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Surficial Backscatter of the Eel River Margin: IT'S JUST GAS!

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Introduction

Our involvement with STRATAFORM had two primary objectives:

1- to conduct a multibeam sonar survey of the Eel River margin and produce high-resolution maps of bathymetry and backscatter that would serve as the base maps for subsequent work. These maps were produced and distributd within days of the completion of the multibeam survey (Figs. 1, & 2).

2- to understand the causes of variations in multibeam backscatter -- OUR CONTENTION WAS THAT THE BACKSCATTER REPRESENTED CHANGES IN LITHOLOGY AND THUS PRESENTED A COMPLETE AND SYNOPTIC PICTURE OF THE PRESENT-DAY DISTRIBUTION OF SURFICIAL LITHOFACIES.

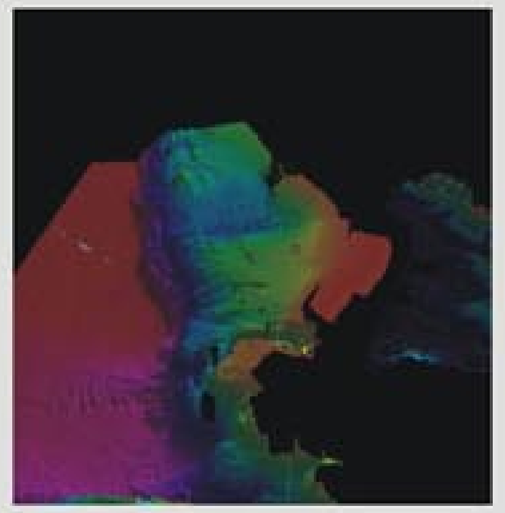


Fig. 1. Bathymetry of Eel River margin. Composite of Em1000, Em300, Seabeam and Hydrosweep multibeam data sets

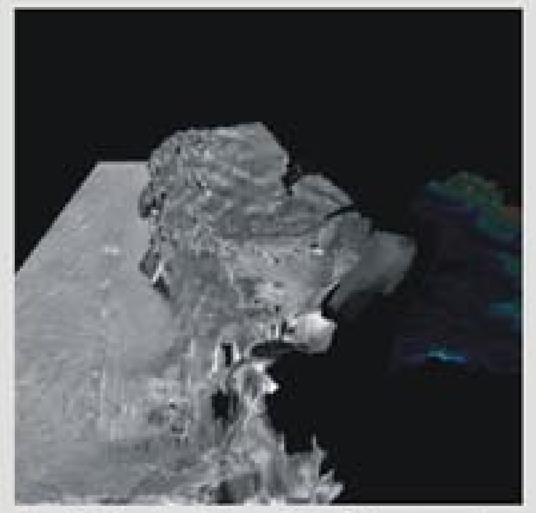


Fig. 2. Backscatter of Eel River margin. Composite of GLORIA, Em1000, and Em300 data sets.

Approach

1- Our initial approach was an empirical one. We gathered the existing core and other data sets collected in the Eel River region to see if we could find a statistical relationship between the observed backscatter and the measured sediment properties. To facilitate these comparisons and analyses we created the STRATAFORM GIS -- an ARCVIEW GIS with 64 layers of data (Fig 3.)

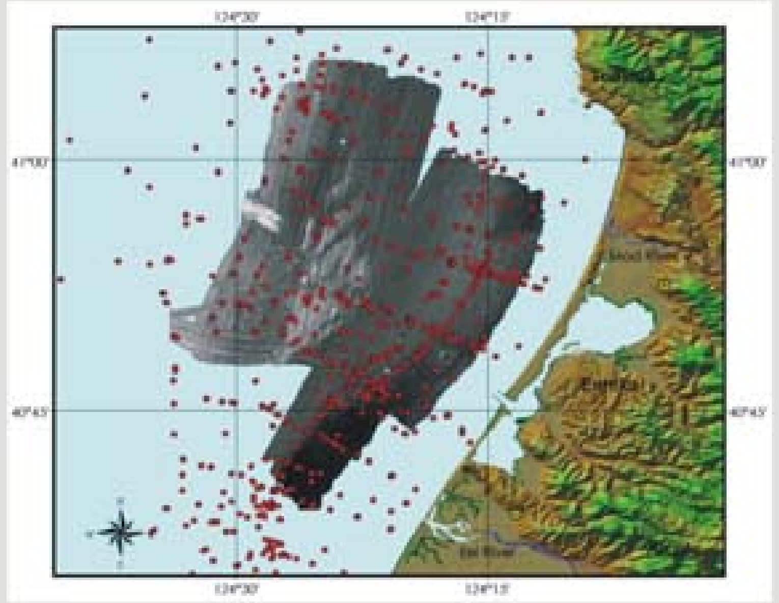


Fig. 3. ARCVIEW GIS showing multibeam sonar survey area showing acoustic backscatter response (High backscatter in white, low backscatter in black). The red dots are core-sampling sites.

2- WE COULD NOT FIND A ROBUST STATISTICAL RELATIONSHIP BETWEEN THE INITIAL BACKSCATTER AND THE LITHOLOGY AS DESCRIBED BY THE CORE SAMPLES -- WE THUS EMBARKED ON A MORE THEORETICAL APPROACH

3- We started by fully correcting the backscatter for all degrading factors (side lobes, area of insonification, AND LOCAL SLOPE -- a correction rarely made. Additionally we looked only at the angular sector between 30° and 60° This sector is the most sensitive to volume backscatter, as in the near nadir region the backscatter is dominated by seafloor roughness and impedance contrasts. Furthermore, beyond the critical angle only a small fraction of the acoustic energy penetrates the seafloor, which makes volume scatter a secondary contribution.

Fig. 4. Typical backscatter versus grazing angle curve for the EM 1000 data collected on the Eel River Margin. Only the sector between 30 and 60 degrees was used for these analyses.

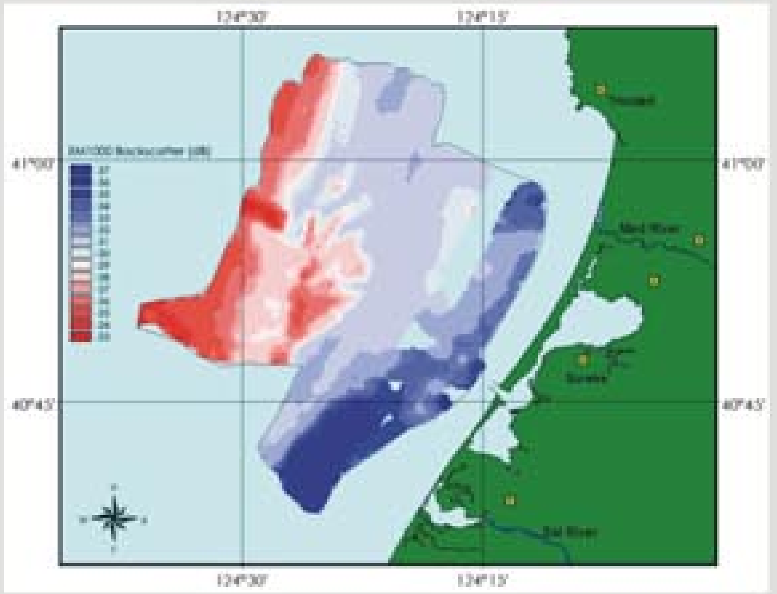
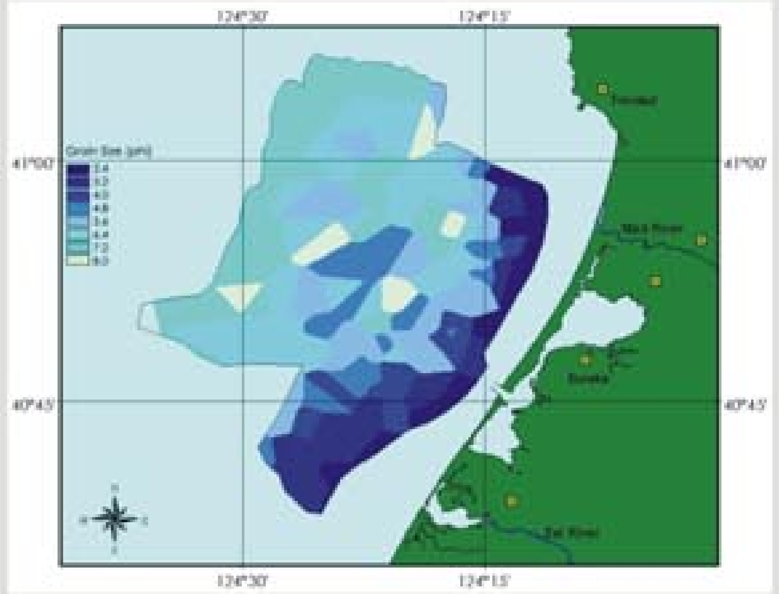
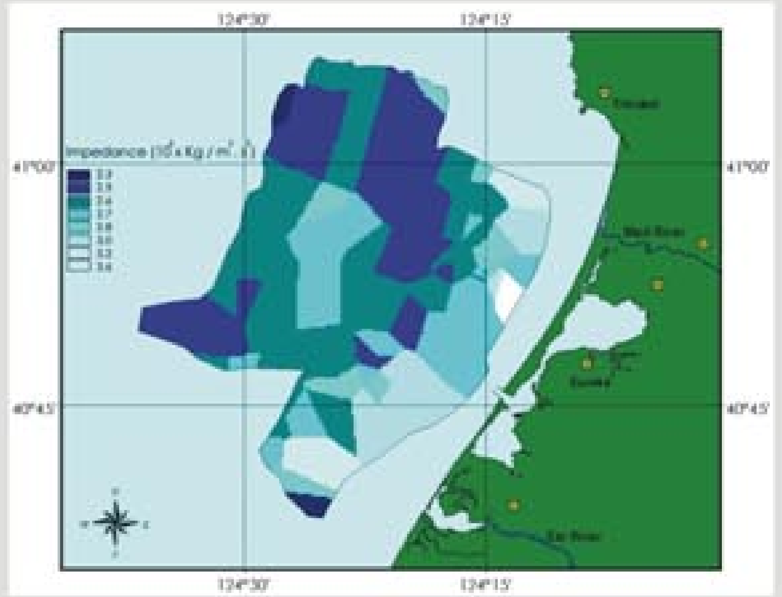


Fig. 5. The fully corrected backscatter for the Eel River Margin. Note te high backscatter in the deep waters and the low backscatter in the shallow water -- this is counter-intuitive as we would expect higher backscatter associated with the coarser grained sediments.

4- At the same time we used the model the core data base to extract physical properties for the surficial sediments. These physical property values were used to predict what the backscatter values should be using the model of Jackson et al., 1986 (Figs. 6, 7, and 8)



.Figs. 6 and 7. Thiessen polygons drawn aroundmeasurements of grain size (top) and acoustic impedance (bottom) obtained from core samples.



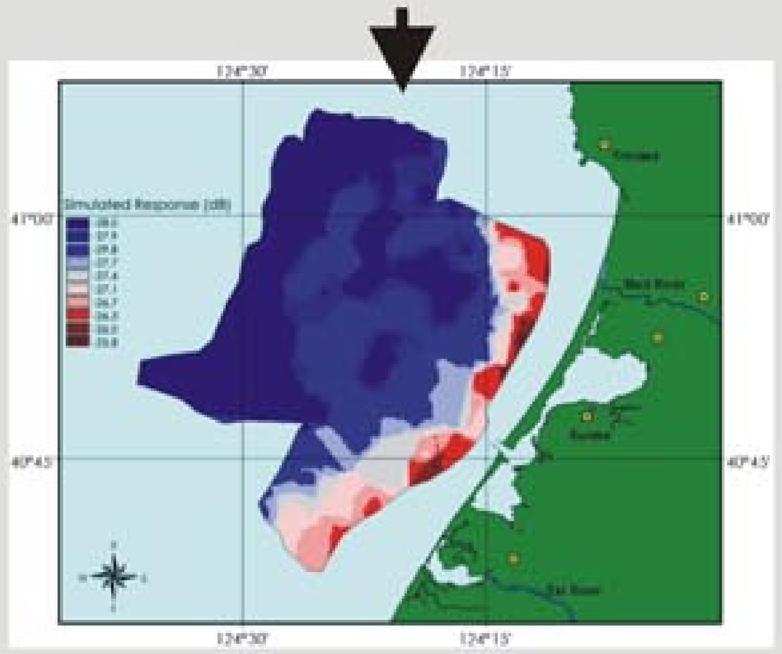


Fig. 8. Simulated backscatter response. The model predicts a higher backscatter in shallow water, where coarser high-impedance sediments are present. In deeper waters, the model predicts lower backscatter, due to the low acoustic impedance and finer grain sizes. This is in contrast to the measured backscatter -- WHY???

5 - We calculated the differences between the predicted (based on physical properties) and measured (with Em1000) backscatter and present it as the "backscatter anomaly" (Fig. 9) which shows anomalously high backscatter in deeper waters and anomalously low backscatter in shallow water.

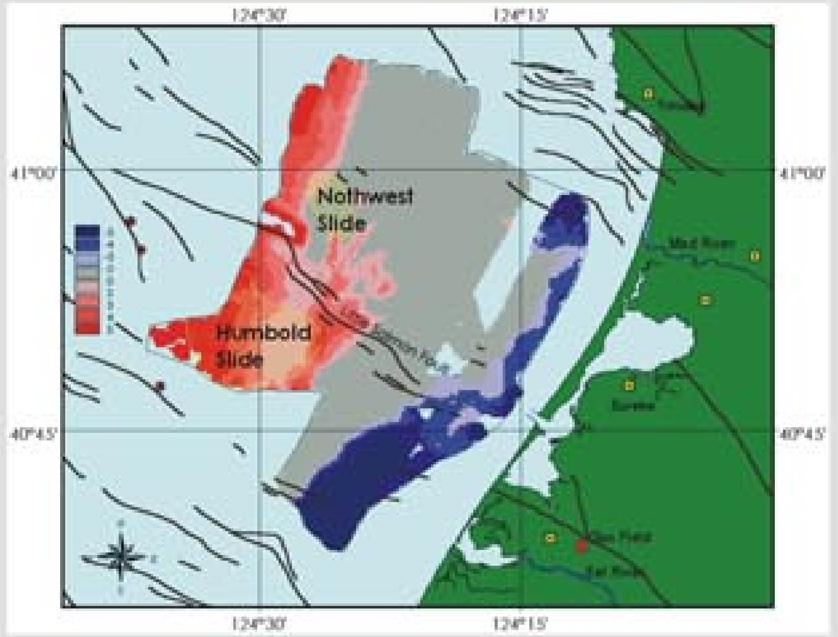


Fig. 9. Backscatter anomaly with distribution of faults. The proximity of the Little Salmon Fault can facilitate the gas migration from the reservoir to the crest of the anticline. In fact, the extension of this

6- Is it gas?? Several lines of evidence suggest an association of gas with the backscatter anomalies (Fig. 10 and 11) - - but why would gas cause low backscatter in some areas and high backscatter in others???

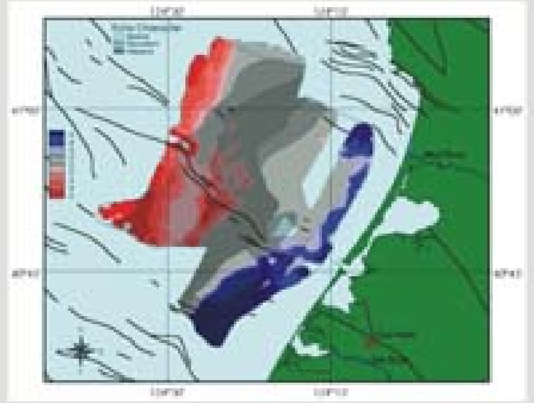


Fig. 10. A small amount of free gas on the sediment structure can explain the prominent negative backscatter anomaly on the Eel River subaqueous delta. Gas was reported on the Eel subaqueous delta based on measured geochemical anomalies using a towed gas chromatograph.

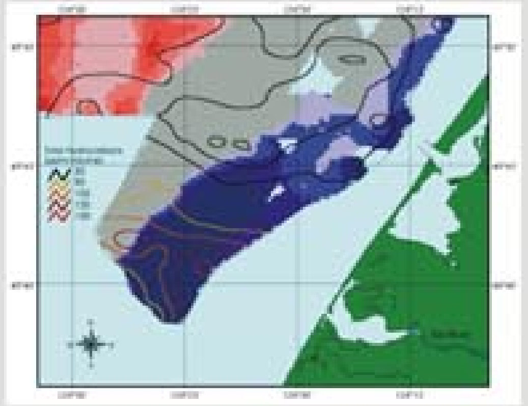


Fig 11 Echo character map showing the distribution of subsurface gas. The presence of gas was inferred in seismic profiles based upon the presence of bright spots (abundant gas), and wipeout zones, which are acoustically transparent areas (Yun 2000). Note that the positive backscatter anomalies of the headscarp of Humbold and Northwest slides are inside a gas wipeout zone inferred from the seismic profiles

Results:

7- To better understand the effect of gas on backscatter, we extended the Jackson model to include gas as a function of volume concentration and depth (Fonseca and Mayer, 2001). The model shows that depth plays an important role in the backscatter response of gassy sediments. In deep water a small amount of gas can result in a very high backscatter, a consequence of the higher bubble stiffness at high ambient pressure. In shallow water (less than 100m), the interface backscatter is severely reduced when the sediment is charged with free gas, due to decrease of sediment sound speed. Additionally, the volume contribution in shallow water is lower, due to higher attenuation of the bubbles in lower ambient pressure. This combination of factors often results in a net decrease in the total backscatter response in shallow water, relative to a gas-free sediment with the same physical properties. This explains the backscatter anomaly (Fig. 12).

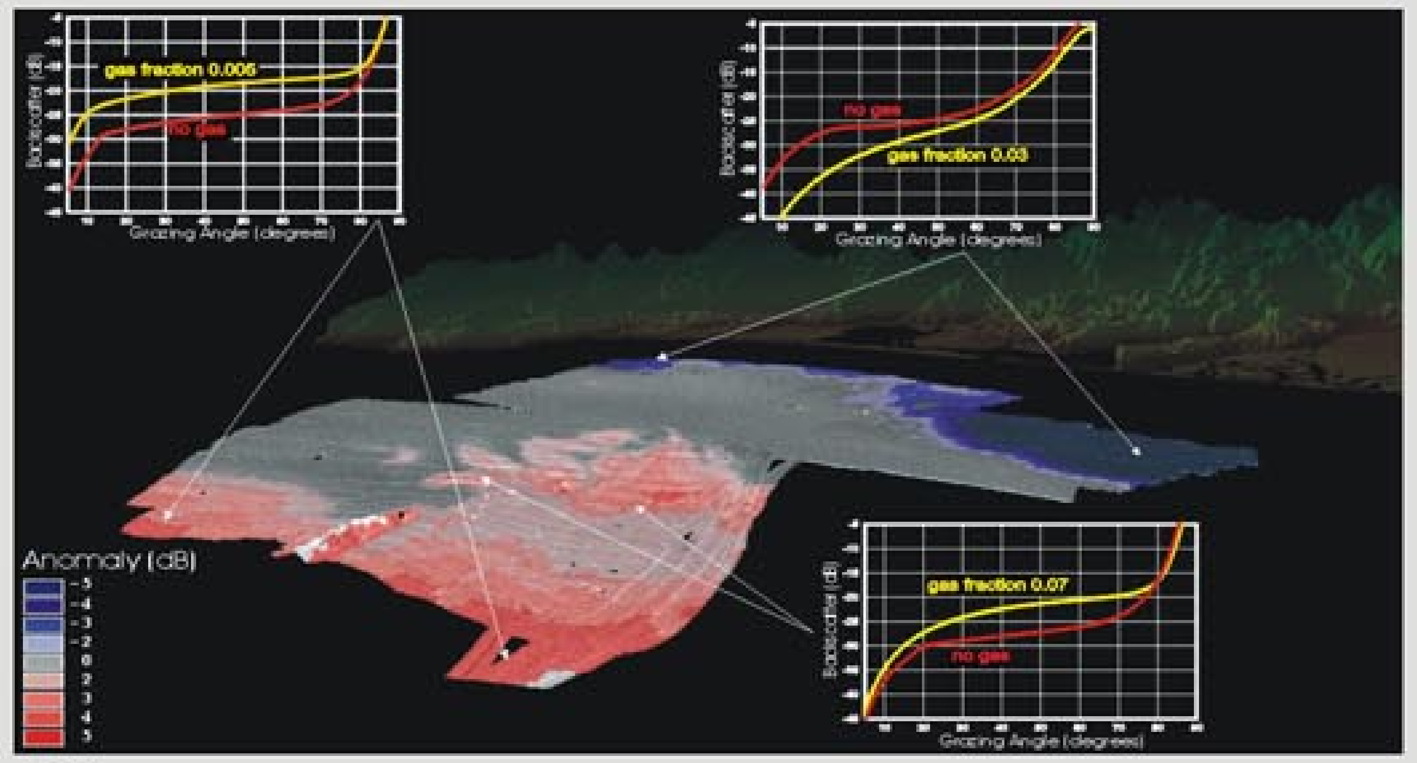


Fig 12

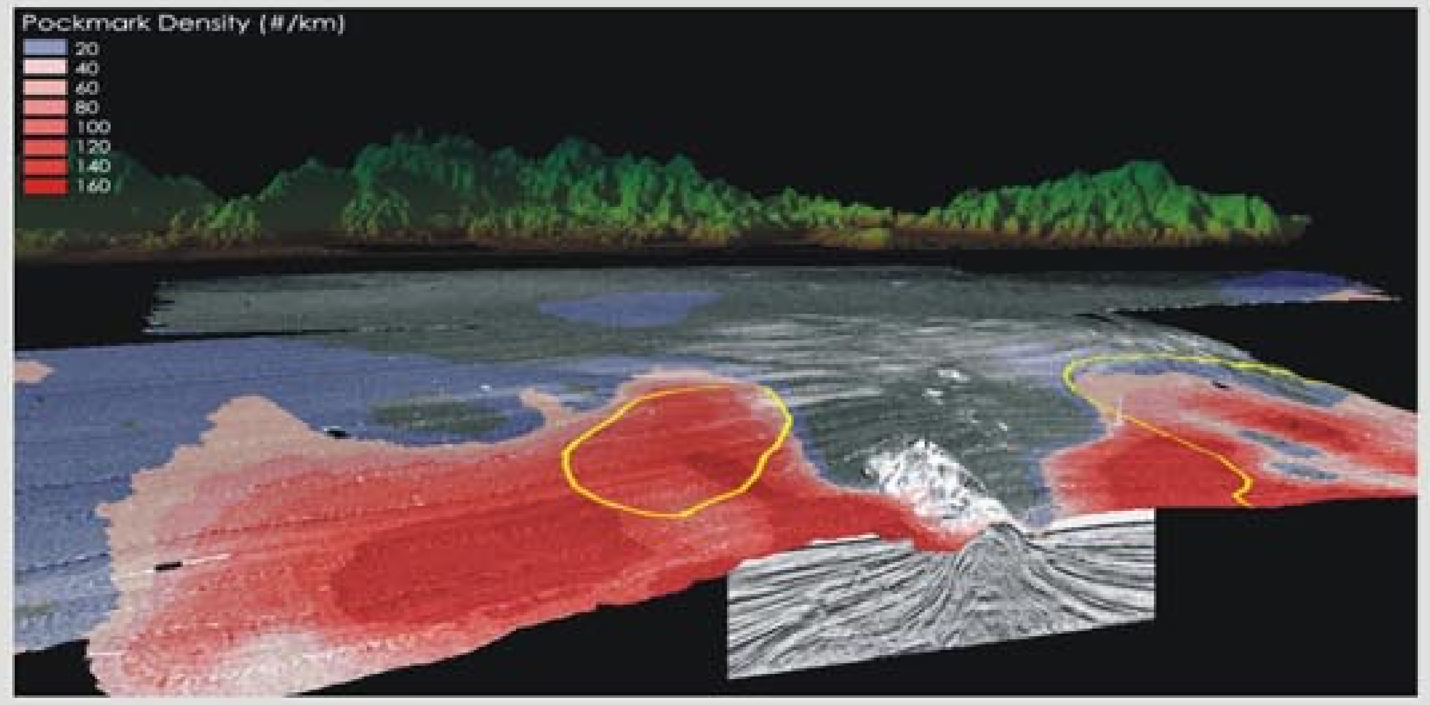


Fig. 13. Density of pockmarks determined from deep-towed sidescan sonar with areas of landslide (yellow polygons).

The positive backscatter anomaly associated to the high concentration of pockmarks in water depths beyond 400m suggests the presence of active seeping gas in this part of the survey area. The gas probably comes from the dissociation of hydrates, which were indicated in these areas by the presence of bottom-simulating reflections in high-resolution seismic lines (Yun, 1999).

There is evidence that the near-surface gas on the headscarps of Humbold and Northwest slides may come from deep reservoir sources.Gas probably accumulates at the impermeable crest of this anticline until it seeps to the surface through factures at the base of the folded structure. This seeping gas can explain the positive backscatter anomalies around the folded structure

Conclusions:

Our initial hypothesis that the surficial backscatter represented lithologic change appears to be wrong for the Eel River Margin. Through the use of 2D and 3D GIS combined with theoretical modeling we have been able to demonstrate that the surficial backscatter of the Eel River margin appears to be responding, in a complex way to gas in the sediment. While this is disappointing in terms of interpreting the spatial distribution of surficial facies, it is exciting in that it may be possible to predict near-surface gas content from carefully collected and analyzed multibeam sonar data.