Regional Geochemical Tool Targets Black River Gas in New York

By David Seneshen, Jim Viellenave and John Fontana
Direct Geochemical, Golden, Colorado

The deep Black River gas play in central New York is fast becoming a significant discovery for this decade, particularly for Fortuna Energy, Inc. which is producing 100 mmcf/d from several new fields. A study of this play, funded by the New York Research and Development Authority (NYSERDA), was undertaken to evaluate the effectiveness of surface geochemical methods over existing Black River gas fields and unexplored areas. A new exploration area, which was being drilled during the study, served as a blind test for the methods. Geochemical methods were chosen to test because they are low cost with a rapid turnaround and are environmentally non-invasive. This last feature is important in light of the high population density and amount of private land access required in this region of central New York.

The results of this study indicate these methods are effective for outlining prospective corridors of the Black River for subsequent leasing, seismic surveys and drilling. In combination with geology and geophysics, surface geochemistry is a complementary tool that can help to reduce risk and exploration costs. In addition to identifying prospects, surface geochemical methods can also identify deep faults that may breach and reduce production from hydrothermal dolomite reservoirs.

The premise behind any surface geochemical method is that light (C_1-C_5) hydrocarbons migrate vertically and rapidly as buoyant microbubbles along water-filled fractures from a pressured reservoir to surface. The result of this microseepage is that hydrocarbons become sorbed to organic and clay particles in overlying soils, and the mineralogy along the hydrocarbon chimney is altered because of reduced conditions brought on by the bacterial oxidation of hydrocarbons. Anomalies at surface degrade once the reservoir pressure has been reduced through production. Anomalies at surface can be apical or halo-like in morphology depending on the plumbing in the reduced chimney. Geochemical anomalies at surface can include soil gas hydrocarbons (free, sorbed and occluded), major and trace elements (e.g. I, Mg, Ni, V, U etc.), and hydrocarbon-consuming bacteria. Surface geochemical methods can help:

Figure 1. Example of soil profile developed on basal till that overlies Upper Devonian shale along a creek bed in the new exploration area.

continued on page 13

Note: *This EXPLORE article has been extracted from the original EXPLORE Newsletter. Therefore, page numbers may not be continuous and any advertisement has been masked.*

https://doi.org/10.70499/KHCX2086

Focus on: Regional Geochemical Tool Targets ... *continued from page 4*

- ❑ Differentiate between oil and gas
- ❑ Define areas for leasing and seismic surveys
- ❑ High grade seismic anomalies
- ❑ Find traps invisible to seismic surveys
- ❑ Identify by-passed pay
- ❑ Define structural trends

The methods cannot, however, provide information about reservoir depth or quality. In addition, interpretation is made difficult in under-pressured basins with stacked pays. These are by no means "stand alone" techniques, but they can help reduce risk when used properly in conjunction with geology and geophysical methods. A multi-component approach to geochemical exploration is therefore preferred to reduce risk and maximize rewards. Orientation surveys should be performed prior to any regional survey to select optimum sample media and analytical methods for a particular play or basin. In other words, one might consider testing the effectiveness of several sample media, sample spacings and analytical methods over existing production to select optimum methods for the larger survey.

Geology and Gas Production in the Study Area

Black River hydrothermal dolomite reservoirs in the study area range in depth from 9,000 to 10,000 feet. These narrow, east-northeast trending reservoirs reflect the channeling of hydrothermal fluids along zones of extension in Late Paleozoic time. Extension and dolomitization could have occurred along pre-existing faults during early Paleozoic rifting. The hydrocarbons were probably derived from interbedded Ordovician source rocks.

The reservoirs in the study area produce significant amounts of gas on an annual basis and production rates for individual wells vary from 0.4 to 19 mmcf/d (Figs. 2 and 3). As of 2002, the most productive fields were Wilson Hollow, Quackenbush Hill, Terry Hill South and Cutler Creek (Fig. 2). Recent production data are unavailable, but presumably

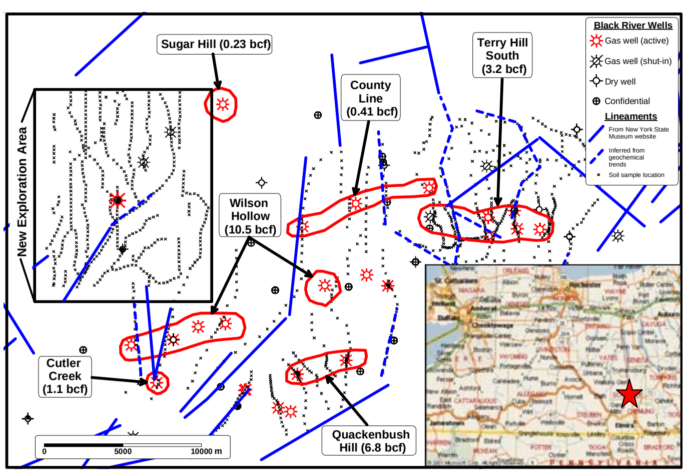

Figure 2. Map which shows location of the study area and distribution of gas fields, wells, lineaments and soil sample locations. Production data for each field represents annual production for the year 2002. These data were obtained from the New York State Museum website.

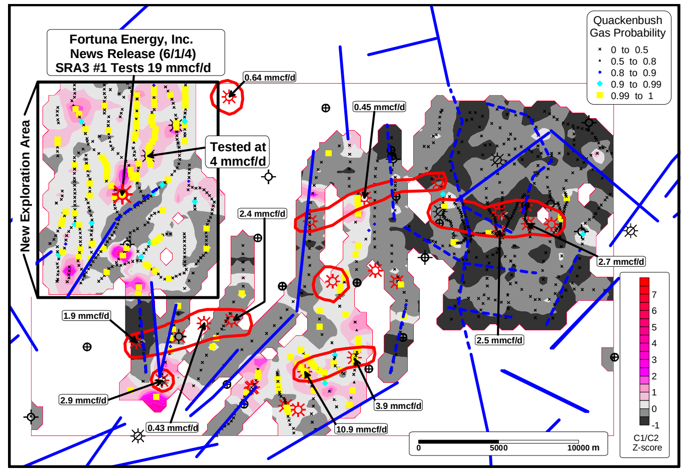

Figure 3. Quackenbush gas probability superimposed on the C1/C2 ratio Z-score. The gas probability was derived through discriminant analysis of C1-C6 hydrocarbon data using the samples collected around Quackenbush gas wells and dry wells. Note that the well drilled by Fortuna Energy, Inc. in the new exploration area is correctly predicted by the discriminant probabilities and anomalous C1/C2 ratio. Production rates for wells outside of the new exploration area are for the year 2002, and these were obtained from the New York State Museum website.

Quackenbush Hill is now outperforming the older Wilson Hollow and Terry Hill South Fields. The dry gas produced is uniform in composition between fields, and it consists mainly of methane with minor C_2-C_5 hydrocarbons, CO_2 and N_2 (Table 1).

Component	Mol%
Methane	97.97
Ethane	0.45
Propane	0.05
I-Butane	0.15
N-Butane	0.13
I-Pentane	0.02
N-Pentane	< 0.01
Hexanes+	< 0.02
Nitrogen	1.07
CO_2	0.16

Table 1. Produced gas composition from the Rice 1301 well in the Wilson Hollow Field (Courtesy of Fortuna Energy, Inc.)

continued on page 14

Focus on: Regional Geochemical Tool Targets ...

continued from page 13

Sample Collection

Soils were chosen as the preferred sample medium in the NYSERDA study because of uniform parent material in the area (99% basal till), ease of collection, ability to evaluate both alteration and hydrocarbon sorption in soils over Black River gas fields, and minimal impact on landowners (Fig. 1, see page 4). The field geologists were careful to collect soils that are consistent in terms of horizon, color and texture. Care is taken when collecting samples to avoid contaminating the soils with hydrocarbons or metals. The soils were collected from 8 to 12"-depth with a tree-planting shovel and stored in teflon-sealed glass jars for transport to the laboratory. Sample site locations were recorded using Global Positioning System (GPS) satellites and field notes were taken at each site.

One of the difficulties commonly encountered in geochemical surveys is that sample intervals are inadequate to resolve anomalies. The sample interval chosen is based on the size of the target such that two consecutive anomalies can be realized over the area of interest. For this study, a total of 1265 soils were collected over an area of approximately 500 km^2 at intervals of 100 to 500 m (Figure 2). Of the 1265 samples collected, 669 (53%) were along public roads that cross gas fields, 394 (31%) were from the new exploration area (blind test), 130 (10%) were samples around productive gas wells, and 72 (6%) were samples around dry wells.

Sample Preparation and Analysis

Soils were dried at low temperature in a temperature-controlled oven to avoid altering mineralogy, which can increase variability in hydrocarbon and elemental concentrations. The samples were sieved to a fine-grain size fraction through stainless steel screens and aliquots of sample were then weighed out for hydrocarbon, elemental, pH and conductivity analyses.

For hydrocarbon data, soils are thermally desorbed using a proprietary technique developed by Direct Geochemical. The desorbed gases are injected into a gas chromatograph with a flame ionization detector (GC-FID) for analysis of C_1-C_6 hydrocarbons. Detection limits are at low parts per billion levels.

For the elemental analysis, the sieved soil is digested in concentrated nitric acid and the supernatant is then filtered and analyzed for 26 major and trace elements by Inductively Coupled Plasma Emission Spectroscopy (ICP-ES). The pH and conductivity of a 1:1 soil slurry was estimated with probes and pH and conductivity meters. Internal standards, duplicates and blanks are analyzed within batches as quality control checks. The precision of the hydrocarbon, elemental, pH and conductivity analyses is better than ±10% at the 95% confidence level.

Interpretation and Mapping

Multivariate statistical techniques were applied to attempt to discriminate between productive and non-productive areas using samples collected around gas and dry wells as a training set. These techniques measure the covariance of several variables in multidimensional space simultaneously. For example, several hydrocarbons may correlate over productive areas as opposed to dry areas allowing for the distinction between favorable and unfavorable exploration targets. Development of a discriminant model allows the classification of samples from an unknown area into "productive or non-productive" categories based on the probability of a sample belonging to either category. In addition to multivariate analysis, several hydrocarbon ratios were examined to evaluate the "dryness and wetness" of the seeping gases. Both the hydrocarbon and elemental data were converted to "Z-scores" so as to better assess anomaly contrast. These scores are calculated by subtraction of the sample mean from individual values and division by the sample standard deviation. The data are then reduced to a mean of zero, and anomalies are represented as standard deviations (1, 2, …etc.) above the mean. The hydrocarbon, elemental, pH and conductivity data are displayed using unbiased computer contour and proportional symbol mapping techniques.

Results of the Geochemical Survey

The results of the study are very encouraging in that the shallow surface geochemical methods tested are capable of:

(1) Outlining areas with high Black River gas potential.

(2) Mapping faults that intersect and possibly breach gas reservoirs.

continued on page 15

Focus on: Regional Geochemical Tool Targets ... *continued from page 14*

Four anomaly types have been recognized in the study area (Table 2). In general, there is more methane relative to ethane (C1/C2 ratio is a measure of gas dryness) in soils over Quackenbush Hill, Cutler Creek, and sporadic parts of Wilson Hollow, County Line, and Terry Hill South (Fig. 3). When Quackenbush gas probabilities are superimposed on the C1/C2 ratio there is significant correspondence (Fig. 3). A post-survey well (SRA3 #1) intersected significant gas production (19 mmcf/d) where anomalous gas probabilities are correlated with the dry gas ratio in the new exploration area (Fig. 3). In addition to the dryness ratio, other variables that contribute to the discrimination of gas and dry reservoirs are ethene, isobutane, isopentane and, to a lesser degree, propane. Factor scores show the spatial distribution of samples with a strong correlation between ethene, isobutane and isopentane in the study area. This hydrocarbon association is anomalous over all or parts of all gas fields in the study area (Fig. 4). Propane is particularly anomalous over the highly charged Quackenbush Field and around the new SRA3 #1 discovery well (Fig. 5). Anomalously low dryness ratios are evident over mapped and inferred

Table 2. Hydrocarbon and Elemental Anomalies Identified in the Study Area

	2002 Production (bcf)	Ethene-iC4-iC5 factor scores	Dryness Ratio (C1/C2)	% Propane	Ethane/ ethene, Ca, Mg, Sr, Pb, Zn, Tl
Quacken-bush Hill	6.8	✓	✓	✓	None
New Discovery (SRA3 #1)	Not produc-ing yet	✓	✓	✓	None
Cutler Creek	1.1	✓	✓	✓	None
Wilson Hollow	10.5	✓	Sporadic	None	✓
Terry Hill South	3.2	✓	Sporadic	Sporadic	✓
County Line	0.4	✓	Sporadic	Sporadic	✓

continued on page 16

Focus on: Regional Geochemical Tool Targets ... continued from page 15

lineaments, particularly in the eastern half of the study area (Fig. 3).

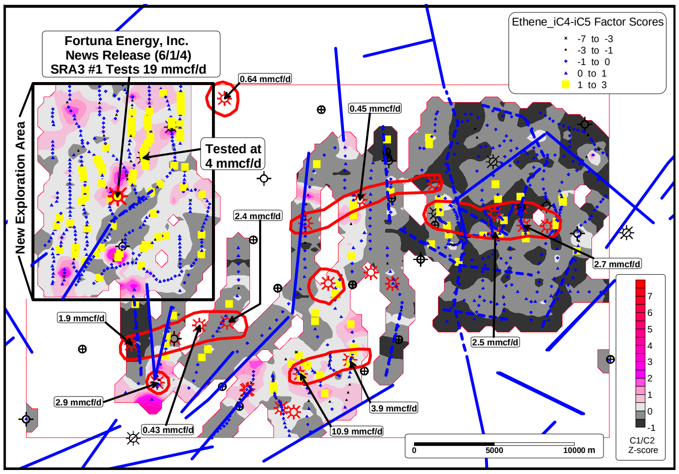

Figure 4. Ethene_iC4-iC5 factor scores superimposed on the C1/C2 ratio Z-score.

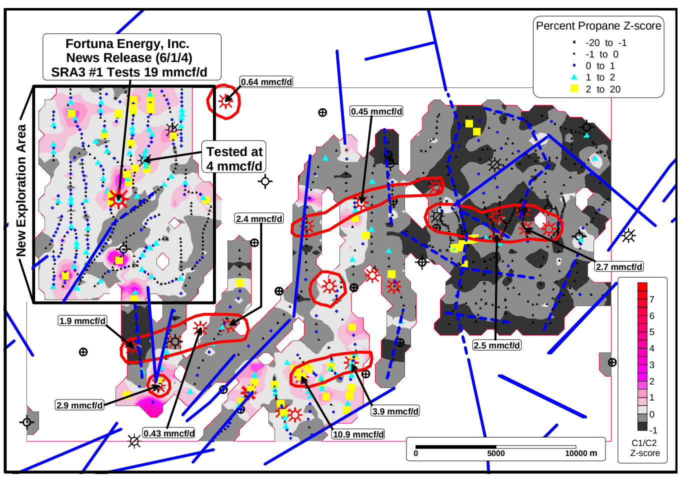

Figure 5. Percent propane Z-score superimposed on the C1/C2 ratio Z-score

Lead in soils, which can be an indicator of Mississippi Valley Type (MVT) mineralization, is antithetic with the C1/C2 ratio, but sympathetic with the ethane/ethene ratio (cf Figs. 5 and 6). Calcium and magnesium show similar anomaly patterns to that of lead, but they are not as widely dispersed (Figs. 7 and 8). Other variables that correlate with the Pb, Ca, Mg association are Sr, Zn, and Tl. This element association shows linear anomaly trends which, in some cases, are aligned with mapped lineaments.

Discussion of Results

Any discussion of the results of this study must take into account:

(1) The linear heavier hydrocarbon/metal anomalies, which are aligned with known lineaments in places.

(2) The variable hydrocarbon signature over fields that produce dry gas of identical composition.

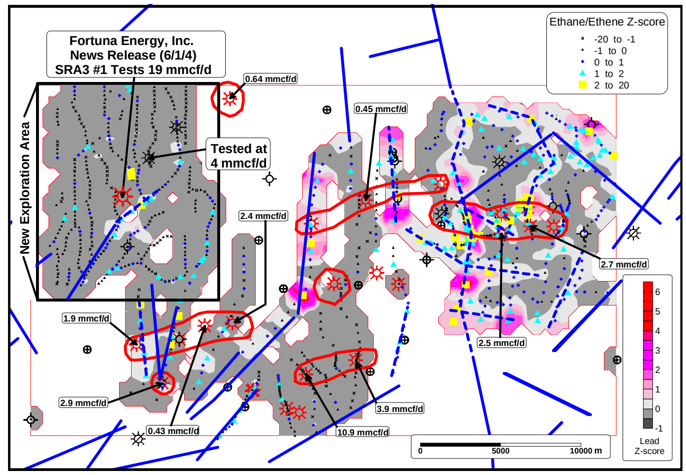

Figure 6. Ethane/ethene ratio Z-score superimposed on the lead Z-score. High ethane/ethene ratios are thought to be indicative of faults because rapid ascent of ethane does not allow adequate time for oxidation to ethene. The correlation of ethane/ethene ratios with lead could reflect the presence of Mississippi Valley Type mineralization along the faults.

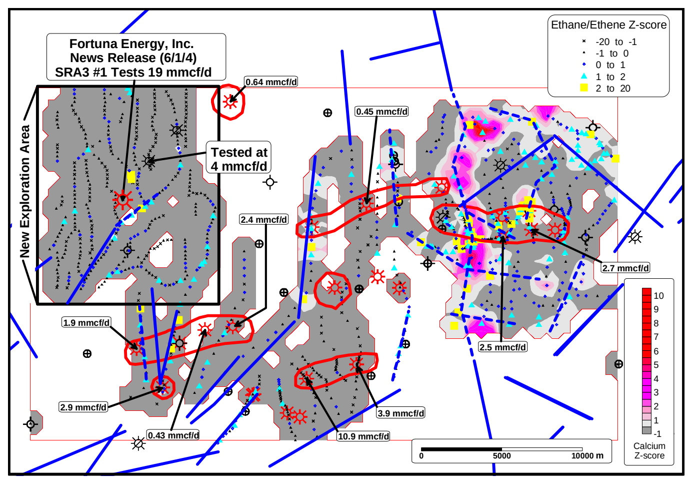

Figure 7. Ethane/ethene ratio Z-score superimposed on the calcium Z-score.

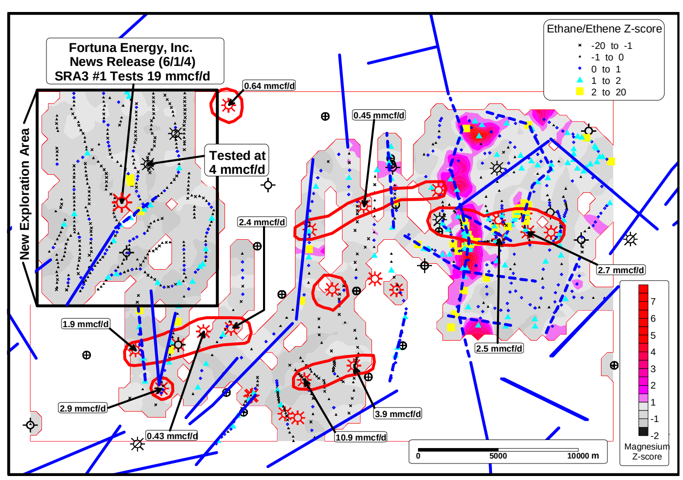

Figure 8. Ethane/ethene ratio Z-score superimposed on the magnesium Z-score.

continued on page 17

Focus on: Regional Geochemical Tool Targets ... continued from page 16

The linear metal-hydrocarbon anomalies could be explained by deep faults that intersect Black River reservoirs. Evidence that supports the occurrence of these anomalies along deep faults is:

(1) Anomalous ethane/ethene ratios relative to methane suggests rapid ascent of a heavier hydrocarbon to surface along faults such that there is insufficient time for oxidation to ethene. In unfaulted areas, where microseepage of ethane is slower, there is abundant ethene in the soils (i.e. over Quackenbush).

(2) The MVT element association (Ca, Mg, Sr, Pb, Zn, Tl) suggests that the Black River hydrothermal dolomite reservoir has been tapped by a deep fault. There are no dolomites at the surface or in the overlying stratigraphic section to derive such a mineral assemblage.

An interesting observation to note is that the most productive fields in the area (i.e. Quackenbush) do not appear (based on surface lineaments) to be dissected by these types of deep faults, possibly implying that the best reservoirs have not been breached by leaky faults.

All of the hydrocarbons present in the soils over Black River gas reservoirs are also in the produced gas (Table 1). The ethane-iC4-iC5 association is noted in soils above all gas fields, but the dryness ratio (C1/C2) and percent propane are more anomalous over Quackenbush, Cutler Creek and the new SRA3 #1 discovery (Figs. 4 and 5).

Ethene can be produced through biological or chemical oxidation of ethane and other hydrocarbons as it gradually ascends to surface. Isobutane and isopentane, which are present in the produced gas, are also part of this "slow" microseepage association. The dryness ratio (C1/C2) and percent propane anomalies over Quackenbush, Cutler Creek and new gas discovery (SRA3 #1) relative to Wilson Hollow, Terry Hill South and County Line is puzzling, considering that produced gas composition from all fields is nearly identical. Possible reasons for the different hydrocarbon signatures observed in soils over the fields are:

(1) Wilson Hollow, Terry Hill South, and County Line have been breached by deep faults along which heavier hydrocarbons can ascend rapidly. This would explain the heavier hydrocarbons and metals over these fields as opposed to Quackenbush, Cutler Creek and the new discovery that have not been breached by deep faults.

(2) Pressure in the older Wilson Hollow, Terry Hill South and County Line reservoirs may have declined more than Quackenbush, Cutler Creek, and the new discovery because of more production and/or breaching by deep faults. The drop in reservoir pressure may have slowed or curtailed microseepage to the surface such that the dryness ratio and percent propane anomalies have disappeared. The ethane-iC4-iC5 association in soils over all gas fields suggests that this assemblage of hydrocarbons is more stable in soils and can exist for some time after microseepage ceases because of pressure drops related to production and/or breaching by faults.

The explanation for the change in the hydrocarbon signature in soils over compositionally identical reservoirs can be further refined once current production pressures for all gas fields are obtained.

<u>Conclusions</u>

The following conclusions are drawn from this test of surface geochemical methods over deep Black River gas targets in central New York:

continued on page 18

Focus on: Regional Geochemical Tool Targets ... continued from page 17

The surface geochemical methods tested are effective in terms of:

(i) Detection of unique microseepage from commercial Black River reservoirs, which will help to pre-screen large areas to focus leasing, seismic and drilling activities. Variables that distinguish gas and dry reservoirs are ethene, isobutane, isopentane, methane and propane. The lack of dryness ratio (C1/C2) and %propane anomalies in soils over some fields might reflect the presence of deep faults that carry heavier hydrocarbons and metals to surface and/or drops in reservoir pressure related to production and breaching by deep faults.

(ii) Mapping of faults that intersect and possibly hinder production from dolomite reservoirs. Indications of these faults are anomalous ethane/ethene ratios relative to methane, Ca, Mg, Sr, Pb, Zn and Tl in soils.

(iii) Minimal impact to landowners because of the rapid, non-invasive nature of the sample collection method.