Avdat Archaeogeophysical Preliminary Report

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In the framework of a Doctoral Thesis, archaeogeophysical and hydrological studies have been ongoing at the Avdat archaeological site in southern Israel since April 2005. This work is focused on hydrogeological studies via Ground Penetrating Radar. Sub-surface hydrogeological features are modeled in the GPR figures below. Data has been acquired to date at this site three times with on-going soil sample analysis to cross-correlate the data. The preliminary results of these surveys are included below and discussed. Data has been acquired from the same two grids within a particular terrace located in the ancient agricultural system of the site. The data is compared over an extended period of time in order to see what changes are visible. This adds to our understanding of the system as a whole and thus contributes to open-area archaeology an increased understanding of the degree to which sub-surface hydrogeological features and changes over an extended period of time can be resolved using GPR at the various determined test sites of the doctoral work.

Introduction

GPR data consists of reflections that have been received from the sub-surface of a gridded area sent by an antenna on the ground. Based on certain characteristics of these reflections we are able to determine the location of sub-surface features spatially within an area. Every positive reflection has a reciprocal negative reflection and we must pay attention to the strength of those reflections. We determine this strength and positive nature by comparing the data we see in the GPR data with the chosen color table, which has been included here as Figure 1, and will suffice as a key for the data, much like a map.

Figure 1: Color Table used in this group of GPR data. This shall be used as a key much like on a map for determining strength of reflection.

Methodology

A particular terrace was chosen at the Avdat archaeological site that has not been reconstructed in any way. The terrace is located relatively in the middle of a particular system and varies in plant growth throughout the year. Grids are 2x2 meters and placed at the top (high-slope) and bottom (low-slope) of the terrace, about 1 meter from the terrace wall along the center line of the terrace itself. Two criss-crossing grids of GPR data are acquired at each grid in order to have high-resolution data. Data is collected every 20 cm, the overlapping helping to boost resolution. Beginning in November, 2006 soil samples were acquired and analyzed for soil moisture and mechanical content. At future surveys we will continue to acquire this data for comparison in cross-correlation of data. All GPR data viewed here has been filtered to eliminate background noise that may make it difficult to see the sub-surface features. Soil samples when taken were at 0-5 cm, 10-15 cm, 25-30 cm, and 45-50 cm depths and marked as 1-4 according to grid letter.

April, 2005 Data

During this survey an additional grid was acquired roughly in the middle of the terrace. Thus this set of data includes Grids A (low/down-slope), B (mid-slope), and C (high/up-slope). GPS points were also acquired for mapping purposes.

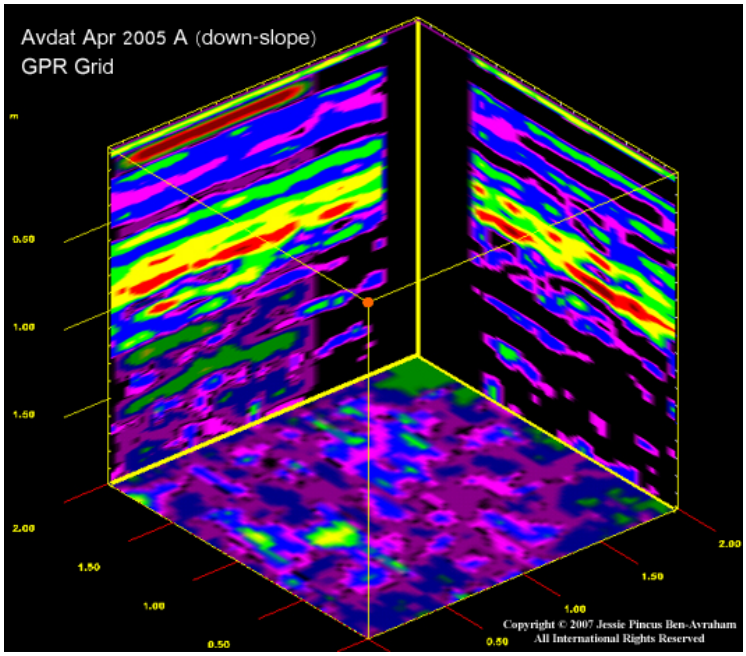

Figure 2: GPR Grid data from Site A (down-slope).

In Figure 2 it appears that we have much low-amplitude reflections signaling a homogenous soil. Moisture appears to be highest ~70 cm depth as evidenced by the yellow, green, and red band seen there. Stratigraphy of the site is roughly horizontal layers of slightly different ranging material. There is a thin layer of other material located around 1.5 meters depth. It will be good to compare this data to the other grids in terms of stratigraphy.

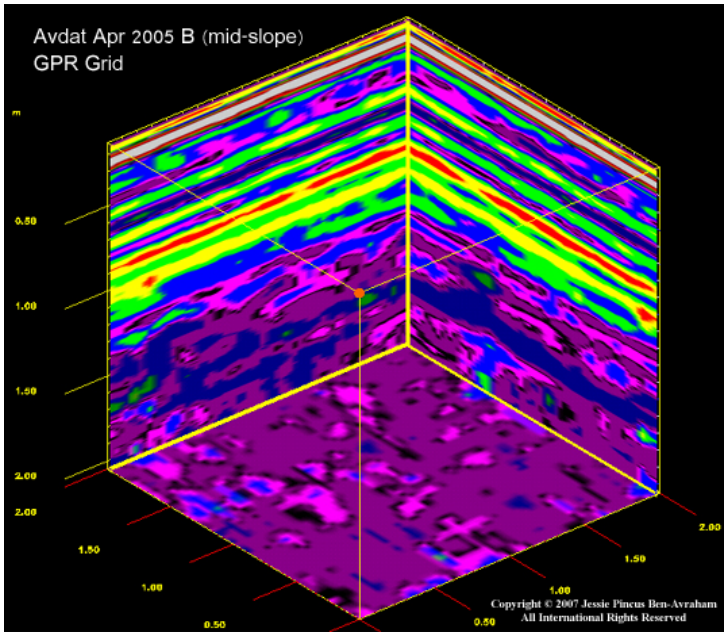

Figure 3: GPR Grid data from Site B (mid-slope).

Figure 3 is more stratified with distinct layers of slightly different soil types. Clay levels may be high here as evidenced by the bright yellow. A comparison to the mechanical analysis still in progress of soil samples acquired in November 2006 will be helpful in determining this information. There is more surface reflection here than in the A grid low-slope. Soil becomes more homogenous around the 1.3 meters depth range.

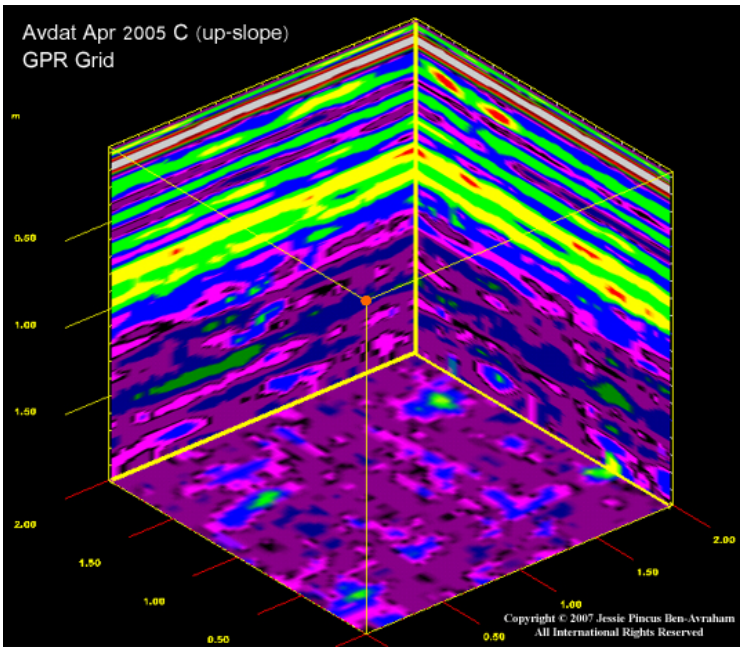

Figure 4: GPR Grid data from Site C (up-slope).

Stratification is more regular in this grid (Figure 4). The yellow-green layer that has appeared in the other grids is at a higher level here (around 0.70 m). It seems that if this were a horizontal layer in the soil throughout the terrace the layer should be at a lower depth at A than it is at C. Thus it seems that this layer must slope with the terrace, rather than stay straight to the horizontal. There are more homogenous layers below and some rounded nodule features at about 1.6 meters depth.

February, 2006 Data

In this survey grids were slightly re-positioned along the central axis of the terrace as guide points had moved during the course of the year. This time points were marked more substantially for the next survey so that readjustment would not be

necessary. GPS points were acquired of the new grids. Also, methodology had been slightly changed and it was agreed that only two grids at the lower and higher slope would be necessary for understanding of the terrace as a whole. Thus Grid A is high-slope and B is low-slope. February at the site was after a few rainfalls and thus the area was much moister than in the previous survey, which was at the beginning of the summer.

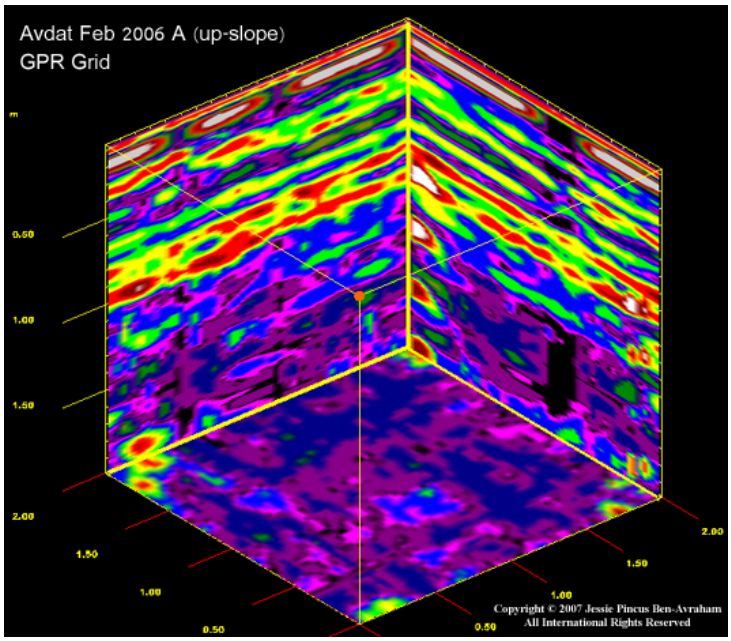

Figure 5: GPR Grid data from Site A (up-slope).

The higher-amplitude yellow red band is still present around 0.70 meter depth, although the water level is increased as evidenced by the significant addition of red and also some high amplitude anomaly features in the layer (white color) (Figure 5). The layers of soil are also much more heterogeneous most likely due to the rain that has occurred in the season. There are several "packs" of high-amplitude features towards the surface. This may indicate that a rainfall event occurred only days ahead of acquisition. Layers become more homogenous with increasing depth especially after ~1.50 meters. In some ways we can expect also that because this is at the top of the terrace where water pours out from the terrace above that stratigraphy would not be "smooth".

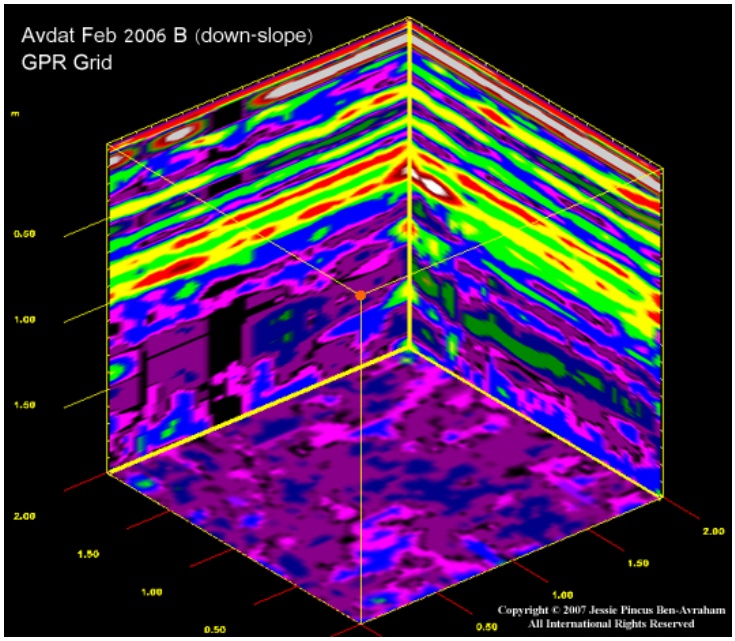

Figure 6: GPR Grid data from Site B (down-slope).

Here (Figure 6) we can see the same lower layer (dark green and blue) that was seen in A of the April 2005 data around 1.50 meters depth. It seems to have also become thicker. As of yet I am unsure of the soil type but hope to clarify this with more understanding from the mechanical analysis of the soil sampled in November of 2006. The same "packs" of high-amplitude reflections are still present as at the higher-slope A grid. Although by now they have spread out more as the water spread across the terrace laterally. Around 0.25 meter there is also a similarly high-amplitude layer. Mechanical analysis data from the next survey will hopefully help to identify the reason (perhaps higher clay content).

November, 2006 Data

In this survey the same grids from the previous data acquisition were re-worked exactly. Soil samples were acquired from both grids in a location 2 meters west of the grid centers. It was noted in the field that grid B was drier than A. This survey was at the end of the summer before the major winter rains had begun. By the time of this writing, mechanical analysis of these soil samples is still ongoing.

However, moisture analysis data is available and will be discussed after the GPR results.

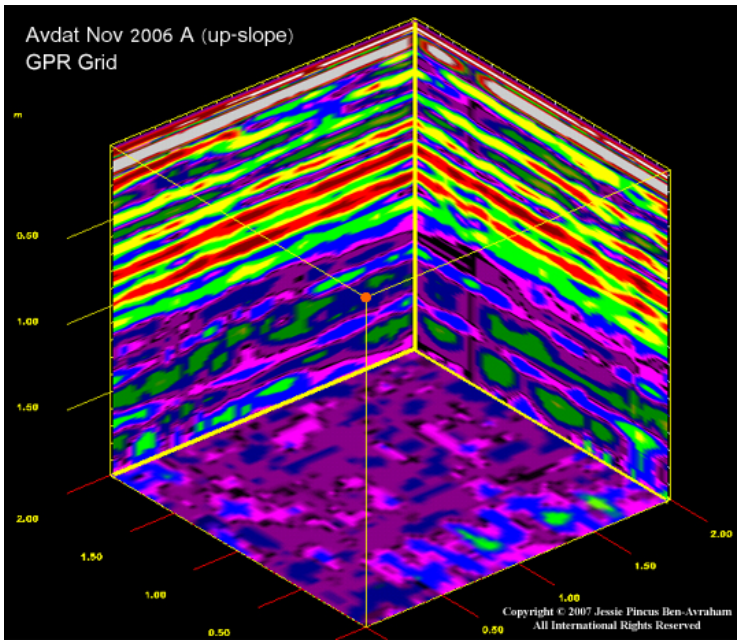

Figure 7: GPR Grid data from Site A (up-slope).

Here (Figure 7) we see the same high-amplitude layer at the surface as in the Grid C from April, 2005 and Grid A from February, 2006. The hot summer months have passed and it is clear in the stratigraphy of the grid. However, boundaries between layers are slightly "wavy" indicating that possibly one or two rain events have occurred at the site already. There is a distinct break in material around 1.25 meters depth. This is possibly due to saturation of the layers and moisture has not yet reached to this depth. The same stratum that has been consistently located just before 1 meter depth range is slightly lower now, reasons for this and identification of the strata will be looked into further as soil data becomes available.

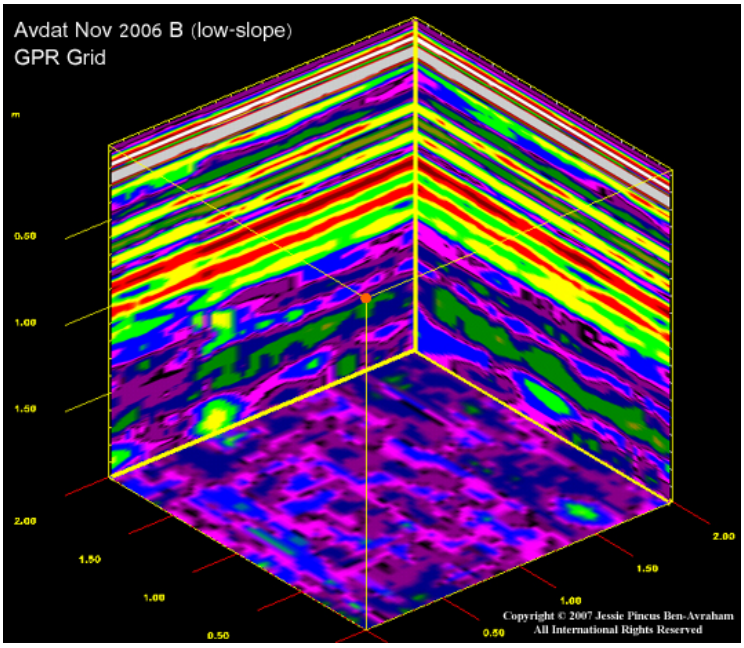

Figure 8: GPR Grid data from Site B (low-slope).

It seems here (Figure 8) that strata are more homogenous, possibly as the result of its location at the end of the terrace where water has had a chance to more spatially be absorbed in a lateral manner. This set of data is actually the most "straight" the strata have been thus far at the low-slope location. Again we see a dark green and blue stratum at about 1.5 meters depth. As of now I am unsure of its identification but hope to fully identify it with more analysis.

Moisture Analysis of Avdat Nov/Dec 2006 Data

Below are the moisture analysis percentages for each depth of soil acquired in samples. A1 refers to 0-5 cm, A2 is 10-15 cm, A3 is 25-30 cm, and A4 is 45-50. B samples follow the same pattern.

% Moisture			
A1	4.88	B1	5.31
A2	5.30	B2	5.51
A3	5.88	B3	6.00
A4	6.05	B4	6.17

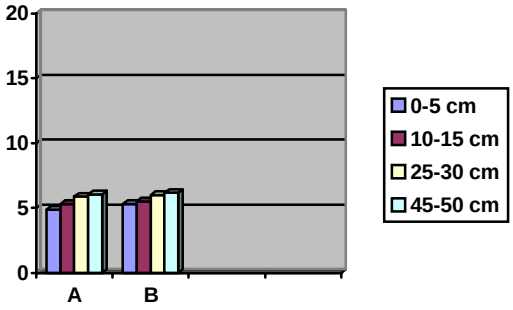

Figure 9: Moisture analysis data of Avdat Nov/Dec 2006 data.

It seems that for both sample holes we have a steady increase of moisture with depth (Figure 9). In keeping with hydrological principles, this means that it most likely rained a few days before the sampling was done. In comparison with other moisture analyses at other sites in the study, this one has the smallest amount of change with depth. It is much more homogenous. This sampling was acquired at the "end" of the summer and moisture levels in general were very low. It will be good to compare this data to the summer data and see how drastically different the levels are.

Conclusions

Thus far it seems that much can be seen from the GPR data in terms of stratigraphy and possible identification of soil types in conjunction with pending soil analysis results. This first preliminary report will be added to as data is collected and analyzed. Similar reports will be completed for the other sites in the doctoral work (Shivta, Nitzanna, Tell es-Safi, and Yattir). Once this data is compiled a broader understanding of spatial moisture relationships at ancient agricultural sites will be gained and the applicability and usefulness of GPR for this purpose will be attained.