Note #4: Depth Conversion – the geophysical black art?

Alan Atkinson – Partner at Rockflow Resources Ltd.

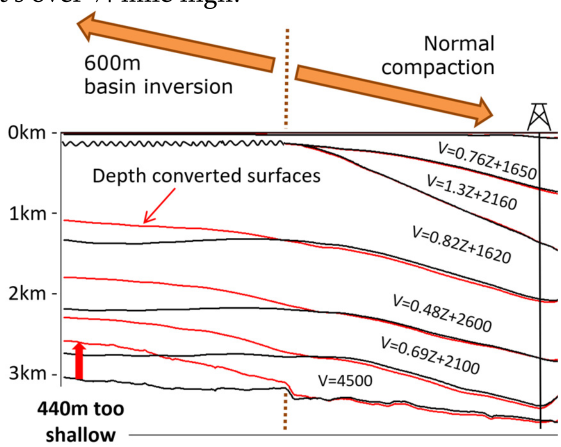
Depth conversion: every seismic interpreter needs to do it, or sidesteps responsibility by using depth migrated seismic directly in depth - not a safe choice as we'll see later. Important things depend on depth. Multi-million dollar wells and investment decisions scaled to in-place volumes, but few interpreters claim expertise in depth conversion.

Geophysicists may interpret seismic every week of their working life, but will only depth convert once in a project with months or years separating their efforts. Its no wonder that the majority feel it is a black art that they might never master. Lack of mastery has led to expensive mistakes, and the need for awareness and training is well understood by companies who have lost money or lost opportunity due to poor depth conversions, but can be overlooked by other companies who have avoided that fate…or failed to identify depth conversion as the cause.

Depth conversion can founder on age-old problems, such as 'I don't have enough time' (projects are always measured in weeks, not days), or 'I always do it this way': a velocity model suitable for the Niger Delta is unlikely to work in North Africa. But even for the diligent worker there are other ways of going wrong, more subtle traps, that he or she can fall into…

How to go wrong 1: not thinking geologically

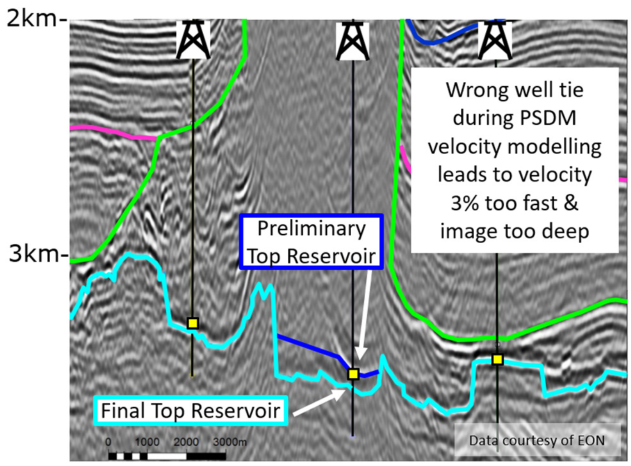
Depth conversion (and depth migration) takes seismic reflections measured in time and transforms them to measurements in depth using velocity. Velocity depends on the type of sediment deposited, how it has changed over time, and the fluid filling its pores i.e. velocity depends on geology. **If your velocity model doesn't stick to geological rules, *you'll* come unstuck**. Let's take a look at the well-known 'Vok' method – the one which says that velocity increases at a constant rate proportional to the depth of burial. This is a widely used tool built into some popular software packages, but rarely is help given on how to wield it. Most importantly, velocity is assigned based on its present-day depth, implicitly assumed to be the rock's maximum depth of burial. This is fine for a subsiding basin, but what if that basin has undergone broad tectonic uplift (e.g. Barents Sea in Norway), or if a salt or shale diapir has caused localised uplift? In many cases the rock does not 'decompact' to its younger state, but largely holds on to the highest velocity it reached at maximum burial. In a fully inverted basin, the shallowest rocks were once the deepest and fastest, so velocity appears to *decrease* with increasing depth, the opposite behaviour to that described by the Vok model. In one example, from the North Sea Sole Pit Basin, the reservoir at 3km (10,000ft) had been inverted by an estimated 600m (2,000ft), and a depth conversion with a Vok model underestimated velocity so badly that the resulting reservoir depth map was 440m shallow – that's over ¼ mile high!



The alert interpreter will recognise this problem and use a velocity model suitable for the tectonic setting.

How to go wrong 2: blind faith in geophysics

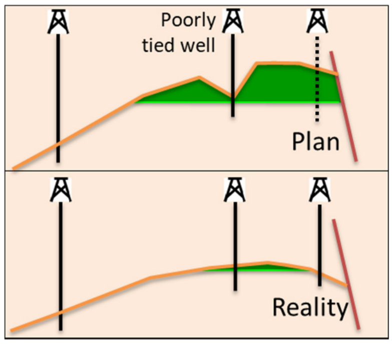
Another way that depth conversions can go wrong is by placing excessive trust in the seismic velocity model: “I don’t need to depth convert, my depth migrated seismic is already in depth”, is a comment made by those who haven’t yet sat through a difficult post-mortem for a disappointing well. If you are interpreting Pre-Stack Depth Migrated (PSDM) data in the depth domain then you have handed over responsibility for depth conversion to the seismic imaging team. Seismic processors have many sophisticated ways of generating detailed, precise velocity fields, but absolute accuracy is only achieved by the remarkably unsophisticated technique of comparing seismic reflection depths with the depth of the reflector in a well, to work out a correction factor. The main reason for any differences is anisotropy which can cause seismic velocity to appear to be too fast, but the correction may be polluted by many other factors including the seismic being in the wrong place (poor migration), or the well tie being wrong (which seismic reflector matches the logs?).



In the demanding PSDM environment of the Southern North Sea, constant correction factors are typically applied per geological layer, with outlier wells being excluded from the averaging process, leaving the best wells tied in depth to +/-1%, and the worst to considerably more. **This may not matter too much in exploration on large structures, but locating development wells, especially for low relief fields, needs much more work.**

How to go wrong 3: falling at the last hurdle

Most depth conversions result in maps which mis-tie well depths (if they don’t, and you don’t know why, then you should be asking questions!) How these residual depth errors are removed is an integral part of depth conversion and in some cases can have as big an impact as the velocity model chosen. Do the depth residuals form a trend? In which case they may be telling you that there is un-accounted for velocity variability. The unwary can go wrong here if they assume the residual is just a localised error and try to apply a depth correction within a small radius of the well: you may find that drilling up-dip from a tied well to find attic oil leaves you down dip in the water leg!



How to do it right

Understanding the geological controls on your velocities is the first step in successful depth conversion. This requires careful analysis of well and seismic velocity data, but once this arduous process has been completed it should become clearer how to build a geologically sympathetic velocity model from well data, and whether seismic velocities capture true geological variation between wells, rather than geophysical artefacts. Understanding the geophysical origins of your seismic image is the next step needed in creating a depth map which inspires confidence. A world beating depth migration algorithm and state of the art velocity model still rely on a less well constrained anisotropy model to put a seismic reflector in the right place. Appreciating that on the steep flanks of a salt diapir what you thought of as a 100m (330ft) vertical depth error was actually a 25m (1-2 seismic trace) lateral migration error can help you avoid ruining a depth map with a poor correction.

Successful depth conversion isn’t a black art. It is the magic that comes about when geological and geophysical understanding combine with mapping know-how to create plausible maps on which to confidently make big investment decisions. Technical integrity matters!

Rockflow Resources Ltd. (www.rockflow.com)
UK Registered Company 7866408