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Origin of the Permian to Triassic Natural Gases from Northwest Sichuan Basin

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Commercial natural gases have been found from the Carboniferous to the Upper Triassic in the Northeast Sichuan Basin. Potential source rocks for the gases include Lower Cambrian, Lower Silurian, Upper Permian and Upper Triassic. Natural gases from the Upper Permian Changxing (P_3ch) to Lower Triassic Feixiangguan Formation (T_1f) show dryness coefficient values greater than 99.4%. The values range from 97.4 to 99.6% for the Lower Triassic Jialingjiang Formation (T_1j) gases. All the gases contain H_2S from nil to 20% by volume. Linear positive correlation relationships of $H_2S/(H_2S+HCs)$ (i.e., extent to thermochemical sulfate reduction: TSR) to methane and ethane $\delta^{13}C$ values were found for Wolonghe T_1j gases (Cai et al., 2003) and NW Sichuan T_1f gases (Cai et al., 2004).

More recently, more gas pools have been found to the west of the previous studied area. When all gases are considered, we find that pre-TSR gases from Puguang, Dukouke, Tieshanpo and Luojiazhai areas, the east to Puguang area (East gases) have methane and ethane $\delta^{13}C$ values significantly lighter than those from Yuanba and Heba areas, west to the Puguang (West gases). Reservoir bitumen in association with the gases show similar hopane and sterane biomarker parameters, but abundant aryl isoprenoids only in association with West gases but not with East gases. Aryl isoprenoids are detected from the upper part of Dalong Formation (P_3d or P_3ch) of Upper Permian and Lower Silurian (S_1l), but not from Longtan Formation (P_3l). Thus, assuming that the West gas was derived from oil cracking, it is reasonable to consider that reservoir bitumen and thus pre-cracking oil and resultant gas in the West were derived from Dalong Fm or Lower Silurian, but not from Longtan Fm, as previously considered. In contrast, reservoir bitumen from the East does not contain aryl isoprenoids, and shows $\delta^{13}C$ values close to Longtan Fm kerogen. The features support that reservoir bitumen and gases in the East were derived from the Longtan Fm.

However, the West gas has methane and ethane $\delta^{13}C$ values significantly heavier than the Carboniferous gas, which are generally considered to have been derived from the Silurian source rocks. Thus, origin of the West gas remains unsolved.

Methane, ethane and propane are well-known to show positive shift in $\delta^{13}C$ values with increasing TSR extent. East gases show a logarithmic relationship between residual hydrocarbon ($HCs/(HCs+H_2S)$) and methane $\delta^{13}C$ values (Fig. 1a). The relationship is similar to the model of

residual methane after oxidization by microbes as proposed by Whiticar (1999), which is derived from Rayleigh fractionation. A similar logarithmic relationship between residual hydrocarbon (HCs/(HCs+H_2S)) and ethane $\delta^{13}C$ values (Fig. 1b) can be found when we plot data from Jurassic gases from the Mobile Bay, northern Gulf of Mexico (Mankiewicz et al., 2009). These relationships well indicate that isotopically light carbon has preferentially been oxidized as a result of kinetic isotope fractionation, and that TSR was dominated by methane in the NW Sichuan Basin and by ethane in the Mobile Bay.

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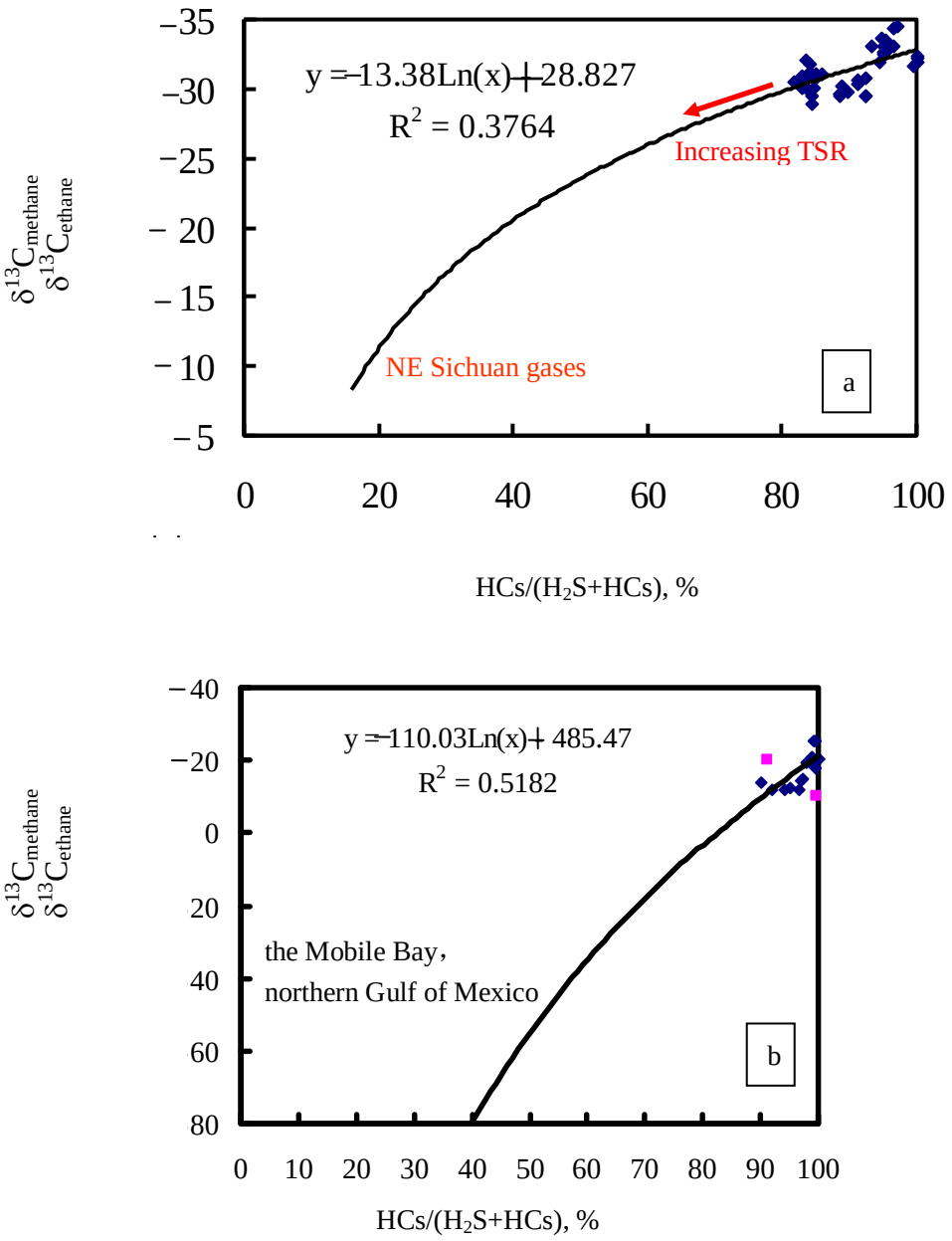

Fig.1 Logarithmic relationships between residual hydrocarbon (HCs/(HCs+H_2S)) and $\delta^{13}C$ values of methane of NW Sichuan Basin (a) and ethane of the Mobile Bay (b).