

The Delphi consortium: Overview of activities

Eric Verschuur

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Delphi Consortium (www.delphi-consortium.com)

Delphi Studio for Imaging (www.delphistudio4imaging.com)

Seminar at EBN meeting, Utrecht

Thursday, February 20, 2014

Delft University of Technology:

- 1983: founding of **PRINCEPS** consortium on seismic inversion (spin-off: Jason, now part of CGG)
- 1986: addition of **TRITON** consortium on seismic imaging
- 1989: merge into **DELPHI** consortium (2014 is 25th anniversary)

- **Advisory board:** sponsor delegates, on personal title
- **Written reporting:** once a year a progress report per project and PhD theses as they come out
- **Sponsor meetings:** twice a year, one in Houston in Feb. , one in The Hague in June
- **Software:** interactive programs based on Seismic Unix and Matlab
- **Personnel involved:** 12 Ph.D. students, three full (emeritus) professors, two associate professors and support.
In addition, we have Post-docs and visiting Ph.D. students

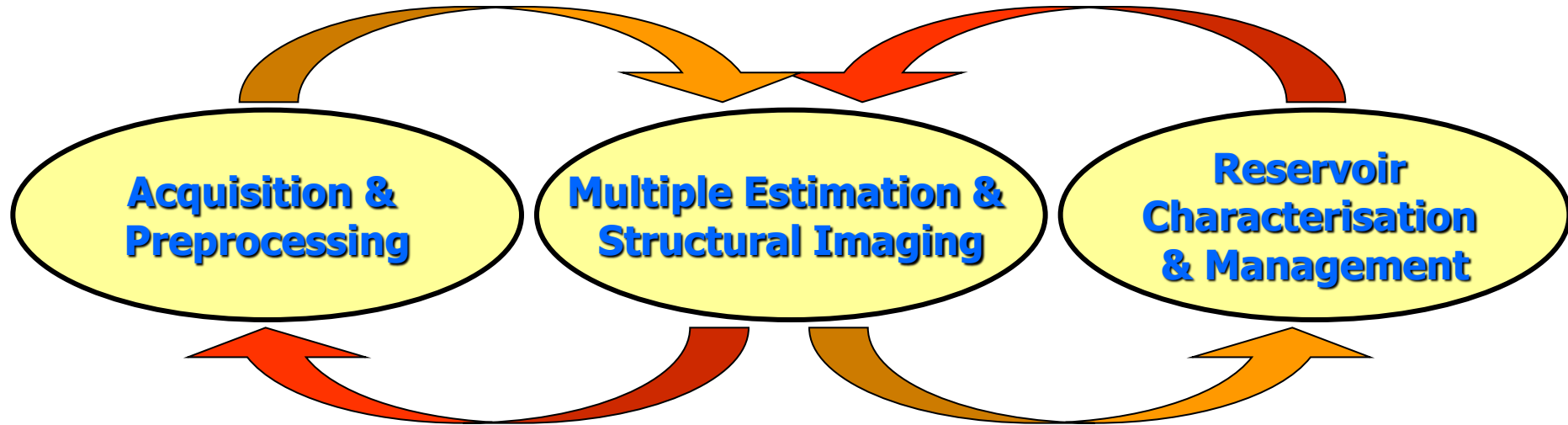
Delphi scientific coordinator: Guus Berkhout

- Acquisition & Preprocessing (A&P)
Project director: Gerrit Blacquière (Appl. Earth Sci. / TNO)
- Multiple estimation & structural Imaging (M&I)
Project director: Eric Verschuur (Lab. Acoustical Wavefield Imaging)
- Reservoir Characterization & Management (C&M)
Project director: Guus Berkhout (Interim)

Sponsors of the Delphi consortium

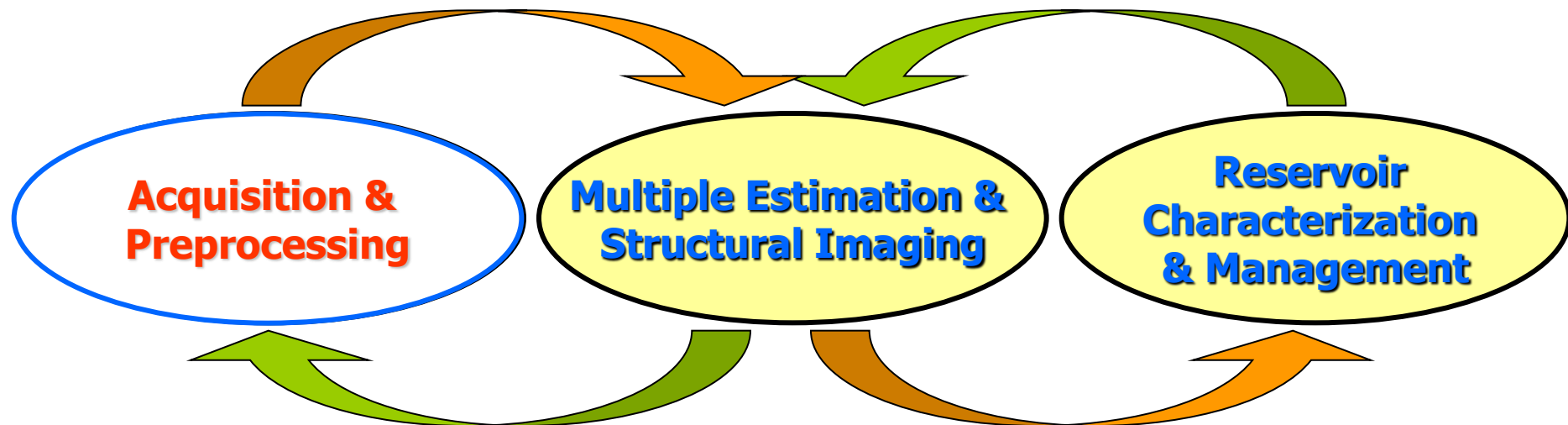


Sponsoring Companies	A&P	M&I	C&M	Sponsoring Companies	A&P	M&I	C&M
Anadarko Petroleum Corporation				Petrobras			
BGP				Petronas			
BHP Billiton				PGS			
BP				PSS-Geo			
CGGVeritas				RWE			
Chevron				Saudi Aramco			
ConocoPhillips				Shell Intl. Expl. & Prod.			
Delft Inversion				Spectrum Geo Inc.			
DMT Petrologic GmbH				Statoil			
Dolphin Geophysical				TEEC			
Eni				TGS			
ExxonMobil				TNO-NITG			
Fairfield / Nodal				Total			
GDF Suez				Tullow Oil			
INPEX				Western Geco			
ION/GX Technology				Wintershall			
OMV							



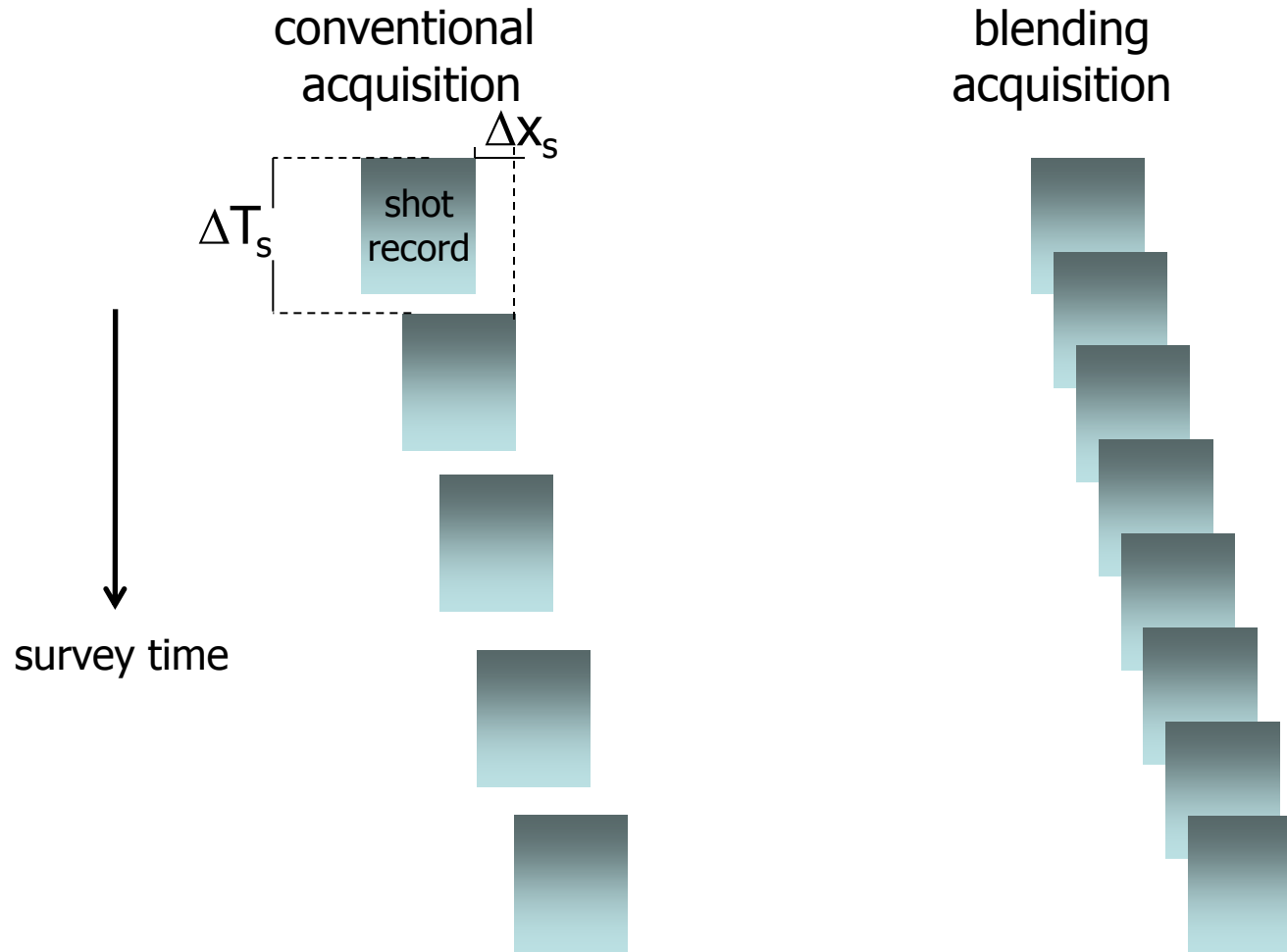
- New capabilities in acquisition should inspire innovations in imaging as well as characterization (*double feedforward loop*)
- Characterization needs should drive both imaging and acquisition research (*double feedback loop*)

Acquisition & Preprocessing (A&P)



- Blended acquisition
- Deblending algorithms
- Near-surface replacement
- Data reconstruction and interpolation
- Robotization – New acquisition techniques
(separately sponsored project for additional fee)

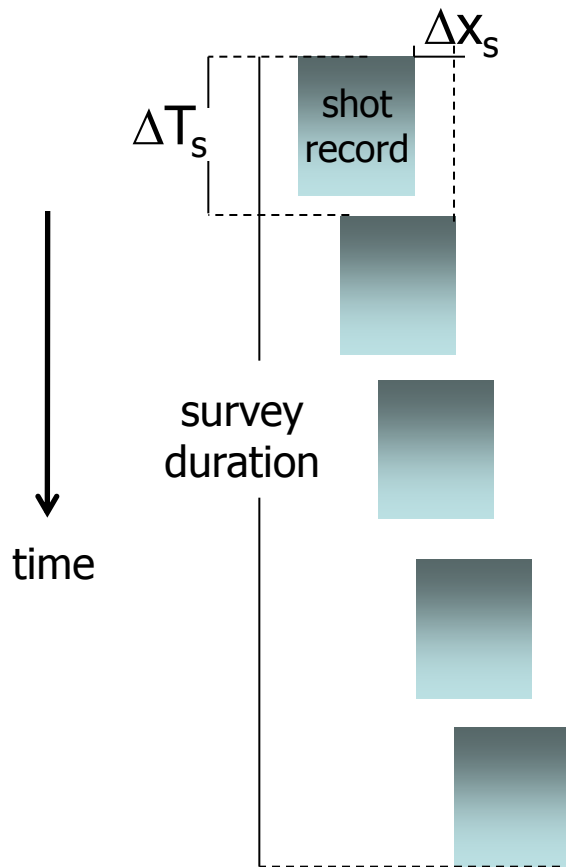
Conventional vs. blended acquisition



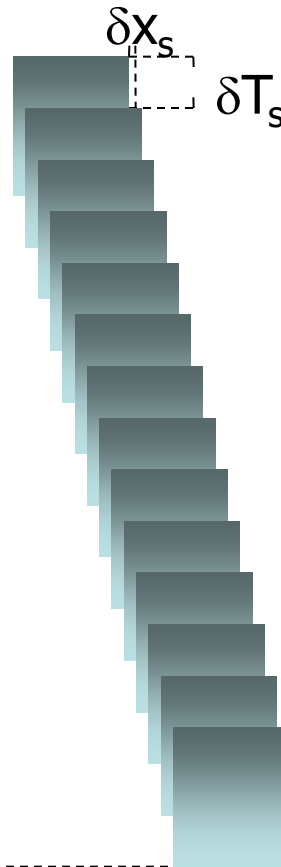
Blended (or SimSrc) acquisition: start next shot before recording of previous shot is finished

Aiming at improved quality or reduced costs

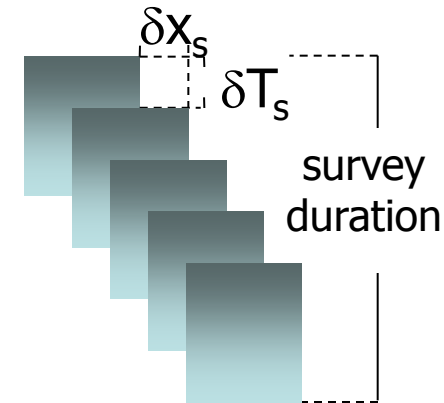
conventional
acquisition



blending with
focus on quality



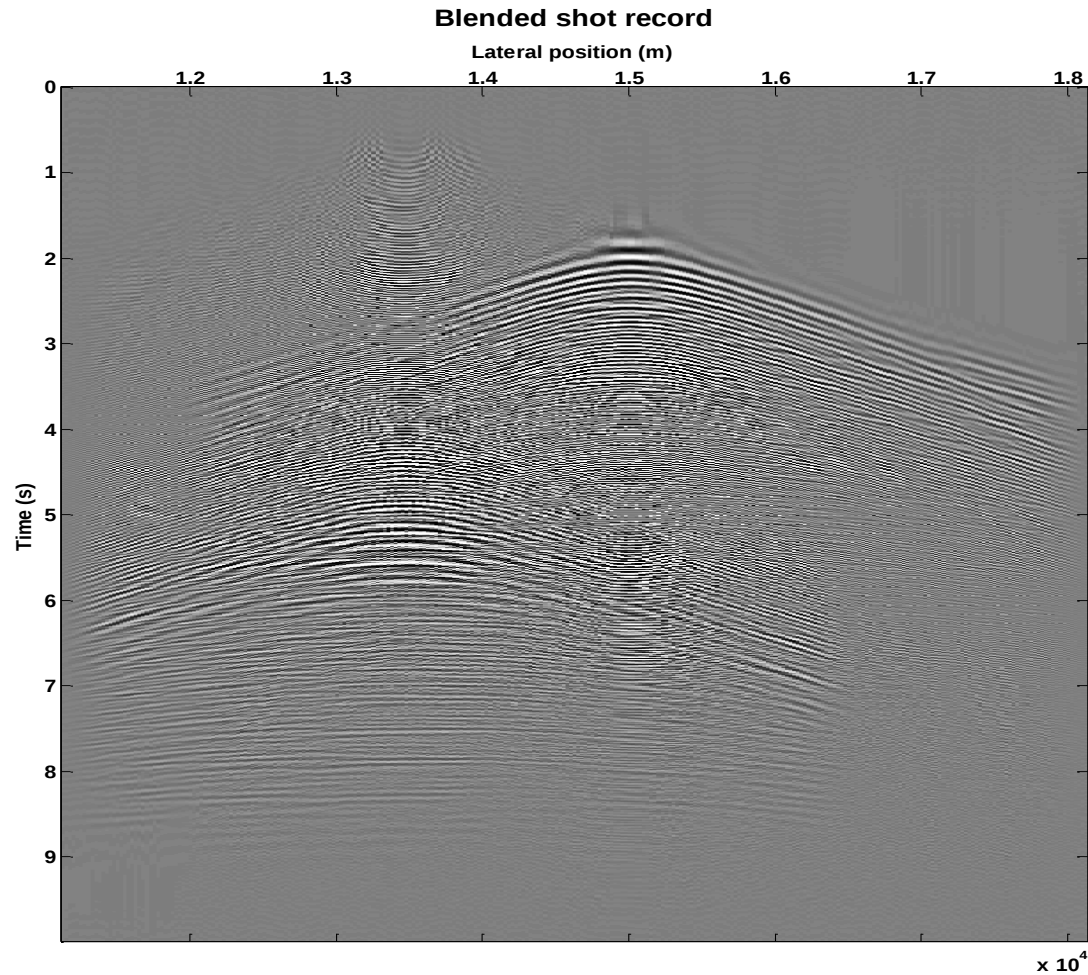
blending with
focus on cost



$$\Delta T_s / \delta T_s = \text{blending factor}$$

In practice a combination
may be preferred

Blended shot record (with sweeps)

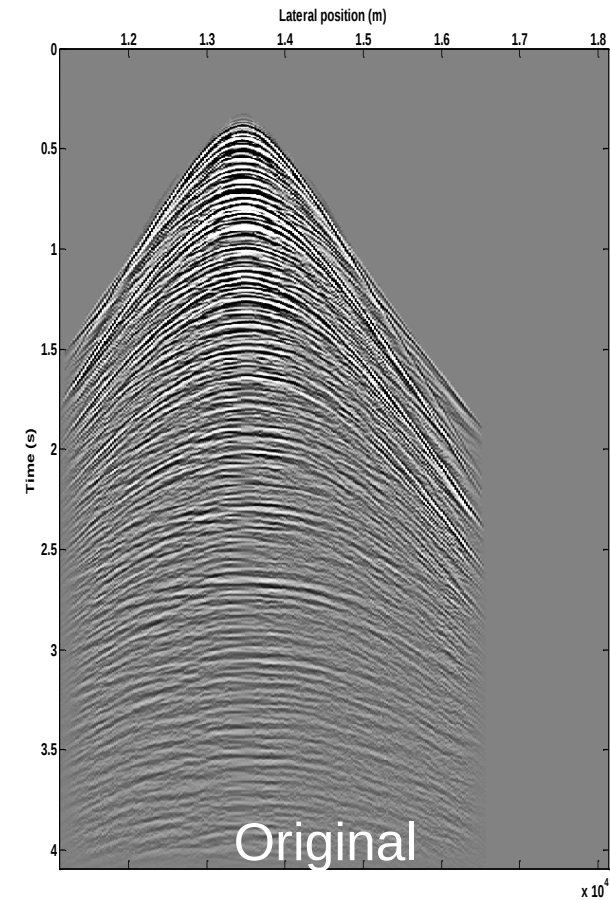
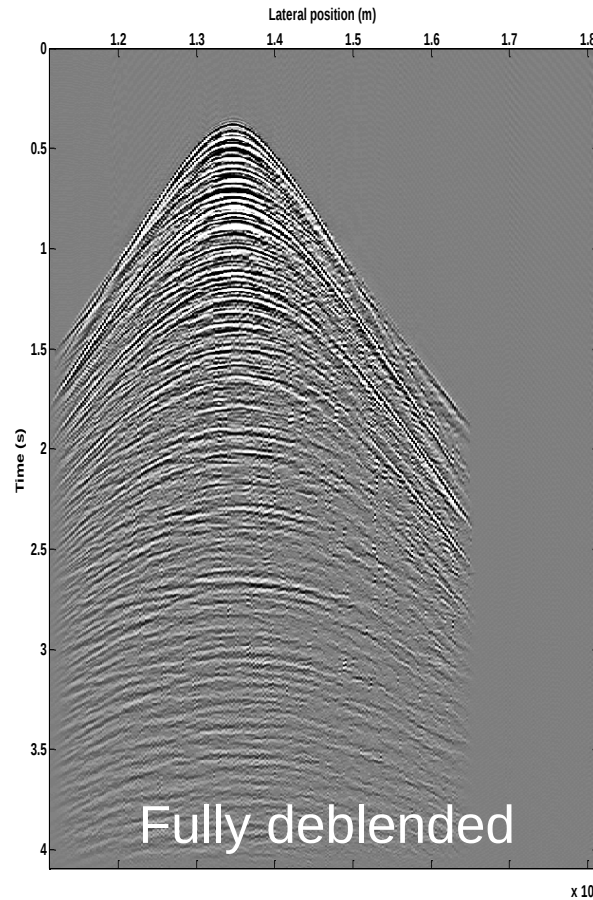
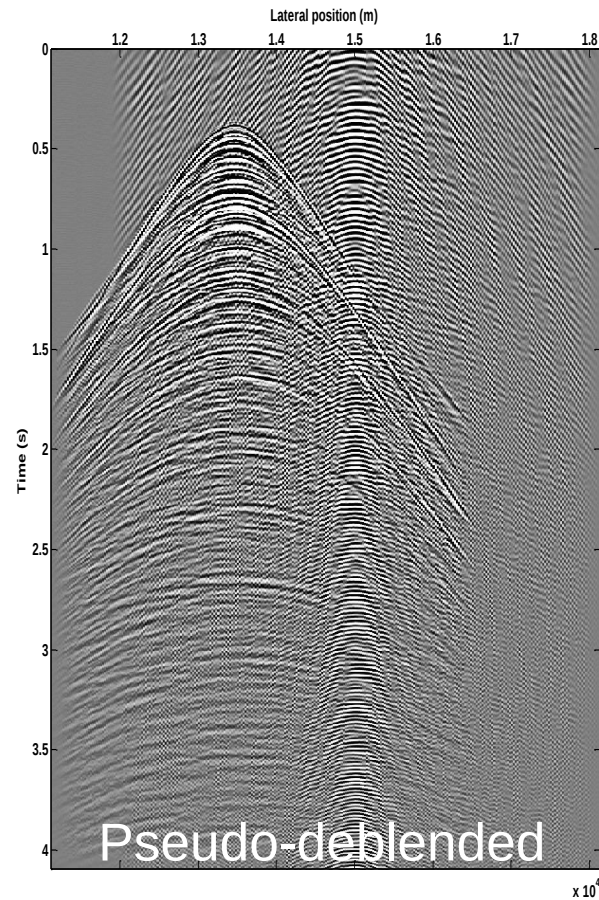


Pseudo-deblended or fully deblended

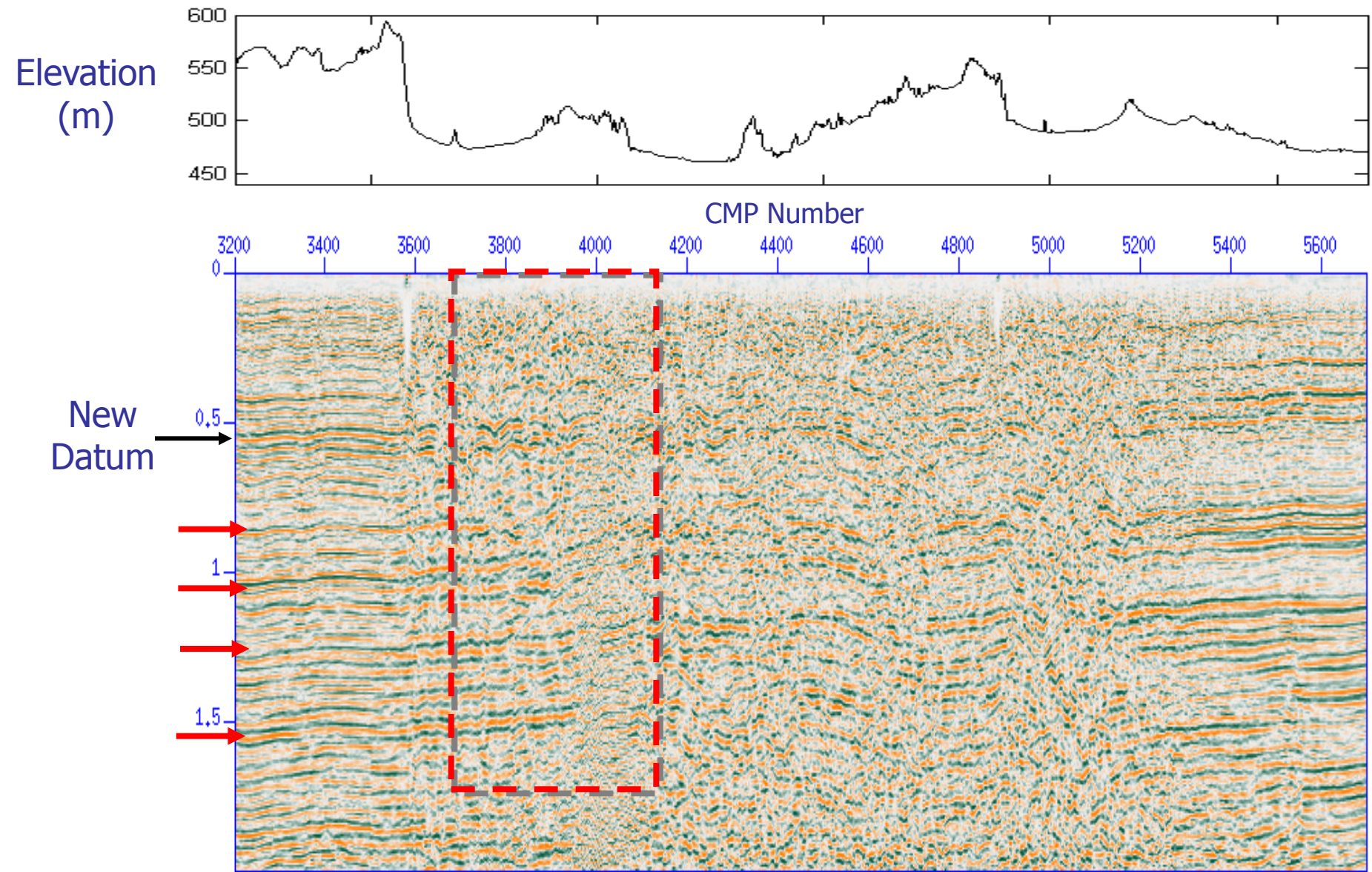
Pseudo-deblended shot record 1

Estimate of shot record 1 in iteration 67

Shot record 1

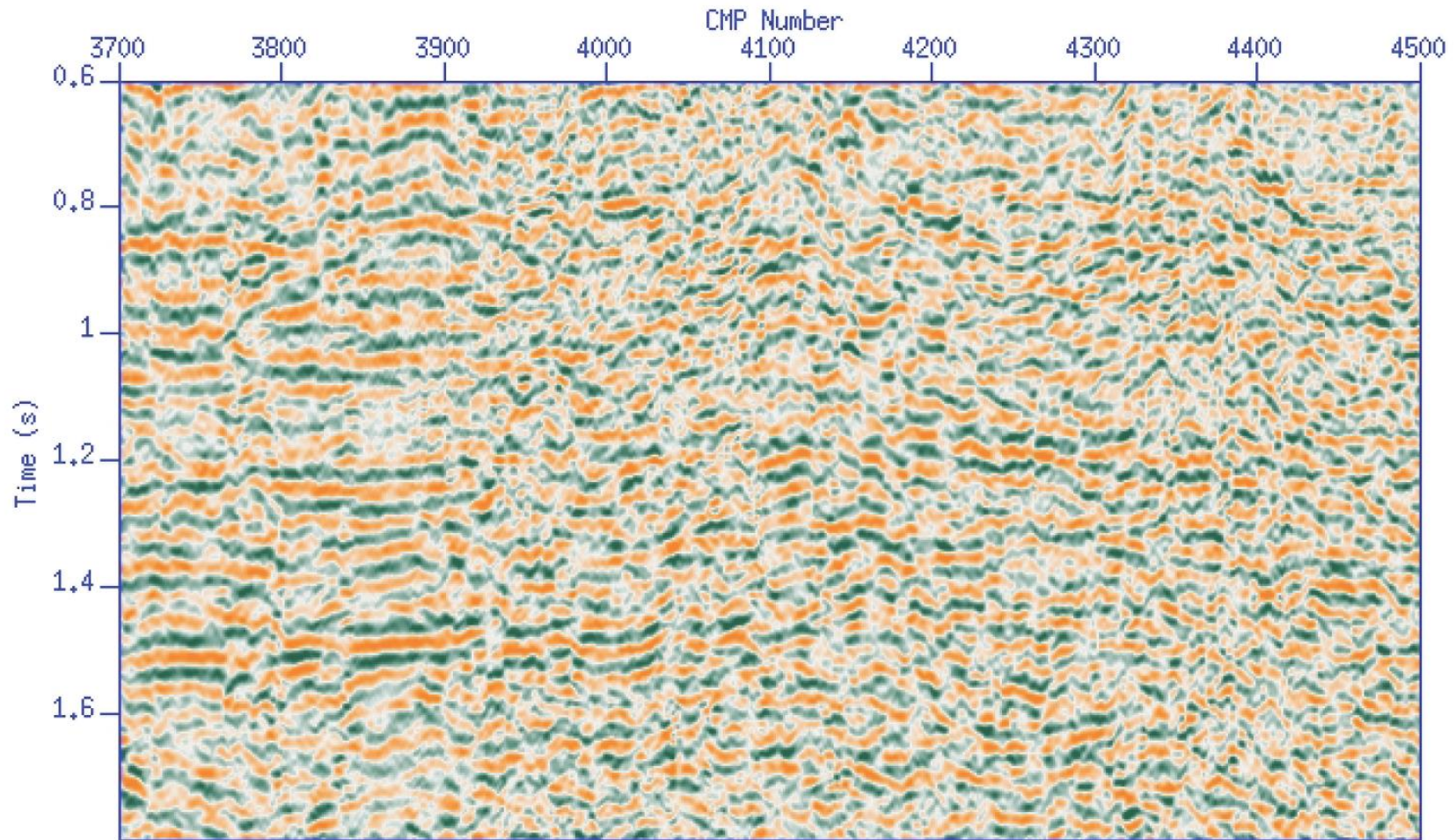


Saudi Aramco line (EAGE 2005 workshop)



Field data results

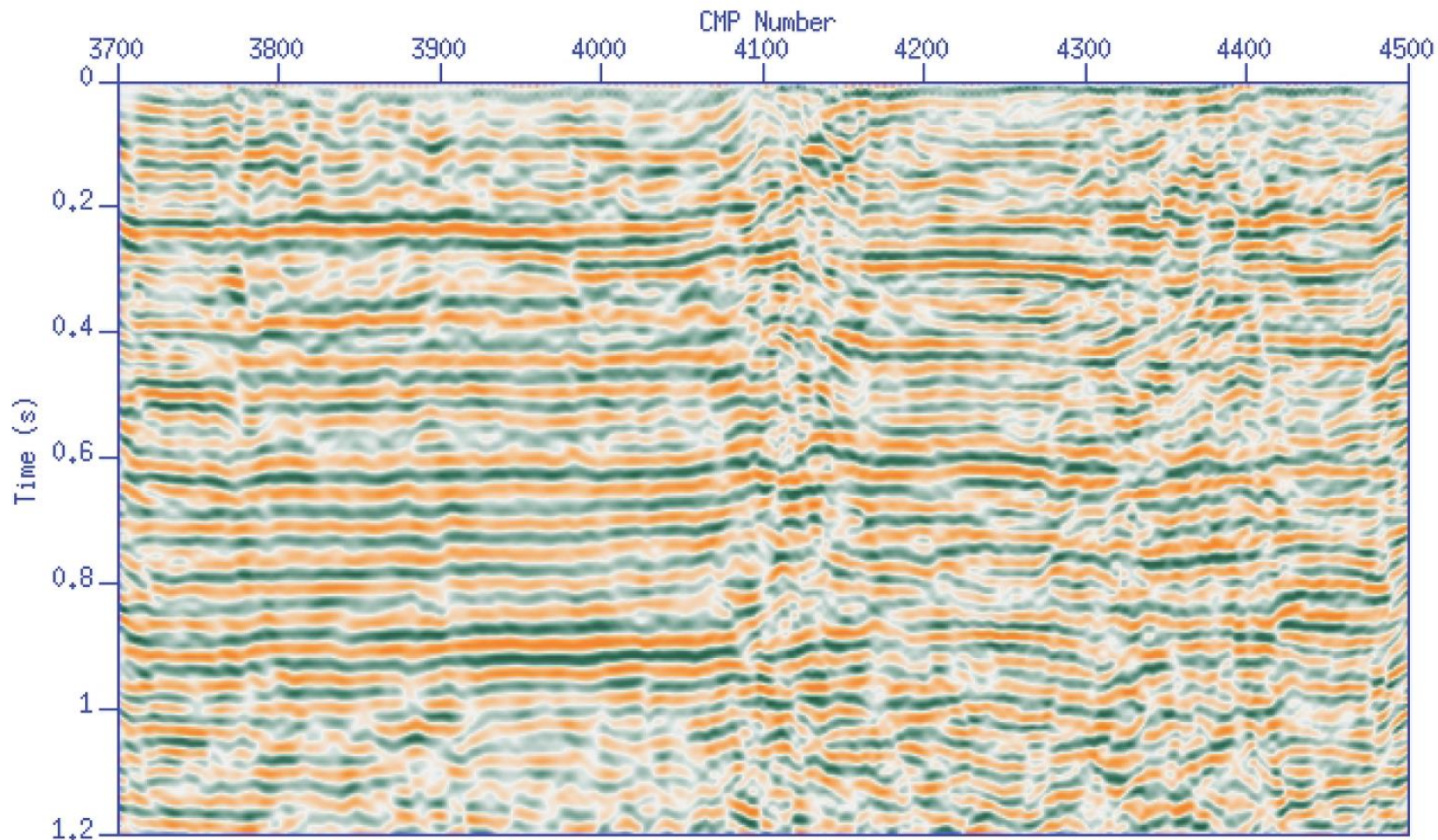
Stack from input data



Results from Jan-Willem Vrolijk (Vrolijk et al., 2012, Journal of Applied Geoscience, 82, 30-45)

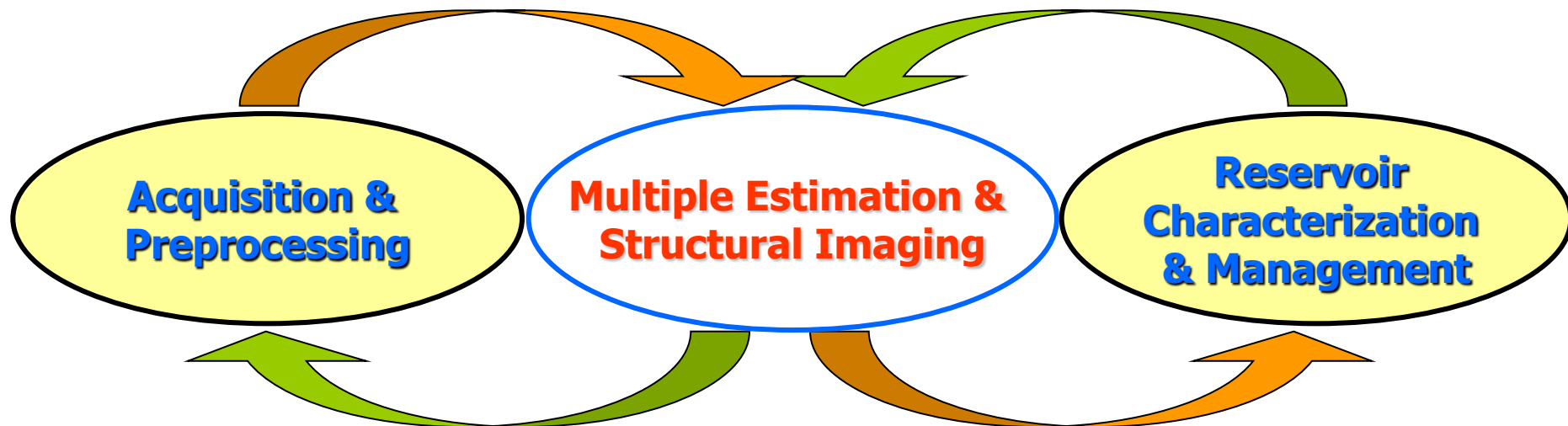
Field data results

Stack after redatuming with full-waveform operators
(multi-datum)



Results from Jan-Willem Vrolijk (Vrolijk et al., 2012, Journal of Applied Geoscience, 82, 30-45)

Multiple Estimation & Structural Imaging



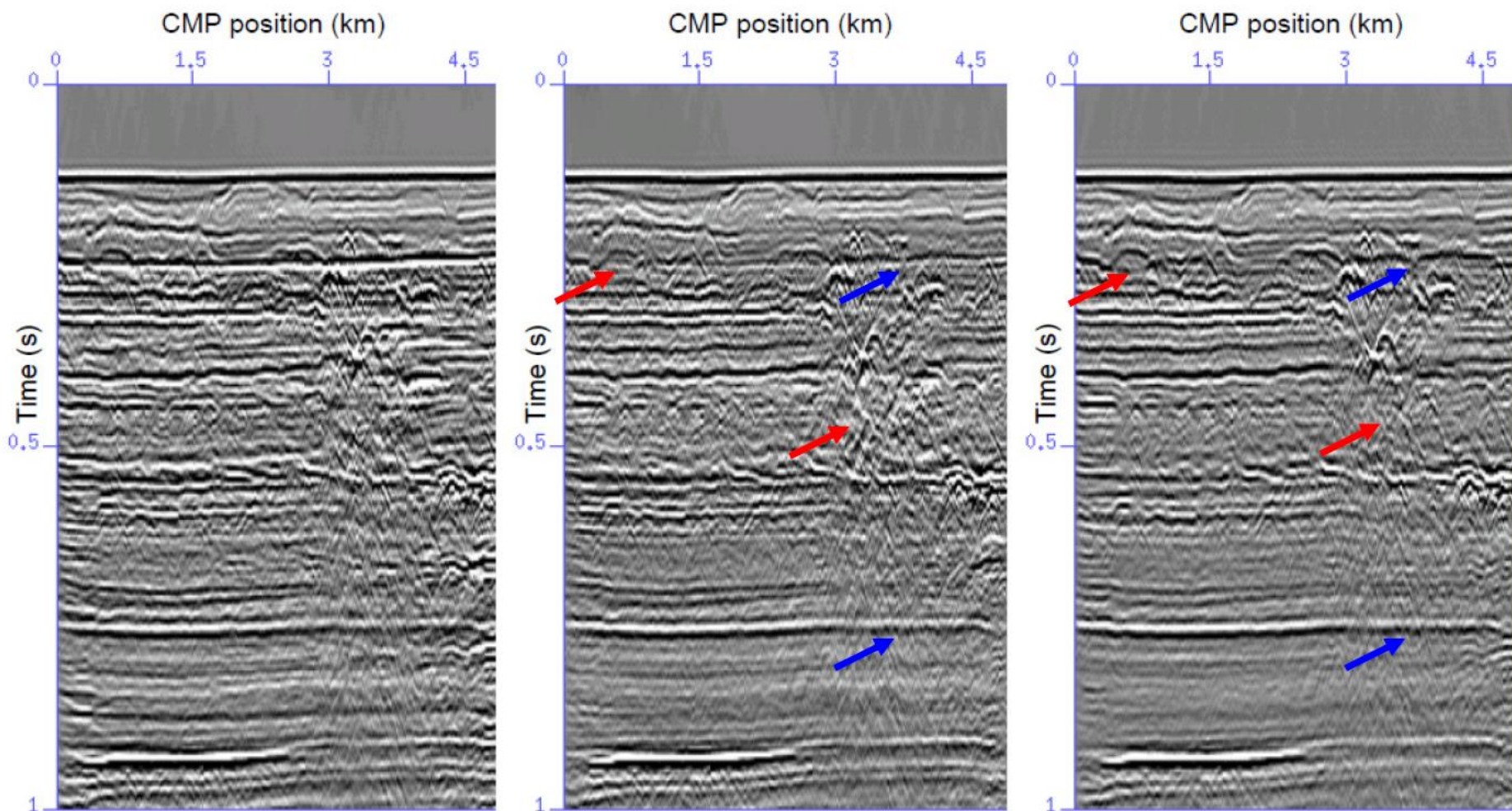
- Multiple estimation:
 - Surface multiple estimation (SRME)
 - From multiple removal to primary estimation (EPSI)
 - Primary estimation for internal multiples
 - Extending closed-loop primary estimation to 3D
- Imaging:
 - Imaging of blended data and surface multiples
 - Full wavefield migration: including all internal multiples
 - Joint-Migration-Inversion: Automatic estimation of the background velocity model (including multiples)

Primary estimation: Marine field data



- Upgoing wavefield extracted from dual-sensor measurement
- Subset from 2D line for comparing SRME vs Primary Estimation (EPSI)
- State-of-the-art SRME-based method, including predictive tau-p deconvolution

SRME vs. EPSI: Marine field data example



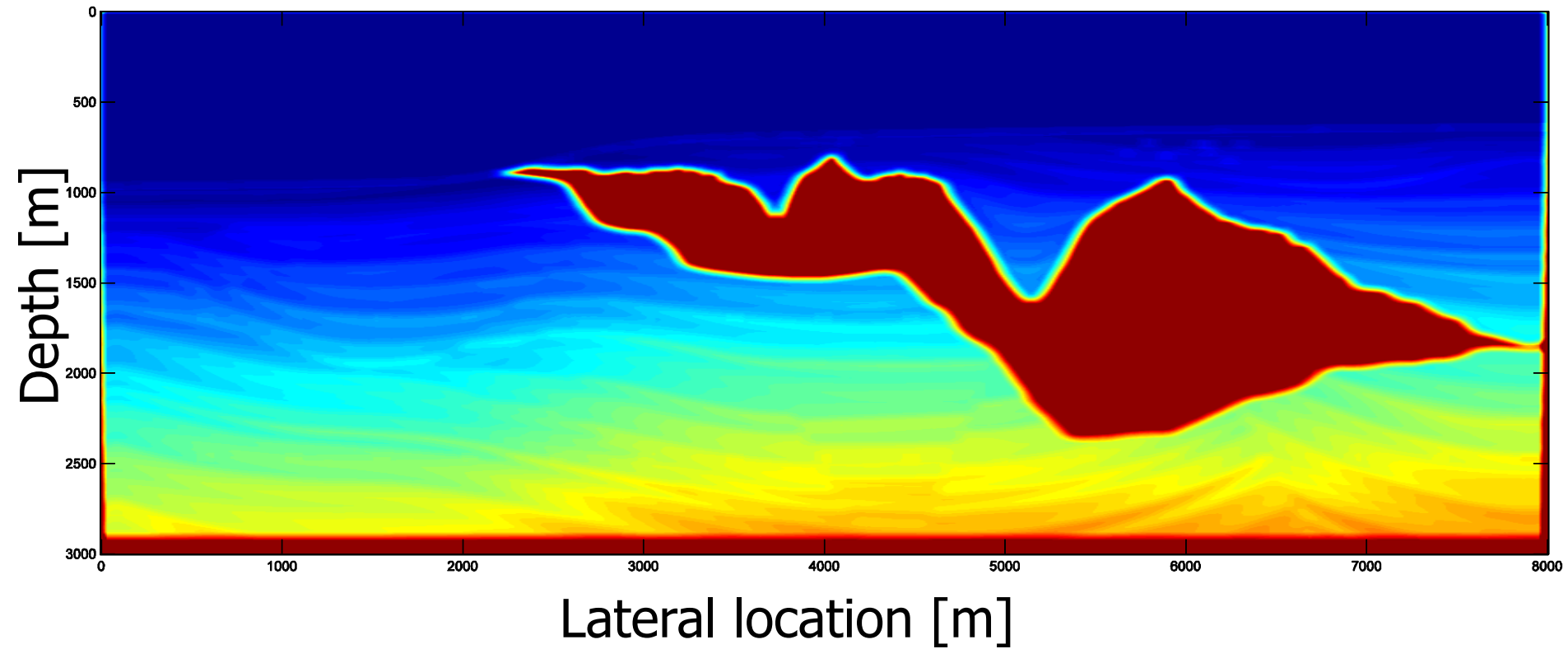
Stacked section: input

SRME output

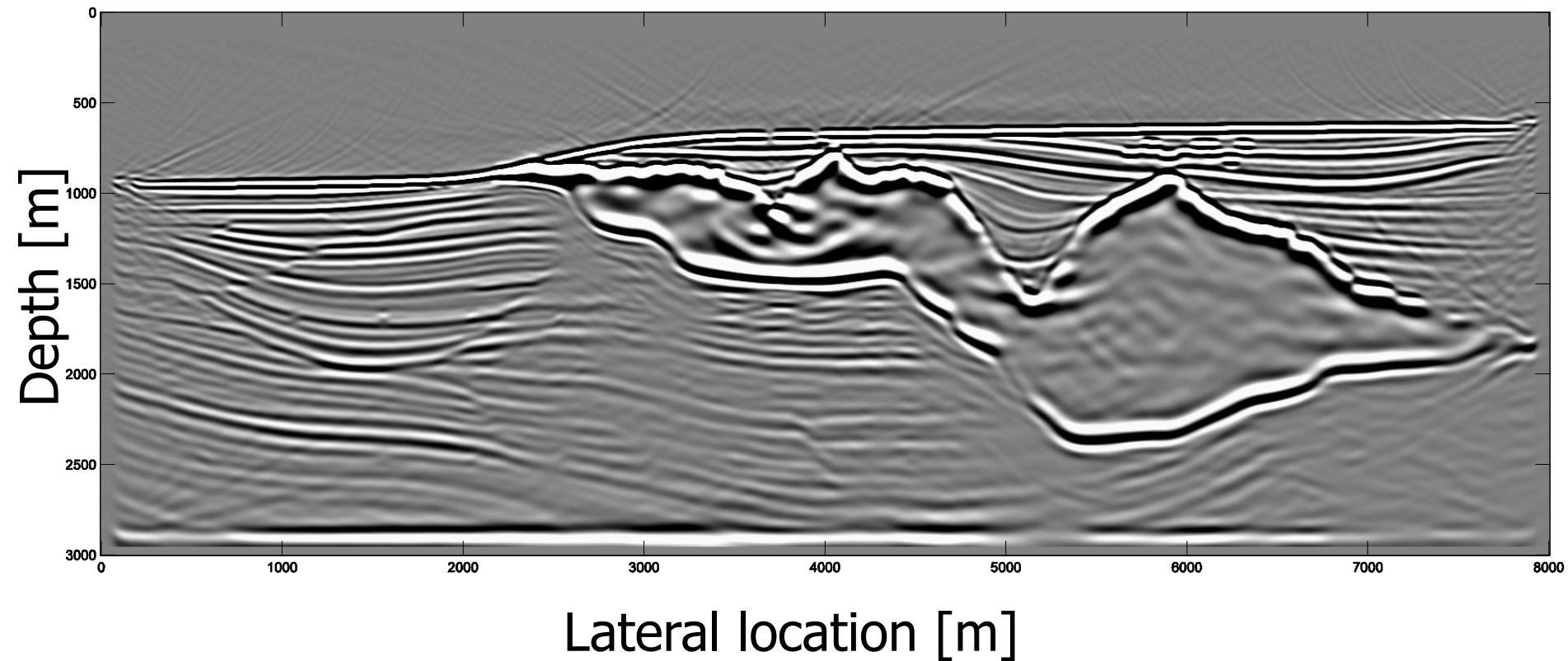
EPSI output

Result from Rolf Baardman et al., SEG 2010

Migration velocity model:

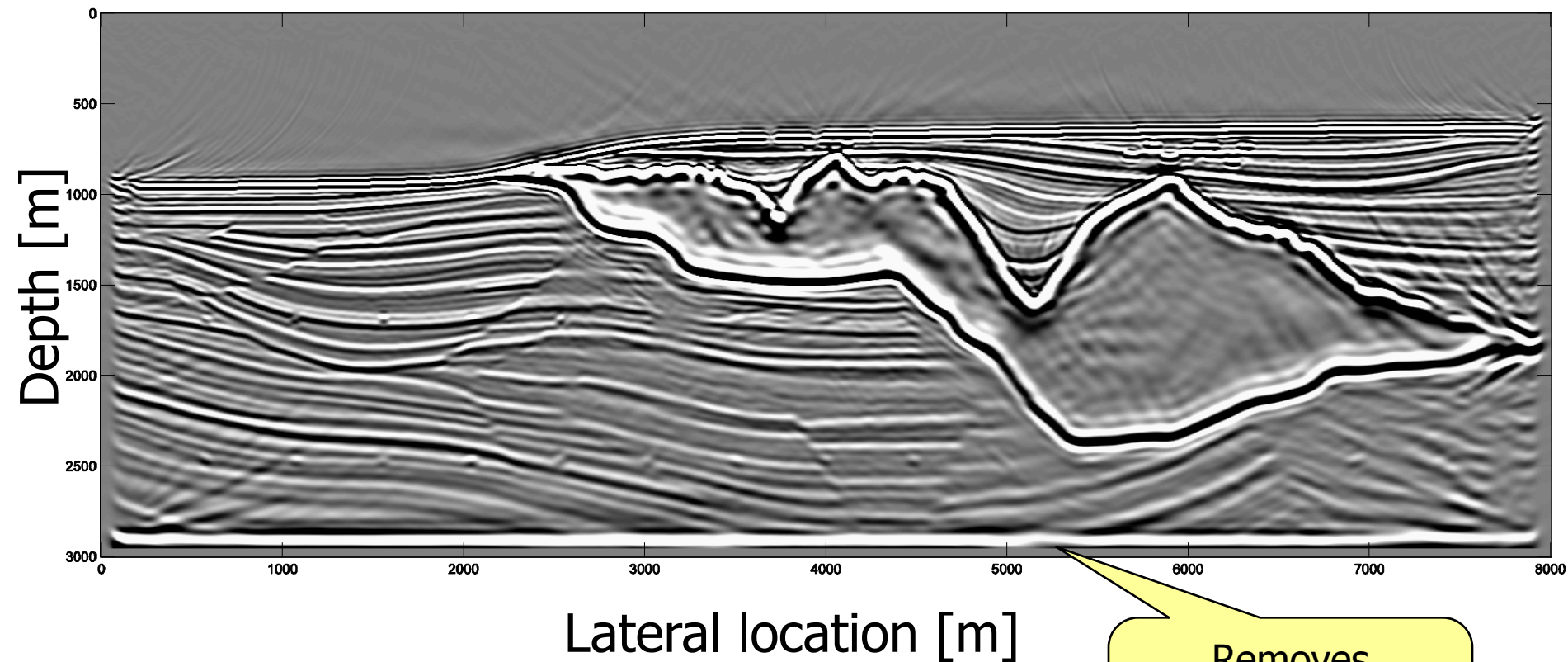


Imaging with primary reflections only



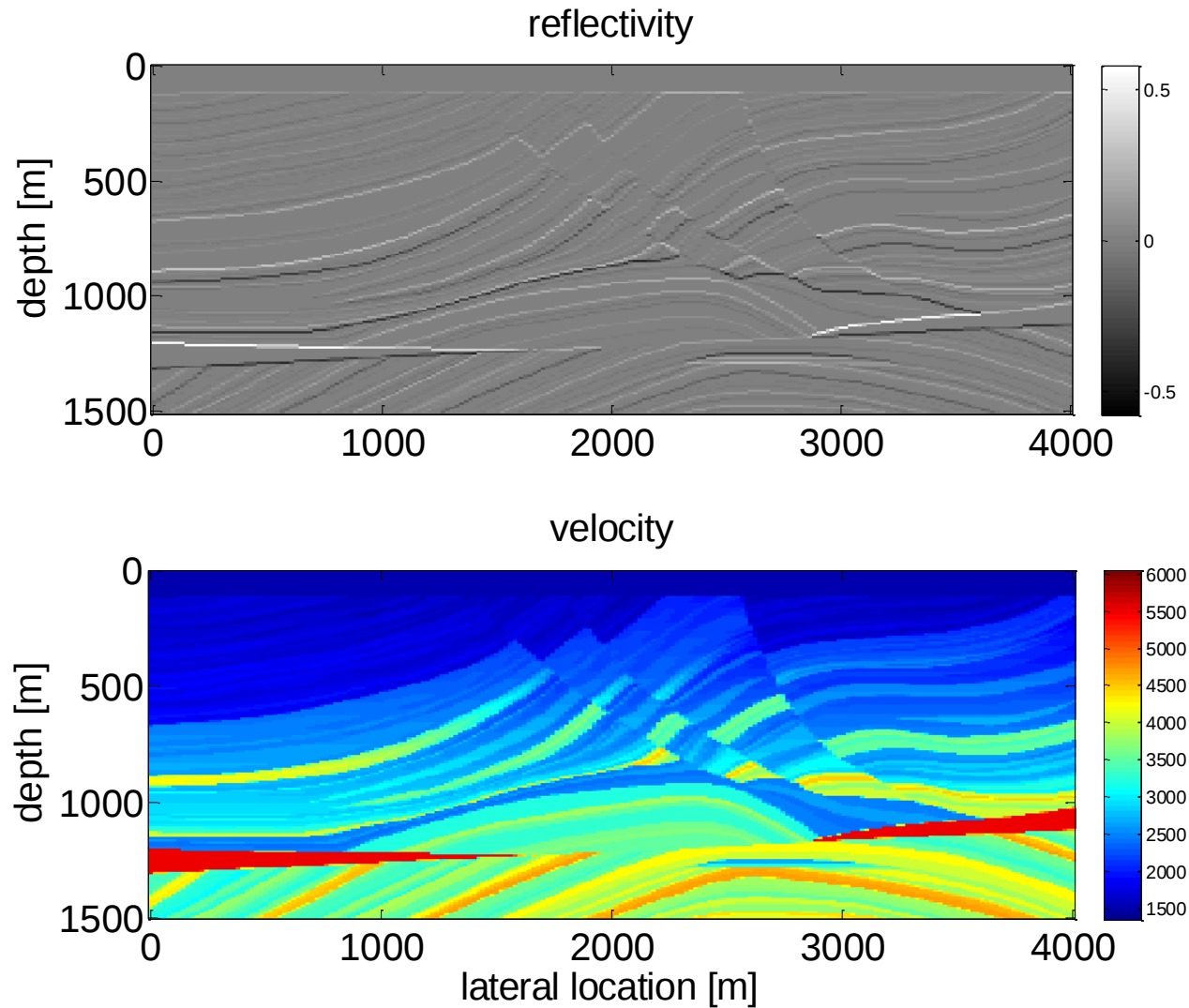
Full Wavefield Migration (FWM)

Using primaries and internal multiples



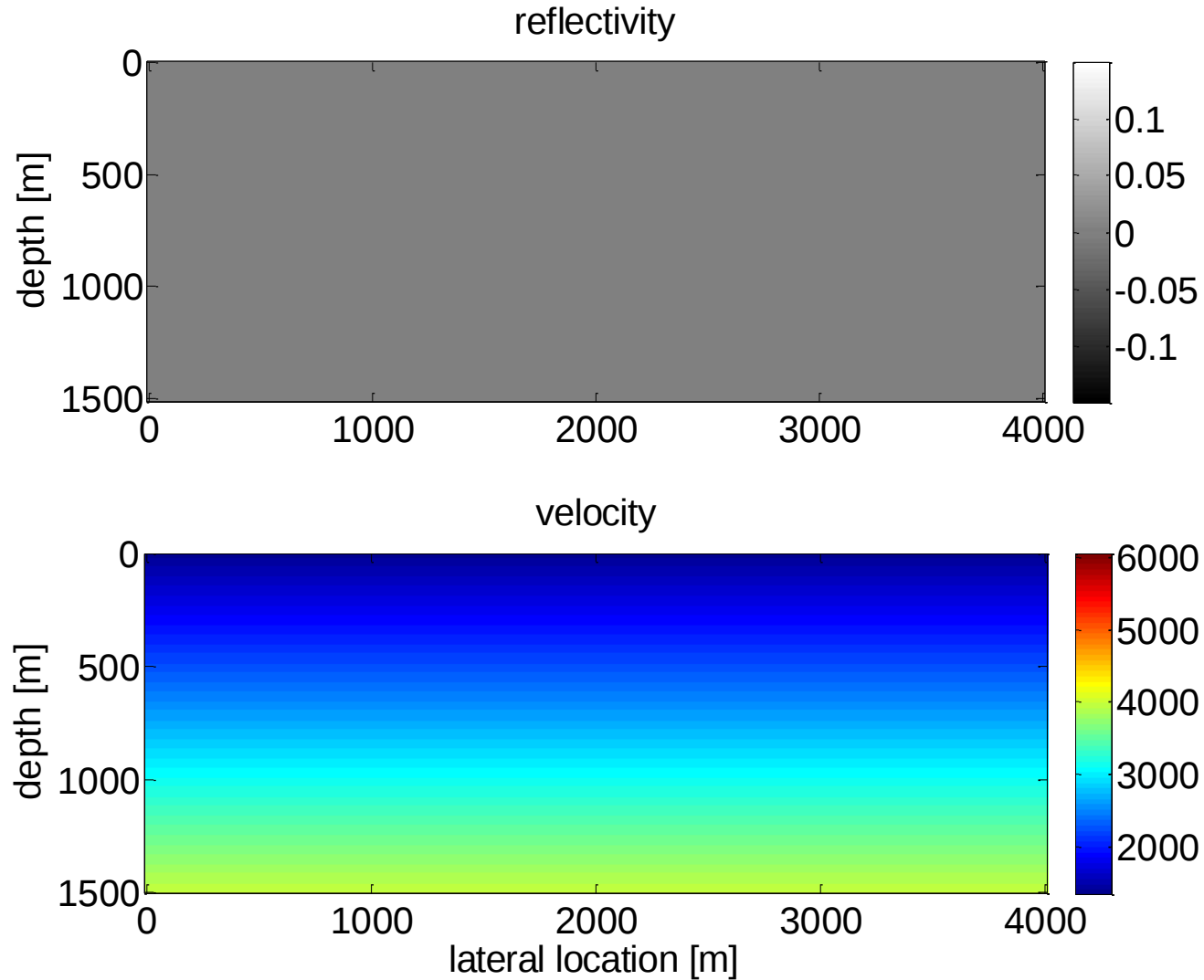
Results from Mikhail Davydenko (SEG 2013)

Including velocity estimation in FWM



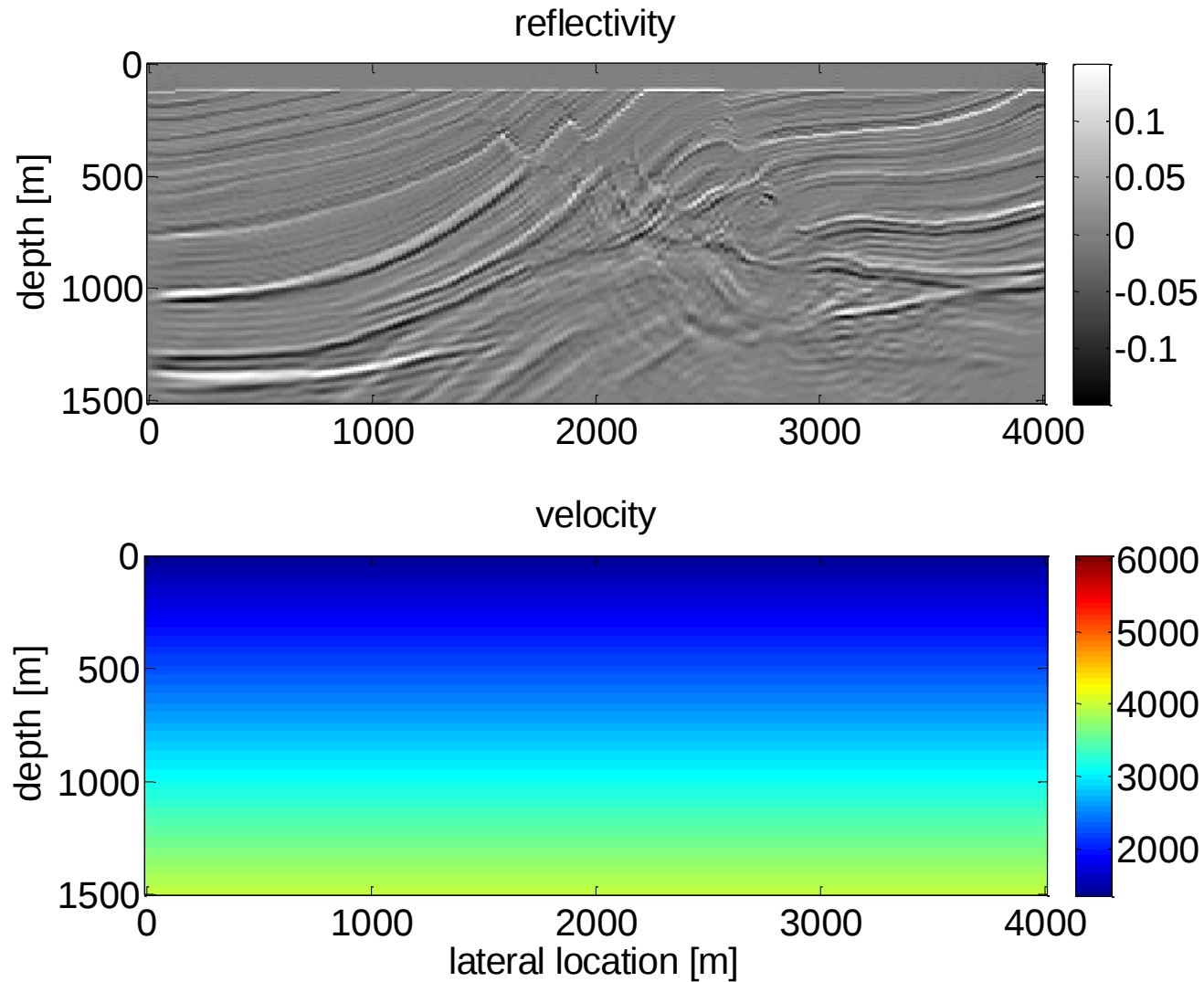
Results from Xander Staal (EAGE 2013)

Marmousi - Initial model



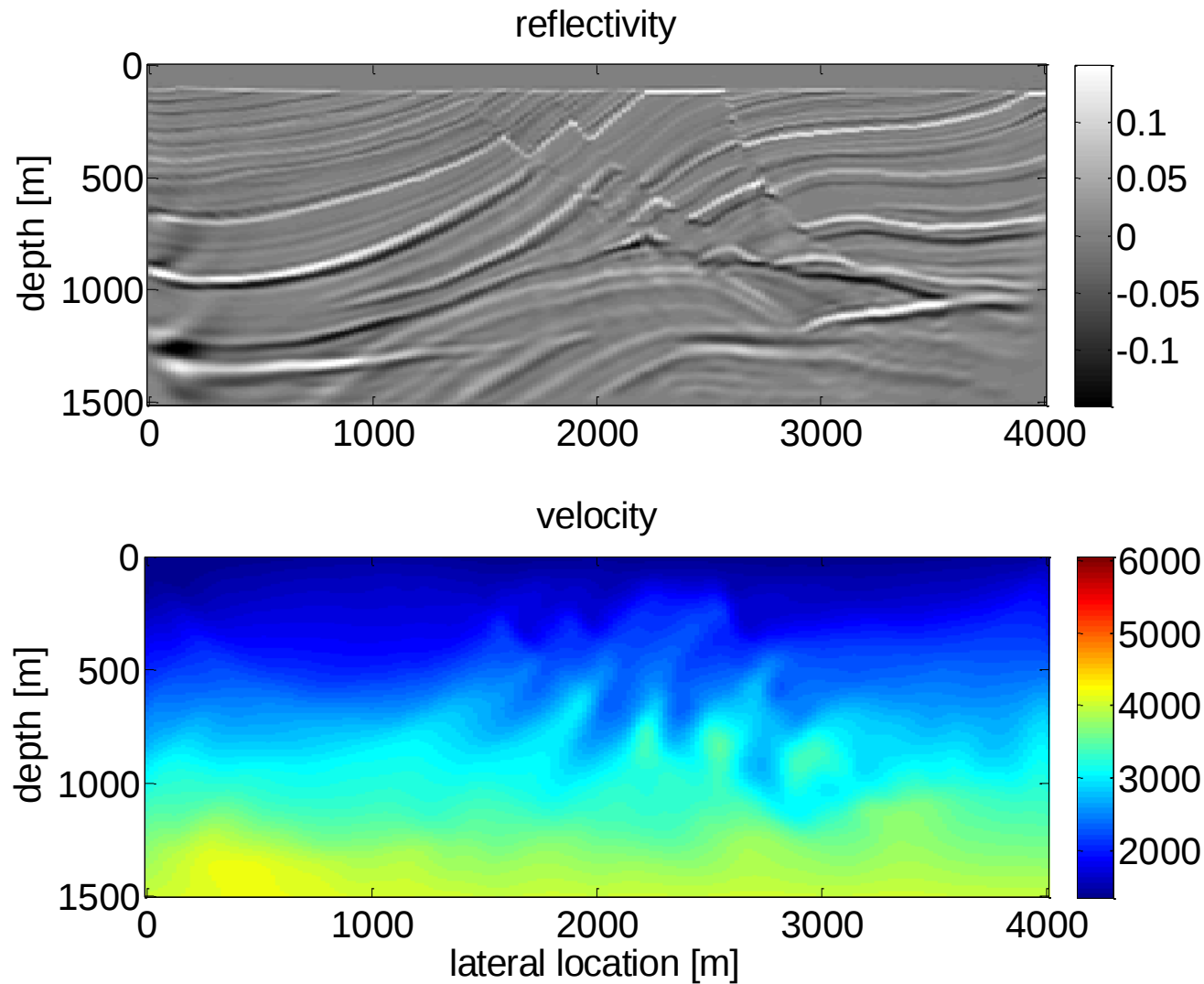
Results from Xander Staal (EAGE 2013)

Marmousi - Imaging only

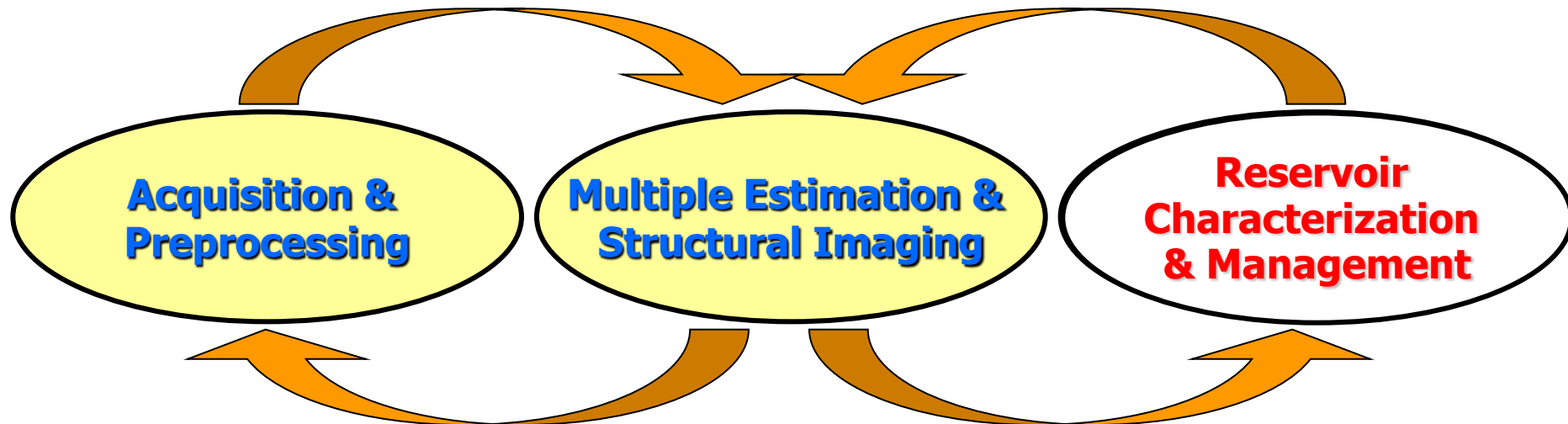


Results from Xander Staal (EAGE 2013)

Marmousi – Joint Migration Inversion (JMI)



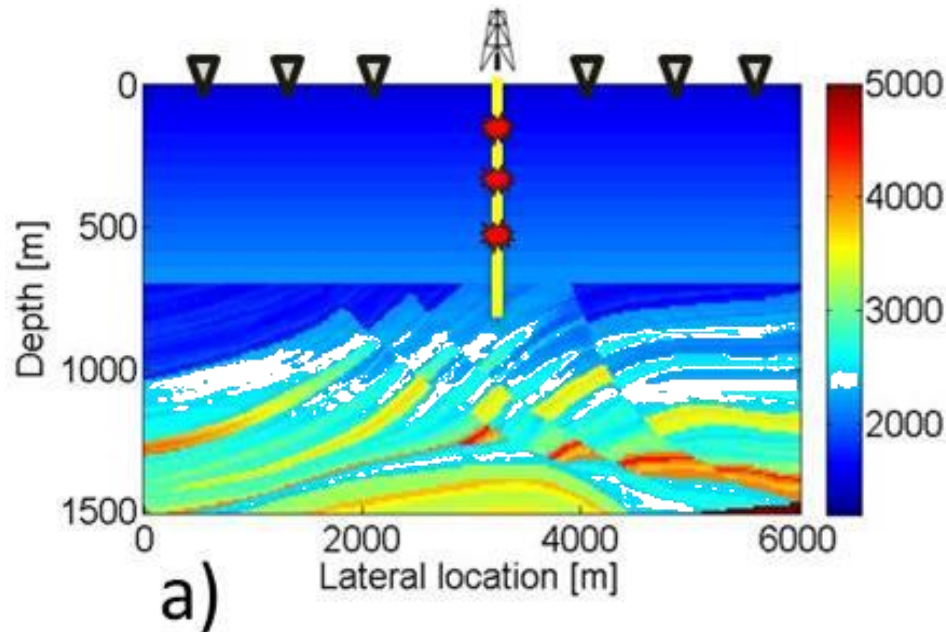
Results from Xander Staal (EAGE 2013)



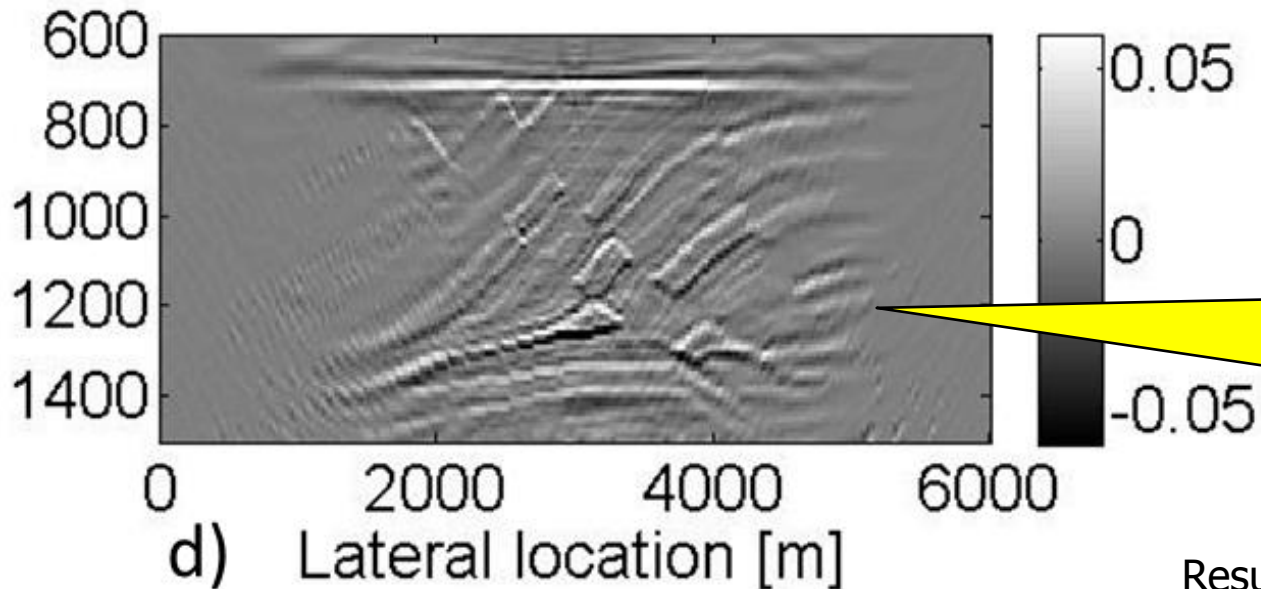
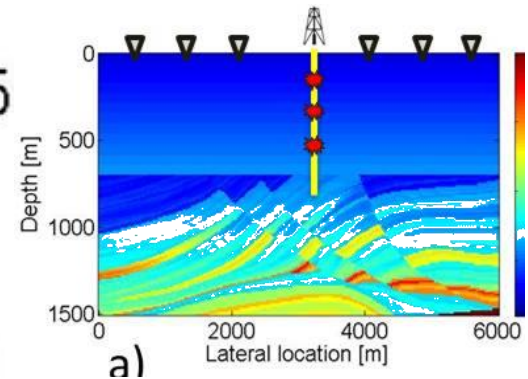
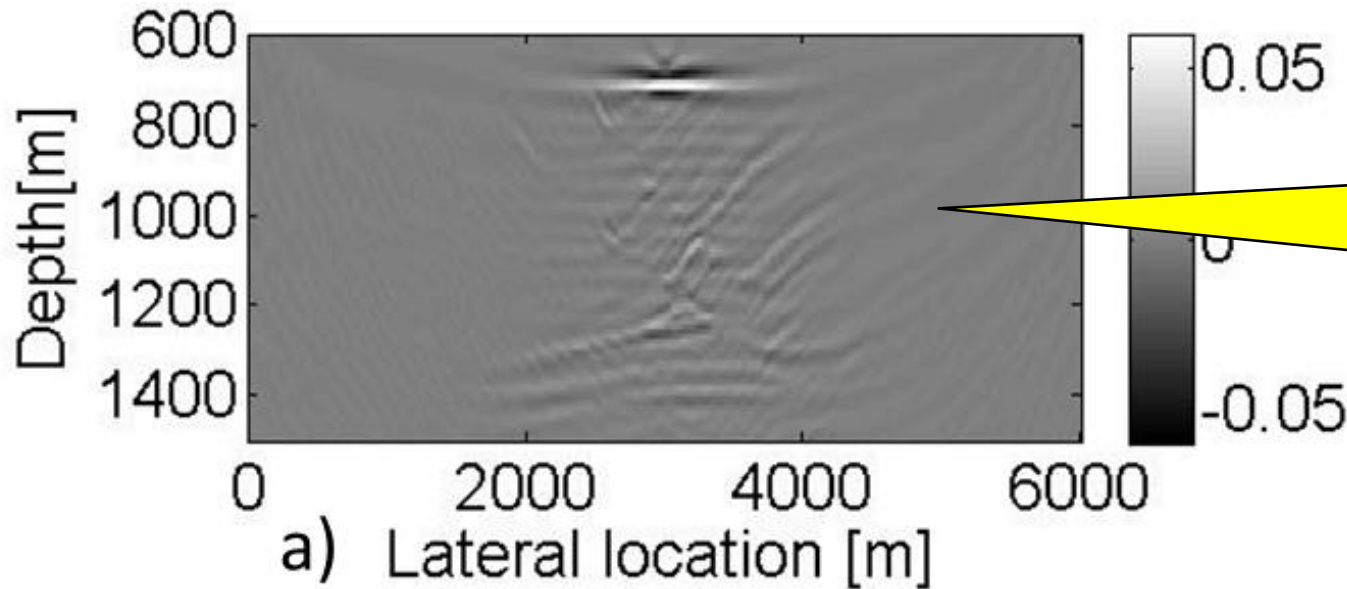
- High-resolution full waveform inversion:
 - Local, reservoir-oriented FWI
 - FWI including geological scenarios
- Joint inversion-migration:
 - Include with JMI for overburden solution → JMI-res
- VSP full wavefield migration
 - Using all multiples to image away from the well
 - Integrate with surface seismic data
- Time lapse monitoring
 - Multi-physics (EM, Seismics, Remote Sensing)

Introduction: example for VSP

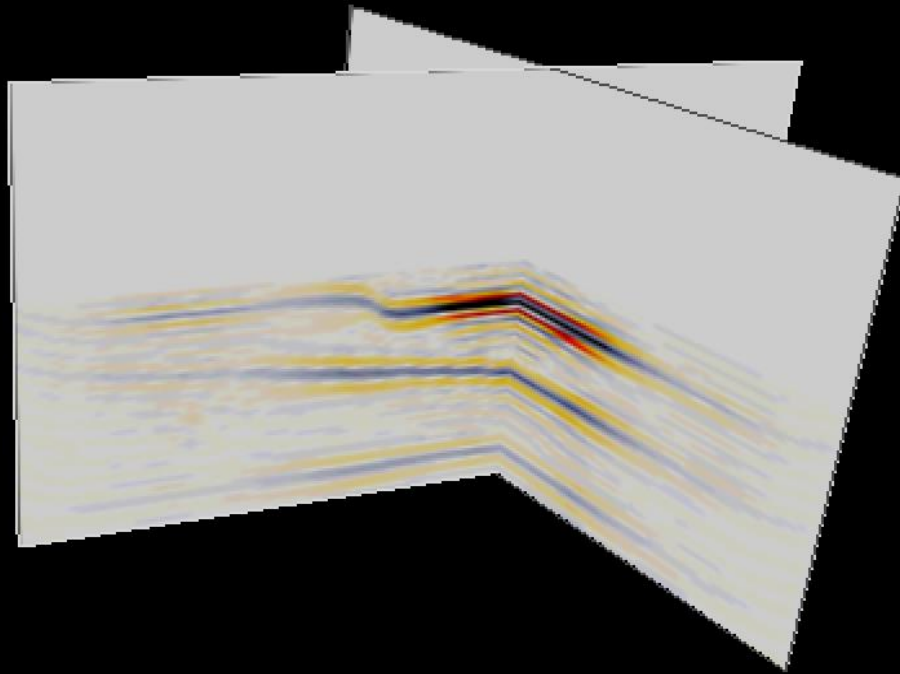
- Example of using multiples in VSP imaging (Work of Ph.D. student Alok Soni)



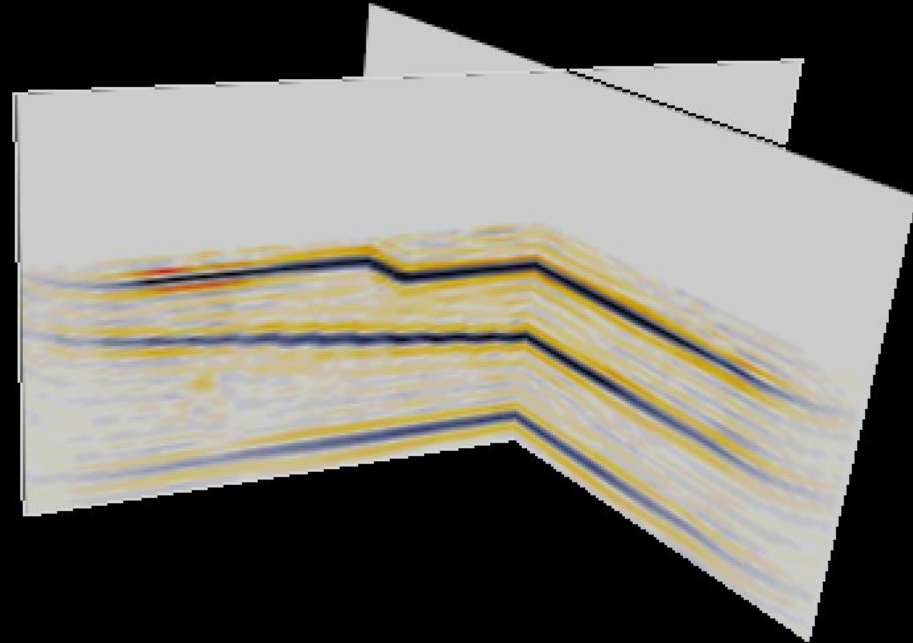
Introduction: example for VSP



3D VSP migration using multiples



First iteration of FWM



After 10 iterations of FWM

- 2008 : Delphi Studio for Imaging (DS4I)
 - Founded by Guus Berkhout and Eric Verschuur
 - One-to-one projects for sponsoring companies Delphi
 - Early applications of developed technology
 - Dedicated development of software products related to the research
- 2012 : Delft Inversion
 - Founded by Dries Gisolf, Peter Haffinger and Panos Doulgeris
 - Commercial entity (also for non-sponsoring companies)
 - Focus on high-resolution elastic inversion

- Currently:
 - Guus Berkhout & Eric Verschuur founders
 - One employee (former M.Sc. Student)
 - One consultant (former M.Sc. Student)



- One-to-one projects for Delphi Sponsoring companies
 - Demonstration of newly developed methods to client's dataset (beyond capabilities of the involved Ph.D. project)
 - Further development of newly developed technology tailor-made for client (software development)
 - Consultancy to help client in using the Delphi tools (for in-house application → transfer of technology)



- Selection of projects from last few years:
 - Deblending of SimSrc measurements
 - Primary estimation (EPSI) on marine data
 - Internal multiple removal on land data
 - Near-surface layer-replacement for land data
 - Developing interpolation software for specialized applications (3D marine, 3D land)
 - Imaging of 3D VSP data (software development)

