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Results of a Soil Gas Study In the Vicinity of the Bath Petroleum Storage Facility Final Report

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Introduction

Samples of gas were collected from soil at over 900 sites in and around the Bath Petroleum Storage Facility, Steuben County, near Bath, New York to aid in determining if fracture pathways for gas seepage exist from the petroleum storage caverns at the facility to the surface. The location of the facility, and of the soil gas samples, are shown on Figure 1.

Soil gas analyses provide information on gas seepage along fractures (or faults) because gas will rise along open fractures and can accumulate in overlying soil. Bedrock in most units in Western New York contains natural gas (Jenden et al., 1993), providing a source for the gas. Although most rock units in Western New York contain natural gas, flow from these units is so minute that normally the gas content in overlying soils is not detectably enriched. Only when fractures or faults provide a pathway to the surface will thermogenic gas (natural gas) accumulate in the soil (Fountain and Jacobi, 1997; Jacobi and Fountain, 1993; Jones and Drozd, 1983). Gas may also accumulate from biogenic decay of organic matter. Gas produced by biogenic processes is characterized by a composition of almost pure methane and no significant amounts of heavier hydrocarbons such as ethane occur (Whiticar et al., 1986). In contrast, thermogenic (natural) gas of Western New York has ethane contents in the range of a few percent to over 15% of the methane content plus lesser amounts of propane and heavier hydrocarbons (Jenden et al., 1993).

Data from well logs and seismic data have been cited by Tom Magorian to suggest a structure, possibly a fault, exists in the area of petroleum storage facility near well no. 7. If a fault is present, and provides a pathway for gas migration to the surface, anomalously high contents of propane or butane, the principal gasses stored in the facility, should occur. This study was undertaken to determine if such an accumulation occurred.

Results

No butane was detected in analysis of over 900 samples of soil gas in the vicinity of the Bath Petroleum Storage Facility. Additionally no propane in excess of that expected from local thermogenic natural gas was found. Most importantly, the study uncovered no evidence in support of any structural pathways, including faults and fractures, between the petroleum storage caverns and the surface on the site of the Bath Petroleum Storage facility. Nor was evidence of a fault oriented as suggested by Magorian found.

If either faulting or folding occurred in the study area, and the related fracturing extended to the surface, the fractures would be concentrated along the structure and hence gas leakage would be expected. Some anomalously high concentrations of hydrocarbon gas were found, most of which had significant ethane concentrations indicating a thermogenic (as opposed to a biogenic) origin. These occurred primarily away from the

Bath Petroleum Storage facility property, along the valley walls near bedrock outcrops. The trend of the anomalies suggested leakage from fractures parallel to the main valley walls, with higher concentrations at the intersections with fractures forming the side valleys. The composition of the gas (methane and ethane) indicates an origin from the shallow bedrock.

Study Design

Several sets of fractures occur in bedrock throughout Western New York, although the trend of the dominant fracture set is different at different locations. Most of the major fracture sets were formed during the multiple orogenies that produced the Appalachian Mountain chain (Zhao and Jacobi, 1997) and hence are several hundred million years old. Old fractures typically are sealed and thus do not provide pathways for gas migration, as evidenced by the retention of natural gas for many millions of years throughout the region. Uplift and erosion during the recent glaciations has also caused extensive fracturing near the bedrock surface in many units, thus the presence of open fractures near the surface may not be indicative of open fractures at depth.

The study consisted of a number of soil gas traverses, each traverse consisting of a line of soil gas samples collected every 30 feet, typically along the sides of roads. Traverses were conducted on both the north and south sides of the valley as well as within the storage facility itself (Figure 1). On each traverse samples were collected every 30 feet from a depth of approximately 2 feet with stainless steel probes. Samples were collected with gas tight syringes and were immediately analyzed on-site with a portable organic vapor analyzer (Century OVA 128 GC) equipped with a flame ionization detector and a gas chromatograph column to separate hydrocarbon gasses. The instrument was calibrated daily with a calibration gas of known methane content. Methane, ethane and butane elution times were also verified with calibration gasses. Duplicate samples were taken periodically, and duplicate samples were taken whenever large spikes (anomalously high hydrocarbon contents) were found. Samples with high organic vapor content were injected in Gas Chromatograph (GC) mode to determine relative methane/ethane/propane and butane abundances.

933 samples were analyzed over 26,220 feet of traverse. The location of the individual traverses are shown on Figures 1 and 3. Data for each traverse is shown on plots in Appendix I, and tabulated in Appendix II. In this section the data are discussed in terms of local geology.

Discussion

Local Fracture Sets:

Fractures typically occur in sets, groups of fractures that have a similar trend over a relatively large area. Fracture sets from the local area thus provide a context for interpretation of soil gas anomalies. Study of outcrops adjacent to traverses on both the north and south sides of the valley, and in several creeks outside the area, determined that there are three prominent fracture sets in the area. A very strong fracture trends roughly northeast; this fracture is related to the prominent NE trending side valleys in the area (but not at the facility, which is not on trend with a side valley). A second strong fracture trends about northwest, parallel to the main valley through which highway 17 runs in this area. The prominent steep sided valley is strongly suggestive of a fracture controlled valley. Finally, a weakly developed fracture system trends almost due north. This fracture system has less topographic expression that the other two sets, perhaps the most prominent is the large valley running north from Bath.

Soil Gas Anomalies, General Characteristics:

Although fractures occur in all bedrocks in Western New York, most do not result in soil gas anomalies. Anomalies occur only where the fractures are open, presumably due to reactivation of a portion of the fracture zone providing a pathway for gas migration. Typically this results in anomalously high gas content over only a narrow zone of a fracture set, typically a zone ranging from 50 to several hundred feet (based on over 10,000 analyses in Western New York). A traverse running perpendicular to a fracture set usually yields a number of anomalously high abundances, with the samples with maximum magnitudes near the center of the anomalously high group. In contrast a traverse running nearly parallel to an open fracture set would have an extensive number of spikes, not showing a regular pattern.

Valley Wall Traverses:

A series of traverses were run along the walls of the valley, both the northern wall and the southern wall. The traverse along the northern wall followed route 415 (Figure 1). We believe that the steep-sided straight-edged valley wall reflects erosion along a fracture set that trends parallel to the valley itself. Thus we would expect some gas to be emitted from the fractures that are parallel to these traverses. The northern traverse begins approximately 0.8 miles north of the Petroleum Storage Facility, in an ENE trending side valley, continues along the bedrock on the valley wall, and ends south of the Petroleum Storage Facility (Figure 1). The traverse can be divided into three segments based on the soil gas analyses (Figure 2). In the northern-most segment north of the side-valley wall, soil gas contents are fairly low, with no significant spikes. In the central section, which runs from 2000 feet north of the bridge to 1000 feet south of Irish Hill Road, there is a nearly continuous occurrence of anomalies of 10 ppm or more. These anomalies are consistent with a trend along a fracture, the pattern is of continual anomalies of similar size, not increasing in size towards the center of the anomaly cluster as expected for traverses that cross a fracture set. The southern end of the section, south of Irish Hill

Road, again has low abundances. This corresponds to an area without bedrock outcrop and of much lower relief. Gas chromatography determined that the spikes all along this traverse contained methane and ethane, but no butane or anomalously high propane (propane is present at abundances less than ethane in all natural gas, if propane was from propane storage, its abundance would be higher than expected ratio to ethane and methane). The ethane indicates the gas is from thermogenic natural gas in the shallow bedrock.

The principal spikes on this traverse, and on the southern traverse described in the next section, are shown on Figure 1. At each location that one or more samples yielded a value of 10 ppm or more (the maximum reading for the scale used) an "x" is marked on the Figure. Where several anomalies occur together, only 1 "x" is shown.

The traverse along the southern wall of the valley is quite different. It begins on Wagner Road, crossing a side valley, and continues down Eagle Valley Road past the Storage Facility (Figure 1). The northern end of the traverse, along Wagner Road and continuing to the bridge has many spikes of about 12 ppm (Figure 2). The central section past the Bath Petroleum Storage facility has few spikes, then a cluster of spikes is found approximately 0.4 miles south of the facility. Since the side valley cut by Wagner Road is also linear and aligned with the NE regional fracture set, it is presumably also a fracture controlled valley. The northern cluster of spikes, along Wagner Road and the remainder of the traverse in the side valley, is located at the intersection of the NE and the NW set that controls the main valley. Large concentrations of anomalies at fracture intersections are expected. This interpretation is supported by the smaller gas concentrations found along Eagle Valley Road. These spikes presumably arise from the valley wall parallel fractures in a similar manner to the spikes on the north side of the valley. The southern cluster of spikes on this traverse may represent another intersection of the NE fracture set and the NW fracture set. As with the northern traverse, no butane or anomalously high propane was found on the southern traverse.

Traverses on the Bath Petroleum Storage Property:
Traverses were run on Bath Petroleum Storage Facility property parallel to highway 17 and perpendicular to it (Figure 3). A circle of analyses was also made around well 8. A traverse was also run along the river, approximately centered on well 7 since an alleged fault postulated by Magorian was located in this area These traverses were close to a number of active and proposed storage wells. As shown on Figure 3, samples were also taken near wells 13, 11, 6, 9 and 5.

There was no correlation between distance to the wells and gas content . No anomalies were found close to any of the wells indicating that no detectable leakage occurs near the wells. No butane and no propane was found in of these any analyses indicating that no detectable leak from the depth of the storage reservoir was present. A number of spikes were found along the road that leads to the old barn (the road that runs past well 9 and 12). These spikes contained methane and ethane, but no butane; they were from shallow bedrock not from the depth of the storage caverns. No spikes were found along two traverses run perpendicular to this road, except right along the road (Figure 3). A circle of samples taken around well 8 yielded no spikes (Appendix I). The traverse parallel to the river yielded one isolated spike, not close to any of the wells. The conclusions from this data are that no detectable butane or propane leakage occurs, that no systematic open fractures were detected anywhere except parallel to the access road and that these fractures are not concentrated near well 8 nor along the traverse centered on well 7.

The data suggest that there is no fracturing that reaches the surface associated with the monocline postulated by Jacobi based on well log analyses. This conclusion is consistent with Jacobi's observations that the Onondaga and overlying units are flat lying and that local outcrops do not display faulting or increased fracturing in this area. Traverse 97-7 (Figure 3) crosses the axis of the monocline, but no spikes were found along the portion of the travese near where the axis crosses the traverse. If open fractures were associated with the monocline and did reach the surface, spikes would be expected along the traverse. Analyses near well 9, which is located on the edge of the monocline, did not detect any butane, although the well is used for butane storage. If open fractures to the surface were associated with this structure, butane anomalies would be expected from samples near well 9.

Other Data:

A short traverse was run perpendicular to highway 415 approximately 1 mile south of the Bath Petroleum Storage facility (Figure 1). This segment passes under overpasses for highway 17. Several spikes were found along this traverse. Due to the extensive excavations and filling for the overpasses, it is not clear if the data on this traverse are reliable. No butane nor anomalous propane was found in any samples.

Conclusion

The intensive soil gas study conducted at this site is far beyond those characteristically done at conventional storage facilities. It provides perhaps the most comprehensive documentation of the integrity of any facility of which I am aware. There have been no published soil gas studies of this detail on other gas storage facilities. Based upon my personal experience, the Bath Petroleum Facility evidences less likelihood of the existence of faulting which would affect the structural integrity of the storage facility than any I have tested. There is no evidence of any leakage in the existing caverns which would cause concern regarding the storage of natural gas.

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