A Comparison of Airborne and Ground EM data at a Calibration Site near the Grand Canyon

L.J. Davis

R.W. Groom

Petros Eikon Inc.

Purpose of Calibration Site

Airborne TEM :

- used extensively for picking conductors in mining exploration

- **can it used for more quantitative interpretation and thus in a in a wider range of applictions?**

Quantitatively consistent with:

1) Ground TEM ?

1) Geological information ?

Calibration Study

To compare data and structural results from

1) 2007- Airborne surveys: MegaTEM, GeoTEM, VTEM

2) 2008- ground TEM surveys: extensive Protem (Geonics), small GDP-32 (Zonge)

3) 2008- ground FEM systems: VLF-R (2 frequencies),

MaxMin (2 separations, 4 frequencies)

4) 2008- drill logs

over the calibration site.

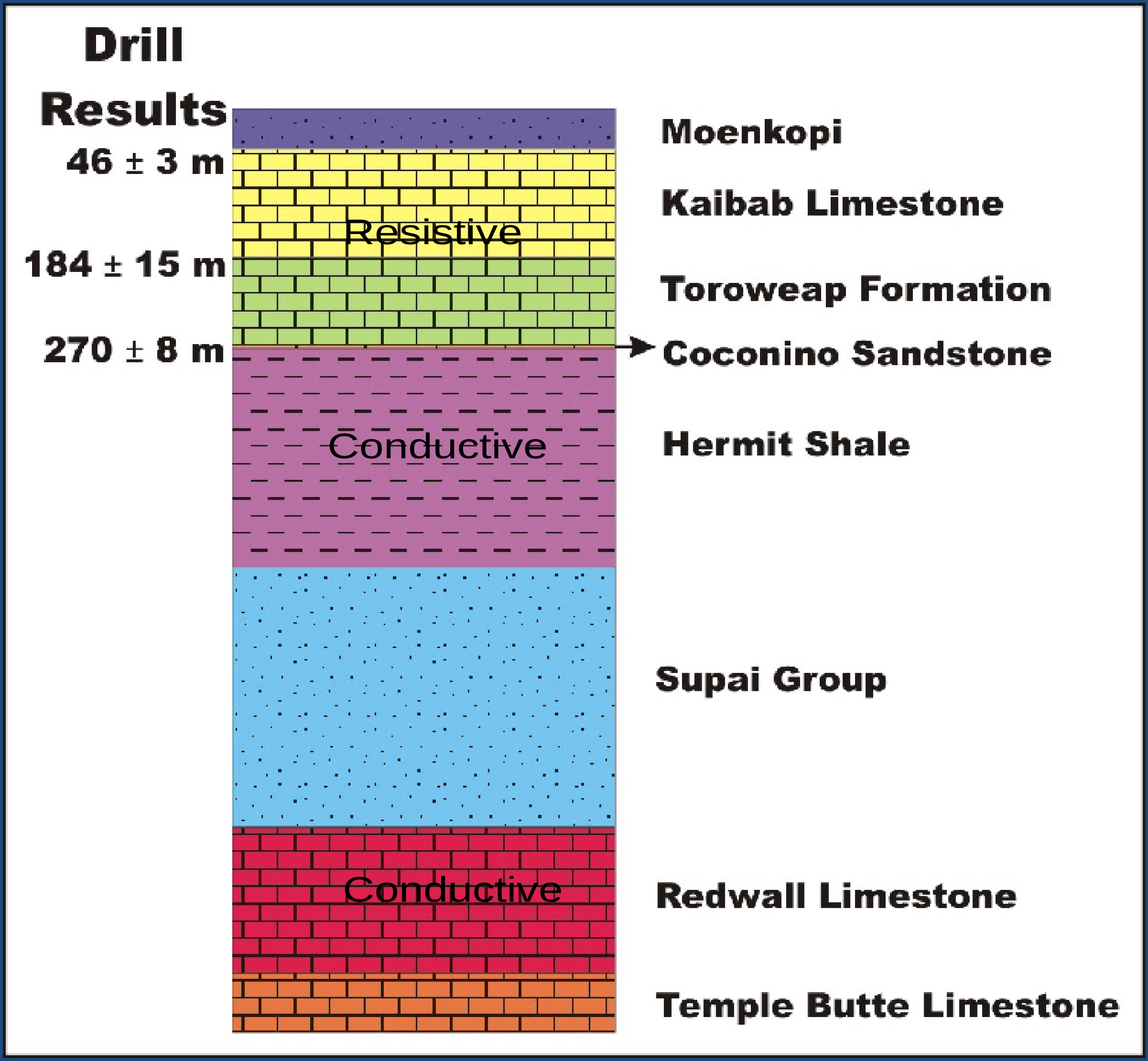
Data thanks to Uranium One USA

Site

[from Google Earth]

- North of the Grand Canyon (Arizona Strip)
- 2005-2009, *active exploration for breccia pipe uranium deposits*
- Host environment: *a deep sequence of sedimentary rocks*

Geology

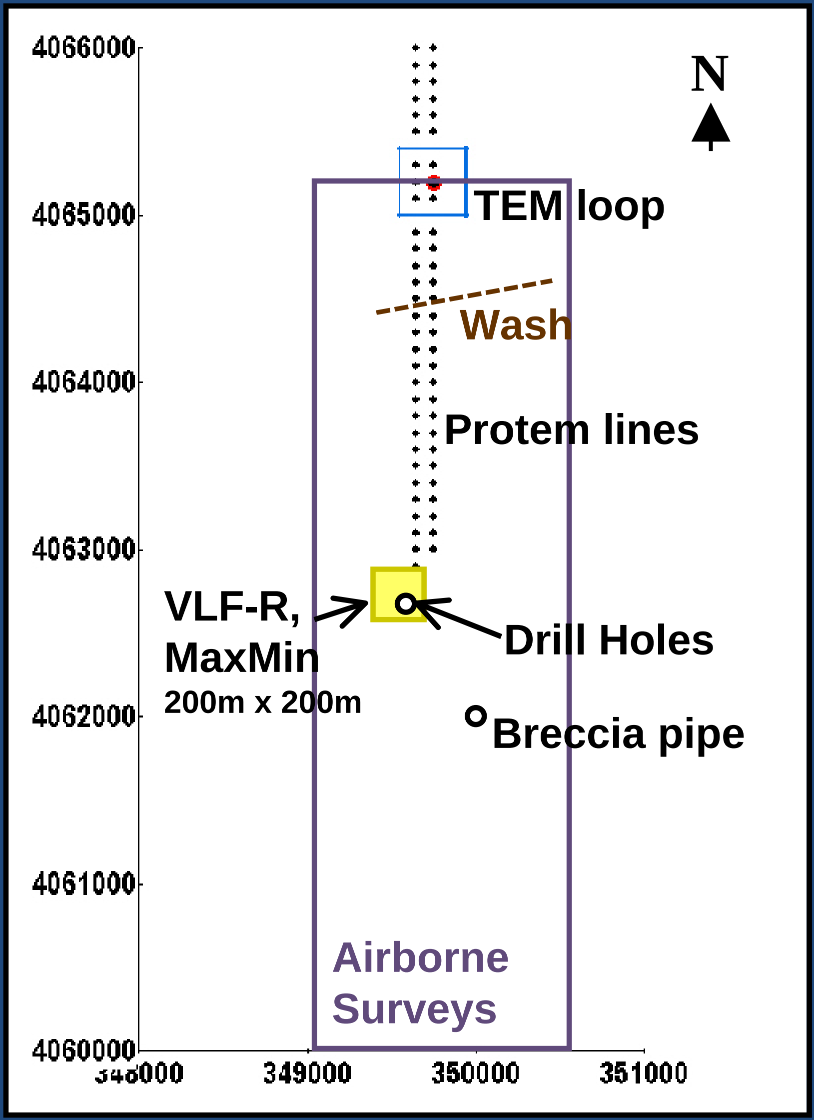


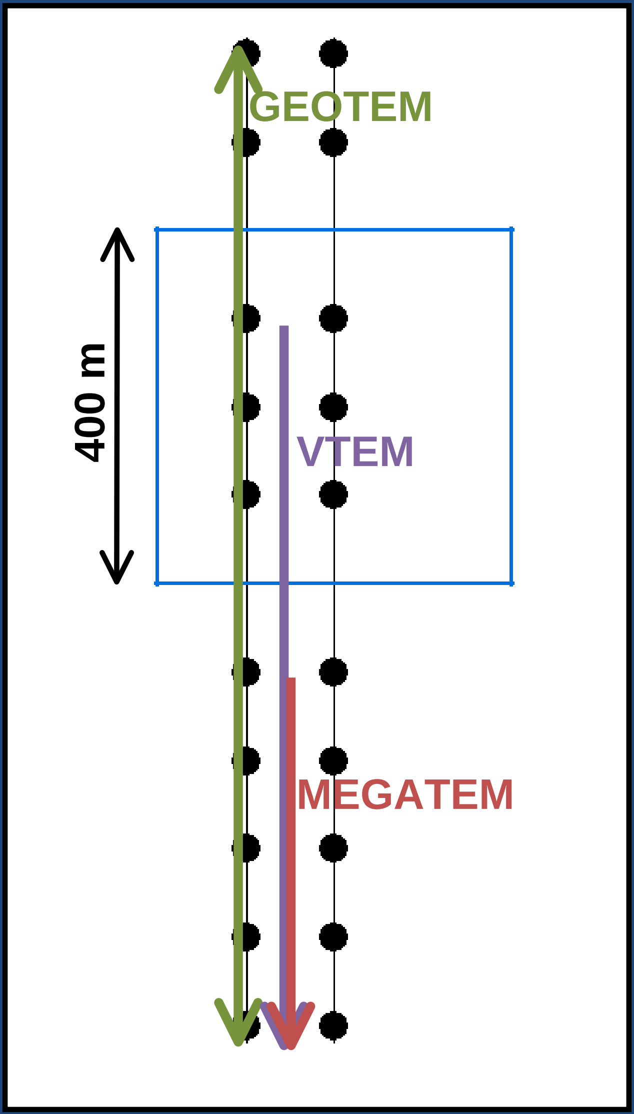
Suitable calibration site:

- Sedimentary layers with contrasting EM properties
- Limited 3D structure

Toroweap?
Supai ?

Survey Location

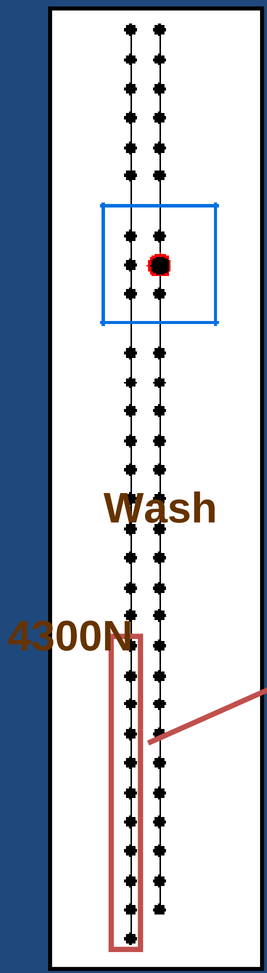


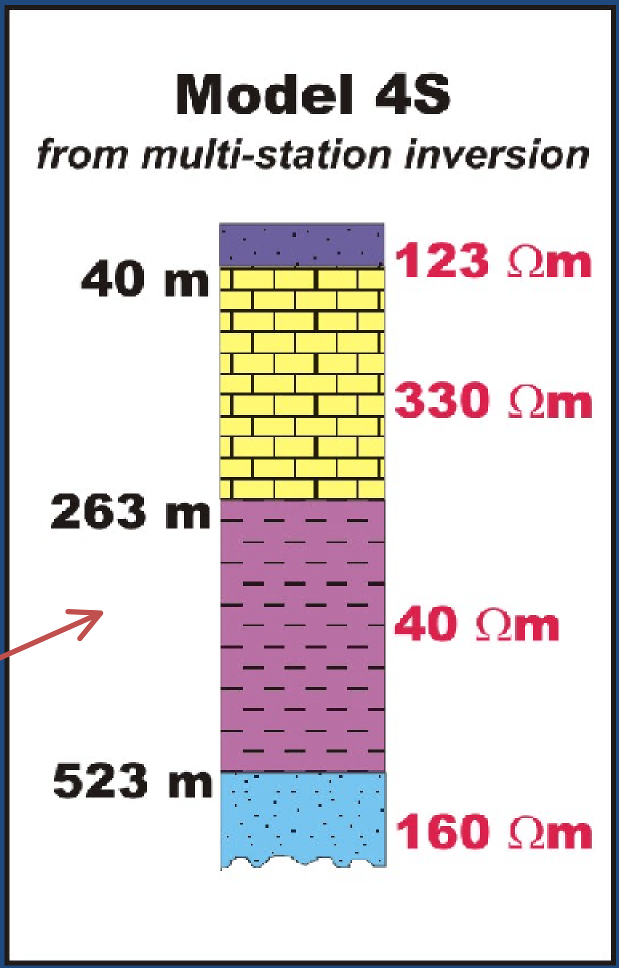


Calibration Area: 5km x 1.5 km

Line Spacing: approx 100m

Ground TEM: Model



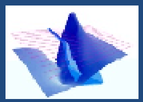


Ground Model 4South
from multi-station 1D inversion using 11 wide-offset stations (1.3 – 2.3 km S of loop center 2900-4300N).

Model 4S fits Hx, Hz
across entire survey indicating limited lateral variation.

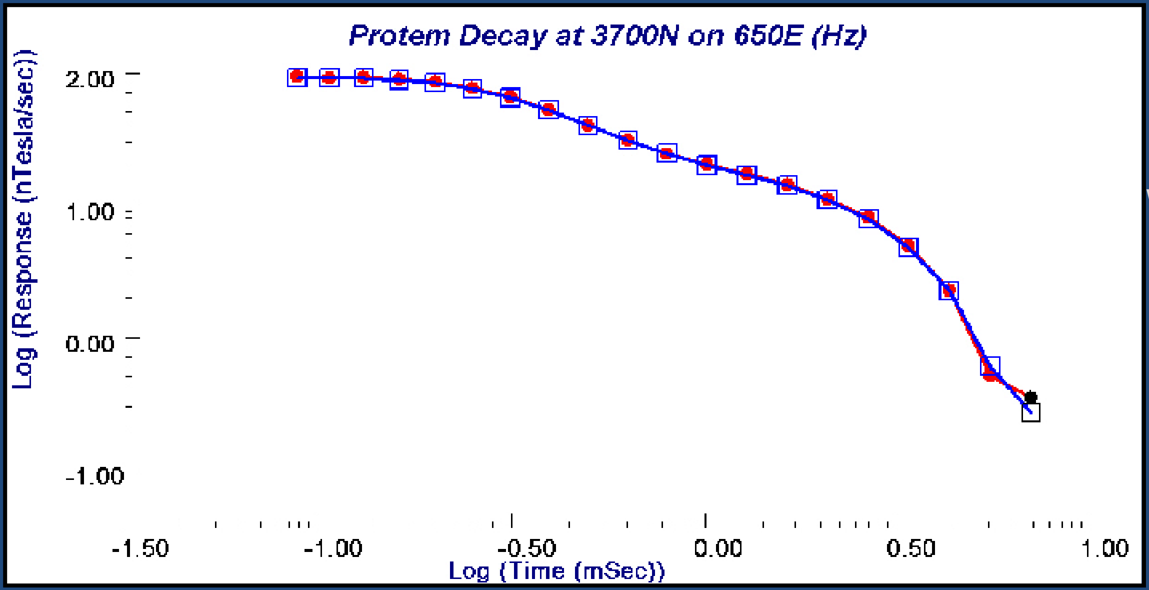
Ground Model 4North
Slightly thinner limestone north of wash (4500N)

Inloop and Short Offset Data
Provides less depth resolution



Modeling and inversion were performed using EMIGMA v8.1 *(PetrosEikon, 2009)*

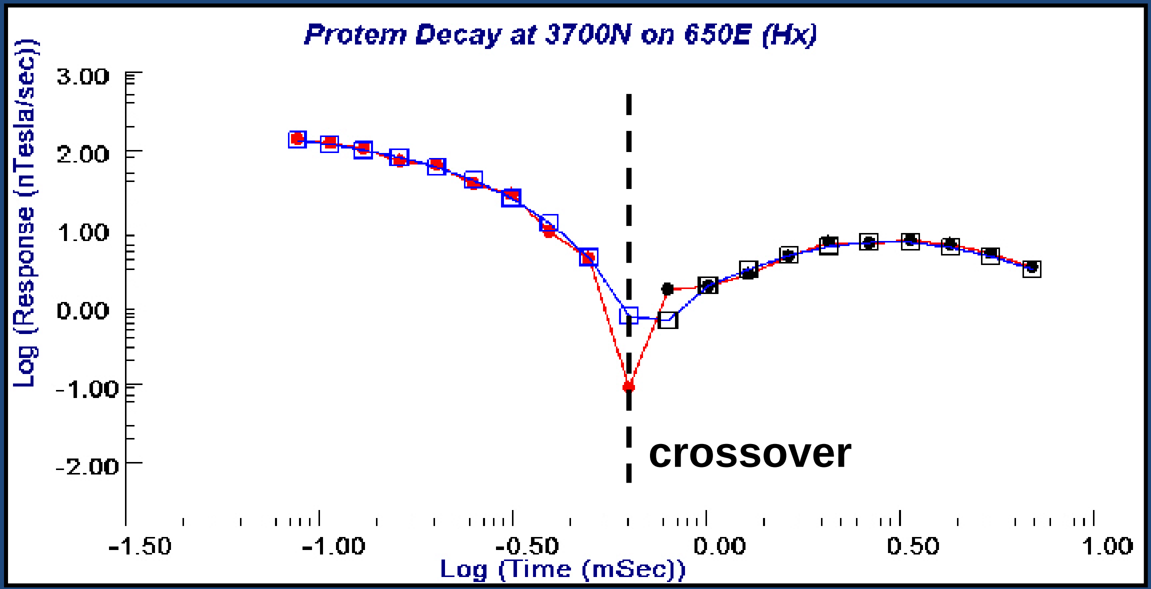
Ground EM: Model to Data



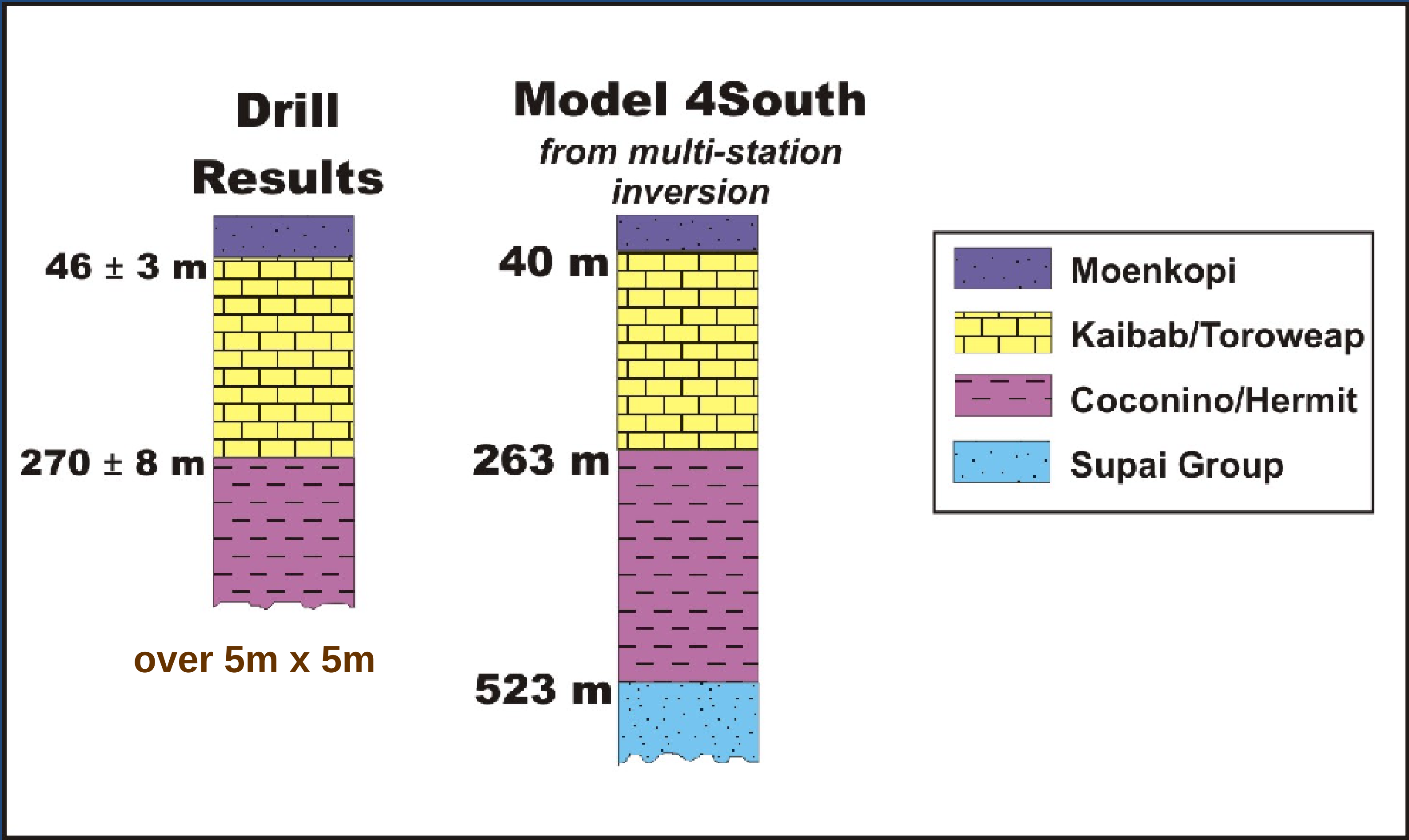
Why not show 3 stations?

Bandwidth?

- Measured
- Model 4South

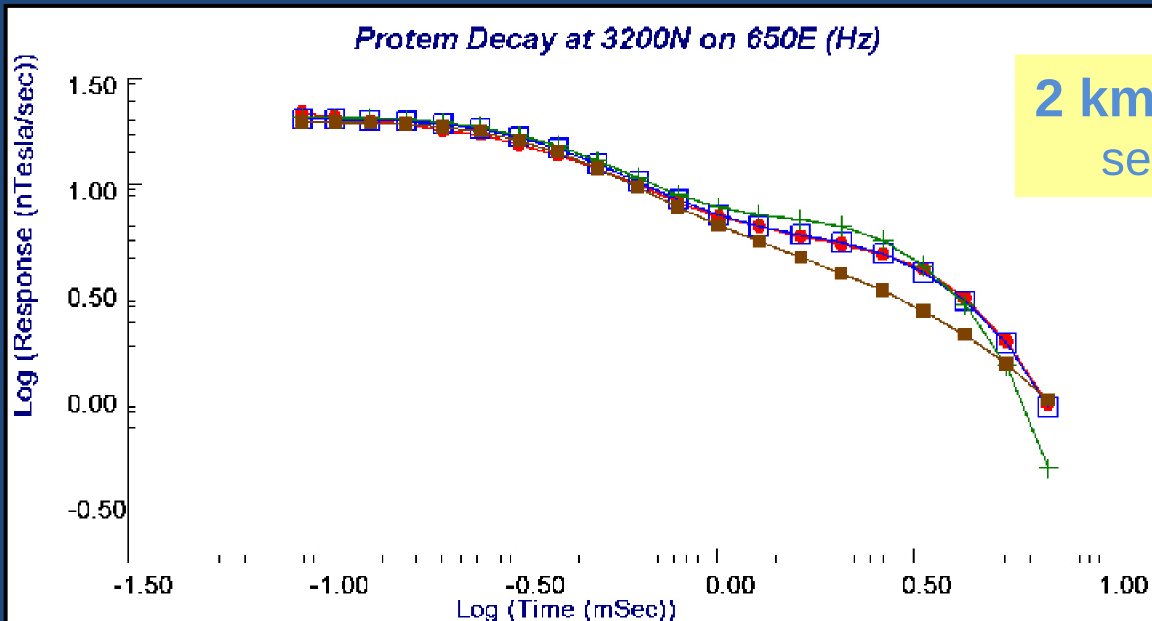


Comparison of Model with Geology



- Drill results just south of ground survey confirm Model 4S.
- Moenkopi resistivity (123 Ωm) of Model 4S close to resistivity determined from VLF-R and MaxMin data. (thickness uncertain)

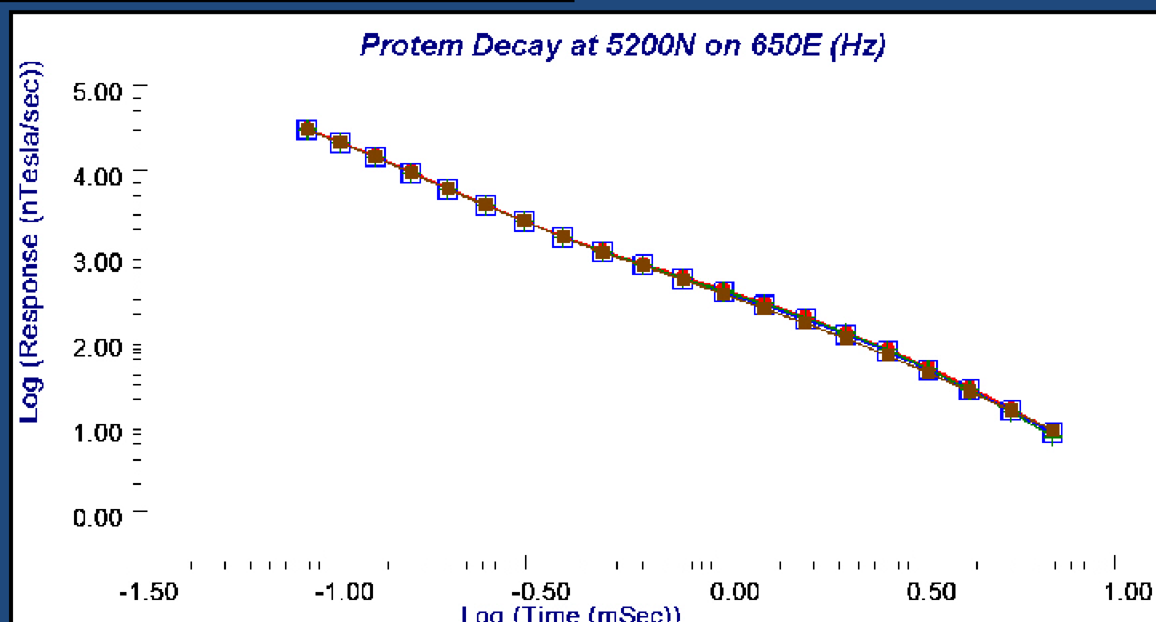
Ground EM: Depth Resolution



2 km south of Loop Center
sensitive to Supai

- Measured
- Model 4South
- Resistive Supai
- No Supai

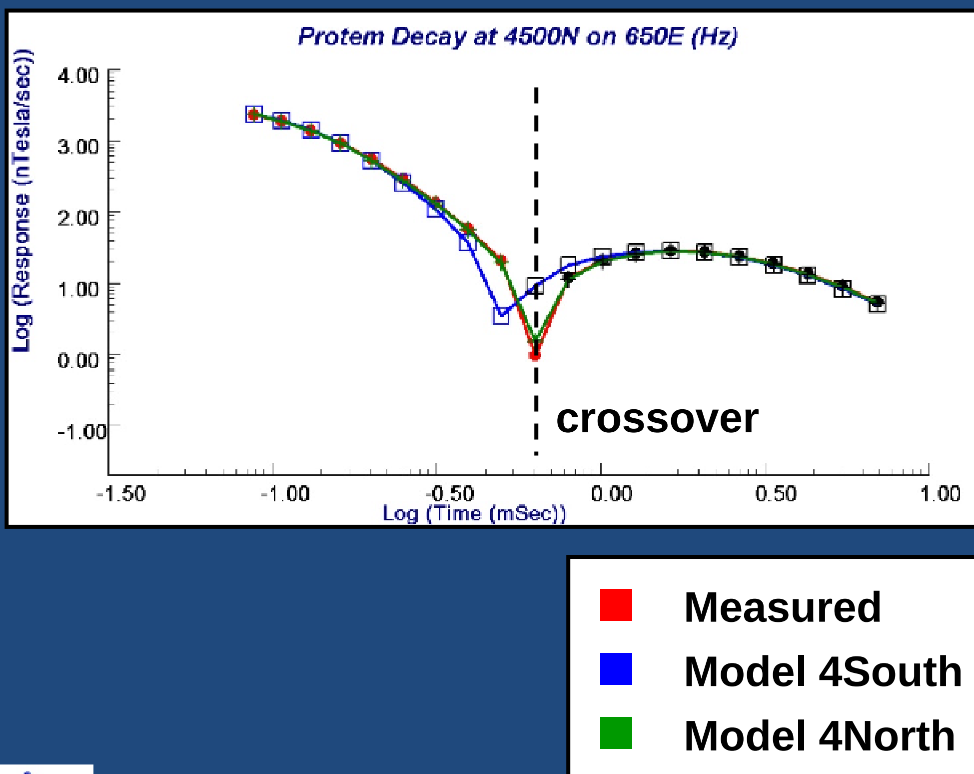
Center of Loop
Limited sensitivity to Supai
All 3 models fit equally well

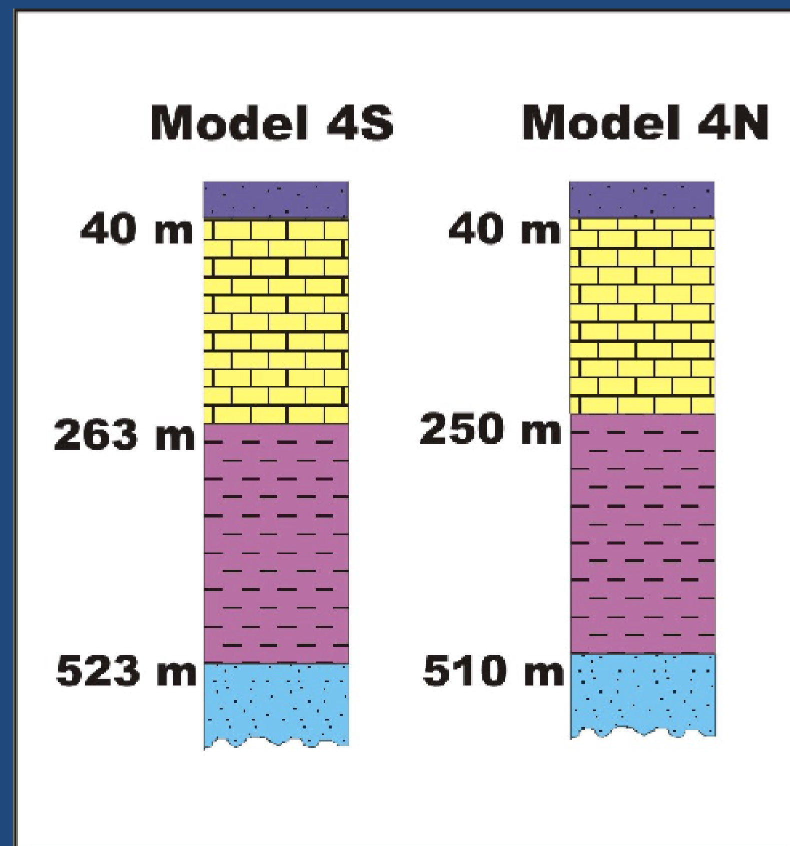


Ground EM: Variation across Survey

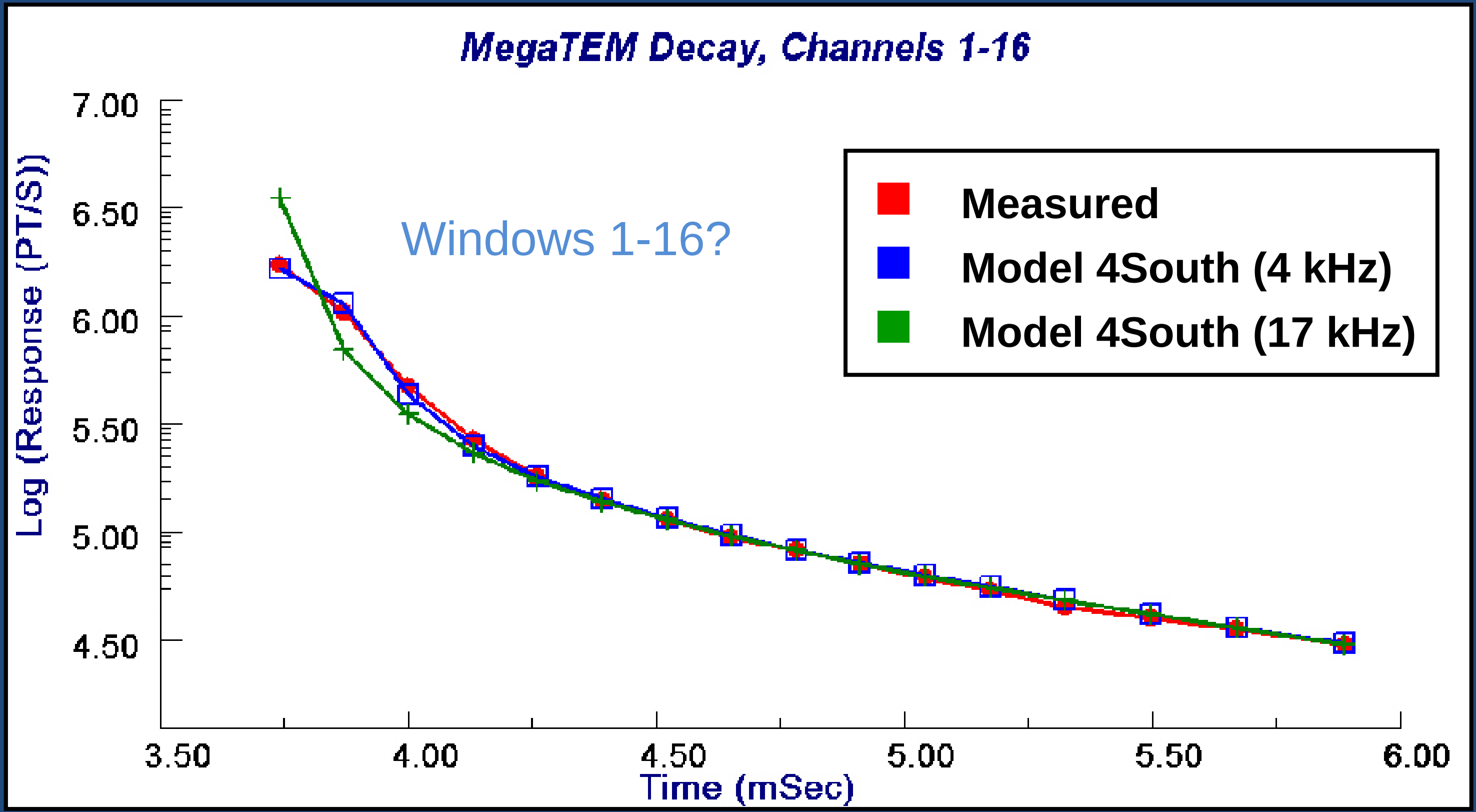
- Model 4N: North of 4400N. thinner Kaibab/ Toroweap by 13 m

➢ ***With careful analyses of the ground data, we can detect small changes in lithology.***



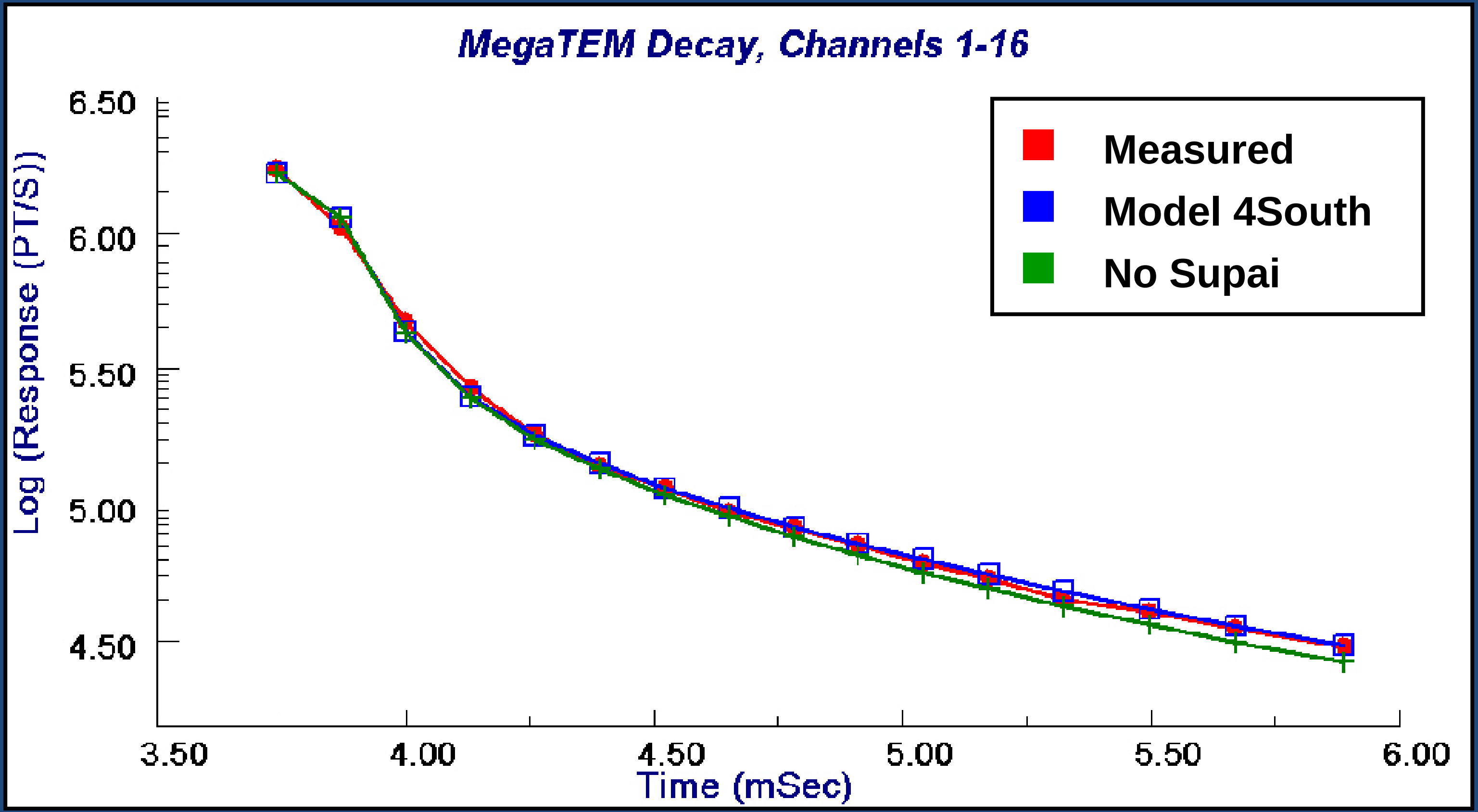


MegaTEM: Fit to Ground Model



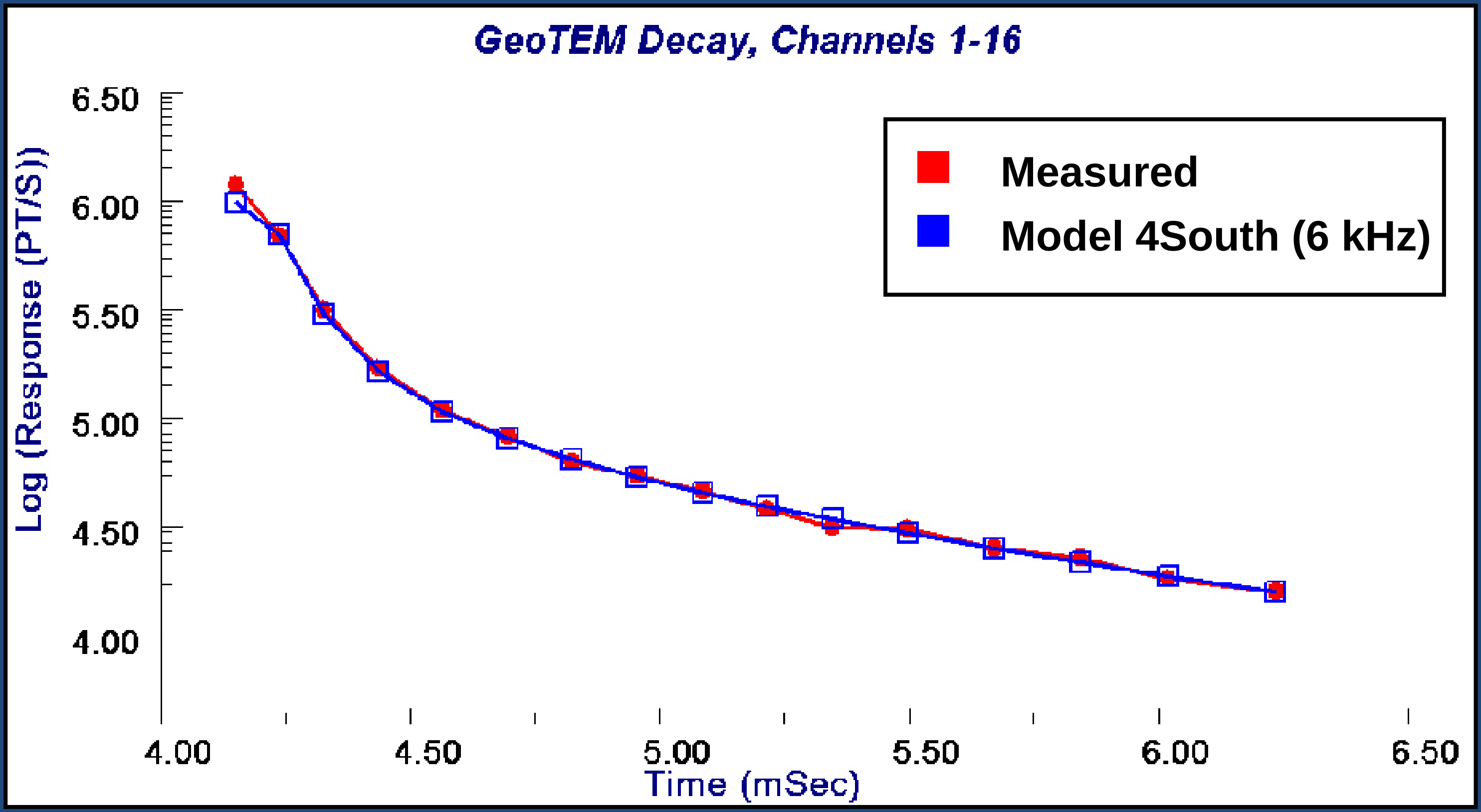
- Model 4South fits the MegaTEM data just south of the wash (4300N) if an upper frequency bandwidth of 4 kHz is used.
- Waveform files were used to study pulse width, dipole moment, window positions, Tx-Rx separation and system bandwidth. Accurate modeling requires precise knowledge of settings.

MegaTEM: Depth Resolution



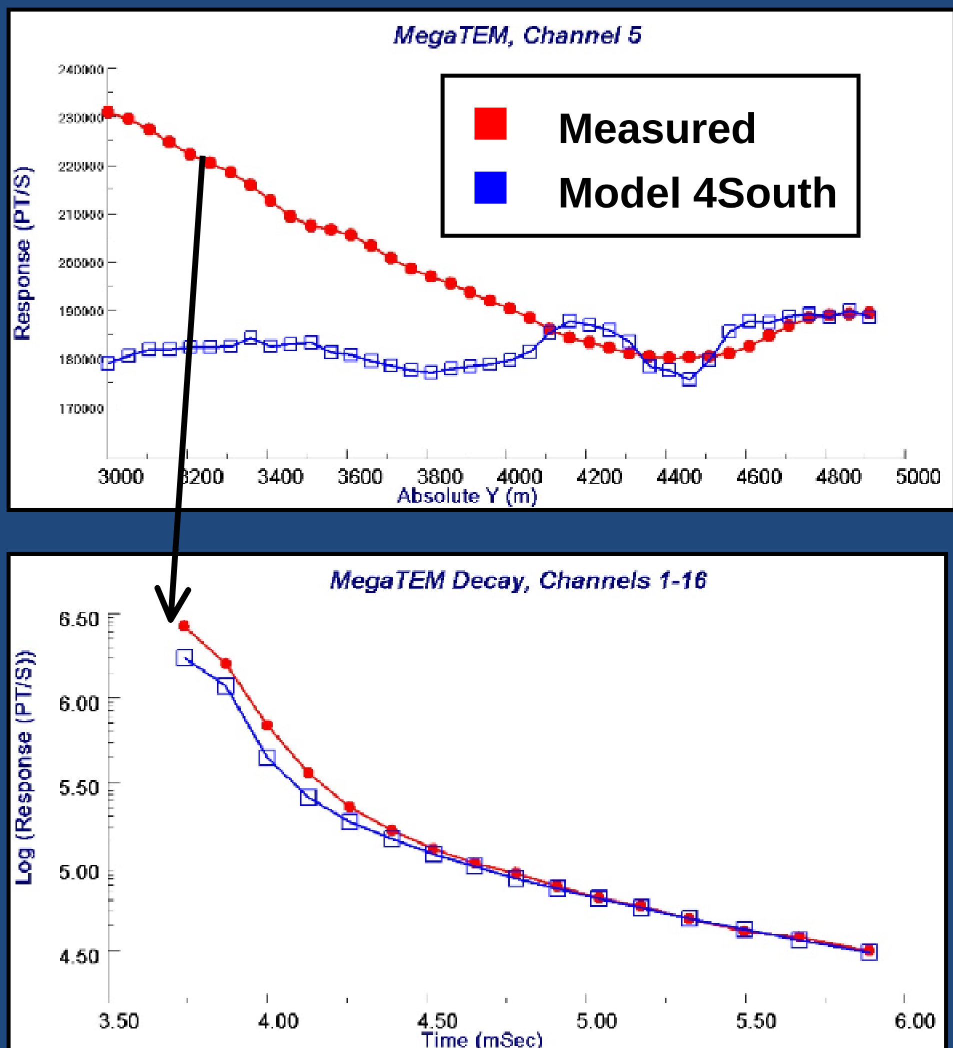
Removing the fourth layer (Supai Group) has a small but definite effect on the response at mid to late times.
Note: This 4th layer has a significant effect on the ground response at wide offsets. MEGATEM offset is 125m only

GeoTEM: Fit of Ground Model



Model 4South fits the GEOTEM reasonably well just south of the wash, provided an upper bandwidth frequency of 6 kHz is used. Again the Supai structure is required to fit late time

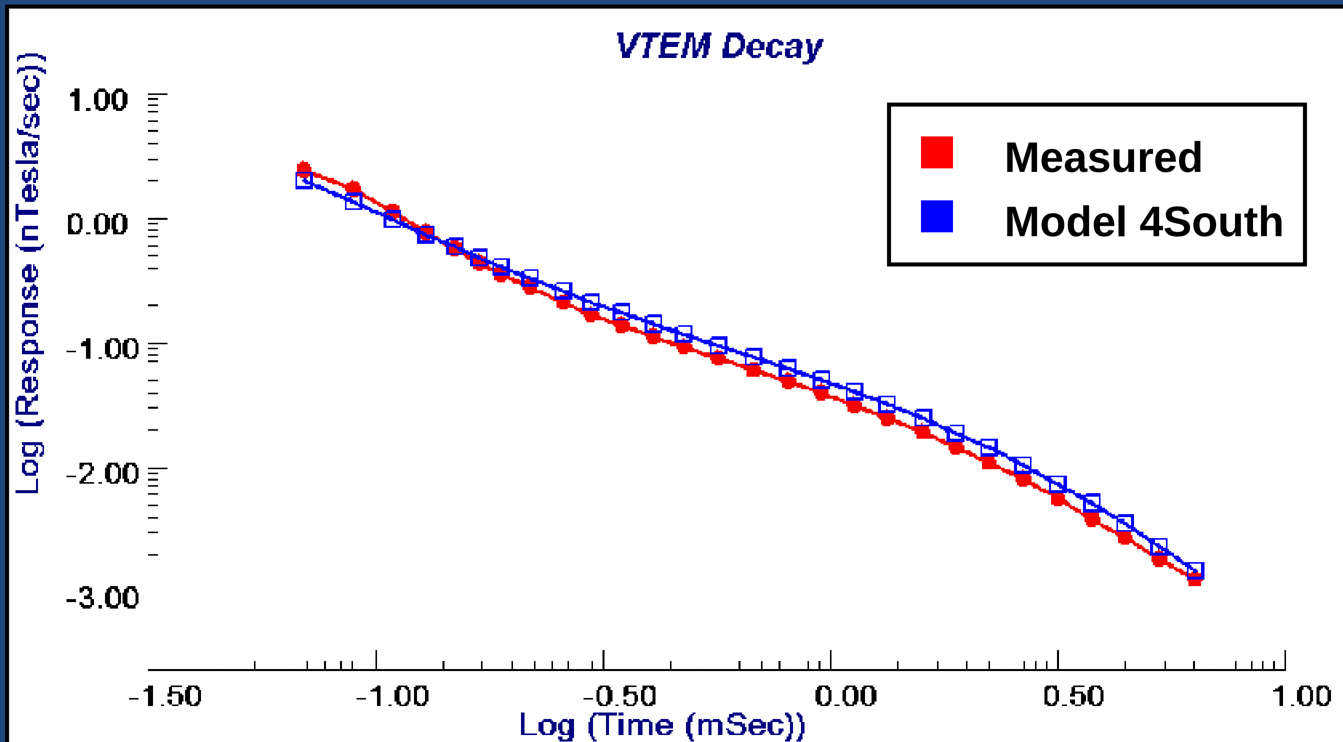
MegaTEM: Variation across Survey

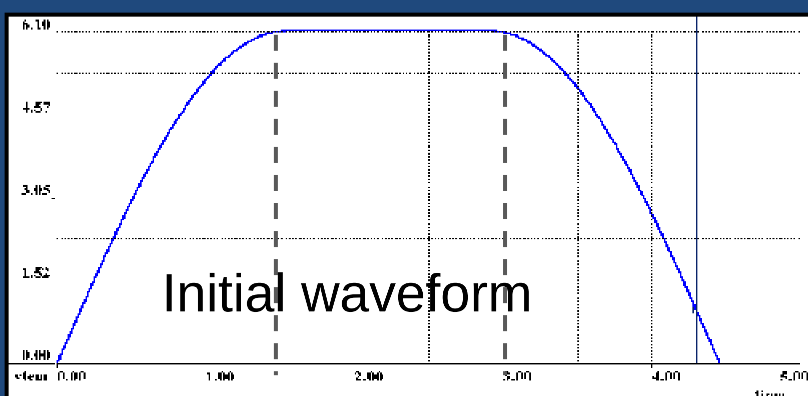


- MEGATEM data suggests shallow conductance south.
- ground survey has limited sensitivity to a shallow conductor far from the loop.
- more conducting surficial structure likely a layer of lower resistivity at the base of the Moenkopi.

Station: ?

VTEM: Initial Waveform



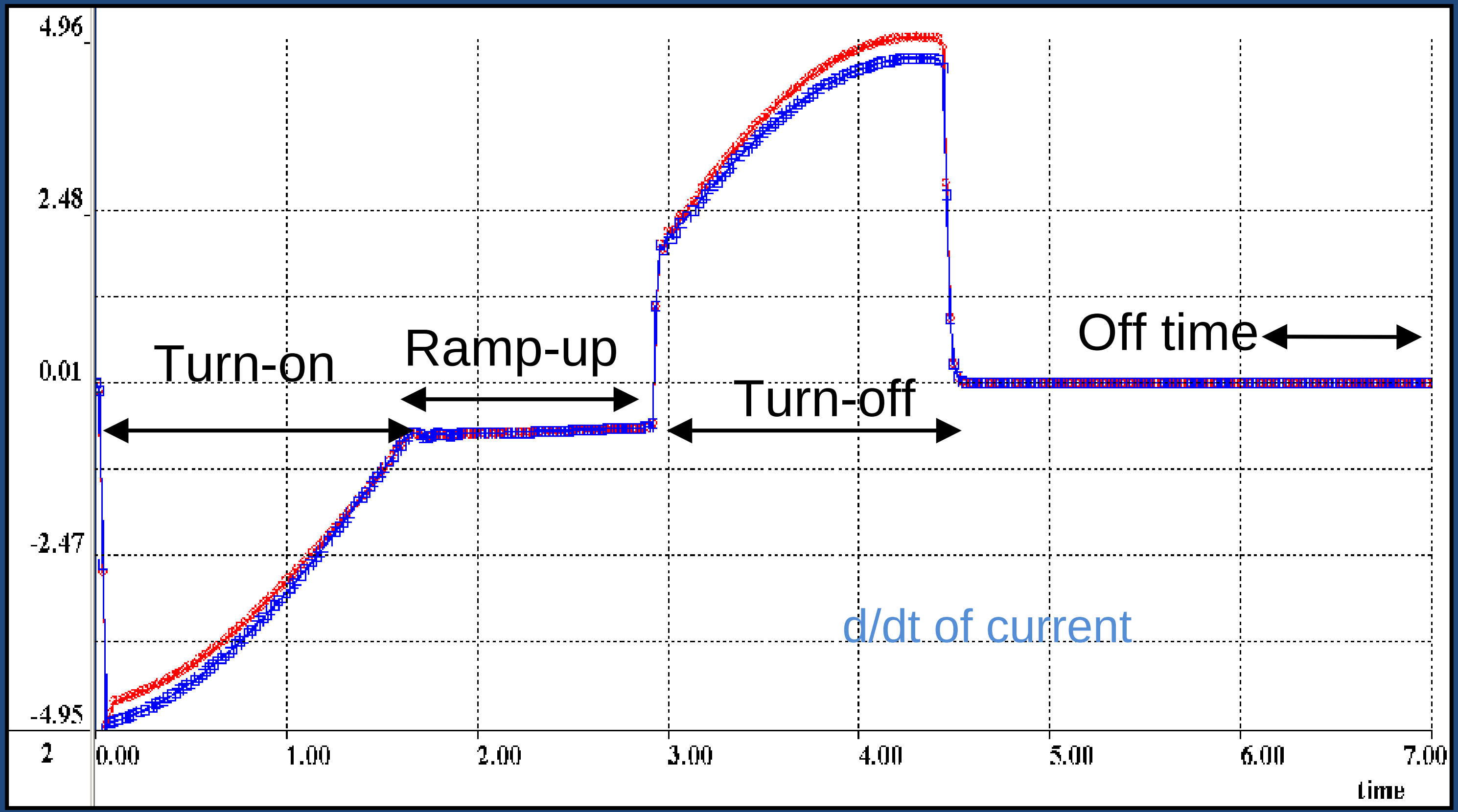


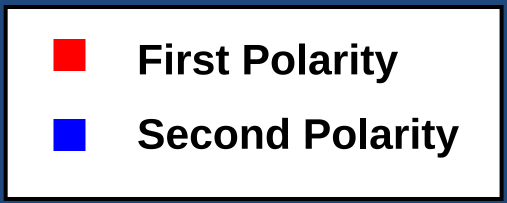
- Initial waveform for simulation:

¼ sinewave turn-on and turn-off utilizing a turn-off time as given by waveform files

- Model 4South does not fit the data
- Too large at mid to late times, too small at early times.

VTEM: Waveform File

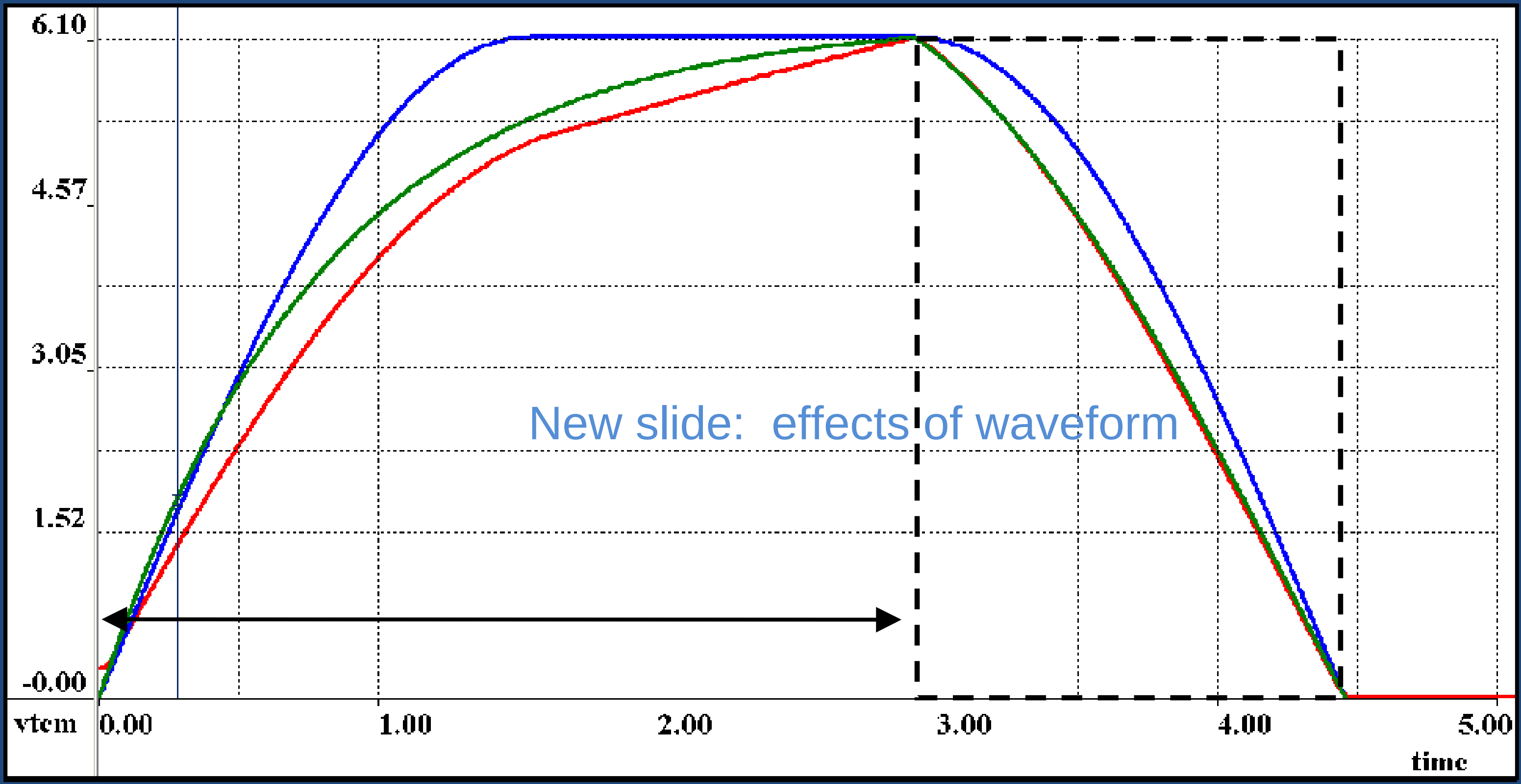




The system uses a bi-polar waveform stacking measurements from both polarities

Bandwidth of early time spike not consistent with the bandwidth of the mid ontime ringing and early off-time response

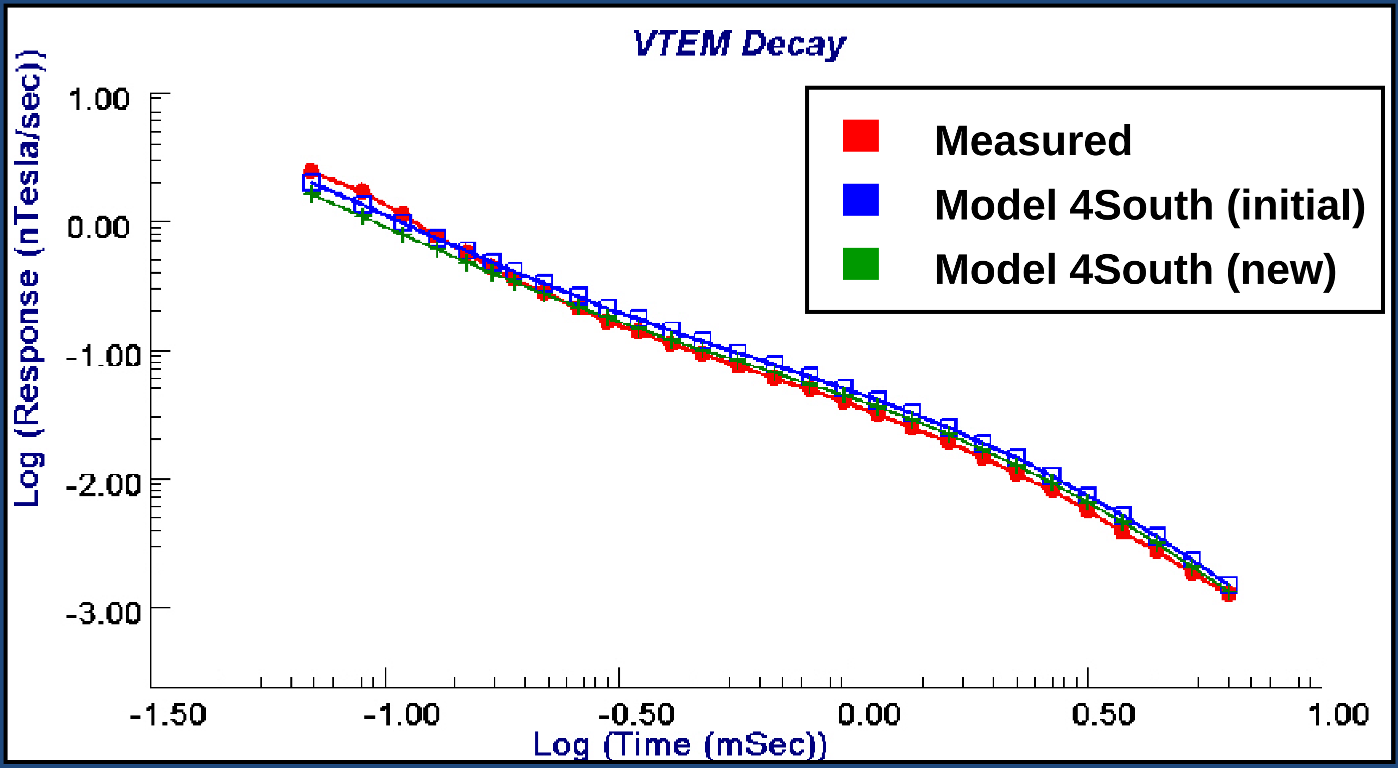
VTEM: Integrated Waveform



- Integrated Waveform
- Initial Waveform: Quarter sine turn-on and turn-off
- Modified waveform: turn-on : f(t) = A (1-e-t/t)
  turn-off: 77% of a quarter sine

VTEM: New Waveform

Will Model 4N fit the VTEM data with the modified waveform?



- With new waveform representation, Model 4South still a poor fit
- Model responses differences primarily due to turn-off definition.
- The turn-on has limited effect on the model response.

VTEM

More information needed on VTEM for accurate modeling:

- Normalization by dipole moment
- Upper bandwidth
- Time channel positions

VTEM may provide better shallow discrimination than fixed-wing airborne systems. However, we cannot use it quantitatively without more knowledge of system parameters.

Conclusions

Accurate modeling of the airborne response depends on precise knowledge of system parameters. These include pulse width, exact window locations, waveform details, and impulse response of the receiver coils.

MegaTEM and GeoTEM calibrate with the ground data provided bandwidths of 4 kHz and 6 kHz are used.

VTEM may calibrate with other data but more information on system settings is required, such as how the data is reduced by dipole moment and the upper bandwidth of the system. This information would assist us in accurately modeling the VTEM response.