Songliao Basin: the Largest Lacustrine Oil Field in East Asia —— Time, Biota, Climate

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The Songliao Basin is the largest Cretaceous oil and gas-producing lacustrine basin in China. The modern Basin is 700 km long from north to south, and 370 km wide from east to west, covering 260,000 km^2 areas of Heilongjian, Jilin, Liaoning and Inner Mongolia provinces. Its greatest aerial extent happened in the middle Cretaceous while the thickness of sedimentary strata grew up to 8000m. The first commercial oil well in the Daqing Oil Province was completed in 1959. Its available resources are 6.0*109 t with the production of more than 40*106 t/a, and the cumulative oil production is over 2 billion tons.

The geologic history of this basin is well known because of the extensive drilling for hydrocarbons. However, the background of lacustrine hydrocarbon is scientific issues, which needs to understand the links and feedbacks of the carbon cycle during times of global greenhouse. For this purpose, numerous studies have focused on the Cretaceous climate,, much of what we know about this warm period in Earth's history comes from the study of ocean sediments from both ocean drill cores and marine sediments exposed on the Earth's surface. In contrast, there are few studies of Cretaceous terrestrial sediments. The Songliao basin located in northeast China offers a unique opportunity to perceive Cretaceous paleoclimate of terrestrial settings as it contains a nearly complete record of lacustrine sediments deposited throughout the Cretaceous and an active drilling program to recover core from this paleolake.

A coring program (SK1) has to date yielded 2485.89m of continuous core (96.46% recovery) and provides significant material for Cretaceous research. The sequence of the core consists mainly of lacustrine sandstone, dark grey mudstone, shale and oil-shale. The Upper Cretaceous stratigraphic section has been subdivided into the Quantou, Qingshankou, Yaojia, Nenjiang, Sifangtai and Mingshui formations in ascending order. Late Cretaceous microfossils are diverse and abundant. A detailed biostratigraphic study has subdivided the sequence into high precision biozones: 21 ostracod assemblages, 10 phytoplankton assemblages, 7 palynological zones and 4 charophyta assemblages, respectively. In addition, marine foraminifera were first discovered from the basin. Three 206Pb/238U ages of 91.4 ± 0.5 Ma, 90.1 ± 0.4 Ma, 83.7 ± 0.5 Ma and one 40Ar/39Ar age of 88.3Ma were analyzed.

Eleven local magnetozones have been recognized in the well SK1. Based on biostratigraphy, high-resolution magnetostratigraphy and SIMS U-Pb zircon analyses, the SK1 stratigraphy is correlated with Upper Cretaceous stages. The upper part of the Quantou Formation is lower Turonian; the Qingshankou Formation is upper Turonian- lower Coniacian; the Yaojia Formation is from upper Coniacian to middle Santonian; the Nenjiang Formation is upper Santonian to middle Campanian; the Sifangtai Formation is limited to upper Campanian; and the Mingshui Formation is uppermost Campanian to Maastrichtian. It is likely that the upper part of the Mingshui Formation belongs to Paleocene, and the K/Pg boundary is within the uppermost part of the Mingshui Formation.

The Cretaceous Period is a paradigm of a greenhouse climate and provides significant records of global climate changes and driving processes. For the paleoclimate study, we present carbon, oxygen and strontium isotopic data from ostracods collected from drill core SK1. These data record robust isotopic trends with numerous carbon and oxygen isotope shifts that are not only rapid but also long-term. We tentatively interpret this record to reflect the changes in both global climate and regional basin evolution. In the Turonian and Coniacian Qingshankou Formation we observe several carbon isotope shifts that appear to be correlative to marine isotopic records based upon timing and magnitude of the isotopic changes. Thus we suggest that the carbon isotope record in the Songliao basin reflect the decrease in carbon isotope ratios following the strong positive excursion at the Cenomanian/Turonian boundary, a positive isotope excursion in the late Turonian, and the negative isotope shift that occurs at the Turonian/Coniacian boundary. Upward in the section, however, the marine and Songliao isotopic records diverge as sediment sources shift from the southwest, east and north to more northerly. Strontium isotopes record the change in source region as they increase markedly between the Coniacian/Santonian Yaojia and Santonian/Campanian Nenjiang Formations. The rich isotopic records are compared to global climate changes and basin evolution as well.

Lake water salinity changed in a freshwater–brackish water –freshwater cycle, along with a Coniacian-Santonian marine incursion. Lake-level fluctuations resulted in the development of periodic anoxic environments in the deepest parts of the basin. One of these times of deposition of organic-rich mud correlates with the mangnetochron boundary of C34N/C33R and Coniacian-Santonian planktic foraminifera. This marine flooding correlates with OAE 3 and it is possible that the global oceanic anoxic event may have influenced organic carbon burial in the Songliao Basin for this brief period. The signal from Songliao Basin shows that the terrestrial climate change is somehow similar to marine recode as under one single Earth system.