Integration of Remotely-Sensed Geobotanical and Structural Methods for Hydrocarbon Exploration in West-Central West Virginia

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U.S. Department of Energy
Office of Fossil Energy
Federal Energy Technology Center
Morgantown Site
P.O. Box 880
Morgantown, West Virginia 26507-0880

MASTER

By
West Virginia University
Department of Geology and Geography
P.O. Box 6300
Morgantown, West Virginia 26506-6300

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1. Soil Gas Survey

A reconnaissance soil gas geochemical survey was carried out at the Volcano test site on 5/21/96 and 6/17/96. In addition, a smaller survey was carried out at the Lewis County (Stonewall Jackson Lake) test site on 7/1/96. A total of 32 samples were collected (25 and 7 from Volcano and Stonewall Jackson sites, respectively). Although this is a rather small sample collection, their distribution provides an excellent overview of the soil gas geochemistry of the Volcano test site. The Stonewall Jackson survey will be supplemented by a second reconnaissance survey in October, when the pressures will be higher in the reservoir.

The soil gas samples were collected with a 4 foot soil gas probe, which was inserted into a hole made with a slide hammer plunger bar. The sample bottle was evacuated to a pressure of 25 psi, and then allowed to draw vapor from the gas probe. After filling the sample bottle, the septum was sealed with silicon caulk. The samples were analyzed for light hydrocarbons by Exploration Technologies, Inc., of Texas. The sample locations were digitized and overlaid on a satellite image (see attached map).

Preliminary analysis indicates that hydrocarbon gas concentrations tend to increase over the Volcano structure (see attached map). However, the pattern is fairly complex, and some higher values can be found away from the structure. This is not unexpected, as hydrocarbon reservoirs are also found off the Volcano structure, albeit generally at a greater depth.

Particularly interesting is a comparison between gas concentrations and lineaments that were previously mapped on the Landsat imagery by two independent observers. In Figure 1, it can be seen that concentrations of ethane and propane, and to a lesser extent methane, are correlated with distance from the nearest Landsat lineament. However, when gas concentration is plotted against distance from lineaments that cut across the strike of the Volcano structure (Figure 2), the pattern becomes a much clearer - especially for propane. By comparison, when gas concentration is plotted against distance from lineaments sub-parallel to strike, the association is very weak (see Figure 3). Thus cross-strike lineaments are much more likely to be indicators of zones of increased permeability for oil migration, compared to lineaments that are sub-parallel to strike. This suggests for the Volcano structure, lineaments sub-parallel to strike represent fractures that have been sealed, or that they are represent stratigraphic or other non-structural features. Field observations lend support to this latter argument, especially for the lineaments that bound the Volcano anticline.

2. Geobotanical Analysis.

A geobotanical analysis of the September imagery was carried out, in order to highlight the spectral anomalies that appear to be associated with the historic Volcano field, and the Stonewall Jackson Lake area. A spectral transformation was developed, using the nPDF suite of programs of Cetin (1991) and Cetin and others (1993). Training samples were

selected from the anomalous areas, as well as nearby areas that did not exhibit increased infra-red reflectance. The two areas (anomalous and non-anomalous areas) were fed into a routine that suppresses differences in illumination, and finds a "corner" in the data space that provides a perspective of the entire data set that gives the greatest difference between the two classes (Foote and others, 1994). This resulted in a transformation of (1110001) (i.e. data are projected from the maximum value in the visible bands (bands 1, 2, and 3), and the origin in the near and mid-infra-red bands (bands 4, 5, and 7), and the maximum in the thermal band (band 6.)) In the attached map, the transformed data is shown as a black and white image for low values (DN values 0 - 214), and as a density sliced image for the high DN range (215 - 255), so as to high-light those values.

It is clear from the map that high values of the transformation are dominantly found associated with the Volcano structure, and also to a certain extent with higher soil gas concentrations. However, as was expected, the geobotanical transformation is highly noisy. The combination of geobotanical transformation and lineaments seems to be a very effective solution to this problem, thus supporting one of the major rationales of this work in the first place.

3. Spectral Reflectance Library.

The multi-temporal spectral reflectance measurements are continuing. An initial reconnaissance series of measurements were made in October of 1995, which coincided with the Landsat overpass (see the Quarterly report dealing with October 1995). From analysis of the Landsat image data base, it was clear that the spectral anomaly associated with both Volcano and the Stonewall Jackson Lake region was most clearly developed in the early fall (September). Consequently, it was decided to make repetitive spectral measurements in the field every two weeks, covering the late summer and the fall of 1996. Four sites have been identified, one in a spectrally anomalous area in the September 1985 image, and one in a background area, for each of the Volcano and Stonewall Jackson sites. At each site leaf reflectance spectra were measured over the range from 400 to 2500 nm for at least 5 different tree species. Although an attempt was made to collect spectra of the same trees at all the sites, this was not always possible. The species for which spectra have been collected include:

- Tulip poplar *Liriodendron tulipifera* L.
- White oak *Quercus alba* L.
- Chestnut oak *Quercus prinus* L.
- Black oak *Quercus velutina* Lam.
- Red oak *Quercus rubra* L.
- Red maple *Acer rubrum* L.
- Sugar maple *Acer saccherum* Marsh.
- Shagbark hickory *Carya ovata* (Mill.) K. Koch
- American beech *Fagus grandifolia* Ehrh.

So far spectra have been collected on 8/6/96 and 8/21/96. It is anticipated that this pattern of collection (twice per month) will be continued through September and October.

4. References:

- Cetin, H. and D. W. Levandowski, 1991. Interactive classification and mapping of multi-dimensional remotely sensed data using n-dimensional probability density functions (nPDF). *Photogrammetric Engineering and Remote Sensing* 57 (12): 1579 - 1587.
- Cetin H., T. A. Warner and D. W. Levandowski, 1993. Data classification, visualization and enhancement using n-dimensional probability density functions (nPDF): AVIRIS, TIMS, TM and geophysical applications. *Photogrammetric Engineering and Remote Sensing* 59 (12): 1755 - 1764.
- Foote, H., D. Beaver and T. Warner, 1994. Development of band selection and analysis techniques to improve environmental applications of hyperspectral data. *Abstracts, Spectral Analysis Workshop: The Use of Vegetation as an indicator of Environmental Contamination, Desert Research Institute, Reno, Nevada, November 9 - 10, 1994.*

Figure 1. Hydrocarbon gas concentration and distance from nearest lineament.

Figure 2. Hydrocarbon gas concentration and distance from nearest cross-strike lineament.

Figure 3. Hydrocarbon gas concentration and distance from nearest sub-parallel lineament.

Geobotanical and Structural Interpretation Map

UTM Projection
Zone 17

Topographic Control
USGS 1:24,000 Maps
Willow Island,
Petroleum,
Schultz, and
Cairo, WV

1 : 75,000

Satellite Image Interpretation Map of Volcano, WV

Landsat Thematic Mapper Image
Acquired September 20 1985

Provisional Geobotanical interpretation
nPDF (1110001) transformation
Gray tone density slice DN 0-214
Color tone density slice DN 215-255

Lineaments with strike sub-parallel
to Burning Springs

Lineaments with strike near perpendicular
to Burning Springs

Soil gas sample location and ethane
concentration (ppb)

WVU Remote Sensing Laboratory
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/usr3/warner/gqnb07/gqnb07_interpret/lin_qgis_gqnb07_interpret.mxd