PS Power Imaging — A Passive Electromagnetic Hydrocarbon Detection Method: Examples from Railroad Valley, Nevada*

Dietmar (Deet) Schumacher[1], W. Barry Weaver[2], and Roy K. Warren[2]

Search and Discovery Article #40966 (2012)
Posted July 2, 2012

*Adapted from poster presentation at AAPG Annual Convention and Exhibition, Long Beach, California, April 22-25, 2012

[1]Independent Consultant, Mora, NM (deetschumacher@gmail.com)
[2]Wave Technology group, Houston, TX

Abstract

Power Imaging is a passive electromagnetic method used for pre-drilling detection of hydrocarbons in onshore settings. Power Imaging is a geophysical prospecting method that utilizes the electric power grid as a continuous source of energy for investigating the earth's subsurface geological structure, stratigraphy, and hydrocarbon potential.

The electric power grid induces electromagnetic waves in the earth. These electromagnetic waves are at specific frequencies, which are harmonics and sub-harmonics of 60 hertz (50 hertz in many areas of the world). These secondary harmonics include multiples of 60, 30, 15 and 7.5 hertz (or 50, 25, 12.5 and 6.25 hertz) and extend up to frequencies in the tens of kilohertz. The waves propagate into the subsurface as plane waves and encounter the various geologic boundaries. Those boundaries having dielectric and/or conductivity contrast reflect a portion of the waves back to the earth's surface. With continuous sourcing from the electric power grid, the waves resonate between the subsurface boundaries and the surface of the earth. Because the power grid as a whole creates the resonance, the distance and attitude to any one or more power lines is not important. In fact an effort is made to null out the effects of nearby power lines. The power grid induced waves become organized such that there is a direct relationship between the many resonating frequencies and the depths to the various geologic boundaries.:

Because of the electrical contrast between hydrocarbon-bearing rocks and their surrounding formations, an electromagnetic signature can be detected by measuring the resonant frequencies at the surface of the earth. Interpretation of this signature yields an electromagnetic hydrocarbon indicator or EHI, thus allowing the direct detection of hydrocarbons, along with the depth and approximate thickness of the hydrocarbons. This presentation is illustrated with examples from Railroad Valley, Nevada.

Selected Bibliography

Anna, L.D., L.N.R. Roberts, and C.J. Potter, 2007, Geologic assessment of undiscovered oil and gas in the Paleozoic-Tertiary Composite Total Petroleum System of the eastern Great Basin, in Geologic Assessment of Undiscovered Oil and Gas Resources of the Eastern Great Basin Province, Nevada-Utah-Idaho-Arizona: USGS, Digital Data Series DDS-69L, p. 1-55.

French, D.E., 1994, Results of drilling and testing at the Meridian #32-29 Spencer Federal, Railroad Valley, Nye County, Nevada, *in* R.A. Schalla and E.H. Johnson, eds., Oil Fields of the Great Basin: Nevada Petroleum Society, Reno, Nevada, p. 171-186.

Johnson, E.H., 1994 Geologic and seismic analysis of the Bacon Flat-Grant Canyon area, Ney County, Nevada, *in* R.A. Schalla and E.H. Johnson, (eds.), Oil Fields of the Great Basin: Nevada Petroleum Society, Reno, Nevada, p. 227-240.

Meissner, F.F., J. Woodward, and J.L. Clayton, 1994, Stratigraphic relationships and distribution of source rocks in the greater Rocky Mountain region, *in* F.F. Meissner, J. Woodward, and J.L. Clayton, (eds.), Hydrocarbon Source Rocks of the Greater Rocky Mountain Region: RMAG, Denver, Colorado, p. 1-34.

Poole, F.G., and G.E. Claypool, 1984, Petroleum source rock potential and crude oil correlation in the Great Basin, *in* J. Woodward, F.F. Meissner, and J.L. Clayton, (eds.), Hydrocarbon Source Rocks of the Great Rocky Mountain Region: RMAG, Denver, Colorado, p. 179-229.

Schumacher, D., 1996, Hydrocarbon-induced alteration of soils and sediments, *in* D. Schumacher and M.A. Abrams, (eds.), Hydrocarbon Migration and Its Near-Surface Expression: AAPG Memoir 66, p. 71-89.

Weaver, W.B., and R.K. Warren, 2012, Power Imaging - a new exploration tool, *in* D. Schumacher and R.K. Warren, (eds.), Non-Seismic Detection of Hydrocarbons: Assumptions, Methods, and Exploration Case Histories: SEG, Special Publication, in preparation.

POWER IMAGING

A Passive Electromagnetic Hydrocarbon Detection Method: Examples from Railroad Valley, Nevada

Dietmar (Deet) Schumacher (1), W. Barry Weaver (2), and Roy K. Warren (2)

(1) Independent Consultant, Mora, NM, USA
(2) Wave Technology Group, Houston, TX, USA

ABSTRACT:

Power Imaging is a passive electromagnetic method used for pre-drilling detection of hydrocarbons in onshore settings. Power Imaging is a geophysical prospecting method that utilizes the electric power grid as a continuous source of energy for investigating the earth's subsurface geological structure, stratigraphy, and hydrocarbon potential.

The electric power grid induces electromagnetic waves in the earth. These electromagnetic waves are at specific frequencies, which are harmonics and sub-harmonics of 60 hertz (50 hertz in many areas of the world). These secondary harmonics include multiples of 60, 30, 15 and 7.5 hertz (or 50, 25, 12.5 and 6.25 hertz) and extend up to frequencies in the tens of kilohertz. The waves propagate into the subsurface as plane waves and encounter the various geologic boundaries. Those boundaries having dielectric and/or conductivity contrast reflect a portion of the waves back to the earth's surface. With continuous sourcing from the electric power grid, the waves resonate between the subsurface boundaries and the surface of the earth. Because the power grid as a whole creates the resonance, the distance and attitude to any one or more power lines is not important. In fact an effort is made to null out the effects of nearby power lines. The power grid induced waves become organized such that there is a direct relationship between the many resonating frequencies and the depths to the various geologic boundaries.

Because of the electrical contrast between hydrocarbon-bearing rocks and their surrounding formations, an electromagnetic signature can be detected by measuring the resonant frequencies at the surface of the earth. Interpretation of this signature yields an electromagnetic hydrocarbon indicator or EHI, thus allowing the direct detection of hydrocarbons, along with the depth and approximate thickness of the hydrocarbons. This presentation is illustrated with examples from Railroad Valley, Nevada.

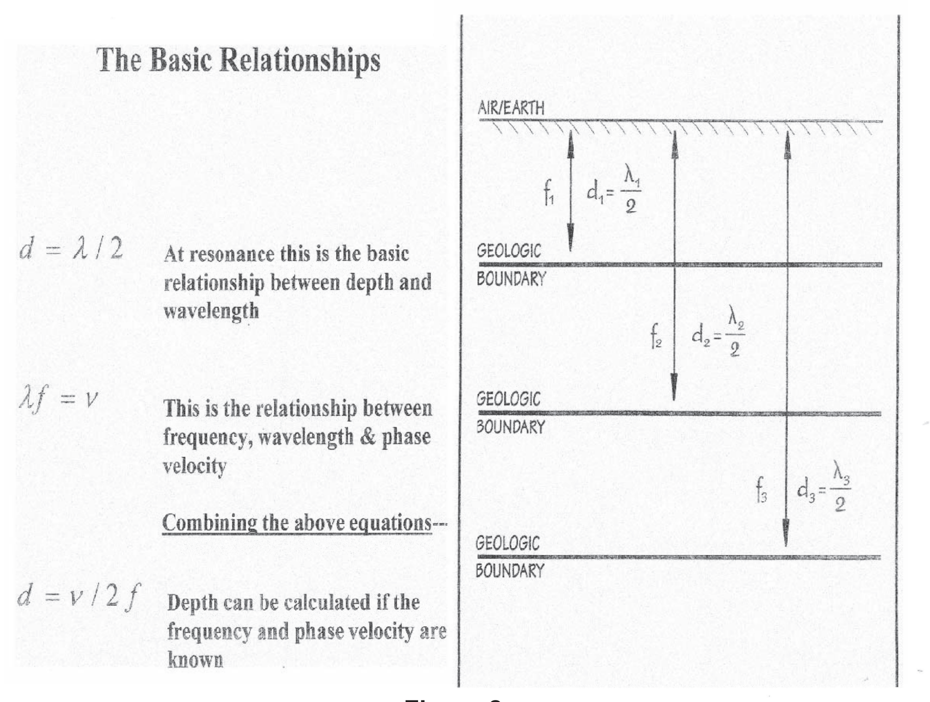


Figure 2

This figure shows the basic relationships. At resonance the depth (d) to the subsurface boundary is related to the wavelength (symbol for lambda) of the secondary harmonic by the tuning equation, such that depth is equal to one-half of the wavelength. As with all waves, the wavelength is equal to the velocity of propagation v (phase velocity) divided by the frequency f.

Using these two relationships, the depth to a resonating boundary can be calculated if the frequency and the velocity are known. As it turns out, the velocity of propagation (v) has proven to the remarkable constant in all areas tested.

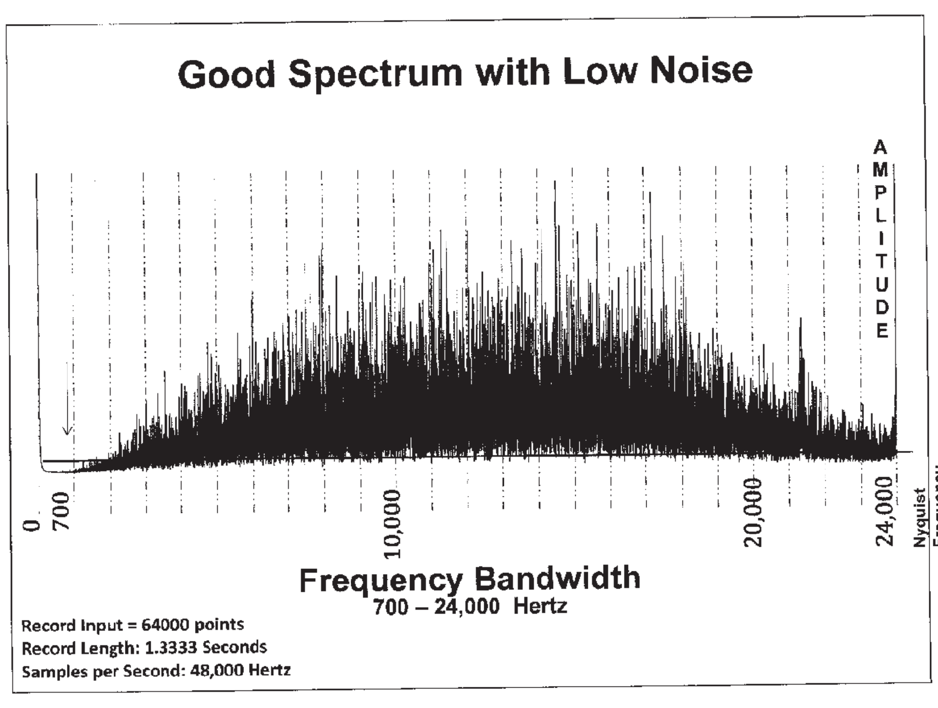


Figure 3

The figure shows a typical power spectrum of frequencies measured at the surface. Power Imaging utilizes the frequencies in the range of one kilohertz.

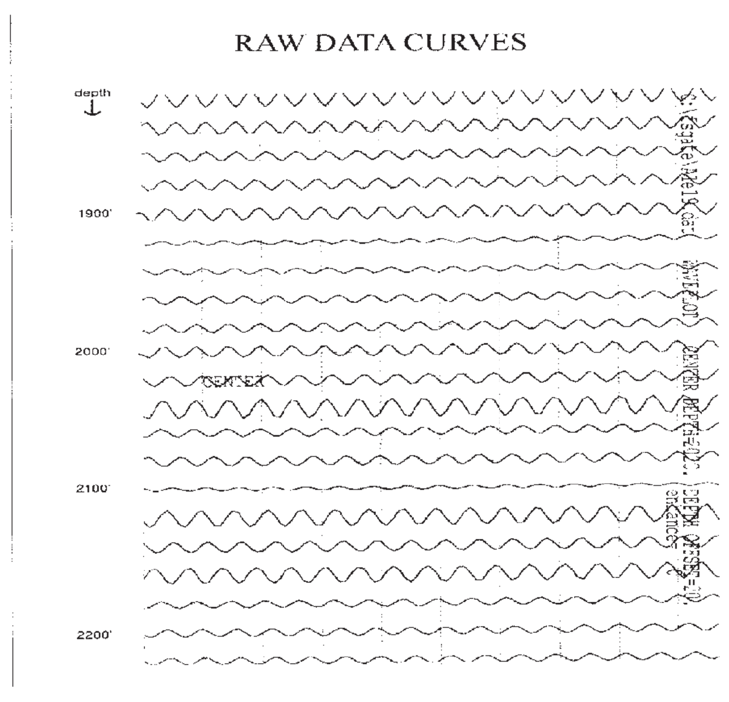


Figure 4

This is an example of what the raw data looks like. As expected, the waves are sinusoidal since they are generated by the power grid. Notice also that they have different amplitudes and also have phase differences.

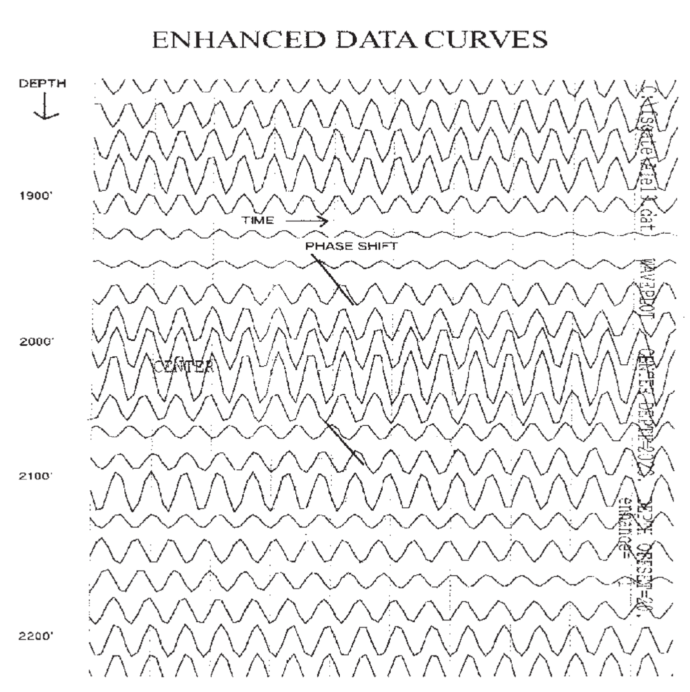


Figure 5

In order to enhance the wave differences, this figure illustrates what the waves look like when one wave is multiplied by the next. Notice that around 2000 feet there is a phase shift followed by an increase in amplitude, and below that another phase shift. This is the electromagnetic signature of a hydrocarbon zone or EHI (Electromagnetic Hydrocarbon Indicator).

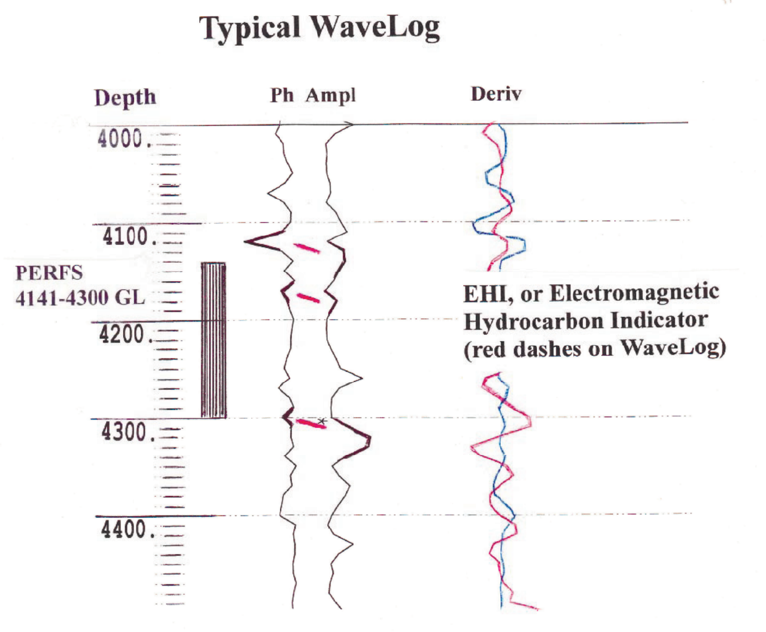


Figure 6

When these data are displayed by depth, it is known as a WaveLog. This figure illustrates a representative WaveLog with the phase data shown on the left, the amplitude data on the right, and derivatives of the phase (blue) and amplitude (red) curves on the far right. Several typical EHI's are present between 4100 and 4300 feet, and their location is marked by the short red dashes. Note that the phase response precedes in depth the amplitude response. This example is from the Trap Spring Munson Ranch 13-45 well, and the EHI's correspond closely with the location of the perforated zone in this producing oil well.

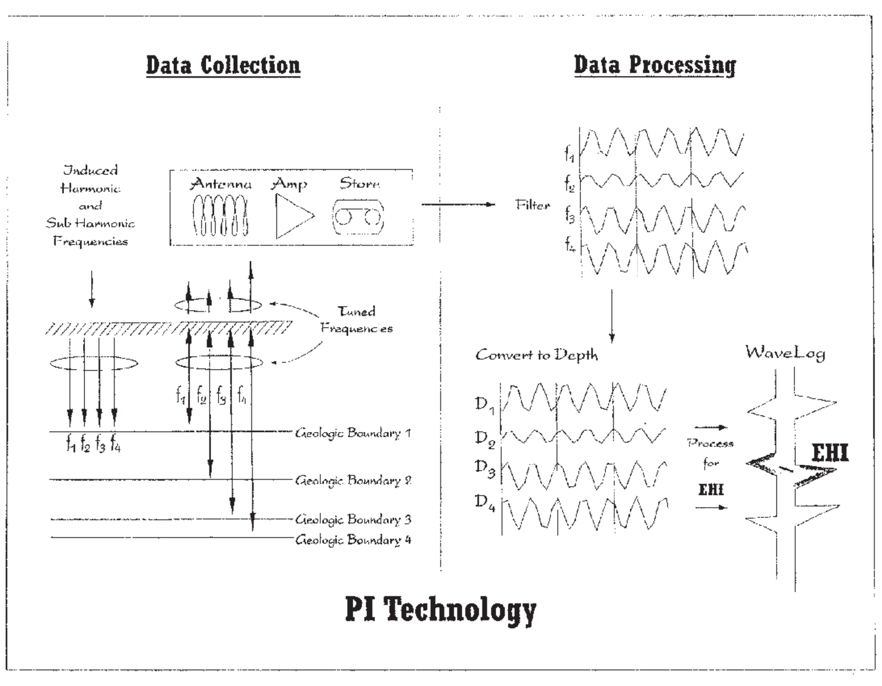


Figure 7

This figure summarizes the entire process. On the left we see the waves entering the earth. Through tuning, the frequencies become depth organized. With continuous sourcing, resonance occurs and this becomes strong enough so that some leakage occurs at the surface. A coil antenna is placed on the ground and the magnetic components of the waves are recorded on a digital storage device.

The recorded digital data are processed through a digital filter which is designed to capture the frequencies of interest while filtering out everything else as unwanted noise. Next the frequencies are converted to depth and the waves are processed to produce a Wave Log.

DATA PROCESSING FOR POWER IMAGING

The time-domain signal recorded at the measurement site has 64000 points and is digitized at 48000 samples per second. A low cut filter in the field instrument rolls off at 700 Hz; the high cut is 24000 Hz. The 48000 samples per second divided by the 64000 points allows for a one hertz bandwidth window for time-domain processing. A comb filter procedure is used to extract the harmonics carrying the resonance information. Harmonic number 20 (1200 Hz) to number 400 (24000 Hz) including all the subharmonics are the ones used for further processing of PI data. On a strong resonance boundary, the frequency and the amplitude is a record of the response. Two adjacent frequencies are studied to estimate a phase shift. Noise in the power grid can be a big problem, but making multiple files for stacking in a separate process significantly reduces the effects of noise.

POWER IMAGING EXAMPLES FROM RAILROAD VALLEY, NEVADA

The results presented here are part of a larger study to evaluate the capability and reliability of Power Imaging to detect hydrocarbon-bearing zones in the subsurface. Other applications of Power Imaging, such as its value to provide stratigraphic and structural information, were also investigated but are not part of the presentation.

Power Imaging data were recorded at 25 well locations in Railroad Valley, as indicatedin Figure 8, a Google Earth image of the area. Sites 1 - 7 are from Trap Spring field; sites 9 - 13 are from Eagle Springs field; 14 - 19 from Grant Canyon field; sites 20 - 21 from Bacon Flat field; and sites 22 - 25 from Sans Spring field. Site 8 is the Spencer Federal 32 - 29 well, a significant exploration well located near the basin depocenter, about midway between Trap Spring and Eagle Springs field. Of the 25 wells surveyed, 12 are producing wells, and several of the others encountered significant shows.

Power Imaging data are presented as WaveLogs on Figures 11 - 17 and 19 - 21. These figures display the EM phase and amplitude curves as a function of depth. The presence of Electromagnetic Hydrocarbon indicators (EHI) are indicated by short red dashes. The perforated intervals in producing wells are highlighted in green.

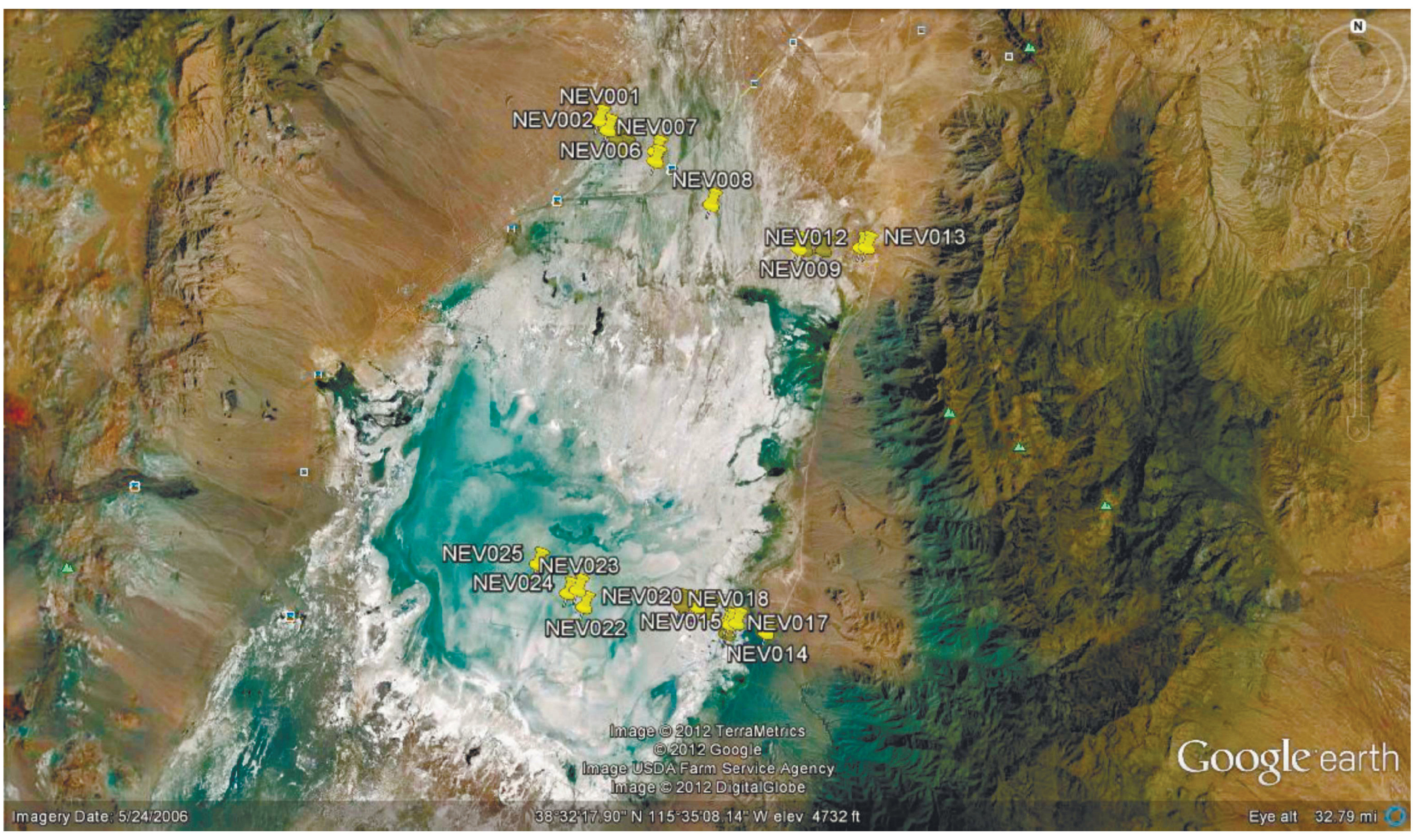
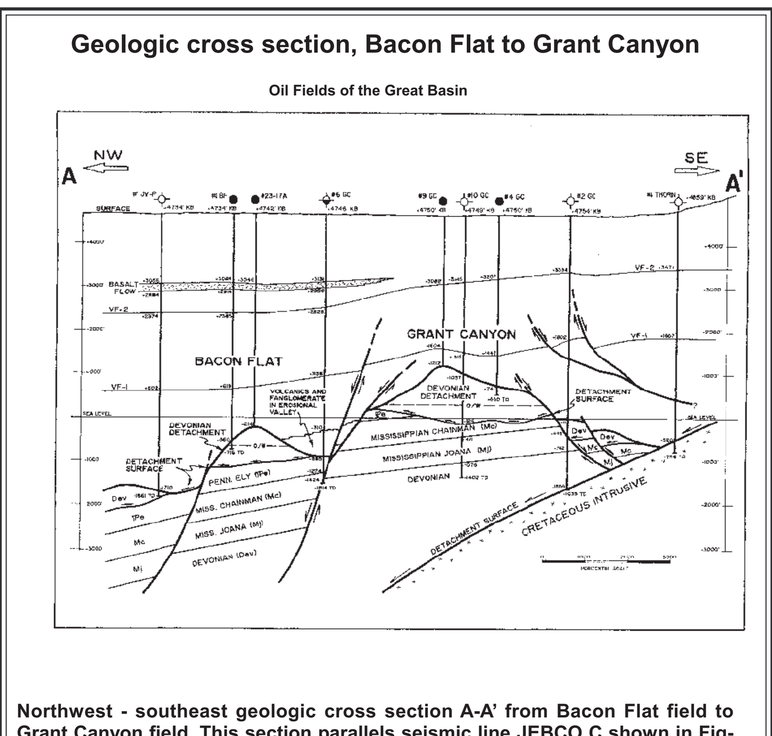


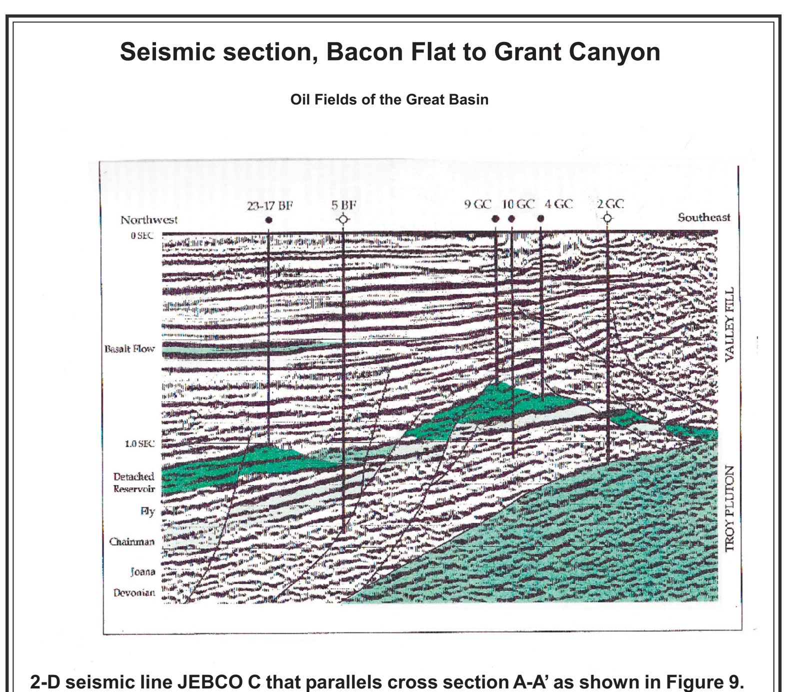
Figure 8

This Google Earth Image of Railroad Valley, Nevada, shows the locations of the 25 wells for which Power Imaging data was recorded, processed, and interpreted.



Northwest - southeast geologic cross section A-A' from Bacon Flat field to Grant Canyon field. This section parallels seismic line JEBCO C shown in Figure 10 (from E.H. Johnson, 1994).

Figure 9



2-D seismic line JEBCO C that parallels cross section A-A' as shown in Figure 9. The detached Devonian rocks are highlighted by dark shading, the Mississippian Chainman by light shading, and volcanic and plutonic rocks by medium shading (from E.H. Johnson, 1994).

Figure 10

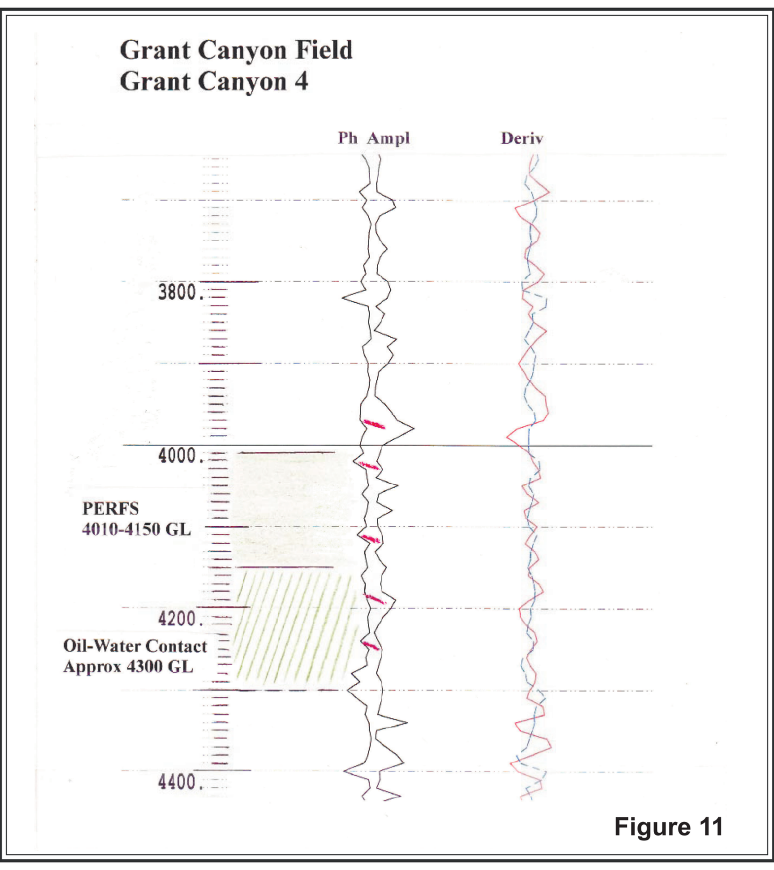


Figure 11

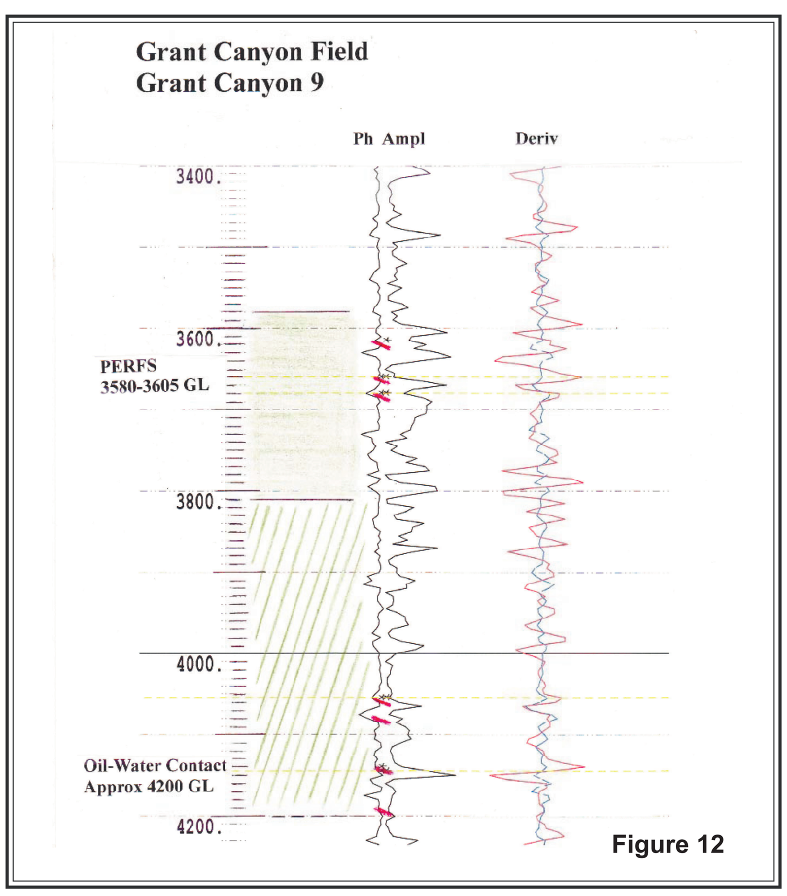


Figure 12

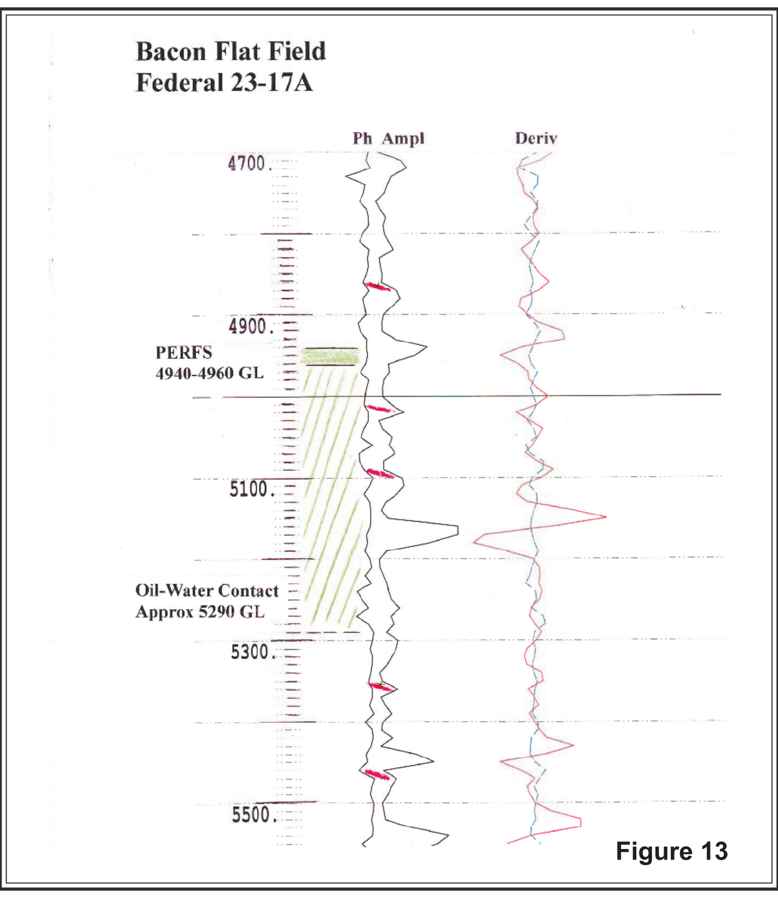


Figure 13

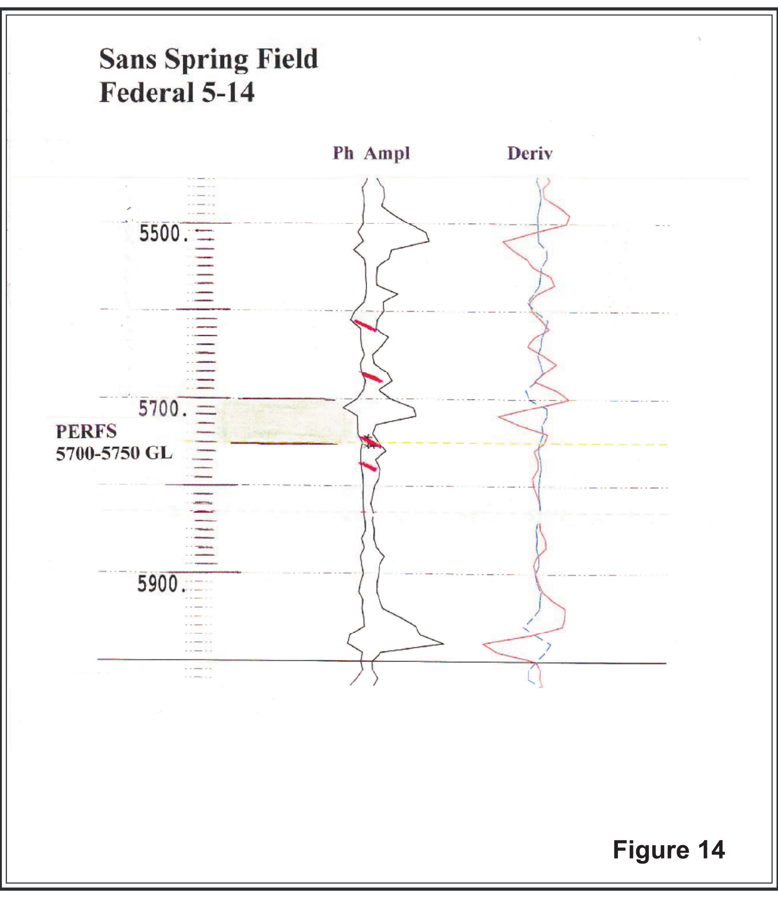


Figure 14

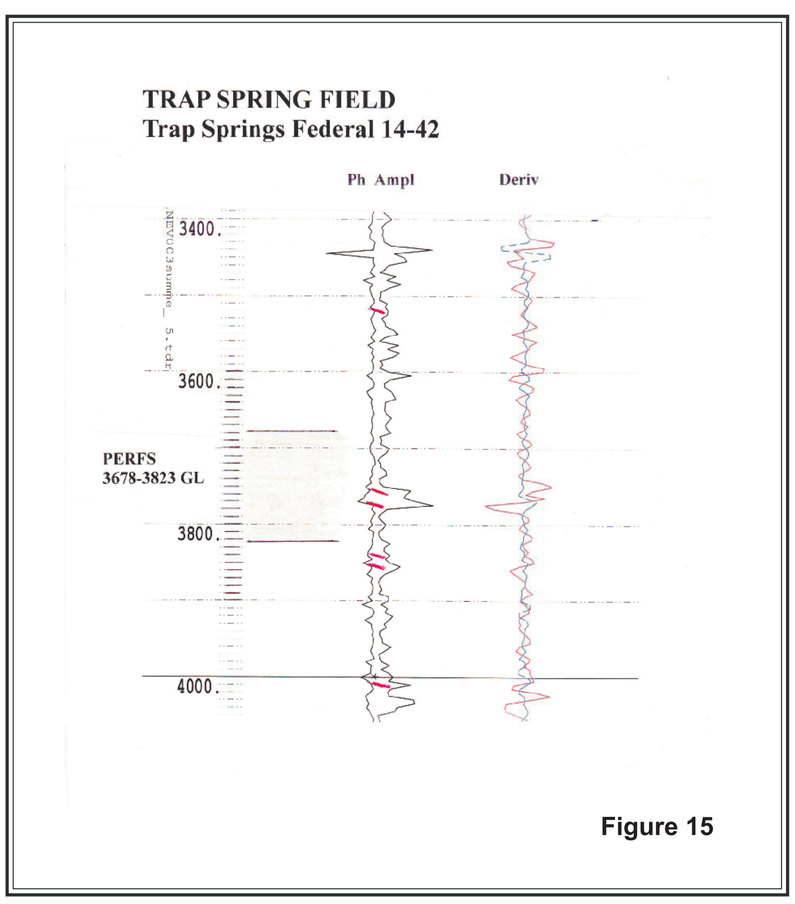


Figure 15

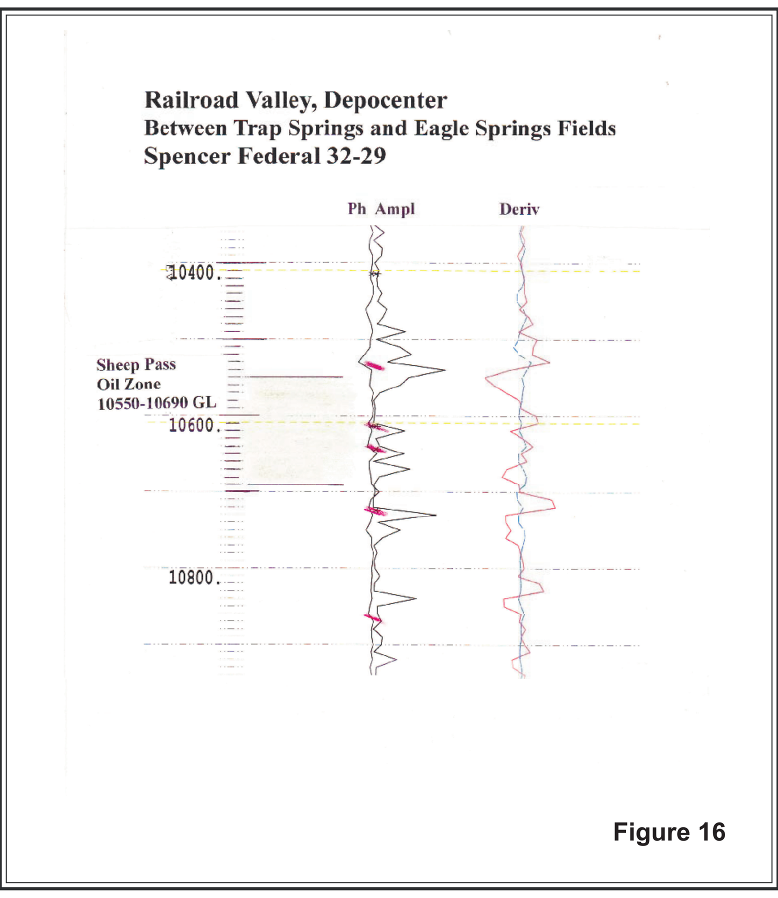


Figure 16

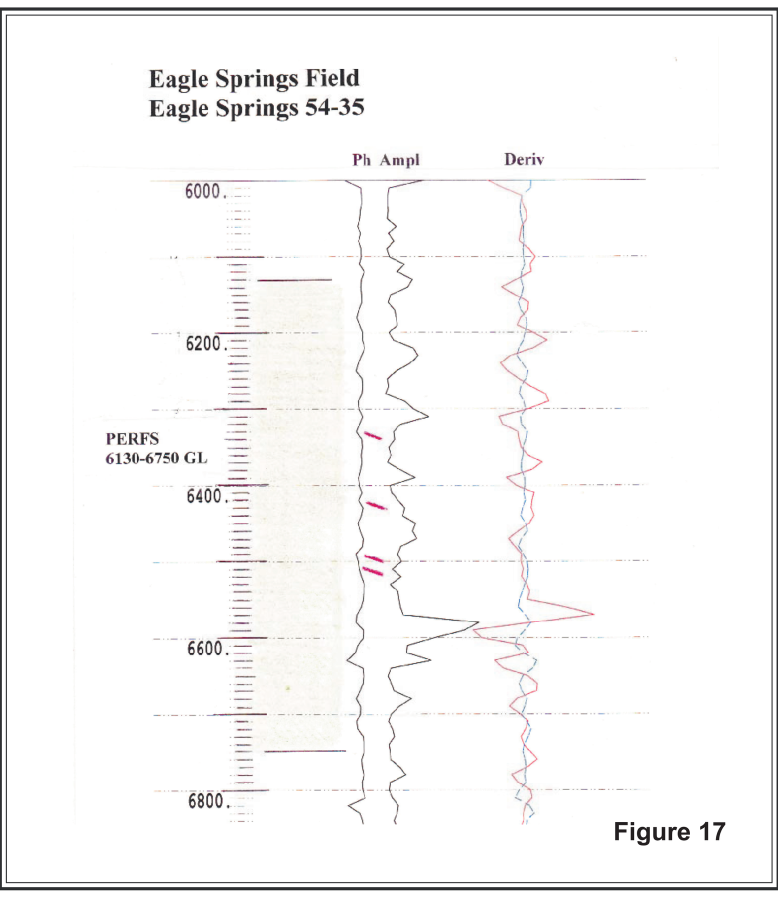


Figure 17

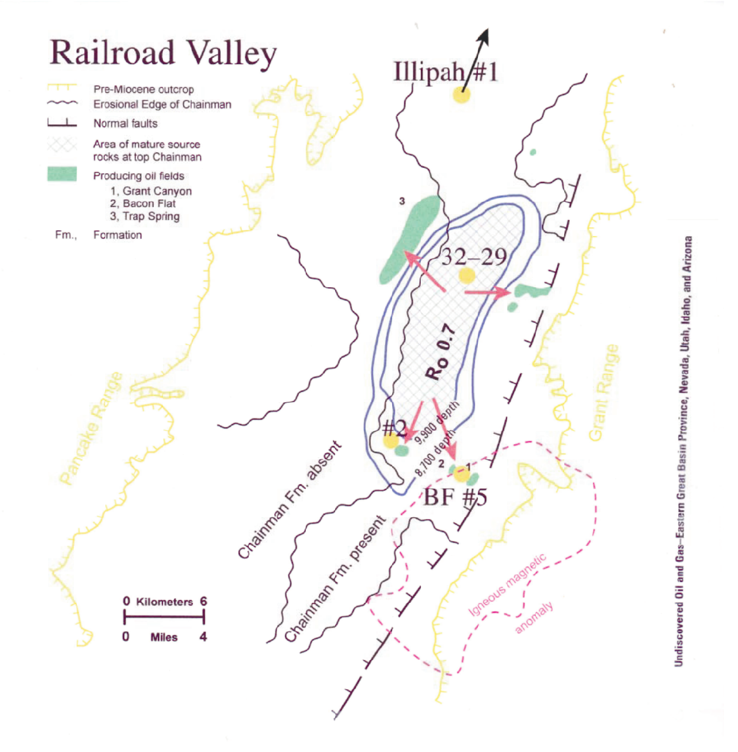
ELECTROMAGNETIC CHARACTERISTICS OF THE CHAINMAN SHALE

The Mississippian Chainman Formation is considered to be the main petroleum source rock in Railroad Valley (and in much of the eastern Great Basin) because it is (1) a thick, organic-rich marine shale, and (2) its expelled oil has been geochemically correlated with several producing oil fields including Grant Canyon, Bacon Flat, Trap Spring, and Blackburn field. Thickness of the Chainman ranges from a few hundred feet in southeast Nevada to more than 6000 feet in northwest Utah. More than 2200 feet of Chainman was penetrated by the Spencer Federal 29-32 well, located between Trap Spring and Eagle Springs fields in Railroad Valley. The distribution of mature Chainman shale in Railroad Valley, as interpreted by the USGS, is shown in Figure 18.

Power Imaging data document that the organic-rich shales of the Chainman possess a distinctive electromagnetic response characterized by (1) strong amplitude, (2) numerous, closely spaced EHI's and (3) long depth intervals for which the red and blue derivative curves move together in phase. These characteristics are well illustrated in Figures 19-21.

The unique and distinctive EM response observed in the Chainman shale may be characteristic for all mature, organic-rich shales, however, that remains to be documented.

What we can say with confidence is that Power Imaging data enables us to recognize and map the distribution of the mature Chainman shale in Railroad Valley down to depths of 16000 feet. For example, 800-1000 feet of Chainman occur beneath Eagle Springs field below 11000 feet (Fig. 20). Similarly, beneath Sans Spring field, the Chainman can be recognized 2400-3000 feet beyond the total depth of the Federal 5-14 well (Fig. 21). This distinctive Chainman EM response can also be recognized at depths of 11000-13000 feet below parts of Bacon Flat and Grant Canyon fields.



Oil generation region (crosshatch) for the Mississippian Chainman Formation in Railroad Valley, Nevada. Red arrows show generalized oil migration directions from the oil generation window. (from Anna et al., 2007, USGS DDS-69L)

Figure 18

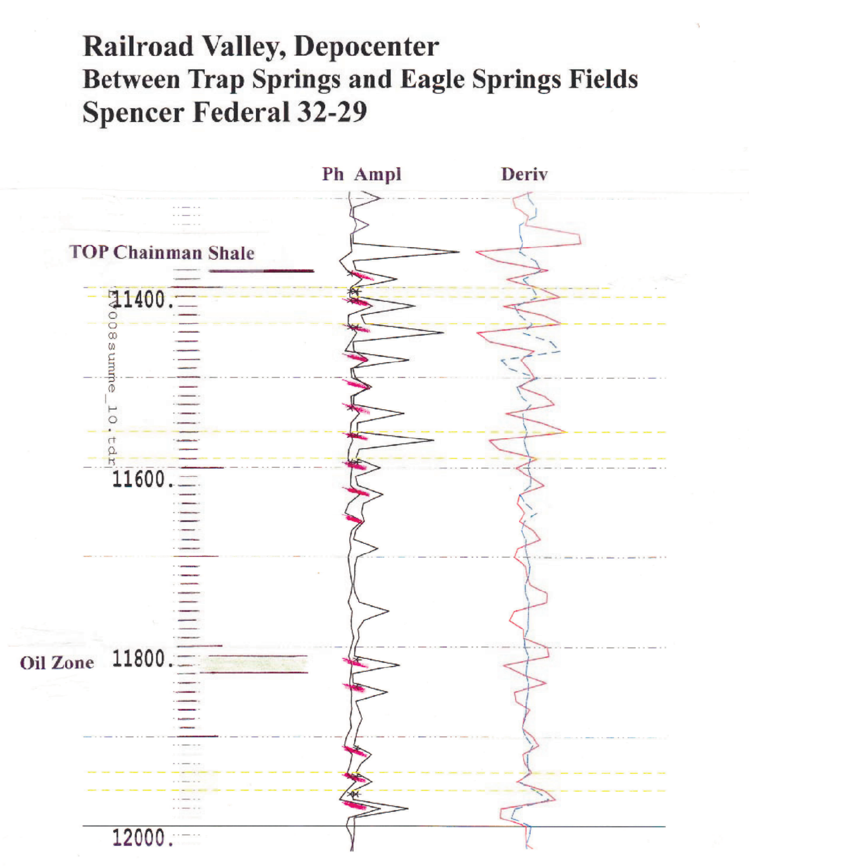


Figure 19

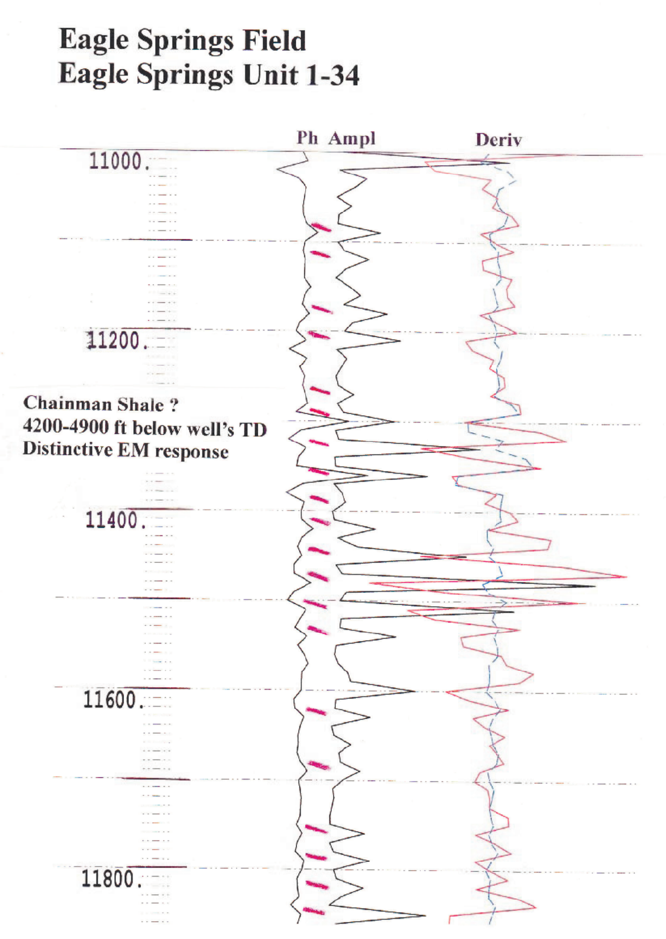


Figure 20

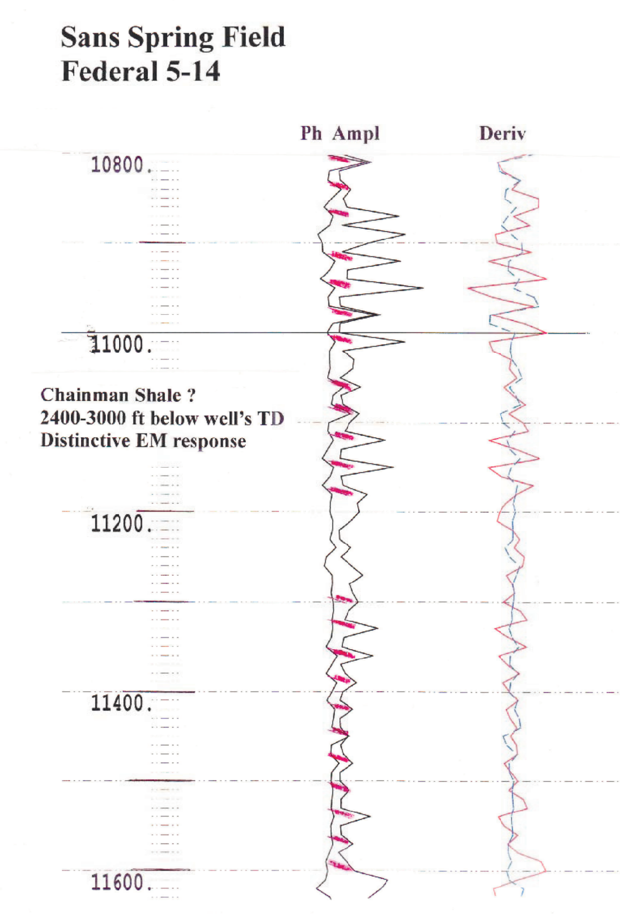


Figure 21

SUMMARY AND CONCLUSIONS

Power Imaging (PI) is a passive electromagnetic geophysical prospecting method that utilizes the electric power grid as a continuous source of energy for investigating the earth's subsurface geological structure, stratigraphy, and hydrocarbon potential. The results presented here focus on the ability of Power Imaging to detect oil/gas bearing zones from an EM measurement taken at the surface.

Of the 25 well locations included in this study, 12 are producing oil wells or wells with strong but not commercial oil shows. *Power Imaging recorded Electromagnetic Hydrocarbon Indicators (EHI's) within or vary near each one of the hydrocarbon-bearing zones.* EHI's were frequently located within thick pay zones, and about one-half of the time; EHI's were also located at the top and/or bottom of the productive zone. *A distinctive pattern of EHI's is also associated with the organic-rich and thermally mature Chainman shale*, the principal source rock in Railroad Valley.

Despite the ability of Power Imaging to correctly predict the presence of, and depth to, hydrocarbon-bearing zones, it should be noted that false EHI anomalies are present at each site evaluated. These false anomalies seem to occur (1) at boundaries having strong dielectric or conductivity contrasts, or (2) between units possessing sharply contrasting resistivity. One can discriminate between true and false EHI anomalies through careful analysis of the Power Imaging data, and/or by acquiring PI data at sites 200-400m apart; true EHI's tend to be traceable from site to nearby site, whereas false anomalies are not.

SELECTED REFERENCES

Anna, L.D. and others, 2007, Geologic assessment of undiscovered oil and gas in the Paleozoic-Tertiary Composite Total Petroleum System of the eastern Great Basin, in Geologic Assessment of Undiscovered Oil and Gas Resources of the Eastern Great Basin Province, Nevada-Utah-Idaho-Arizona: USGS, Digital Data Series DDS-69L, p. 1-55.

French, D.E., 1994, Results of drilling and testing at the Meridian #32-29 Spencer Federal, Railroad Valley, Nye County, Nevada, in R.A. Schalla and E.H. Johnson, eds., Oil Fields of the Great Basin: Nevada Petroleum Society, Reno, p. 171-186.

Johnson, E.H. 1994 Geologic and seismic analysis of the Bacon Flat-Grant Canyon area, Ney County, Nevada, in R.A. Schalla and E.H. Johnson, eds., Oil Fields of the Great Basin: Nevada Petroleum Society, Reno, p. 227-240.

Meissner, F.F., and others, 1994, Stratigraphic relationships and distribution of source rocks in the greater Rocky Mountain region, in F.F. Meissner, J. Woodward, and J.L. Clayton, eds., Hydrocarbon Source Rocks of the Greater Rocky Mountain Region: RMAG, Denver, p. 1-34.

Poole, F.G. and G.E. Claypool, 1984, Petroleum source rock potential and crude oil correlation in the Great Basin, in J. Woodward, F.F. Meissner, and J.L. Clayton, eds., Hydrocarbon Source Rocks of the Great Rocky Mountain Region: RMAG, Denver, p. 179-229.

Schumacher, D., 1996, Hydrocarbon-induced alteration of soils and sediments, in D. Schumacher and M.A. Abrams, eds, Hydrocarbon Migration and Its Near-Surface Expression: AAPG Memoir 66, p. 71-89.

Weaver, W.B., and R.K. Warren, 2012, Power Imaging - a new exploration tool, in D. Schumacher and R.K. Warren, eds., Non-Seismic Detection of Hydrocarbons: Assumptions, Methods, and Exploration Case Histories: SEG, Special Publication, in preparation.

For more information about the Power Imaging technology or this project, contact Deet at deetschumacher@gmail.com and/or visit www.wavetechnologygroup.com