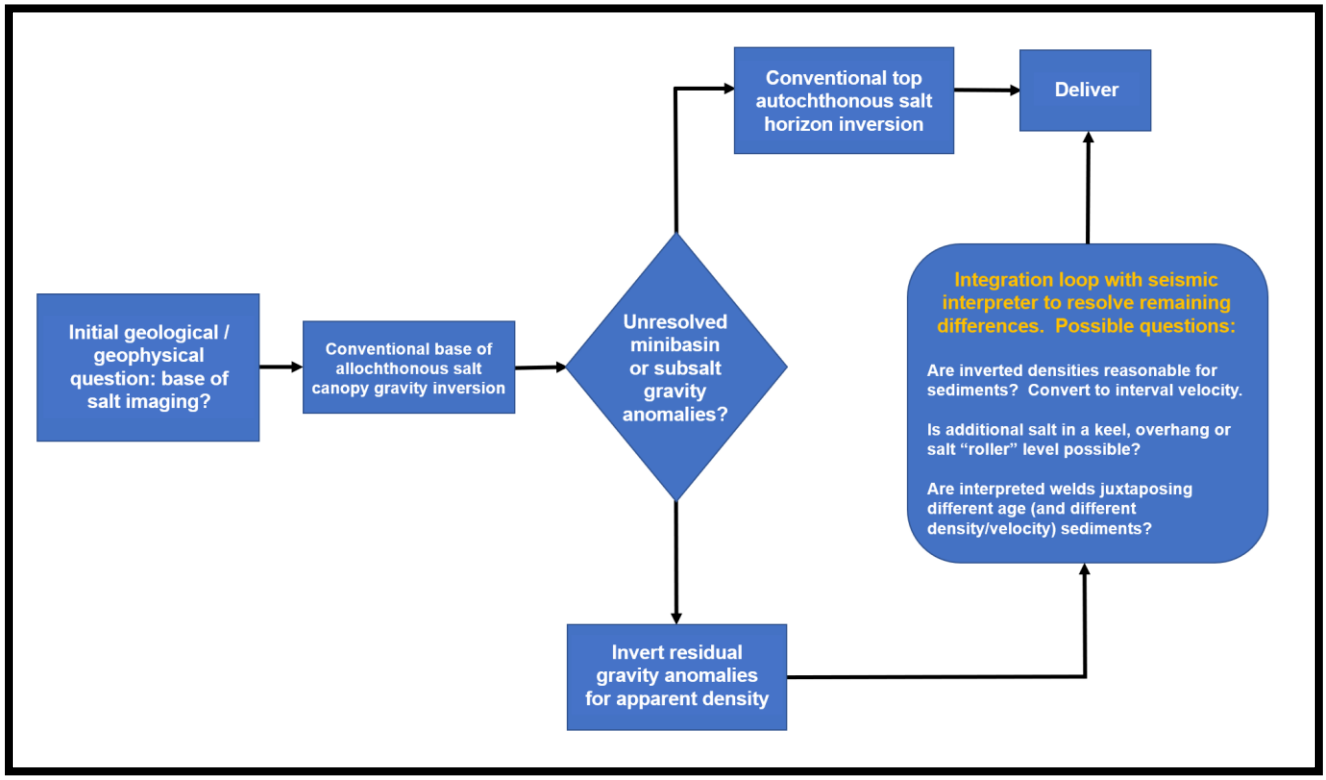
Integrated 3-D Modeling & Inversion for Subsalt Exploration

In addition to the use of gravity and magnetic modeling and inversion to assist with understanding the structural tectonics of an area, we spend a tremendous effort on building better 3-D models in and around complex salt features, carbonate reefs, volcanics, etc. The following illustrates the workflow commonly used during our careful, integrated (seismic /gravity/well control) 3-D modeling studies.



Recommended Decision Path: Use of Gravity to Enhance Seismic Velocities to Improve Base of Salt Imaging

The process for using gravity inversion and modeling to aid the interpretation of complex salt features can involve multiple phases throughout an imaging project, such as:

- Careful build of canopy salt using multiple salt body construction - often involving top salt 1, 2, 3 and base salt 1, 2, 3 over the lifespan of the seismic imaging effort
- Comparison of difference gravity from alternative salt interpretations
- Compare with and without deep autochthonous salt
- 3-D gravity inversion and modeling to derive alternative base of salt at each stage and each salt body level (various levels of base salt canopy, multiple tree branches of salt canopy, top salt roller, etc.)

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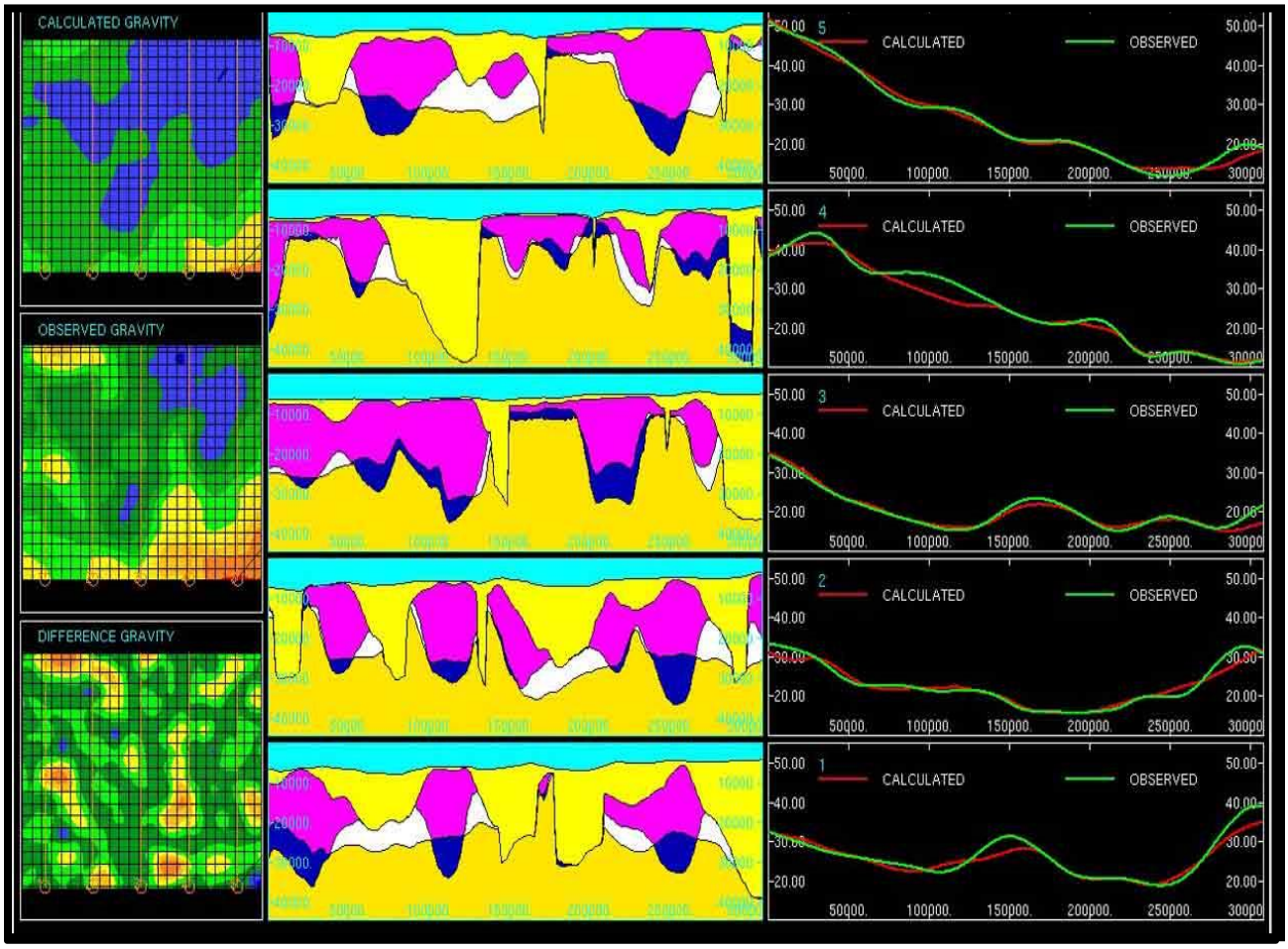
- Inversion of sedimentary densities, holding well-imaged seismic base of salt fixed – transform alternative densities back to velocity & compare with seismic velocity model.

An example integrated (seismic & gravity) 3-D salt model is shown below, where magenta regions indicate salt from seismic acceptable to gravity, dark blue indicates salt added by gravity inversion, and white indicates salt removed by gravity inversion. Interesting areas show deeper keels or possible feeders (dark blue) and areas suggesting less salt (white), or higher density in these areas than the density of typical salt. Although the results are shown in cross section below, all work is done in 3-D.



Integrated (Seismic & Gravity) 3-D Salt Model (CGG-3MOD™)

Once the salt geometry has been finalized through a careful seismic and gravity integration effort, there is often a remaining gravity difference between the observed gravity and the model gravity. We like to say at this point: “ignore the gravity at your peril!”. There is clearly something still missing in the model that should satisfy the remaining difference gravity field. We then invoke a gravity inversion using the sediment density as our inversion variable, to understand one possible reason for the remaining gravity field differences.

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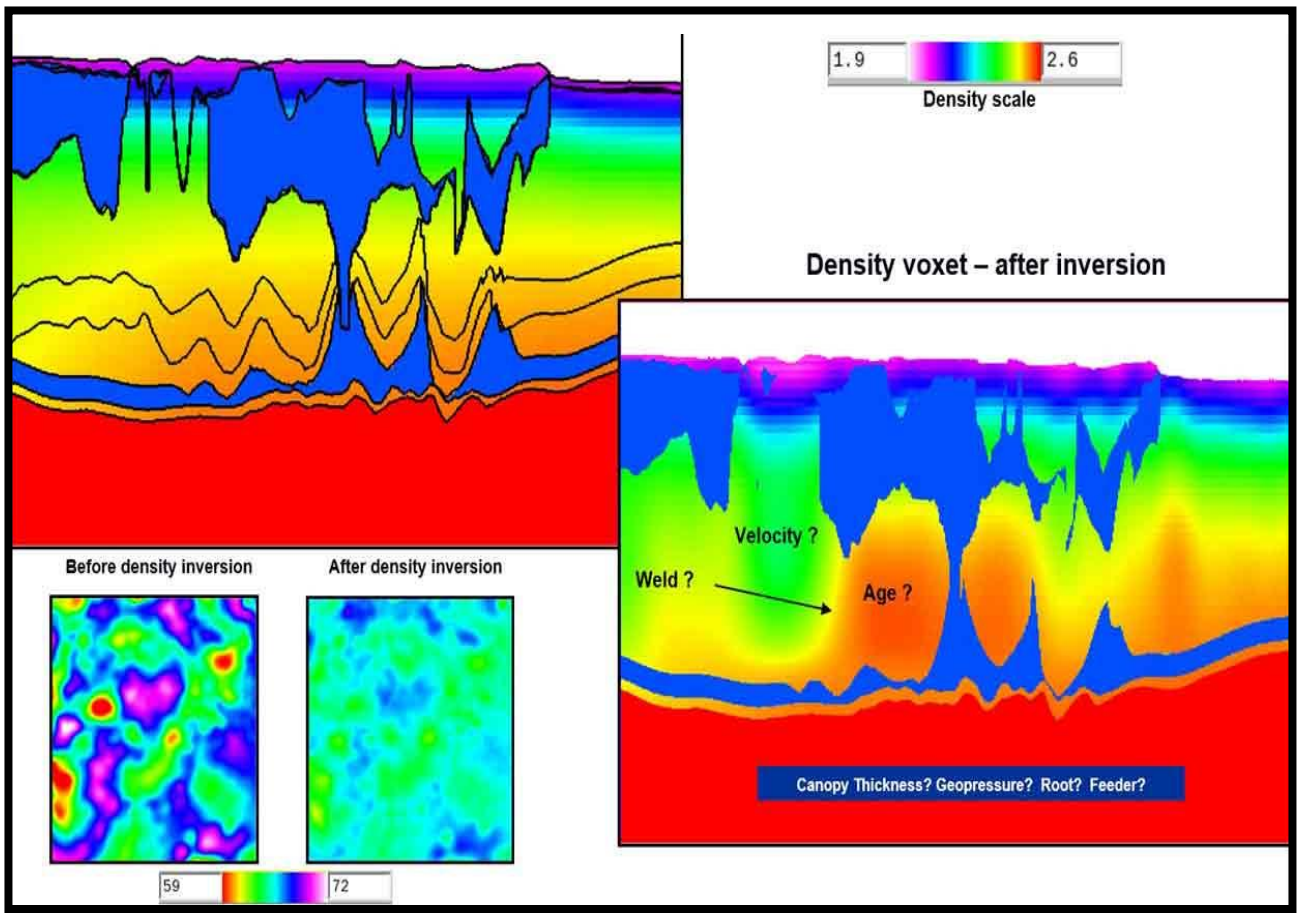
In the example below, the salt geometry (canopy and authochthonous / roller level) was finalized and held fixed during subsequent gravity inversions. The sedimentary densities had been created from a density vs. depth function derived from a study of density logs (upper left cross section). We then invert the gravity data by allowing the sediment densities to be altered. On the lower right we see the amount of density change that is required to match the remaining gravity field differences. An area of higher density is predicted to lie just beneath the central canopy, possibly indicating a salt weld that juxtaposed younger rocks on the left against older, more dense rocks beneath the primary canopy.

At this point, we can convert the inverted density cube back to apparent velocity to directly overlay and compare with the then-current seismic velocity model. In this way, we can study alternative velocities beneath and around the salt canopy, driven by our gravity inversion results and closely constrained by seismic control. Gravity difference maps before and after inversion for apparent density are shown on the lower left. Our results indicate a much-improved difference gravity field using geologically plausible alternative model densities.



Use of Gravity Inversion to Depict Zones of Anomalously High/Low Density & Velocity

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