Technical Report M-TR 121
Magnetics at Fort Lowell Archeological Site

A demonstration of the G-858 Cesium Magnetometer/Gradiometer was performed for the National Park Service Archeological Conference at Ft. Lowell on the outskirts of Tucson, Az. Ft Lowell was a military outpost established in the 1860's, a good review can be found at

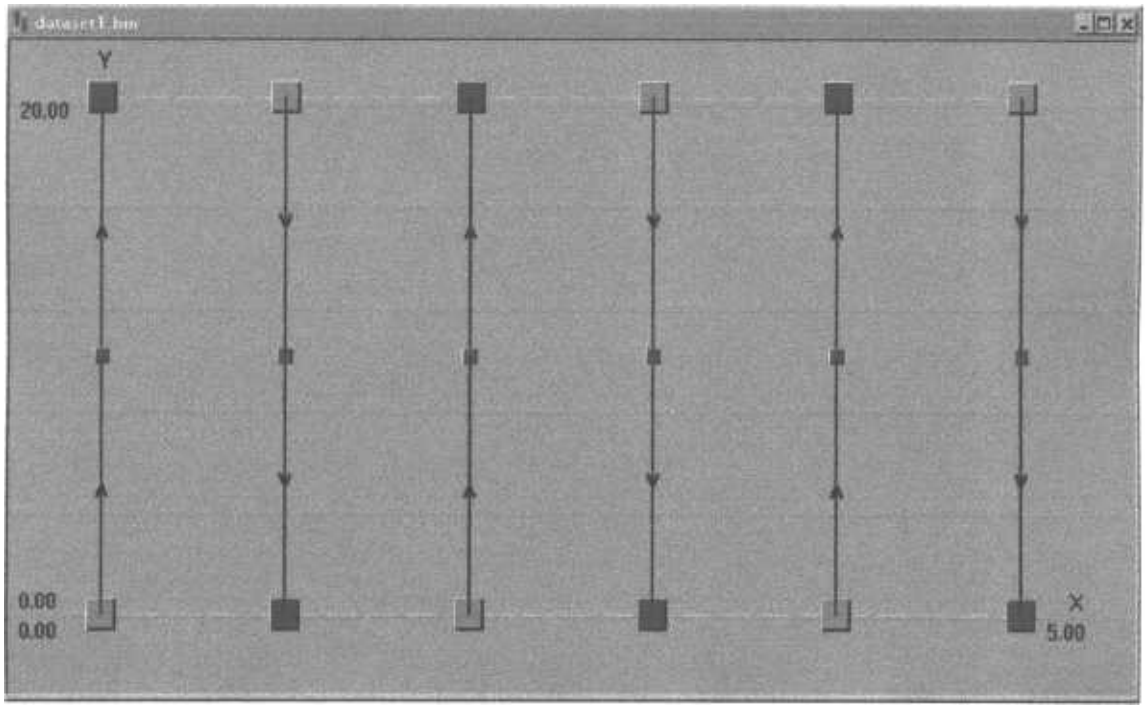
http://dizzy.library.arizona.edu/images/diverse/ftlowell/ftlowell.html

The magnetometer was used over a 20m x 5m plot that had been previously marked in one-meter lines. The surveys were conducted along the 20m axis.
Two surveys were conducted, one with the dual magnetometer sensors deployed in the horizontal "wide" mode (2 sensors covering two lines simultaneously, separated by 0.8m) and the second survey done in the vertical gradiometer mode, one sensor deployed above the other. See pictures Nicole (horizontal) and Chris (vertical) in Egypt for example.

Nicole

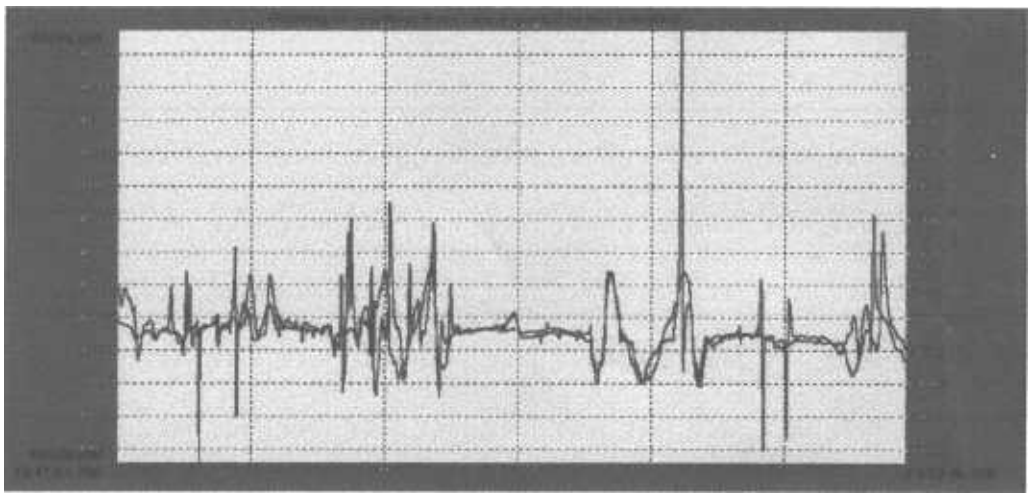
Chris

Dataset 1 was collected in the horizontal - two mags cover two lines mode, which gives excellent lateral coverage. Data was uploaded from the magnetometer console and brought into MagMap2000. The first screen we see is the position map below (datal-pos). We see that there were linear interpolation "marks" positioned at the 10-meter line and that the positions look correct. Next we select "plot sensor data on position plot" and we see the profiles of the two sensors "stack plotted" on top of the position trace. This gives us an immediate review QC of the data, allowing us to see if there are any spikes, dropouts and where the major anomalies are located.



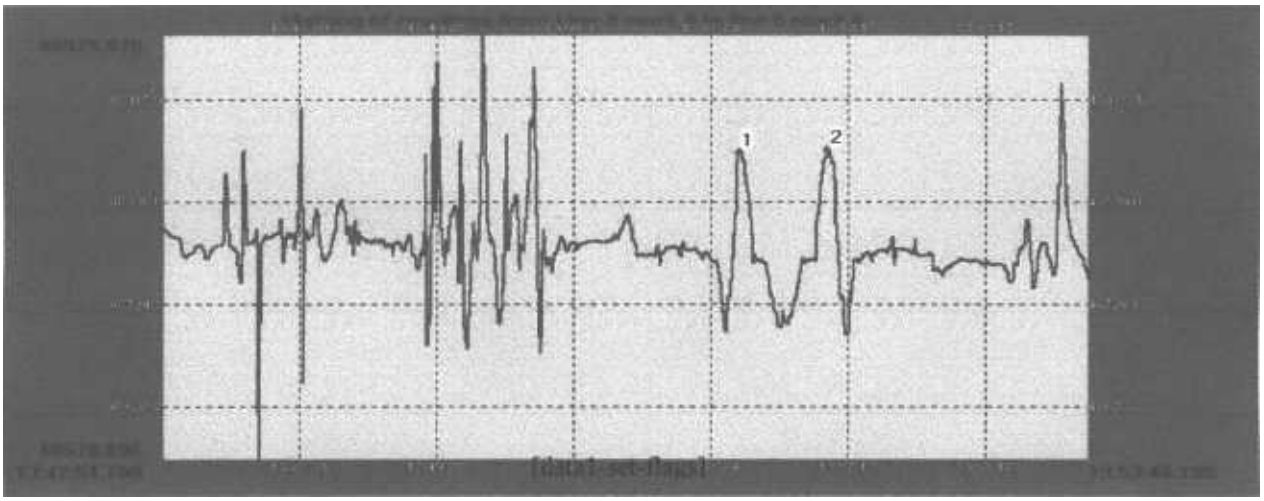
[data1-pos

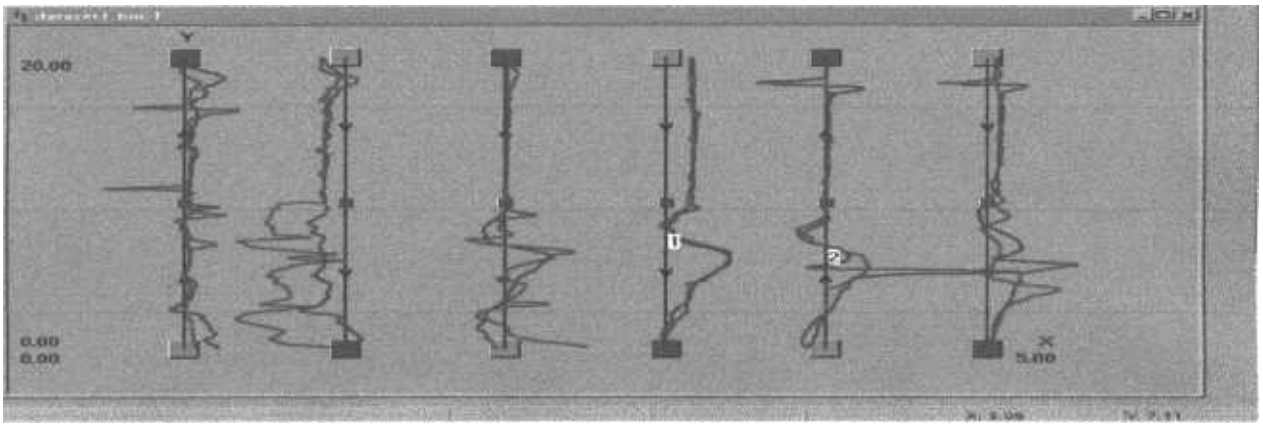
Next we plot the data from the entire Data1 survey in a linear mode in order to once again check for any irregularities and to analyze the data for important anomalies. See data1-profile below. Note that the amplitudes of the two sensor responses as they traverse the line are not equal. This is due to the fact that one sensor may be closer to a near surface ferrous debris and therefore has a higher response. Note that the anomalies that have very sharp anomalies are small and close to the sensor.



[data 1-profile]

One may choose to mark one or more anomalies in order to locate them on the position map (see data1-set-flags). Once the anomalies are marked, one can return to the position map and locate the anomalies by putting the cursor on the flag that appears there. (See data1-flags-on-pos-map) Note the position of Flag 1 in the lower right hand corner.

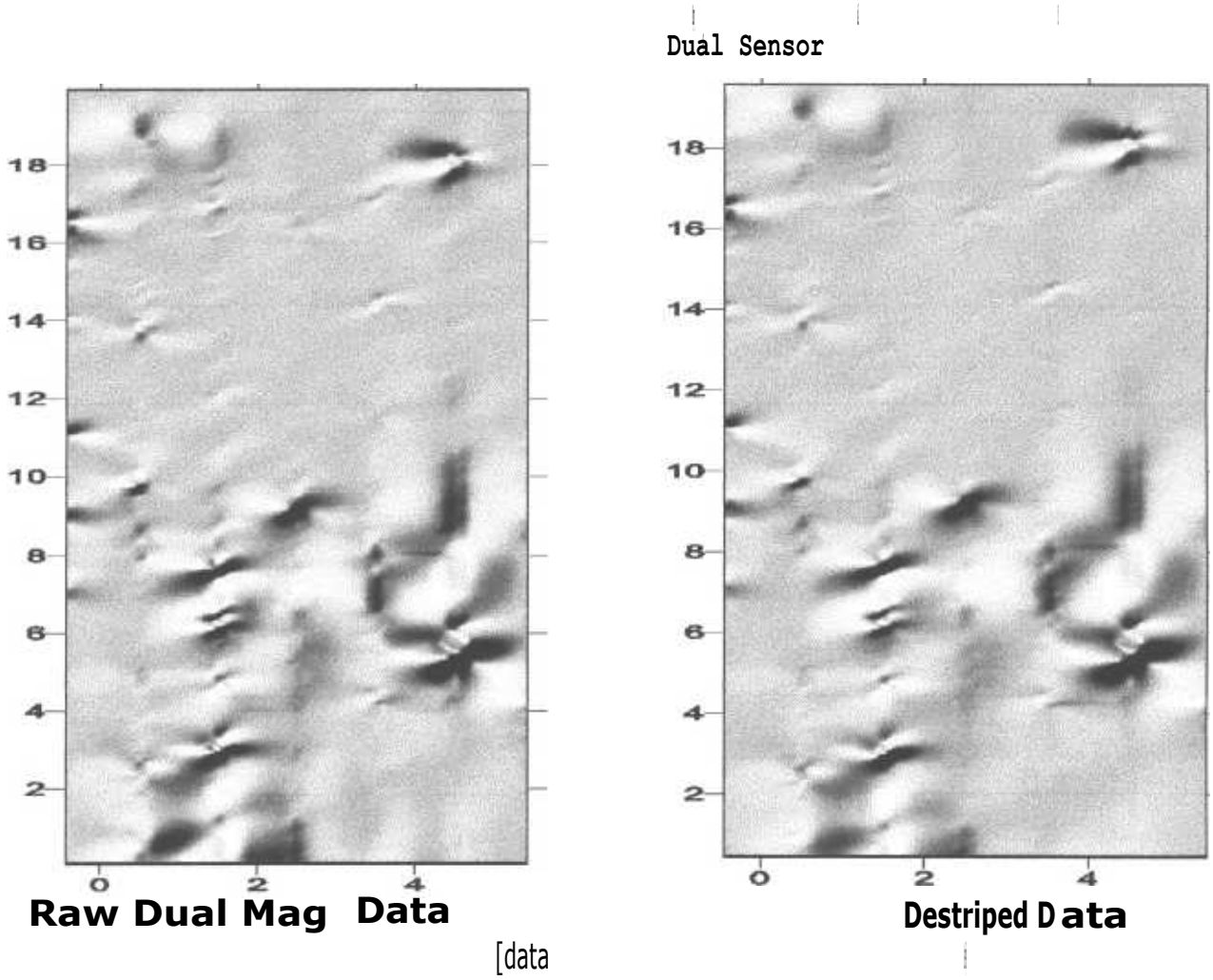




[data1-flags-on-pos-map]

We are now ready to 2D contour the data to better see the shape and size of the anomalies. In MagMap we can only contour one sensor at a time, and these are shown in data-contour-sens1 and sens2. Note the clear anomaly in the upper left hand corner of the map of both sensors and the sharp anomaly from sensor 2 in the upper right hand corner probably some surface debris. The aspect ration of the maps is slightly stretched in the x-axis; in general if possible it is best to have a survey area that is squarer than long thin rectangle in shape. There are some deeper anomalies that traverse the survey area in a lateral manner that may signify a change in soil type, soil disturbance, artifacts or building material.

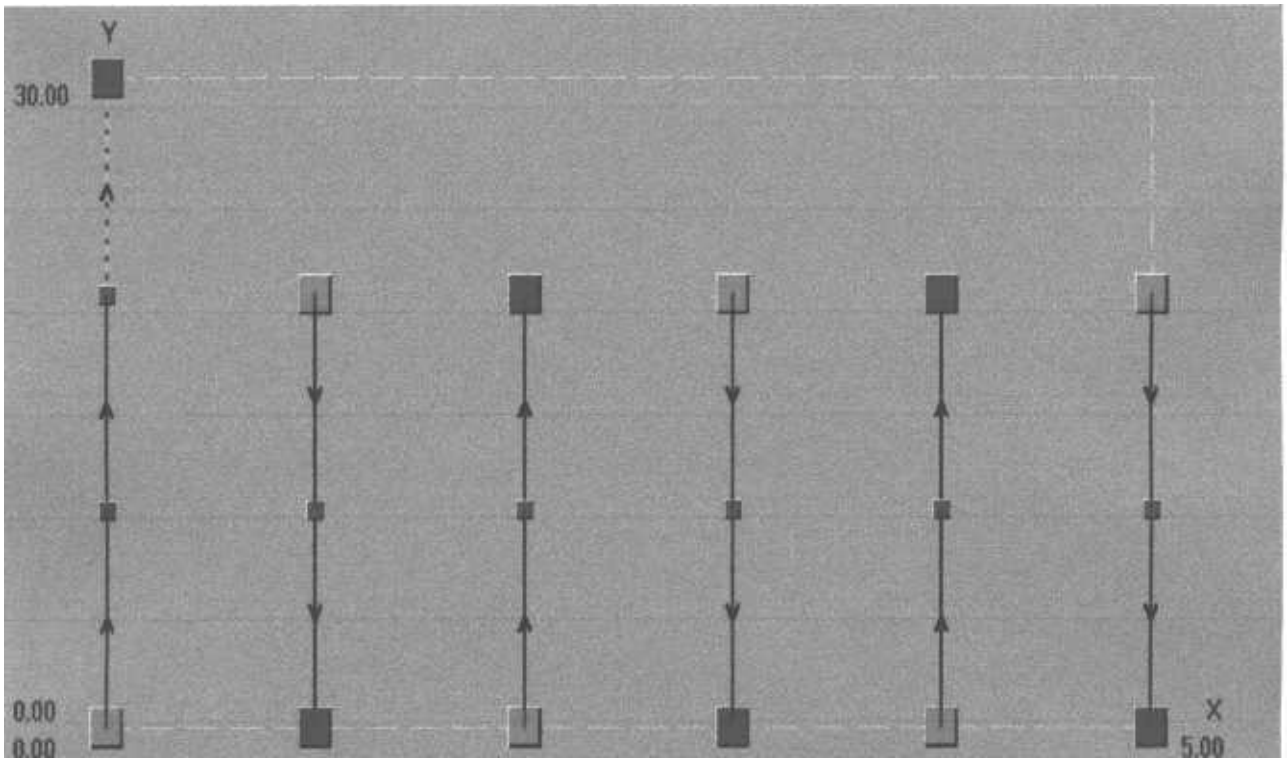
I have included a Surfer shaded relief map of the area for comparison (data1-surfer-relief). This mode of display has the ability to show point objects very well, although it tends to filter out the longer wavelength anomalies. This map was made from the data from both sensors; note the previously described anomalies in the upper left and right of the map. After destriping (leveling line to line removing heading error and walking noise) some of the anomalies in the lower quadrant are clearer and their positions more easily analyzed.



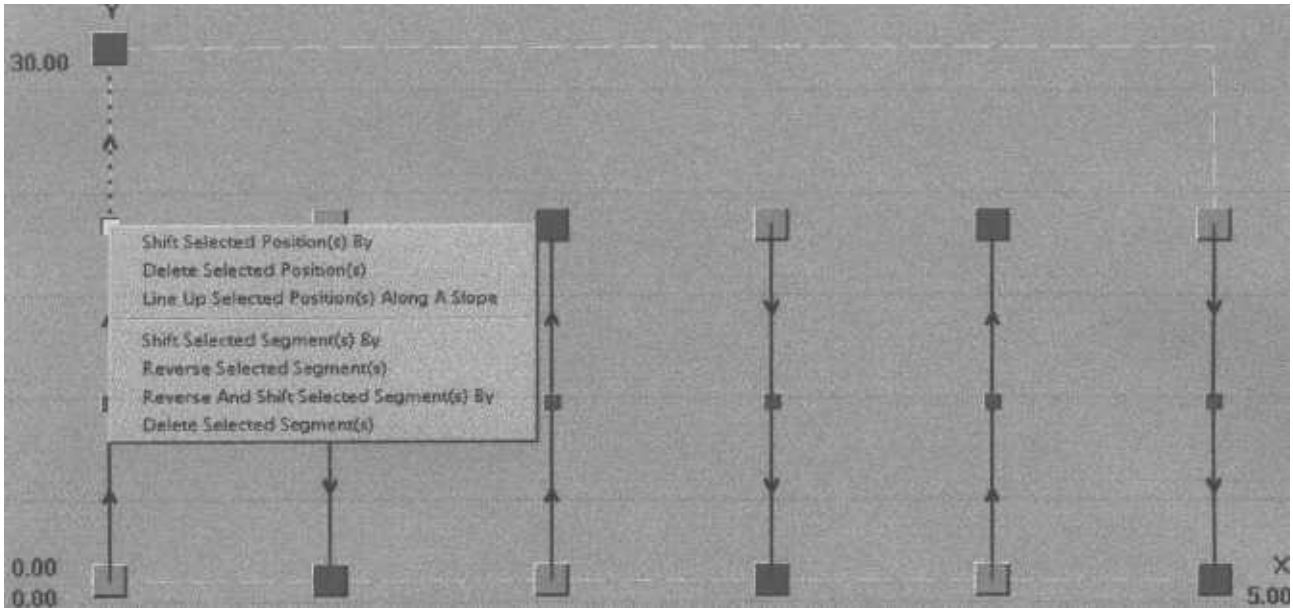
Dataset 2 was collected in the vertical gradiometer mode over the same 20m x 5m plot. The difference of course is that the surface is not covered in as much detail but the magnetic field is measured at two different heights. When the magnetometer sensors are deployed in a horizontal mode with 0.8m spacing on 1-meter lines, the sensors are actually only 0.2 m apart in between lines (each sticks 0.4 m into the area between lines). The software automatically pastes the sensor properly upon export; hence the Surfer plot of Dataset 1 incorporates all sensor readings.

There are specific advantages to the vertical gradiometer technique. For one, gradient plots (subtraction of one sensor from the other divided by the separation gives us a plot in nT/m) are free of diurnal variation and any distant source of perturbation (cars, trains, even chain fences if off to the side a bit) because the distortion at the sensors are seen equally and at the same time. Also, the gradient falls off as the 4th power with distance (compared to 3rd power for total field), which means that the gradiometer will enhance targets along the axis of the gradiometer to within about 5 to 7 times the separation of the sensors. This gives the ability to enhance targets while rejecting deeper geological contribution or magnetic objects off to the side.

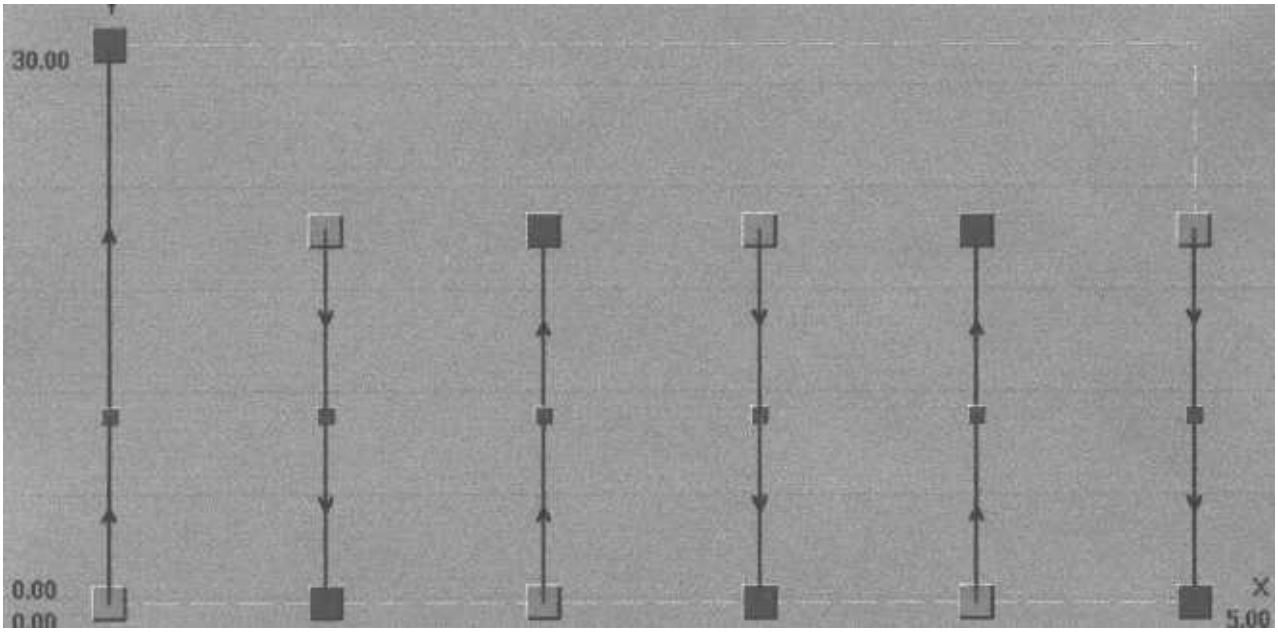
We begin by bringing in Dataset2 as seen below in data2-pos below. We immediately see that there has been an inadvertent push of the mark button followed quickly by the press of the end of line button on line zero. We know this because when placing the cursor on the marks, we get the time that the button was pushed. The mark at X=O, Y=20 was pressed at 13:59:11, the mark at X=O, Y=30 at 13:50:12. So clearly we need to remove the mark at 0,20 and move the End of Line mark from 0,30 to 0,20. We see this process in the series of pictures starting with data2-pos-reset menu, data2-pos-bad pt removed, data2-pos-shift end line and data2-pos-final shown below.



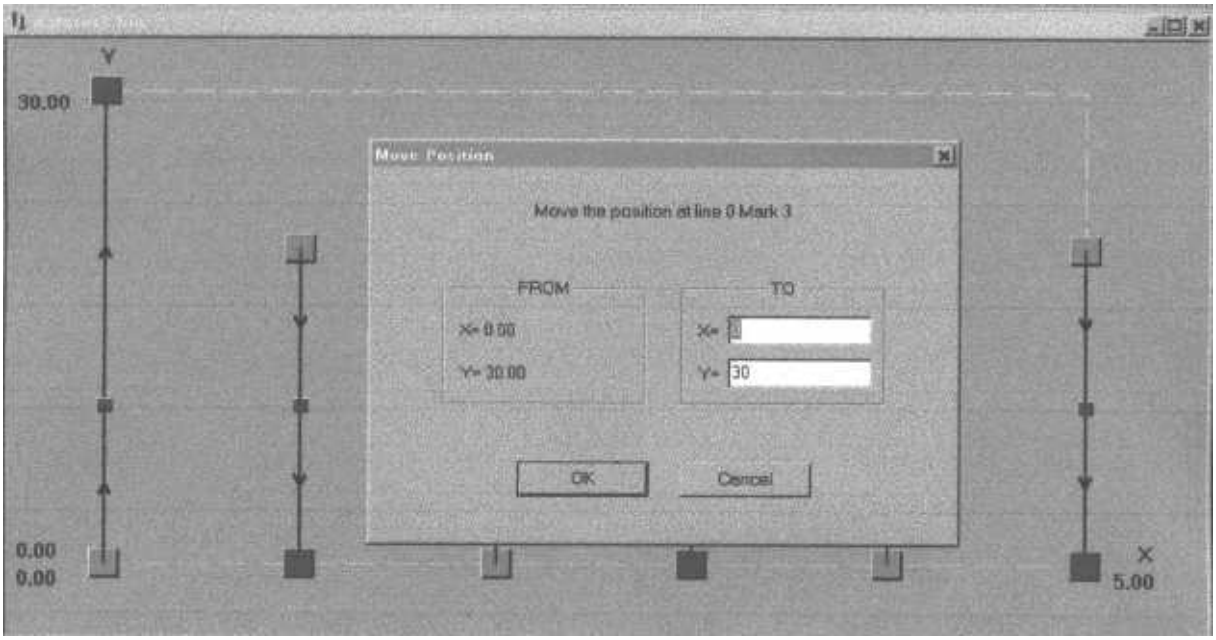
[data2-pos]



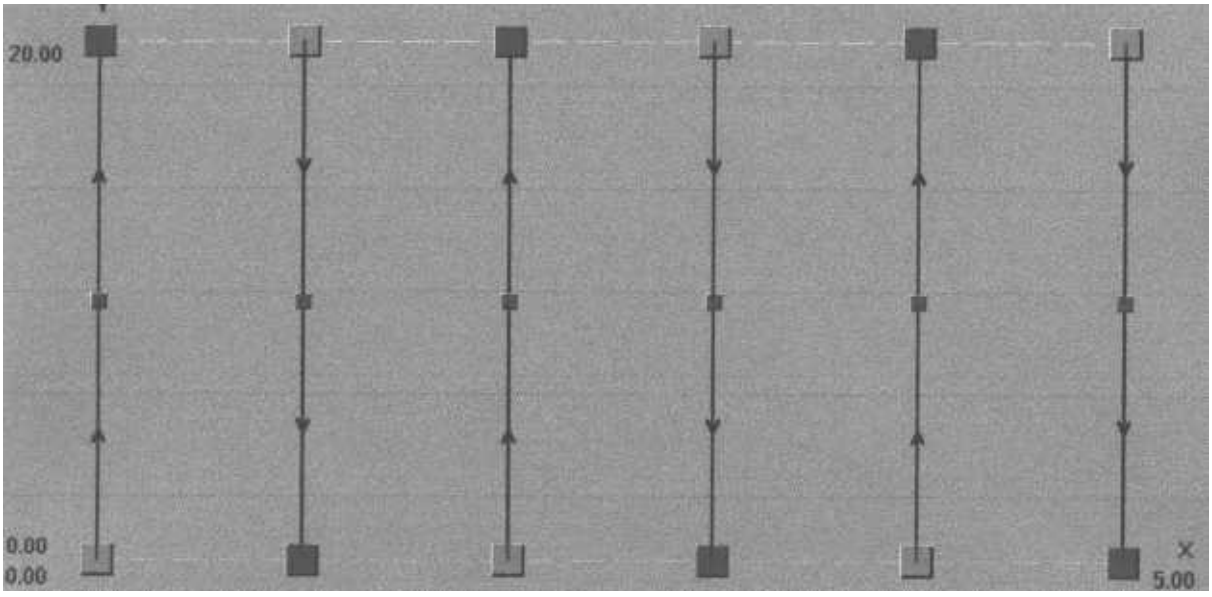
[data2-pos-reset menu]



[data2-pos bad point removed]

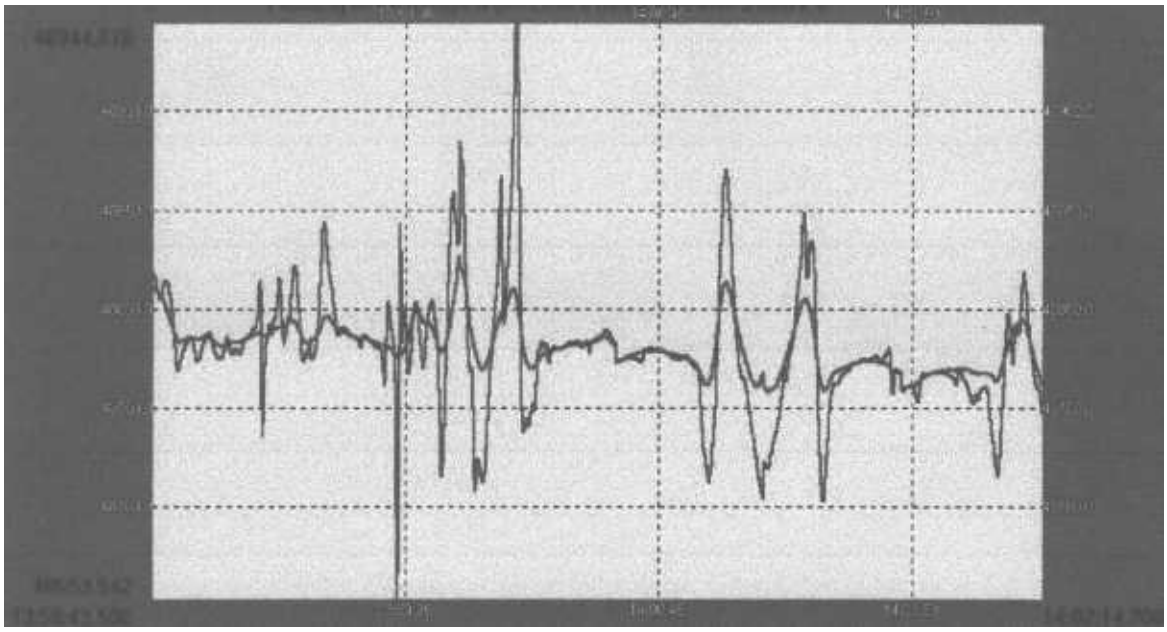


[data2-pos-shift end]

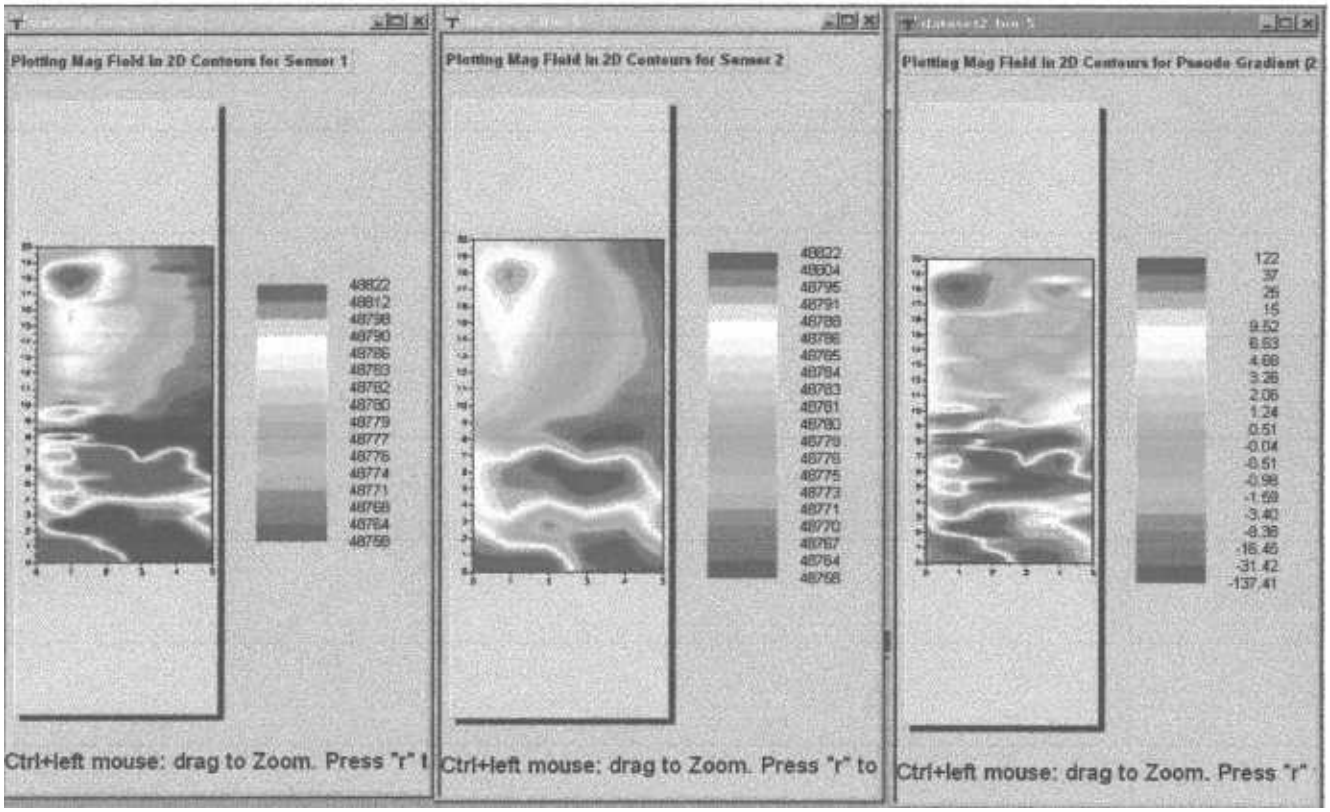


(data2-pos-final]

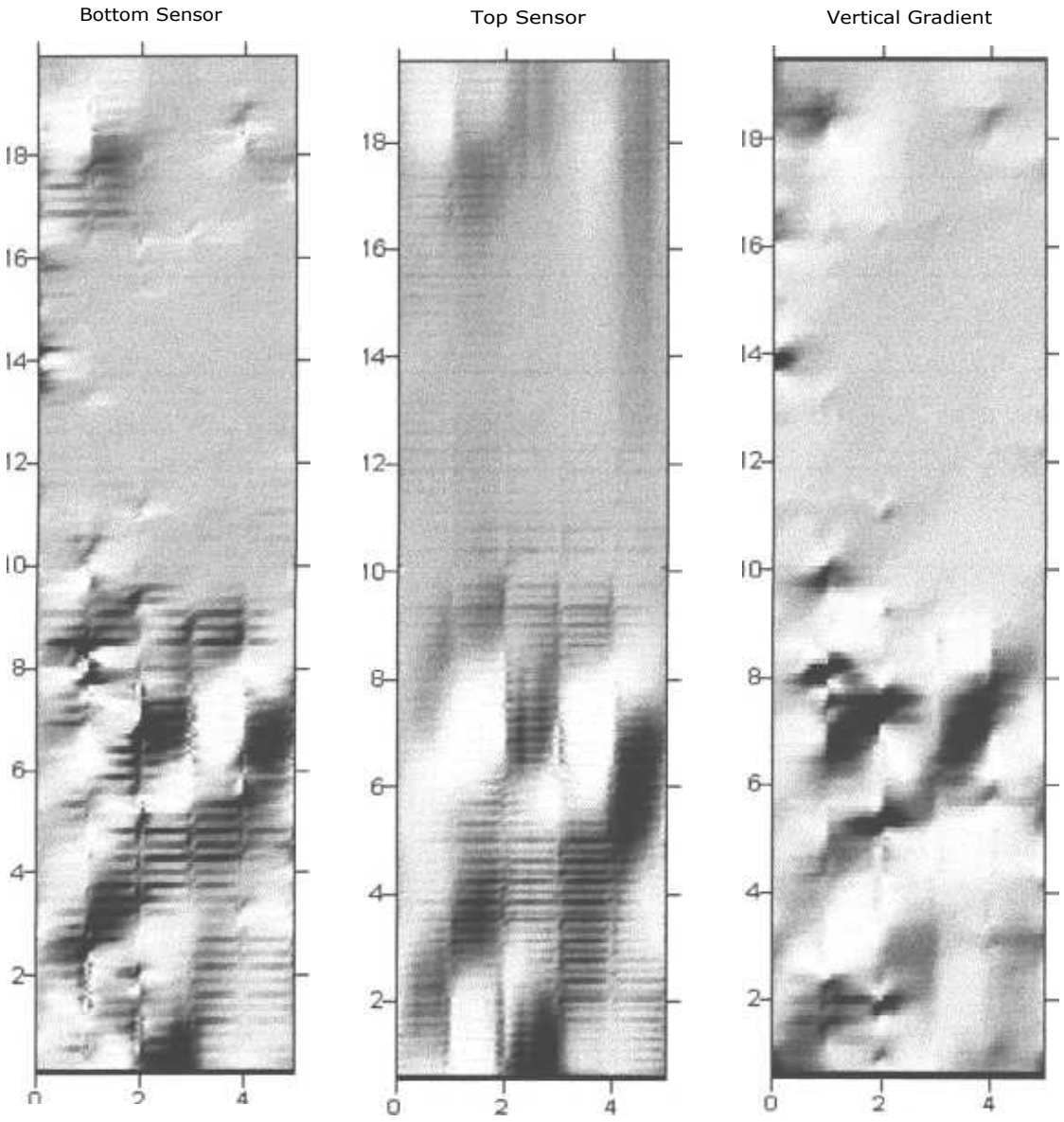
Next we plot the profile of the data to see if there are any spikes, dropouts or other irregularities that need to be fixed. Looking at data2-profile below, the data looks proper. If there had been any spike or dropouts, etc we would have removed them using the selections from the Filter menu.



[data2-profile]



Ft. Lowell Archeological Site
G-858 Cesium Magnetometer - Vertical Gradiometer



[surf-3]

[3-pic]

Next we plot the two sensors and the vertical gradient (3-pic) one at a time using MagMap2000 contour capability. We see remarkable congruency between these data sets and the data we collected in Dataset1. Most of the same features are visible.

Some things to note:

1. Sensor 1 is the one closest to the ground. We can tell that by the fact that there are many more "high frequency" components in the map, small point like anomalies associated with small debris that is close to the sensor. Because sensor two is about a meter off the ground, this altitude essentially acts like a high cut or low pass filter, removing small high frequency anomalies (spatially speaking) and showing the more gentle curves of the field at 1-meter altitude.

2. Note that the small anomaly identified in the upper right hand corner is visible in sensor 1 but not sensor 2. However, when we plot the vertical gradient, by definition nearby small targets will be enhanced and we see this in the gradient data. Many smaller targets are suddenly visible in the upper part of the map suggesting that we have increased our detection efficiency in this area.

3. See attached Surfer maps on next page (Surf-3). We can clearly see the effects of the sensor height in the two plots of top and bottom sensor. Additionally we have the option in shades relief mode of increasing the vertical exaggeration and in a sense enhancing the small anomalies. This can be seen in the enhance version of the map. Remembering that large anomalies either suggest a deep target or in some cases a disseminated target (as in varying soil types or burn residue), we can easily discriminate between those object that are within a few centimeters of the surface and those that are deeper.

Magnetics has become one of the primary tools of large and small-scale archeological investigations. Huge tracts of land are now being investigated in this manner often using carts in order to afford a rapid and yet highly concise reconnaissance of the site. Magnetic interpretation skills are needed to make full use of the very high sensitivity data afforded by today's optically pumped cesium magnetometers. Multiple high sensitivity sensor arrays deployed from carts will no doubt become a standard investigative tool for archeological studies in the future.

For more information, please contact Geometrics at sales@geometrics.com or visit our web site www.geometrics.com.