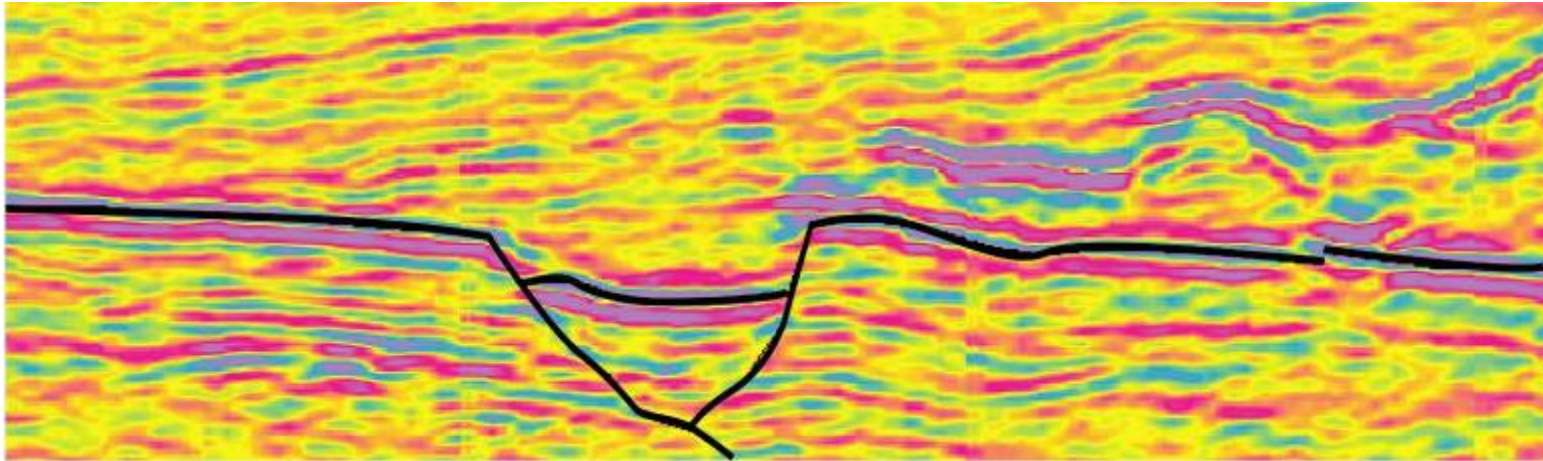


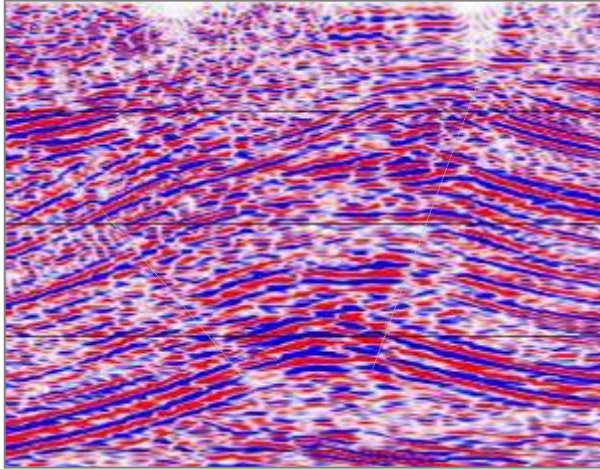
# ***Seismic acquisition and processing systems - applications from applied geophysics -***



***Charlotte Krawczyk***

( [lotte@liag-hannover.de](mailto:lotte@liag-hannover.de) )

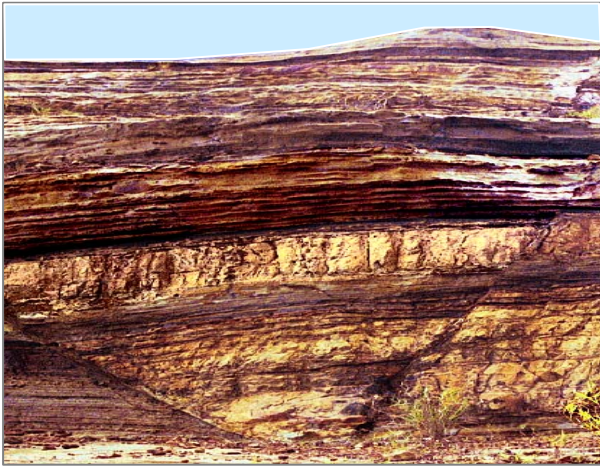
# Advantages of the reflection seismic method



- high resolution and accuracy
- variable depth penetration
- application to many objects

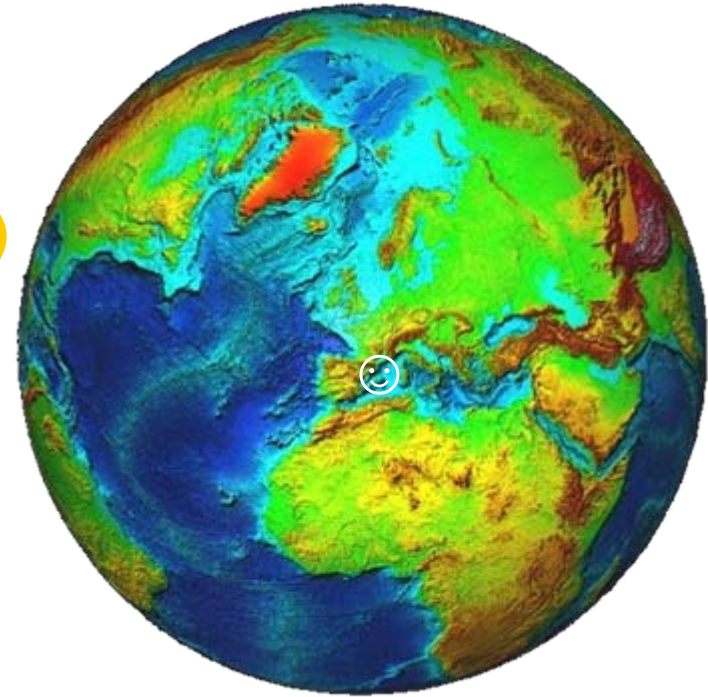


**structural image  
of the temporal evolution  
in the subsurface**



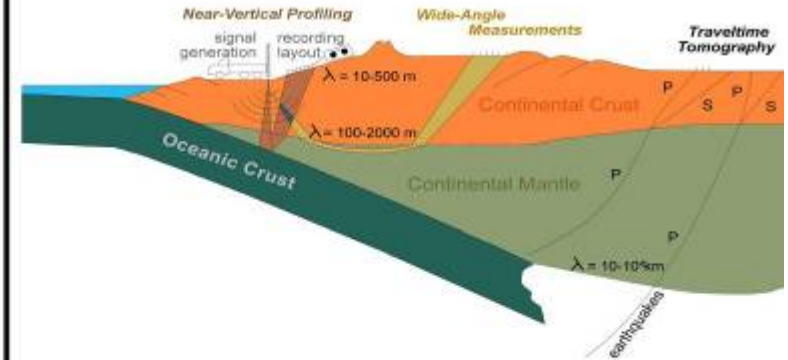
# Applications of reflection seismics

- basic research (structure and physical properties of the Earth)
- exploration and exploitation of resources (hydrocarbons, water, geothermal energy)
- subsurface studies for engineering (tunnels, foundations)
- risk analysis of waste deposit locations (waste bodies, groundwater flow)
- mapping of natural disasters (landslide processes, sinkholes)
- .....



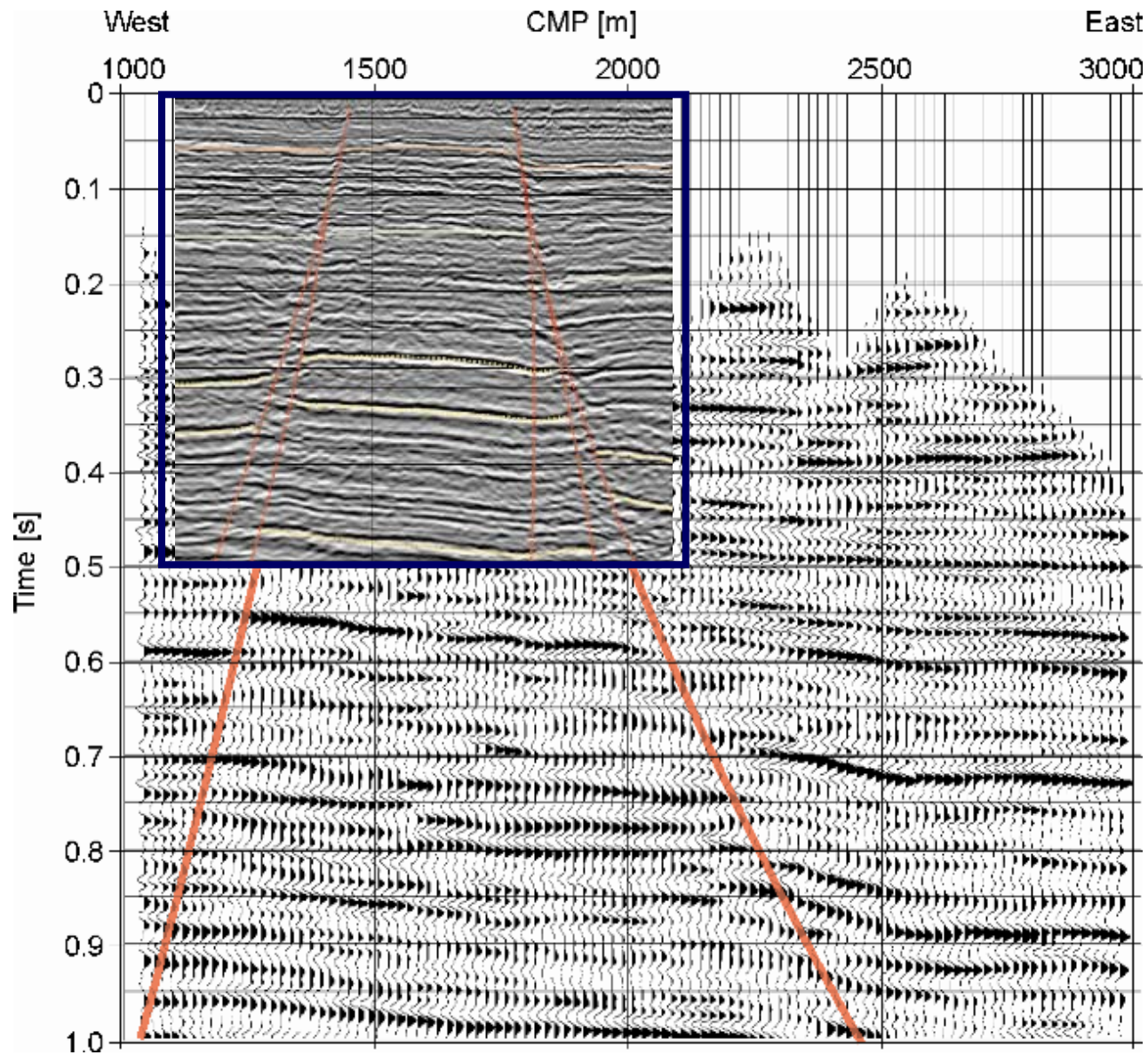
# Typical seismic wavelengths

	seismology		
<b>Frequency [Hz]</b>	$10^{-4} - 10^{-2}$	$10^{-2} - 10^{-1}$	$10^{-1} - 10^0$
<b>Wavelength [km]</b>	26.000-800	800-80	80-8
<b>Source</b>	oscillation of the earth	long-distance earthquakes	short-distance earthquakes
<b>Application</b>	entire earth		mantle/crust
<b>Depth range [km]</b>	$10^4$	$10^3 - 10^2$	$10^2 - 10^1$
<b>Resolution [km]</b>	$10^2$	$10^1$	$10^1 - 10^0$



	deep	exploration	seismics	shallow seismics	laboratory	
<b>Frequency [Hz]</b>	1 – 10	10 – 100	$10 - 10^0$	$10^1 - 10^3$	$10^2 - 10^4$	$10^4 - 10^6$
<b>Wavelength [km]</b>	6 – 0.6	0.3 – 0.03	0.1 – 0.01	$10^{-1} - 10^{-4}$	$10^{-2} - 10^{-4}$	$10^{-4} - 10^{-6}$
<b>Source</b>	earthquakes explosions	seismic shots and non- explosive sources		non-explosive sources	non-/explosive and ultrasonic sources	
<b>Application</b>	upper/crust	upper crust	short offset	engineering	mining	models
<b>Depth range [km]</b>	$10^2 - 10^1$	$10^1 - 10^0$	$10^0 - 10^{-1}$	$10^2 - 10^1$	$10^1 - 10^0$	$10^0 - 10^{-1}$
<b>Resolution [km]</b>	$10^1 - 10^0$	$10^{-1} - 10^{-2}$	$10^{-2}$	$10^1 - 10^0$	$10^{-1} - 10^{-2}$	$10^{-2}$

# Exploration



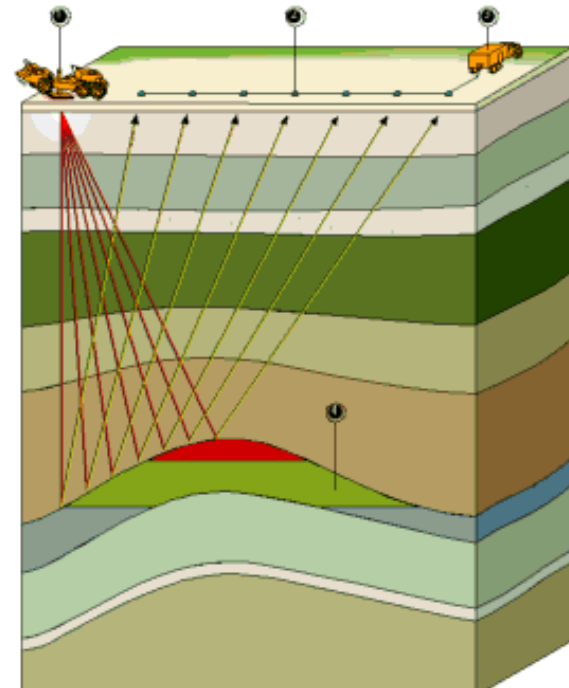
# Outline

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## Introduction

- ***Acquisition***
- ***Processing***
- ***Interpretation***
- ***Modelling***

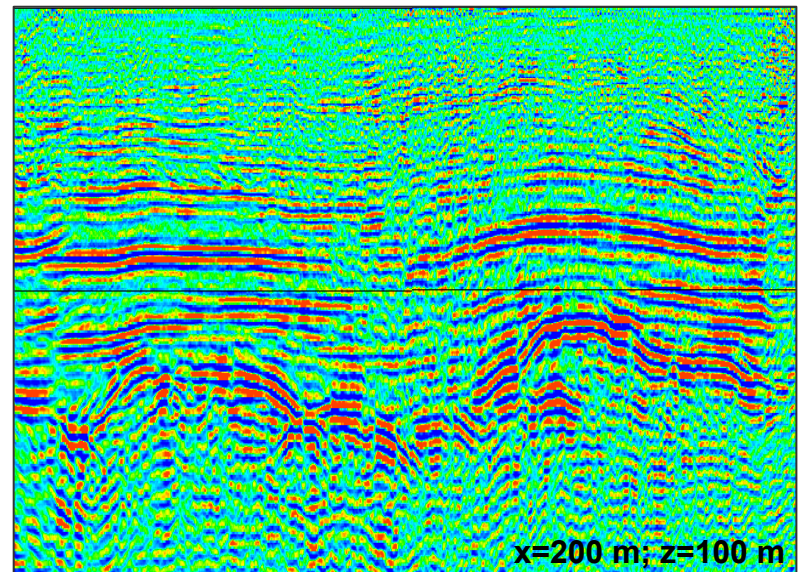
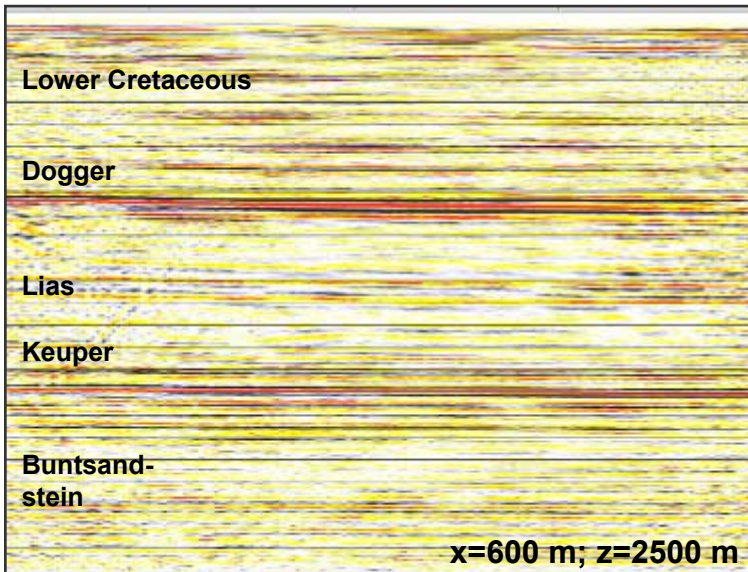
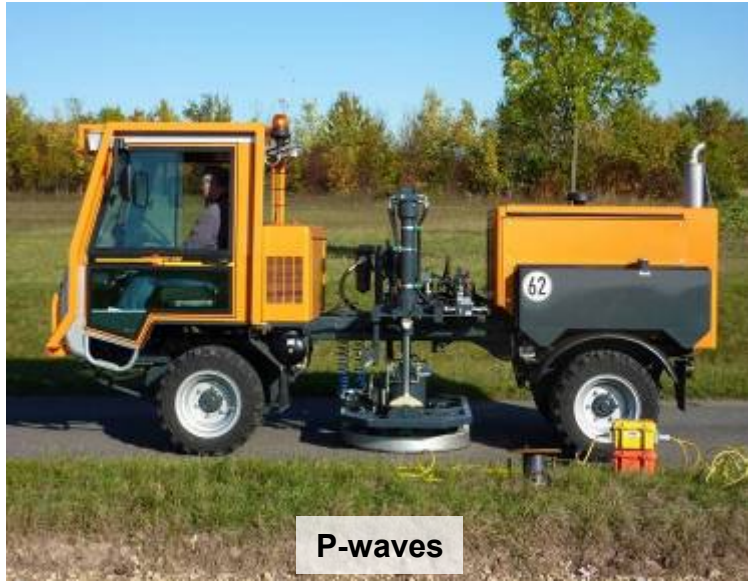
## Summary



# Seismic sources



# Mini-Vibrators





# Mikro-Vibrator ELVIS (ELectrodynamic Vibrator System)



# Seismic receivers - single



3-component  
geophone



P-wave geophone



# Seismic receivers - streamer



1. Frastadt, Sweden
2. Container harbour Trondheim
3. Frastadt, Sweden
4. Factory building

# Recording systems



recording truck in  
exploration survey



recording system in  
shallow seismic survey

# Development potential for acquisition systems

- monitor stability of dynamic behaviour of oscillating systems
- introduce more feedback mechanisms (optimize source efficiency, avoid resonance)
- completely wireless communication, incl. 'soft processing' (clouds ?)
- high sampling interval for shallow acquisition targets ( $< 1$  ms)
- fast recording
- multi-component mathematics



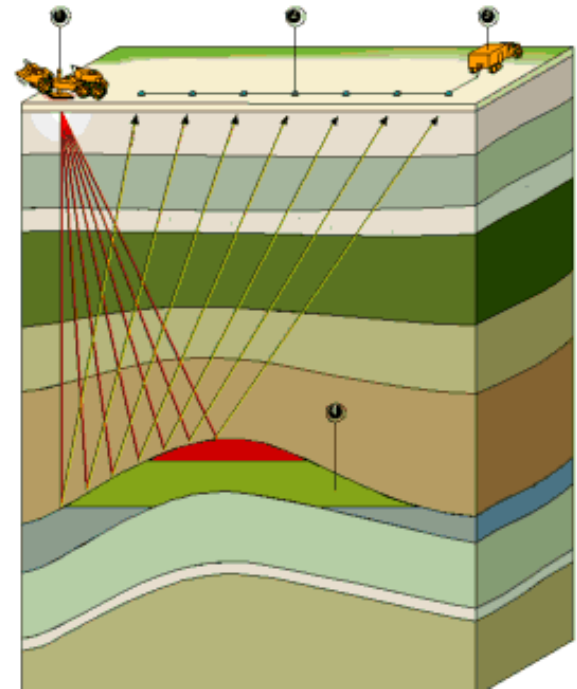
# Outline

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## Introduction

- **Acquisition**
- **Processing**
- **Interpretation**
- **Modelling**

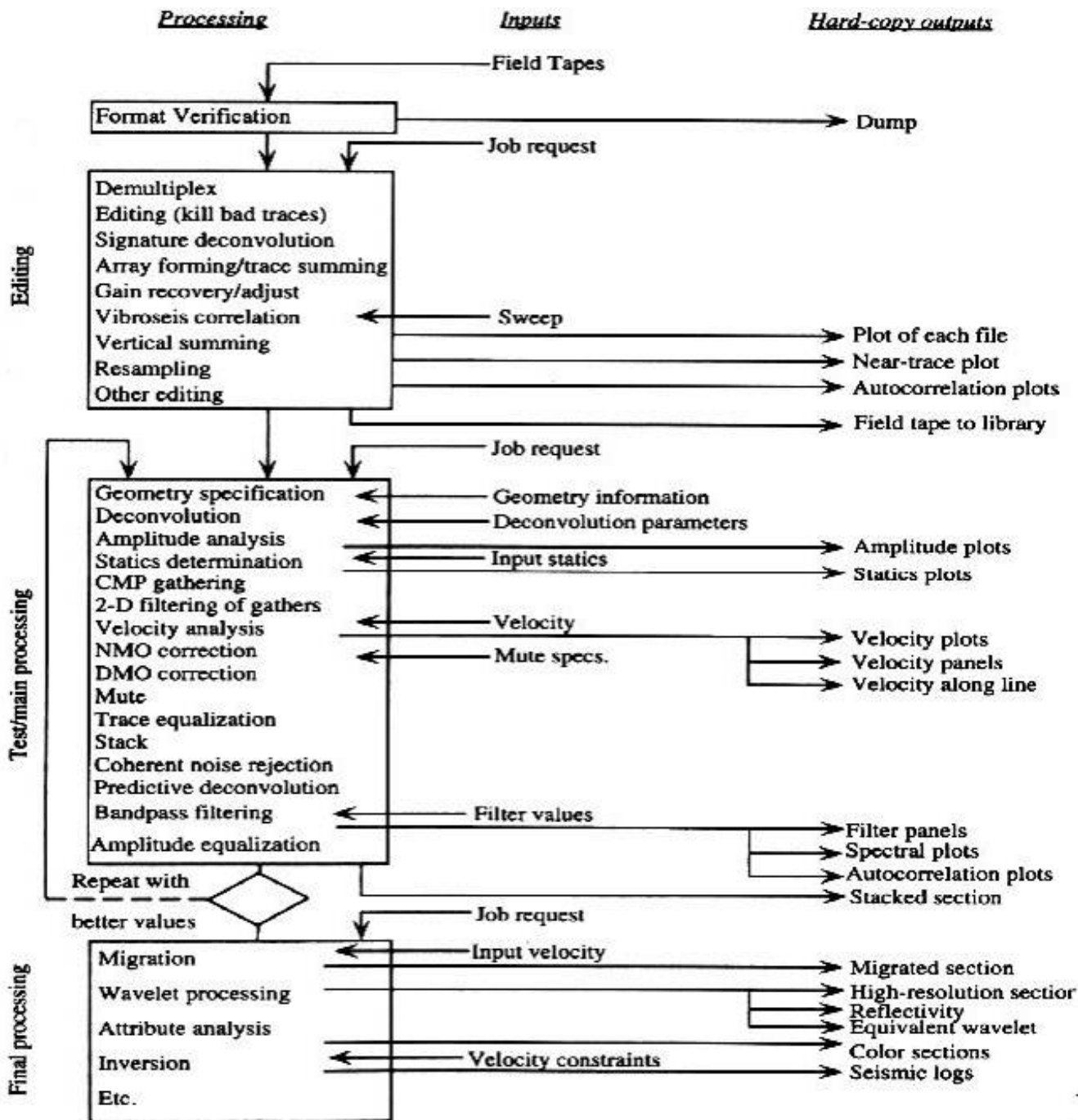
## Summary



# Processing

There are many options and possibilities, but.....

.....only individually designed flows are successful !



# Geometric stacking enhances the signal quality

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# f-K filtering of raw data suppresses noise

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# Processing result

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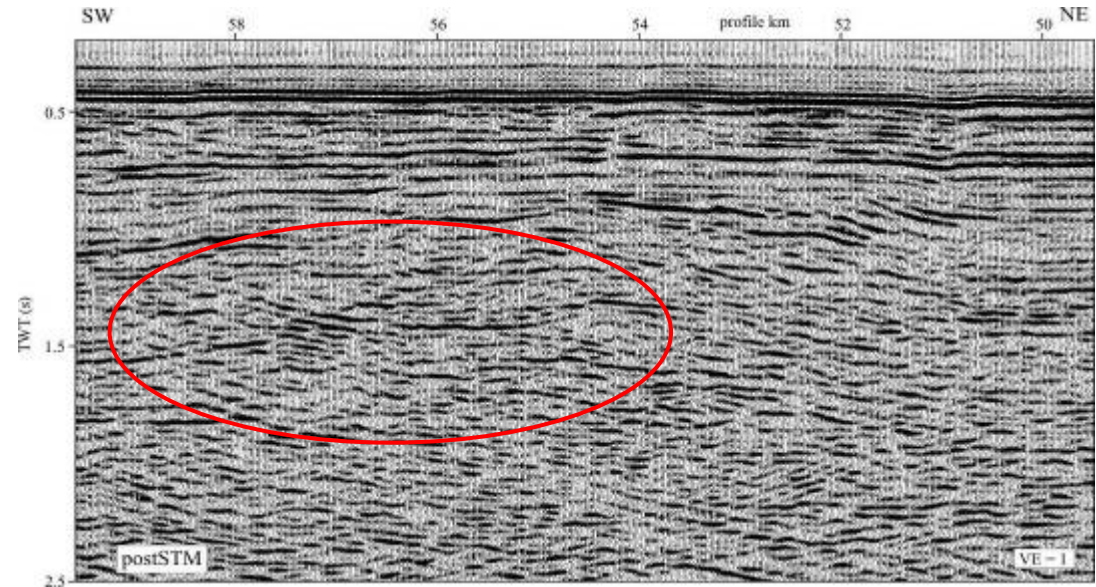
# Migration yields true reflector geometry

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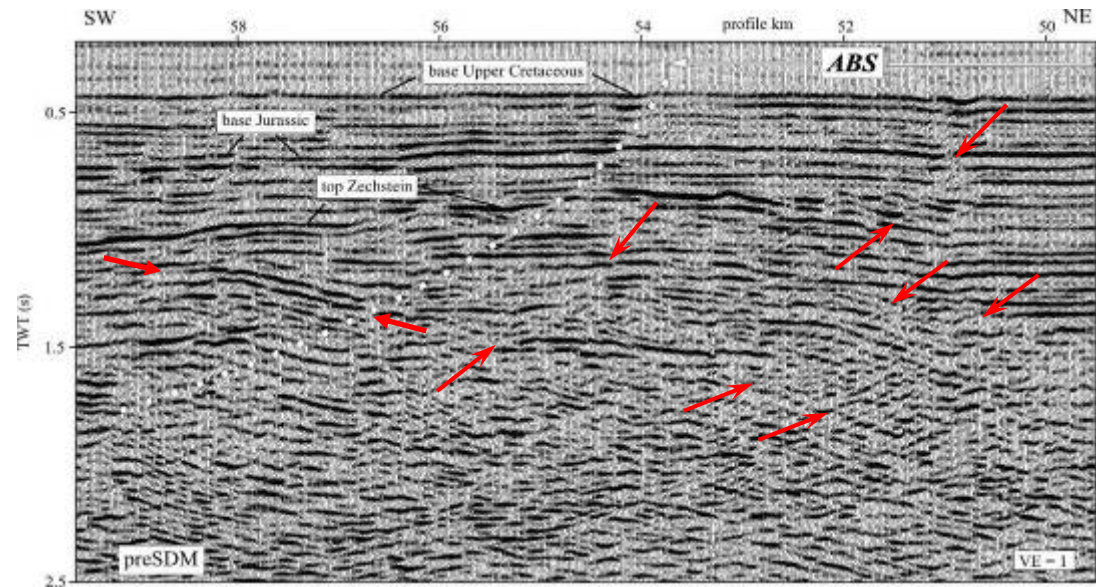
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# Imaging different dips

post-stack  
time migration



pre-stack  
depth migration



# Migration strategies

Geology/Task

monitoring of changes

3-D structures

complex non-hyperbolic moveout

strong lateral velocity variation

3-D behaviour of faults

and salt flats

conflicting

dip angles

Requirement

time-lapse algorithms

3-D migration

*migration*

*depth migration*

3-D pst-migration

*prestack migration*

*time migration*

**time and money**

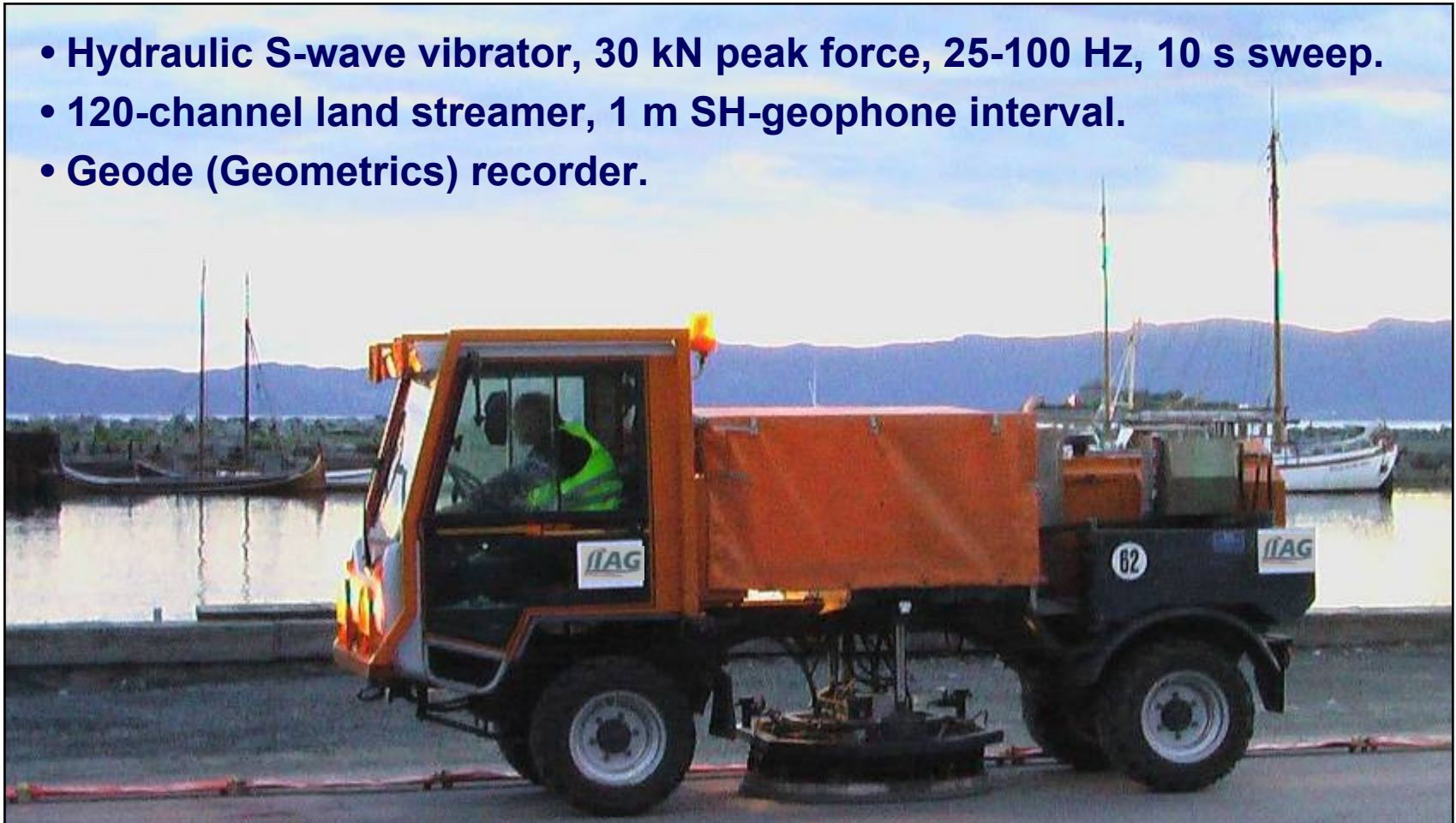
# Investigate structure and soil stiffness

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# Seismic survey: structure + physical properties

- Hydraulic S-wave vibrator, 30 kN peak force, 25-100 Hz, 10 s sweep.
- 120-channel land streamer, 1 m SH-geophone interval.
- Geode (Geometrics) recorder.



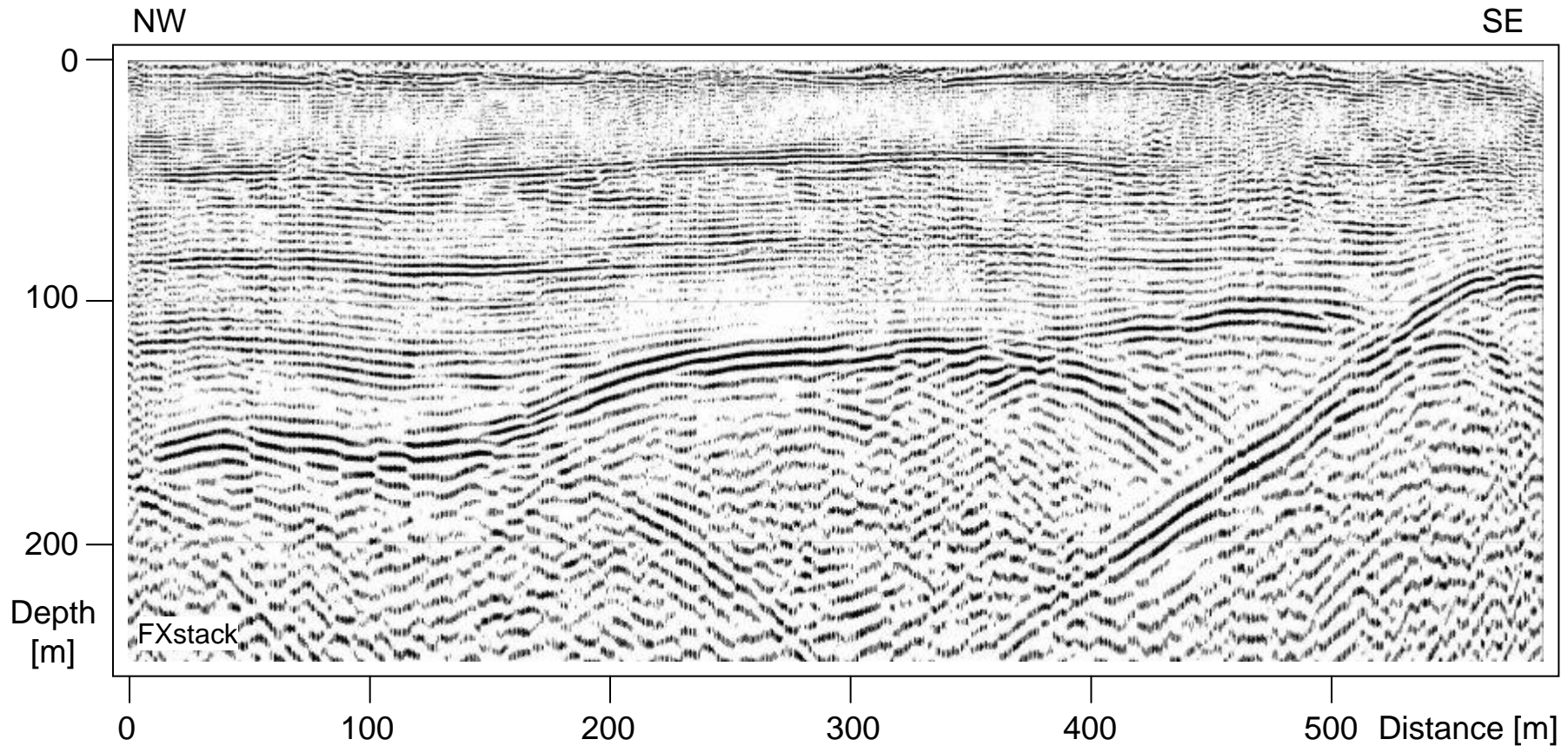
Brattøra stengt  
19 juni-2 juli  
mellom kl. 00 og 05

sponsored by



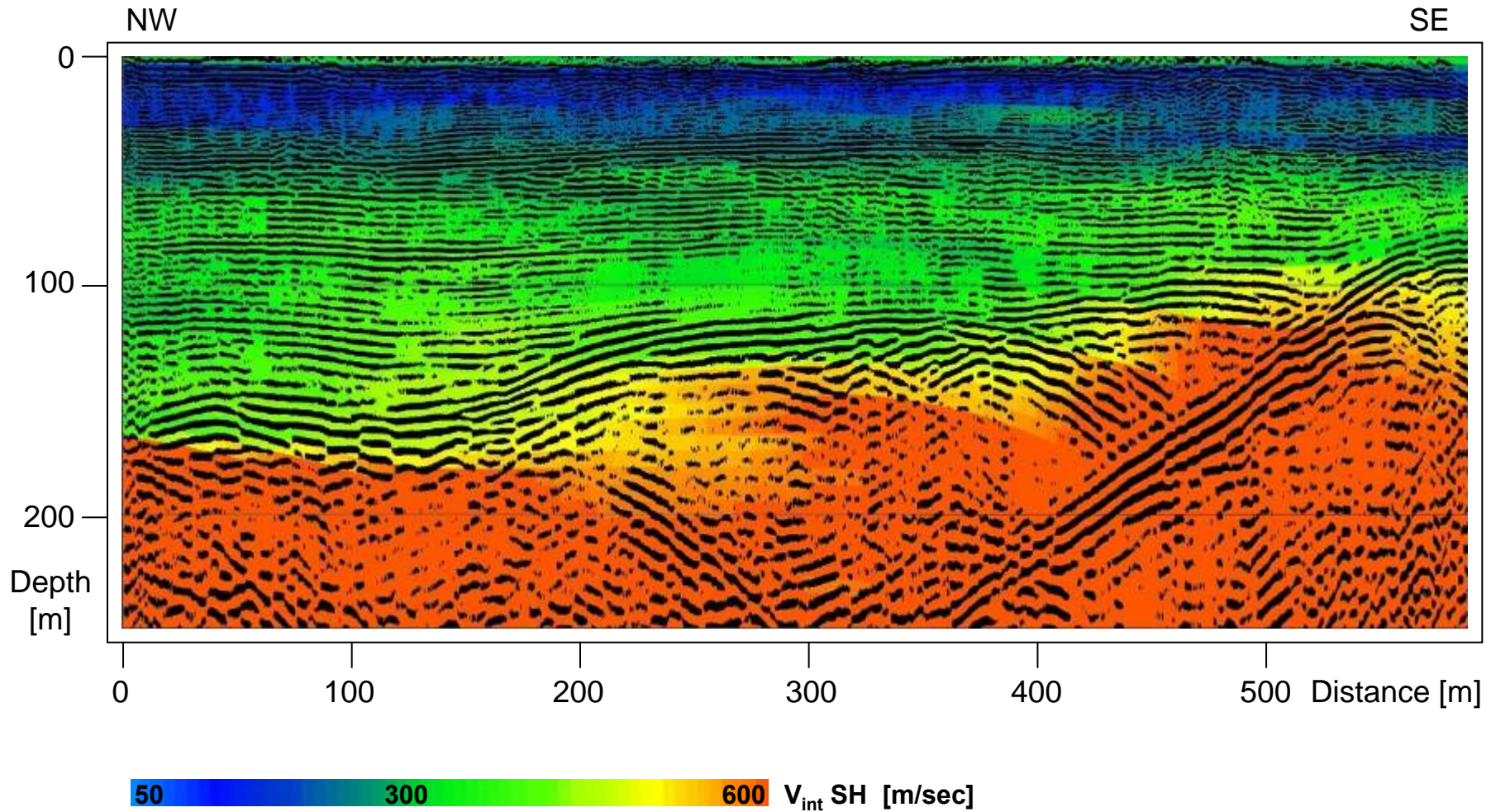
Statoil

# SH-wave reflection seismic section

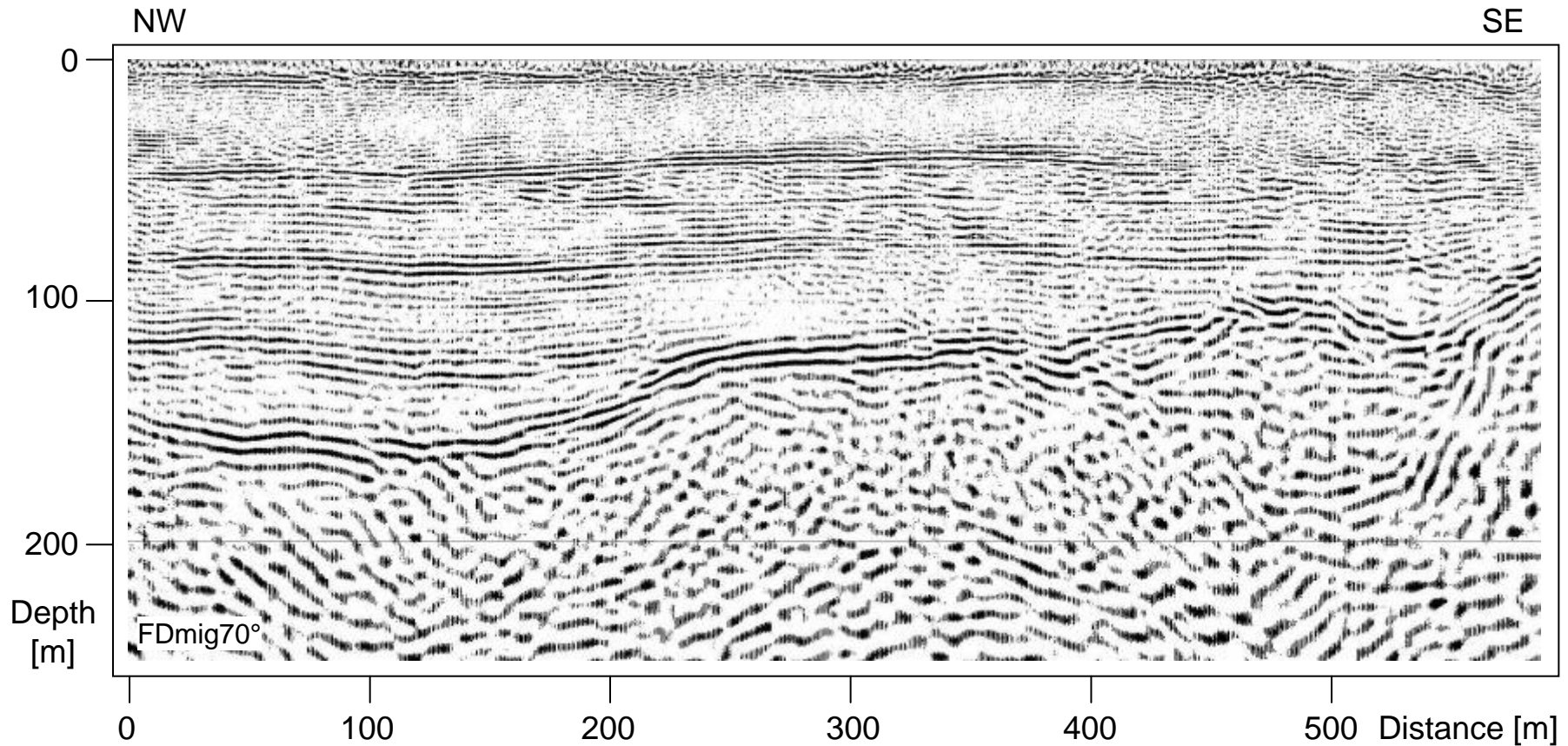




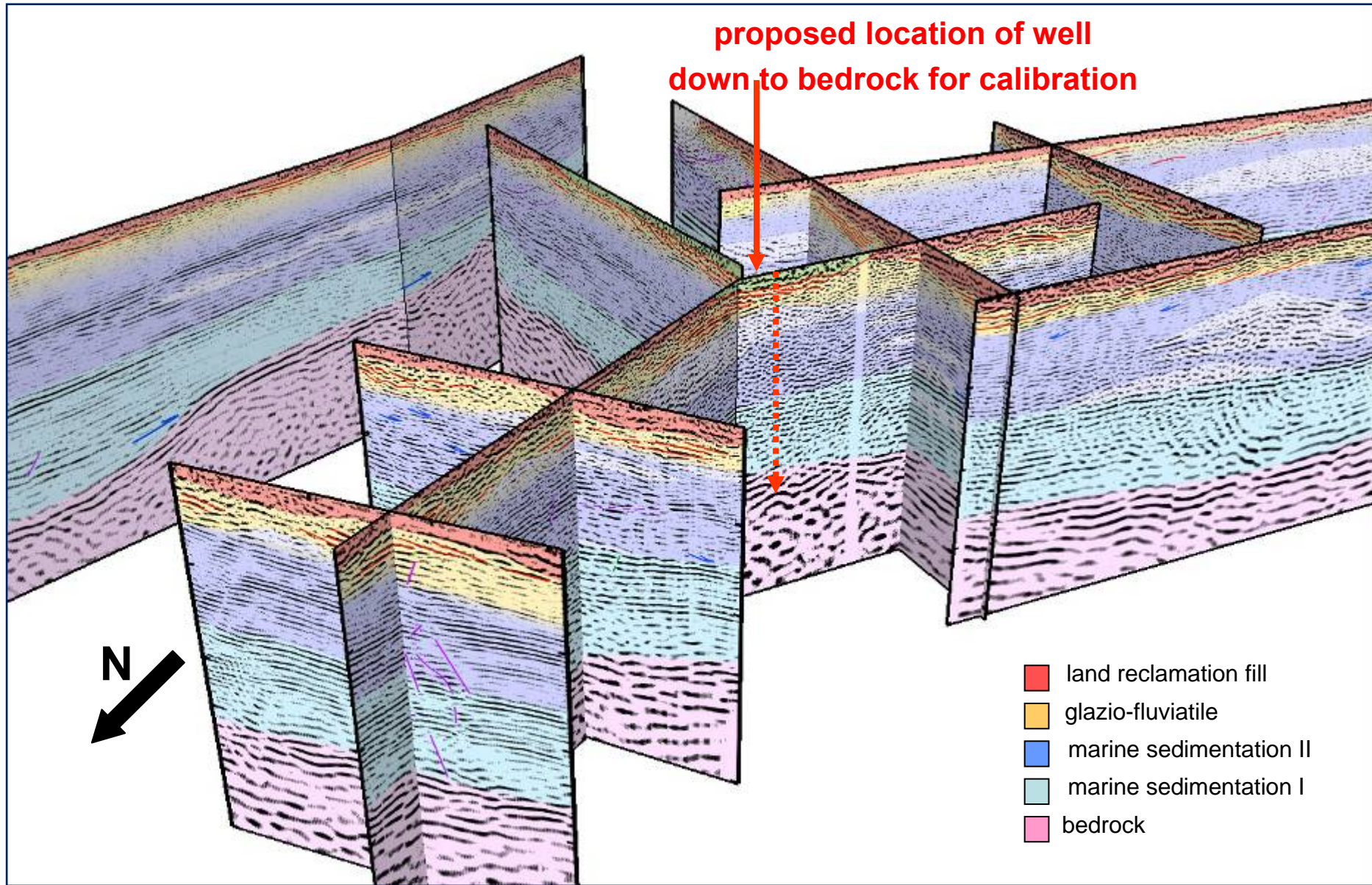
# SH-wave velocity structure



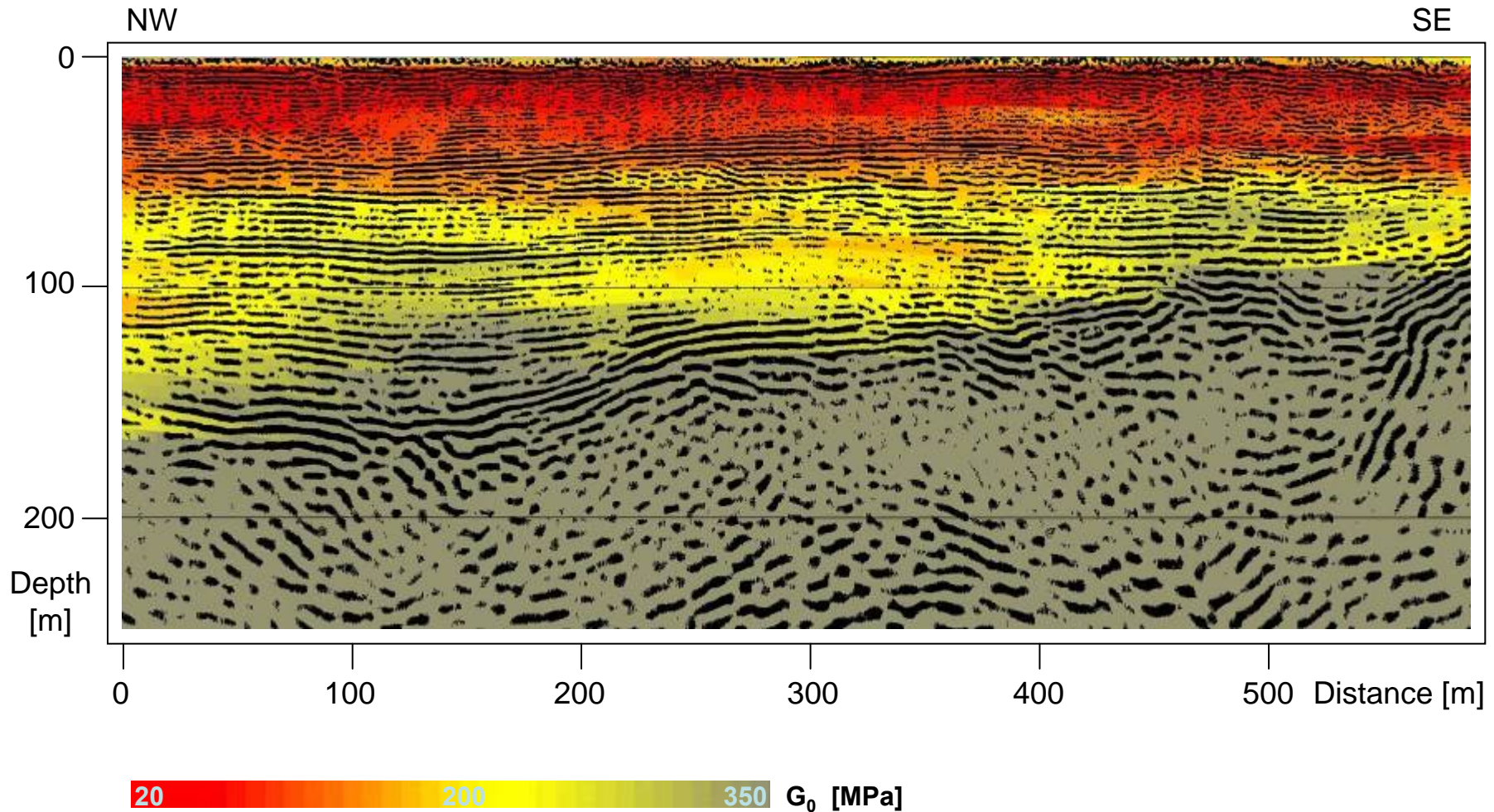
# SH-wave reflection seismic depth section



# Interpretation of sediments and fill masses



# Geotechnical parameter: dynamic shear modulus





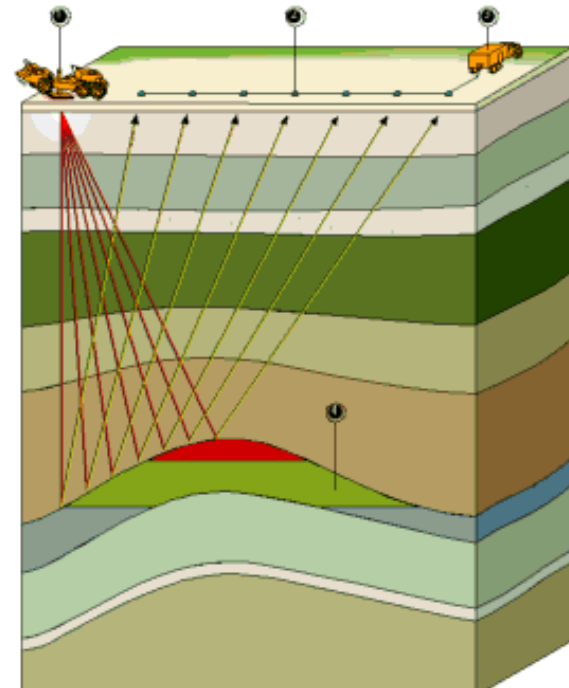
# Outline

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## Introduction

- *Acquisition*
- *Processing*
- *Interpretation*
- *Modelling*

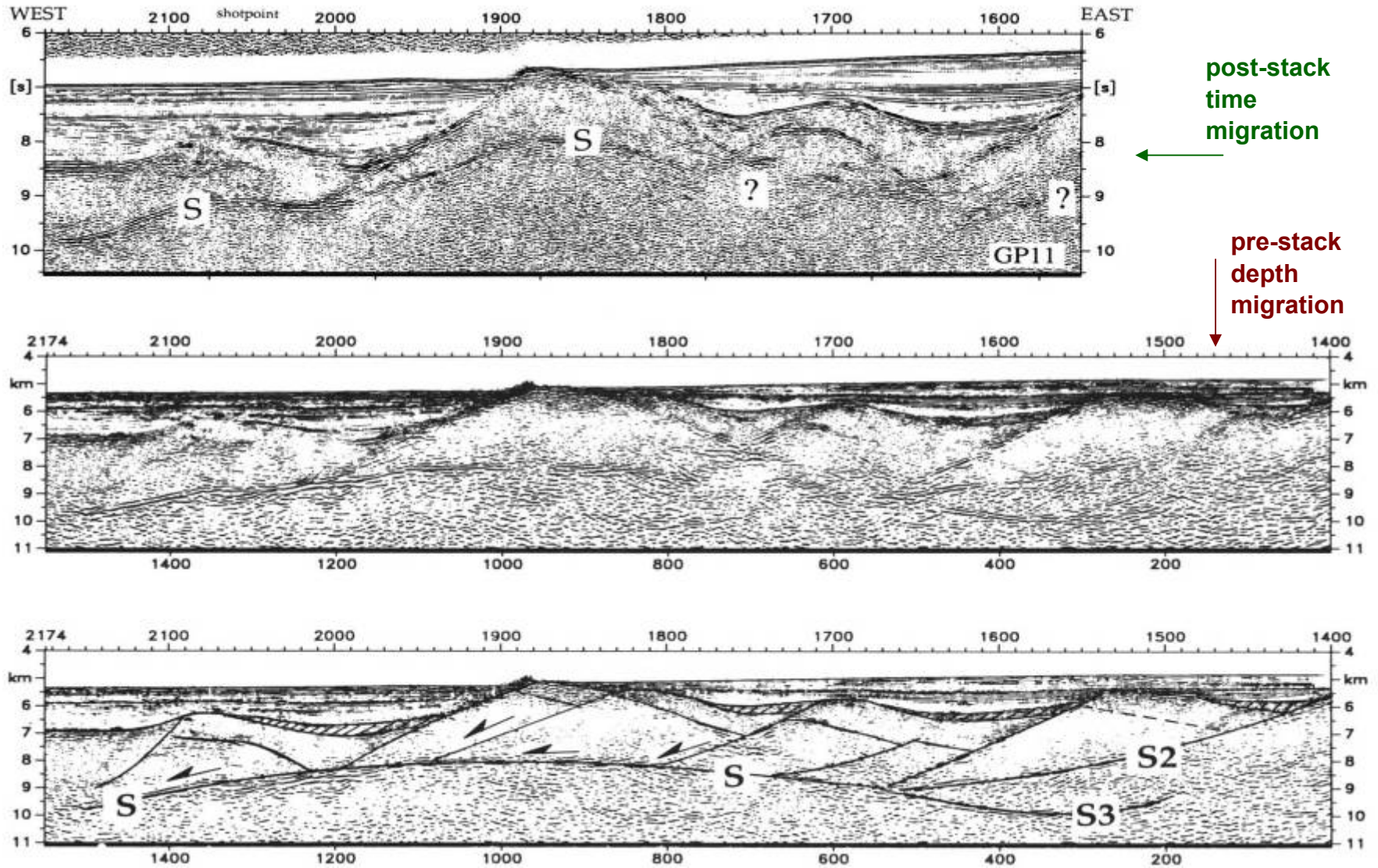
## Summary



# Geological structure - domino faulting



# Seismic structure - detachment tectonics

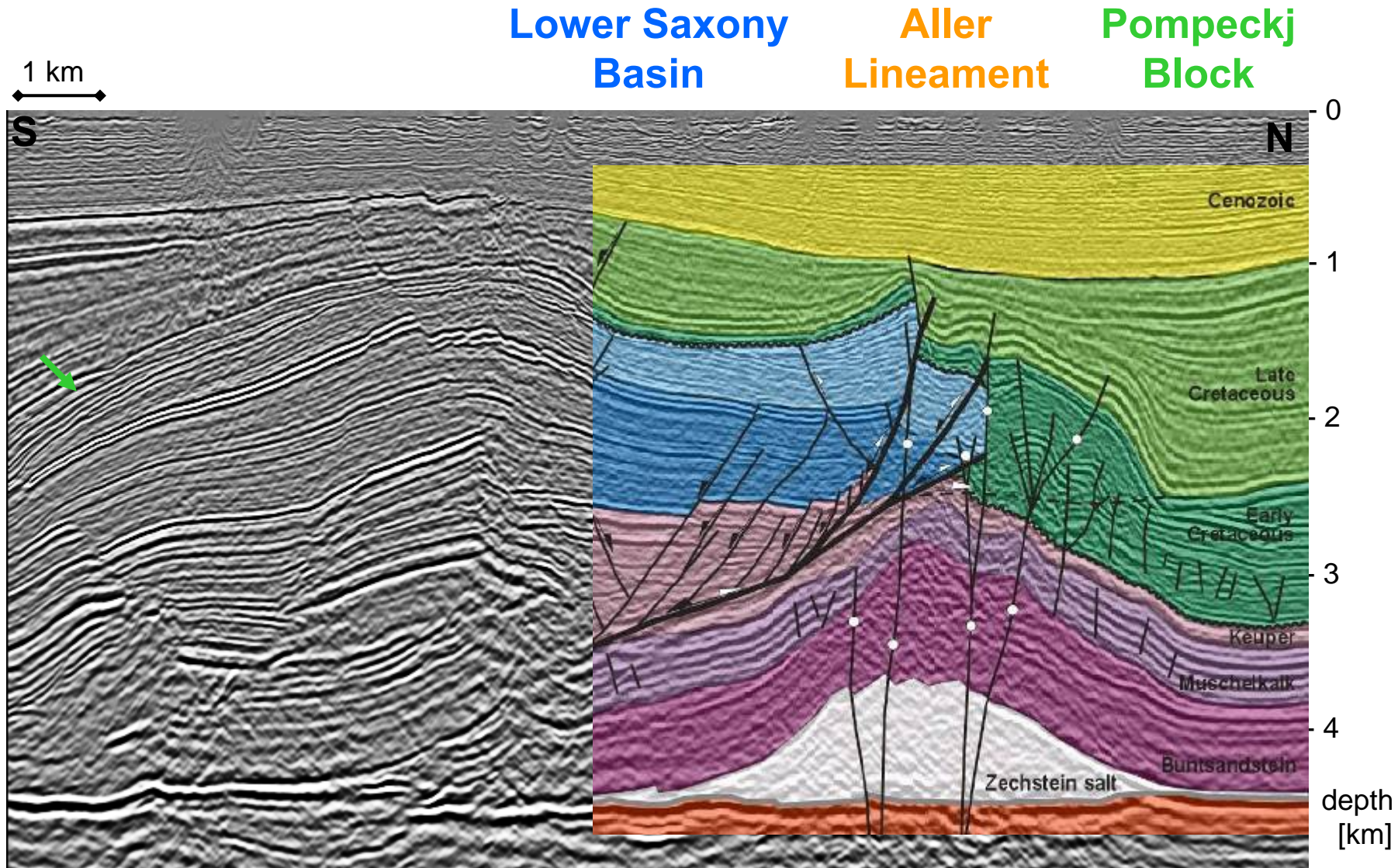




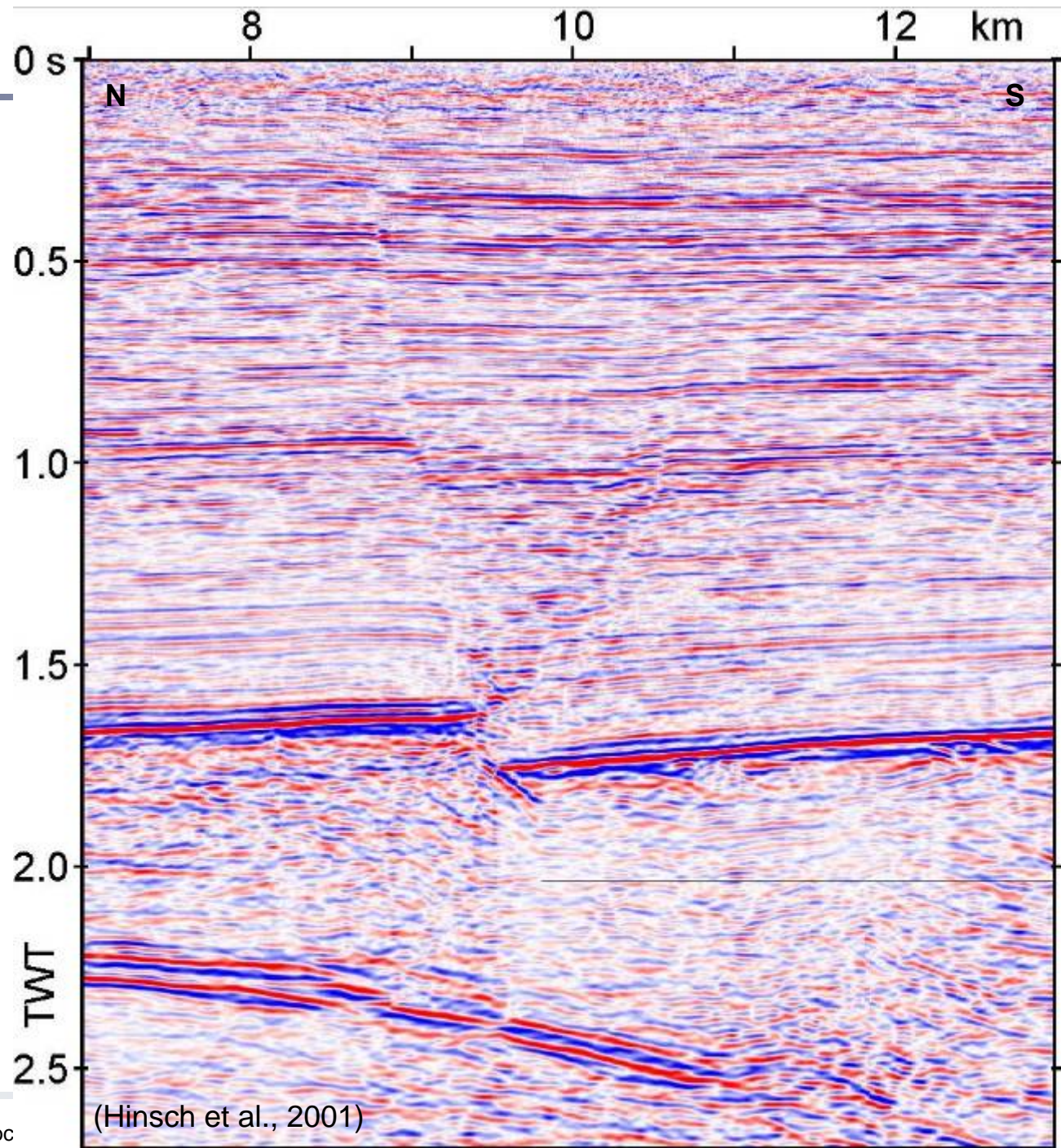
# Seismic interpretation is pattern recognition

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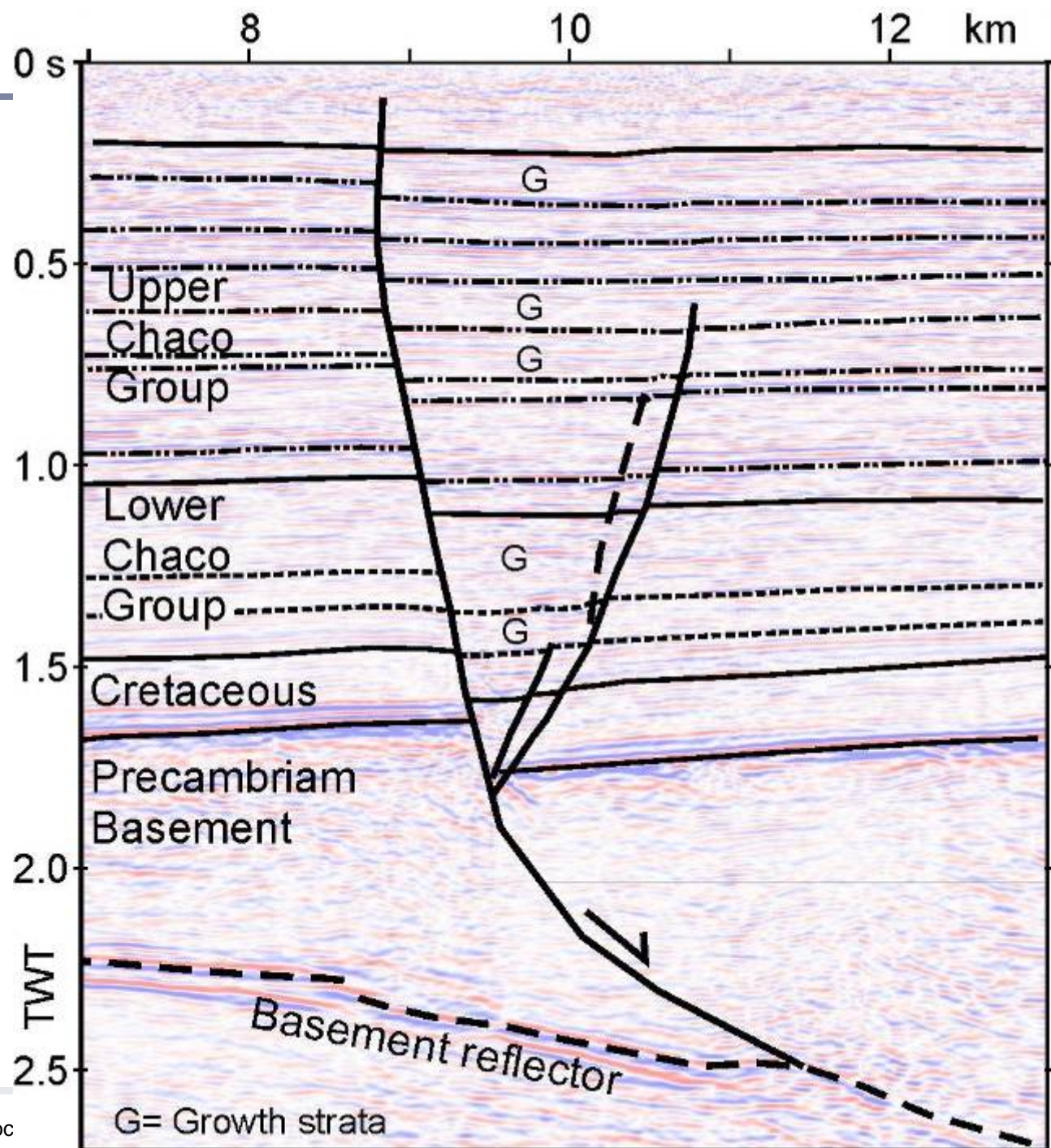
# Seismic interpretation of a fault system



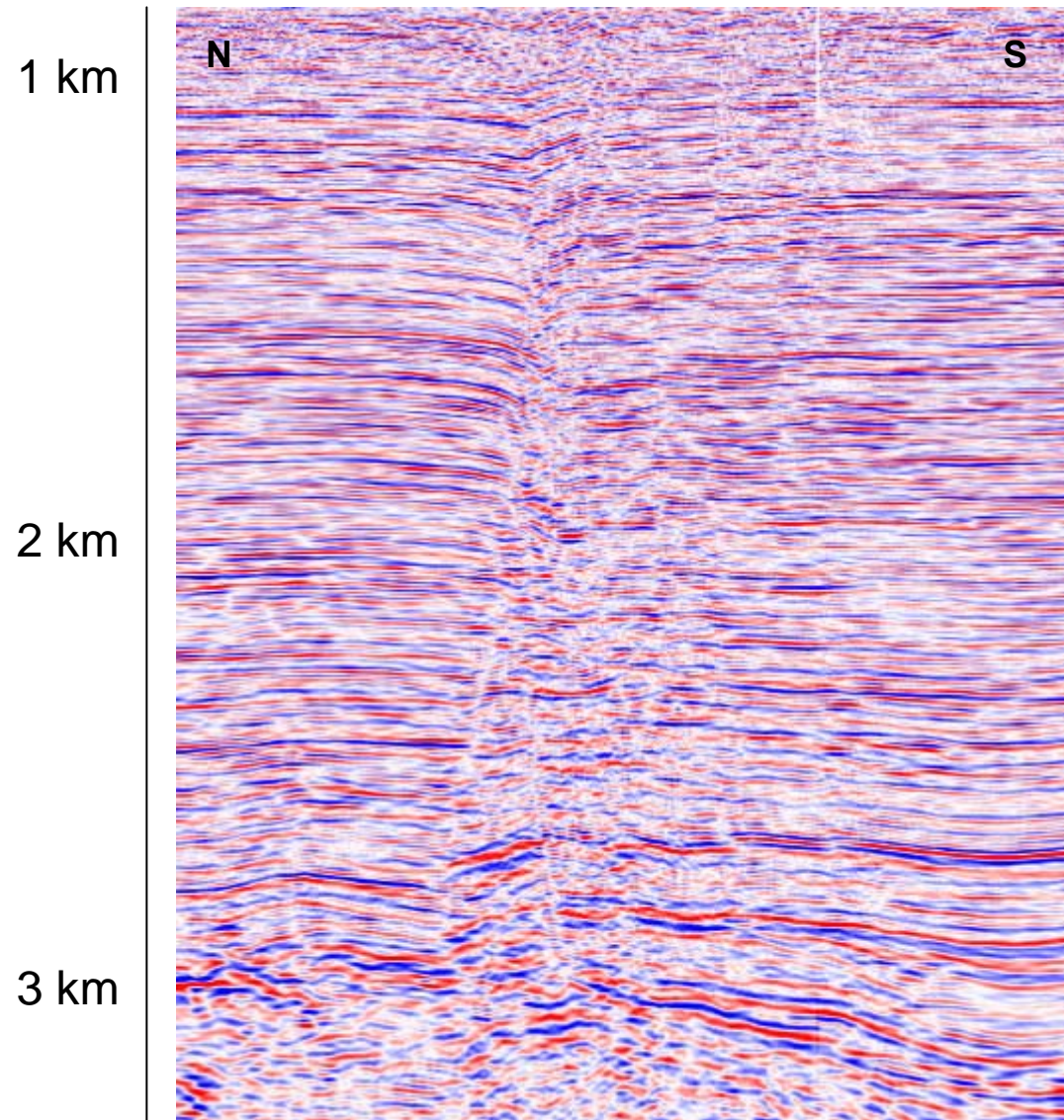
# Fault type ?



# Normal fault



# Any idea here ?



# 3-D: Horizontal slices show fault extent

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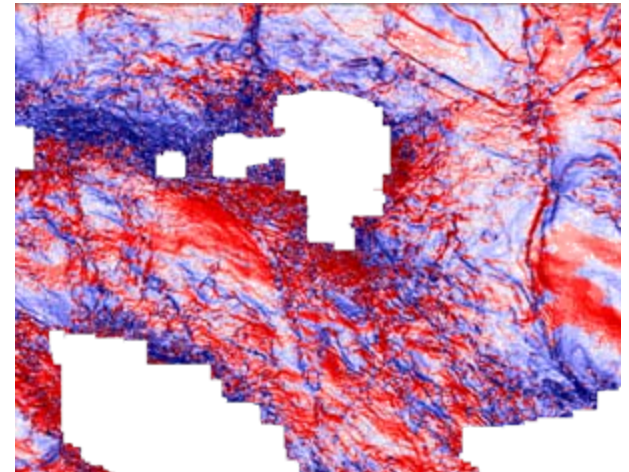
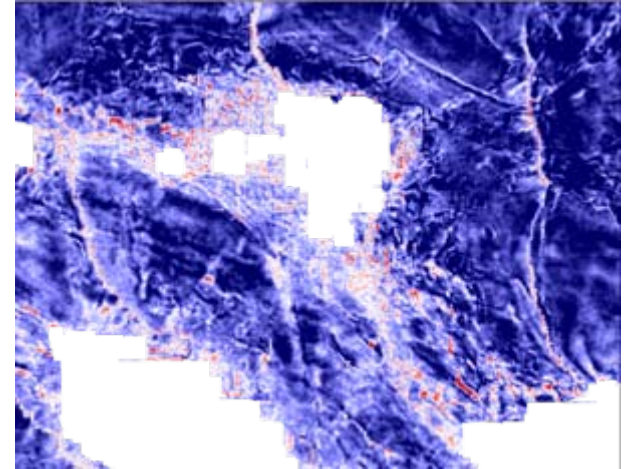
# Seismic attribute analysis

**A seismic attribute is:**

**any measure of seismic data  
that helps better visualize or  
quantify features of interest,**

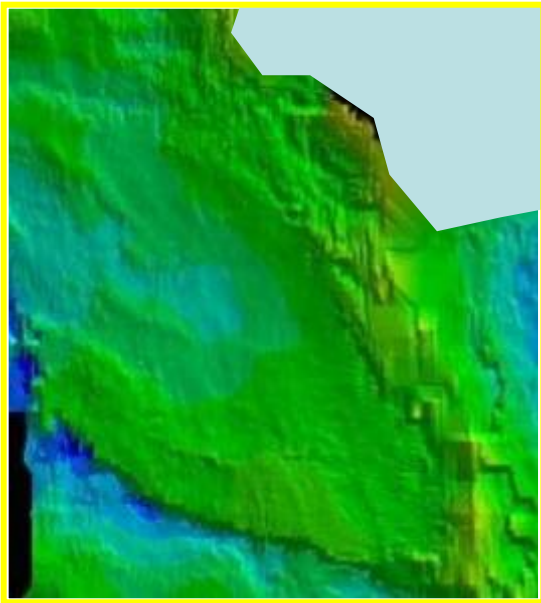
**a specific measure of geometric,  
kinematic, dynamic or statistical  
features in seismic data.**

**These have a physical as well as  
a statistical basis !**

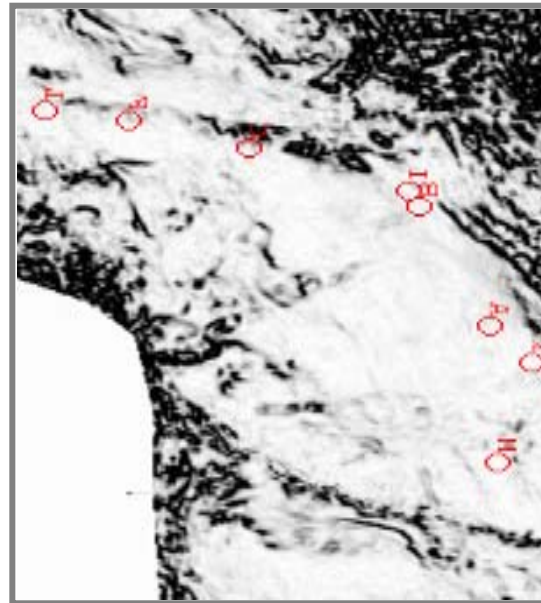


# Advanced coherency processing

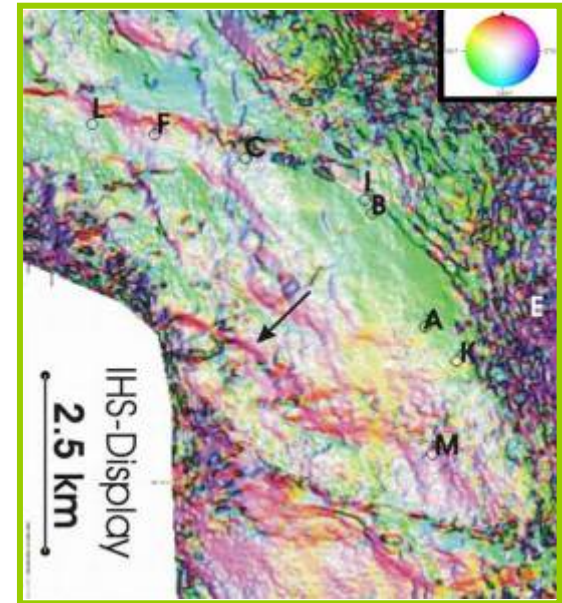
horizon map



regular coherency



new coherency





# Spectral decomposition of a seismic volume

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# Amplitudes in the 35 Hz cube vary with depth

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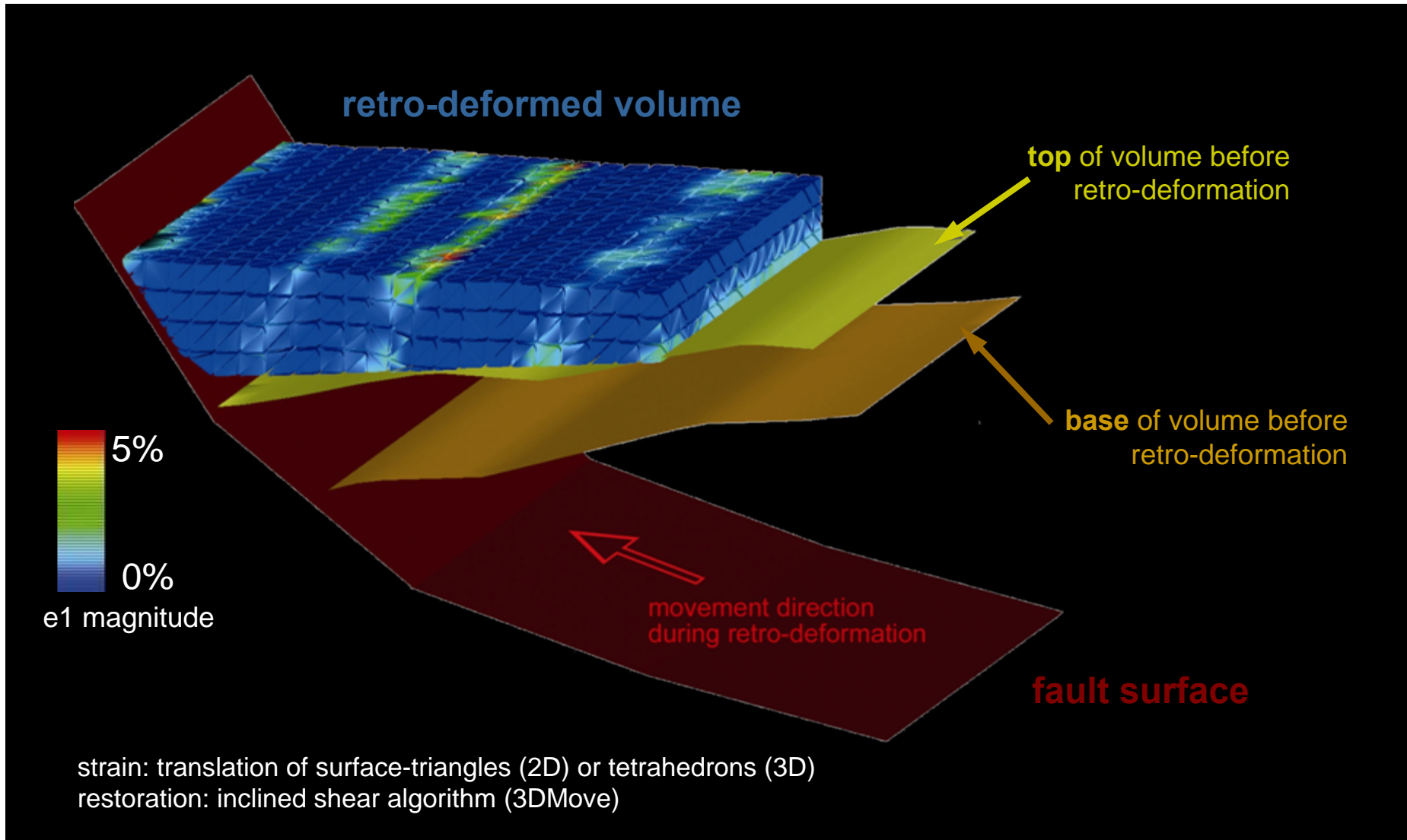
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# Amplitude image vs variance cube

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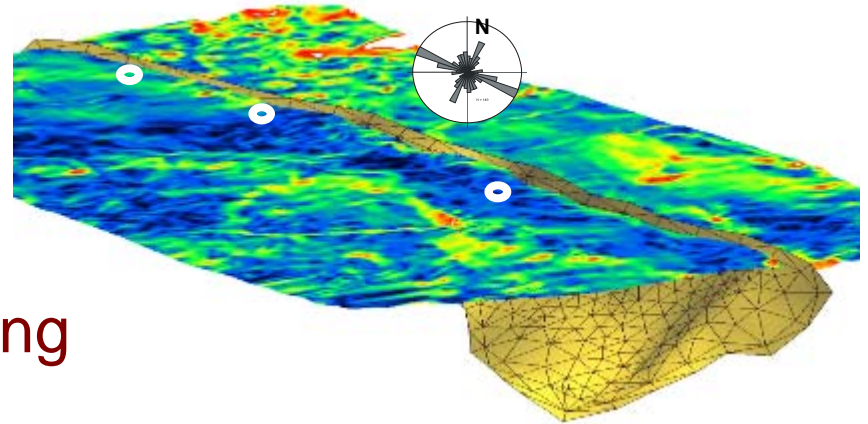
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# Strain prediction by 3-D retro-deformation

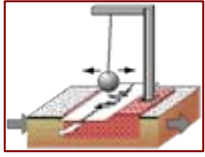


# Requirements for data interpretation and modelling

- visualization tools
- meshing and parallel computing
- interpolation and gridding methods
- 3-D algorithms with laterally and vertically variable properties

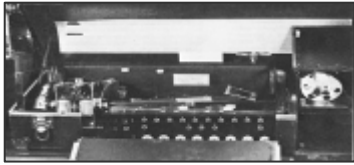


# Summary - Milestones in seismic progression

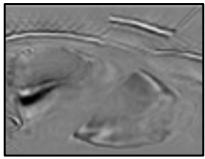


**1960s** from analog to digital

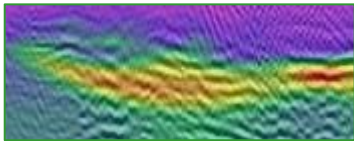
**1970s** from calculators to computers



**1980s** from 2-D to 3-D



**1990s** from time to depth



**2000s** from 3-D to 4-D (p-waves and time)

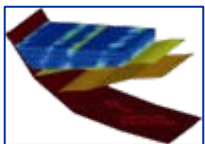
from 4-D to 4-C (p-waves and s-waves)



**2010+** from isotropy to anisotropy

from physical to geotechnical property

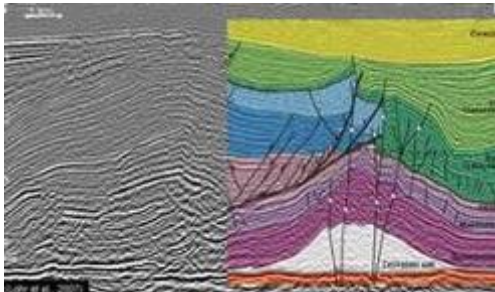
from structure to deformation prediction



**Thank you for your attention !**

# Section Seismics ~ Gravimetry ~ Magnetics at LIAG

**Structural analysis & deformation modelling**



**Geohazards**



**Seismic sources & acquisition techniques**



**Gravimetry & Magnetics**

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