Automatic interpretation of salt bodies by iterative image segmentation

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Introduction

Velocity model building is the most human-intensive component of the depth-imaging process, and it is often the bottleneck when trying to reduce the cycle time of large seismic imaging projects. For near-salt or sub-salt imaging the interpretation of the salt-body geometries can be extremely time consuming. Current automatic methods based on horizon tracking are prone to errors, in particular when the salt boundaries are poorly imaged. Lomask et al. (2007) have proposed an automatic method to interpret salt boundaries that segments the image cube by solving a global optimization problem, and thus it is more robust than local methods based on horizon tracking. We apply the image-segmentation method to the iterative velocity-model building process. We show how it can be applied to a conventional sediment and salt flooding procedure and we discuss how to use the boundaries picked at the previous iterations as a constraint to the iterative solution and thus make the method more reliable.

Automatic picking of salt boundaries by image segmentation

The picking of salt-sediment interfaces in complex areas is particularly challenging when the interface is not well imaged by migration. The most common causes of poor focusing are errors in the velocity model and poor illumination. In these situations the salt boundaries are broken and/or discontinuous and conventional horizon-tracking methods fail because they cannot bridge the gaps between the well-imaged parts of the boundaries. The image-segmentation method proposed by Lomask et al. (2007) provides good-quality picks even in these areas, because it is based on the solution of a global optimization problem that can effectively use the low-grade information contained in poorly focused reflections.
Figure 1 shows an example of automatic picking of the salt boundaries from a migrated image from a Gulf of Mexico data set. The depth slice shows the complexity of the salt geometry and the quality of the automatic picks, notwithstanding discontinuities in the image of the salt interface.

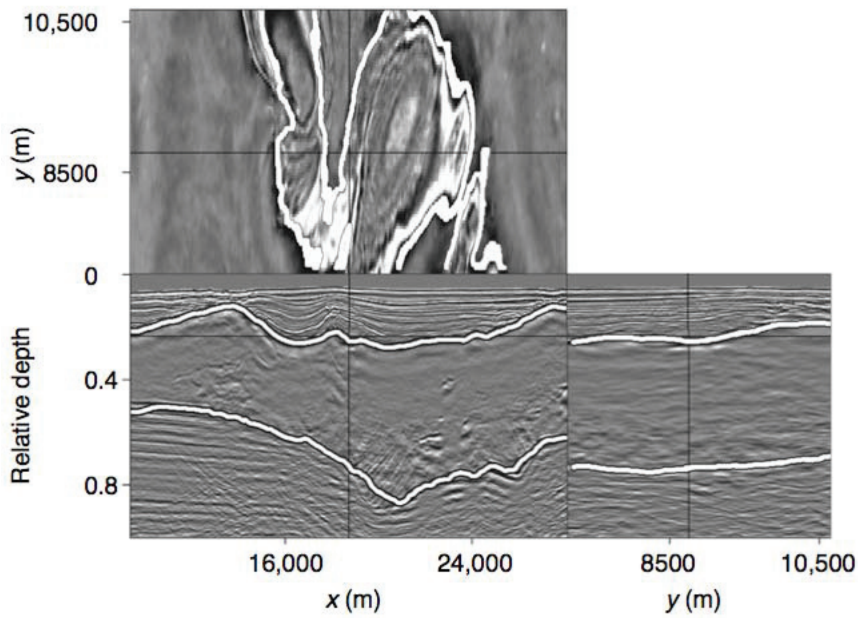

Figure 1 – Example of automatic picking of the salt-top boundary by image segmentation from the migrated image of a Gulf of Mexico data set (image from Lomask et al., 2007.)

Automatic picking applied to the velocity-model building flow

The automatic image-segmentation method is particularly useful when applied to an iterative velocity model-building procedure. In this process the velocity model and the salt-body geometry are iteratively defined by successive cycles of migration followed by salt picking and tomographic sediment-velocity updating. There are two characteristics of the method that makes it particularly fit for the iterative model building process. The first one is its ability to provide reliable picks even when the salt boundary is not well imaged because of velocity errors. This crucial characteristic enables the process to converge towards a good solution even when the starting velocity model is too inaccurate to produce a well-focused image.

Figures 2-5 illustrate the application of the method to the following four-steps model-building flow: 1) sediment flooding, 2) salt-top picking, 3) salt flooding, and then finally 4) salt-bottom picking. Figure 2 shows the migrated image for the Sigsbee synthetic data set obtained by removing the salt from the true velocity model and infilling the model with sediment velocity. The image of the bottom of the canyon is very poor because of the missing salt from the migration velocity. This is a common problem with sediment flooding when imaging areas with rough salt-top topography. Figure 3 shows the automatic picking of the salt-top boundary. As expected, the shallower parts of the salt top are well tracked, since the image is well focused in those areas. However, the method also provides an acceptable picking at the bottom of the canyon. This salt-top interpretation is sufficiently accurate to be used for the salt-flooding step; the new migration, which is shown in Figure 4, yields a well-focused image of the salt-bottom boundary. This image can then be used to identify the bottom of the salt with high accuracy, as shown in Figure 5.

The second useful characteristic of the image segmentation method follows directly from posing the boundary picking as the solution of a global optimization problem. In the areas where the salt boundaries are not well defined by the image, the reliability of the automatic picking can be improved by using the picks at the previous iteration to guide the new picking. This additional constraint can be particularly useful when an expert interpreter had manually edited the picks from the previous iteration. The "a priori" information provided by the previous picks can be easily included by adding to the objective function a term that penalizes the distance of the new picks from the old picks. Residual map migration can be used to remove the bias in the old picks caused by the movements of the migrated reflectors with respect to the image obtained with the old velocity. We have not fully tested this important feature, but we plan to illustrate it with examples during the presentation.

Acknowledgments

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References

Lomask, J., R.G. Clapp, and B. Biondi, 2007. Application of image segmentation to tracking 3D salt boundaries, Geophysics, v. 72, pp. P47-P56.

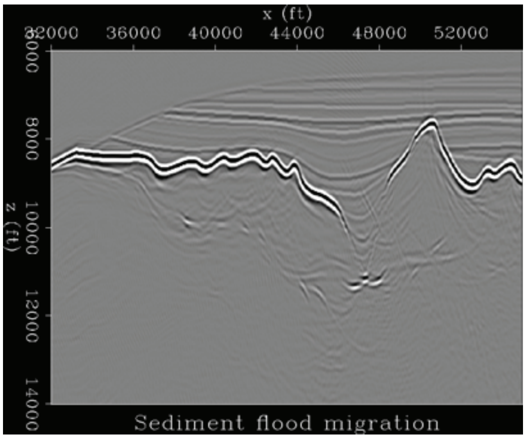

Figure 2 –Migrated image after sediment flooding of the velocity function. Notice the poor focusing of the salt-top boundary in the canyon.

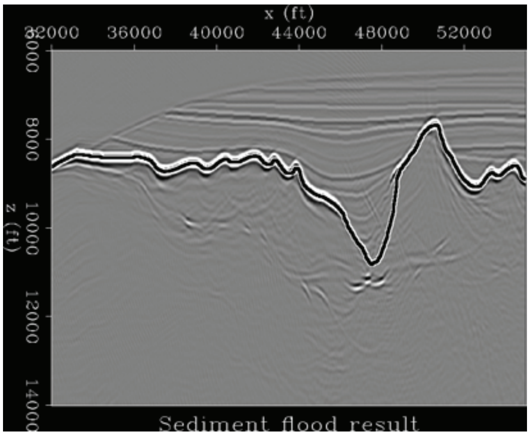

Figure 3 – Migrated image after sediment flooding with superimposed the automatically picked salt-top boundary. The bottom of the canyon has been identified fairly well.

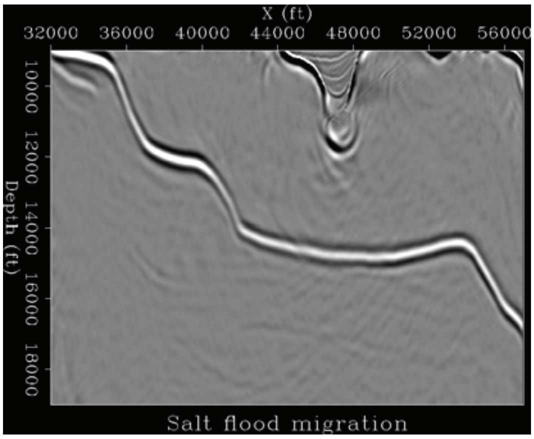

Figure 4 – Migrated image after salt flooding of the velocity function starting from the salt-top boundary showed in Figure 2.

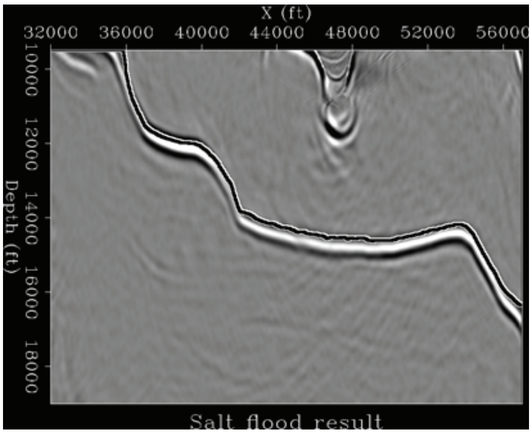

Figure 5 – Migrated image after salt flooding of the velocity function. The automatically picked salt-bottom boundary is superimposed onto the image