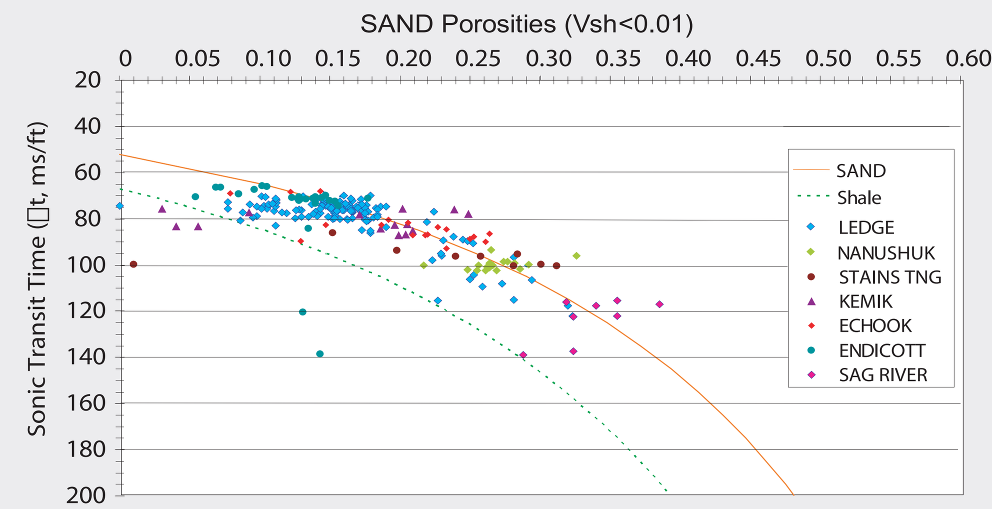
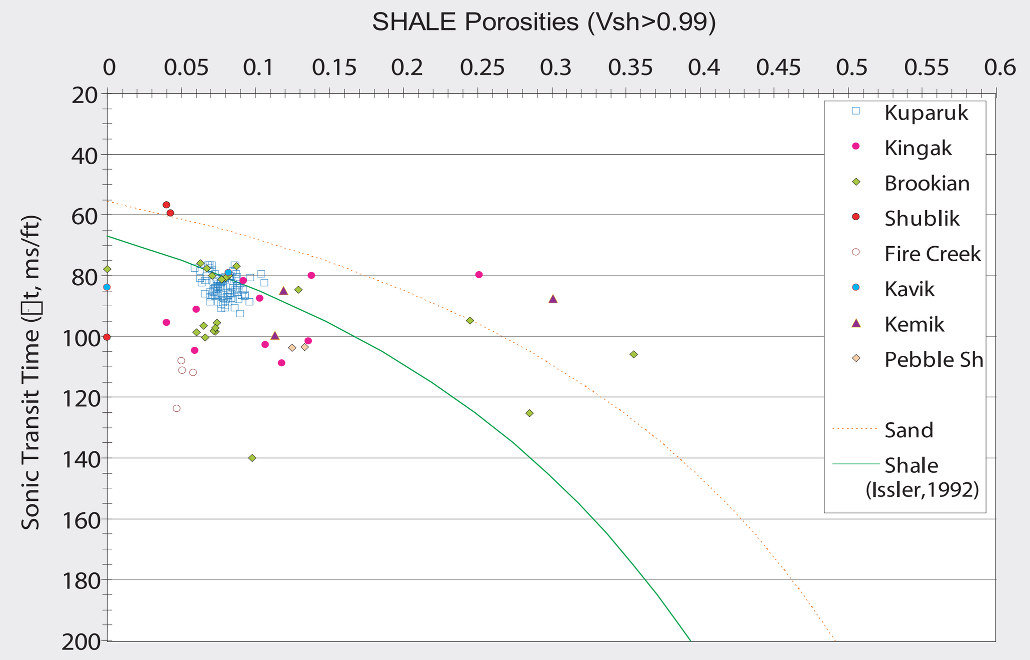
Sonic Transit Time vs. Porosity





The data shown above are laboratory porosity measurements made on core samples at specified depths. The sonic transit times at the corresponding depths in each well were matched with the measured porosities using WALDO, a tool developed by D. Hayba.

The relationship developed by Raiga-Clemenceau (1988) was used to translate sonic transit time (Δt) to porosity (ϕ):

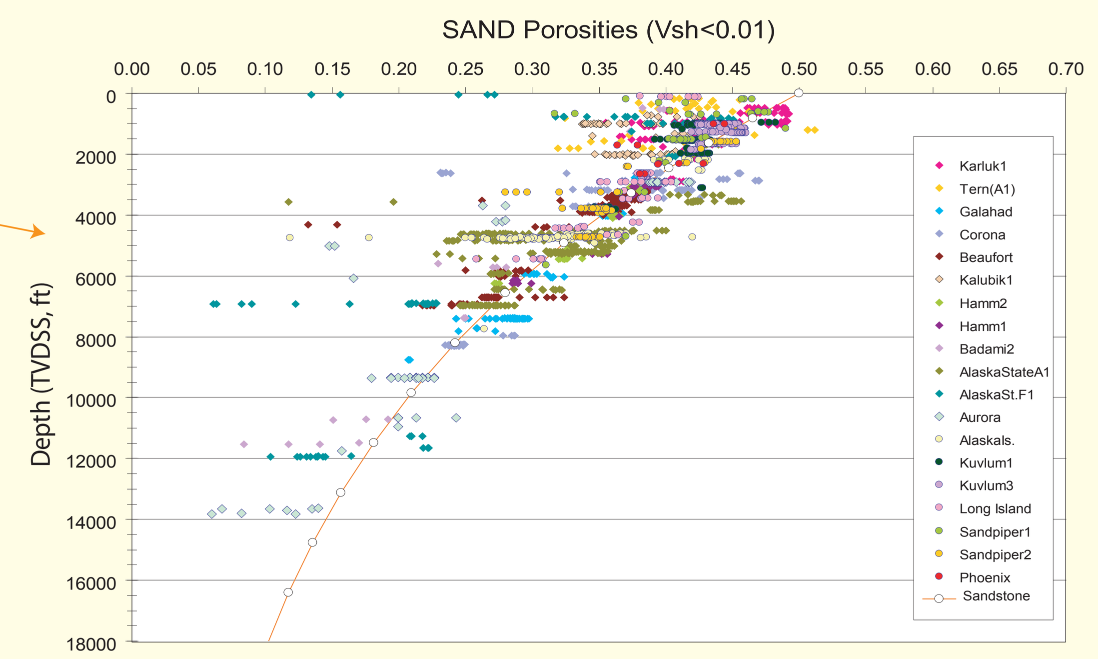
$$\phi = 1-(\Delta t_{matrix}/\Delta t)^{1/x}$$

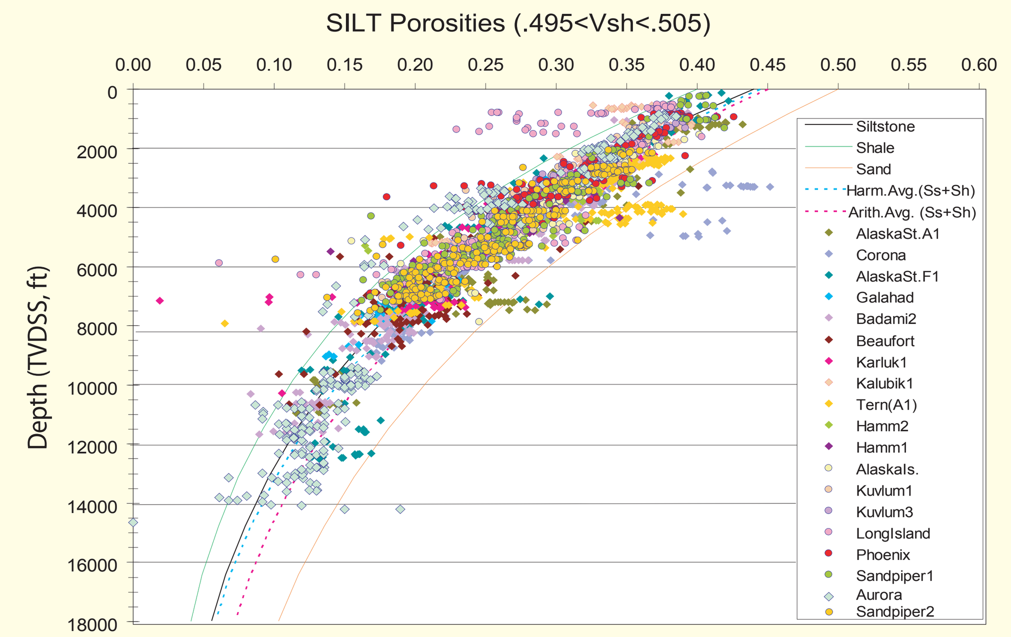
Δt_{matrix}, the matrix transit time at zero porosity, was determined from the y-intercepts of the curves shown above for sand and shale. The formation factor, x, controls curvature, and was adjusted to fit our data from within the range of published values.

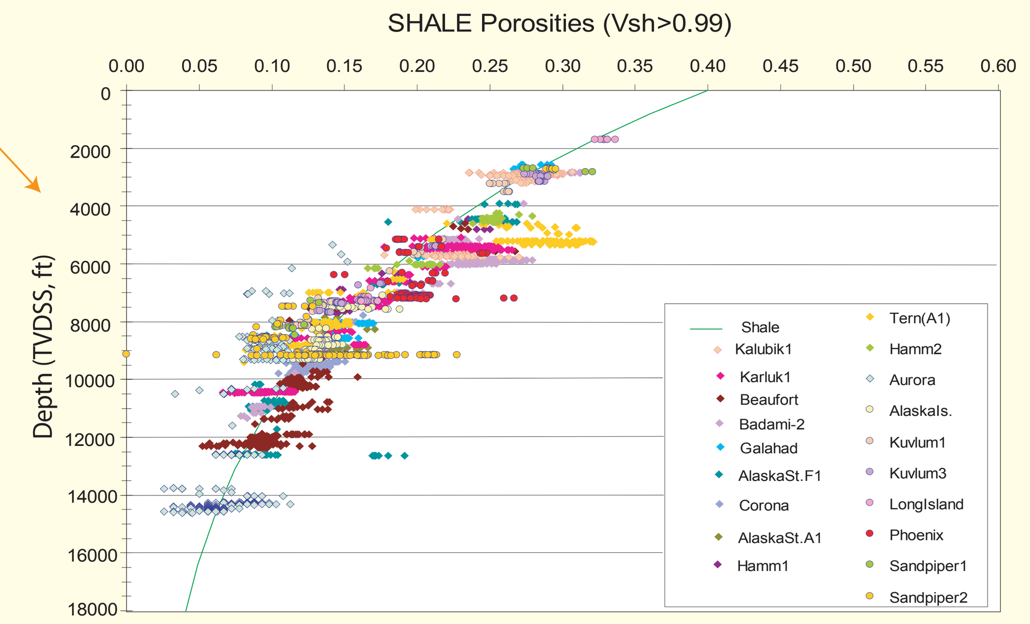
The parameters that we use are as follows:

	Δt_{matrix} (µs/ft)	x
Sand	52	2.05
Shale	67	2.19

Compaction Curves







Composite porosity-depth profiles are shown for 19 offshore wells. No *individual* well had near-pure sand and shale over a sufficient depth interval to construct compaction curves.

Erosion at the end of Brookian sedimentation was minimal or non-existant in these wells. However, overpressures appear to be relatively common in the shale, even at depths of 1000-3000 ft. We eliminated porosity intervals where there was a clear spike in the shale's sonic transit time. Nevertheless, some porosities recorded in overpressured, under-compacted rocks still remain in the data set, and account for some of the scatter in the data set.

Other sources of error include secondary porosity and cementation which are not addressed by the compaction curves. Four of the wells, Corona, Kuvlum 1 & 3, and Aurora are located on the flanks of anticlines and thus have undergone some uplift. However, based on seismic reflection profiles through the wells and on their porosity-depth profiles, we made the assumption that these sites have not undergone significant erosion despite gentle folding.

In our basin models, porosity (and related properties such as thermal conductivity and permeability) for individual formations are calculated as averages of sand, silt, and shale properties.

We fit the following porosity-depth (compaction) curves to the sand, siltstone, and shale data sets:

$$\phi_{SAND} = 0.5\, e^{(-0.29 \times Z)}$$

$$\phi_{SILT} = 0.44\, e^{(-0.38 \times Z)}$$

$$\phi_{SHALE} = 0.4\, e^{(-0.42 \times Z)}$$

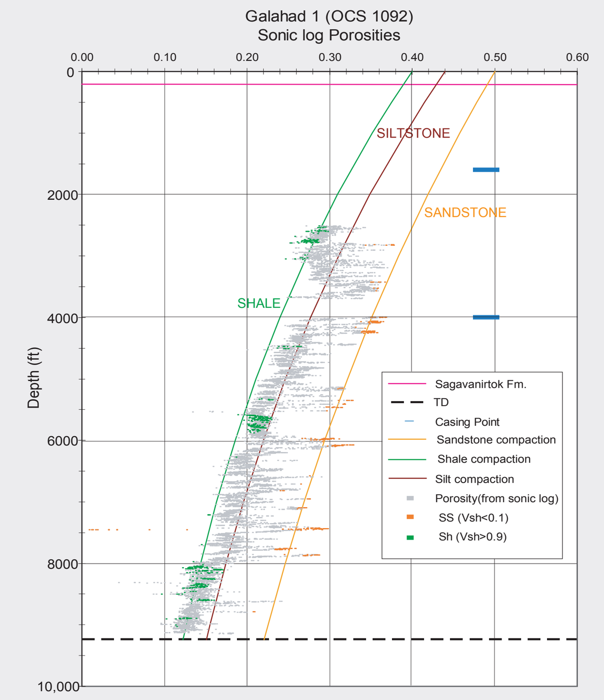
where ϕ = porosity and Z = depth (km).

Individual Well Profiles

The sandstone, silt and shale compaction curves that we have defined can now be applied to individual wells. A spreadsheet named WALDO (Well And Log Data Organizer) was developed by D. Hayba using Excel's macro programming language to facilitate efficient analysis of the geophysical log data. The two plots below are examples of output from WALDO.

The plot to the right shows sonic porosity data for the Galahad well with the sand, silt and shale compaction curves superimposed.

Near-pure (Vsh>0.9) shale is highlighted in green and near-pure sand (Vsh< 0.1) in orange. The speadsheet, WALDO, allows one to shift the compaction curves up or down relative to the data. The best match of the curves to the data allows an estimate of erosion. No significant erosion has occured in the Galahad well.



This plot shows the difference between the sonic-derived porosities and porosities predicted by our compaction curves (compositionally-averaged at each point among the sand, silt, and shale endmembers). The plot essentially shows the error or deviation of our curves from each measurement.

A positive deviation from the zero line, particularly in shale may be an indication of overpressure. A systematic deviation to the left of the zero line is an indication of erosion. The compaction curves (top figure) are then shifted up (representing erosion) until the errors in the difference plot are minimized and centered around the zero line. (In practice, it is more accurate to visually judge when the data set is centered around the zero line in the 'difference plot' than to judge an ideal fit to the curves in the top figure).