Greenhouse gas footprint of shale gas obtained by hydraulic fracturing

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Introduction

Only in the past 10-15 years have high-volume hydraulic fracturing and precision directional drilling been combined to make extraction of natural gas from shale commercially viable. Industry and many governments promote shale gas, often describing shale gas as a bridge fuel that allows continued use of fossil fuels while reducing greenhouse gas emissions (GHG) compared to other fuels. In April 2011, we published the first comprehensive analysis of the GHG footprint of shale gas, concluding that in fact full-lifecycle GHG emissions from shale gas are comparable to or larger than those from oil and coal [1]. Since our paper was published, the US EPA issued new estimates on GHG emissions from natural gas systems, and many other papers and reports have also evaluated aspects of the GHG footprint of shale gas. In Feburary 2012, we published a paper synthesizing and summarizing this new information [2]. In this talk, I will further update the rapidly changing state of knowledge on the GHG footprint of shale gas.

Uncertainties and sensitivity analysis

Methane venting and leakage dominates the GHG footprint of shale gas, particularly when considered using the most recently available information on global warming potential that integrates the effect of methane over a 20-year time period. The influence of methane is diminished at the 100-year time frame. Over a wide range of estimates of methane emission, the GHG footprint of shale gas is worse than other fossil fuels, when viewed at the 20-year scale. The most recent evidence suggests that many studies continue to underestimate the magnitude of methane emisisons.

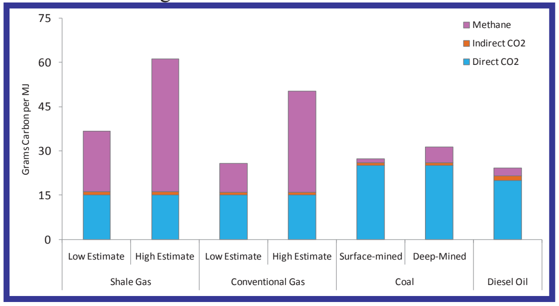

Figure 1: Comparison of the GHG footprint of shale gas with other fuels, using 20-year global warming potentials for methane. From [1].

[1] Howarth et al. (2011) *Climatic Change Letters,* doi: 10.1007/s10584-011-0061-5. [2] Howarth et al. (2012) *Climatic Change*, doi:10.1007/s10584-012-0401-0.

Trace element partitioning in mixed-habit diamonds

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Mixed-habit diamonds are those that exhibit periods of growth during which they were bound by two surface forms [1], namely smooth faceted octahedral growth in combination with hummocky, non-facetted "cuboid" surfaces whose mean orientation is {100} [2]. This type of diamond is commonly referred to as *star* or *centre-cross*, because the cuboid sectors can sometimes have a much darker appearance compared to the gem-quality octahedral sectors.

Analysis of mixed-habit diamonds has already revealed a preferential partioning of nitrogen between the two sectors [3]. Nickel has also been identified as being present and the cause of the green luminescence in these diamonds [3]; however, exact concentrations or trace element patterns have never been reported.

Laser ablation inductively coupled plasma mass spectrometry (LA-ICPMS) analysis of diamonds has yielded abundant valuable trace-element information and helped to further our understanding of metasomatic fluids in the deep Earth. Traditional *in situ* techniques have had to overcome the issue of using a suitable standard reference material [4-8], but have provided great insights when applied to fluid inclusion-rich diamonds. More recently a closed-system (i.e. off-line) laser ablation technique has been developed [9] that has been applied succesfully to measure the low impurity levels present in gem-quality diamonds. The sacrifice made to obtain these low detection limits is a loss of spatial resolution. This is due to the large ablation areas required (approximately 500 × 500 μm in area, with depths ranging from 200 – 400 μm).

In this study we present a modified off-line LA-ICPMS method for analysing diamonds. Instead of trapping the ablated material in a closed cell, it is collected in a liquid. We apply this larger-scale ablation technique to investigating the partitioning of trace elements between octahedral and cuboid sectors in a collection of large (>6mm) mixed-habit diamonds. This is the first set of trace element data to be collected from mixed-habit diamonds, and integrated with several other types of analysis (infrared mapping, cathodo-luminescence imaging and spectroscopy, in-situ carbon-isotope analysis by secondary ion mass spectrometry), they will provide further insights into the specific geochemical conditions of formation for this interesting subset of diamonds.

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