Comparison – Scale Modelling of a Broad Anticline with MultiLoop III.

As part of a UTEM modeling study carried out in 1983 by Lamontagne Geophysics Ltd., vertical magnetic field profiles over a bent sheet simulating an anticline were studied. In this paper, the scale modeled anticline response is compared with the response from MultiLoop III. The shape of the mesh used in MutliLoop III is then iteratively modified to improve the fit between the modelling and the data.

Files used in this paper are archived in MLPIII Comparison / ScaleModelBroadAnticline.

The source of the scale model data is the plot illustrated in Figure 1. The description of the anticline indicates it to be parabolic, meaning that the shape of the mesh can be described as a quadratic equation. The base of the anticline is indicated to be 1000 meters in extent, with a depth extent of 500 meters. The depth to the top of the anticline is indicated to be 100 meters.

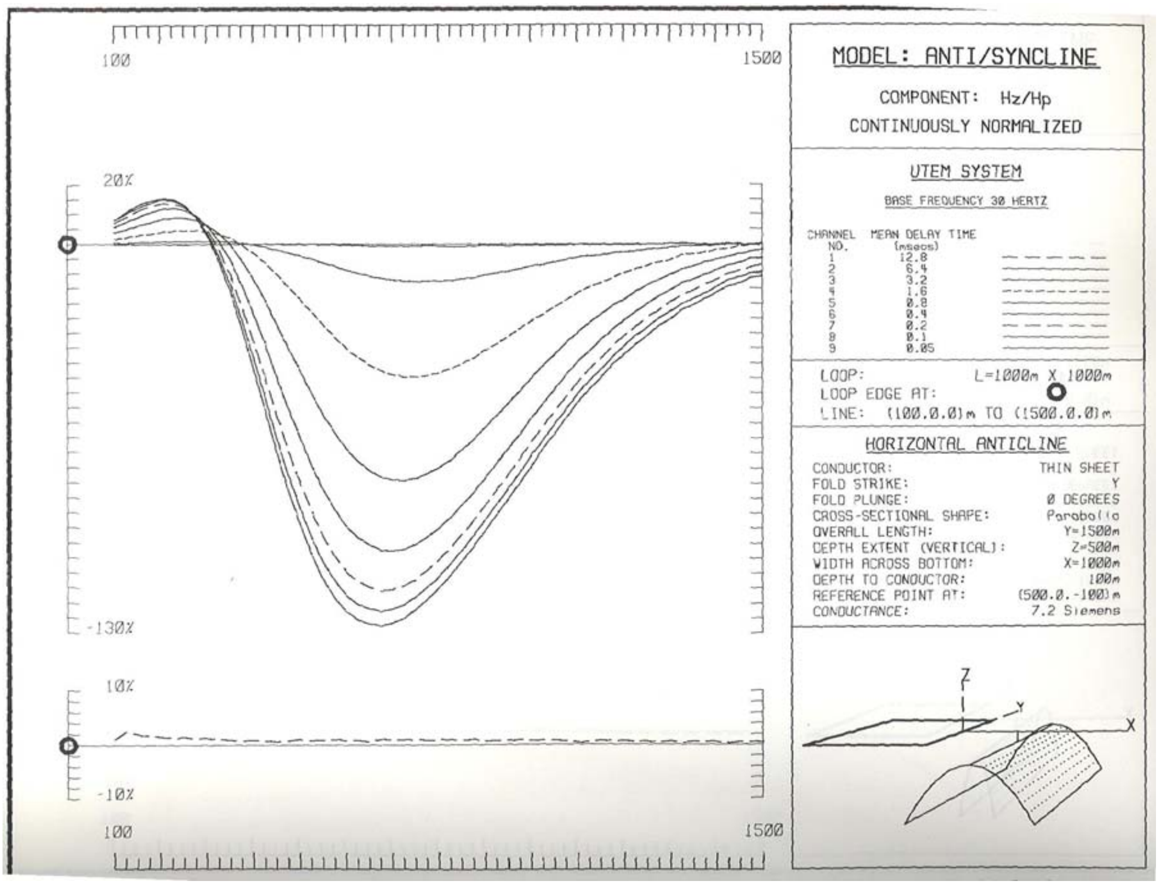

Figure 1: Scale model data.

The mesh was generated using Pebble, with the strike angle of the mesh parallel to the x-axis. A scaling factor of 100 was used, so the mesh intersected the following points: (y,z) = (-5,-5), (0,0) and (5,-5). Letting the mesh have the shape, $z + \beta y^2 = 0$, it is easy to see the required parabola can be built by assigning β = -0.2. The Pebble file describing this shape is “BroadAnticline750_V1.txt”, and the resulting mesh is illustrated in Figure 2.

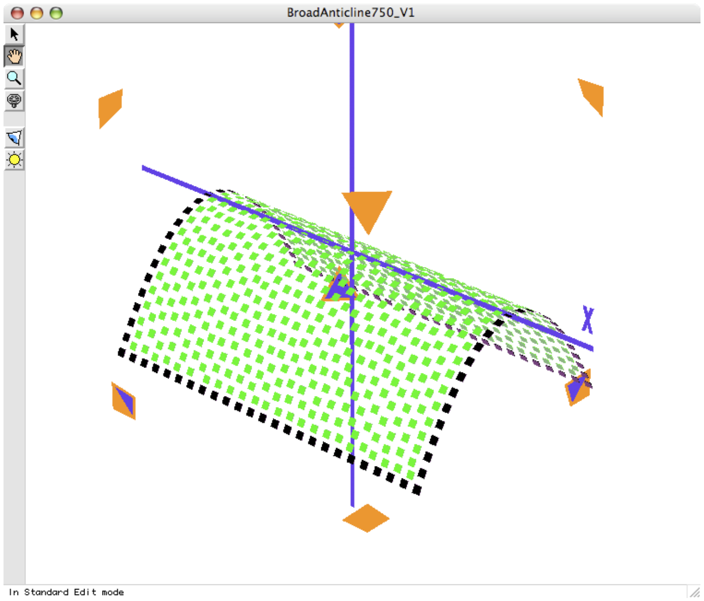

Figure 2: Pebble mesh for the broad anticline model.

To generate the MutliLoop III model, the pebble mesh (BroadAnticline750.mcl) was inserted into an empty MultiLoop III document using a scale factor of 100 and an offset of (0, 0, 0). The traverse line was set to run from (0, -400,100) to (0., 1000,100) with the loop located accordingly. The antennae were defined using a vertical dipole for the receiver and the loop for the transmitter, and modeled in fixed loop – moving receiver mode. Presentation was in continuous normalization in percent, with no waveform normalization.

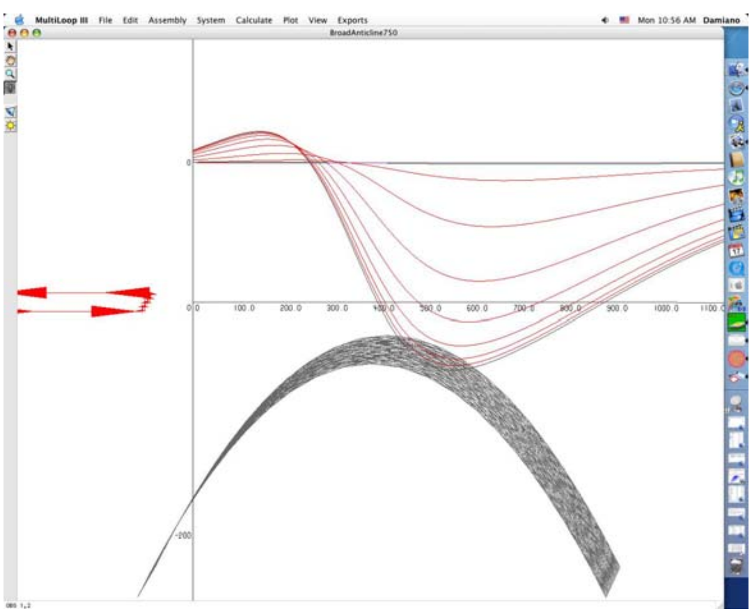

Figure 3: MultiLoop response

The MultiLoop III model is illustrated in Figure 3. The general character of the results bears a strong resemblance to the scale model data illustrated in Figure 1. Slight discrepancies are present in the location of the crossover and in the shape of the profiles, particularly for large y. Initially these were attributed to a small positioning error in the scale model, but repositioning the mesh did not remove all the differences. To study the differences in more detail, the Channel 9 data were digitized from Figure 1, and plotted over the MultiLoop III data. The result is illustrated in Figure 4.

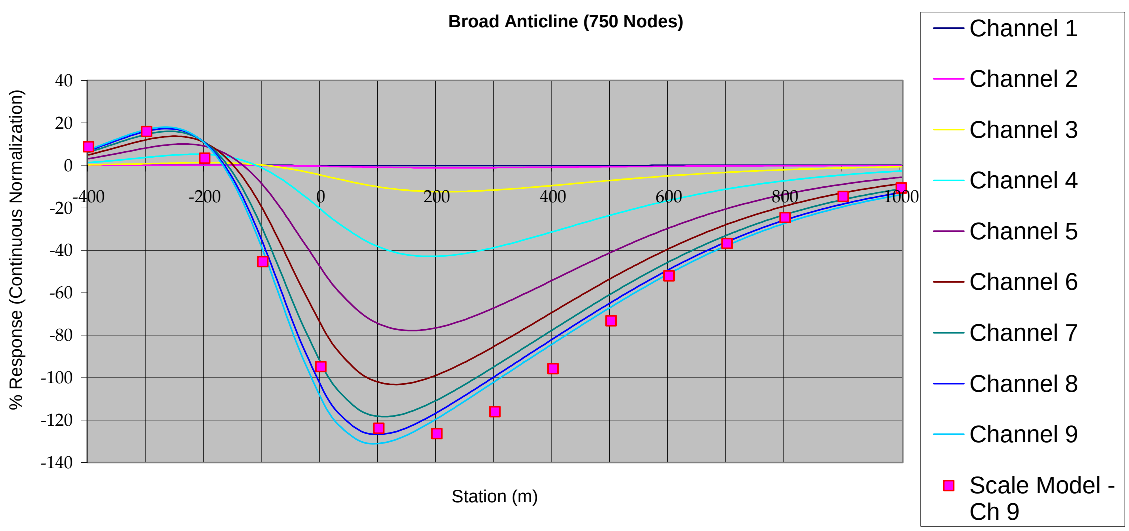

Figure 4: MultiLoop III response and scale model data for the parabolic anticline.

It is clear from Figure 4 that the crossover and the negative peak are both mislocated, and that the negative peak is too narrow compared to the scale model data. It was discovered during the course of modeling that the amplitude of the tail in the response (past station 600) was affected by small vertical position changes in the location of the anticline.

It is assumed that the discrepancies seen between the scale model and the MultiLoop III data are due to the fact that the shape of the scale model was not perfectly quadratic. In the following iterations, the shape of the mesh is progressively changed to improve the fit between the scale model and MultiLoop III data.

Iteration 2:

To try to improve the fit near the negative peak in the response (which was too narrow) the anticline was broadened by inserting a flat section into the top of the parabola. The top of the new mesh was horizontal from $-0.5 < y < +0.5$, and parabolic from these limits to y,z = (-5,-5) for the left limb and (y,z) = (5,-5) for the right limb. The equations for each limb were setup assuming a quadratic, namely $z + \alpha y + \beta y^2 = 0$. With a little algebra, and using the condition (y,z) = (-5,-5) and (y,z) = (-0.5,0) for the left limb, and (y,z) = (5,-5) and (y,z) = (0.5,0) for the right, the following quadratics were derived:

$z - y/9 + 2/9\, y^2 = 0$ (left limb)

$z + y/9 + 2/9\, y^2 = 0$. (right limb)

$z = 0$ (flat section, $-0.5 < y < 0.5$)

The resulting Pebble mesh is illustrated in Figure 5. The corresponding Pebble text file was FlatBroadAnticline750_v1.txt.

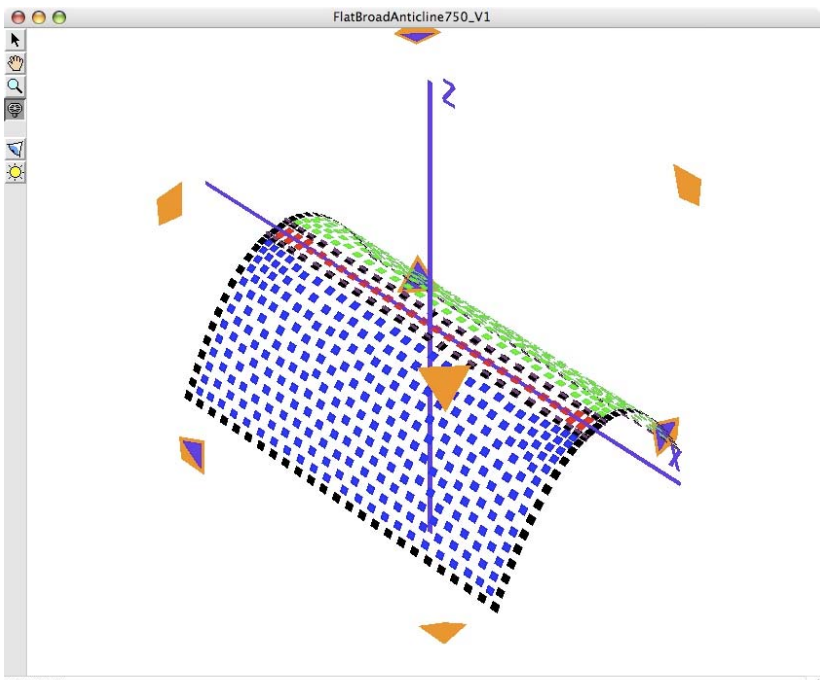

Figure 5: Pebble mesh of the flattened broad anticline.

The original quadratic mesh in MultiLoop III was replaced with the new mesh, and the model was regenerated. To replace an existing mesh with the new mesh in MultiLoop III, use the “Displace Assembly” dialogue (accessible from the Assembly/Displace menu) and click on the replace button, and select the new mesh from the file dialogue.

The result was a slight broadening of the negative peak, as well as improved fit at stations –200 and –100, but no significant improvement was observed in the fit from stations 200 to 600.

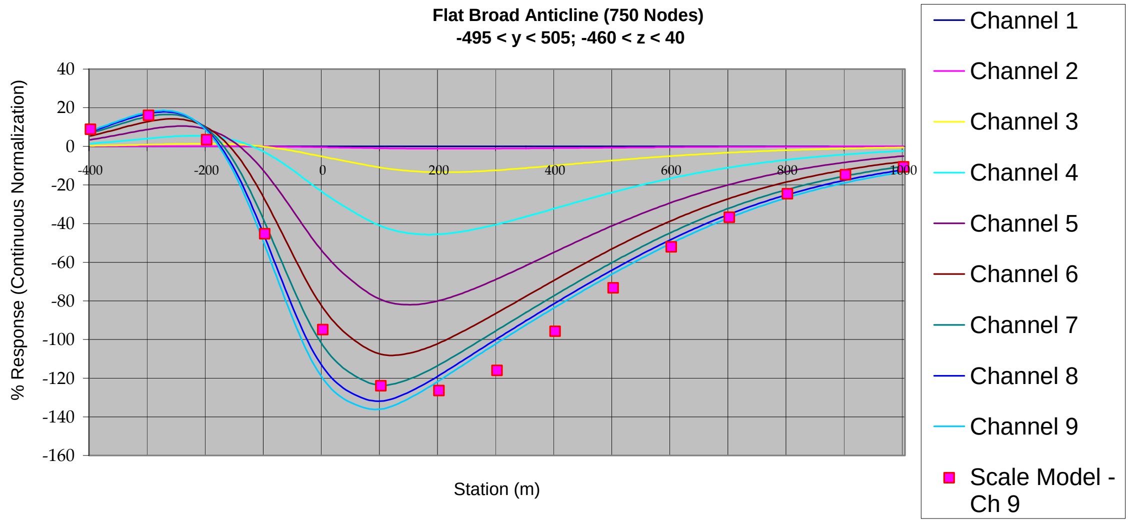

Figure 6: MultiLoop III and scale model data for the flattened anticline model

Iteration 3:

To try to fit the tail of the data better, the anticline was skewed by moving the flat section to $0 < y < 1$. The resulting equations were:

$z + y^2/5 = 0$ (left limb)

$z - y/4 + y^2/4 = 0$ (right limb)

$z = 0$ (flat section, $0 < y < 1$)

The corresponding Pebble file is SkewFlatBroadAnticline_750.txt. The mesh is shown in Figure 7 and the model data in Figure 8.

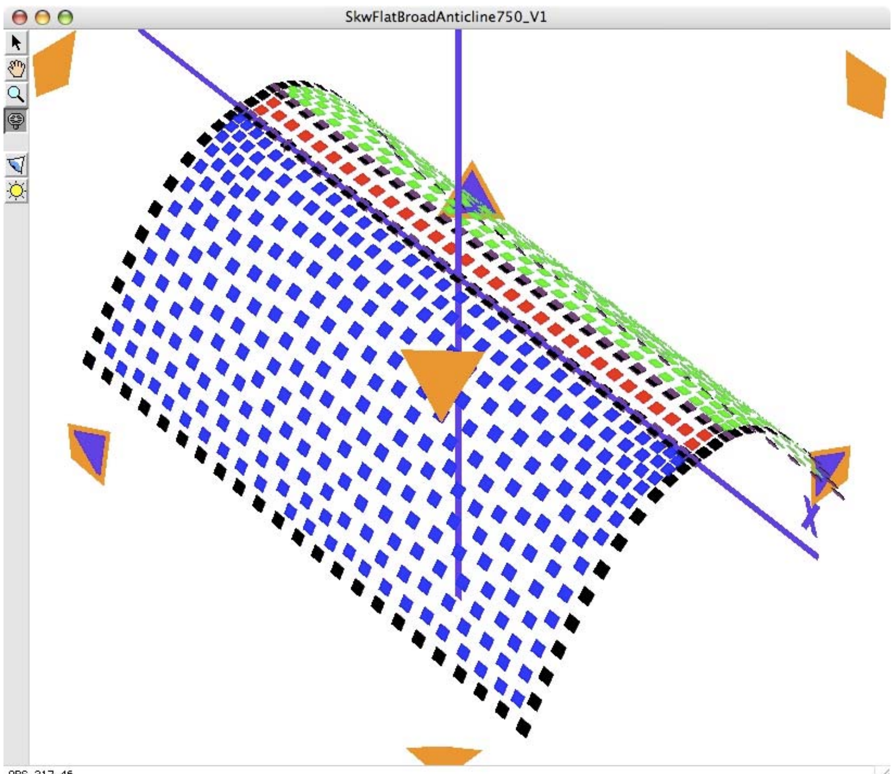

Figure 7: Pebble mesh for the skewed flat anticline model.

Skewing the anticline improved the match between the MutliLoop III and the scale model data over stations 0, 100 and 200, but did not significantly improve the response from stations 300 to 600.

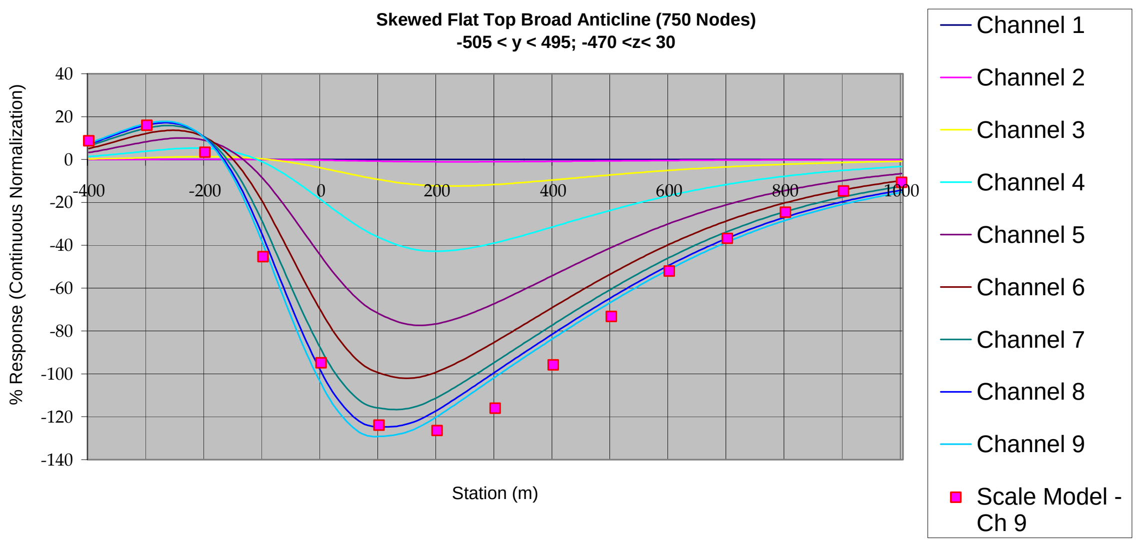

Figure 8: MultiLoop III and scale model data for the skewed flattened anticline model

Iteration 4:

In a further attempt to improve the fit the data from stations 300 to 600, the anticline was further skewed by moving the flat section to $0 < y < 2$. The resulting equations were

$z + y^2/5 = 0$ (left limb)

$z - 2y/3 + y^2/3 = 0$ (right limb)

$z = 0$ (flat section, $0 < y < 2$)

The resulting Pebble mesh is illustrated in Figure 9 and the data in Figure 10.

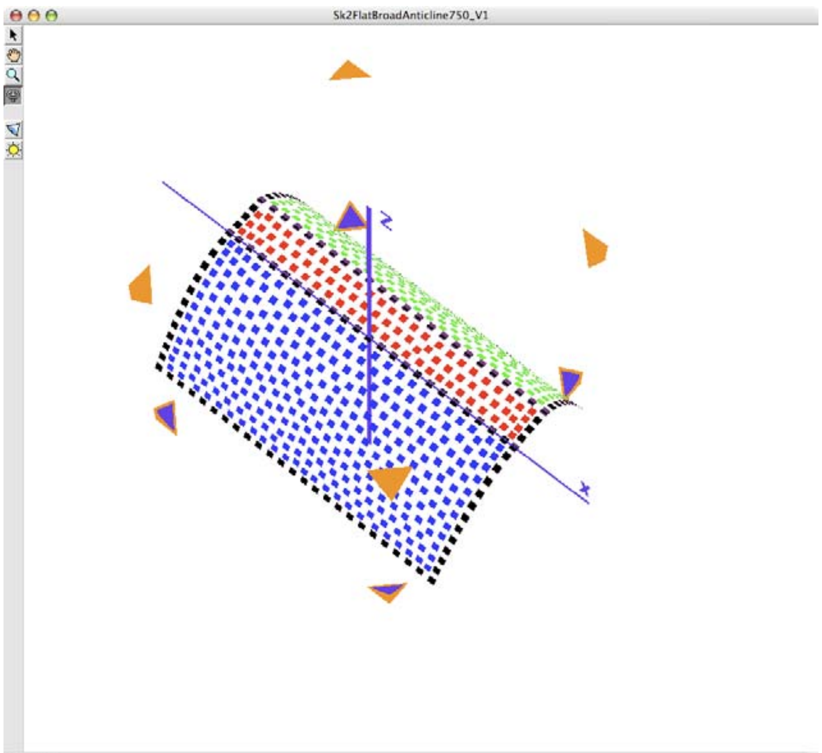

Figure 9: Pebble mesh for the anticline skewed with the flat section from $0 < y < 2$.

The resulting mesh has a sharp discontinuity in the derivative of the surface in the y direction at y=2. In the data, this crease causes the field to fall-off in the y-direction more rapidly than is seen in the scale modeling. Furthermore, the shape is not consistent with the assumption that sheet metal was continuously bent to form the parabola in the scale model experiment[1].

In Figure 10, the maximum MultiLoop III response tends to peak too far to the left, and falls at a rate that is considerably more rapid than the scale model data.

[1] The discontinuity in the derivative would have corresponded to a crease in the metal, and would have been noticed.

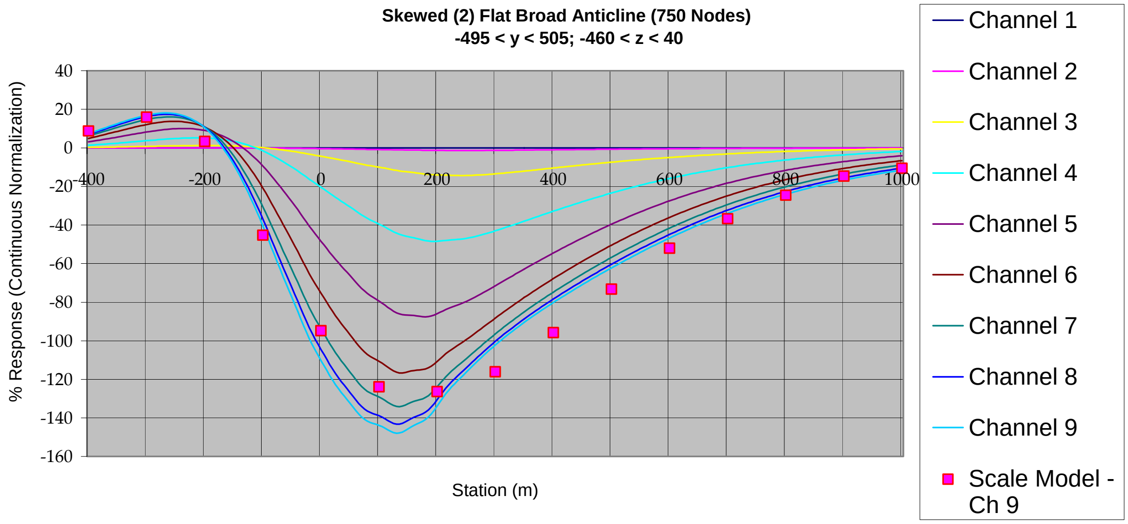

Figure 10: Scale model and MultiLoop III data for the mesh skewed with the flat part for 0 < y < 2.

Iteration 5:

The mesh in iteration 4 was refined by removing the crease at y = 2. This was done by applying a continuity condition on the derivative with respect to y at y=2 (dy/dz =0 at y=2), in addition to the conditions (y,z) = (2,0) and (y,z) = (5, -5). The extra condition required an extra degree of freedom in the surface equation, which was now assumed to be in the form of the cubic equation: $z + \alpha y + \beta y^2 + \gamma y^3 = 0$. These conditions on the function and derivative generated three equations in α, β and γ. Solving for α, β and γ resulted in:

$z + y^2/5 = 0$ (left limb)

$z + 4y/9 - 4y^2/9 + y^3/9 = 0$ (right limb)

$z = 0$ (flat section, $0 < y < 2$)

The resulting mesh is shown in Figure 11, the MultiLoop model is shown in Figure 12, and data are plotted in Figure 13. There is no doubt that the results from iteration 5 can still be improved, but the results are significantly better than those from the initial model using the pure quadratic.

This paper has demonstrated that the shape of the scale model was unlikely to have been a pure quadratic. By iteratively editing the equations defining the surface in Pebble and using the “Replace” and “Apply” (x, y, z shifts) functions in the MultiLoop III “Displace Assembly” dialogue, new models were developed to better fit the scale model data. Using such methods, new meshes can be easily tested to improve the match between the data and the modeled response.

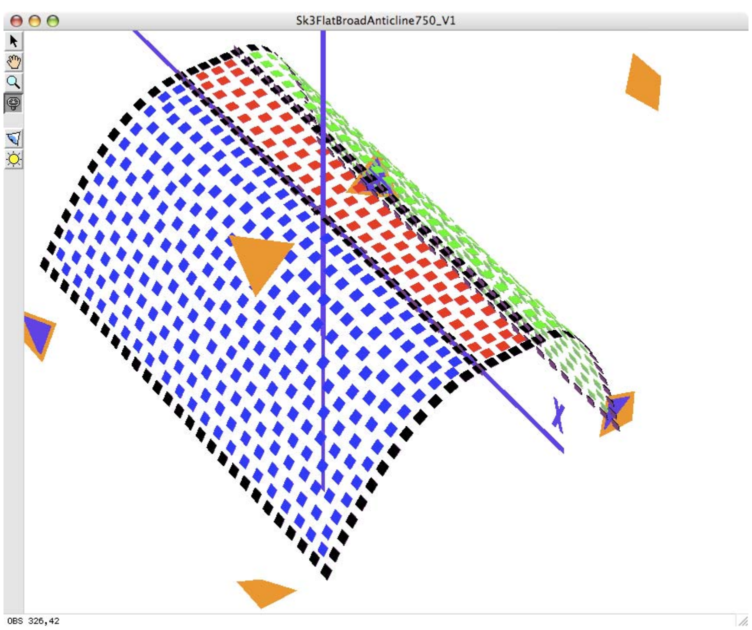

Figure 11: Skewed Pebble mesh with a cubic right limb.

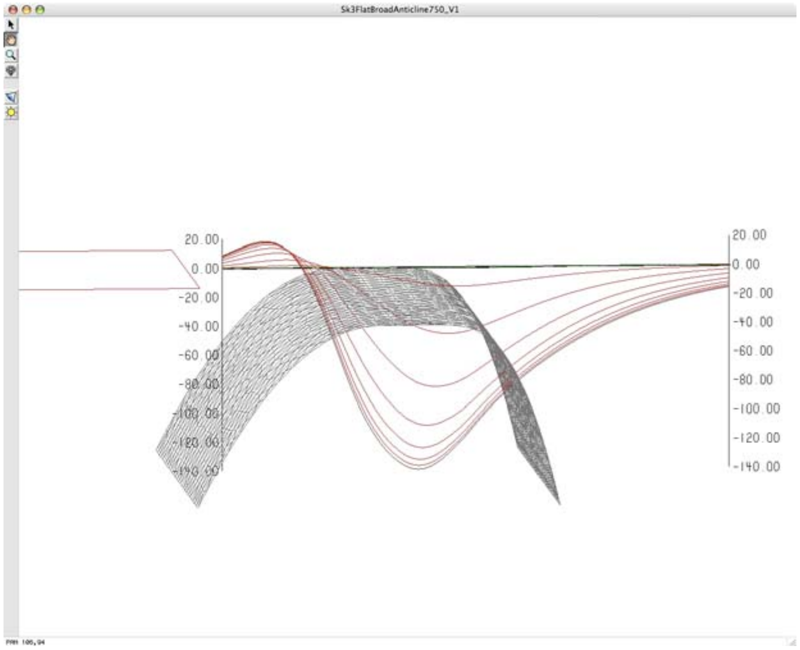

Figure 12: MultiLoop model for the skewed mesh with the cubic right limb.

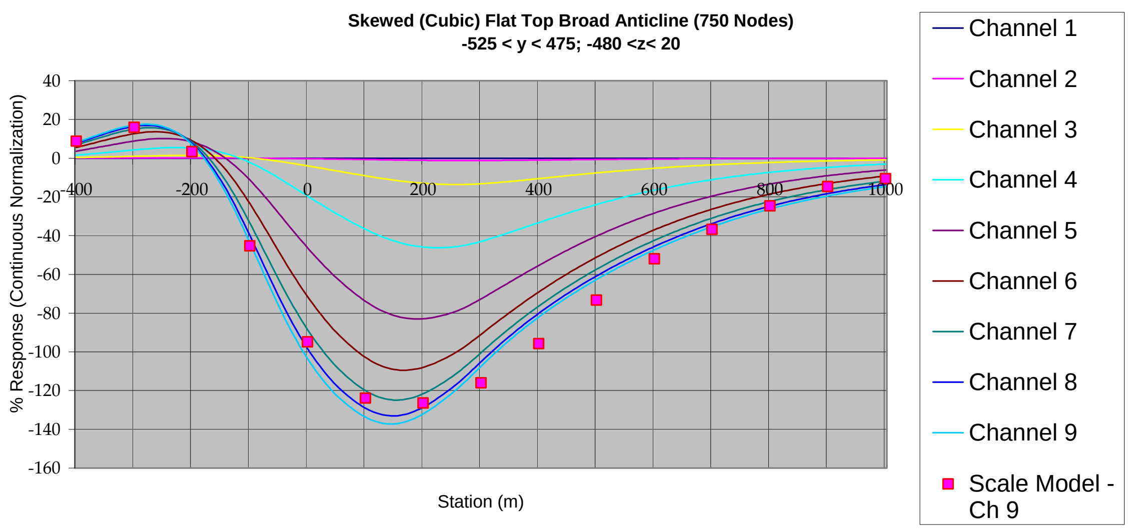

Figure 13: Comparison of the MultiLoop III and scale model data for the anticline with the cubic right limb.