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# Controls on organic matter accumulation in the Triassic Chang 7 lacustrine shale of the Ordos Basin, central China

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ABSTRACT

The Triassic Chang 7 Formation is a rich lacustrine source rock in the Ordos Basin, central China. Petrographic and geochemical analyses were performed in order to research the mechanism of organic matter (OM) enrichment in the Chang 7 shales. Bulk geochemical data indicate that the OM-rich shales were formed in a fresh and brackish water, which is not usually the case for high TOC (Total Organic Carbon Content) sediments. Therefore, there must be some special conditions favorable for OM enrichment in Chang 7 shales.

Petrography and element geochemistry show that the Chang 7 OM-rich shales are abundant in OM-enriched laminae, framboidal pyrites, collophanes, and some elements including iron (Fe), diphosphorus pentoxide ($P_2O_5$), copper (Cu), vanadium (V), molybdenum (Mo), and uranium (U). High bio-productivity (algae blooming) and anoxic depositional environments are critical for OM enrichment. As the organic carbon contents increase, the Fe, $P_2O_5$, Cu, V, Mo, and U element contents increase as well and the ratios of U/Th and V / (V + Ni) are growing. Many geochemical data demonstrate that the water was oxic, while the environment under the sediment-water interface was anoxic as a result of a high organic supply that sufficiently consumed oxygen.

Taking into account the geological settings and our previous studies, we propose that the frequent volcanic events and hydrothermal activity caused by the collision of the North China landmass with the Yangtze landmass and consequential formation of the Qingling Mountains had a significant role in the OM enrichment in the fresh and brackish lacustrine shales. Deposition of volcanic ash into aqueous environments might lead to the increase of some key nutrients, such as Fe and $P_2O_5$, which might enhance primary bio-productivity. New evidence for hydrothermal activity, the reddingite, was demonstrated in this study. Not only can the hydrothermal activity provide elements necessary for life, but is also favorable for formation of anoxic settings.

The deposition of the Chang 7 lacustrine OM-rich shales can be explained using the High-Bio-Productivity-Driven Model, which is related to volcanic events and hydrothermal activity as a consequence of regional tectonic movements. An anoxic depositional setting is beneficial for OM preservation and slow sedimentation rates in the deep lacustrine environments are favorable for OM enrichment.

## 1. Introduction

Source rocks are the basis for petroleum systems (Magoon and Dow, 1994), and their distribution, quality, and richness are critical in assessing the exploration risks (Harris, 2005). Therefore, knowledge of the controlling factors for the formation of such rocks is an important element in reducing the exploration risks (Katz, 2005). The mechanisms of organic-carbon (OC) enrichment in these rocks have long been a topic of interest to bio-geochemists and petroleum geologists, dating back to at least in the 1920s (Tyson, 2005). However, there is still significant disagreement among researchers regarding the key factors that govern the deposition of OC-rich source rocks. Three main controls for source-rock deposition have been identified, including bio-productivity, anoxia, and sedimentation rate. Several researchers suggested that elevated bio-productivity, which is associated with either upwelling and/or river input, is the dominant factor controlling the formation of OM-rich rocks (Pedersen and Calvert, 1990; Parrish, 1995; Hay, 1995). Others proposed that the deposition of OM-rich source

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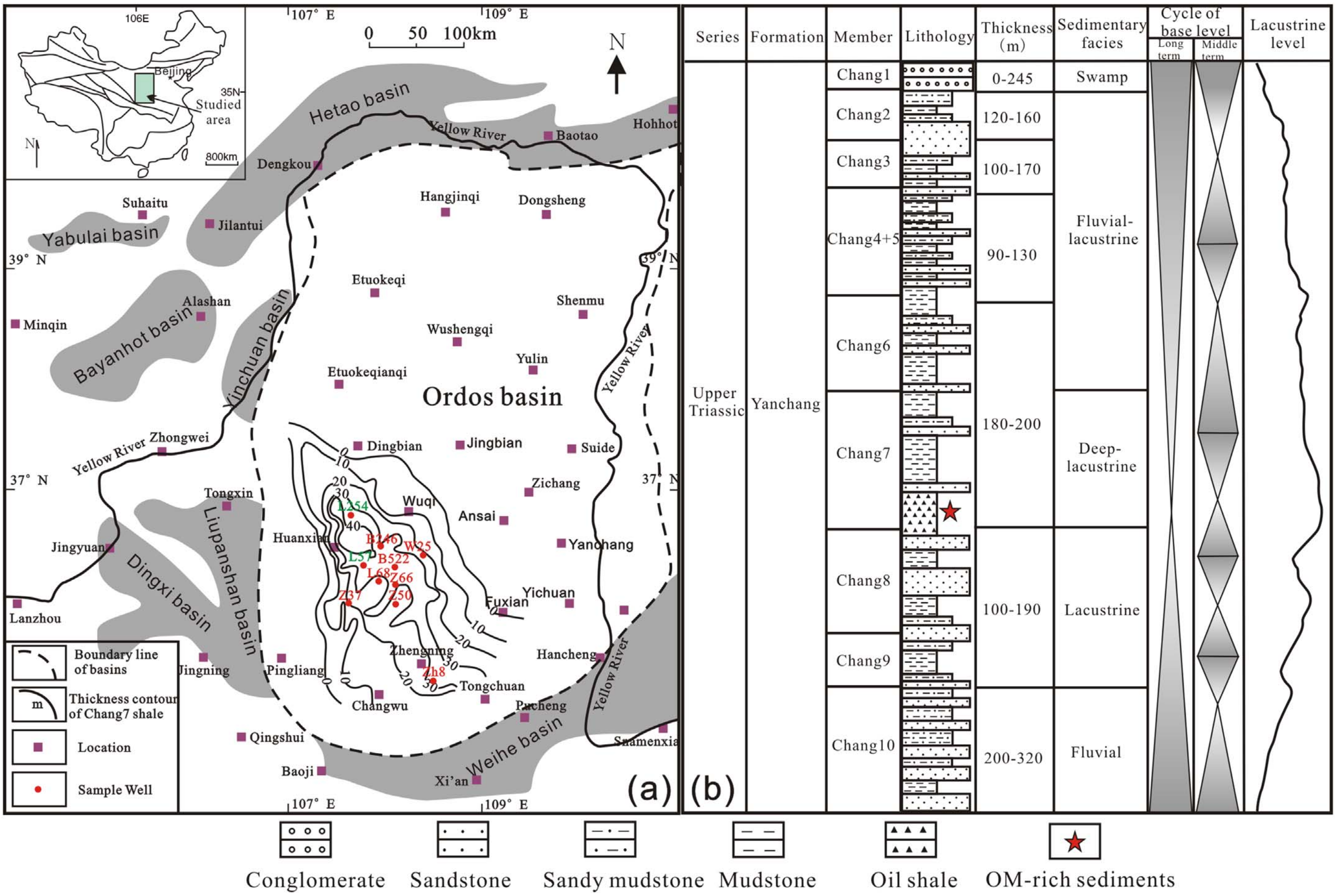


**Fig. 1.** (a) Isopach map (in meters) of the Chang 7 OM-rich shale in the Ordos Basin (after Qiu et al., 2014), and (b) stratigraphic and lithology column (after Yang, 2002) of the Upper Triassic Yanchang Formation in the Ordos Basin.

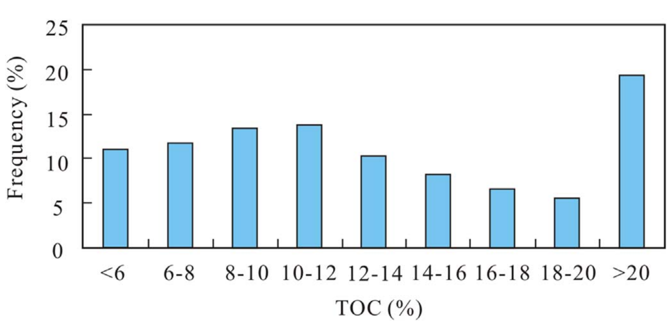


**Fig. 2.** TOC histogram for the Chang 7 OM-rich shales (290 samples) showing the shales are abundant in organic carbons (after Yang and Zhang, 2005).

rocks results from enhanced preservation of OM within anoxic settings (Demaison and Moore, 1980; Bralower and Thierstein, 1987; Hollander et al., 1991; Curiale and Gibling, 1994; Katz, 1995; Gélinas et al., 2001), such as the water-column stratification (Demaison and Moore, 1980). A third group pointed out that two opposing models of sedimentation rate can be used to explain the development of OM-rich source rocks. One model is based on elevated sedimentation rates which may enhance OM preservation (Coleman et al., 1979; Ibach, 1982), and another model is based on very slow sedimentation rate and absence of mineral dilution, which would result in OM concentration (Creaney and Passey, 1993). Although individual examples can be found for each independent mechanism, a number of researchers have stated that the

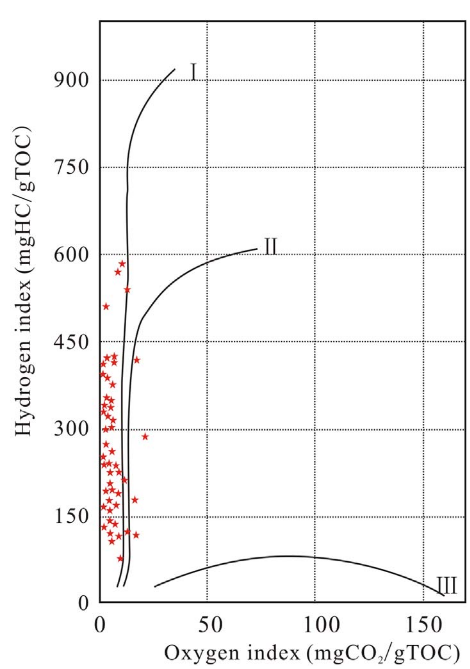


**Fig. 3.** Rock-Eval pyrolysis hydrogen and oxygen indices of the Chang 7 OM-rich shales (48 samples) indicating high hydrogen indices and sapropelic organic matters (after Yang and Zhang, 2005).