UNRECOGNIZED EXTENSIVE EARLY CHARGE OF BIOGENIC GAS INDICATED BY EXTREMELY $^{13}$C-DEPLETED CALCITE AND METHANE IN JUNGGAR BASIN

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Introduction

Natural gas in Mahu Sag in NW Junggar is considered to have thermally cracked from both kerogen and oils (Tao et al., 2016) and biogenic gas is limited to Shazhang area in the eastern Junggar Basin (Sun et al., 2016), based on relationships of $\delta^{13}$C$_1$ to $\delta^{13}$C$_2$, $\delta^{13}$C$_3$ and C$_1$/C$_2+3$). Interestingly, extremely negative $\delta^{13}$C values (−70 to −22.5‰) and high Mn (average MnO = 5 wt.% calcite have been reported from Lower Triassic Baikouquan Formation sandy conglomerates in Mahu Sag (Hu et al., 2018), leading to a possibility for the oxidized methane to have been biogenic, although a thermogenic origin was proposed (Hu et al., 2018). Thus, it is necessary to re-explain the natural gas data, update petroleum charge history and hopefully to find new biogenic gas pools in the basin.

Results and Discussion

81 Natural gas data from the Carboniferous to the Lower Cretaceous reservoirs were collated from Tao et al. (2016) for Mahu sag region in the NW Junggar basin and from Sun et al. (2016) for Dibei, Dixi and Shazhang areas in eastern Junggar basin. These gases have dryness from 0.71 to 1.0, $\delta^{13}$C$_1$ from -26.6 to -60.7‰, $\delta^{13}$C$_2$ from -21.6 to -40.9‰ and $\delta^{13}$C$_1 < \delta^{13}$C$_2 < \delta^{13}$C$_3 < \delta^{13}$C$_4$. $\delta^{13}$C values of calcite cement from Lower Triassic Baikouquan Formation fan delta facies sandy conglomerates and sandstones in Mahu Sag were from Hu et al. (2018), and range from -24.3 to -81.9‰ (n=50). To my knowledge, for the whole basin, only three gases from reservoir depths <512m in Upper Permian Pingdinquan Fm in Shazhang area are considered as biogenic. These gases are composed of methane with $\delta^{13}$C$_1$ from -54.6 to -60.7‰, nitrogen and small amount of carbon dioxide. However, when I plot the data on 1/n - $\delta^{13}$C$_n$ diagram of Chung et al. (1988), it is clear that 70 of the total 81 gases show that current $\delta^{13}$C$_1$ values are significantly lighter than those of the respective extension from the 1/n - $\delta^{13}$C$_n$ (n=2 to 4) (Fig. 1), suggesting that thermogenic gas must have mixed with biogenic methane with lighter $\delta^{13}$C$_1$ than the current. The biogenic gas can be concluded to occur from the Carboniferous to the Lower Cretaceous in the Northern Zhongguai Uplift, Ke-Kai fault zone, Wu-Xia fault zone, Mahu sag, Dibei and Dixi uplifts and Shazhang area, suggesting a widespread biogenic gas charge in the basin, which has not been recognized before.

The source and charge history of the biogenic gas are puzzled. Biogenic methane is generally accepted to generate from type III kerogen at vitrinite reflectance Ro < 0.5%. The Pingdiquan Fm in Dongdaohai Sag or Shazhang area with the biogenic methane is isochronous with Lower Wuerhe Fm in Mahu sag, and is composed of freshwater lacustrine facies type III kerogen mudstone, and thus is the most likely source rock for the gas in the Mahu sag and likely other areas. The biogenic gas may have charged earlier than thermogenic gas and oil. This proposal is supported by the following two aspects: 1) biogenic gas is generated at low temperatures favorable for microorganisms to grow at; 2) most of the calcite cements have $\delta^{13}$C values close to the biogenic methane (Fig. 1), suggesting that only biogenic methane was charged prior to or during the oxidization. Otherwise, heavier hydrocarbons are expected to have been oxidized preferentially over methane (Machel, 2001) and to produce
significantly more $^{13}$C-rich calcite than the present. Biogenic CH$_4$ with $\delta^{13}$C of about -55 to -80‰ is most likely to have migrated up from Lower Wuerhe Fm during and immediately after the deposition of Baixiangtangan Fm seal rock by the end of the Triassic when Lower Wuerhe Fm has organic matter maturity <0.5% and no significant oil and gas has been generated from the underlying Lower Permian Fengcheng Fm, the main source rock for the petroleum in Mahu sag (Cao et al., 2016).

Figure 1 Alkane $\delta^{13}$C-$I/n$ diagram showing that all the Mahu gases have methane $\delta^{13}$C$_1$ significantly lighter than the co-generative, unaltered gas of Chung et al. (1988) model, suggesting mixing with biogenic methane. Both gas and calcite cements from the Well M18 are plotted in red colour for comparison.

Conclusions

Extensive biogenic gas charge may have occurred during and immediately after the deposition of the Upper Triassic seal rock in the Mahu sag and other areas. Part of the biogenic methane was oxidized by MnO$_2$ or Mn$_2$O$_3$ in hematite biologically and subsequently thermochemically to generate Mn(II) rich calcites with $\delta^{13}$C of about -60 to -82‰. This event was followed by the charge of oil and associated gas from the underlying Fengcheng Fm source rock. Thus, the present gases show mixing between thermogenic gas and biogenic methane. Biogenic gas should be explored in the basin.

References