Post-stack iterative modeling migration and inversion (IMMI)

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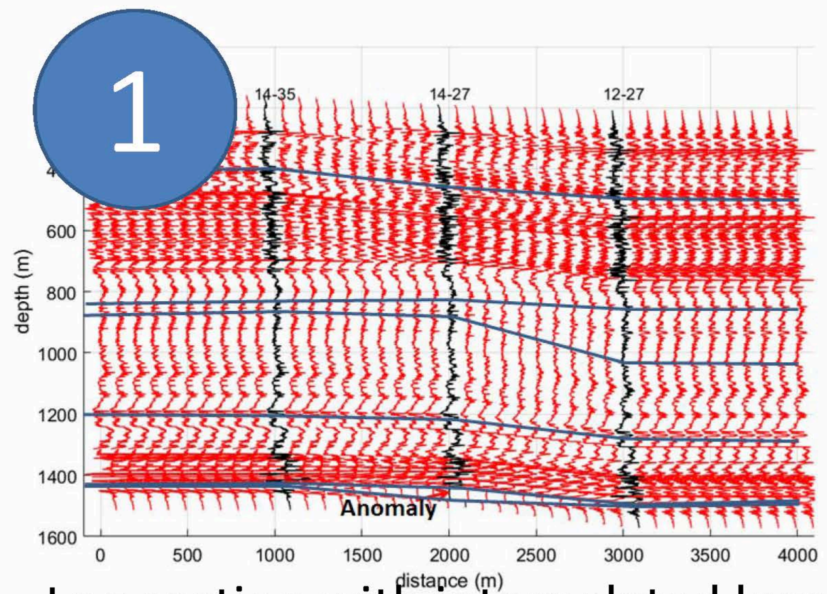
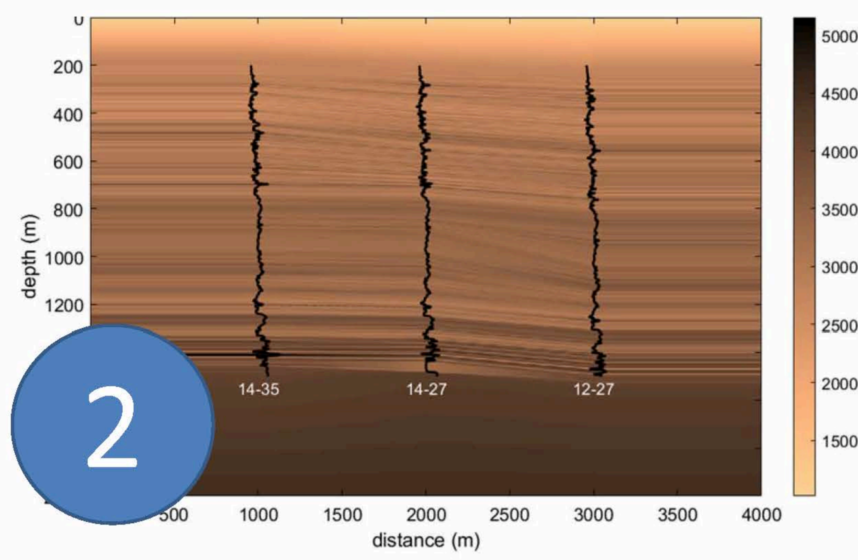
Summary

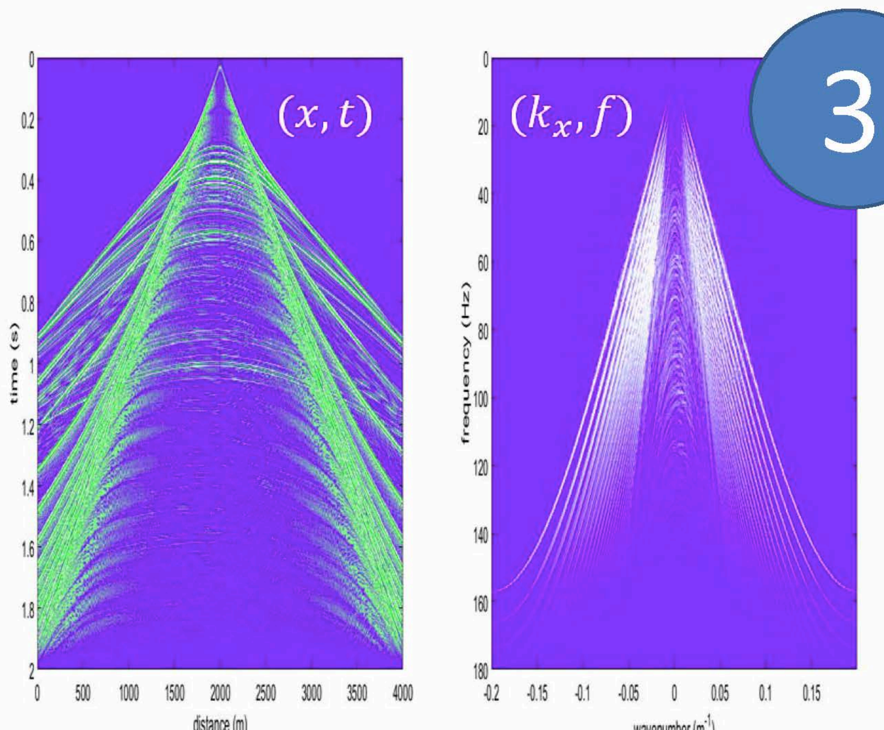
The possibility of a post-stack process resembling full-waveform inversion (FWI) is investigated. As generalized by the IMMI concept, this implies an iterative process of modeling, migration, and inversion all done in the post-stack domain. To test this idea, a detailed stratigraphic p-wave velocity model was created by interpolating between 3 sonic logs from the Hussar dataset. The overburden (upper 200m) was created with smooth lateral and vertical gradients, and the underburden (1.55km to 2km depth) has similar smooth gradients while the detailed stratigraphy is contained in the 200m-1.55km interval. The wells were placed at 1km, 2km, and 3km distances along the line, the interpolation was guided by picked formation tops, and the resulting velocity model was created on a 2.5m square grid (2D). Using acoustic finite-difference modeling, 60 shot records were created at even intervals along the 4km line. The data were then processed with gain, f-k filter, normal-moveout removal, and stack to create a conventional CMP stack. Then, an IMMI process of exploding reflector modeling, post-stack migration, and matching to known impedance at a presumed well was employed. The exploding reflector modeling was chosen for its simplicity compared to the modeling and processing of all 60 shots in each iteration. The migration was a post stack depth migration, and the matching to well control was conducted using a single simulated well at coordinate 1000m. It was assumed that the overburden (upper 200m) velocity was known through tomography or refraction statics and it was further assumed that the velocity was known in detail at the well from 200m to 1.55km depth. The starting model contained the true overburden and then a simple linear gradient from the base of the overburden to a presumed-known basement velocity of 4500m/s. Shown below is the result after 11 iterations during which the maximum frequency allowed into the process was gradually increased from 10 to 60 Hz. At each step in the iteration, the depth migration at the well was scaled to approximately match the well velocity and this scaling was then applied to the entire migration. While a better result is desired, the process appears to be both feasible and worthwhile.



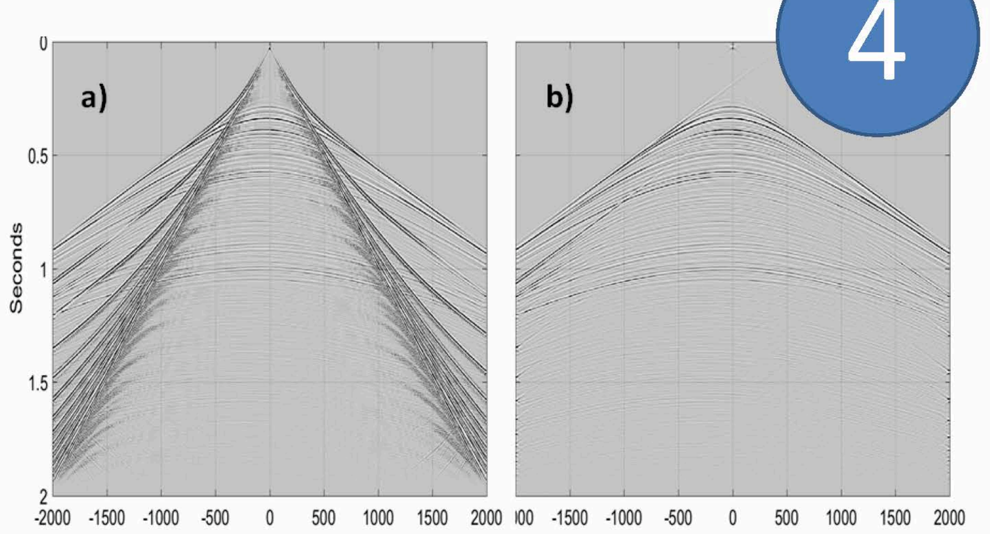
1 Log section with interpolated logs every 100m. Interpolation is guided by formation tops.



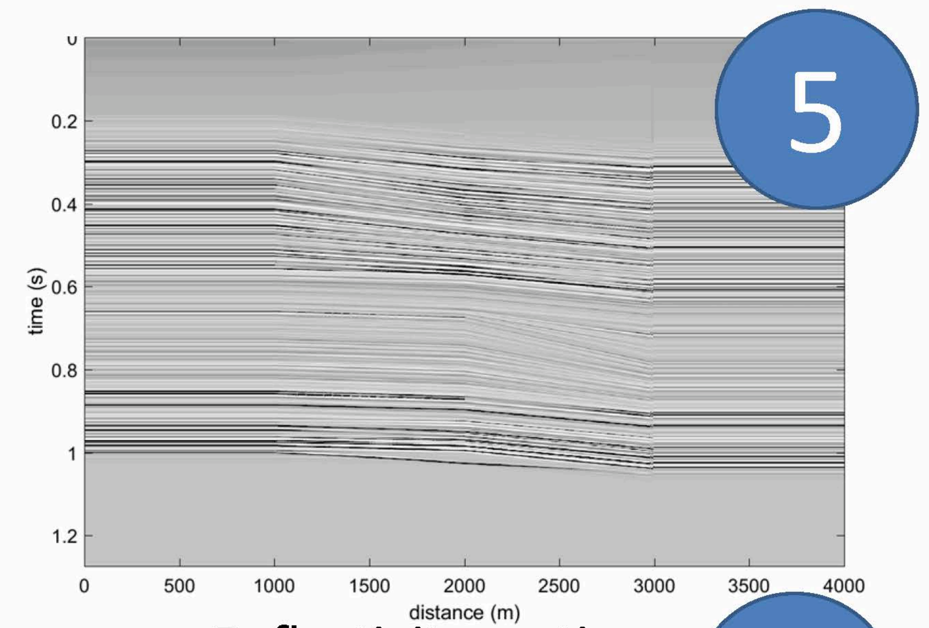
2 Final log section sampled 2.5m in both x and z.



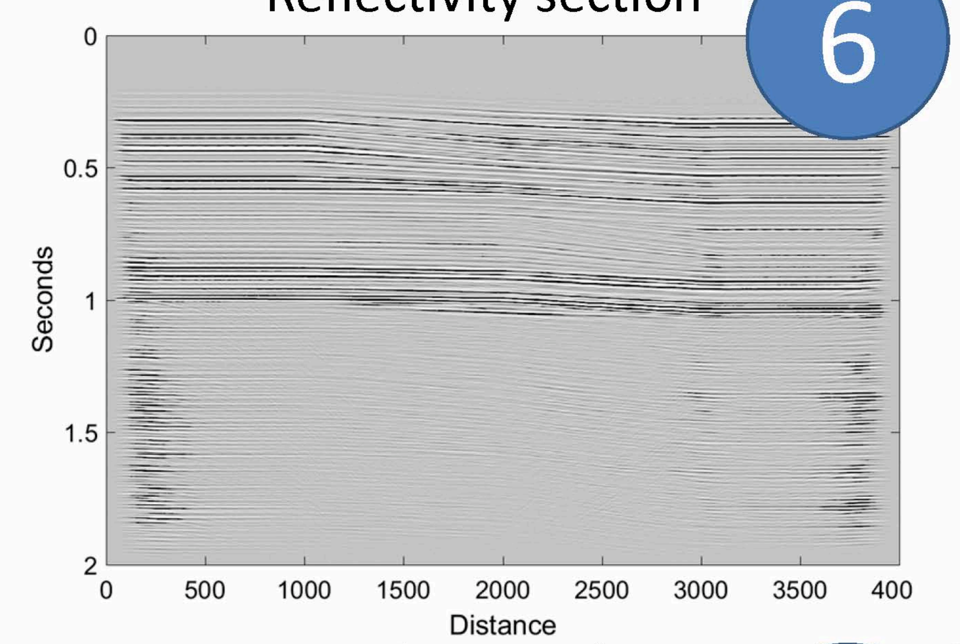
3 Center shot from acoustic modelling. A total of 61 shots were made



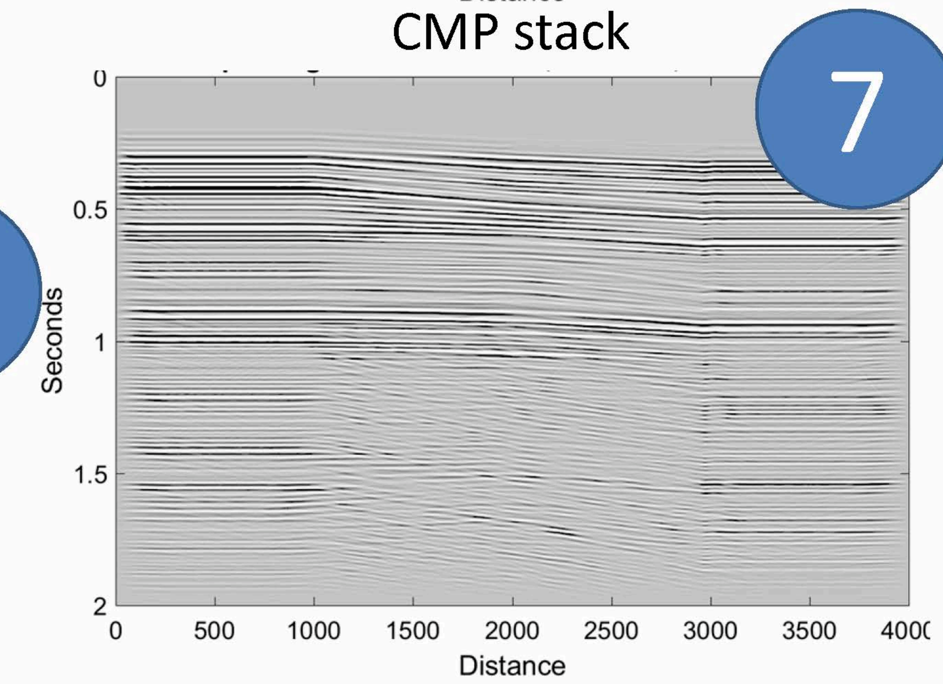
4 Before and after f-k filter to remove turning waves.



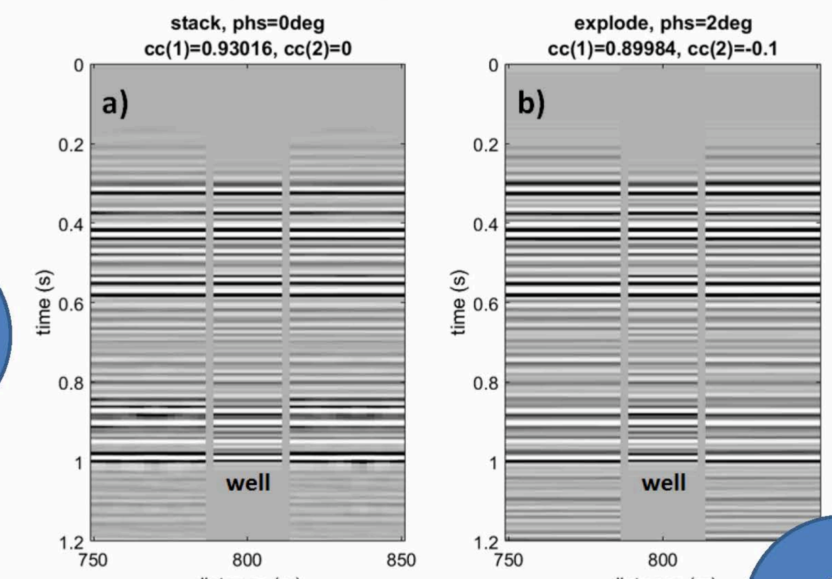
5 Reflectivity section



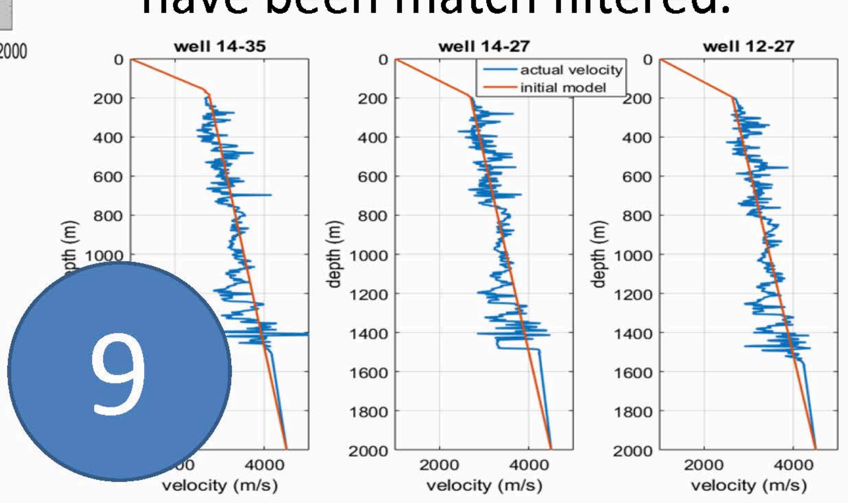
6 CMP stack



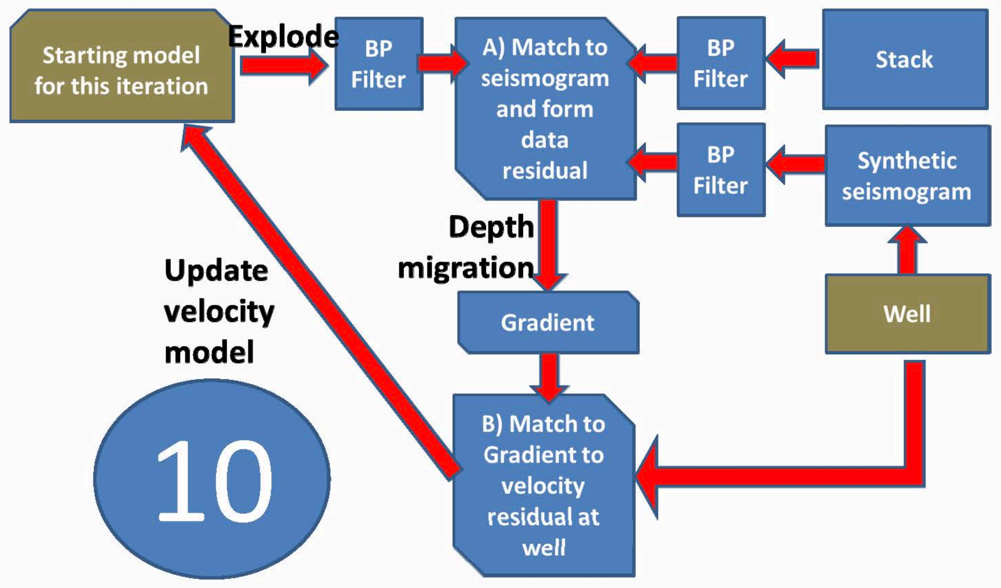
7 Exploding reflector section



8 Tie to synthetic seismogram well at x=800. Both sections have been match filtered.



9 Initial model

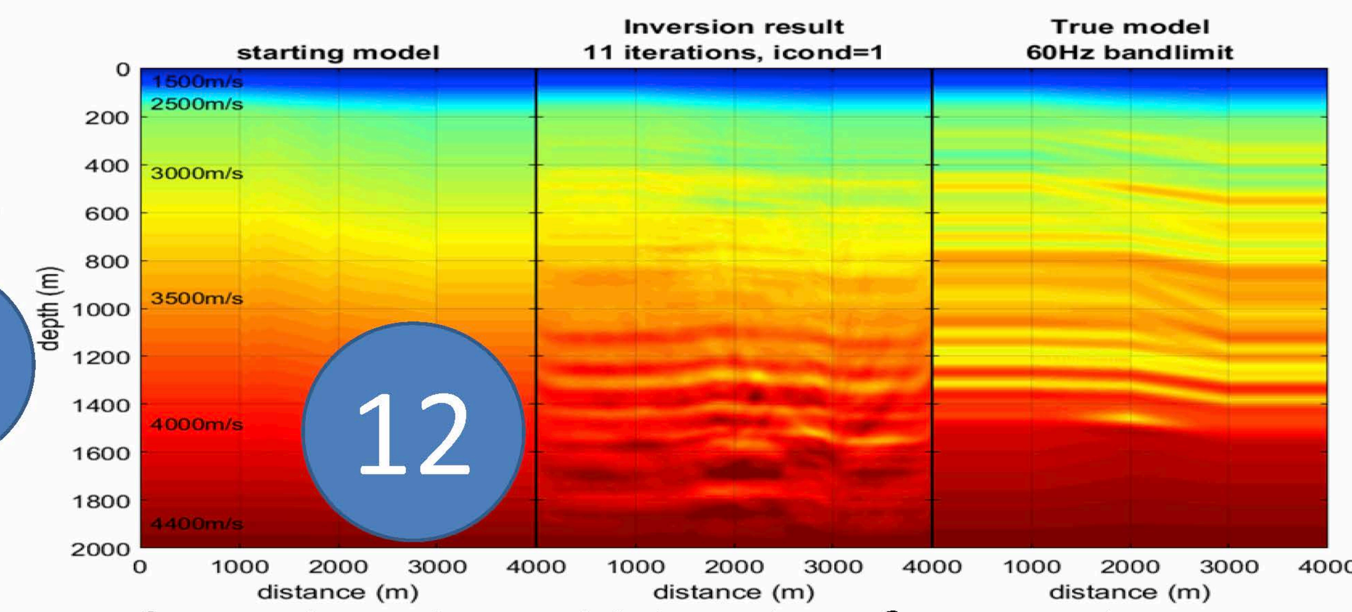


10 Post-stack IMMI process

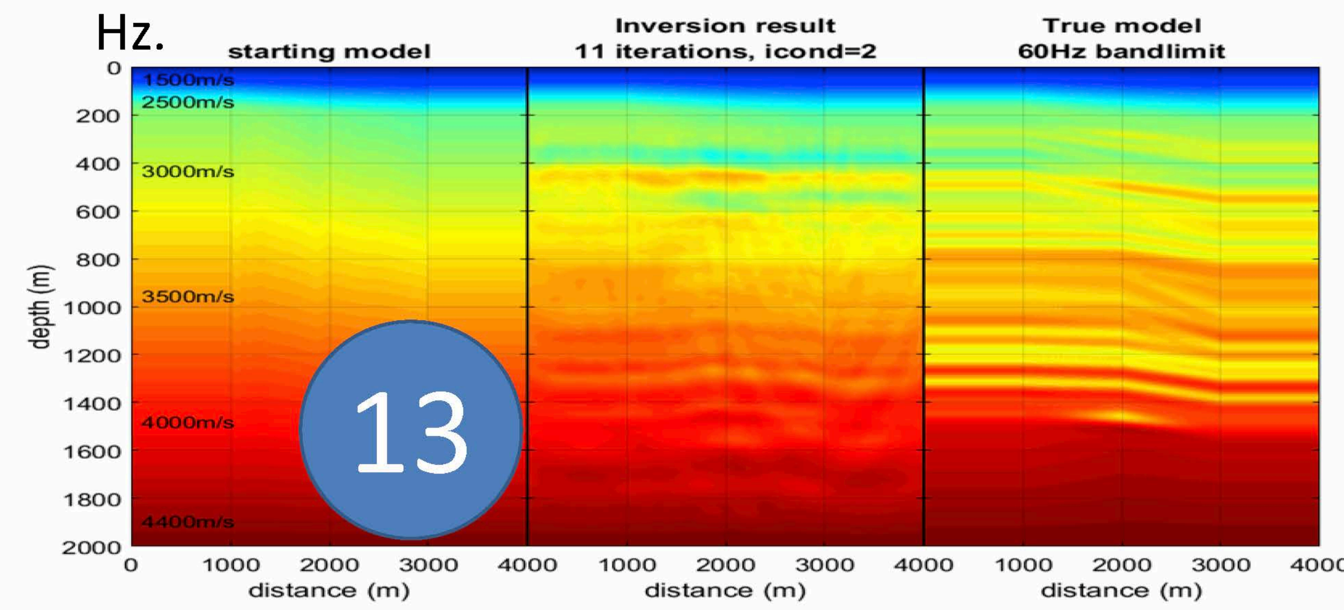
11 Two alternative impedance conditions (icond) for converting the gradient to velocity:

1) (Best) $v_{n+1} = v_n + 2 a v_n G_w$
2) (Conventional) $v_{n+1} = v_n + a G_w$

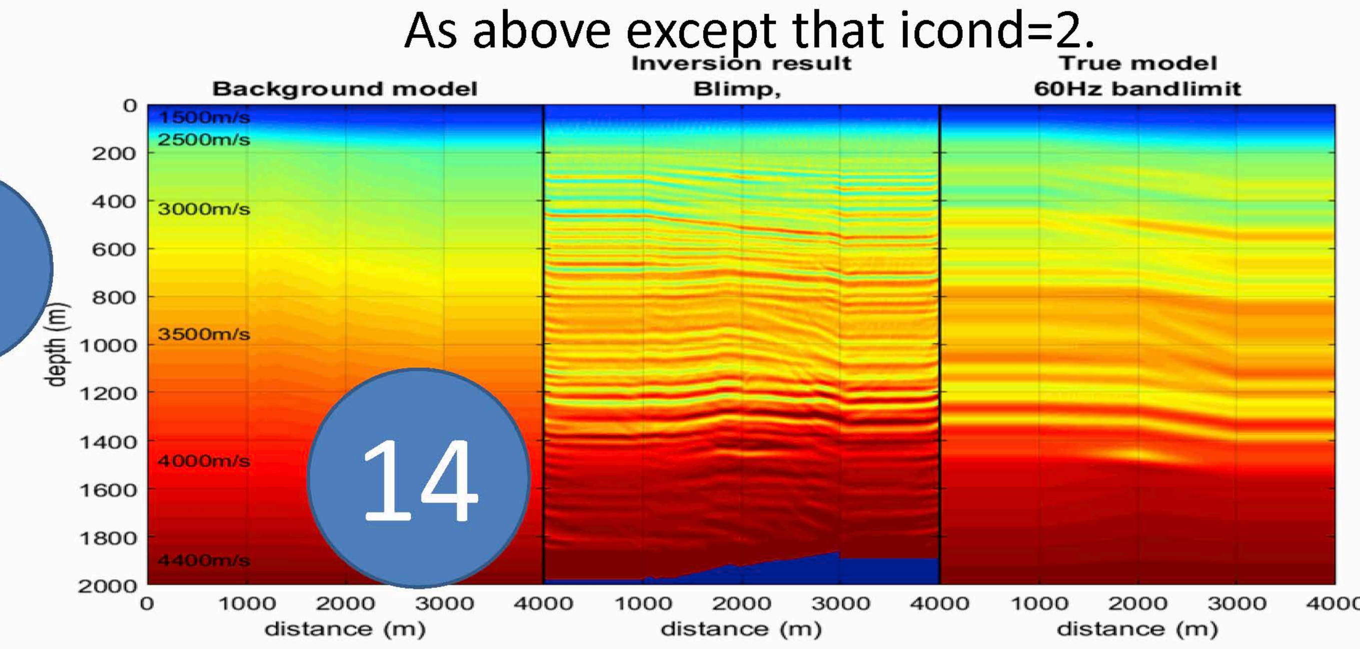
In both cases a is estimated at a well.



12 After 11 iterations with icond=1: f_{min} was always zero and f_{max} was 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60 Hz.



13 As above except that icond=2.



14 Conventional impedance inversion.