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COGCC Rule 608 Soil Gas Survey Report

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Executive Summary

A soil gas survey was conducted on behalf of Pioneer Natural Resources USA, Inc (Pioneer). over abandoned coal mines and plugged & abandoned (P&A) wells in parts of the Raton Basin in Las Animas County, Colorado. The survey was done to comply with new regulations from the Colorado Oil & Gas Conservation Commission (COGCC), which require monitoring of soil gas emissions within buffer zones of proposed coal bed methane (CBM) wells over time (COGCC Rule 608 a/c http://cogcc.state.co.us/RR_Training/presentations/608_Summary.pdf).

The soil gas survey was conducted over abandoned coal mines within a 2-mile radius of proposed CBM wells and over P&A wells within a 1/-4-mile radius of the proposed wells. A total of 11 coal mines and 5 P&A wells were surveyed where access was granted by landowners, including the Division of Wildlife (DOW) and XTO Energy. The survey involved the detection, mapping and sampling of gas seeps on foot over 215 miles of arduous terrain. The field work was carried out intermittently over an 8-month period (Early October 2009 to Late May 2010) as a result of weather delays through most of the winter. The survey included 1,028 man-hours of field work, chemical analysis of soil gas and spring water samples, compilation of data, interpretation, mapping and reporting.

A Toxic Vapor Analyzer (TVA) with both Flame Ionization (FID) and Photo Ionization Detectors (PID) was used to detect natural gases seeps over and around the mines and wells. Data were collected and geo-referenced in the field using a custom Geodatabase system operated on ArcPad software on a Trimble Geo-XH GPS-PDA computer. Soil gas and spring water samples were sampled for hydrocarbon and carbon-deuterium isotopic analysis where significant seeps were encountered.

Methane seeps were detected over 3 of the 11 mines surveyed. Methane seeps are evident over the eastern 11% of the 1,316 acres surveyed at Golden Eagle mine and the southwestern 23% of the 50 acres surveyed at Prairie Canon mine. Isolated seeps were also found over the Quinto mine. Some seeps are spatially associated with open-spaced fractures in bedrock, void spaces between boulders and the concrete carapaces of historic ventilation shafts. The seeps over Golden Eagle mine trend both northeast and northwest and those over Prairie Canon mine trend southwest. The linear nature of the seeps suggests they are controlled by prominent structures. Gas compositional data suggest that these seeps are biogenic in origin and are probably derived from shallow Raton coals.

An intermittent spring with weak methane seeps is evident down-slope of a produced water pit at the Quinto mine. A water sample from the spring contains only trace amounts of methane, which was insufficient for isotope analysis.

Methane was detected at 1 of the 5 P&A'd well sites surveyed (Black Rabbit well), and it is derived from leaking infrastructure (heater and gas line) in a shed that was built over the P&A well. Seeps were not found to be associated with leaking CBM wells or P&A'd oil & gas wells.

This soil gas survey meets the requirements of the COGCC Rule 608 in that (i) the survey was carried out on accessible parts of abandoned coal mines and P&A wells within the buffer zones of Pioneer's proposed CBM wells, (ii) the areal extents of gas seeps and springs were mapped, (iii) gas seep composition was documented through sampling and analysis, and (iv) the results are being reported within 3 months of completion of the field work.

1.0 Introduction

The Denver office of Pioneer Natural Resources USA Inc (Pioneer). contacted Vista Geoscience to conduct soil gas surveys over abandoned coal mines and P&A wells in part of the Raton Basin in Las Animas County, Colorado to comply with new regulations from the COGCC concerning proposed locations of CBM wells (Figures 1 and 2). Rules 608a and 608c, which are applicable to Pioneer's proposed CBM wells, are as follows:

608a. Assessment and monitoring of plugged and abandoned wells within one-quarter (1/4) mile of proposed coal bed methane (CBM) well.

(1) *Based upon examination of the Commission and other publicly available records, operators shall identify all plugged and abandoned (P&A) wells located within one-quarter (1/4) mile of proposed coal bed methane (CBM) well. The operator shall assess the risk of leaking gas or water to the ground surface or into subsurface water resources, taking into account plugging and cementing procedures described in any recompletion or P&A report filed with the Commission. The operator shall notify the Director of the results of the assessment of the plugging and cementing procedures. The Director shall review the assessment and take appropriate action to pursue further investigation and remediation if warranted and in accordance with Colorado Revised Statute 34-60-124(4)(A).*

(2) *Operators shall use reasonable good faith efforts to obtain access to all P&A wells identified under Rule 608.a.(1) above to conduct a soil gas survey at all P&A wells located within one-quarter (1/4) mile of a proposed CBM well prior to production from the proposed CBM well and again one (1) year and thereafter every three (3) years after production has commenced. Operators shall submit the results of the soil gas survey to the Director within three (3) months of conducting the survey or advise the Director that access to the P&A wells could not be obtained.*

608c. Coal outcrop and coalmine monitoring.

(1) *If the CBM well is within two (2) miles of the outcrop of the stratigraphic contact between the coal-bearing formation and the underlying formation, or within two (2) miles of an active, inactive, or abandoned coal mine, the operator shall make a good faith effort to obtain the access necessary to survey the outcrop or mine prior to drilling the CBM well to determine whether there are gas seeps and springs or water seeps that discharge from the coal-bearing formation in the area.*

(2) *If a gas seep is identified during the survey, then its location and areal extent shall be surveyed in accordance with Rule 215 and the concentration of the soil gas shall be determined. If possible, a sample of gas shall be collected from the seep for compositional analysis and stable isotope analysis of the methane (carbon and deuterium). Thereafter, the operator will inspect the gas seep, survey its areal extent, and measure soil gas concentrations annually, if access can be obtained. The operator shall submit the results of the outcrop or mine monitoring to the Commission and the landowner within three (3) months of its completion of the field work. The analytical data shall also be submitted to the Director in an electronic data deliverable format. 600-13 As of March 30, 2009*

(3) *If a gas seep is identified during the survey, the Director shall advise the landowners, local government, Colorado Geological Survey (CGS), and the Colorado Division of Reclamation, Mining, and Safety (DRMS), as appropriate, of the findings. In collaboration with state, local, and private interests, the CGS, DRMS, and the Commission may elect to develop a geologic hazard survey and determine whether the area should be recommended to be designated as a geologic hazard in accordance with Colorado Revised Statute 34-1-103 and 24-65.1-103.*

(4) *If the CBM well is within two (2) miles of the outcrop of the stratigraphic contact between the coal-bearing formation and the underlying formation, the operator shall survey the outcrop, review publicly available geologic and hydrogeologic data, and interview landowners to identify springs or water seeps that discharge from the coal-bearing formation.*

Pioneer geologists determined that 11 coal mines and 5 P&A wells are within the buffer zones of their proposed or possible wells and therefore required soil gas surveys as described in Rules 608a and 608C (Figure 2). The shapes and locations of coal mines and core holes were provided by Lewicki (2001). Pioneer requested permission from landowners, other operators (XTO Energy) and the Division of Wildlife (DOW) for Vista Geoscience to conduct the soil gas surveys on their property. Pioneer supplied access boundaries to Vista Geoscience and the survey was started in October of 2009.

This report describes the methods employed for the soil gas survey in Section 2.0 and the results of the survey in Section 3.0. Conclusions and a schedule for monitoring seeps identified on an annual basis are provided in Section 4.

2.0 Soil Gas Survey Method Used

Vista GeoScience provided experienced environmental technicians equipped with portable gas detection and sampling equipment to conduct the soil gas survey. The field technician is also equipped with a Trimble Geo-XH Global Positioning Satellite (GPS) system with customized ESRI/ArcPad database software to record all acquired data and spatially locate all data using the real-time differential correction for sub-foot accuracy collection parameters (according to COGCC Rule 215). This system is especially important for mapping the areal extent of gas seeps.

2.1 Gas Detection System

The Foxboro TVA-1000B is an intrinsically safe FID/PID gas detection system that is used to detect ground surface soil gas seeps and oil & gas infrastructure leaks (well-heads, pipelines, tanks, etc). The instrument's flame ionization detector is calibrated over multiple points (similar to EPA SW-846 environmental lab methods) with methane calibration gas at 100 ppm, 1,000 ppm, 5,000 ppm, and 50,000 ppm and the instrument is checked several times daily to ensure accuracy. The photo ionization detector (10.2eV) is calibrated using a single point of 100-ppm iso-butylene. Both instrument's zero points are calibrated relative to ambient air, so that normal ambient levels of methane (2 ppm) are removed from the readings and all FID readings are equivalent to ppm methane above ambient.

The FID detects any flammable gases in an oxygenated atmosphere and the PID detects other non-methane compounds and is especially sensitive to aromatic hydrocarbons, such as benzene, toluene, etc. It will therefore detect poly-aromatic hydrocarbons (PAH's) if crude oil or "wetter" petroleum gases are present. The instrument can detect 1 ppm of methane over ambient air on the FID, 0.1 ppm of aromatic hydrocarbons on the PID. If the heavier hydrocarbons are present in the gas, the FID readings will be biased high relative to methane. The internal sample pump draws 1-liter of air per minute, and device is attached to the instrument intake allowing the operator to collect gas sample at the soil/air interface. This eliminates the need for plunger-bar holes for gas detection and mitigates the risk of damaging buried utilities. If soil gas samples are collected, they can be screened using the instrument and concentrations up to 100% can be measured using a field dilution method.

Based on comparisons with other soil gas surveys, the soil gas at the soil surface/air interface is generally about 1/10th the concentration of the soil gas (using sealed probe methods) and is much more sensitive than the plunger bar/multi-gas meter method. Gas reading are made continuously along a slow walking path, about 1 to 2 mile/hour pace, so that gas readings are taken at the surface approximately every 3 to 5 feet along the traverse, which reduces the risk of missing seeps. Where gas is detected, the operator marks the location on the GPS system and records the hydrocarbon concentration.

The potable FID/PID gas detector and data acquisition system allowed Vista's technicians to cover large areas on tightly spaced lines in arduous terrain over the 11 coal mines and 5 P&A wells (Figure 3).

2.2 ArcPad GIS Data Acquisition System

Vista GeoScience developed an ESRI ArcPad software based field data acquisition system that significantly reduces data acquisition time, transcription errors, and data compilation time over conventional data collection methods using hard copy field notes and manual data entry. A Geodatabase was created using ArcGIS/ArcEditor software, and was operated in the field using ArcPad software on a Trimble GeoXH or equivalent PDA-GPS handheld field computer. The Trimble GPS system used is a sub-foot accuracy system (settings are programmed to comply with Rule 215 requirements) that allowed direct entry of data points, tracing of feature shapes and lines directly into the Geodatabase without manual data entry or drafting. Descriptions and attributes for all recorded features were selected from standardized pick lists and additional comments were entered directly into the GPS-PDA. Photographs were taken to document all features of interest linked to the locations recorded in the Geodatabase, including photo direction. At the end of the day, each of the GPS/PDA units and camera were downloaded directly (data check-in) to a computer with the main Geodatabase (ArcGIS) and all features were instantly updated so they could be viewed back at the office as data was collected. Each day the technician checked out background map data in the areas they need to complete work. The GPS units have the ability to include all the ArcGIS features including "go-to" target points from client targets, air-photo interpretations, topography maps and air photos making it easier to find and map these features. GIS Features mapped in the field with this system include:

- FID/PID survey walking tracks
- Areal extent of gas seep areas (> 1ppm outline), stressed vegetation, salt crusts, springs, ponds, geological units, etc.
- Linear features such as faults, dikes, pipelines etc.
- FID and PID concentrations (ppm) of natural gas seeps and infrastructure leaks.
- Photo or video locations of surveyed features

Numerous attributes for each mapped geographic feature were also included in the geodatabase. Point features were recorded on the GPS using real-time differential correction for sub-foot data collection parameters according to Rule 215.

The path of the traverse was recorded continuously. Readings were entered into the GPS data system at any required grid interval with ease and the entire track of the operator was recorded on the GPS. This system allows soil gas to be measured without the need for utility clearances since there was no ground disturbance. The system allowed the operator to easily detect and map the areal extent of an above ambient level seep.

2.3 Sample Collection Methods

Soil Gas

Soil gas samples were collected at selected seep sites over the Golden Eagle and Prairie Canon Mines using a slide hammer driven 1-inch steel rods with a “Post Run Tubing (PRT) System” at the tip (Figure 4). Using this system, soil gas samples can be collected quickly and with a high degree of assurance that the samples are representative of the targeted depth, i.e., using this method, there is no leakage at probe rod joints that will compromise the integrity of the sample. At the desired sampling depth the rod is pulled back to disengage the retractable point and expose the soil interval for sampling. The PRT adapter is secured to a length of tubing sufficient to reach from the sampling interval to the surface, with several feet of excess tubing extending beyond the top of the probe rod to facilitate sampling. The volume of the tubing is then calculated. The tubing is attached and three volumes of this tubing are purged before sampling.

Ambient and sample gas compositions (hydrocarbons and CO_2) are monitored with portable infra-red and FID/PID gas meters to monitor ambient air infiltration to the sample. The infra-red gas meter is calibrated with methane, CO_2 and O_2 standards and the FID/PID is calibrated with methane and isobutylene standards as described in Subsection 2.11. Ambient readings and initial sample gas readings are taken by these instruments The instruments pumps perform at known rates and are used to purge the appropriate tubing volumes while monitoring the parameters. After purging and stabilization of gas readings, samples are collected by using a 60ml syringe with a 2-stage manual valve system to ensure no sample loss or ambient air infiltration between cycles. Samples are collected in a 1-liter Cali-5 Bond (5 layer) metal-lined bags, which are pre-purged in the lab with nitrogen. Before sampling the Cali-5 bag is connected to the valve system and purged three times with sample gas before the final sample volume is collected. Samples also included a trip-blank, duplicate and an ambient sample. Sample gas and ambient air concentrations are rechecked after the sample collection to note any changes that may have occurred.

These protocols were followed for soil gas collection from seeps over the Golden Eagle and Prairie Canon mines. Two of the five gas samples had considerable ambient air infiltration possibly due to fractures in the soil substrate at 5-foot depth.

Spring Water

Spring water discharge at Quinto mine was sampled using these protocols. The discharge is called a spring because there was visible discharge of groundwater at surface. The United States Geological Survey defines a spring as an a*rea where there is* *a concentrated discharge of ground water that flows at the ground surface. (http://pubs.usgs.gov/gip/gw/glossary.html#Spring).*

Vista water sampling protocols require that all preparations for sampling events and ingress to the sampling location of a surface water site are performed down-stream to avoid sample disturbance. Where surface water or spring discharge is shallow or the discharge is weak, a “section” is created into the discharge channel enough to record parameters, take a discharge measurement and submerge the sample bottles sufficiently without risking hitting bottom. This is done no later than 24hrs before the sampling event is to occur to allow for recovery and sediment settling.

Vista uses a YSI-556 Multi-parameter probe to collect water quality parameters. These parameters recorded include: pH, temperature (T), conductivity (SC), resistivity, dissolved oxygen (DO), total dissolved solids (TDS), oxygen reducing potential (ORP) and salinity. The YSI is calibrated daily and re-checked between each sampling location. The YSI probe cable is attached to a small floatation device to ensure the probes never touch the bottom and that the parameters are taken at the depth from which samples will be collected.

Parameter stability is demonstrated when there is no significant change in measured parameters for a duration of five consecutive measurements separated by 3 to 5 minute intervals. For surface water sampling, this time allows the instrument to become temperature equilibrated while submerged just downstream from the designated sample location.

After the YSI has become temperature equilibrated, the parameters have stabilized and the values have been recorded, water sampling may proceed. The sample bottles are cooled to at least the ambient surface water conditions before sampling. The sampling technician will sometimes use grab sample extension devices or integrated sediment samplers and the like when necessary to collect a stream composite and to avoid coming in direct skin contact with the water while sampling at depth. The technician always faces upstream to avoid disturbed sediments while collecting these samples. After the samples are collected the final parameters are recorded to ensure no changes have occurred during the sample collection.

3.0 Results of the Survey

Weather conditions and arduous terrain prolonged the soil gas surveys, but all mines and P&A wells where access was granted were surveyed in extreme detail to avoid missing seeps. The high resolution maps presented in this section attest to the amount of time and energy put into this project.

3.1 Abandoned Coal Mines

Methane seeps are evident at 3 of the 11 mines surveyed.

Golden Eagle Mine

At Golden Eagle, methane seeps cover the eastern 11% of the 1,319 acres surveyed over the mine (Figure 5; Table 1). Seeps in the southern part trend both northeast and northwest and those in the northern part mainly trend west to northwest. In the southeast part of the mine, methane seep concentrations range from just above ambient to 10% (Figure 6). In places, the seeps are leaking from void spaces between boulders or open fractures along outcrops (see photo inset on Figure 6). The edges of concrete carapaces over historic ventilation shafts are extremely leaky (see photo inset on Figure 6). There does not appear to be any spatial correlation of the seeps with historic core holes (Lewicki, 2001). The distinct linear northeast and northwest trend of the seeps could reflect structural control. Areas of stressed vegetation are evident in proximity to seep areas, particularly near gas sample GE-11109-1155 (Figure 6).

Gas composition analysis of 5-foot deep gas samples over 4 of the seep areas reveal indicate a “dry” gas composition composed mainly of methane with trace amounts of C2+ hydrocarbons (Table 1). Samples GE-11109-1601 and 1354 contain considerable ambient air based on high concentrations of oxygen, nitrogen and argon, which is probably the result of sampling in a fractured substrate with ample air ingress.

Samples without obvious ambient air infiltration fall into the biogenic category on a cross-plot of carbon and deuterium isotopes (Figure 7). The more oxidized samples (GE-11109-1601 and 1354) have heavier carbon and deuterium values because of alteration through oxidation, but are still in the biogenic field within the compositional range of Raton coal bed methane (compositional fields from Gorody, 2009).

In the northern part of the mine, very intense seeps (1 to 10%) are evident in proximity to a “hissing” concrete carapace over a historic ventilation shaft (Figure 8). The seeps form a large 1000 x 600 foot cluster that dissipate in size and intensity to the northwest. As for the southern part of the mine, there is no spatial correlation of core holes with seeps (Lewicki, 2001).

Prairie Canon Mine

Methane seeps comprise about 23% of the 50 acres surveyed over the Prairie Canon mine (Figure 9; Table 1). A large (1000 x 500 foot), moderately intense 10 to 1000 ppm seep occurs over the southwestern part of the Prairie Canon mine and it becomes more intense along a creek valley southwest of the mine (Figure 9). Smaller seeps are found to the north and east of the large seep. The strong northwest trend to the seeps, particularly along the creek valley to the southwest of the mine implies a structural control to the seeps. Possible mine shaft remnants are evident to the east and northeast of the large seep, but seeps were not detected at these features.

A soil gas sample collected at the southwest edge of the mine is compositionally similar to the dry gas in the Golden Eagle samples (Figure 9; Table 2). On the carbon-deuterium cross-plot the sample falls in the thermogenic field straddling both the Raton and Vermejo CBM field (Figure 7), but considering the high oxygen concentration in this samples (11% on Table 2), the heavier isotopic values probably reflect oxidation effects, and the original isotopic composition of this sample may be more biogenic.

Quinto Mine

Two weak to moderate methane seeps are associated with a spring site over the Quinto mine (Figures 10 and 11). Hydrocarbon analysis of surface discharge from the spring reveals only trace amounts of methane and no C2+ hydrocarbons suggesting a near-surface microbial origin.

Other Mines Surveyed

Portions or all of 8 other mines were surveyed where landowner access was granted, but ground surface methane seeps were not detected on any of the traverses (Figures 12 to 15). Historic mining infrastructure (e.g. shafts) was not found over these mines.

3.2 Plugged and Abandoned Wells

Methane was only detected at 1 of the 5 P&A well sites in the survey. Methane concentrations near the Black Rabbit well range from 10 ppm to 10%, but these are associated with a leaky gas line and heater in a shed that was built over the well and not the P&A'd well itself (Figure 16). Tight-spaced traverses over and around the P&A'd Polly, McDonald, and Maverick wells did not reveal any methane seeps (Figures 17 to 19).

4.0 Conclusions

The following conclusions are drawn from soil gas surveys over abandoned coal mines and P&A wells within the buffer zones of Pioneer's proposed CBM wells:

(1) Methane seeps are were found over 11% of the 1,319 acres surveyed at Golden Eagle Mine, 23% of the 50 acres surveyed at Prairie Canon Mine, and isolated sites over the Quinto mine (Figures 5, 9 and 10; Table 1).

(2) Some of the seeps are spatially associated with void spaces between boulders in local talus slopes and also along open-spaced fractures in

outcrops (Figure 6). There is a definite spatial correlation of historic mine shafts with methane seeps, particularly over the eastern part of Golden Eagle (Figure 6).

(3) The dry gas released from seeps is biogenic in origin and compositionally similar to Raton CBM based on isotopic evidence, even though some samples show oxidation to heavier isotopic values (Figure 7).

(4) Methane detected at the Black Rabbit P&A well is related to leaking surface infrastructure rather than the well itself (Figure 16).

(5) This soil gas survey meets the requirements of the COGCC Rule 608 in that:

(i) The survey was carried out on accessible parts of abandoned coal mines and P&A wells within the buffer zones of Pioneer's proposed CBM wells,

(ii) The areal extents of gas seeps and springs were mapped,

(iii) Gas seep composition was documented through sampling and analysis, and

(iv) The results are being reported within 3 months of completion of the field work.

References

Gorody, A. W. 2009. Review and analysis of hydrogeologic data, Thomas J. Churan water well. Internal Report for Pioneer Natural Resources, USA Inc. pp. 1-8.

Lewicki, G. 2001. Raton Basin Coalmine Feature Inventory. COGCC internal report (*http://cogcc.state.co.us/*). pp. 1-42.

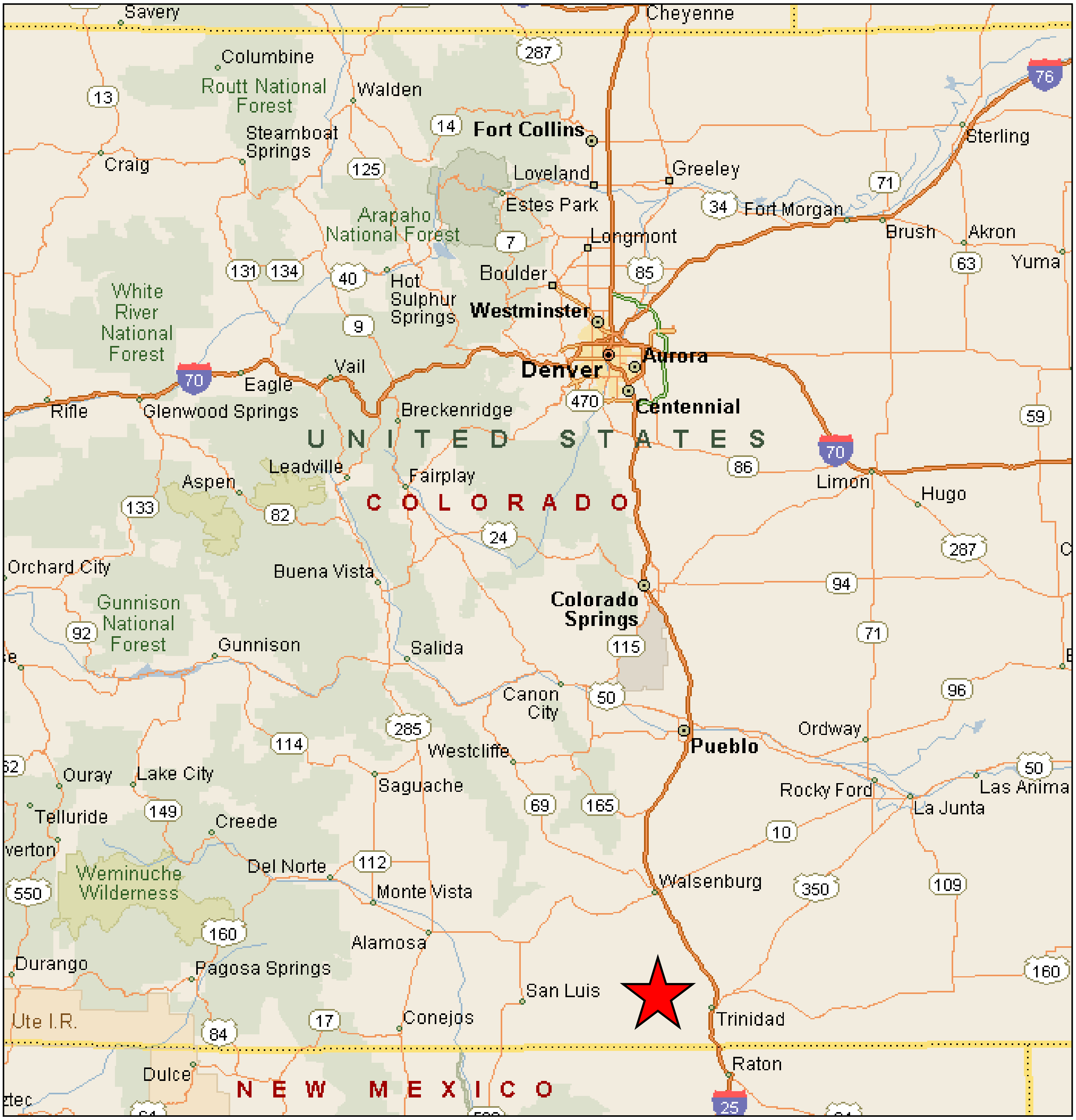


Figure 1. Location of the Rule 608 soil gas survey in Las Animas County, Colorado.

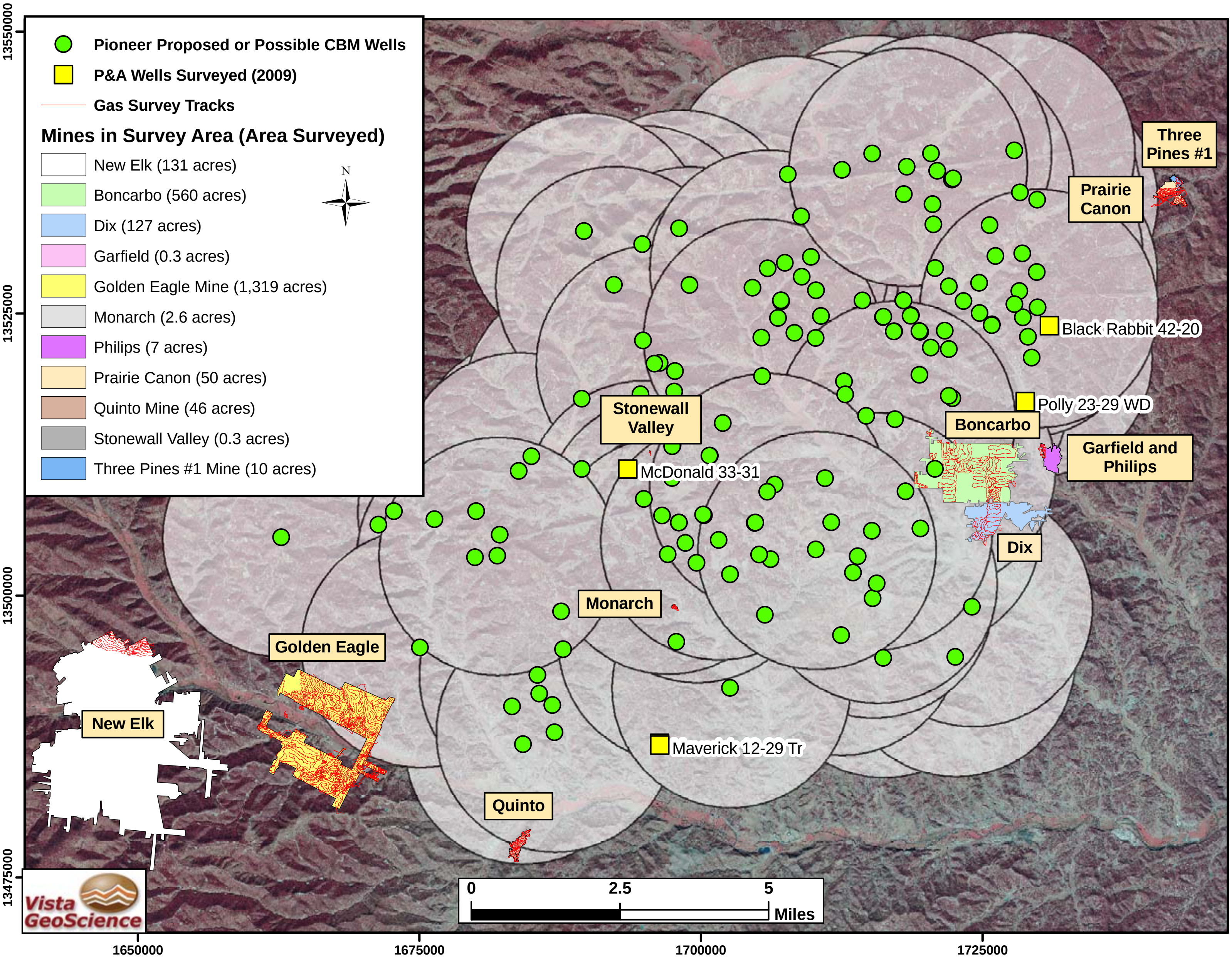


Figure 2. Coal mines within the 2-mile buffer of proposed or possible CBM wells and P&A wells within ¼ mile of the wells. The New Elk mine is in a 2-mile buffer of new CBM wells proposed by Pioneer in mid-2010.

Figure 3. Soil gas mapping with a Foxborough TVA 1000B FID/PID instrument and a Trimble Geo-XH GPS with sub-foot accuracy.

Figure 4. Soil gas sampling at site GE-11109-1237 over the Golden Eagle mine. The 1-inch steel probe was forced 5 feet into the ground with a slide hammer and ¼-inch Teflon tubing was then inserted into the rod and secured in a “Post-Run Tubing System”. Gas within the tubing was purged and then a soil gas sample was drawn into a metal-lined Tedlar bag for transport to the laboratory.

Table 1. Summary of gas seeps mapped over abandoned coal mines and number of acres and linear miles surveyed over each mine.

Coalmine	Mine area (acres)	Area surveyed (acres)	Gas seep area (acres)	%Percent of surveyed area covered by gas seeps	Gas survey tracks (miles)
Golden Eagle	1366.0	1319.2	144.6	11.0	131.6
Boncarbo	933.4	560.0	0.0	0.0	32.4
Dix	322.2	127.0	0.0	0.0	6.9
New Elk	4113.0	130.6	0.0	0.0	12.6
Philips	71.3	7.2	0.0	0.0	2.9
Prairie Canon	64.7	50.2	11.8	23.5	13.2
Quinto	45.7	45.7	0.0	0.0	7.2
Three Pines	23.2	23.2	0.0	0.0	4.1
Monarch	2.6	2.6	0.0	0.0	1.2
Garfield	0.3	0.3	0.0	0.0	0.2
Stonewall	0.3	0.3	0.0	0.0	0.3
				Total survey tracks over coal mines	212.6

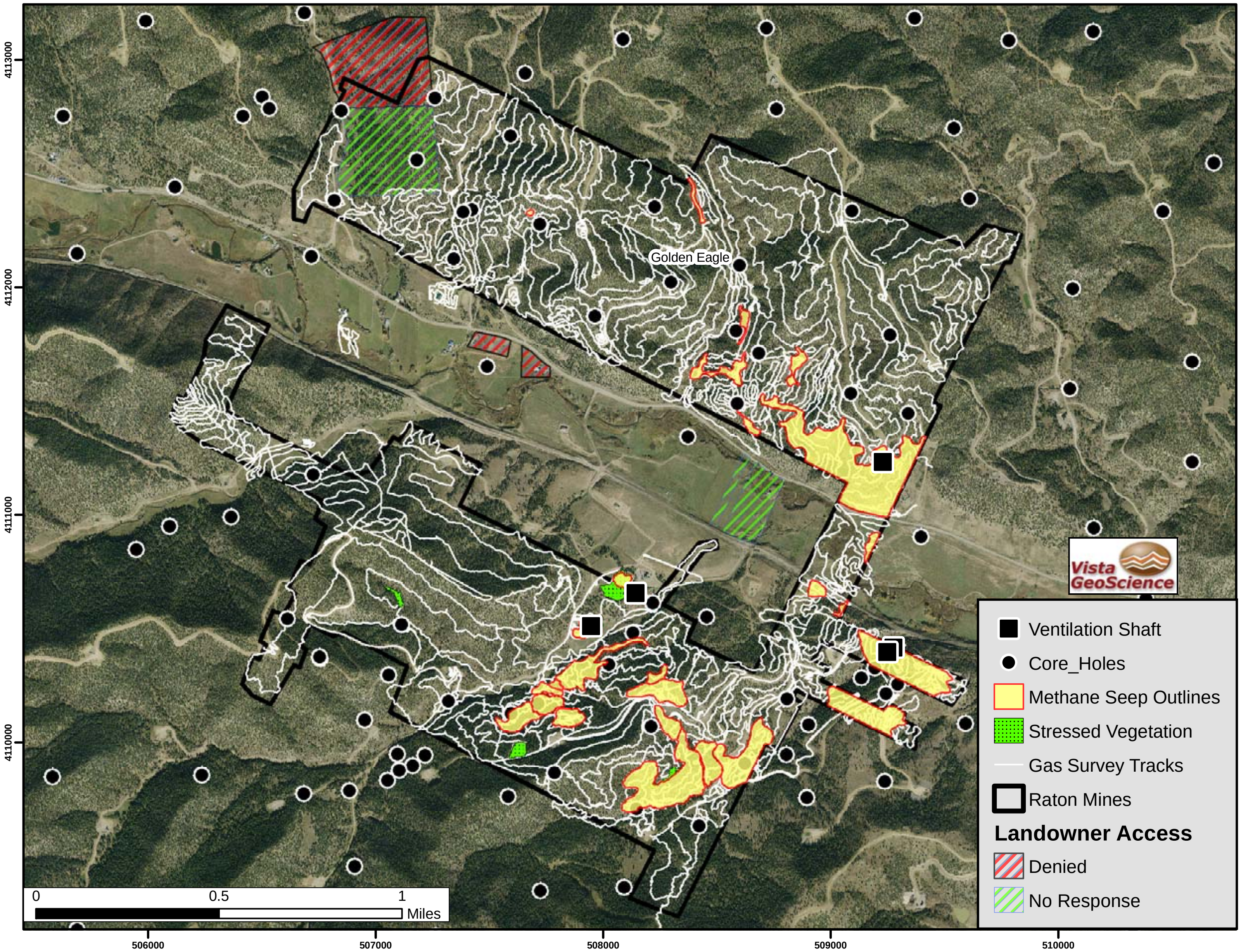


Figure 5. Distribution of gas survey tracks and mapped seep extents over the Golden Eagle mine.

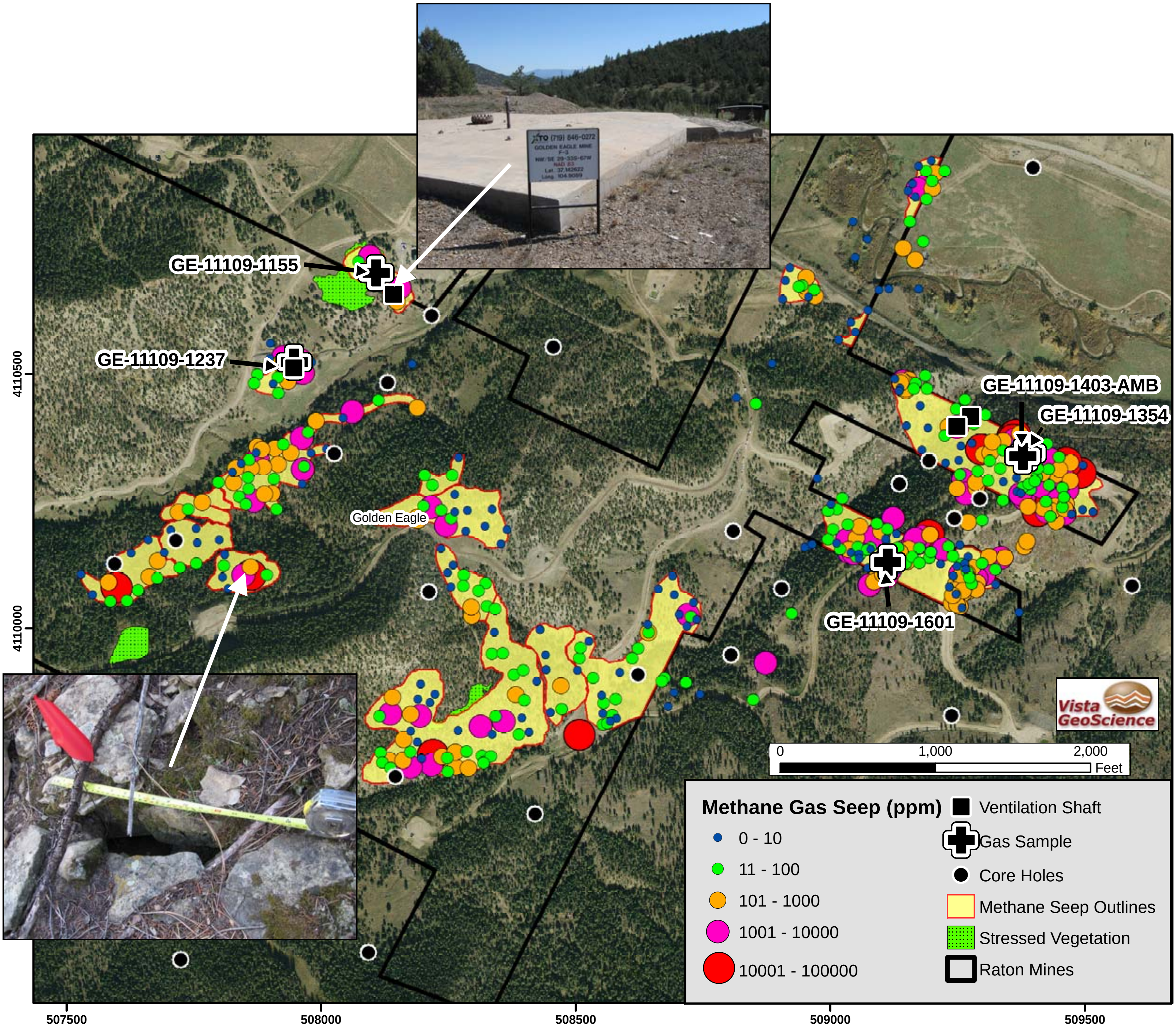


Figure 6. Distribution of methane seep concentrations over the southeast part of the Golden Eagle mine. Some of the seeps are spatially associated with fracture voids in outcrops and with the concrete carapaces over former ventilation shafts. The seeps have a distinct northeast trend.

***Table 2.** Gas composition data for 5-foot deep soil gas samples collected over the Golden Eagle and Prairie Canon mines.

Sample Number	$\delta^{13}C_1$ (‰)	δDC_1 (‰)	Methane %	Ethane %	Ethene %	Propane %	Propene %	iButane %	nButane %	iPentane %	nPentane %
GE-111209-1237	-60.8	-262.3	97.4585	0.0207	ND	ND	ND	ND	ND	ND	ND
GE-111209-1155	-66.1	-268.5	97.0413	0.0267	ND	0.0009	ND	0.0016	0.0001	0.0002	0.0000
GE-111209-1354	-56.8	-248.8	53.4926	0.0065	0.0000	0.0000	0.0000	ND	ND	ND	ND
PC-111109-1504	-49.7	-245.2	46.5393	0.0046	ND	0.0000	ND	ND	ND	ND	ND
PC-111109-1504-LD	NA	NA	46.4196	0.0044	ND	0.0000	ND	ND	ND	ND	ND
GE-111209-1601-LD	NA	NA	4.8798	0.0001	ND	ND	ND	ND	ND	ND	ND
GE-111209-1601	-54.5	-237.6	4.7210	0.0001	ND	ND	ND	ND	ND	ND	ND
PC-111109-1510-AMB	NA	NA	0.0117	0.0000	ND	ND	ND	ND	ND	ND	ND
GE-111209-1403-AMB	NA	NA	0.0025	ND	ND	ND	ND	ND	ND	ND	ND

Sample Number	iHexane %	nHexane %	CO2 %/v	Argon %	Oxygen %/v	Nitrogen %/v	Helium %	Hydrogen %	Neon %	CO %	Total
GE-111209-1237	ND	ND	0.3771	ND	ND	2.1	0.0008	0.0010	ND	ND	100
GE-111209-1155	0.0000	0.0000	0.4676	ND	ND	2.5	0.0010	0.0004	ND	ND	100
GE-111209-1354	ND	ND	1.2621	0.4069	6.5	38.3	0.0005	0.0010	ND	ND	100
PC-111109-1504	ND	ND	0.1825	0.47	11.1	41.7	0.0003	0.0005	0.0008	ND	100
PC-111109-1504-LD	ND	ND	0.1819	0.4864	11.1	41.8	0.0005	0.0005	0.0009	ND	100
GE-111209-1601-LD	ND	ND	0.2850	0.89	19.7	74.3	0.0004	0.0001	0.0018	ND	100
GE-111209-1601	ND	ND	0.2855	0.88	19.7	74.4	0.0005	0.0001	0.0018	ND	100
PC-111109-1510-AMB	ND	ND	0.0414	0.9242	21.0	78.0	0.0005	0.0001	0.0018	ND	100
GE-111209-1403-AMB	ND	ND	0.0443	0.93	21.1	78.0	0.0005	0.0001	0.0018	ND	100

*C1-C6 hydrocarbons and fixed gases analyzed at Vista Geoscience (Golden, CO)
Carbon and deuterium isotopes analyzed at IsoTech Laboratories (Champaign, IL)

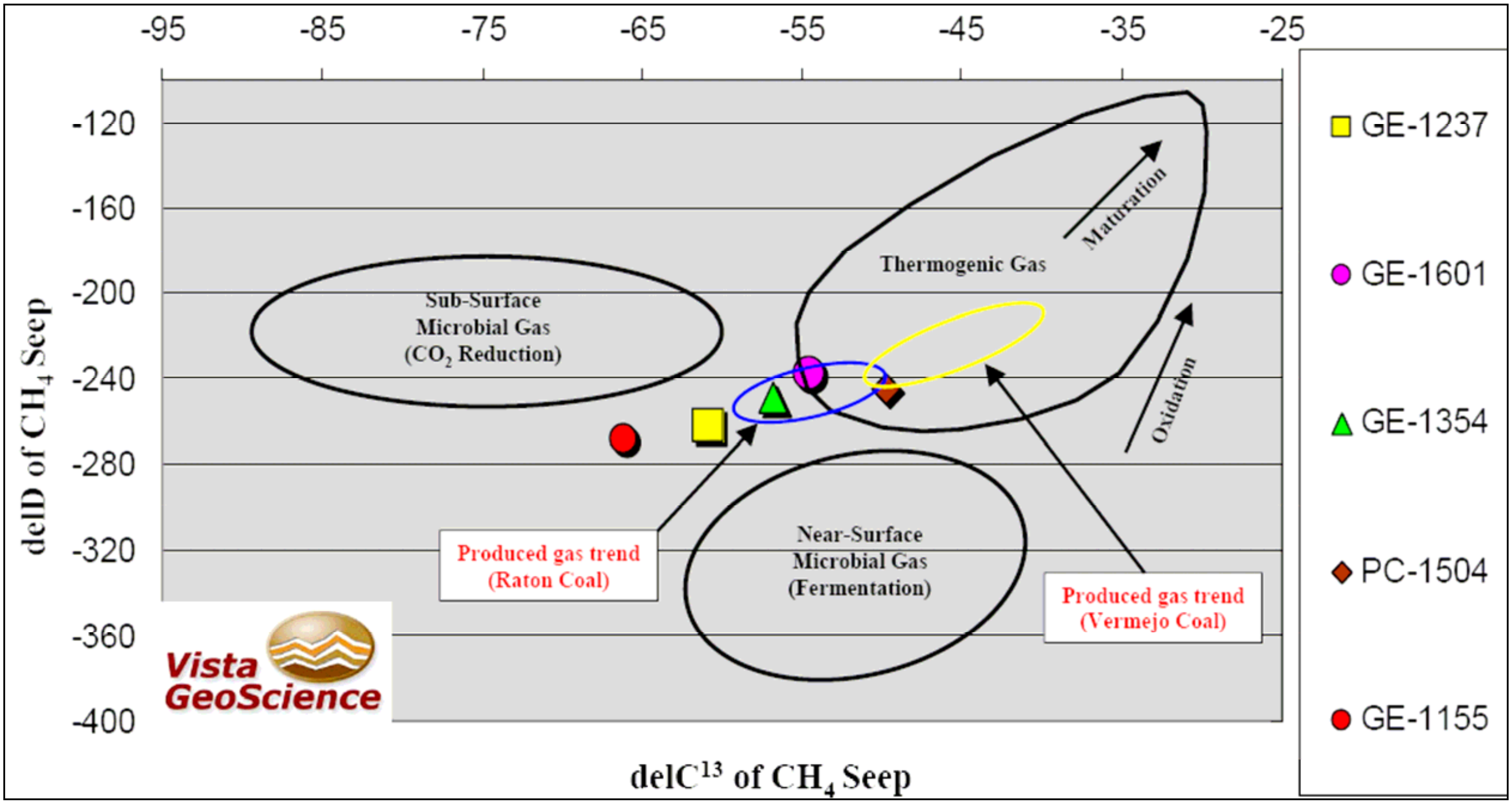


Figure 7. Deuterium-carbon isotope cross-plot showing fields for biogenic and thermogenic derived methane. Soil gas samples from the Golden Eagle mine plot within or close to the Raton CBM field. Sample GE-1601 has heavier carbon and deuterium isotopes because of the oxidation effect (see oxygen concentration of GE-1601 in Table 2). Sample PC-1504 has also contains considerable oxygen (see Table 2).

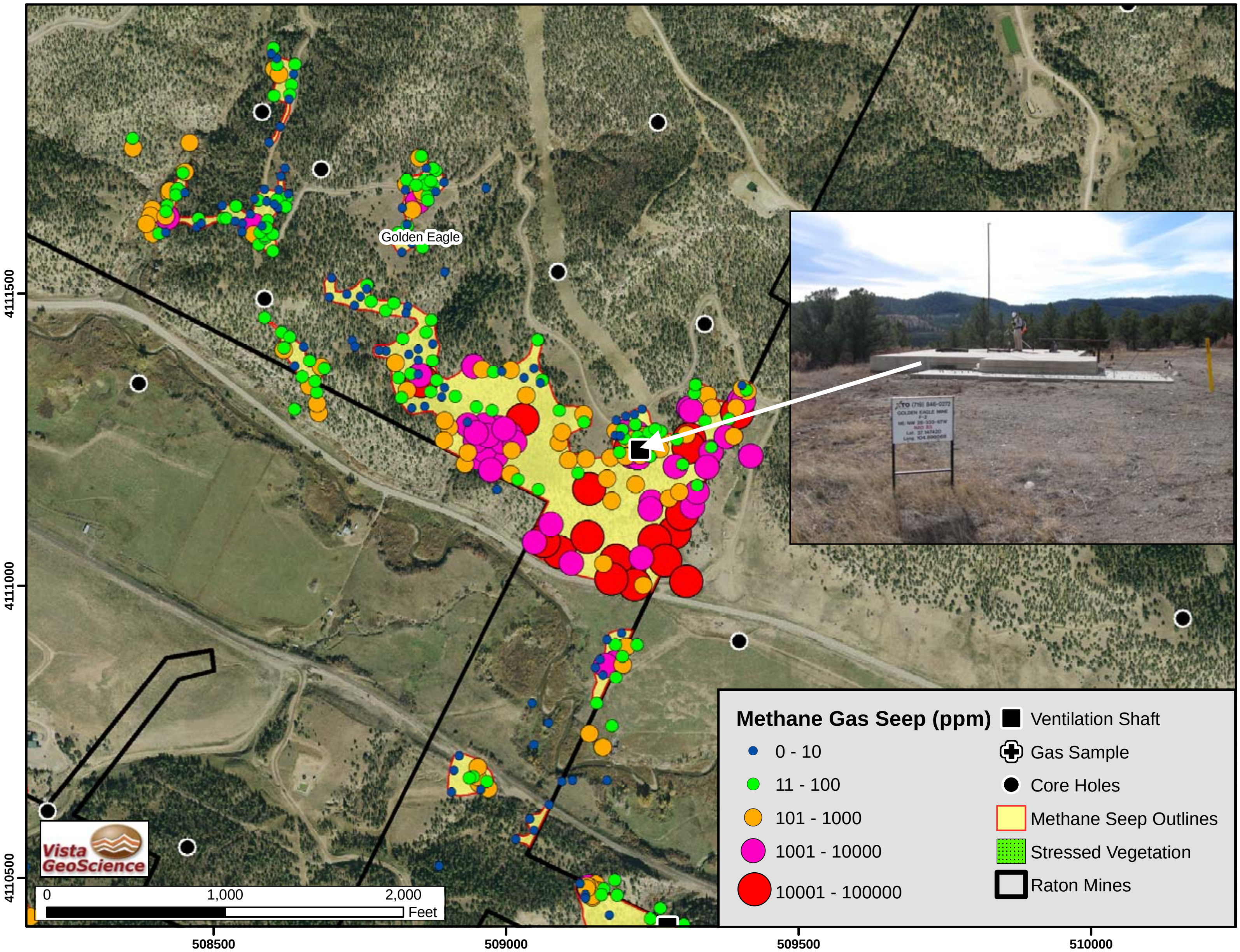


Figure 8. Distribution of methane seep concentrations over the northeast part of the Golden Eagle mine. Some of the seeps are spatially associated concrete carapaces over former ventilation shafts.

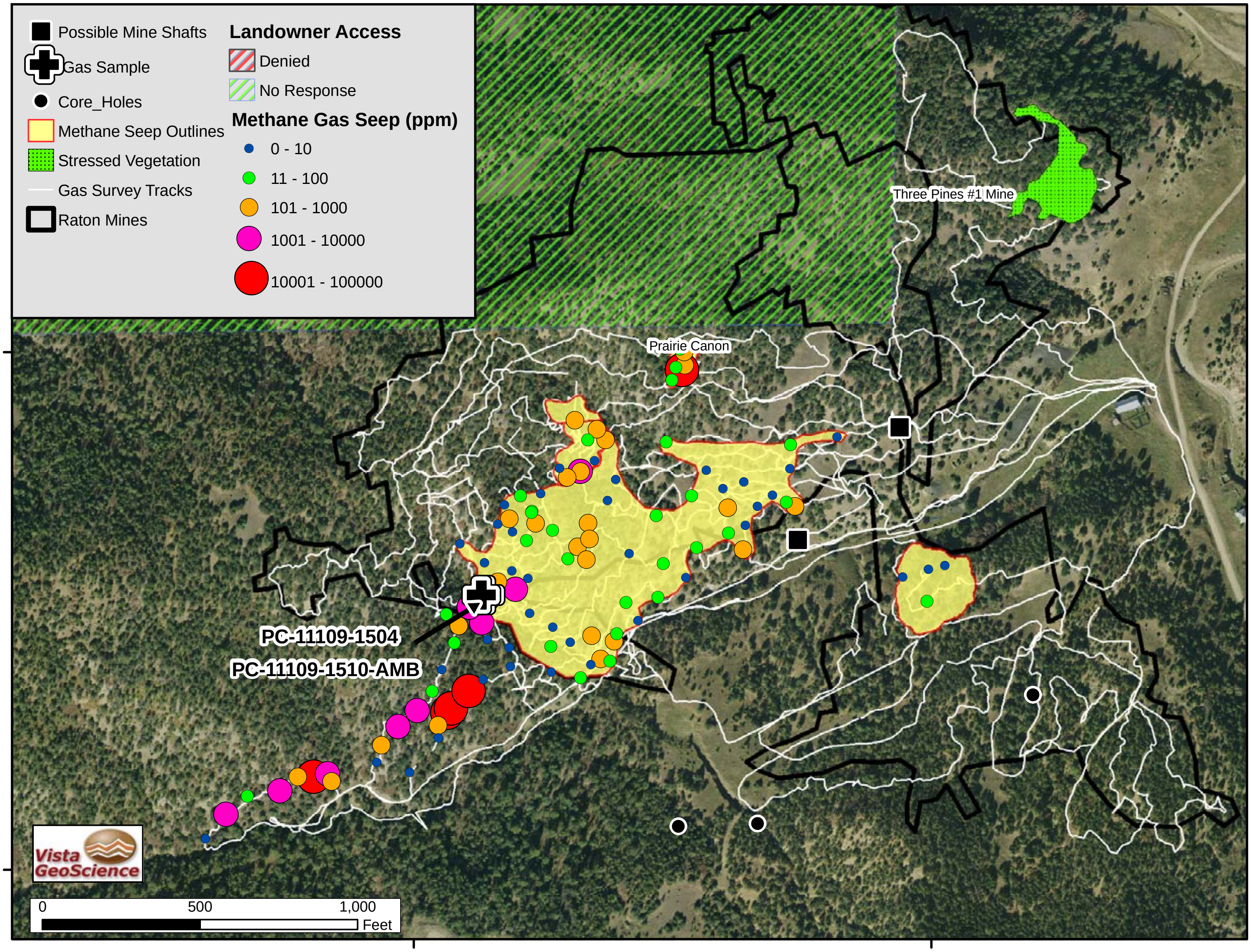


Figure 9. Distribution of methane seep concentrations over the southwest part of the Prairie Canon mine. The seeps extend southwest of the mine along a creek valley.

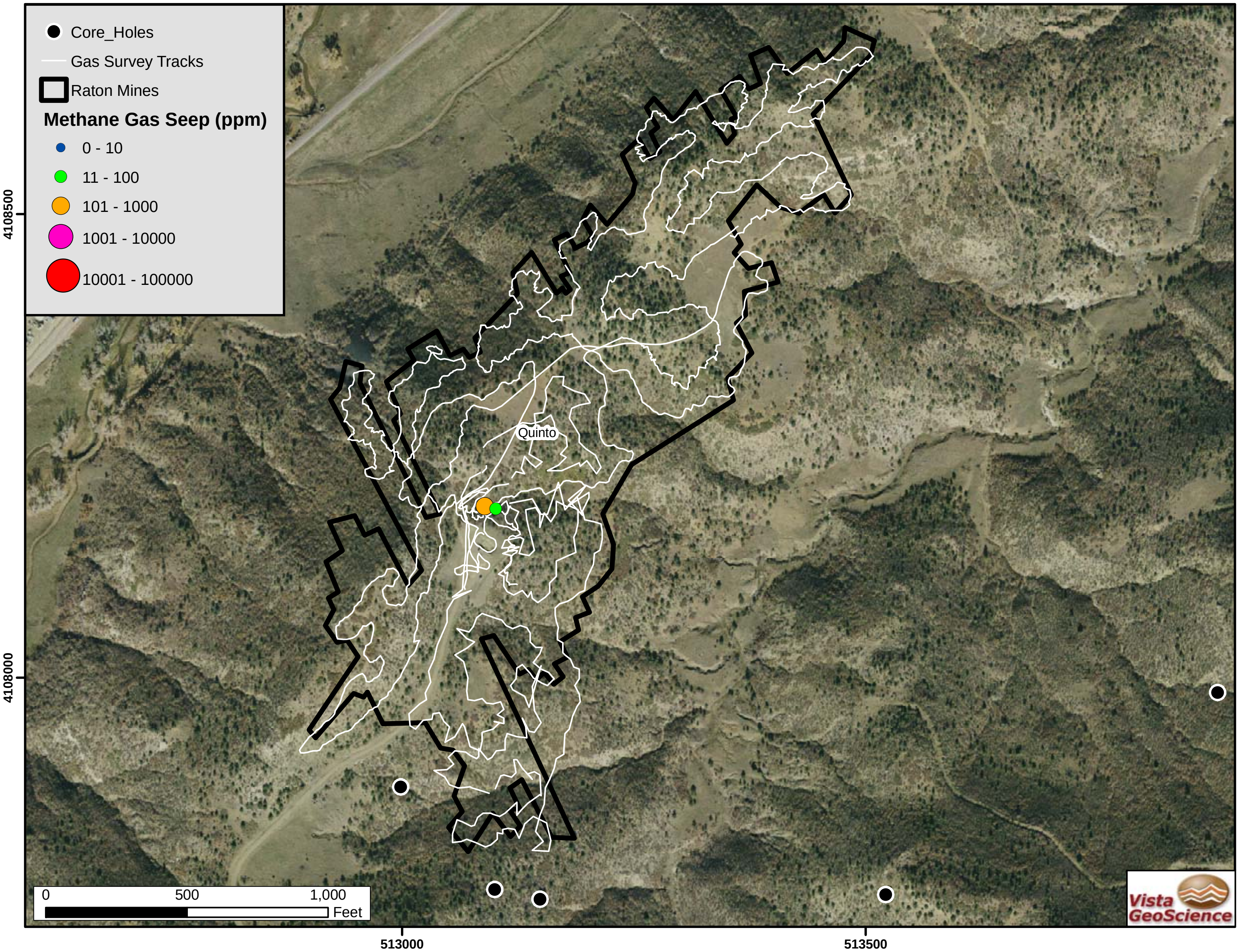
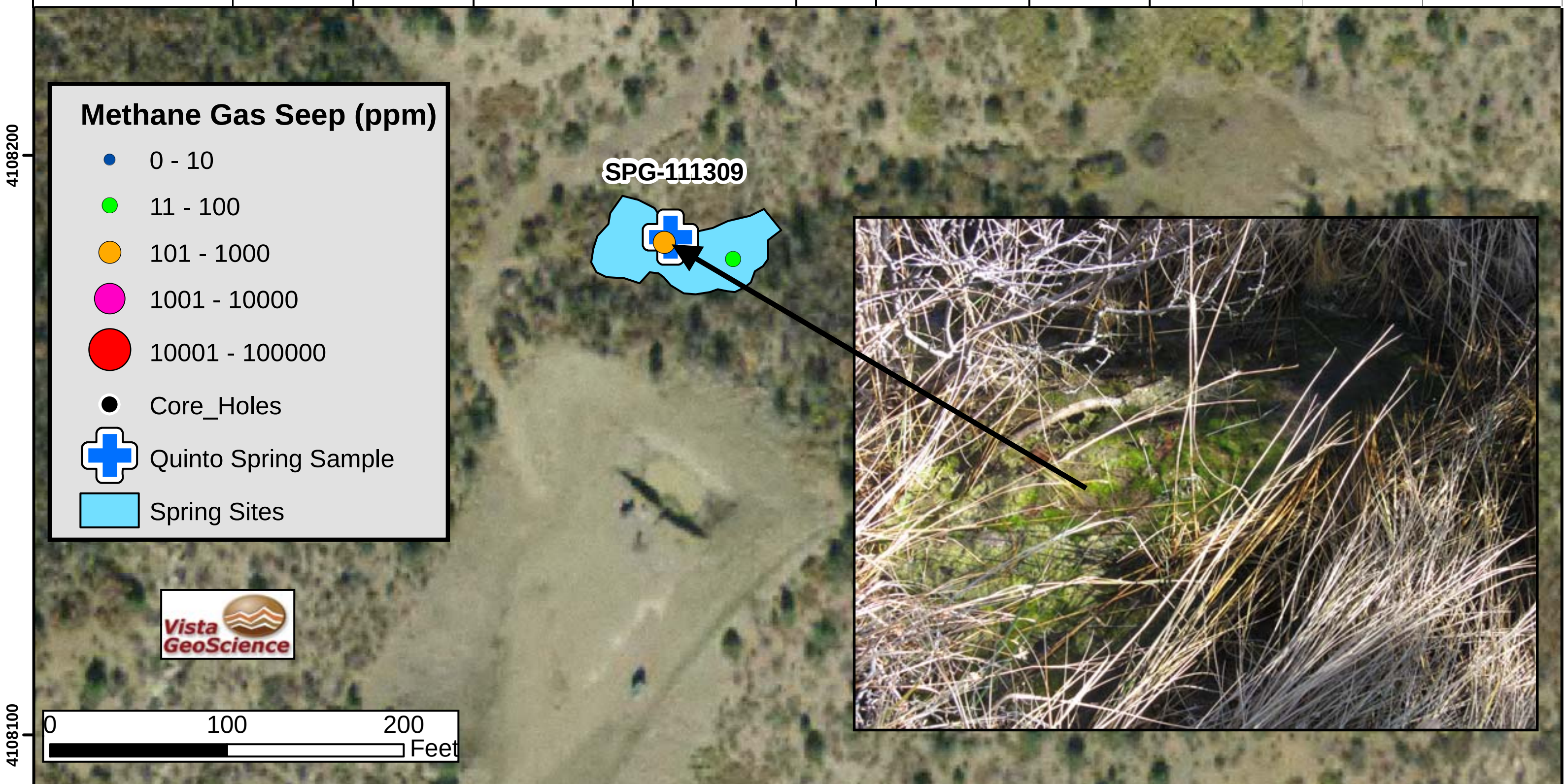


Figure 10. Distribution of methane seep concentrations over the Quinto mine. Minor seeps were detected near a spring.

Sample_ID	Color	Width_ft	Discharge (ft^3/hour)	Temperature (^oC)	pH	Conductivity (mS/cm)	Total Dissolved Solids (g/L)	Salinity (ppt)	Dissolved Oxygen (mg/L)	Oxidation-Reduction Potential (mV)
Spring (Quinto-SPG-111309)	Light brownish grey	0.5	0.024	7.820	8.97	2.155	2.086	1.68	8.25	141.4



Dissolved C1-C6 Hydrocarbons (ug/Liter) Parts-per-Billion by Weight in water - Spring Sample															
Sample ID	Sample Date	Analysis Date	**Methane**	**Ethane**	**Ethylene**	**Propane**	**Propene**	**iButane**	**nButane**	**Butene**	**iPentane**	**nPentane**	**Pentene**	**iHexane**	**nHexane**
Quinto-SPG-11309	11/13/09	11/16/09	1.600	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Quinto-SPG-11309LD	11/13/09	11/16/09	1.570	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

513000 513100 513200

Figure 11. An alkaline, low salinity, patchy spring was sampled for hydrocarbon analysis.

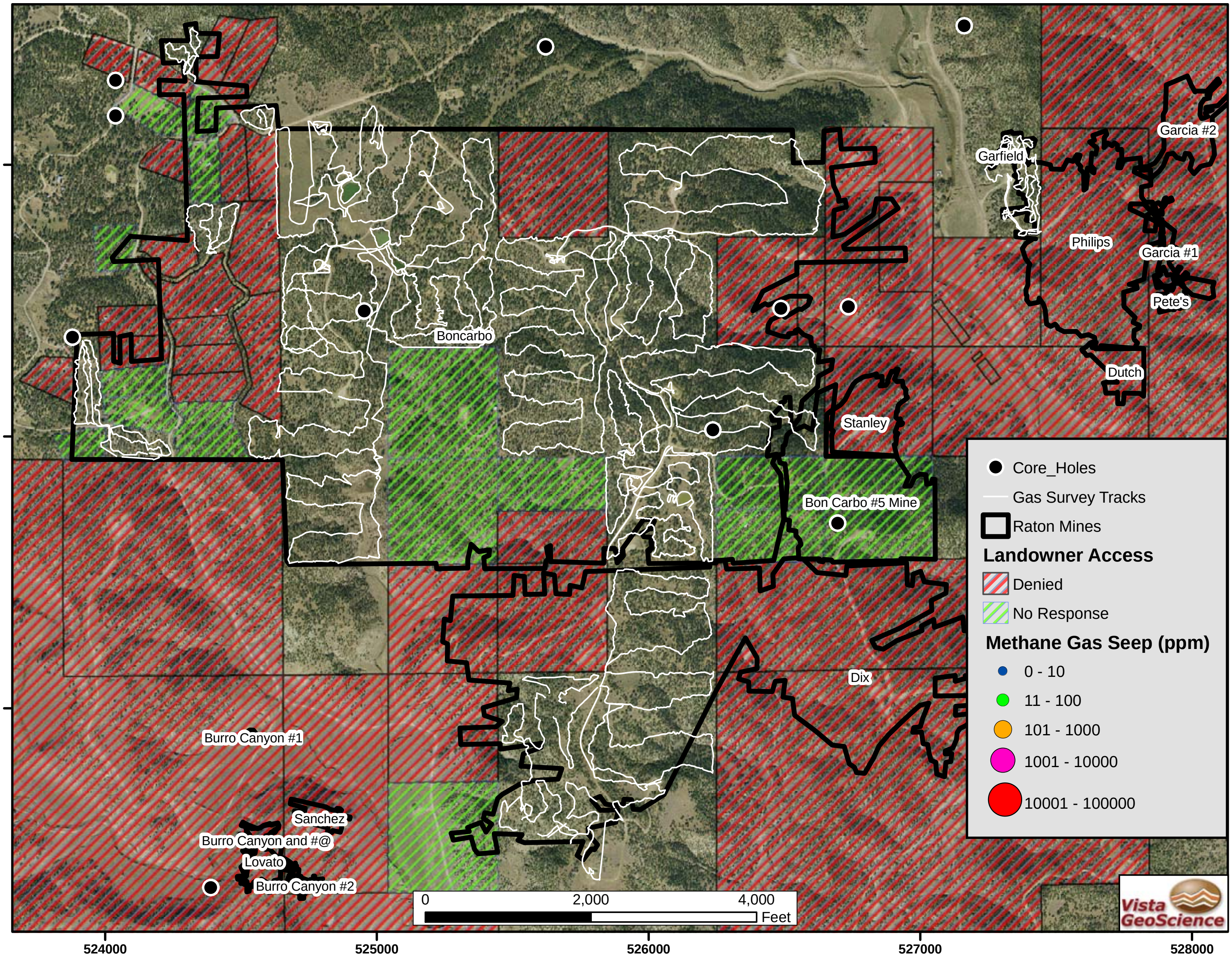


Figure 12. Distribution of gas survey tracks over accessible parts of the Boncarbo, Dix, Philips and Garfield mines. Ground surface methane seeps were not detected over the 42 mile-long tracks.

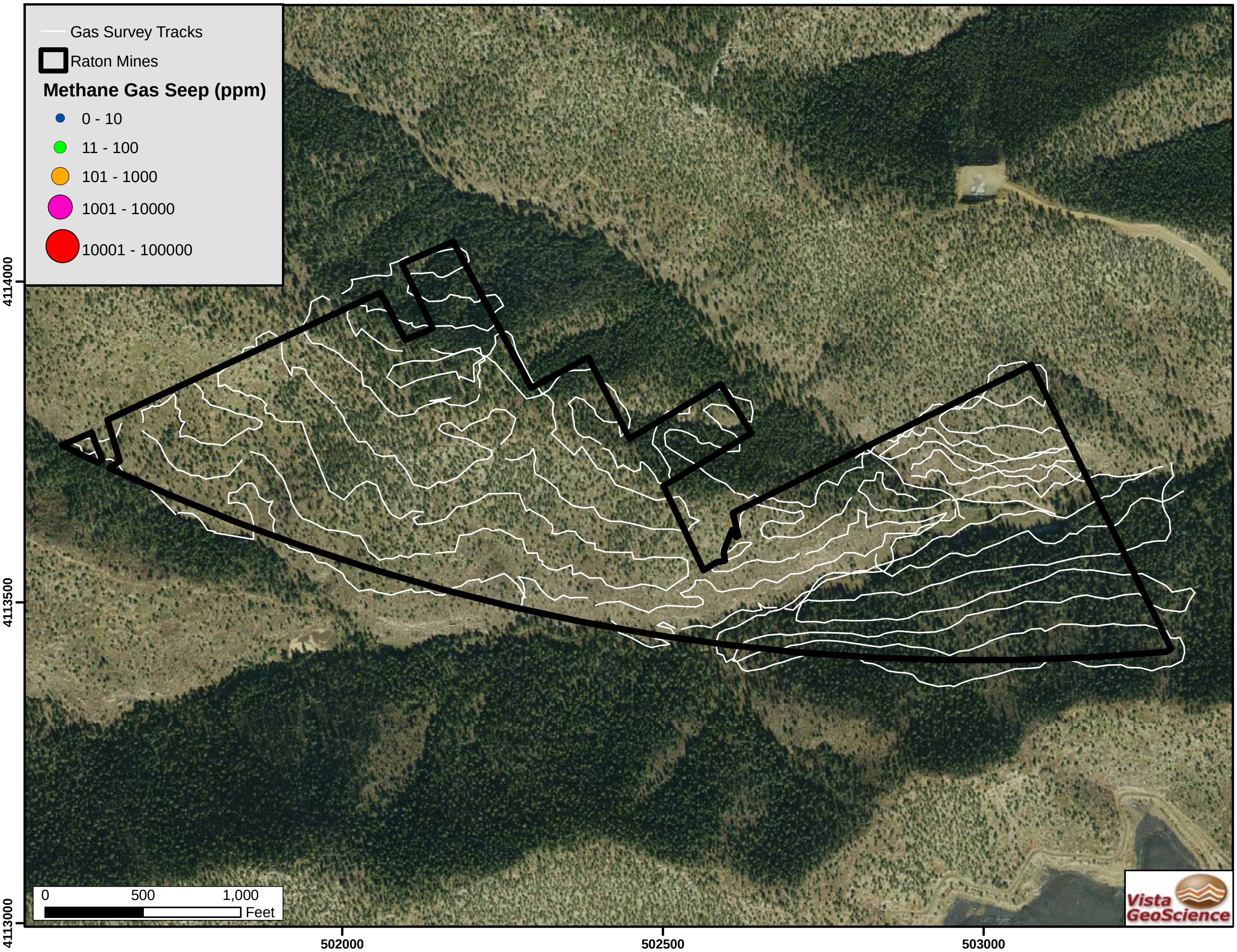


Figure 13. Distribution of gas survey tracks over the northern part of New Elk mine. Ground surface methane seeps were not detected over the 12.6 mile-long tracks.

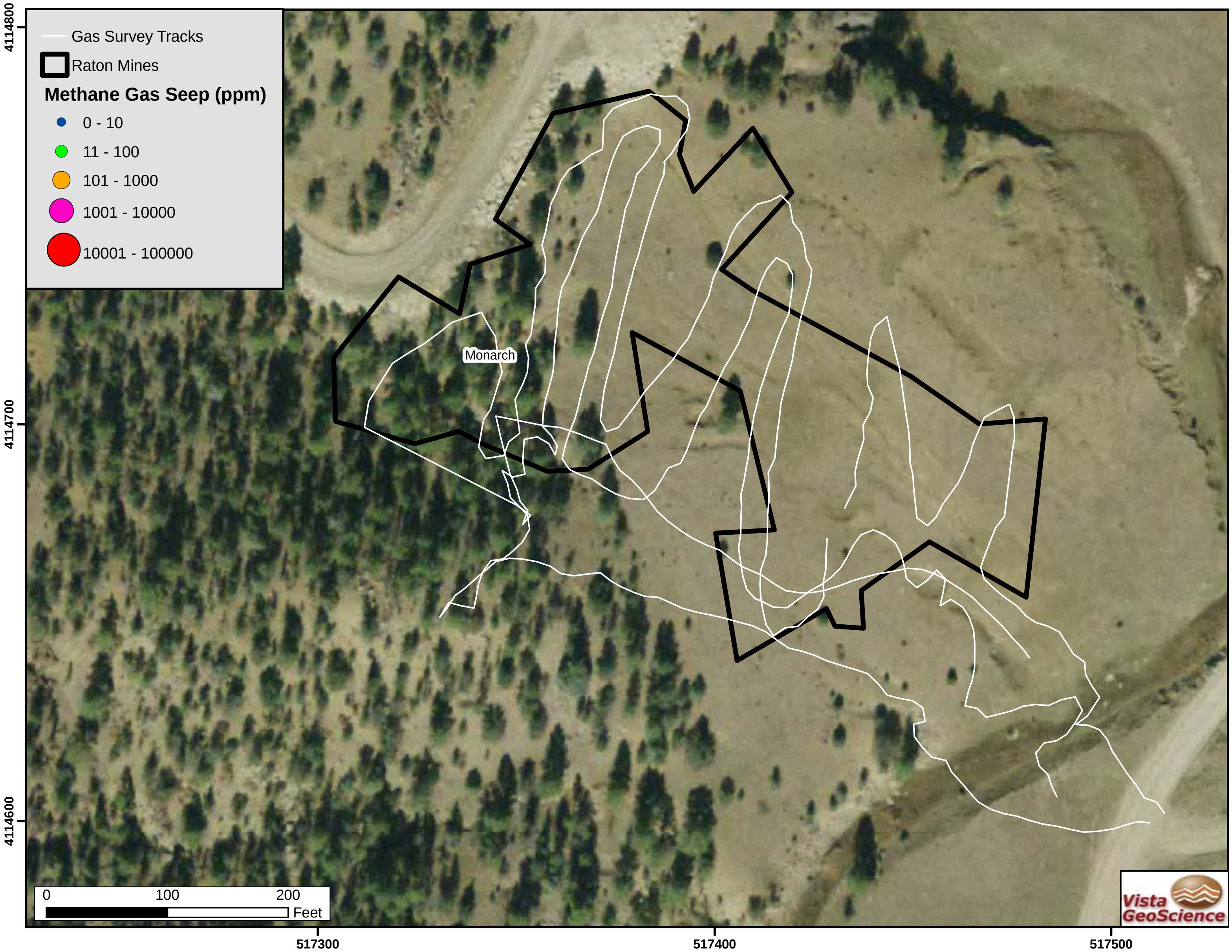


Figure 14. Distribution of gas survey tracks over the Monarch mine. Ground surface methane seeps were not detected over the 1.2 mile-long tracks.

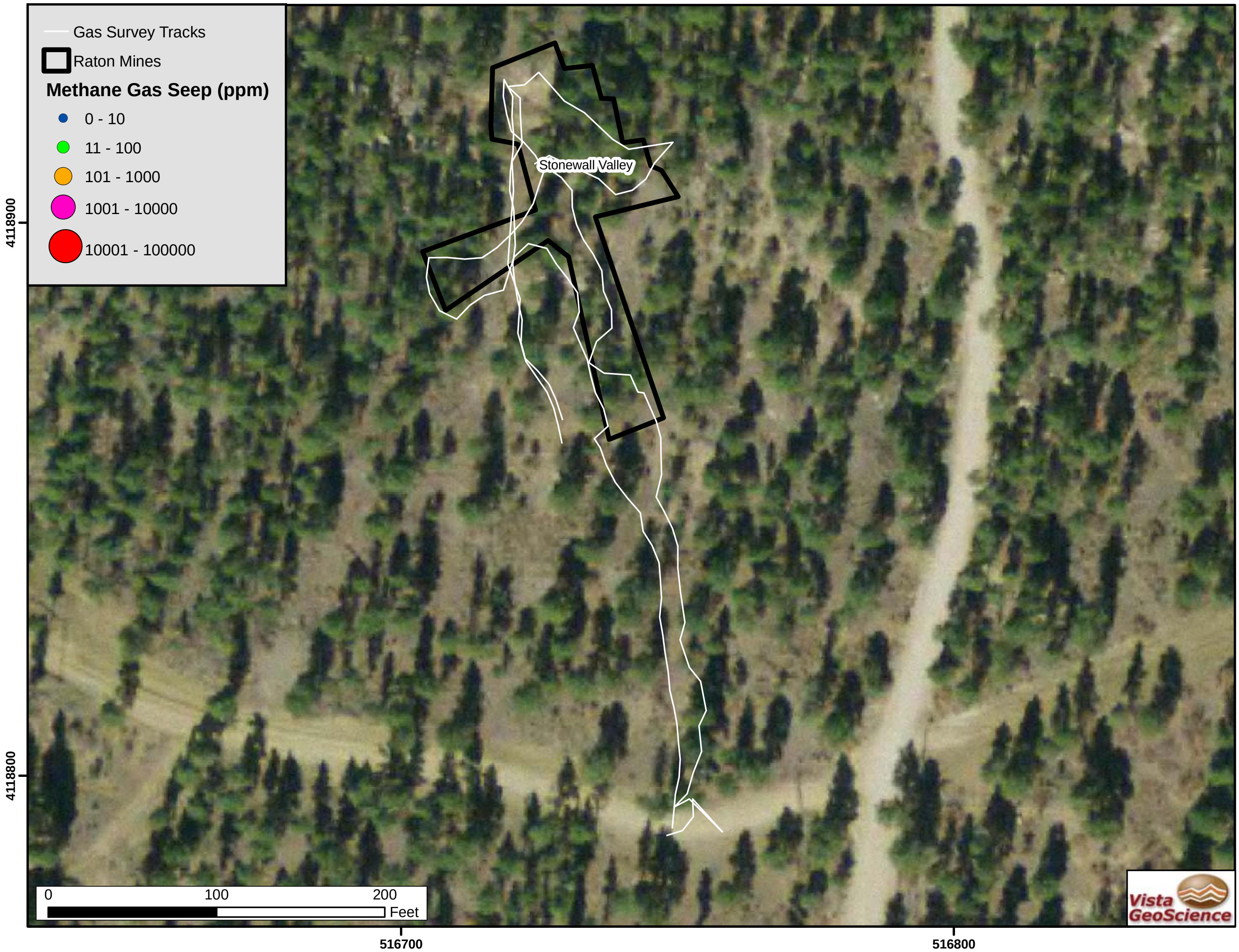


Figure 15. Distribution of gas survey tracks over the Stonewall mine. Ground surface methane seeps were not detected over the 0.3 mile-long tracks.

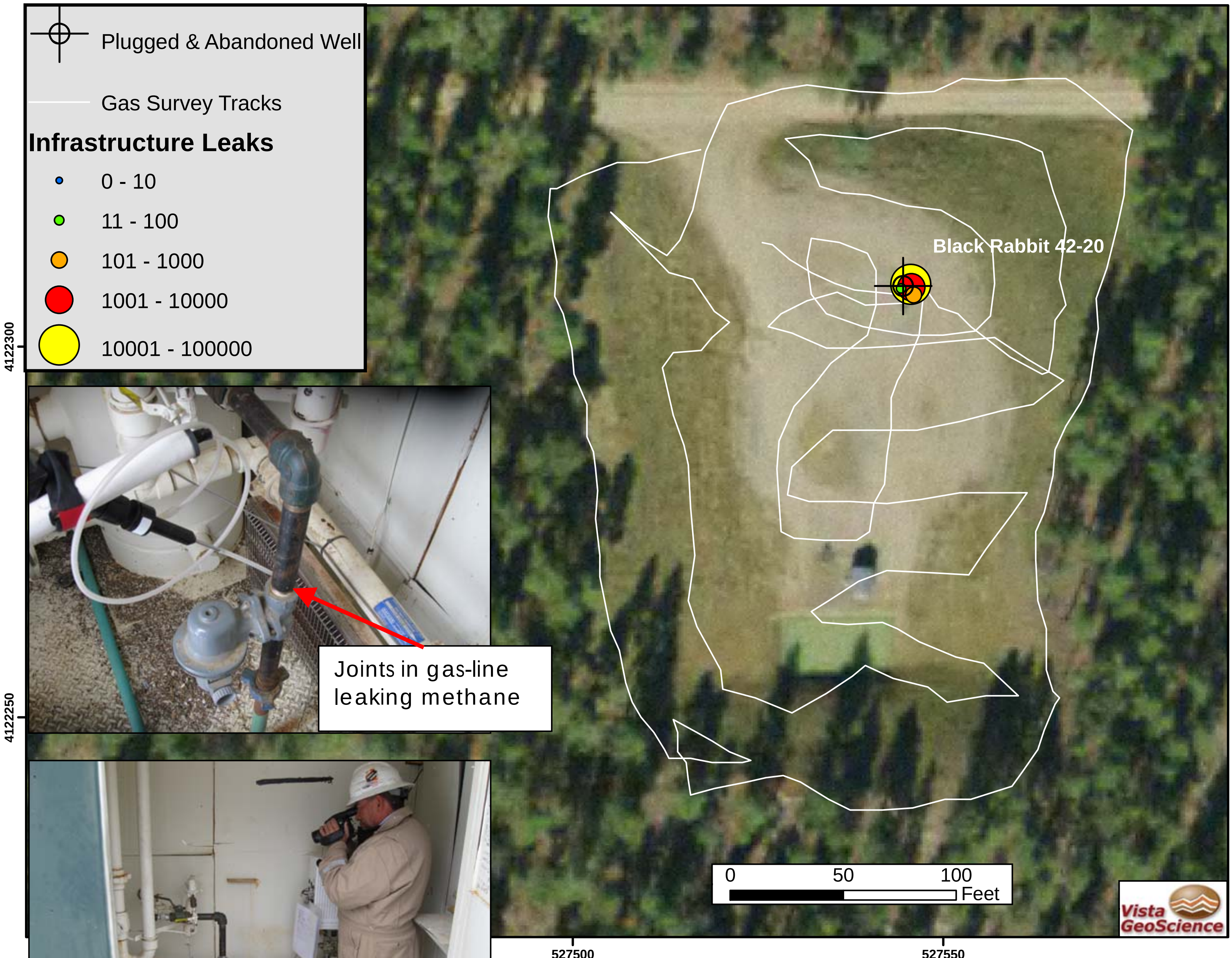


Figure 16. Distribution of methane concentrations over and around the Black Rabbit plugged & abandoned well. A shed that was built over the P&A well contains infrastructure that is leaking methane.

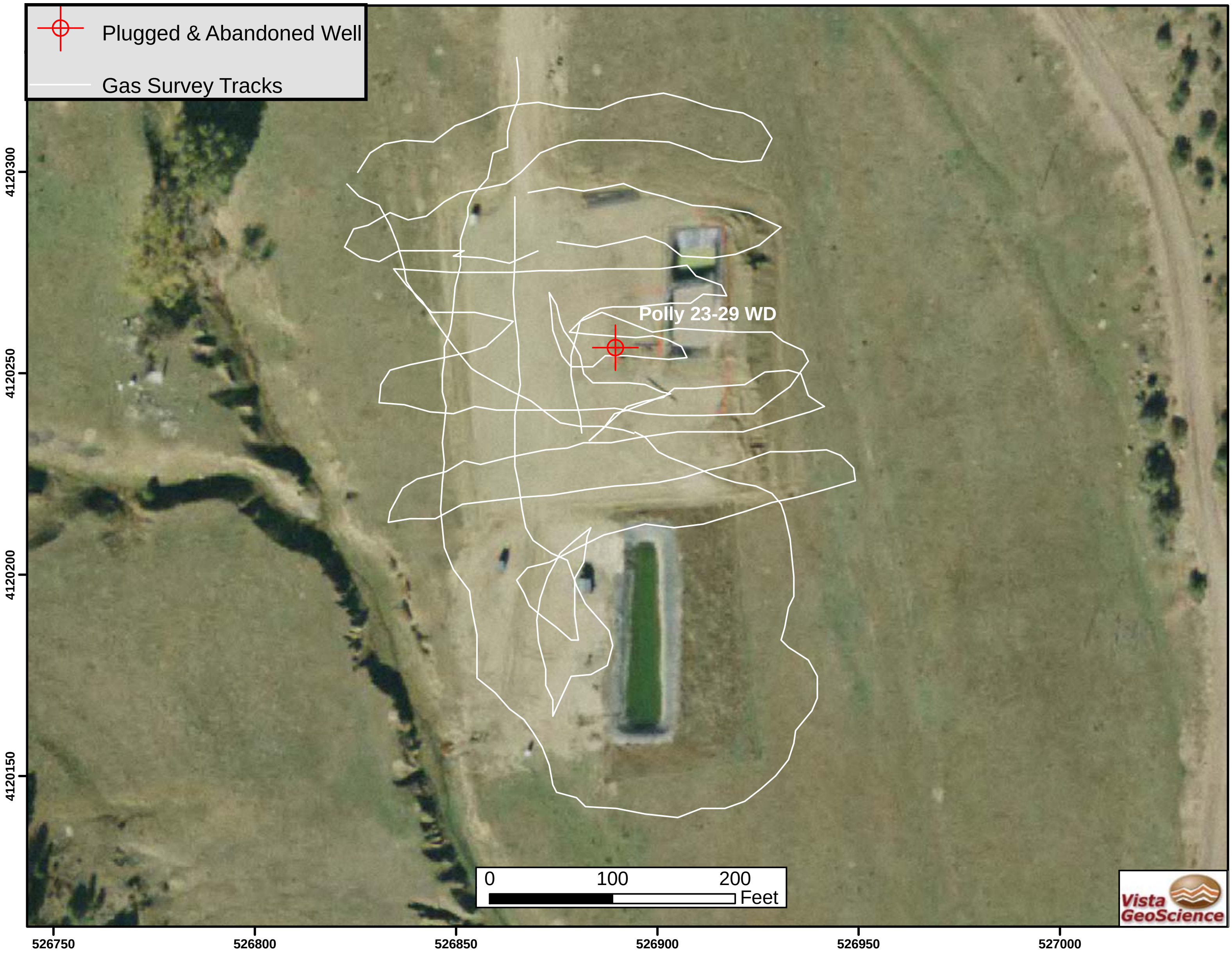


Figure 17. Distribution of gas survey tracks over and around the Polly plugged & abandoned well. Ground surface methane seeps were not detected over the 1.3 mile-long tracks.

Figure 18. Distribution of gas survey tracks over and around the McDonald plugged & abandoned well. Ground surface methane seeps were not detected over the 1 mile-long track.

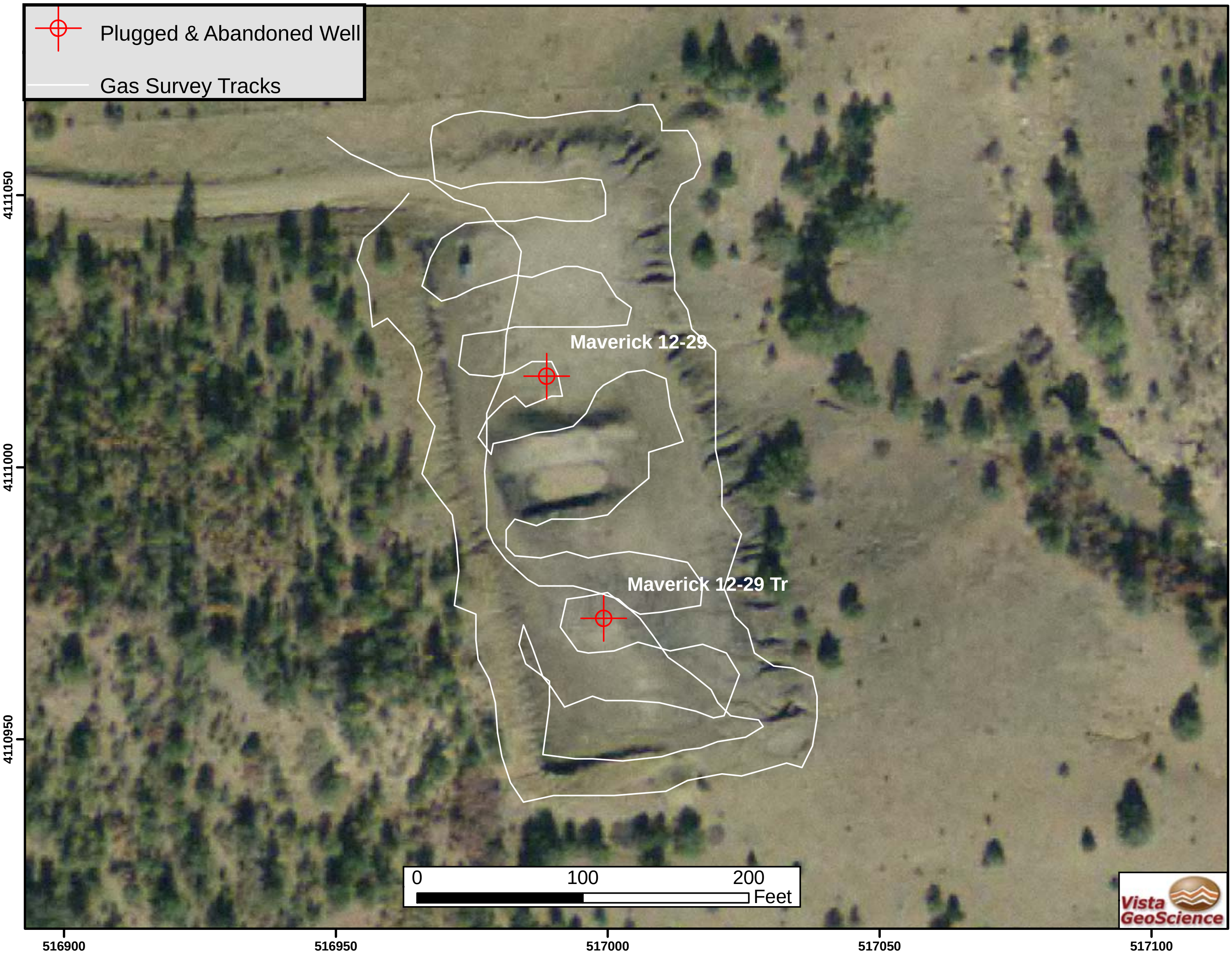


Figure 19. Distribution of gas survey tracks over and around the Maverick plugged & abandoned wells. Ground surface methane seeps were not detected over the 0.7 mile-long tracks.