

GEOMARK PETROLEUM SERVICES LAB

MUD GAS ISOTOPE ANALYSES Capabilities & Price Schedule



Petroleum Services Division

INTRODUCTION

Mud Gas Isotope Analyses (MGIA) is a gas fingerprinting technique that uses isotopic analyses of mud stream gases to evaluate the composition of reservoir hydrocarbons. Although there are many potential uses for these data, the primary purpose of MGIA is to assess the extent (lateral and vertical) of a reservoir and identify communication with any other formations (vertically in the same well, or laterally in one or more wells).

Carbon isotope analyses are necessary for this service because gas compositions measured by conventional mud loggers may be fractionated by the process of liberating the gas from the mud system. This is especially true in oil-based mud systems where significant gas is entrained in the mud stream. The stable carbon isotopes are not substantially fractionated by mud transport and the degassing process.

In addition, traditional mud gas analyses could miss or incorrectly identify hydrocarbon-bearing intervals, due to the effects of drilling conditions on the hydrocarbon concentrations in the mud gas. For example, pay zones could be missed where they have been flushed by drilling while overbalanced. Mud gas isotope values are not a function of gas concentration, and hence do not suffer from this problem.

Mud gas samples are collected on the rig during drilling. Sampling is performed by the mud logger, resulting in little or no additional costs or lost rig time. The samples are transported to shore and sent to the lab for analyses. GeoMark's Lafayette laboratory operates on a 24 hour schedule, and Gulf of Mexico samples can be analyzed in near real time.

As illustrated in the figure below, carbon isotope values are similar in connected zones, and dissimilar in zones separated by flow barriers. As the figure indicates, MGIA analyses can be combined with carbon isotope analyses of flash gas samples to confirm the results and strengthen the interpretation.

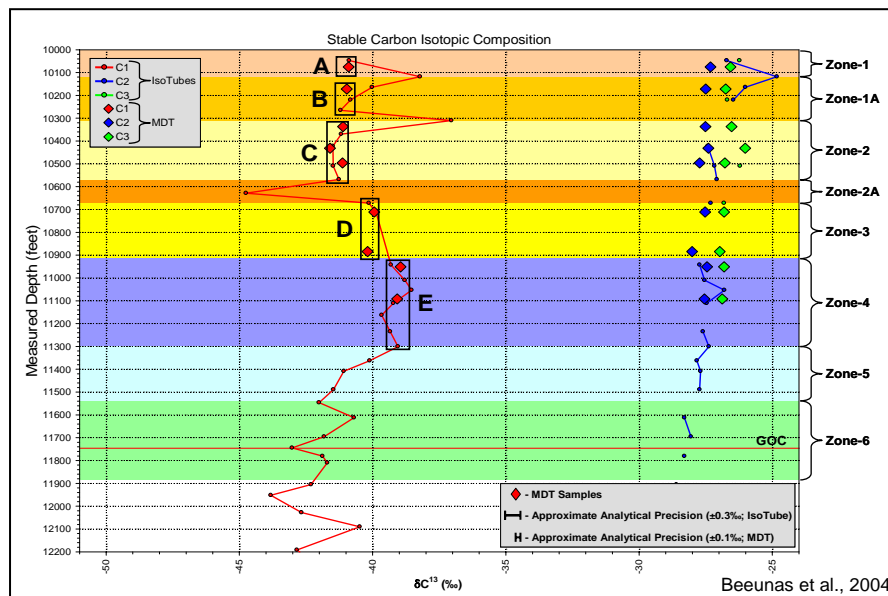


Figure 1. Carbon Isotope Composition Log from a development well. Similar methane isotope values within the individual sands A, B, and C indicate reservoir connectivity (vertically continuous reservoir) within these sands. The compositional differences between sand package A-C and sands D and E suggests no vertical continuity. Note that the MDT stable isotopic data are consistent with the MGIA results.

MGIA MUD GAS ISOTOPE ANALYSES

MGIA has become crucial to pre-sampling well evaluations and reservoir compartmentalization studies. In exploration wells, data are used to evaluate vertical communication between zones and to plan sampling programs. Formations that are likely not in communication can be more aggressively sampled to determine the range of fluid properties that may be produced to surface. In contrast, significantly reduced formation testing programs can be achieved (or even eliminated) in appraisal and development wells if rapid isotopic data suggest that formations are in communication with those penetrated by earlier wells.

MGIA gas fingerprinting can also be used to determine the cause of the compositional differences seen in disconnected reservoirs. The diagrams below show a common way to present gas isotope data. The left hand graph compares the Carbon 13 isotope value of methane against the value for its deuterium isotope. Gases with very negative ^{13}C methane isotope values (i.e., approaching -70) are generated from bacterial sources like swamp gas, while those with less negative values are generated from increasingly mature source rocks. The right hand diagram presents the ^{13}C methane isotope value against a compositional variable called the Gas Wetness which is the relative amount of hydrocarbons heavier than methane. As biogenic (or bacterial) gases are composed almost solely of methane, they plot in the upper left corner with their very negative ^{13}C isotope value. Conversely, gases generated from thermal breakdown of organic matter in source rocks (called thermogenic gases) have much higher concentrations of C_{2+} components and plot more in the center of the diagram.

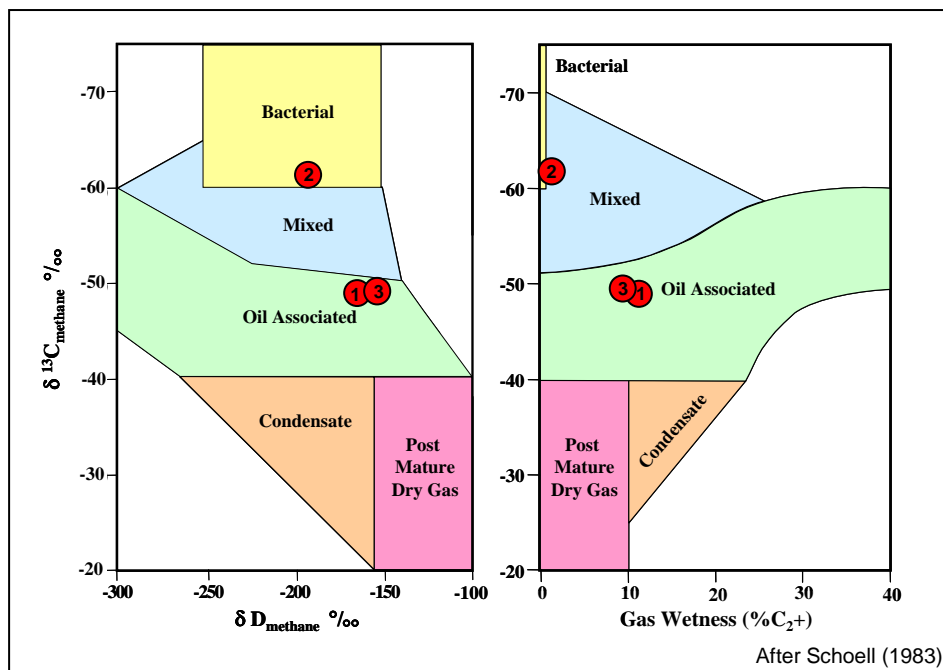


Figure 2. In the three example Gulf of Mexico gases shown below, carbon isotope variations in a reservoir horizon suggest that the #1 & #3 wells are in communication while the #2 well is compartmentalized, and contains abundant biogenic gas.

MGIA analyses are inexpensive and require no additional rig time for sample collection. The results are invaluable for downhole sample program design and can also provide "data insurance" against a lost well or insufficient downhole formation appraisal.

GeoMark's Lafayette, Louisiana laboratory is perfectly placed to offer rapid sample turn-around for Gulf of Mexico wells. And, by combining the MGIA service with PVT analyses, GeoMark can handle all of your petroleum fluid evaluation needs.

SAMPLING PROCEDURES

The MGIA technique utilizes samples collected from the same mud stream from which conventional mud gases are analyzed. The Mud Logger collects the samples, labels them with accurate interval information, and sends them to shore for analysis. GeoMark supplies the sample containers (sample tubes), and the sampling manifold used by the Mud Logger, if needed. Sampling is accomplished during the drilling process and there is no lost drill time.

A sampling manual with detailed procedural advice is available upon request.

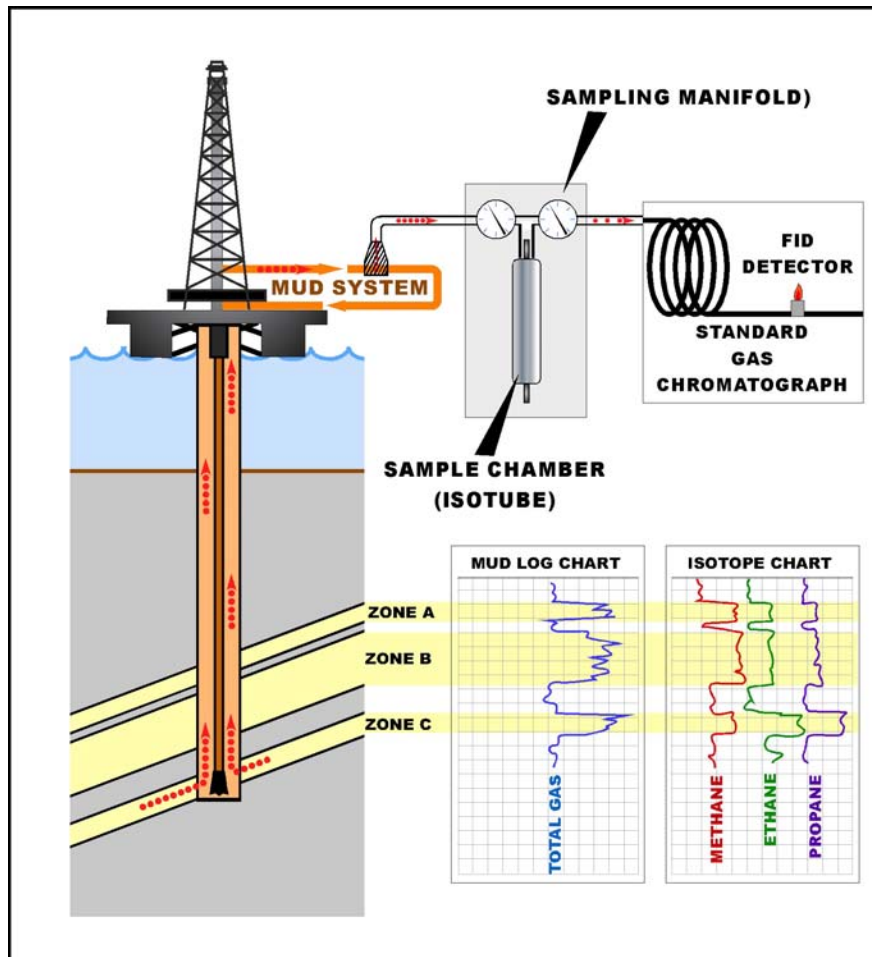


Figure 3. Generalized diagram of sampling procedure.

Sampling intervals vary from well to well, but in general we recommend the following schedule.

Interval	Frequency
Up-hole Background	150' interval
Objective Interval	30' interval
Show interval	10' interval

It is advisable to take an abundance of samples knowing that it is not necessary to analyze all samples collected. Samples can be stored up to one year before being analyzed. GeoMark can supply all necessary sampling equipment, and can work with your mud logger to arrange sampling protocols.

ANALYTICAL PROGRAM

GeoMark offers the full range of oil and gas analyses shown below. Each of these can be useful in establishing reservoir connectivity, although the MGIA service remains the only technique that provides continuity evidence prior to subsurface well testing.

- Mud Gas Compositions
- Mud Gas Methane, Ethane, Propane Carbon Isotopes
- Cuttings Gas compositions and Carbon Isotopes
- Flash Gas compositions and Carbon Isotopes

The MGIA analytical package normally involves both detailed compositional and $\delta^{13}\text{C}$ stable carbon isotope analyses. A gas chromatograph is used to separate and measure methane, ethane and propane plus heavier hydrocarbons. This analysis provides an initial evaluation of reservoir gas composition, concentration, and screens samples to allow selection for the more expensive carbon isotope procedure.

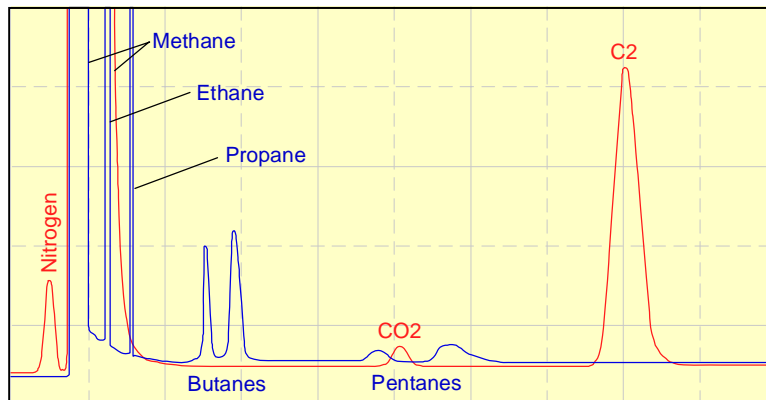


Figure 4. C1- C7 light hydrocarbon analysis.

To measure the $\delta^{13}\text{C}$ character of methane, ethane, propane and iso- and normal butane gas components, a GV GC-IRMS instrument is utilized. This procedure couples a gas chromatograph to a combustion interface and an isotope ratio mass spectrometer (IRMS). This technique converts gas components to CO_2 and then measures the $\delta^{12}\text{C}$ to $\delta^{13}\text{C}$ ratio of the individual gases. This gives us a detailed fingerprint of the gas in a reservoir unit and is unaffected by drilling fluid contamination.

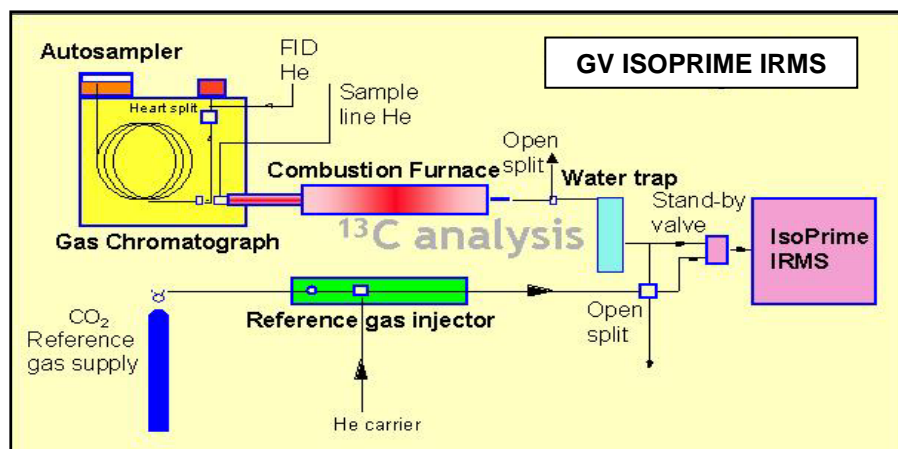


Figure 5. Schematic diagram of the GC-IRMS carbon isotope analyzer.

INTERPRETATION

GeoMark provides all types of reservoir geochemical analyses and interpretive support for every level of investigation. A full complement of tabulated and graphical data is provided free of charge for companies that have in-house interpreters. For companies needing interpretive support, GeoMark can provide reservoir continuity conclusions based on an integration of the geological, geochemical, and engineering data.

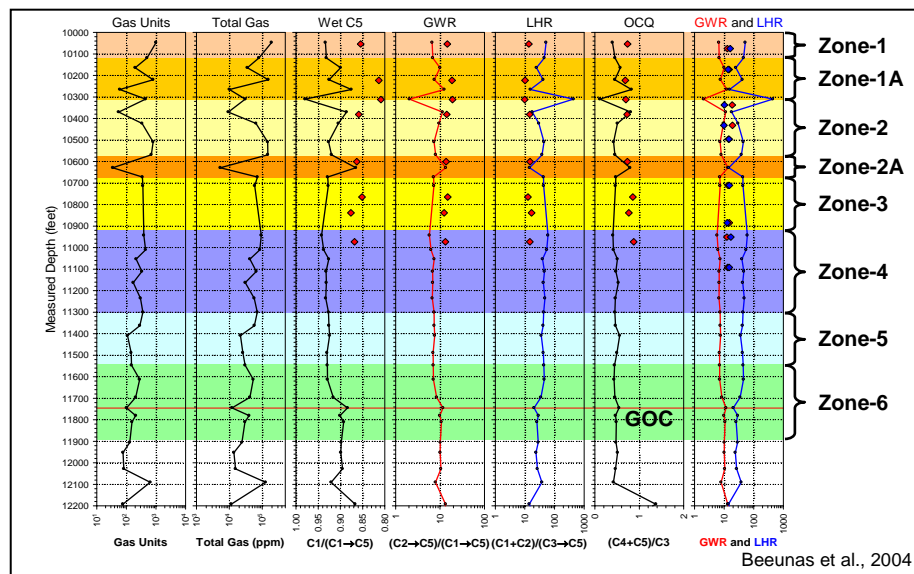


Figure 6. Well depth profile plots combining Mud Gas Isotope results along with other types of data (standard mud logging results, flash gas and oil analyses, pressure data, etc.) are provided free of charge.

Reservoir continuity can be assessed with numerous types of geological, geophysical and engineering data. Wireline logs, pressure gradients, seismic data, fluid contact depths, production testing, production histories, etc. all provide useful data for assessing reservoir connectivity. However, reservoir geochemistry (gas and/or oil) is one of the few techniques that provide a direct continuity analysis. Gas composition is most useful since gas has the greatest mobility. Light gas components have the greatest in-reservoir mobility and, therefore, tend to quickly homogenize. Therefore gas isotope analyses are useful for determining reservoir continuity either vertically within the same well, or horizontally between two or more wells. The gas analyses can be performed on flash samples from downhole or surface test samples, or on gas samples collected from the degassed mud stream.

GeoMark also provides a database (RFDbase) service for the storage, review and manipulation of all petroleum fluid analyses. This “universal” database has a field level module which permits all field data to be viewed, captured, and manipulated at will. Additionally, all modules within the RFDbase structure are exportable to Excel or databases holding other types of data (rock properties, wireline measurements, etc).

The RFDbase application has a number of functions in addition to the ability to store and maintain all analytical petroleum fluid reports. The mapping interface may be used to search for specific fluid studies or to locate similar fluids (based on geochemical and bulk characteristic classifications) in different geographic regions. These “similar” fluids may be further utilized in estimating fluid properties or parameters, and in linking to commercial or in-house simulation programs.

COSTS

GeoMark offers Mud Gas Isotope Analyses (MGIA) on a rapid turn-around basis, but does not charge for rush services. This bridges the gap between typically slow onshore laboratory operations and very costly offshore operations. Routine turn-around is between 12 & 36 hours. This provides data to the client well in advance of most downhole sampling schedules. There is no extra charge for rush samples.

Costs for sample containers, supplies and analytical procedures are provided below. A comprehensive data report is prepared at no charge. Integrated interpretive reports will be provided upon request.

ANALYSES

GeoMark's standard composition program involves the gas chromatographic measurement of the concentrations of nitrogen, carbon dioxide, methane, ethane, propane, iso and normal butane, iso and normal pentane, and hexane (and higher components if present). The carbon isotope analysis uses GC/IRMS to determine the $\delta^{13}\text{C}$ composition of methane to butane with sufficient concentration.

Mud Gas analytical charges are given on a per sample basis. These prices are also applicable to cuttings gases and flash gases from PVT samples.

MUD GAS ISOTOPIC GAS ANALYSES	TOTAL
GC Composition to C6 (PVT Quality GC Analysis)	\$100
GC Composition to C6 & GCIRMS Methane Carbon Isotope Composition	\$200
GC Composition to C6 and GCIRMS Methane plus Higher Carbon Isotope Compositons	\$400

SAMPLING

Sampling containers and a sample manifold can be supplied if needed. Isotubes cost \$25.00 each and IsoJars cost \$10.00 each. The sampling manifold can be purchased or rented. The well site sampling manifold will be provided free of cost if GeoMark is conducting the analyses.

MUD GAS ISOTOPE SUPPLIES	TOTAL
Gas Isotope Containers (price per each)	\$25
IsoJar Cuttings Contalners (price per each)	\$10
Gas Isotope Sampling Manifold	\$1,000

SAMPLE TRANSPORTATION

Sample tubes can be transported by ground and air as long as DOT and IATA shipping regulations and protocols are followed. GeoMark can supply clients with shipping instructions and can containers if needed.

Turn-around time is key in the usefulness of mud gas isotopic analyses. GeoMark's laboratory in Lafayette, Louisiana is immediately adjacent to Highway 90, the Lafayette airport, and a base of Petroleum Helicopters, Inc.