

Amplified Geochemical SURVEY for Petroleum Exploration

DESCRIPTION OF SERVICE

Exploration Survey Applications

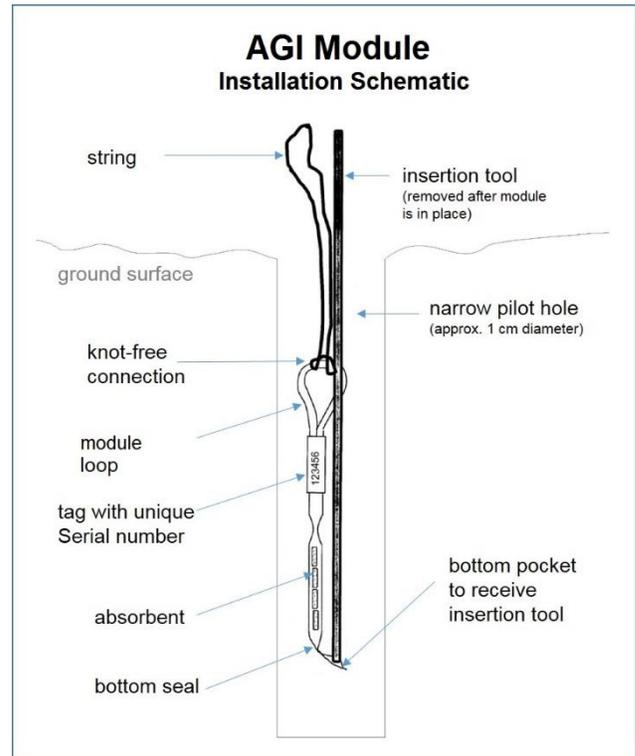
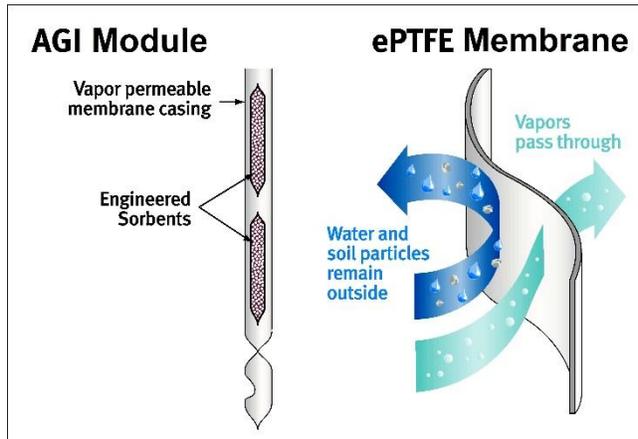
The Amplified Geochemical Imaging Service (AGI Service) is an advanced surface geochemical prospecting tool capable of detecting and quantifying many organic compounds up through phytane. This geochemical sampling system employs the AGI Geochemical Module (patented passive soil vapor sampling device), advanced chemical analysis, and sophisticated statistical pattern recognition techniques, and has evolved from over twenty years of experience in soil gas geochemical exploration and analytical chemistry. It is capable of differentiating reservoir hydrocarbons from “background” hydrocarbons, such as those emanating from source rock or residual migrated oil.

Typical applications of this technique include: 1) Frontier - to determine hydrocarbon potential over large previously unexplored areas; 2) Exploration – to focus geophysical efforts, prioritize leads and investigate stratigraphic traps; 3) Development – to define the areal extent of producing fields and locate potential areas for secondary recovery. Prudent use and integration of the geochemical results can have significant benefits to the success of an exploration program, resulting in fewer dry holes.

Description of AGI Geochemical Module

Each AGI Module contains a minimum of two samples (duplicates), each consisting of separate passive sorbent collection units (“sorbent”). Each sorbent contains an equal amount of engineered sorbent material, specifically selected for affinity to a broad range of volatile and semi-volatile organic compounds (VOCs and SVOCs), while minimizing uptake of water vapor (the principal soil gas constituent in most areas). The sorbents are sheathed in a vapor permeable retrieval cord looped at the top. The loop is used as a means of tying the module to a string for installation and retrieval. The figure below shows a typical AGI Geochemical Module. The retrieval cord and the sorbent containers (sorbent) are constructed of an inert, hydrophobic, microporous expanded polytetrafluoroethylene (ePTFE) membrane. The microporous structure of the membrane allows vapors to move freely across the membrane and onto the sorbent material.

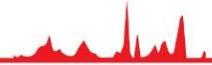
The microporous structure also protects the granular adsorbents from physical contact with soil particulates and water, ensuring a consistent medium for collection of organic compounds (vapor-phase transfer only). The AGI Geochemical Module is installed to a depth of approximately 60-80 centimeters by creating a small pilot hole using a narrow steel rod or similar tool (a long screwdriver works well), and inserting the module manually using a narrow insertion tool provided by AGI. The module is retrieved by hand and returned to AGI for analysis and data processing.



The unique ability to protect the sorbents from contact with ground and soil pore water without retarding soil vapor diffusion facilitates the application of AGI's *Amplified Geochemical Imaging* method in very low permeability and poorly drained soils and swampy areas. Indeed, the AGI Geochemical Module can even be deployed into shallow marine sediments. Deeper marine applications involve acquisition of seabed cores which are subcapped and placed in an airtight container with the AGI Geochemical Module.

Quality Assurance (QA) Measures

As standard practice, all modules are individually numbered and tracked throughout the entire manufacturing, field deployment, and analytical process. Completed modules are sealed into clean glass vials, and stored under zero grade air until shipment to the customer. Cleanliness is verified by testing a select number of modules from each manufacturing lot. Prior to shipment, a minimum of ten inventory blanks are randomly selected and set aside as controls to be analyzed along with returned modules. All modules are transported to and from the customer's site in sealed glass vials and boxes supplied by AGI. Additional trip blanks (a minimum of ten, or one per box, whichever is greater) are provided to accompany the modules to and from the site for QA/QC purposes. Upon receipt, returned modules along with associated inventory blanks and trip blanks are randomized to minimize analytical bias.



Geochemical Survey Design

Prior to initiating a survey, specific survey objectives are established with the client and an appropriate sampling scheme and geochemical modeling strategy are identified. Information relating to target size, trap type, reservoir orientation and geometry, structural fabric, and details of analogous production and background wells, are important factors in developing an appropriate survey design. Of paramount importance is the objective of the survey and an understanding of the decisions expected to be made based on the geochemical results. The survey design must therefore be consistent with the agreed program objectives.

Sampling plans typically follow a grid pattern with regular or variable spacing of modules, module traverses, or a combination of both. Module spacing generally ranges from 300 meters to one kilometer. Appropriate wells are selected for the purpose of modeling surface geochemical character over analogous production and dry/background areas.

In most cases, available maps and satellite imagery are used to plot the planned module locations and extract target module location coordinates for use by field teams. Location coordinates are usually rendered in geodetic degrees or UTM relative to WGS84 datum, or some other standard coordinate system appropriate to the survey location.

Accurate topographical surveys using geodetic receivers, ground- and satellite-based augmentation systems, long-period data acquisition and a whole host of sophisticated post processing, are beyond the scope of our services, and are not a necessary component to our work.

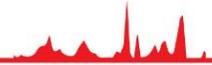
Exploration Survey Installation and Retrieval Procedures

GPS Positioning:

The field team navigates to the pre-planned module location using consumer grade GPS receivers in stand-alone mode. Due to the relatively wide module spacing of several hundred to perhaps one or two thousand meters, horizontal positional accuracies of +/- 10 meters are acceptable. In most cases, accuracies of <5 meters are achievable depending on terrain and vegetation cover. Because AGI Survey data require no correction for altitude or variations in ground elevation, vertical positioning accuracy is not required. In general, consumer-grade hand-held GPS receivers can achieve horizontal accuracies of 6 meters or better; however, vertical errors of 10-20 meters are not uncommon.

Onshore Geochemical Survey:

Installation of the modules is performed either by experienced subcontract field personnel or by the customer. The AGI Geochemical Module is installed to an average depth of 60-80 cm below grade by creating a narrow (1cm diameter) pilot hole using a steel tool (such as a long screwdriver) and a mallet, if necessary.



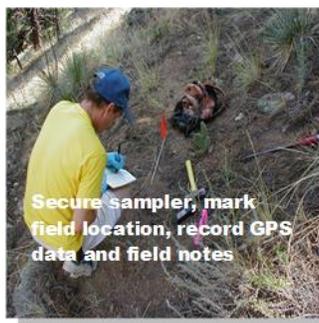
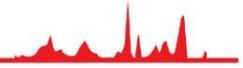
After the pilot hole is completed, a module is tied to a section of cord and inserted into the hole using the stainless steel insertion rod supplied by AGI. The cord is secured at the ground surface by collapsing the hole. The location of the module is marked on a map and location coordinates are secured where possible by GPS receiver, preferably equipped with a buffer for data storage and subsequent download to a personal computer. Additional modules designated as trip blanks should be noted on the installation/retrieval log and left unopened in the shipping box, for the duration of the field exposure.

Module retrieval requires that field personnel locate the retrieval cord and manually pull the module from each location. The cord is separated from the module and discarded properly. The exposed modules are resealed in their respective designated shipping vials and placed in the supplied shipping box. Boxes with field-exposed modules and trip blanks are returned along with the Chain-of-Custody (COC) form to AGI's laboratory in Delaware, USA, usually via priority courier service. Detailed instructions are provided in our Module Storage, Installation & Retrieval Guidance documents.

During field work, field personnel should make every effort to protect the security of modules from interference or contamination. Steps may include:

- Informing local government or security officials and landowners of field activities;
- Ensuring that local populations do not observe field activity at close proximity;
- Using unobtrusive means to mark sample locations so these can only be identified by the field teams;
- Placement of modules along field borders in areas of active farming.

Despite the best efforts of field teams, some loss may occur. Losses may result from human or animal interference, or from other natural causes such as landslides or floods. In general, loss rates range from 0-3%. Such data loss rates if reasonably distributed do not generally impact the integrity of the survey and will not be cause to ship additional modules for redeployment. Should module loss rates exceed 5%, with spatial distribution affecting data integrity, AGI and Client will work together to decide on an appropriate solution. Fieldwork conditions or project timing may not allow for redeployment and thus an adjustment to module number and cost may be appropriate. As a normal practice, AGI provides additional modules (at no charge) for use as needed: opportunistic sampling of an unexpected field condition; to replace a module with a broken container; to replace a module that is found to have been destroyed (by plowing, for example).



Shallow Offshore / Transition Zone Survey:

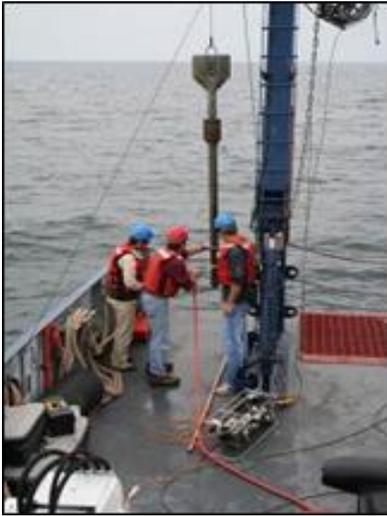
These are conducted with the help of scuba divers if the water depths will allow for safe diving. Divers can insert the AGI Geochemical Module into the ocean bottom using various tools, or the module can be placed under a concrete block or similar weight. The location is marked using a concrete block with flagging or a small flotation device, in order to find the location upon retrieval. Where water depths are too great to dive safely, the AGI Geochemical Module can be lowered onto the ocean bottom beneath a block or clump weight.





Deep Offshore:

Sampling a deep offshore survey requires the collection of sediment cores at each specified location. Core material is sub-cropped on the vessel shortly after the core is brought on board, with approximately 60-80 cc of sediment placed into a 100 ml glass jar. The jar is sealed and the location is noted with regard to GPS coordinates. The sediment samples should be frozen once sealed, to at least -20° C. The jars are to be shipped back to the AGI laboratory for further processing. In the laboratory, adsorbent modules are added to the sediment for subsequent collection of hydrocarbon compounds contained within the sediments.

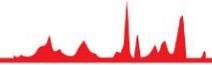


Module Exposure Time:

The suggested time for module exposure is 17 to 20 days. This time period has been evaluated over the course of hundreds of surveys and has been found optimal for most regions and climatic conditions. However, this period is modified at times to accommodate special site conditions, such as excessive rainfall, extreme cold, etc.

Analytical Procedures

All AGI Geochemical Modules or seabed sediment samples are inspected upon receipt at our laboratory. Among the conditions checked are container seal integrity, condition of modules / samples, and proper sequence of module / sample numbers. All received samples and project trip blanks and inventory blanks are then randomized, re-sequenced, and transferred to a temporary storage location until analysis.



Each AGI Geochemical Module contains a minimum of two samples which are available for analysis. One sample is extracted prior to analysis by cutting the bottom of the membrane casing. The duplicate sample remains in sample storage until needed or discarded. All soil gas samples are analyzed by thermal desorption followed by gas chromatographic separation and mass selective detection (TD/GC/MS). The laboratory analytical method has been developed by AGI specifically for application with geochemical petroleum exploration, and yields chemical data for a wide variety of organic (including thermogenic) compounds up to C20 (phytane).

Before each analytical run sequence, system flush (empty thermal desorption tube), BFB (bromofluorobenzene) sample, method blank, calibration standards, and instrument blank are analyzed. Method blanks, calibration standards, and instrument blanks are analyzed at the beginning, middle, and end of the run sequence. QC samples are evaluated according to set criteria to ensure proper system performance. If after review the system is found out of control, appropriate actions are taken to restore proper operating conditions, and the replicate samples are analyzed. Compound identification is based on the presence of appropriate target compound mass fragments within a specific retention-time window, as determined through use of reference standards.

Prior to data processing, trip blank, method blank, inventory blanks and instrument blank data are reviewed to identify potential ambient exposure or laboratory condition issues which may affect data quality.

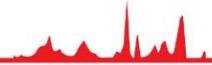
AGI's laboratory operates under the guidelines of its "Quality Assurance Manual, Operating Procedures and Methods".

Data Processing and Geochemical Modeling

AGI's Amplified Geochemical Imaging Service incorporates sophisticated statistical processing and modeling techniques for complex geochemical signatures obtained from each sample. Some of the techniques used include the following:

Hierarchical Cluster Analysis (HCA)

HCA is an "unsupervised" multivariate technique, since no additional information other than the data itself is required to perform the operation. It is not necessary to identify "end-members" from the data or qualify the data in any manner in order to perform this technique. HCA proceeds by grouping samples of like composition according to the values of all input variables. The result is a list of sample subsets which are alike (form "clusters" of similar samples). Since the input variables of the data are hydrocarbon compound responses, the clusters are subsets of chemically similar samples. The HCA method is used to determine the structure of a set of data when no other geological or geophysical information is available for the area.



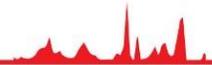
The results of HCA may be used to further classify the samples of the data (i.e.; whether particular samples show petroleum hydrocarbon influence, or whether more than a single known petroleum system is present in the area).

Principal Components Analysis (PCA)

PCA is a data transformation technique which is used to express a set of data from measured variable space into principal components space. The measured variables are target organic compound response values, and it is understood that many of the compound recordings made by this geochemical method are correlated; suites of compounds will vary in concert. The components derived through PCA are by definition not correlated, so that with the components as coordinate axes in a data space, the components are orthogonal. With n measured variables as input to PCA, n components may be calculated. By definition, the orientation of the components is determined by the primary variance orientation in data n -space. Hence component “1” is oriented along the prime variance of the data, component “2” is constrained to be orthogonal to component “1” and oriented along the next most variant direction, and so forth for the entire n component set. There are significant advantages offered by PCA, particularly for this form of data (surface geochemical measurements of volatile organic compounds). One has subsequently fewer data variables to process, without significant loss of information (recalling that many of the original measurement variables are correlated). Also, the components are linear combinations of the original measurement variables and are more akin to geochemical influences, being mixtures of numerous compounds. One further advantage to components is that these facilitate plotting the data, and hence allow easier evaluation of data trends and outlier identification.

Canonical Variates Analysis (CVA)

CVA is a data processing technique that is used determine data “fitness for use” by investigating the relationship between subsets of samples, plotted as the subset centroids. The technique determines the orientation of the data such that the defined sample subsets are viewed as most separate. The separation between sample subsets is then expressed as a linear combination of measurement variables (“canonical variates”). In so doing, relationships between subsets can be evaluated more efficiently. Given a data matrix of n variables, and m subsets of samples, this technique will derive minimum of $(m-1, n)$ canonical variates. In practice, we use CVA to evaluate whether there is reasonable separation between sample subsets in the data space. Typically, input sample subsets include various blank sample classes and the samples deployed in a survey area. If distinct separation is noted between field samples and the various control blank samples, then one can be reasonably assured that the field sample data is meaningful (in the sense that it is not “manufactured” signal).



Linear Discriminant Analysis (LDA)

LDA is a multivariate data classification technique. At least two subsets of input samples must be identified as belonging to separate groups (with each sample “group” presumed to represent a particular physical influence in the sampled environment). LDA will then determine the best separation of groups in a minimum residual sense, in terms of the input variables for the samples. Since the input variables are of a chemical nature, the separation of the sample groups is expressed as a chemical difference between the groups. The classification of samples of unknown influence is then performed; each unknown sample is compared to the identified groups of samples and a probability of match to each sample group is calculated. If a group of samples is identified as “petroleum influence”, and another group of samples is identified as “geochemical background”, LDA will define the difference between these two groups; the comparison of unknown samples to these groups will yield for each unknown sample a probability of being like “petroleum influence” or “geochemical background”.

Factor Analysis (FA)

FA is a technique whereby components derived by PCA of data set are evaluated against correlations with original variable axes (organic compound mass response for the samples), and then rotated in data space into closer alignment with the original variables. The rotation has the effect of maximizing the correlations between all original variables and some specified number of factors to be extracted. The purpose of this operation is to enhance the interpretability of the factors, in terms of combinations of original compound variables. A common component rotation technique is “varimax” rotation, in which the factors are orthogonal through rotation. A sample’s value against a factor is termed a “factor score”. Depending on whether the combination of original variables expressed as a factor is of interest (e.g., a suite of thermogenic hydrocarbon compounds highly correlated with a given factor), the scores of that factor may be plotted or mapped in order to evaluate the distribution of the effect within a survey area.

Contour Maps of Geochemical Probabilities

AGI Geochemical Survey for Petroleum Exploration results are often expressed in terms of petroleum influence probability, as described above. The sample groups referred to are often designated as “geochemical model sets”, and the resultant probability values as “geochemical model probabilities”. Calculated probabilities are interpolated and contoured, using minimum surface curvature (spline), inverse distance, or kriging algorithms. Maps are plotted at a scale appropriate to the size of the survey and spatial distribution of the samples; typically 1:50,000 or 1:100,000.



Where possible, geographical information system (GIS) layer files containing relevant geological and geophysical (G&G) information (seismic line locations, structural interpretation contours, mapped fault polygons, etc), should be provided by the client for appropriate integration with geochemical results. All GIS layer files (shape files, ASCII XYZ) provided by the customer are projected in real-world coordinates (Latitude-Longitude, UTM, etc). Map projection and coordinate system details information should be clearly indicated.

Reporting of Results

The results of AGI Geochemical Survey for Petroleum Exploration are summarized in a deliverable report, which includes a review of survey objectives, design, modeling information, results and discussion. Field summary documentation, grid sample results tables, and color contour maps of model probability value and compound mass response are also included. Report deliverables will be in written document, slide presentation, or possibly montage/poster format. Electronic deliverables are provided via e-mail / ftp transfer, and may contain links to supporting electronic information.

Interpretation and Integration of Geochemical Survey Results

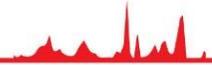
Survey results should always be integrated with other geological or geophysical information to prioritize areas for further exploration. In reviewing the results of a specific survey the following factors should be considered:

Fault Zones:

Greater emanation of hydrocarbons is generally associated with fault zones. The geochemical signatures of emanations along fault zones will likely differ from those of geochemical models developed for specific reservoirs. Thus, near surface free petroleum associated with fault zone seepage is not expected to correlate with or appear anomalous to models developed over reservoir accumulations.

Correlation with Structures:

A geochemical anomaly map is a surface plan view of the distribution of all analogous petroleum influences present throughout the stratigraphic section. The surface anomalies may correlate with structural traps in one or more horizons, or with stratigraphic traps that have not been resolved with geophysical methods; similarly a potential target may be shown to be geochemically unprospective.



Contour Plots:

Geochemical contour maps provided by AGI represent an objective computer-derived surface which has been interpolated from sample values. In general, no effects or influences from the underlying geology (such as fault boundaries or other structures) are accounted for in the data interpolation. However, such boundary conditions or other geological features should impact the configuration of geochemical anomalies. The exploration geoscientist is encouraged to evaluate the contoured data surface with this in mind.

When provided by the client, AGI can incorporate appropriate fault lines and polygons, or structural trend bias information into the data contouring process.

Contour Uncertainty:

Data values (model probabilities or compound mass responses) are most accurate at the sampled locations. The contour surface developed between the data points is an estimate of these values in space, and is subject to uncertainty which increases with distance from each sample location. Further resolution of the contoured surface may be appropriate through additional soil gas sampling depending on the end-use of the data.

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