Monitoring for Potential Impacts from CBM Development

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Summary

Coal bed methane's (CBM) relatively shallow depth of development as compared to conventional oil and gas, has brought it into closer proximity with water wells than conventional development. One CBM play in particular is found in the Horseshoe Canyon Formation (HSCN). The formation is situated largely within the zone of usable groundwater, and is therefore above the base of groundwater protection. Paradoxically the coal seams are essentially dry and CBM is produced together with virtually no water.

Even though CBM production in the HSCN is largely without water and therefore industry is not competing for groundwater resources, water well owners and other stakeholders are concerned that gas wells have the potential to affect the quantity and quality of the groundwater. Their concerns include the creation of fractures during CBM stimulation, the contamination of aquifers with drilling and completion fluids, the long term effects on water levels from CBM production and the migration of methane gas. Monitoring is therefore being conducted by industry and the Alberta Research Council (ARC) to provide more information regarding potential impacts.

Results of monitoring water levels, water quality and gas composition are presented here. Monitoring is being carried out in monitoring wells at two locations in south central Alberta: near Torrington, in township 32, range 26 W4M, and near Strathmore in township 23, range 23 W4M. Monitoring wells are completed within the HSCN and in the overlying formations. Preliminary results and conclusions of the monitoring include the following:

- Water types can be divided into three groups.
    - Strathmore monitoring well (MW)16-18 is Ca-Mg-SO_4 type water with 11 tritium units (TU) and falls on the local meteoric water line indicating recent precipitation.
    - Strathmore MW 2-18 (shallow) is similar to most surrounding residential water wells in the same aquifer and is Na-HCO_3-SO_4 type water with <0.8 TU and falls on the local meteoric water line indicating meteoric precipitation greater than 50 years old and possibly much older.

  - Strathmore MW 2-18 deep, MW 4-18 and Torrington MW are Na-HCO_3-Cl type water with <0.8 TU (not measured at Torrington) and fall on the local meteoric water line indicating meteoric precipitation greater than 50 years old and possibly much older.
- Groundwater in most Strathmore water wells is meteoric in origin and appears to have recharged during a colder climate. Tritium is not found in significant quantities showing that none of the groundwater is recent (recharged within the last 50 years).
- Hydraulic testing in Strathmore monitoring wells showed no connection between shallow and deep aquifers over the monitoring period.
- Water levels in Strathmore monitoring wells showed no response to drilling, completing and producing in nearby CBM wells.
- An elastic response of the rock framework to stimulation in the uppermost HSCN coal seam, resulted in temporary 8 cm water level change at Torrington.
- Depth profiles for methane and ethane gas isotopes have been generated that can help in determining the origin of gas in the Strathmore area.
- Carbon and hydrogen isotopes of ethane may be more diagnostic of gas origin than isotopes of methane.
- The genesis of methane gas found in water wells is not clearly biogenic. Drilling of CBM wells in the area commenced after sampling of the monitoring wells (and other local residential wells) and cannot be the source of hydrocarbon gas in the water wells.
- The genesis of methane gas from CBM wells is transitional between biogenic and thermogenic, and has an origin that is transitional between fermentation and CO_2 reduction.
- Dissolved gas concentrations obtained with bladder pumps are thought to be more representative than samples obtained with submersible pumps, because the sample is less agitated.

Introduction

Reassuring stakeholders and the general public that CBM development can be conducted in Alberta without adversely affecting groundwater, is important to both the Oil and Gas Industry and to the concerned public. This is a presentation of results from two groundwater monitoring locations in South Central Alberta that are designed to provide more information regarding potential effects. Monitoring included groundwater levels and quality, dissolved and free gas composition, gas and water isotope analysis, as well as data collected from local water wells. The purpose of the monitoring was to look for impacts during CBM well drilling, stimulating and producing activities. Secondary objectives included establish the isotope and composition characteristics of gas and water from different geologic formations that might be useful in determining the origins of the gas and groundwater. This is known as fingerprinting, and involves the development of isotopic and compositional profiles typical of the stratigraphic sequence. The information can help in resolving questions of whether the presence of say methane in a water well is natural or anthropogenic, and if anthropogenic, as a result of the water well environment or from another source such as CBM. In addition, information was colleted on natural water levels and groundwater quality, and on the hydrogeologic characteristics of the local area.

Theory and/or Method

Monitoring gas composition and isotopes was based on the idea that CBM gas should have a different genesis from gas formed in the water well environment and perhaps in the aquifer. Further, isotopic and geochemical tools can help in characterizing gases from different formations and therefore it should be possible to develop isotopic profiles that may help to "fingerprint" hydrocarbon gases from different formations and recognize if CBM gas has migrated into water wells.

A major concern for groundwater users and CBM developers alike is that fractures generated during coal seam stimulation may propagate outside the coal, and provide preferred pathways for groundwater and gas. These pathways could result in either groundwater leakage or in gas leakage and affect aquifer productivity and quality. In addition, both groundwater and gas leakage would adversely affect CBM productivity. It is also suspected that gas leakage could result in migration of methane into aquifers and thereby into water wells.

Hydrodynamic studies show that undisturbed pore pressures are much less than hydrostatic in the CBM formations and the pressure gradients (rate of pressure increase with depth) are also less than in overlying aquifers. The CBM therefore appears to be "disconnected" from groundwater in overlying aquifers because the gas pressure for example at the top of the CBM formation is not sufficient to support the column of groundwater in the overlying aquifers. Further, production of CBM occurs at pressures only slightly greater than atmospheric and the removal of gas at these low pressures has not resulted in an influx of groundwater. The underpressured nature of the CBM has been attributed to various mechanisms including isostatic rebound following either melting of continental icecaps, or removal of overlying rocks by erosion, or a combination of both mechanisms (Parks and Tóth 1995; Bachu and Michael 2002). Therefore, for significant time periods, at least since the melting of continental icecaps, it appears that groundwater and gas in different stratigraphic units can be considered separately. Following from the disconnected nature of CBM and groundwater, and in the absence of fracturing outside coal zones, impacts on groundwater levels in overlying aquifers would not be predicted as a result of CBM production.

Methods:

ARC established a research site east of Strathmore, and EnCana installed a monitoring well near Torrington, Alberta. Both sites were instrumented and monitoring commenced prior to CBM activity in the area. At the Strathmore site ARC installed four high-quality monitoring wells and tested them to establish aquifer characteristics (transmissivity and storativity). The wells were then instrumented with transducers to monitor water levels on an hourly basis. Baseline water quality was determined by sampling the monitoring wells for major ions, ICP metals, water isotope ratios ($\delta^{18}O$, $\delta^{2}H$, tritium and $\delta^{34}S$ on sulphate), dissolved (and where possible free) gas composition and isotope ratios ($\delta^{13}C$ and $\delta^{2}H$). Drilling of the CBM wells started approximately one month after monitoring of the site commenced. The energy wells were drilled as close as 75 m from the monitoring wells. The CBM wells were perforated and fractured approximately five months later. During the drilling operation ARC collected coal cuttings from the major coal zones encountered in the borehole. Coal cuttings were put in a desorption canister, flooded with helium gas (to minimize atmospheric gases) and then allowed to desorb at room temperature. Desorbed gases were analyzed for composition and isotope ratios ($\delta^{13}C$ and $\delta^{2}H$).

At Torrington, the monitoring well was installed 45 m north of a CBM well and completed at a depth of 249 m. The monitoring well is open to sandstone between 249 and 255 m at the base of the Scollard Formation, and 24 m above the uppermost HSCN coal seam. It is also equipped with pressure transducers that record both the pressure head of groundwater in the well and atmospheric pressures. Water levels in the well have been monitored during stimulation of the HSCN coals and during subsequent CBM production. Water quality and isotopic and gas compositions have been measured in similar manner to the Strathmore wells prior to CBM development and following approximately 6 months production.

Results

Pumping tests:

Pumping tests at the Strathmore site established aquifer transmissivity values between 10 and 20 m^2/day and storativity on the order of 0.0005. A well nest (one shallow and one deeper aquifer completion) at one location established that a potential for downward groundwater flow existed at the site, however hydraulic isolation existed between the aquifers for the duration of the pumping tests. Transmissivity in the Torrington monitoring well was estimated at approximately 0.08 m^2/d.

Baseline chemistry of monitoring wells:

Data from residential wells in the surrounding area indicate the usual water type to be Na-HCO_3-SO_4. This is interpreted as indicative of intermediate age water. The shallow MW 2-18 also shares this water type. The water in MW 2-18 deep and MW 4-18 is of Na-HCO_3-Cl type, indicative of older water. The water in MW 16-18 is Ca-Mg-SO_4-HCO_3, indicating potentially the youngest water age. Groundwater in the Torrington monitoring well is similar to the deep wells at Strathmore and is a Na-HCO_3-Cl type and sulphate concentrations are less than 7 mg/L.

Gas and isotopic composition of monitoring wells:

The monitoring wells at the Strathmore site did not contain free gas upon pumping (with the exception of MW 2-18 Deep). Dissolved gas composition of the water from these monitoring wells showed methane gas concentrations ranging from 4 to 8,110 µg/L (method detection limit of 0.1 µg/L) and no higher order hydrocarbons (C2+). Monitoring well 2-18 deep had dissolved methane concentrations of 13,000 µg/L and no higher order hydrocarbons. Free gas separated from the water from MW 2-18 deep showed methane concentrations of 670,000 ppm and ethane concentrations of 4,320 ppm. The monitoring well at Torrington yielded approximately 1.5 L of free gas after pumping water for 90 minutes at 2.5 L/min. As for the deep Strathmore wells, the gas composition was almost entirely methane at a concentration of 953,000 ppm. The sample contained ethane at a concentration of 1,000 ppm, and no detectable higher order hydrocarbons.

The δ^{18}Oand δ^{2}H isotopes of water from both the Strathmore and Torrington wells fall on or close to the local meteoric water line (Figure 1) indicating the water is of meteoric origin. The depleted oxygen isotope ratio for many of the Strathmore wells is indicative of recharge from a colder period. Tritium results from most of the Strathmore wells show <0.8 TU, indicating ages older than 50 years. One well MW 16-18 has 11 TU, indicating recent water, a result that fits with the Ca-Mg-SO_4-HCO_3 water type. Isotopes from dissolved methane gases could only be determined from the wells with the highest dissolved gas concentrations (MW 2-18 deep and MW 4-18). The δ^{13}C values ranged between -58 to -65 ‰ PDB and δ^{2}H ranged from -176 to -232 ‰ SMOW. These values are transitional between biogenic and thermogenic signatures.

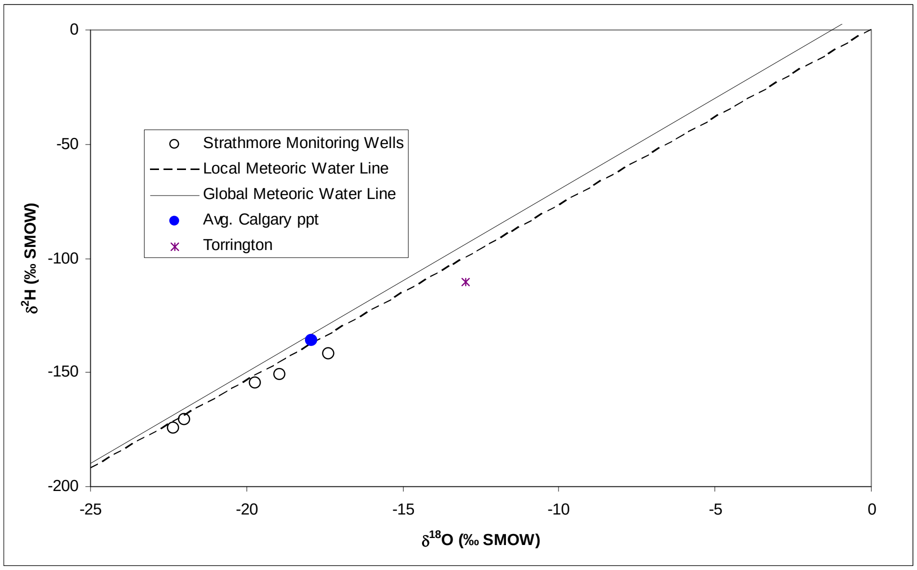


Figure 1 $\delta^{18}O$ and $\delta^{2}H$ isotope ratio of water from the research sites.

Gas and isotopic composition of energy (CBM) wells:

The gas composition of cutting (and a later comingled wellhead) samples from the energy wells was determined (Figure 2). The coals from the well all contain mostly methane, ethane and propane, with much lower concentrations of i-butane and n-butane.

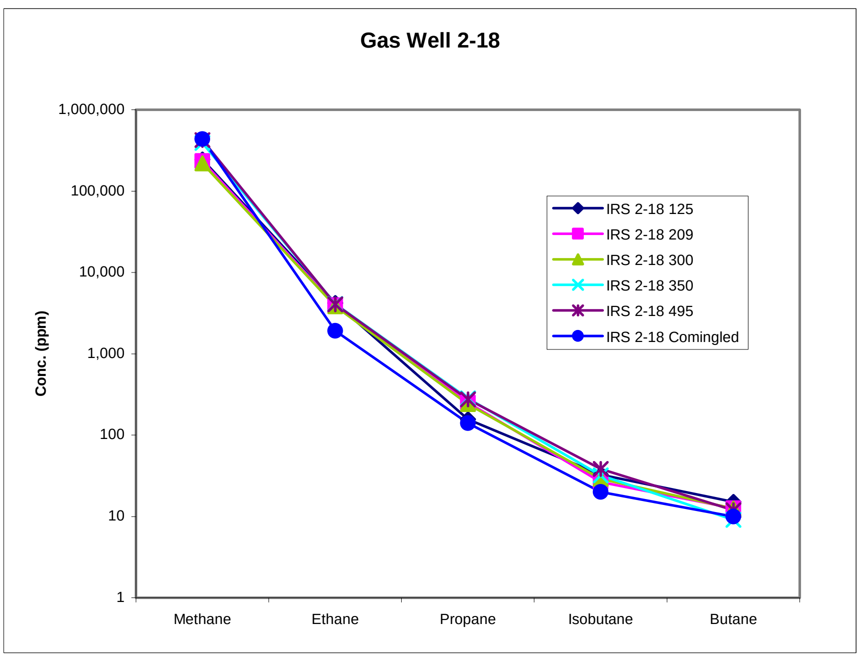
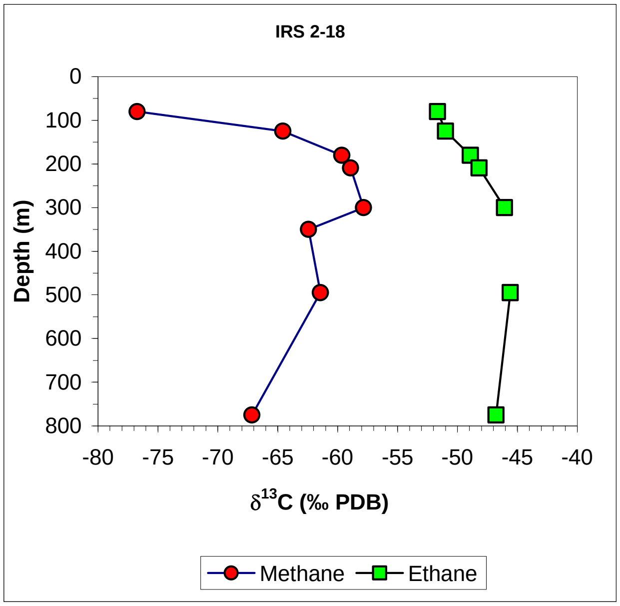


Figure 2 Gas compositions of coal cuttings from the Strathmore research site.

The carbon and hydrogen isotope ratio of cuttings from the energy wells at Strathmore were used to produce a series of isotopic depth profiles for the coals to a maximum depth of about 800 m (Figure 3).



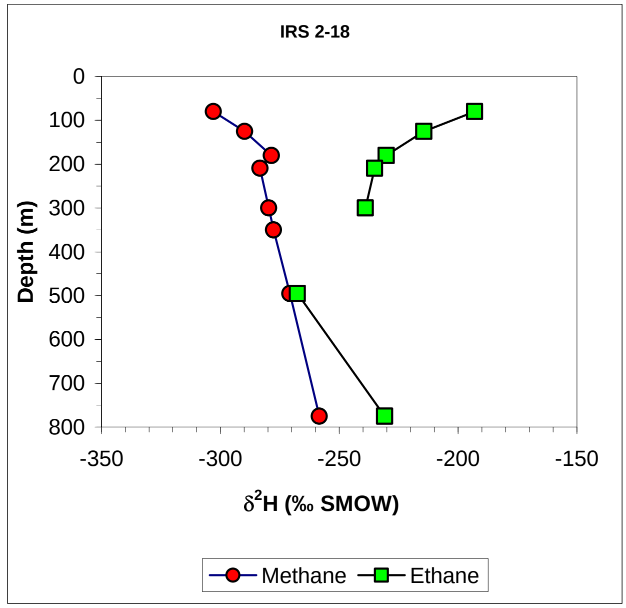


Figure 3 Carbon and hydrogen isotopic depth profile for energy well at the Strathmore site.

The carbon isotope ratio versus the methane/C2+ gas composition (Figure 4) can be used to differentiate methane sources. At the Strathmore site there is a small difference between local water wells with gas and the CBM wells. The local water wells tend to have a higher ratio of methane/C2+ gas. The 2-18 deep monitoring wells is deeper than most of the surrounding water wells and therefore plots very closely to the energy well signature. None of the water wells plot in the biogenic field typical of shallow water wells. This appears to be typical of water wells in the area. Impact from leakage caused by CBM drilling and production is not the cause as testing of these wells was done prior to CBM drilling. Energy wells in the area have a signature that appears to be transitional between biogenic and thermogenic. Examination of the hydrogen isotopes also indicates the origin of the methane is transitional between CO_2 reduction and fermentation. The similarities of the methane in the water wells and the energy wells make differentiation of gas sources difficult. This is not unexpected as the water wells are completed in the upper coal member of the HSCN, while the energy well perforations start in the next deeper HSCN coal zone. Carbon and hydrogen isotopes of ethane may help to differentiate these gases.

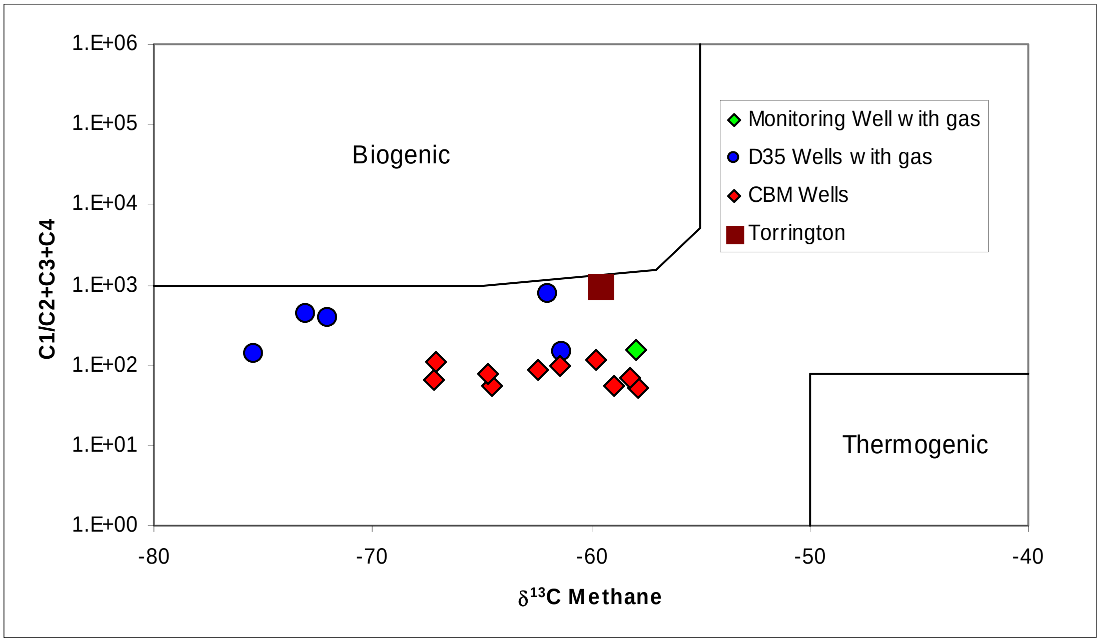


Figure 4 Methane isotope versus C1/C2+ gas composition for water wells and energy wells at the Strathmore site.

Water levels have been monitored at the Strathmore site for over a year (Figure 5). The deep monitoring wells in the southern part of the site show anthropogenic influence a few weeks prior to perforation and fracturing of the energy wells. This could be due to water withdrawals from a deep water well located near the site. A few deep wells are located immediately west of the site, however the pumping histories are not known. No perturbations in monitoring well water levels were observed during drilling, perforating, fracturing or subsequent production of the energy wells.

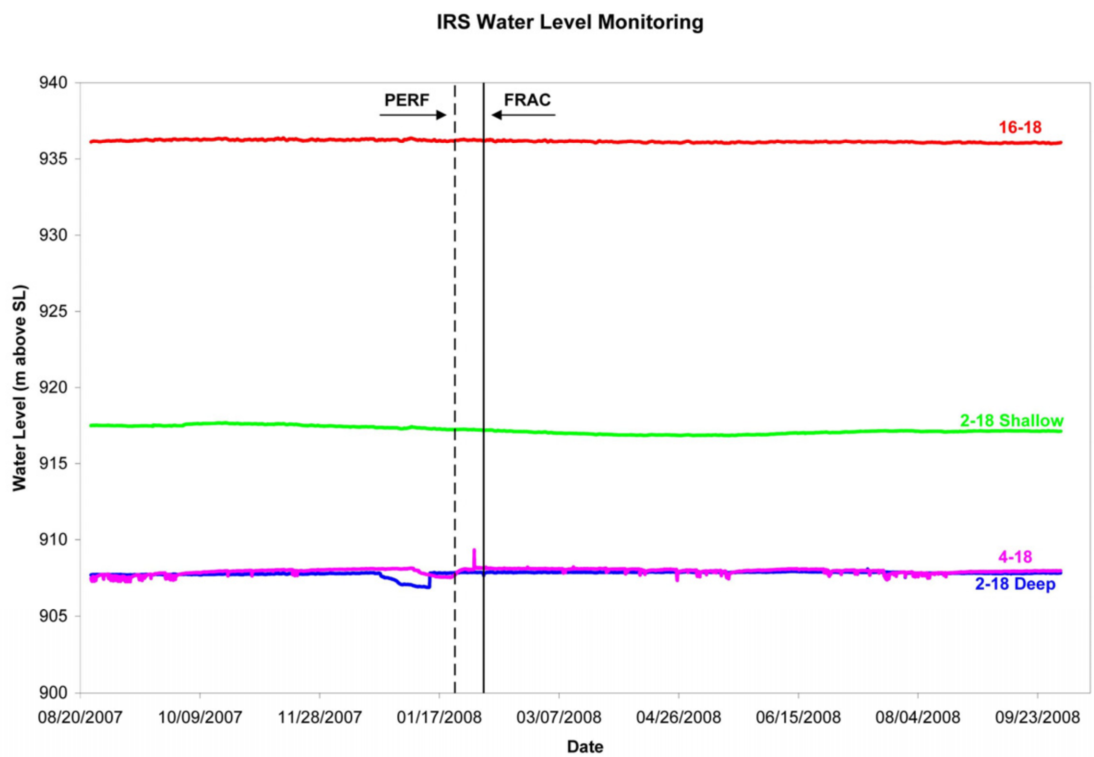


Figure 5 Water level monitoring at the Strathmore site.

In June 2007, the Torrington monitoring well recorded a temporary 8 cm change in water level during stimulation of the uppermost HSCN coal seam. The water level did not respond to any of the deeper stimulations. The water level change was interpreted as an elastic response of the rock framework that did not involve groundwater flow from the coal seam. The response was the same order of magnitude as the rock framework elastic response to barometric pressure changes. The confined aquifer monitored by the well has a barometric efficiency of approximately 70 %. Other than barometric pressure changes, the water level in the well has been stable since June 2007 with a total annual change of 10 cm in 2008.

Conclusions

Monitoring water wells during the drilling, perforating, fracturing and production of the energy wells has shown no significant effect on water levels in the Strathmore area. An elastic response of the rock framework to stimulation of a coal seam 24 m below the Torrington monitoring well, resulted in a temporary water level change of 8 cm. Otherwise, water levels in the Torrington monitoring well have been stable, except for barometric effects.

Results of gas composition analysis show that the gas found in groundwater from local water wells is different from the gas produced from coal seams.

The carbon isotope ratio of methane and C1/C2+ gas ratios from water wells is similar to those from the CBM wells making differentiation difficult. Carbon and hydrogen isotope ratios of ethane may be more diagnostic but ethane concentrations tend to be low.

Acknowledgements

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