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Velocity Model Building and Depth Imaging Challenges - Red Sea 2D Marine Case Study

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SUMMARY

Saudi Aramco acquired an extensive 2D marine seismic program in the Saudi Arabian portion of the Red Sea during 2007 and 2008. Acquisition utilized a 10 km long solid streamer cable with 816 active hydrophone channels spaced 12.5 meters apart and towed at a 10 meter depth. Shots were taken every 25 meters using an airgun array comprising 25 guns and a total array volume of 4060 cubic inches at a tow depth of 7 meters. This survey was part of an initial exploration phase, and is being used to find leads for 3D acquisition. The geology in the region can change rapidly from younger sediments to complex non-homogeneous salt bodies, anhydrites, limestones, and igneous rocks. We present the challenges encountered in processing a large (20,000+ km) 2D dataset through prestack depth migration (PreSDM), and techniques used to generate the depth images within the project timeline.

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The main imaging challenge is the presence of the shallow, structurally complex, “S” unconformity. The unconformity juxtaposes slow sediments beneath the water bottom over much faster salt and inter-salt basin sediments. This layer creates an energy penetration problem and acts as a robust generator of inter-bed and surface related multiples. Imaging challenges also include: a complex and highly variable water bottom (80 – 3000 meters of depth), with scattered pinnacle reefs, low S/N ratio below the unconformity, lack of recorded energy delineating the salt, complex tectonics, significant out-of-plane effects and scarcity of well information and other geophysical and geological data.

Initial time processing of the data was minimized to retain maximum signal for accurate depth migration. Two dimensional shot base surface related multiple attenuation (SRME) was applied to mitigate water bottom multiples. Fast track time processing was performed to generate CMP gathers, prestack time migrated (PSTM) stacks and post PSTM stacking velocity fields for input to PreSDM. Accurate PSTM velocities provided a quick start for creating the depth image velocity models and were instrumental in reducing model building time and effort. Additionally, time processing provided a quick look at the exploration area and a basis for infill shooting in areas of particular interest.

Depth image velocity model building proved difficult due to the challenging geological conditions. Conventional methods of velocity updating either failed or proved too slow to meet the necessary timeline. It was impossible to fully automate the velocity analysis updating process and it proved difficult to obtain convergent and geologically reasonable results. To overcome this problem a hybrid approach of mixing tomographic updating techniques with manual editing was adopted. This approach allowed a rapid convergence to the optimum macro velocity model.

Velocity model building steps were: 1) PreSDM with a constant water velocity (1545 m/s) followed by horizon-based tomography for the water layer velocity, 2) produce an initial sediment velocity model by constrained inversion of the post PSTM stacking velocities, 3) create a scaled depth-interval velocity model by combining the constrained inversion and the water layer tomographic results 4) use grid tomography to update the sediment velocity between the water bottom and the “S” unconformity, 5) increase velocities below the unconformity to better reflect the deeper geology, 6) update the deeper velocities using grid tomography and manual editing, and 7) iterate PreSDM runs and model updates as needed.

The final velocity field was generated via an image scanning technique using wave equation migration and interactive macro velocity updating. Using a Migration Velocity Analysis method based on the quality of the image of the whole section rather than flatness of individual Common Reflection Points is robust in such a challenging data environment. This interpretative approach allowed interpreters to view multiple seismic images simultaneously to help build a velocity field that focused geologically important events. It also reduced the number of iterations necessary for deriving the optimal final velocity model.