoearthquake researches in China.

In 1987–2015, altogether about 140 papers of SSDS and seismites have been published in Chinese journals, which is a significant and positive achievement.

However, the origin of SSDS mentioned in these published papers, was almost with one viewpoint or one voice, i.e., almost all the SSDS were induced by earthquakes, and therefore almost all the layers with SSDS are seismites. It is not a good phenomenon.

1.2. Multi-origin of SSDS

The SSDS have multi-origin. The “seismites” is one type of the layers with SSDS that were caused by earthquakes.

The paper by Moretti and Van Loon (2014) and its references indicated that the SSDS have different origin, such as rapid sedimentation in turbiditic deposits (Moretti et al., 2001), collapse of karst sinkhole activity (Moretti et al., 2011), seismic shocks and overloading induced by sudden deposition of coarse sediments on clays due to the arrival of density currents (Moretti and Sabato, 2007), etc.

Previously, in 1970s, Blatt et al. (1972) in their book, *Origin of Sedimentary Rocks*, pointed out that unconsolidated sediment can form some penecontemporaneous deformation structures, such as “load structures” (denser sediment layers overlying less dense layers), “slump structures” (gravity movement of sediment deposited on a slope), etc. These structures are typical soft-sediment deformation structures.

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