

Chapter 7

Conclusions

This dissertation introduces novel techniques to overcome some important challenges in current time-lapse seismic imaging practice. Even in difficult circumstances, these techniques provide good-quality time-lapse images—from which we can make reliable deductions about changes in subsurface reservoir properties.

In chapter 2, I discussed two conventional time-lapse *post-imaging* cross-equalization methods. Efficient multidimensional warping by sequential one-dimensional cross-correlation and interpolation (Hale, 2009), overcomes cost limitations of full multidimensional warping, and the inaccuracies in approximate *vertical-only* methods. Optimal matched filtering using an evolutionary algorithm provides more reliable match between the time-lapse data sets. A combination of these two methods provides a robust cross-equalization tool. In addition, the warping method is an important step for the inversion methods developed in this dissertation.

In chapter 3, I discussed the theory of regularized joint inversion of time-lapse seismic data sets. Joint inversion allows the introduction of both spatial and temporal constraints, which stabilize the inversion and provide geologically plausible time-lapse images. Formulations of the regularized joint inversion in both the data and image domains are presented. Although the time-lapse imaging problem can be solved in either domain, an important advantage of image-domain inversion is that it enables

a target-oriented solution of the problem.

I applied the methods developed in chapter 3 to various data sets:

- Chapter 4 – two- and three-dimensional synthetic data sets.
- Chapter 5 – two-dimensional field streamer data sets.
- Chapter 6 – three-dimensional field ocean-bottom-cable (OBC) data sets.

The results of these applications show that:

1. Non-repeated simultaneous-source time-lapse data sets can be imaged adequately by data-domain inversion (Chapter 4).
2. Distortions in time-lapse images, which are caused by complex overburden effects, can be corrected by image-domain inversion (Chapter 4).
3. Artifacts in time-lapse images, which are caused by differences in acquisition geometries, can be attenuated using image-domain inversion (Chapters 4, 5, and 6).
4. Because the image-domain approach is relatively computationally inexpensive, different plausible regularizations can be tested in near real-time—until desirable results are obtained (Chapters 4 and 6).
5. Careful preprocessing is essential in time-lapse seismic imaging, and in particular when imaging by inversion (Chapter 5).
6. A common approximation of subsurface illumination—the diagonal of the Hessian—cannot fully account for the effects of geometry differences between surveys (Chapter 5).

Importantly, the inversion methods developed in this dissertation make the time-lapse image less sensitive to geometry differences and to the overburden complexity.