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Tracing Source Kitchen and Gas Charge Scenarios Using Map Based Isotopic Kinetical Tool

Feiyu Wang[1], Meng Xiohui[1], Yongchun Tang[2], Zhiyong He[3], Shuichang Zhang[4], Hu Guoyi[4]

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

The complexity and variability of gas composition and isotope geochemistry in basin depend on the type and maturation of source rock, size and distribution of fetch area, and gas accumulation mode (instantaneous, cumulative or intervenient). Stratigraphic variability of source rocks impacts the quantity and quality of gas generated, fetch area of the gas accumulation were evolutive during the geological time, and most gas accumulation mode were intervenient between instantaneous and cumulative, therefore more reasonable gas generation and charge scenarios tracing from gas geochemistry data should be based on petroleum system modeling with gas yields and isotope kinetics algorithms. In this paper, Gas yields and isotope kinetics algorithms have be used in conjunction with 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 migration and charge history in the play and prospect. Case studies are presented to illustrate how the new map based chemical kinetical quantitative tool to determine the origin of natural gas, source kitchen and fetch area, charge scenarios, and to quantify of migration and accumulation efficiency of tight sandstone gas.

1. Map Based Isotopic Kinetical Tool

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 C_1-C_4 carbon isotope varied with temperature or maturity.

New experimental data of the typical lacustrine and coal measures source rocks in Chinese basin, which uses the temperature-dependent fractionation of stable carbon isotopes in individual gas compounds, calibrated with direct closed system pyrolysis measurements of quantities and isotopic compositions of gases generated from specific source rocks or through secondary cracking of oil.

Gas yields and isotope kinetics algorithms include:

- Kerogen type: Type I, Type II, Type IIII (Fig-1)
- Oil cracking
  - Oil from lacustrine source rocks (Fig-2)
  - Oil from marine source rocks (high sulfur, low sulfur)
  - Oil cracking+TSR
- Kinetic organic facies: A ,B, C, D/E, F

Stratigraphic variability of source rocks significantly impacts the gas yields and carbon isotope. Simple statistic of geochemical screen analysis data or more complicated chemical kinetical model cannot solve the problem of heterogeneity of source rocks. We have revealed that universal covariant relationship of HI and TOC exist for lacustrine and marine mudstone source rocks, to the less degree for terrestrial source rock. Therefore, characterization of type or hydrocarbon potentials of source rocks can be simplied to their counterparts TOC description. HI distribution and activation energy are peculiar for different TOC interval (0.5-1%,1-2%,2-3%,more than 3%) mudstone, Four TOC interval kinetic organofacies, each characterized by HI,TI,GOGI and bulk petroleum generation kinetics, have been established for lacustrine source rocks, which can be related to evaluation of source rock on wireline logs.

Gas yields and carbon isotope kinetics algorithms of various type source rocks and oil cracking can be import into the Trinity 3D, Charge volume history of the play and prospect are calculated from expelled gas volumes of the fetch areas, on the other hand, gas composition and carbon isotope in the mode of instantaneous, cumulative and intervenient also calculated for expelled volume gas from the fetch area, possible scenario of gas generation and accumulation history were postulated through comparison measured carbon isotope data with calculated results.

2. Case studies 1: LW gas field in Baiyun depression, PRM basin

LW gas field is the first great gas field found in deepwater area of China, which located in Baiyun depression, PRM basin, south China sea, Geologists presumed that Eocene Wenchang Formation oil-prone lacustrine source rocks and Oligocene Enping Formation gas-prone humic-type source rocks were co-existed in the Baiyun depression. Where is source kitchen (short range kitchen or long range kitchen?) and what is gas charge scenarios are controversial (Fig.1).

Table 1: Carbon isotopic data of natural; gas from LW gas field

Well No	Depth(m)	C1	C2	C3	iC4	nC4	CO2
LW3-1-1Sa	3070	-37.1	-29.0	-27.2	-27.1	-27.1	-5.7
LW3-1-1	3144.5	-36.6	-29.1	-27.4	-26.8	-26.8	-6.1
LW3-1-1Sa	3189.5	-36.8	-28.9	-27.5	-26.9	-26.9	-5.7
LW3-1-1	3499.5	-36.6	-29.6	-29.1	-28.1	-28.1	-7.8

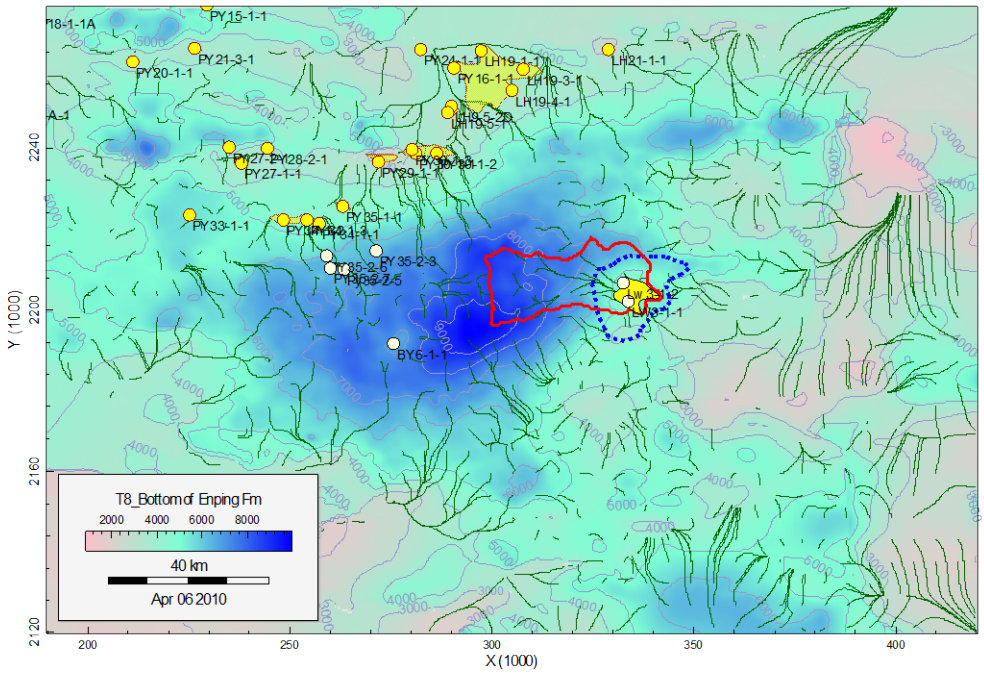

Fig. 1: Possible gas source kitchen for LW gas field in Baiyun depression, PRM basin, south China sea, short range kitchen in blue dot line area, or long range kitchen in red line area

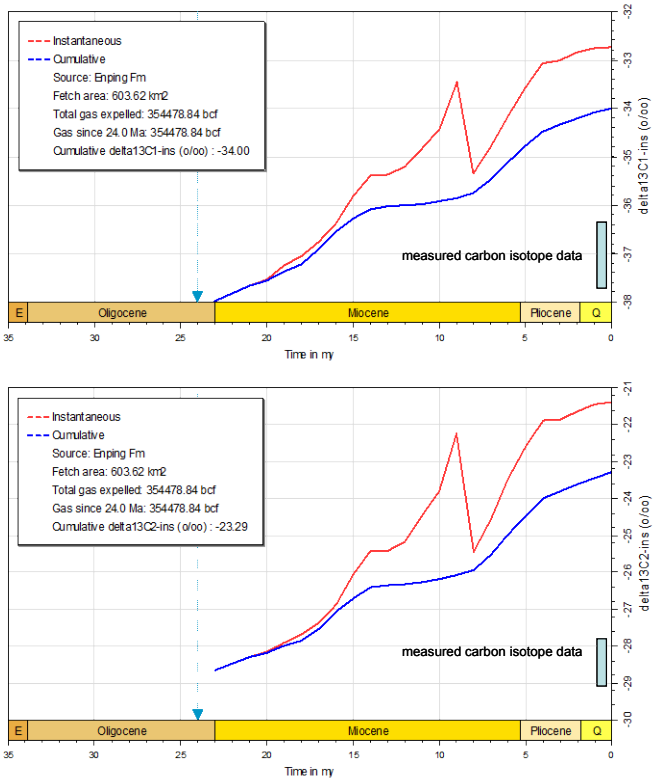

Fig. 2: C_1 and C_2 isotopic value of expelled gas from the long range kitchen in red line area

C_1 and C_2 isotopic value of expelled gas from the long range kitchen and short range kitchen are compared with measured carbon isotope data (Table 1),The cumulative gas from the long range source kitchen is much heavier than natural gas from LW gas field, and The cumulative gas from the short range source kitchen is similar to the natural gas from LW gas field, which indicate that natural gas from LW gas field derived from the short range kitchen, or the early phase gas of the long range kitchen, dry and heavier natural gas from high and overmature kitchen are existed in the downdip direction of LW gas field, but at presently there are no evidences to support it. We postulate that effective gas-prone source rocks in Baiyun depression are localized in delta plain with swamp often developed.

3. Case Studies 2: Paleozoic gas systems in Ordos Basin

The upper Paleozoic coal measures are source rocks for the gas field (Dai et al, 1999), but many geologists suggested that source kitchen mainly located in the south area, and natural gas migrated long distance from the south source kitchen to the present gas accumulation area. Our new map based chemical kinetic analysis indicate that short range are peculiar to the gas generation, migration and accumulation in the Paleozoic gas systems in Ordos Basin, the migration and accumulation efficiency of Sulige tight sandstone gas fields is high, most of expelled gas were accumulated in Lower Permian Shanxi and Xiashihezi Formations tight sandstone reservoir.

Fig. 3: Distribution of $\delta^{13}C_2$- $\delta^{13}C_1$ value of Paleozoic natural gas accumulation (left) and explanation model of gas generation from coal measures (Type III) (Right), which indicate Pennsylvanian－Permian coal measures as predominant source rocks, gas charge in short range cumulative mode, the relative variety of $\delta^{13}C_2$ and $\delta^{13}C_1$ value of gas field reflect emplacement of gas from different maturity phase.

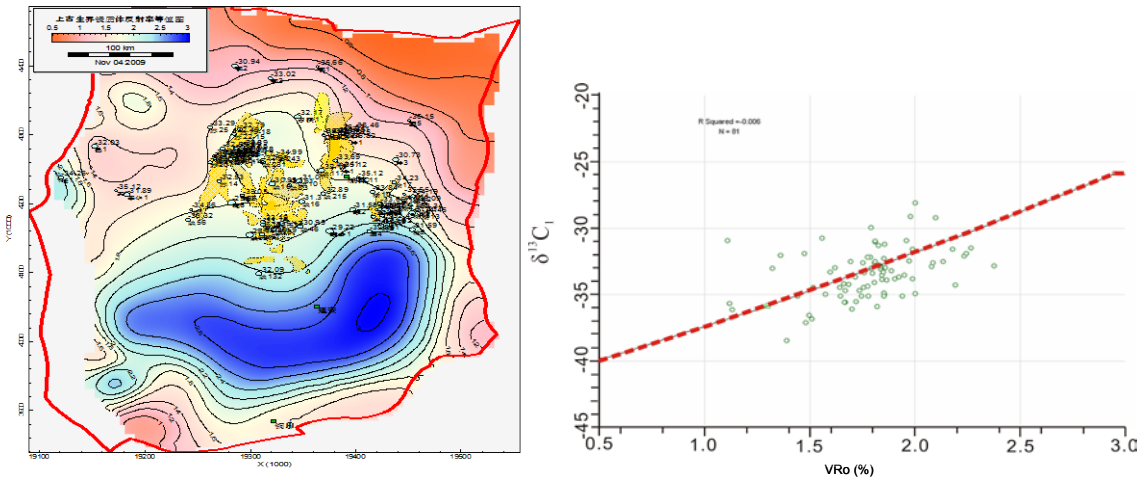

Fig. 4: Isoline of VRo of Pennsylvanian－Permian coal and $\delta^{13}C_1$ value distribution of natural gas accumulation in the dolomites of the Lower Ordovician and sandstones of Lower Permian Shanxi and Xiashihezi Formations (left) and correlation between $\delta^{13}C_1$ of natural gas accumulation and VRo of in-situ Pennsylvanian－Permian coal measures (right).

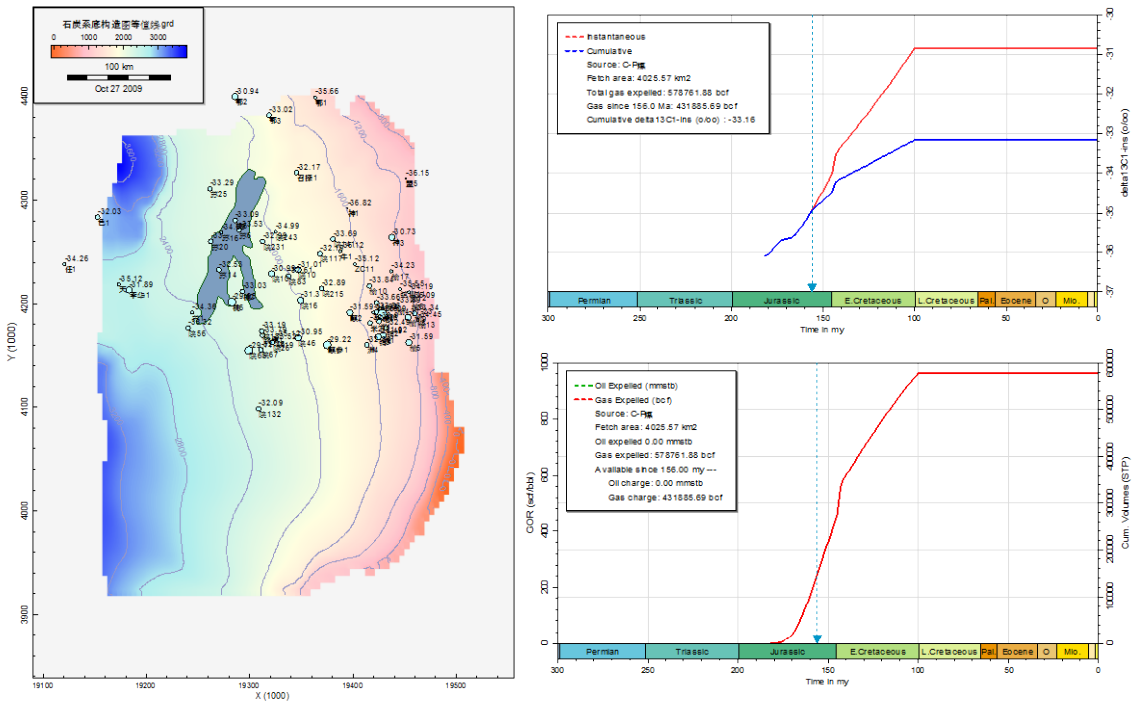

Fig. 5: Sulige gas field (gray area) and distribution of $\delta^{13}C_1$ value of Paleozoic natural gas accumulation (left) and scenarios of short range gas generation, migration and accumulation (right) through comparison measured carbon isotope data with calculated results, in the right calculation case gas fetch is similar to the gas field distribution