Localized reverse time migration for salt model building

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Summary

Salt model building is a key process for successful subsalt imaging. In complex areas, Reverse Time Migration (RTM) provides better images than One-way Wave Equation Migration (OWEM) or Kirchhoff Migration (KMIG). With a superior image, RTM can give improved solutions for delineation of salt geometry. The main obstacle in applying RTM to iterative salt model building is that RTM requires substantially more computing power than OWEM or KMIG. However, the cost of RTM can be reduced by localizing the imaging area. First, perform the redatuming of source and receiver wavefields to a certain depth just above the interested subsalt target area. Second, localize the image zone near the steep salt boundary. After then, update salt geometry iteratively using localized RTM (LRTM) images and an interactive salt modeling tool.

Introduction

Although RTM was introduced a while ago (Baysal et al, 1983; Whitmore, 1983; McMechan, 1983), until recently it has not been commercialized due to an unaffordable cost. RTM uses a numerical solution of two-way wave equation and its solution is closer to the real seismic wave propagation than solutions of one-way wave equation or Kirchhoff approaches. Recently, increased computer power and limitations which OWEM or KMIG have in imaging complex areas renewed an interest in RTM (Biondi and Shan, 2002; Yoon et al., 2003). RTM produces superior images especially in complex areas, than OWEM or KMIG. For velocity model building in complex area, RTM is an attractive tool to build a consistent velocity model and a final image (Jones et al., 2007).

In the imaging process, salt model building is typically the most time consuming process and is being carried out iteratively. Evaluation of a salt geometry is a critical process for successful subsalt imaging. RTM generates an image with better termination of reflectors against the salt and better focused reflectors in subsalt areas. However, RTM is more expensive than other imaging tools such as OWEM, KMIG or beam migration. If the imaging zone is restricted to a small area demanding high quality imaging capability, RTM could be effectively applied to iteratively build a velocity model. Figure 1 shows a schematic of RTM imaging localized to a subsalt area. For subsalt imaging with surface seismic data, migration aperture should be large enough to include horizontal and over-turning ray paths. Supposed the velocities are well determined until a certain depth, the seismic data can be rebuilt by redatuming to the depth (Huimin et al., 2008). Aperture for subsalt imaging could be reduced at the depth of redatuming. By redatuming we can localize the image zone vertically and horizontally. Localized RTM could reduce not only the cost but required core memory and disk space also. With high quality and cost effectiveness, LRTM could be an attractive solution for salt model building

LRTM is cost-effective imaging solution for iterative velocity modeling in the area demanding high image quality. We will describe the procedure of LRTM in details and apply LRTM to the interactive velocity modeling of BP2004 synthetic data

Localized reverse time migration

For LRTM, we need redatuming of surface data. In this study we used BP 2004 velocity benchmark data. Figure 2 shows receiver (the left half) and source (the right half) wavefields after redatuming to a depth of 3km. BP 2004 dataset has a long offset of 15km. For a realistic test, we restricted the maximum offset to 8km. Using the reduced offset data, we rebuilt the wavefields within the x range of *sx*-8km~*sx*+6km (8km to the receiver side and 6km to the source side), where *sx* is the x coordinate of source point.

Figure 3 shows the effect of redatuming. Figure 3a is a part of BP 2004 velocity benchmark model. Figure 3b and 3c are RTM images using left-most 40 gathers which are redatumed to 2.1km and 3km respectively. We localized image zones 2.1km~6km (Figure 3b) and 3km~6km (Figure 3c) in vertically. Horizontal aperture of the image zones is 12km. We used only the redatumed data whose aperture overlap with the image area more than 4km. In Figure 3b and 3c, black arrows indicate ray paths of wavefields which contribute to the imaging of salt flank. The strong reflections and ray paths come from the correlation between the source or receiver wavefields with back scattered wavefields. Figure 3c shows that we may further reduce the horizontal image zone preserving the ray paths which contribute to the salt flank which is located at the center of the figure.

Figure 4 and Figure 5 are RTM images using horizontal localized image zones of 12km and 6km respectively. In Figure 5, although the horizontal image zone was reduced to the half of the image zone in Figure 4, images looks comparable to those in Figure 4. However, as indicated by black arrows, Figure 5a, the image using data redatumed to 2.1km looks to lose wavefields contributing to the salt flank due to the small horizontal image zone. On the other hand, Figure 5b, RTM image produced by the data redatumed to 3km has better focusing on salt flank. As shown in Figure 4 and Figure 5, we may reduce the image zone and the cost of RTM with suitable redatuming.

Figure 6 shows a process of salt model building combined with an interactive salt modeling software (Bin et al., 2008) and localized RTM. In this test, we used the data which were datumed to a depth of 3km and a horizontal image aperture of 8km. The vertical image zone is 3km (from 3km to 6km in depth). As shown in Figure 6. a software through which we may modify salt geometry interactively is essential for economic and efficient salt model building. Localized RTM can provide high quality image within reasonable turn around time for iterative velocity modeling process.

Conclusions

Even though RTM is more expensive than other migration tools, RTM is being widely applied to imaging in challenging area due to its higher imaging capability. By redatuming of seismic data and localizing imaging zone, RTM could be an cost-effective and promising tool for iterative velocity modeling in compelx area. Localized RTM also could be applied efficiently to full waveform inversion which uses RTM to compute the gradient.

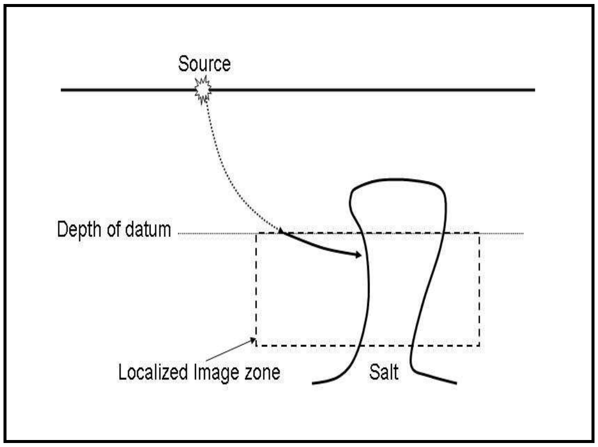

Figure 1. Schematic of localized RTM. At the depth of datum, aperture could be localized around the target subsalt area.

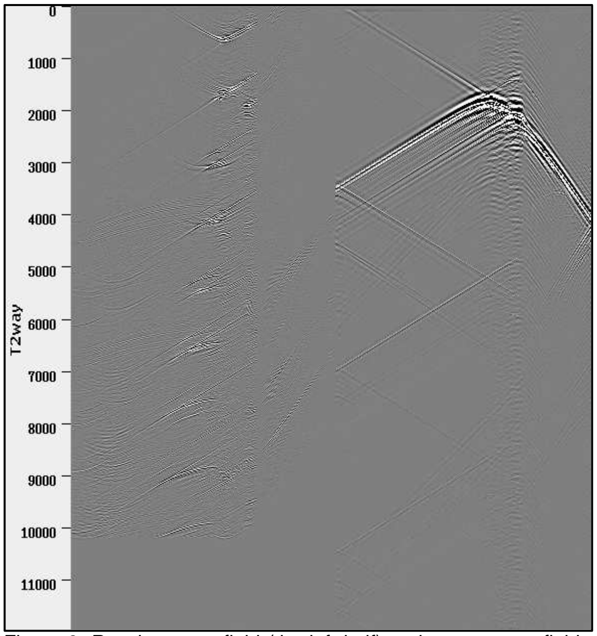

Figure 2. Receiver wavefield (the left half) and source wavefield (the right half) which are recorded at the depth of 3km over the range of 14km (from *sx*-8km to *sx*+6km, *sx* is x coordinate of source at the surface). The offset of surface seismic data has been reduced from 15km to 8km for realistic test before redatuming.

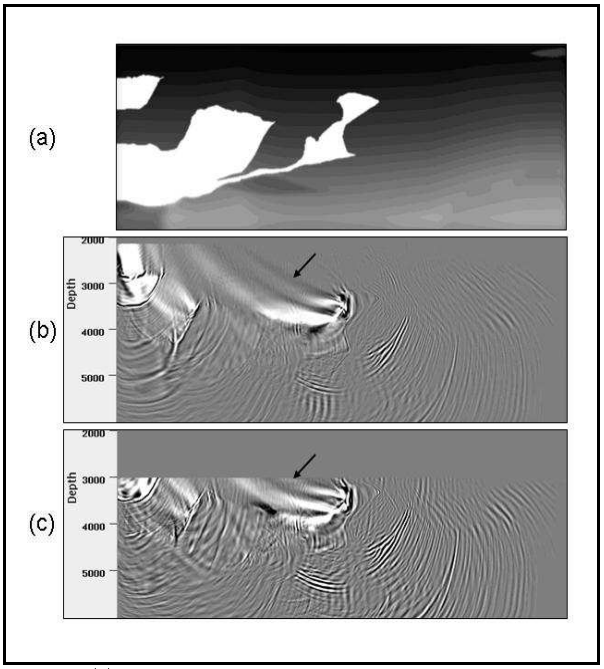

Figure 3. (a) BP 2004 velocity benchmark velocity and Localized RTM images using gathers redatumed to (b) 2.1km and (c) 3km.

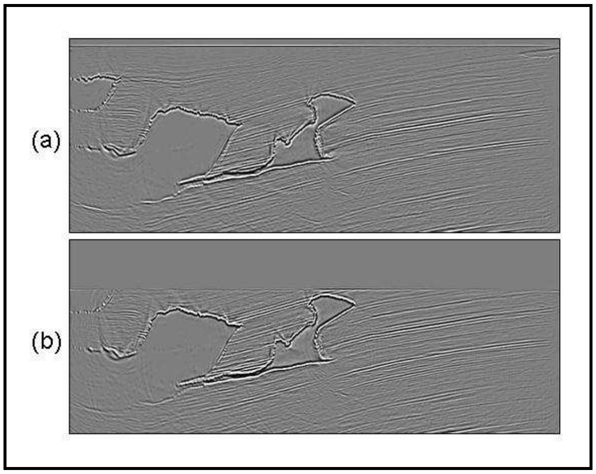

Figure 4. RTM image usimg data which are redatumed to (a) 2.1km and (b) 3km. The horizontal aperture of the image zone is 12km.

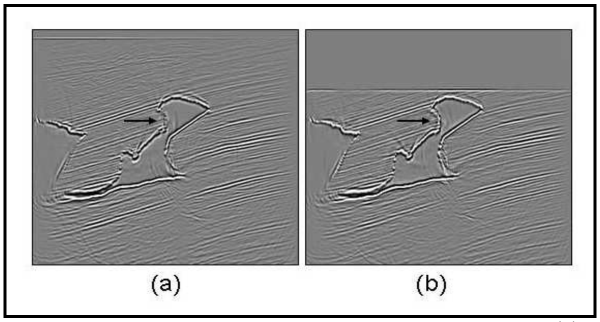

Figure 5. RTM image usimg data which are redatumed to (a) 2.1km and (b) 3km. The horizontal aperture of the image zone is 6km. As indicated by a black arrow in Figure 5a, 6km horizontal aperture is not enough for the data redatumed to 2.1km.

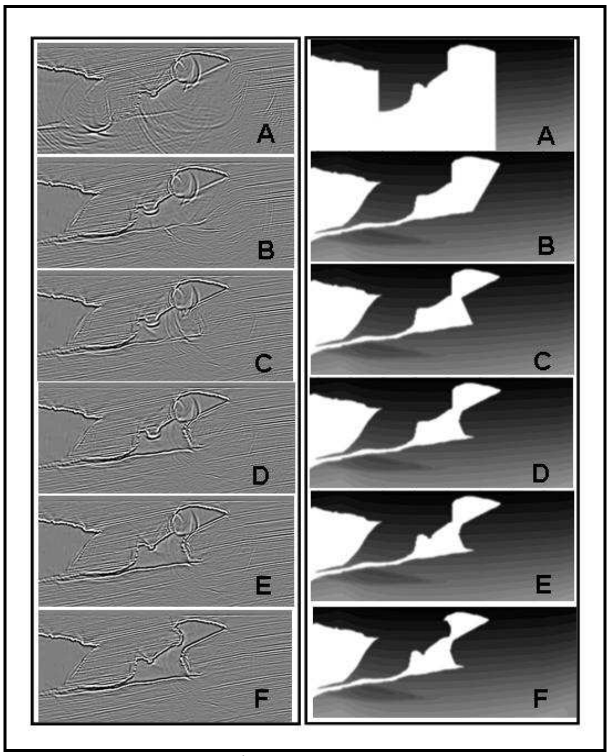

Figure 6. An example of iterative salt model building using localized RTM and interactive salt geometry update. Figures in the left hand side are RTM image using the velocities in the right hand side. From top to down, velocity model started from (A) a salt flood model and was updated iteratively converging to (F) the true velocity model.

EDITED REFERENCES

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