Modeling a Tight Sandstone Gas System by Map-Based Isotopic Kinetic Tool: A Case Study in Ordos Basin, China*

Feiyu Wang[1], Meng Xiaohui[1], Feng Weiping[1], Zhiyong He[2], and Yongchun Tang[3]

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[1]State Key Laboratory of Petroleum Resource and Prospecting, College of Geoscience, China University of Petroleum (CUP),Changping, Beijing, China (fywang@cup.edu.cn)
[2]ZetaWare, Inc.,Sugar Land, TX, USA
[3]Power, Environmental and Energy Research (PEER) Institute, Covina, CA, USA

Abstract

The variability of gas composition and isotope geochemistry in a basin depends on the type and maturation of the source rock, size and distribution of fetch area, and gas accumulation mode (instantaneous, cumulative or intervenient). The Sulige tight sandstone Gas Field in the Ordos Basin is selected as a quantitative, calibrated case study that describes the relationships between source kitchen, fetch area, burial and uplift history, volume of expelled gas, and gas resource size to quantify gas accumulation efficiency from source kitchen to trap. Gas yields and isotope kinetics algorithms have been used in conjunction with the Interactive Basin and Petroleum System Modeling (BPSM) tool (Trinity 3D) to quantify gas generation in the source kitchen and fetch area, and to constrain the gas charge and accumulation history in the play and prospect. Case studies are presented to illustrate how the new map-based chemical kinetic quantitative tool is used to determine the origin of natural gas, source kitchen and fetch area, and charge history.

Gas Yields and Isotopic Kinetics Algorithms

Gas yields and carbon isotope kinetics algorithms of various type source rocks and oil cracking have been established, based on direct closed-system and open-system pyrolysis measurements of quantities and isotope fractionations for gases generated from specific source rocks (Type I lacustrine shale, Type II marine shales, Type III coal and carbonaceous shales) and oil cracking (marine oil and lacustrine oil). With the application of kinetic calculations of hydrocarbon generation we can extrapolate the high-temperature pyrolysis measurements to any geologic heating rate. GOR Isotopes, a PC-based software package for modeling the kinetics of natural gas generation designed by PEER are able to generate algorithms of gas yield and C1-C4 carbon isotope varied with temperature or maturity.

Stratigraphic variability of source rocks significantly impacts the gas yields and carbon isotopes. Simple statistic of geochemical screen analysis data, or the more complicated chemical kinetic model, cannot solve the problem of heterogeneity of source rocks. To constrain the gas generation and accumulation history with gas geochemical data, the prerequisite is that heterogeneity of source rock must be described with various TOC and HI intervals which have characteristic gas yields and isotopic kinetics model (Figure 1).

Map-Based Isotopic Kinetic Tool

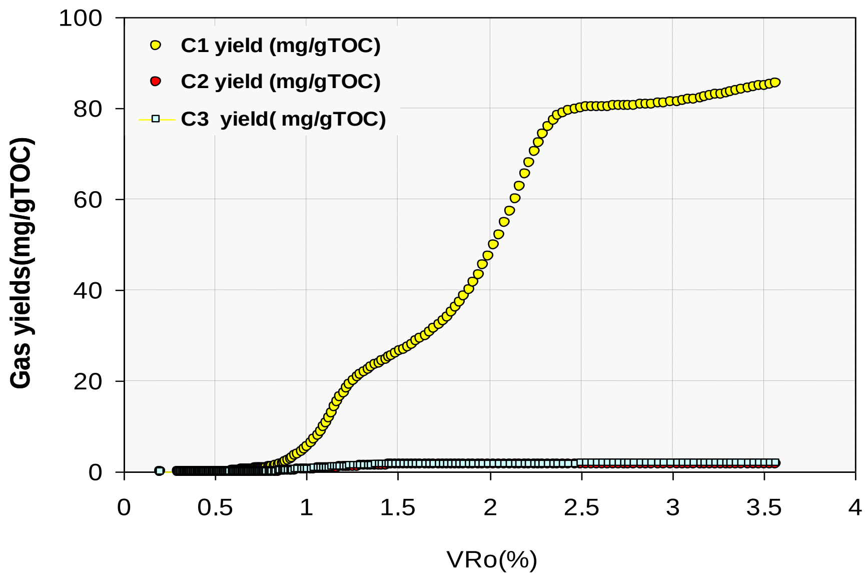
Charge volume history of the play and prospect are calculated from expelled volumes from the fetch area. On the other hand, gas composition and carbon isotopes in the mode of instantaneous, cumulative and intervenient are also calculated for expelled volume gas from the fetch area. The possible scenario of gas generation and accumulation history was postulated through comparison of measured carbon isotope data with calculated results.

Paleozoic Tight Sandstone Gas System in Ordos Basin

The upper Paleozoic coal measures are source rocks for the gas field, but many geologists suggested that the source kitchen is mainly located to the south and natural gas migrated a long distance from the south source kitchen to the present gas accumulation area. Refined geological architecture of the Ordos Basin has been established with 3D seismic and well stratigraphic data, and coal measure source rocks have been drilled and geochemical scanning analysis data have been upgraded with ΔlogR algorithms to describe the heterogeneous source rocks (coal, carbonaceous shale, and shale with different TOC intervals). Our new map-based chemical kinetic analysis indicates that short range is peculiar to the gas generation, migration and accumulation in the Paleozoic gas systems of the Ordos Basin (Figure 2).

Conclusions

The source rocks in close physical proximity to reservoir rock are peculiar to the many tight sandstone gas fields which result in secondary and tertiary migration losses that are relatively small, therefore most of the expelled gas from source rocks was accumulated in proximity to source rocks. Charge volume history of the play and prospect are calculated from expelled gas volumes of the fetch areas using Trinity 3D and calibrated with measured data. Gas accumulation efficiency and the possible scenario of gas generation and accumulation history can be postulated through comparison volume of expelled gas and gas resource size, as well as measured carbon isotope data with calculated results (Figure 3). The Sulige Gas Field in the Ordos Basin displays obvious cumulative accumulation, which is best fitted to the measured carbon isotope data. The gas accumulation efficiency in the Sulige Gas Field ranges from 30% to 35%, which is much higher than previous opinions.



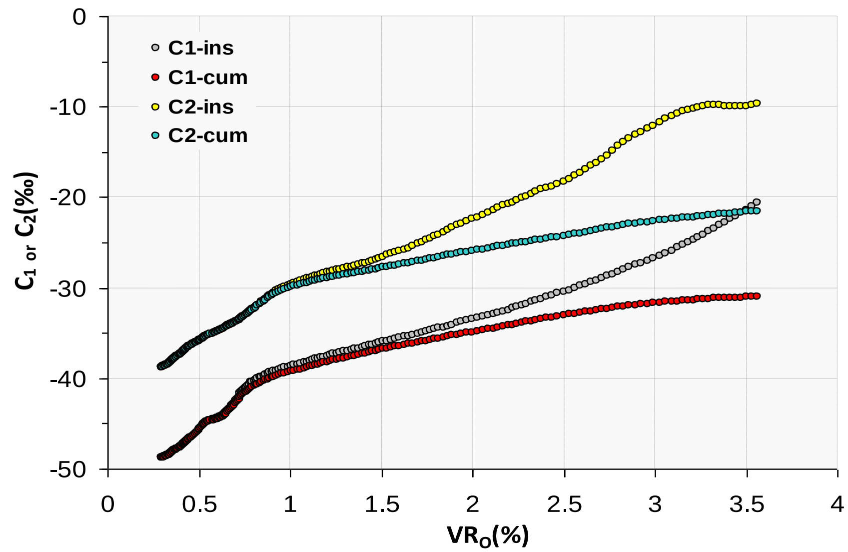


Figure 1. Gas yield and carbon isotope model for Type III coal (HIo=156mg/gTOC, initial carbon isotope of kerogen δ13C = -23.5‰).

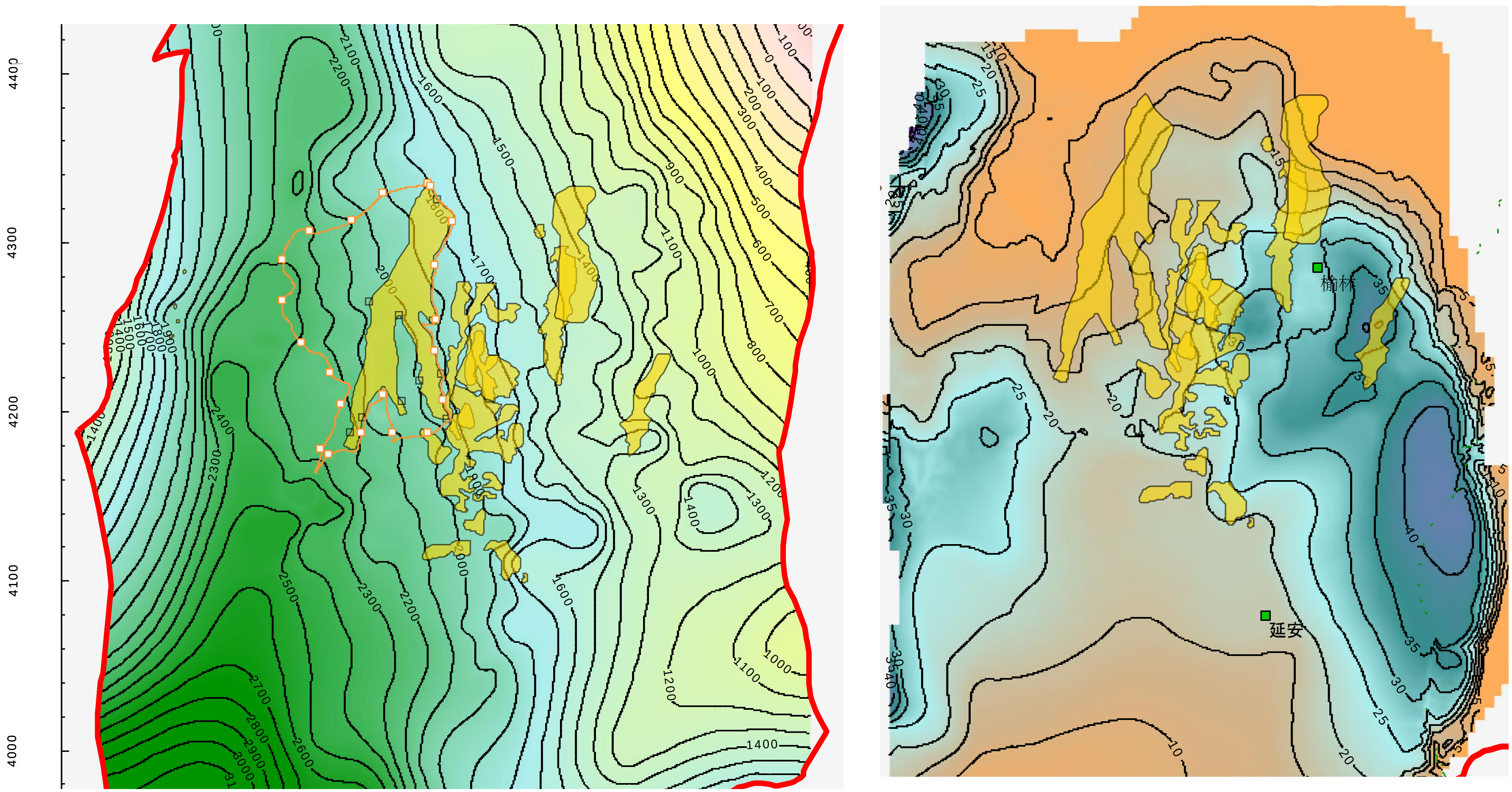


Figure 2. (left) Structure contours (m) on top of the Xiashihezi Formation 8 Sandstone Member. The Sulige Gas Field is located in the shaded areas; the dotted line shows the distribution of the speculative gas source kitchen for the Sulige Gas Field. (right) The amount of expelled gas (10^8 m^3/km^2) for the source kitchen of Pennsylvanian-Permian coal measures.

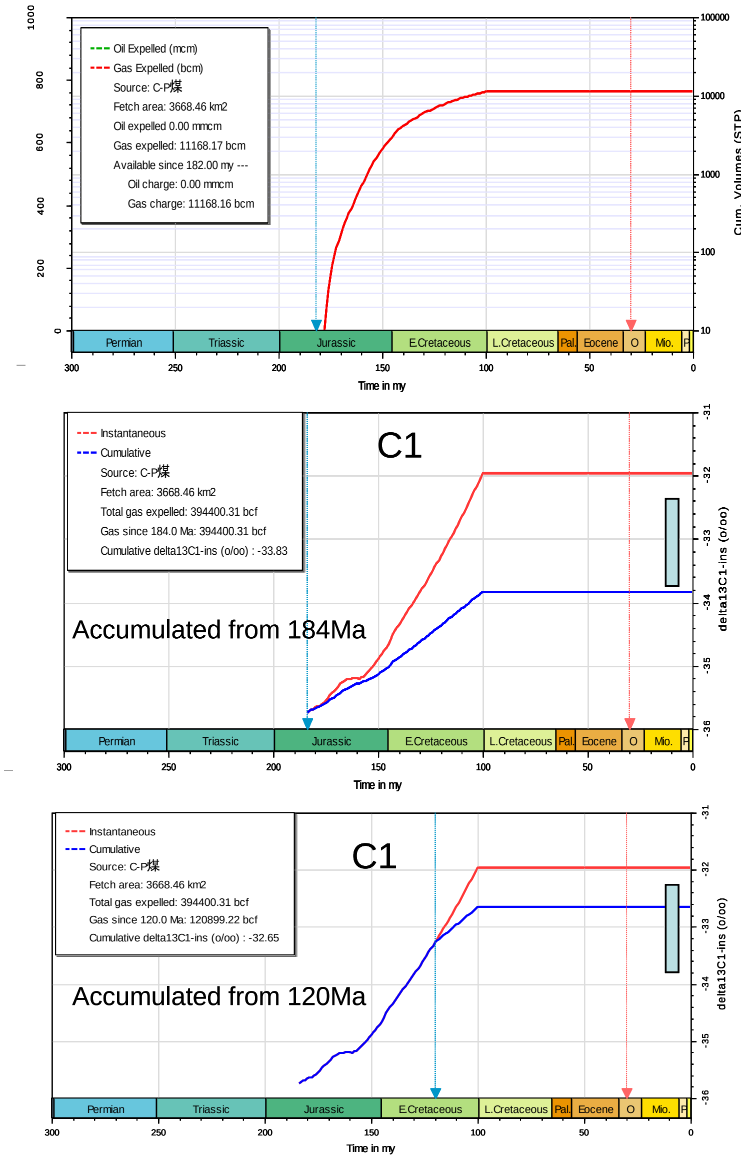


Figure 3. Charge volume history of the Sulige Gas Field. (upper) The amount of expelled gas of fetch area (shown in Figure 2, left) through geological time. (middle) The instantaneous and cumulative C1 isotope value curve for expelled gas of fetch area, accumulated from 184 Ma, compared with measured carbon isotope data (gray rectangular strip). (bottom) The instantaneous and cumulative C1 isotope value curve for expelled gas of the fetch area, accumulated from 120 Ma, compared with measured carbon isotope data (gray rectangular strip).