Update 2010: Airborne Transient Pulse Surveys for Hydrocarbon Exploration—Major Recent Improvements *

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Abstract

Recent major improvements have been made to airborne measurements of transient pulses to automate the efficient airborne collection of data as well as to make estimates of the depth at which reservoirs would likely be discovered. Now referred to by us as the “Audio Frequency Electromagnetic Survey” (A-EM survey), it is based in part on the AFMAG airborne survey discussed by S.H. Ward. Lightning activity worldwide contributes transient pulses, and combined with streaming potentials and oscillating magnetic fields associated with hydrocarbon-related Redox activity, a measureable source of electromagnetic energy radiating to the surface can be detected from low-flying aircraft. The frequency of these emissions radiating from the earth can be related to the depth of subsurface hydrocarbons.

Using an E-field antenna mounted in a low-flying light plane, the newly developed computer software divides a frequency spectrum of 200-2200 Hz into 11 discrete frequency bands and records the segmented data in a spreadsheet format. The maximum signal amplitude of each frequency band is recorded as a data column, including a "sum" data column. The data are averaged and recorded once a second, along with the GPS coordinates, UT Time, Date and Survey Time, all simultaneously with the data columns. The file can be sent from the field via E-Mail and imported directly into mapping programs or spreadsheets for filtering before mapping. Various averaging functions, such as derivative, square root or statistical noise filtering algorithms can be applied to enhance the mapping of the data.

To date, some 50 surveys have been flown in North America, and 30 more in New Zealand and Australia; as well as a major offshore survey flown over the North Sea. Numerous anomalies have been found, and subsequently drilled, resulting in successful producers. One survey was flown over one of author LeSchack’s Alberta prospects; it was recently drilled and oil was discovered as predicted.

Our statistics point to a valuable reconnaissance tool for industry, and certainly for governmental national resource surveys.

Introduction

"Airborne Measurement of Transient Pulses Locates Hydrocarbon Reservoirs" by authors LeSchack and Jackson (Search and Discovery Article #40204 (2006)) describes a reliable, cost-effective, environmentally friendly remote sensing tool for finding oil and gas both onshore and offshore. Recently, major improvements have been made (1) to automate the efficient collection of these airborne data, as well as (2) now being able to make estimates not only of the reservoirs' horizontal location, but of the depth at which they would likely be encountered.

Our airborne surveys are based on the following theory: An inherent passive electromagnetic field is present in the earth that can be sensed at the earth's surface and from low-flying aircraft. Vertical components of this field contain transient random impulses of energy varying across a wide frequency range, including in the audio range. Although speculative, it is widely believed that the impulses are related to a combination of the effects of solar plasmas, lightning activity around the world that produces electronic disturbances called "sprites" and "whistlers," seismo-electric potentials within the earth, and REDOX cells generated by vertical hydrocarbon microseepage from reservoirs into the surrounding lithology (Boissonnas and Leonardon, 1948; Cummer, 1997; Garcia and Jones, 2002; Labson, et al., 1985; Pirson, 1969; Vozoff, 1972; Ward, 1959).

Although no "unifying theory" has yet to be postulated, empirical evidence points to Airborne Transient Pulse Surveys as being a most valuable reconnaissance exploration tool. Over 130 proprietary Airborne Transient Pulse Surveys have already been flown in Australia, Canada, Europe, Kyrgyzstan, New Zealand, and the United States during the past decade, comprising more than 200,000 nautical miles of survey lines over productive areas, both onshore and offshore. Developed in 2001 by author Jackson, and first flown in 2002 over author LeSchack's Devonian prospects in Alberta, more than 40 productive wells through 2007 have been documented as being drilled where Transient Pulse anomalies were present prior to drilling; only four known non-productive wells have been drilled on positive anomalies. Recent drilling results in central Kentucky in the U.S. using Pinemont's recently developed A-EM technology (described below) resulted in eight productive wells out of 11 holes drilled (see Appendix for location of most survey areas).

Typical Airborne Transient Pulse Surveys are flown at an altitude of 100m above ground or water surface, and at a speed of about 90 knots. Both light planes and helicopters have been used as survey platforms. The light-weight portable sensing equipment and antenna are carried entirely within the aircraft. It does not matter if the airframe is made of aluminum or not; transient pulse signals are not attenuated either way. Cultural artifacts on the ground, wells, pipelines, utility lines, etc., have no affect on data quality. Flight line spacing is determined by the Operator based on the size of the expected reservoirs. Generally, East-West lines are flown.

The Airborne Transient Pulse Survey technology works not only onshore, but offshore also. Surveys have been flown over offshore areas of New Zealand's Tasman Sea, and North Sea, which was ice covered at the northern extremity of the survey. Ice cover on the water did not appear to affect data quality. The Tasman Sea survey compares the airborne survey map (produced several years earlier) with a recent gas production map of the same area.

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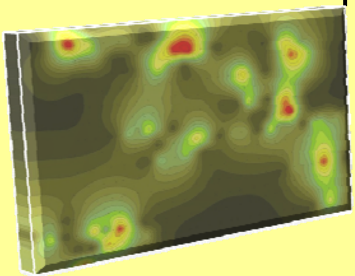
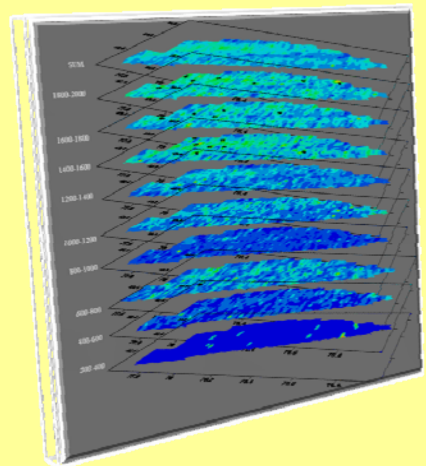
Update 2010: Airborne Transient Pulse Surveys for Hydrocarbon Exploration—Major Recent Improvements





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Notes by Presenter: This presentation is a discussion of a highly successful, cost-effective, non-invasive airborne reconnaissance tool for hydrocarbon exploration. This tool measures from an airborne platform one of the effects of micro-seeping hydrocarbons. There is only a brief description of the geophysics that makes this tool work. Our geophysics is largely based on the energy fields associated with solar plasmas and lightning strikes around the world.

Outline

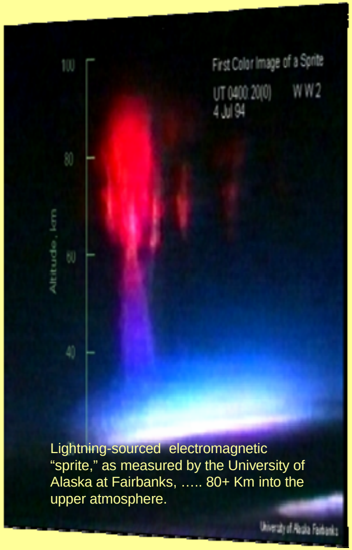
- Motivation: Why collect Airborne Transient Pulse data?
- What are Transient Pulses?
- Examples (P-TEM)
  - New Zealand
  - Alberta
- New Technology-The Airborne A-EM Survey
- Examples (A-EM)
  - Western Australia
  - Larimer County Colorado
  - Silo Oil Field
- Summary

Notes by Presenter: I shall dwell on another science: **statistics**. Our Session Chairman, Deet Schumacher, has recently published a paper (2010), observing that statistically, wells drilled on prospects associated with **positive hydrocarbon microseepage anomalies** are completed 82% of the time as commercial discoveries. In contrast, only 11% of wells drilled on prospects **without** an associated microseepage anomaly resulted in discoveries.

Our airborne tool is based on micro-seepage of HC. Basically, our Airborne Tool locates REDOX cells in the earth. REDOX cells, i.e., fuel cells, are directly related to HC reservoirs, and were described by Sylvain Pirson. **Both Deet's and Pirson's papers are referenced in our Abstract**. Over the past decade some 130 of our proprietary Airborne Transient Pulse Surveys have been flown worldwide. Our successes, also, as Deet's statistics have predicted, are slightly better than 80%!

What are Transient Pulses?

- Transient Pulses can be described as large pulses of energy which rise well above the long-term average of the background energy.
- Transient Pulses occur naturally in the Earth's atmosphere and within the subsurface.
- NASA researchers for the space shuttle program demonstrated lightning discharges are occurring globally at a rate of 80 to100 strikes per second. The energy from a lightning discharge is about 200 kWh (kilowatt hours) and can be measured over very long distances.
- Transients from both the atmosphere and subsurface excite portions of the REDOX cell creating a measurable and localized increase in electromagnetic (EM) transient energy.
- These anomalous areas can be measured both at the surface and from a low-flying aircraft. Based on a decade of data collection, the measured anomalies appear to be a rapid method to identify REDOX cells and, when validated with follow-up ground-based geophysical, geochemical and microbial surveys, have a high correlation with hydrocarbon accumulations in the subsurface vertically below.
- Some130 surveys have been flown worldwide, and so far, have contributed to 40 (known) wells drilled with 80% of these wells encountering hydrocarbons.



Lightning-sourced electromagnetic "sprite," as measured by the University of Alaska at Fairbanks, ….. 80+ Km into the upper atmosphere.

Notes by Presenter: A lightning discharges anywhere from 1,000,000 to 1,000,000,000 volts and between 10,000 and 200,000 amps. The combination of high frequency discharge, high energy release and long distance propagation suggests that lightning is a significant source of atmospheric transients.

The key to this technology is REDOX cells, natural fuel cells where microseeping hydrocarbons from subsurface reservoirs create localized DC current loops in the earth. Excitation of the DC current loops with naturally occurring AC transients results in Transient Pulse density levels that increase significantly above these REDOX Cells.

Oscilloscope Display –

Raw Signal=**yellow**; Detected Transients=**green**

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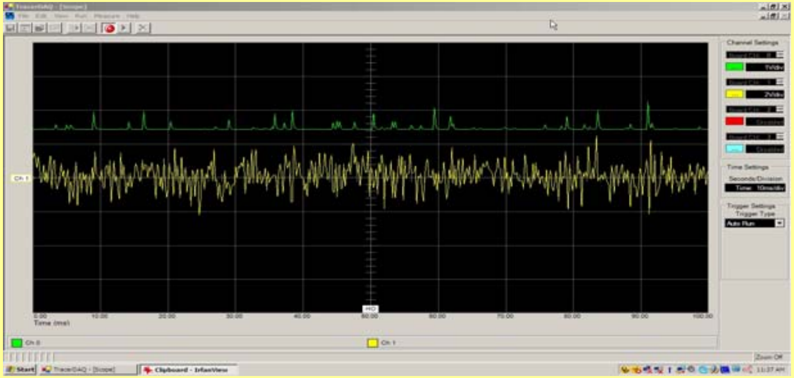
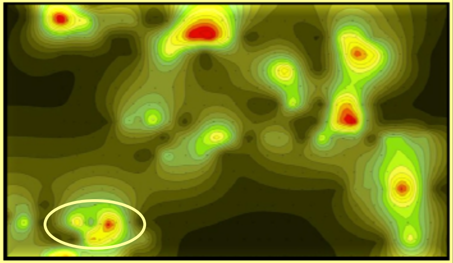


Oscilloscope presentation of waveforms generated by Passive Telluric Transient Electromagnetic Pulses. Filtering of each transient, at any given instant, permits estimating the pulses' instantaneous frequency spectrum. The frequency of the pulses relate to reservoir formation depths from which the measured transient pulses emanated. Horizontal Axis 10ms/division

Notes by Presenter: These transients can be measured anywhere and can be detected by de-modulation of what otherwise appears as just noise. Vertical axis is 1v (green) 2v (yellow); horizontal axis is 10mili/sec per div.

P-TEM Survey- New Zealand



map, courtesy, "oil-price.net", for 17 March 2010.

An Airborne Transient Pulse Survey flown southwest of New Plymouth, New Zealand, is shown. The west half of the survey was flown offshore. The anomalous transient responses are shown in red.

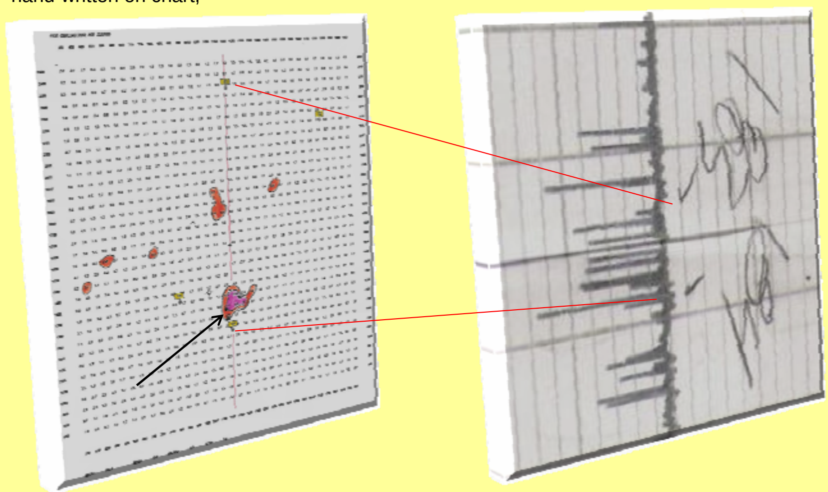
The Maui field (identified by the white circle) is located in a water depth of 110m. Several other anomalies can be seen on the western half of the survey area and should provide a "focus" for further investigation.

The data were collected using an early version of author Jackson's "Airborne Transient Pulse Survey" (P-TEM).

Notes by Presenter: This map was created from a grid of Airborne Transient Pulse data collected by flying parallel flight lines. The anomalous transient responses are shown in **red.** Note the Maui, Kapuni, and Kaimiro fields all have anomalous levels of transient activity. The Maui Field has produced over 2.9 TCF of gas and about 225 million barrels of condensate, whereas the onshore fields are much smaller.

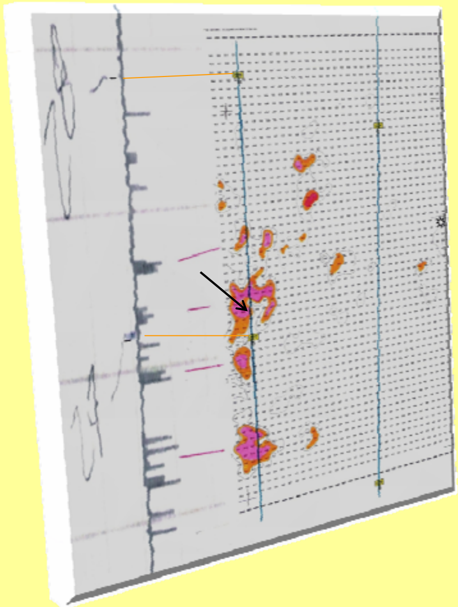
P-TEM Survey- Alberta

In 2002 author Jackson flew his first Airborne Transient Pulse Survey over the Fenn Big Valley area of Alberta. (Left) Gulf-Leland's Leduc-Nisku field Alberta, as mapped by author LeSchack's Magnetic HG' Survey. This field with 3 wells, where the black arrow points, produced 750,000 bbls oil, and is only 150m in diameter. (Right) During that survey, Airborne Transient Pulse P-TEM data were recorded on strip-charts showing pulse density variations (excursions to left of baseline) over oil fields. GPS locations were hand-written on chart,



Notes by Presenter: Illustrated on the left is the Gulf-Leland Leduc pinnacle reef oilfield in the FBV area of Alberta. That reef, 150m in diameter, made 750,000 barrels of light oil in 4 years. We used the Gulf-Leland Leduc reef pinnacle field as a model for pinnacle reef exploration. Author Jackson worked with us here, testing his instrumentation. He knew where the field was located and flew directly over it for this first airborne test.

P-TEM Survey- Alberta (2)



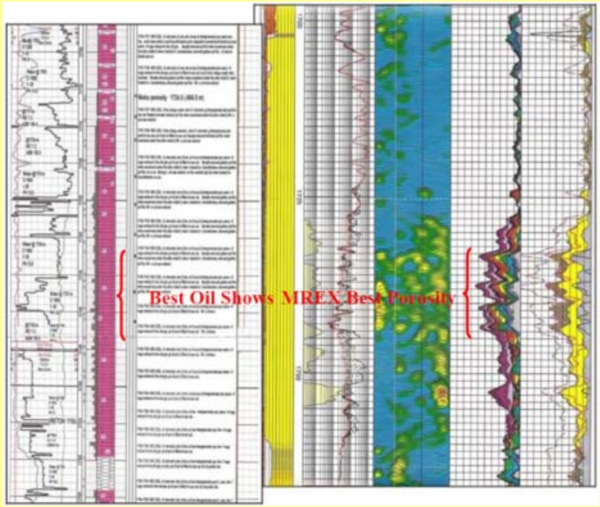
Blind Airborne Transient-Pulse-Survey P-TEM line, also flown in 2002, chanced to fly over the Ground- Magnetic HG' Survey of author LeSchack's Leduc and Nisku prospects, Alberta. Here, the strip-chart recorded over the field has been stretched to the same scale as the map, and Transient Pulses are excursions to the right of the baseline.

An arrow points to well drilled in 2007 at the center of the big HG' Anomaly, just northwest of GPS Point 27. A good Nisku Formation reservoir with 18m of 33.1 API pay was discovered.

Notes by Presenter: During that same first Airborne Survey, Jackson also, by chance, flew over one of my prospect areas. This, therefore, was a blind test. I only gave Jackson the corner-coordinates of our survey area where we had mapped potential Leduc Pinnacle reef prospects, using our magnetic HG' surveys. By chance, he flew over a swarm of such reservoirs and identified every one he crossed. The eastern flight-line to the right crossed no magnetic HG' anomalies, and no Airborne Transient Pulse Anomalies were seen on that line.

We drilled at the black arrow, and a potentially good Devonian Nisku reservoir was discovered.

Well Ties To P-TEM



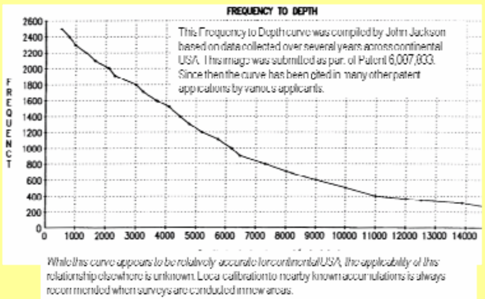
The well as drilled on one of author Jackson's anomalies identified on his first Airborne Transient Pulse Survey, and shown in the previous slide, discovered 18m of Nisku 33.1 API oil as attested to by (1) an analyzed swab sample, and (2) author Ghazar's mud-log on left (note 3 solid oil-show symbols, 5m apart), and (3) author Ionkina's Magnetic Resonance log on right.

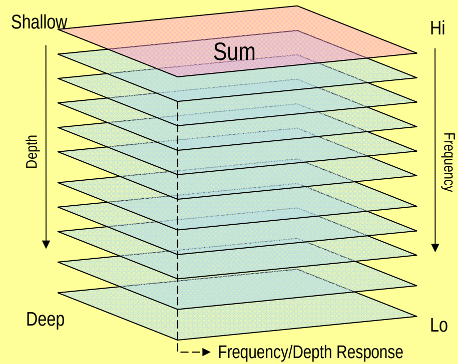
Notes by Presenter: 18m of Nisku 33.1 API oil was encountered. This was confirmed by (1) analysis of swab samples, (2) author Ghazar, the Independent well-site geologist, and (3) author Ionkina, the Independent petrophysicist who insisted we run the MRX log seen at right.

New Technology: A-EM Survey & Frequency-Depth Calibration

Author Jackson empirically observed that the dominant frequencies of Transient Pulses emanating from the subsurface varied as a function of depth. These frequencies, in the audio range, were plotted, as seen below and appear to be a continuous function, as described in his US Patent 5,777,478.

It follows, therefore, that electronically parsing pulses of different frequencies in a survey can estimate the depths from which they emanated. The F-D curve may vary around the world, and recalibration over nearby oil fields should be conducted.



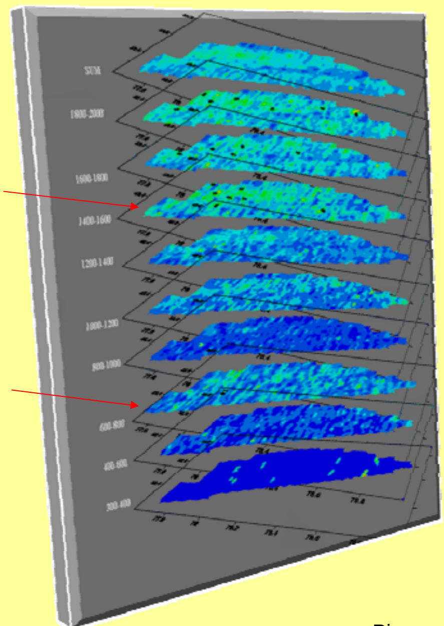


Note: We use Airborne A-EM Transient Pulses for identification of apparent resistivity.

Notes by Presenter: Our "Major Recent Improvements to Airborne Transient Pulse Surveys": **Estimation of depth of HC.**
Author Jackson empirically observed that the dominant frequencies of Transient Pulses emanating from the subsurface varied as a function of depth. These frequencies, in the audio range, were plotted against depth, as seen in the slide and appear to produce a continuous function. So band-pass filters can parse into separate bands the frequencies of the transient pulses.

The diagram to the right illustrates how consecutive frequency/depth slices of Transient Pulse density of different frequency groups can logically be interpreted as lithology.

New Technology- The Airborne A-EM Survey

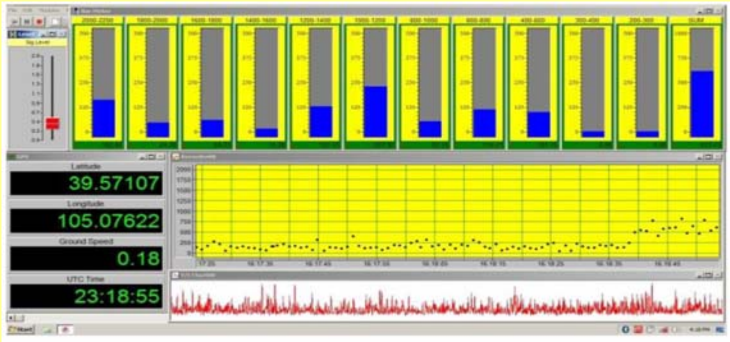


- Our recent technological improvements provide not only the ability to measure subsurface <u>Transient Pulse</u> anomalies from airborne platforms but:
- As opposed to the earlier P-TEM technology just discussed, the current technology, which we call Airborne “Audio-Frequency Electromagnetics” or (A-EM), can record the earth’s passively-generated Transient Pulses that likely are associated with REDOX cells.
- A-EM measures from an airborne platform apparent conductivity as a function of depth in the earth. We note that the higher the conductivity of any given horizon, the fewer the number of Transient Pulses, while the lower the conductivity; e.g., **owing to presence of hydrocarbons, the more Transient Pulses emanating from that horizon**.
- Author Jackson empirically derived a continuous, but non-linear, function which relates inherent frequency of the pulse energy to the depth beneath the surface from which the pulses emanated.
- Shown left - example survey conducted fall 2008 in Kyrgyzstan, Asia. The survey indicates prospective section at the 600Hz level with medium to heavy seepage starting at the 1400Hz level.

Notes by Presenter: Example survey conducted fall 2008 in Kyrgyzstan, Asia. The survey shows Transient Pulse density vs Frequency and indicates prospective HC section at the 600Hz level **(lower red arrow)** with medium to heavy HC seepage—as sometimes occurs—starting at the 1400Hz level **(upper red arrow).**

Our interpretation, therefore, would to look at the 600hz level for the reservoired HC.

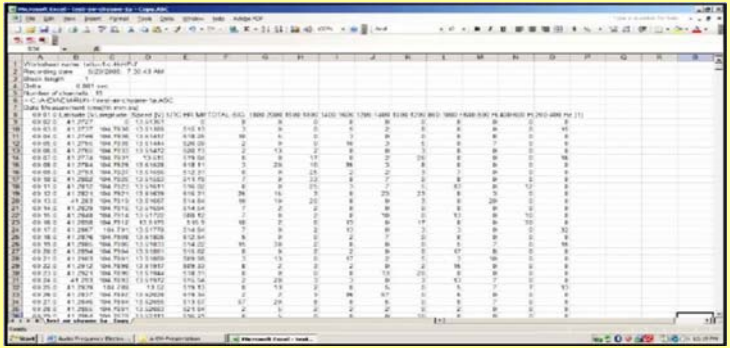
On Board Computer – Airborne Transient Pulse Data Acquisition



Screenshot of the onboard computer processing the parsed pulse frequency data into segregated bands, representing discrete depths. The fuller each bin, the more recorded pulses per unit time, the less the conductivity at the depth that the associated bin represents, and therefore, the greater the likelihood of hydrocarbons at the corresponding depth. These pulse data are collected along with latitude, longitude, ground speed, and time. The top-right data bin on the screen is the summation of all the preceding bandwidth segments.

Notes by Presenter: The screen of the onboard computer graphically shows the 11 band pass bins into which the parsed transient pulse data are collected and pulse density counted.

Data Collection



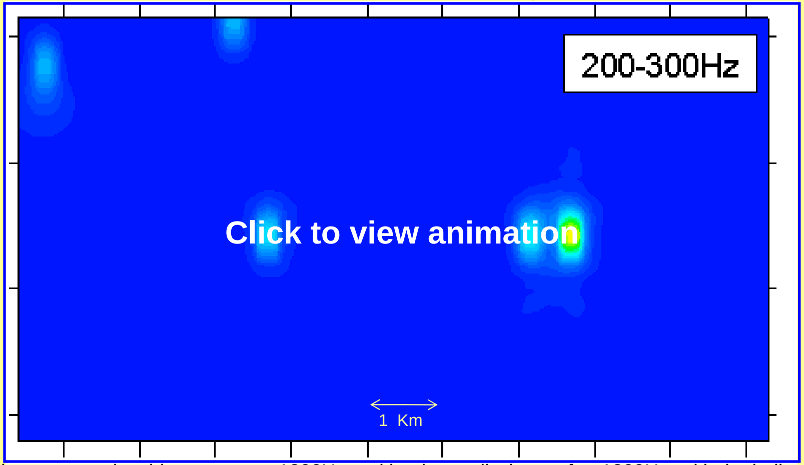
All of these parsed-frequency data are recorded in spreadsheet format as a function of time for the entire survey, at the conclusion of which appropriate processing for map-making can then be conducted. This is our A-EM **Airborne Transient Pulse Survey**, a major recent improvement in airborne reconnaissance for hydrocarbons.

Notes by Presenter: All of these parsed-frequency data are recorded in spreadsheet format as a function of time for the entire survey, at the conclusion of which appropriate processing for map-making can then be conducted.

Example: Western Australia

Airborne
A-EM for identification of apparent resistivity using Transient Pulses.

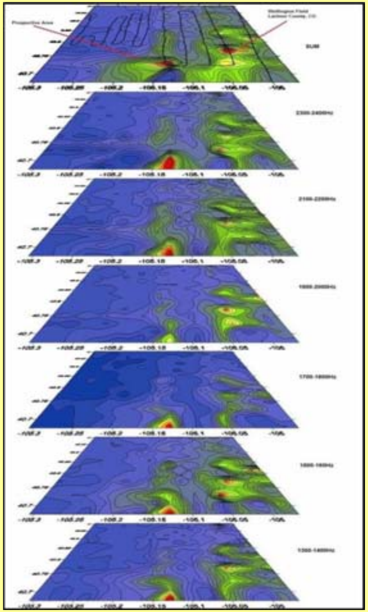
Frequency bands from test over existing onshore (Mt. Horner) field in Australia. (Click to view animation.)



Signal becomes noticeably stronger at 1200Hz and begins to dissipate after 1800Hz, with the bulk of the SUM between 1500Hz and 1700Hz, suggesting a depth range between 910m to 1370m, which corresponds to zones of production (both oil & gas) and hydrocarbon shows.

Notes by Presenter: This slide shows the spatial change in Transient Pulse density as a function of discrete frequency bandwidths, i.e., depths. The lower the frequency, the deeper the depth. The bulk of the Transient Pulse energy appears between 1500hz and 1700hz (approx 910m to 1370m), which is where the producing formation (both gas and oil) is located. Field is approx 7km by 10km.

Example: Larimer County Colorado Frequency vs Depth



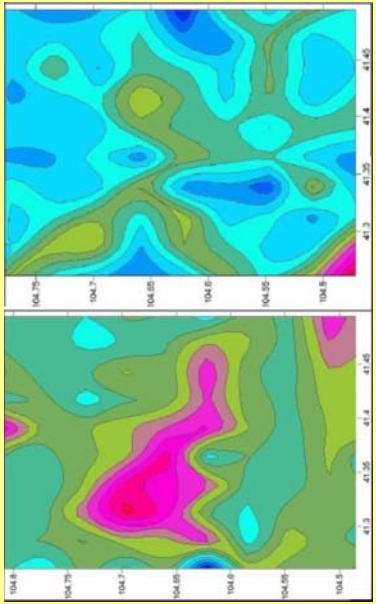
Selected Frequency-Depth slices of an A-EM survey flown over an oilfield in Colorado are mapped and stacked by frequency/depth.

Red indicates highest Transient Pulse activity. Interpretation of the data slices suggest the producing area for this mature field as being between the bottom two slices; i.e., 1280m and 1370m, from the Frequency-Depth Curve (as calibrated for the United States).

The top slice is the Summation of all slices. That slice also shows the flight line path, as well as suggesting an as yet undrilled anomaly.

Notes by Presenter: Selected Frequency-Depth slices over an oil field are mapped and stacked so that geologists can interpret them in terms of lithology and can estimate likely depth at which HC can be encountered.

A-EM Silo Oil Field, Niobrara Production



An Airborne A-EM Survey was conducted over Silo Oil Field in SE Wyoming, producing from the Niobrara Formation. Only two Frequency-Depth slices are shown here; they illustrate the dramatic difference of contour values where hydrocarbons are present (as opposed to where they are not) as differentiated by pulse-frequency parsing.

<u>(Above)</u> The slice corresponds to the 620m-930m depth, and <u>(Below),</u> the slice corresponds to 2230m-2640m depth; this is the producing interval. The contour color scale for both depth-slices is the same. Reds and pinks represent the greatest pulse density, or lowest conductivity, as is expected where hydrocarbons are present. The survey size was 25 nautical miles by 15 nautical miles and survey was conducted with E-W lines spaced 1 NM apart.

Notes by Presenter: An Airborne A-EM Survey was conducted over Silo Oil Field in SE Wyoming that produces from the Niobrara Formation. Only two Frequency-Depth slices are shown here: they illustrate the dramatic difference of contour values where hydrocarbons are present (as opposed to where they are not) as differentiated by pulse-frequency parsing.

Summary

- The Airborne Transient Pulse Surveys described offer a simple, rapid, non-invasive, and cost-effective reconnaissance method to identify areas of abnormal EM transient activity, providing focus for subsequent exploration efforts.
- The techniques appear to be effective at detecting geophysical phenomena related to REDOX cell activity. The A-EM technique appears also to provide an indirect indication of target depth.
- During the past decade, over 130 proprietary Airborne Transient Pulse Surveys have been flown worldwide: in Australia, Canada, Europe, New Zealand, the United States and the North Sea. This comprises more than 200,000 Nautical Miles of survey lines over productive areas, both onshore and offshore, as well as over ice-covered waters. This technology, like all other geophysical exploration techniques, are tools which, on their own, often provide non-unique solutions. When used in combination with other independent methods, they often yield an integrated solution that will reduce non-uniqueness, risk and finding costs.
- **Our statistics, based on drilling positive anomalies, suggest at least 80% success using these surveys.**

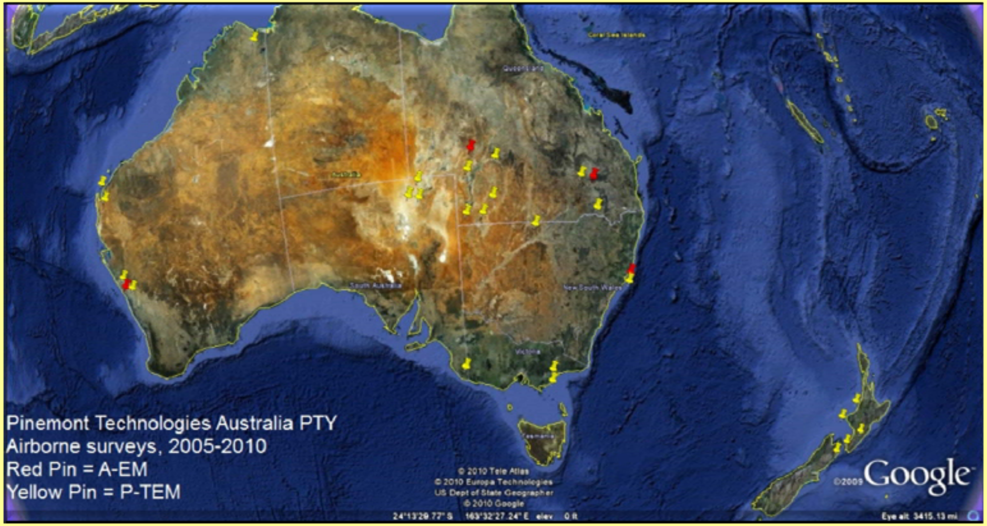
Notes by Presenter: The Airborne Transient Pulse Surveys provide focus for subsequent exploration efforts, such as specific, detailed seismic or geochemical surveys, like soil-gas sampling or Passive Telluric surveys.

The A-EM technique appears also to provide an indication of target depth
During the past decade, over 130 proprietary Airborne Transient Pulse Surveys have been flown worldwide: in Australia, Canada, Europe, New Zealand, the United States and the North Sea. This comprises more than 200,000 Nautical Miles of survey lines over productive areas, **both onshore and offshore, as well as over ice-covered waters, with suggestion of at least 80% success using these surveys.**

Airborne Transient Pulse Surveys conducted in North America

Over 130 Airborne Transient Pulse Surveys have been flown worldwide most of which have been in North America.

Airborne Transient Pulse Surveys conducted in Asia-Pacific



Notes by Presenter: Surveys flown in Australia and New Zealand.

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