CREWES 5-year research plan: Towards broadband multicomponent seismology and practical iterated inversion

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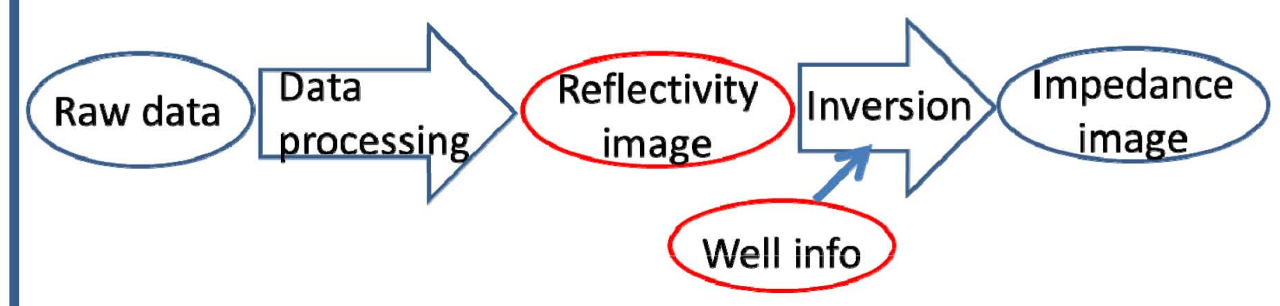
Summary

Seismic images provide the best possible views of the earth below its surface; but, despite an 80 year history, they are still far from optimal. Today, the computer methods used to create such images are transitioning from a standard methodology (SM), which incorporates an evolved blend of physical theory and practical experience, to the very modern full-waveform inversion (FWI) that is much more firmly rooted in mathematical physics. However, this transition is hindered by insufficient low-frequency content in seismic data, by the inherently unknown seismic source waveform, by incompletely understood physics, and by the extreme computational effort required. As a consequence, SM is the dominant approach while FWI is rarely attempted outside of dedicated research labs. SM uses a sophisticated data processing sequence to create a reflectivity image of the subsurface. Then, incorporating well information, an inversion process converts the reflectivity image to earth properties such as impedance. FWI is a fundamentally iterative process that converges on an impedance model by minimizing the difference between real and predicted seismic data. FWI never creates a reflectivity image and does not use well control; while SM does not predict synthetic data and is not iterated. We will create a new class of seismic inversion methods that combines the most robust features of SM with the most promising concepts from FWI. From SM, we will retain most of the data processing steps, the creation of a reflectivity image, and the matching to well control. In particular, matching to well control facilitates the source waveform estimation and provides the needed low frequency information. From FWI, we will incorporate the concepts of iteration, prediction of synthetic seismic data, and imaging of the data residual. The proposed approach, which we call IMMI (Iterated Modelling, Migration, and Inversion), will produce estimates of subsurface properties that both match measurements in wells and also predict most features in the recorded seismic data. Such estimates should be much more reliable than those presently achieved by SM. This will have significant benefits to resource exploration and to subsurface environmental studies.

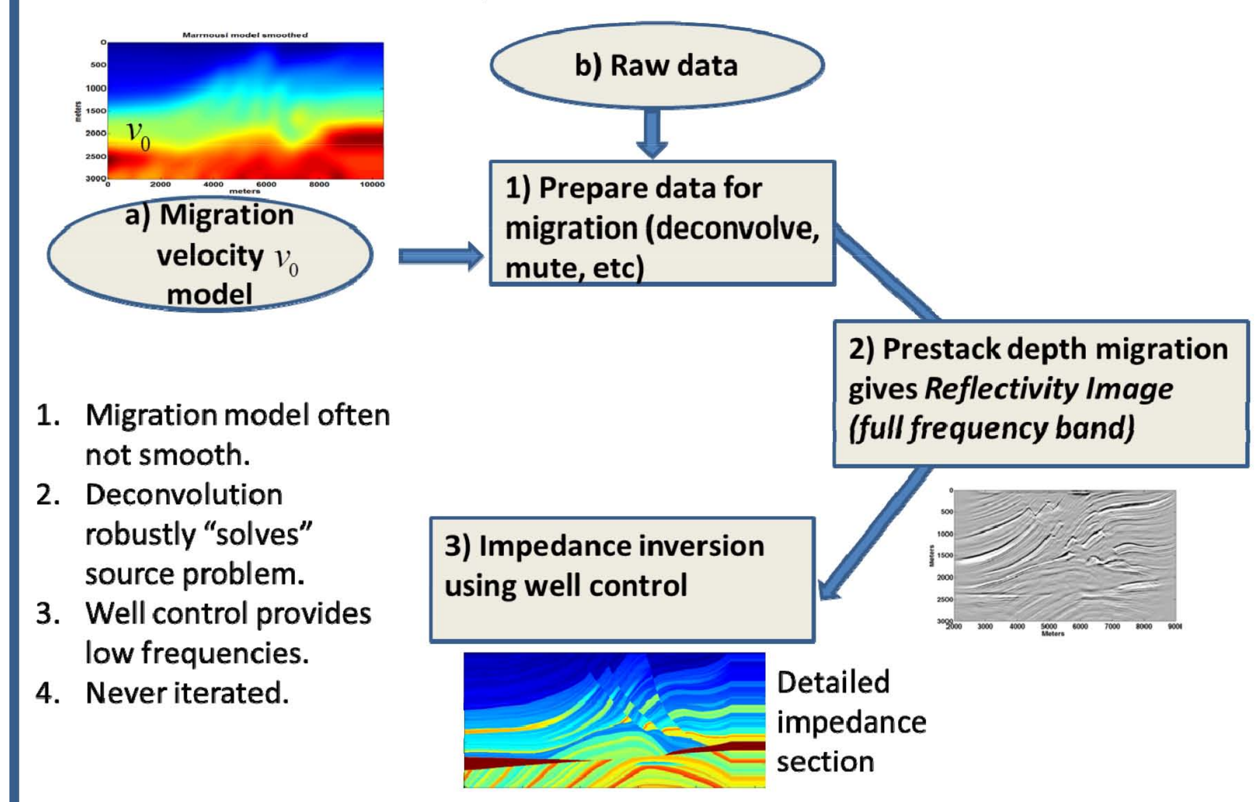
Standard Methodology (SM) for Impedance Estimation

The creation of impedance images from SM is a complex process with a long history rooted both in theory and practice.



Note the absence of forward modeling and iteration.

SM is ¾ of 1 iteration



1. Migration model often not smooth.
2. Deconvolution robustly "solves" source problem.
3. Well control provides low frequencies.
4. Never iterated.

How SM meets some of these difficulties

Difficulty	SM strategy
Unknown source waveform	Deconvolution, well tying
Missing low frequencies	Borrow from wells, record lower frequencies
Inadequate or missing physics	Data processing, Calibrate against wells
Huge computation load	Scalar wave imaging
Too many iterations	Better imaging condition for faster convergence

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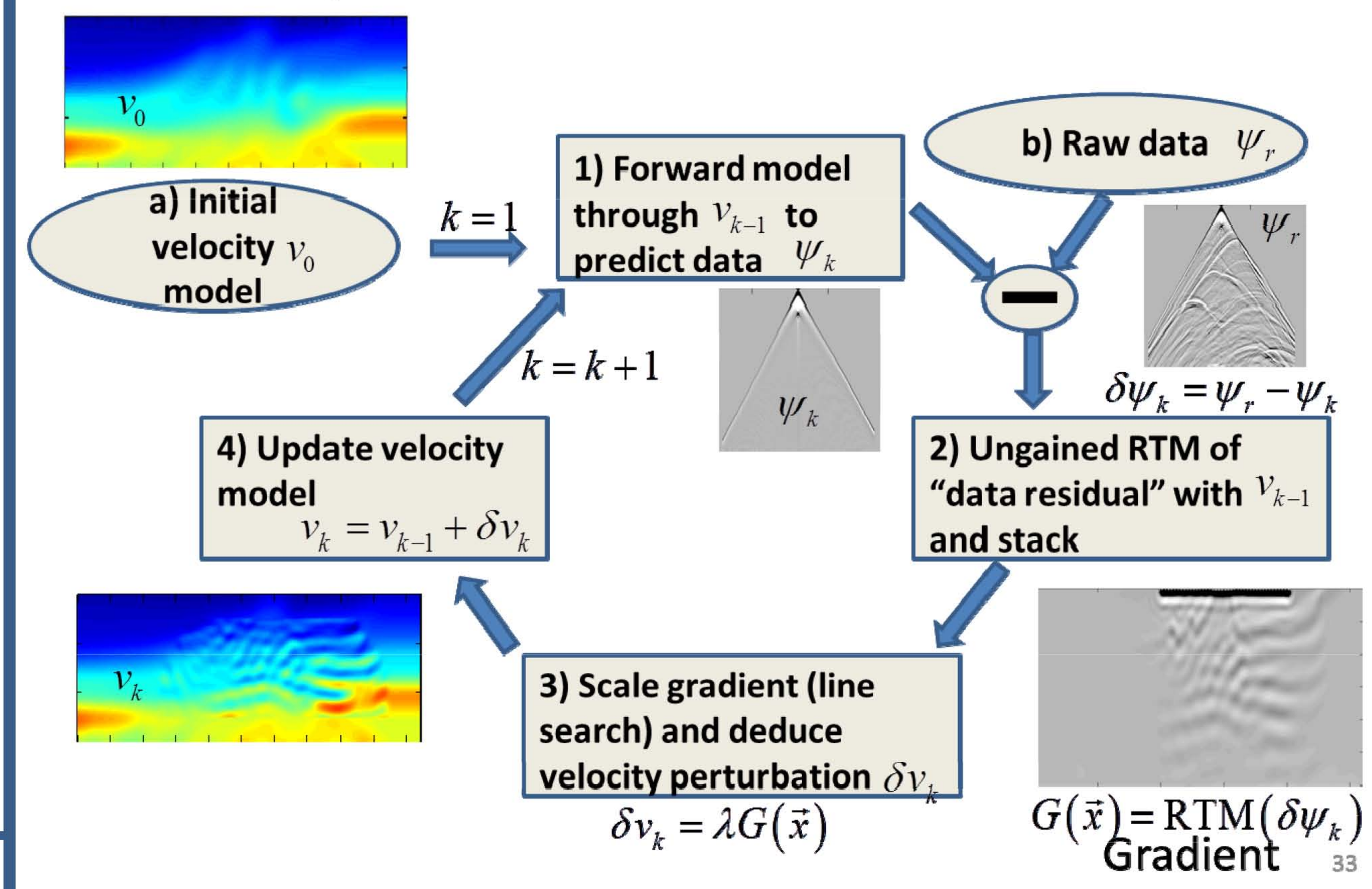
FWI iteration loop

(Steepest descent, assumes wavelet is known)



SM and FWI summary

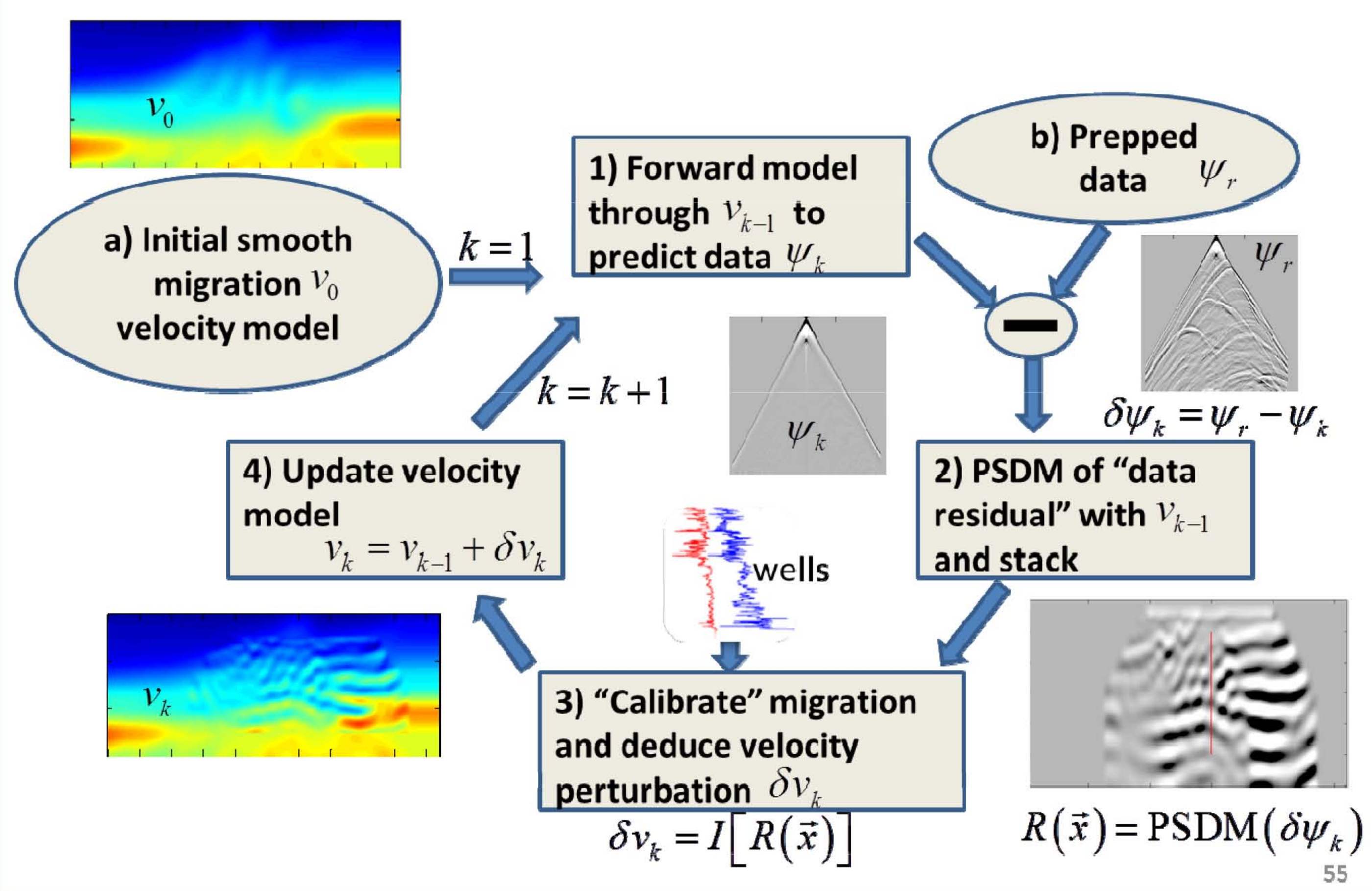
SM

Strengths	Weaknesses
Data processing	Not iterative
Reflectivity image	No data validation
Low frequencies from wells	
Well validation	
Exact physics not required	

FWI

Strengths	Weaknesses
Iterative	No well information
Data validation	No reflectivity image
Imaging the data residual	Physics model must be correct
	Slow convergence

Iterative Modelling, Migration, and Inversion IMMI



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