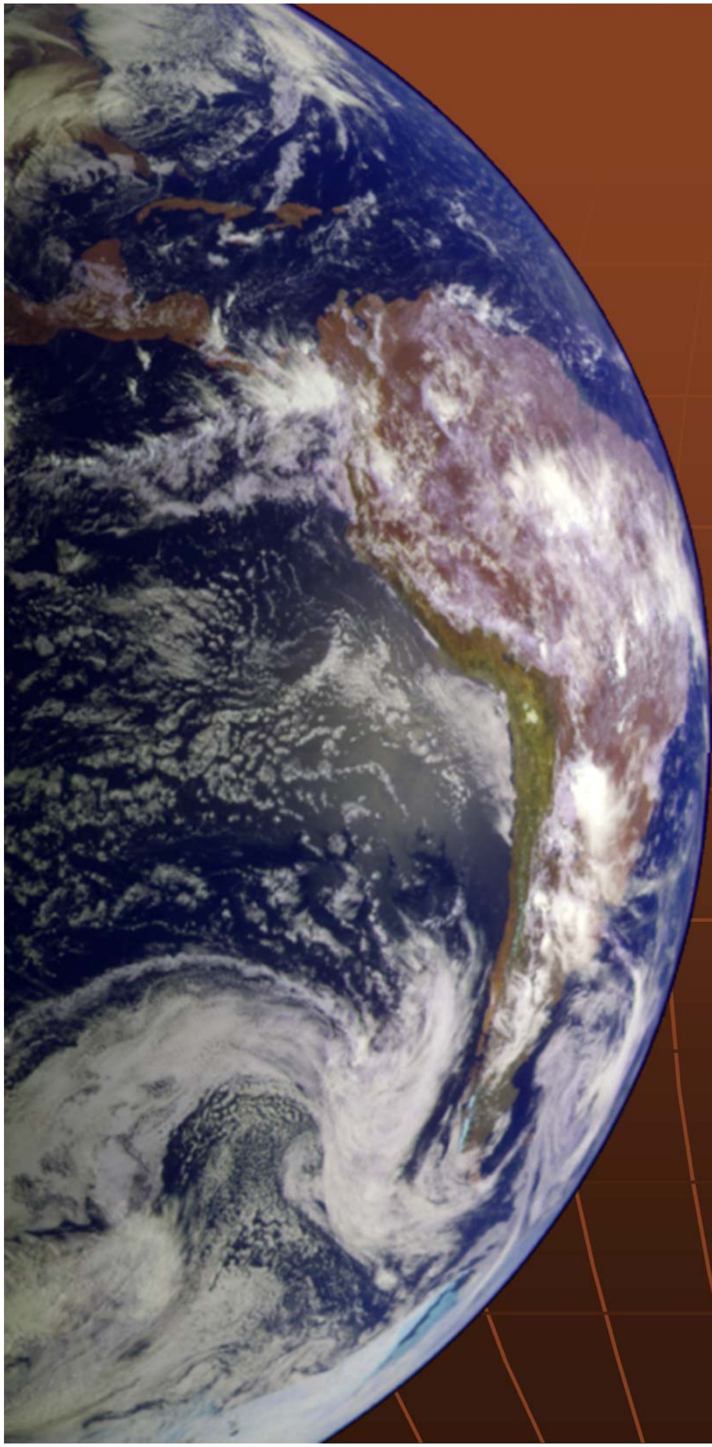


UT-AUSTIN EDGER FORUM

Inversion for Splay Fault Interpretation in the Nankai Trough, Japan

PhD Student: Yi Tao

Advisor: Mrinal Sen

THE UNIVERSITY OF TEXAS AT AUSTIN

JACKSON

SCHOOL OF GEOSCIENCES

Objective

- Use seismic inversion to combine reflection seismic data and well log data to get elastic and rock properties.
- Seismically active splay faults in subduction zones.

Splay faults and subduction zones

- Splay faults: A series of branches of secondary faults diverge from a major fault which spread the displacement over a large area.

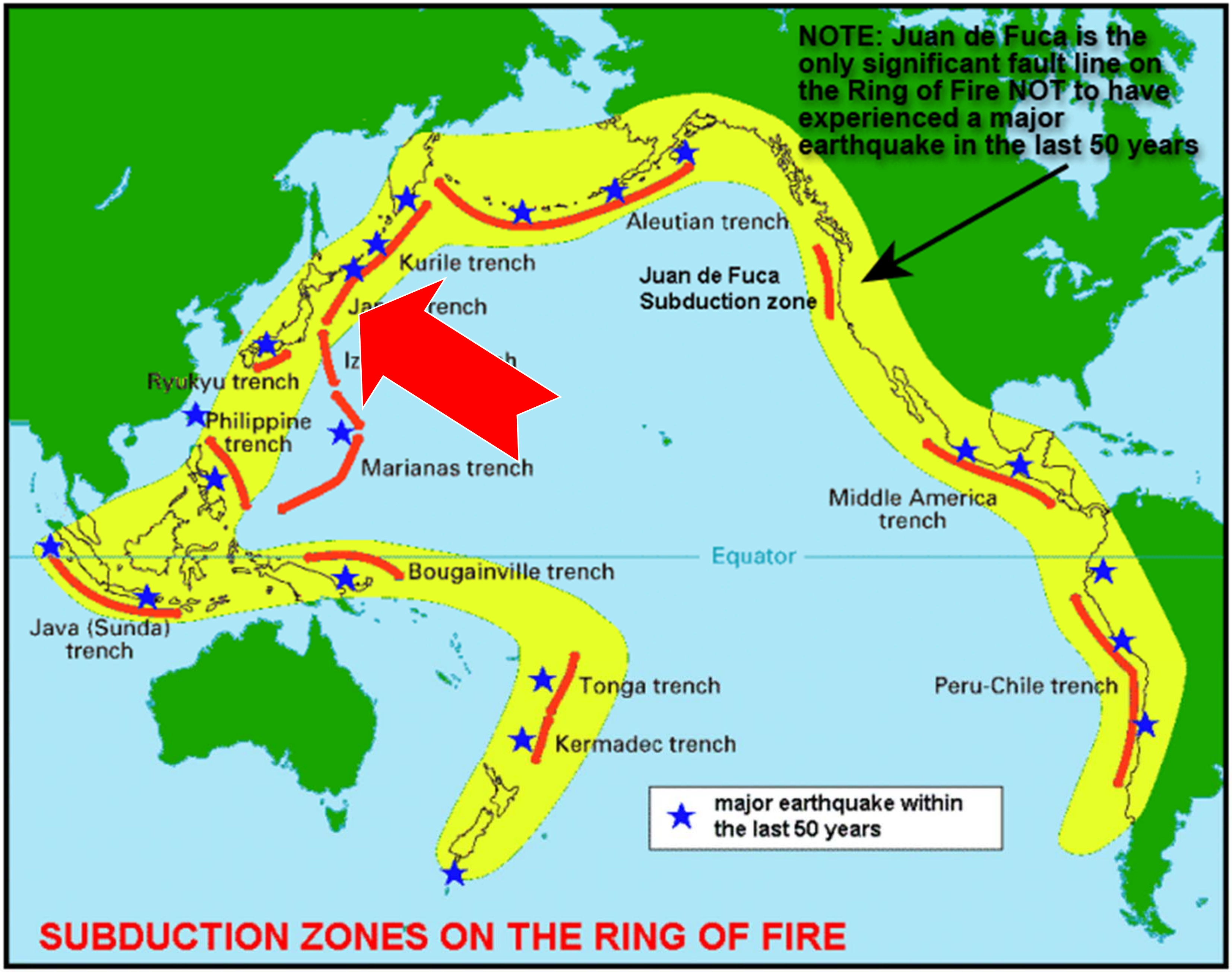
- Splay faults are commonly observed in subduction zones, where great earthquakes (Mw>8) and tsunamis are generated. (e.g. 2004 Sumatra earthquake)

How subduction zone earthquakes generated

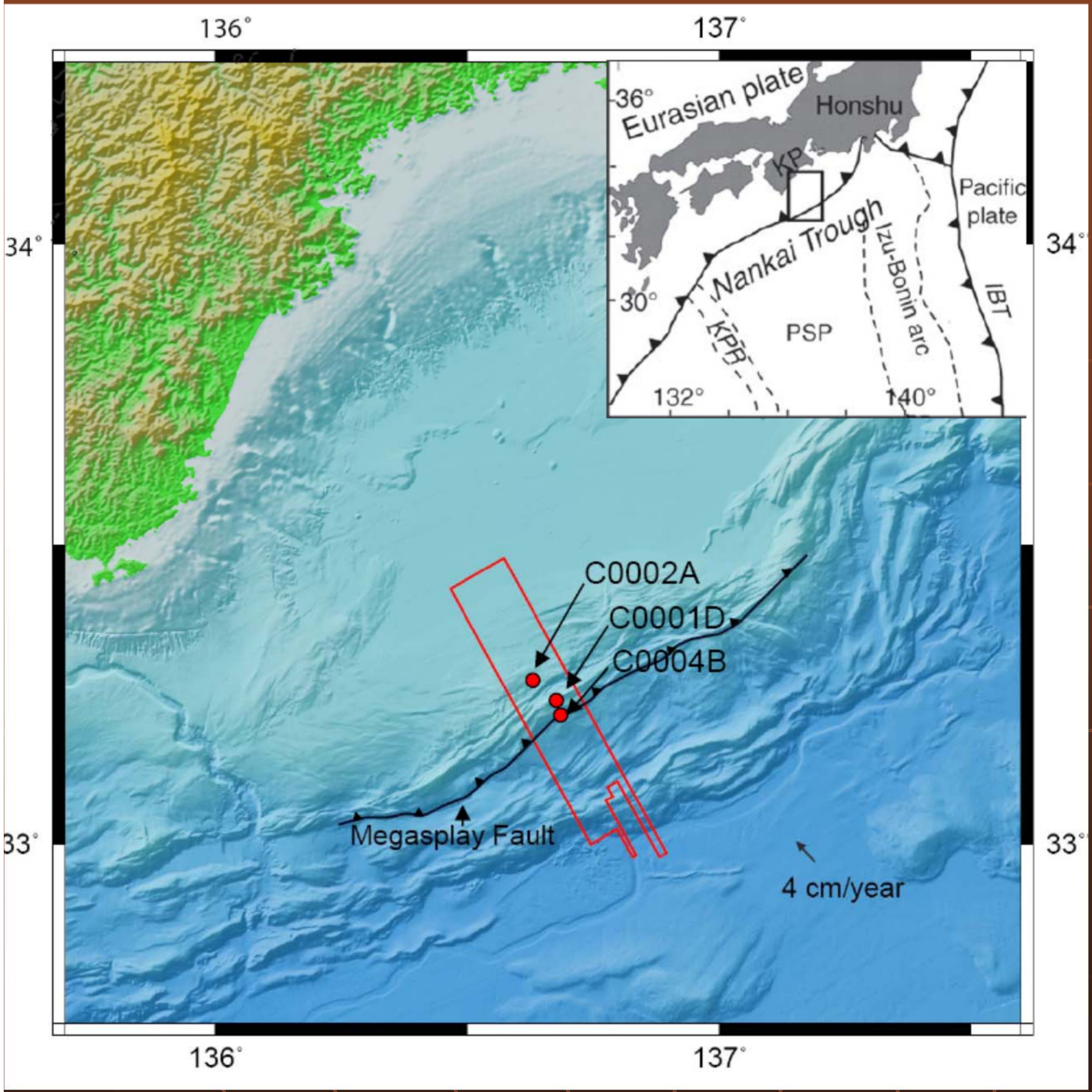
- Major earthquakes along subduction zones are usually generated when a large area of the mega thrust ruptures.

- Co-seismic deformations are propagated along splay faults, generate small earthquakes and tsunamis.

- Splay faults also accommodate a large portion of plate convergence stresses at a larger geological time scale.


NOTE: Juan de Fuca is the only significant fault line on the Ring of Fire NOT to have experienced a major earthquake in the last 50 years
Aleutian trench
Kurile trench
Juan de Fuca Subduction zone
Ryukyu trench
Philippine trench
Marianas trench
Middle America trench
Equator
Bougainville trench
Java (Sunda) trench
Tonga trench
Kermadec trench
Peru-Chile trench
major earthquake within the last 50 years
SUBDUCTION ZONES ON THE RING OF FIRE

Study area—Nankai Trough



- Convergent plate boundary (Philippine sea plate and Eurasian plate)
- Deep sea trench (water depth 2000m-4000m)
- Splay faults
- Gas hydrates

- 3-D reflection seismic data

(12km*56km, shot by PGS at 2006, two airgun source arrays and four towed hydrophone streamers)

- Well log data

(Provided by Integrated Ocean Drilling Program (IODP) Expedition 314, the first stage of Nankai Trough Seismogenic zone Experiment (NanTroSEIZE))

- NanTroSEIZE is a multistage investigation of subduction fault mechanics and seismogenesis.

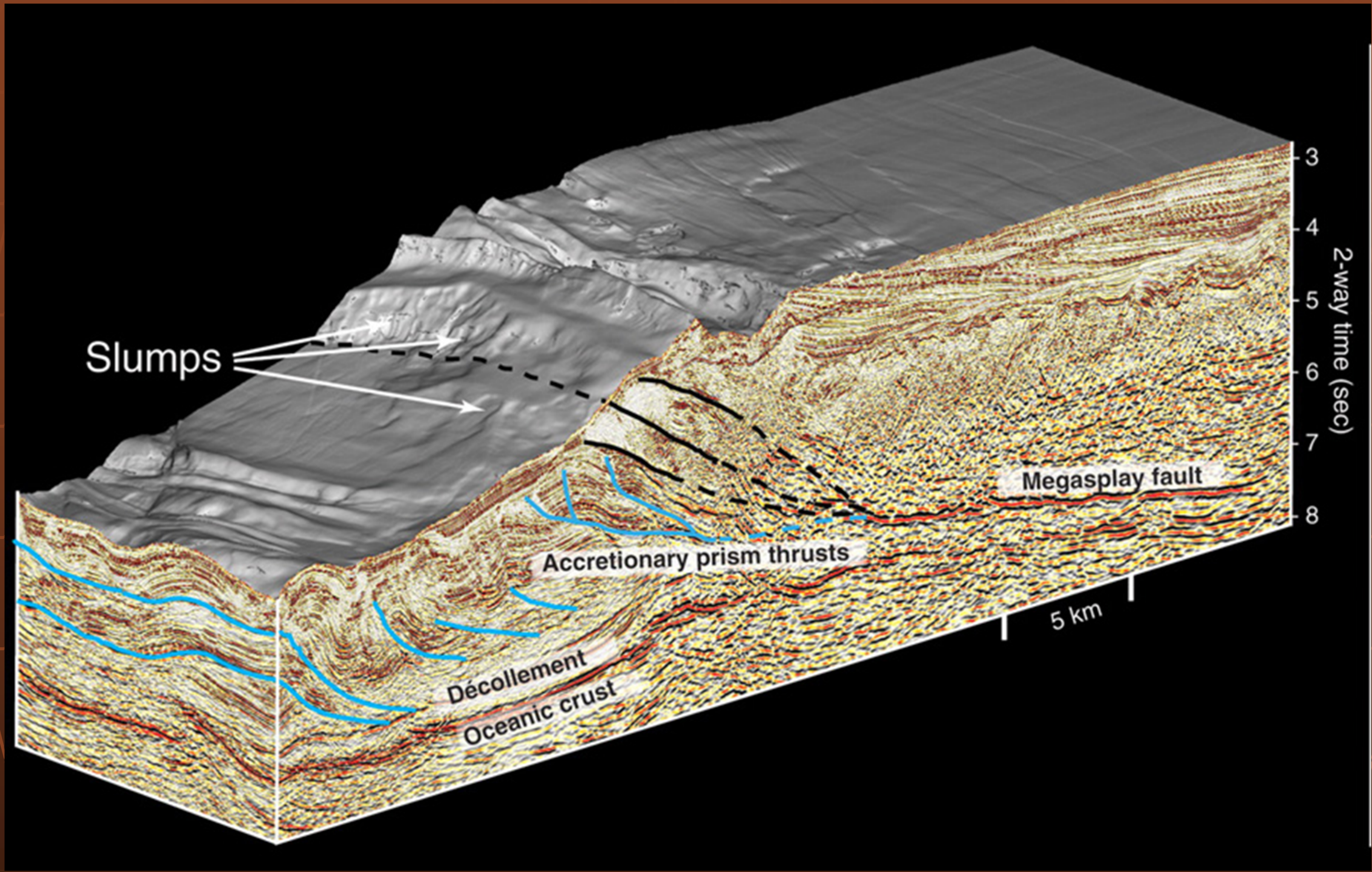
Some problems of the dataset

Seismic data are generally considered of good quality for academic study.

However, shallow splay faults have not imaged clearly because of the complexity of geological structures seismic resolution limit and maybe processing artifacts.

Well log data are not complete at all depths. No shear wave logs, no density log at one well location.

3-D view of the splay faults in Nankai Trough



Bangs et al., 2006

Some results from other studies within this area

- Well logs and core samples:

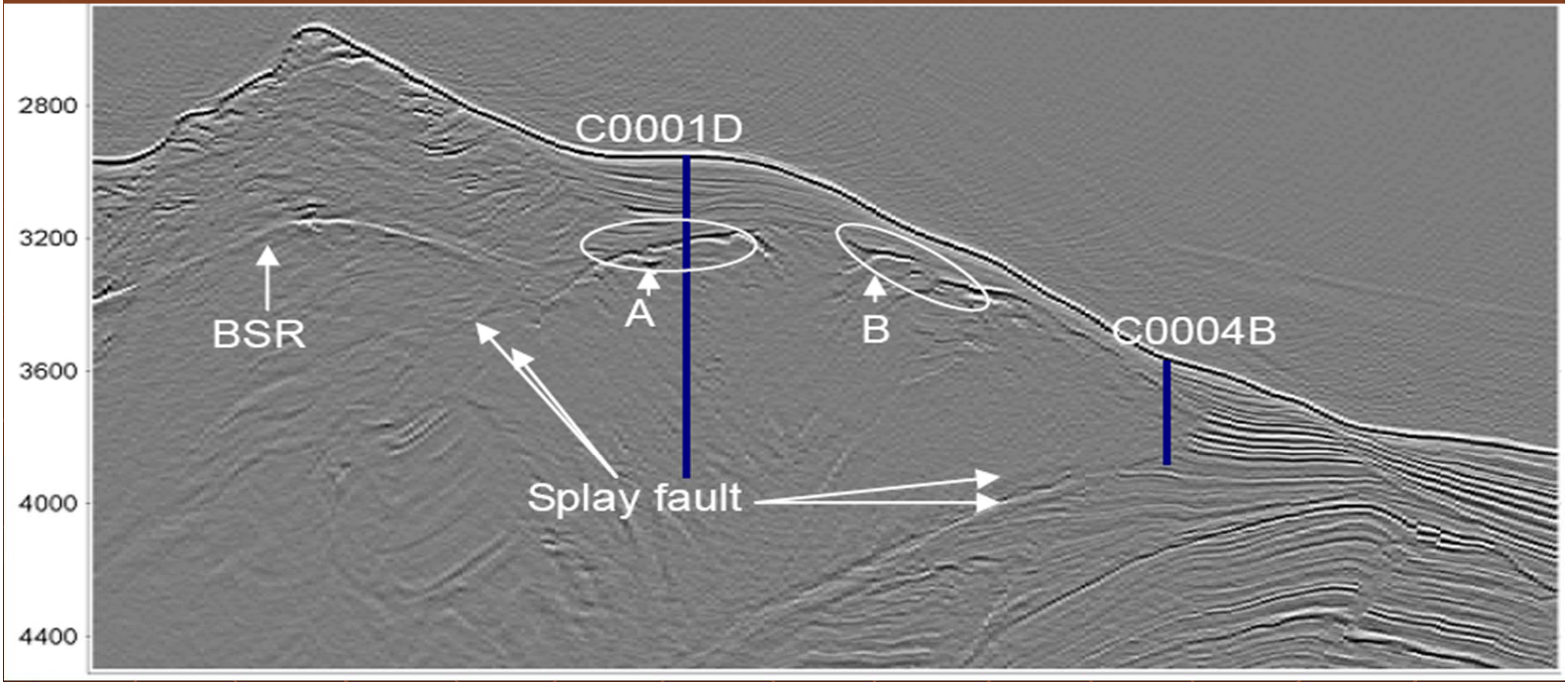
  Age: 0.0Myr-4.0Myr (Kinoshita et al.,2008)

- Stress changes dramatically between the inner and outer wedge.

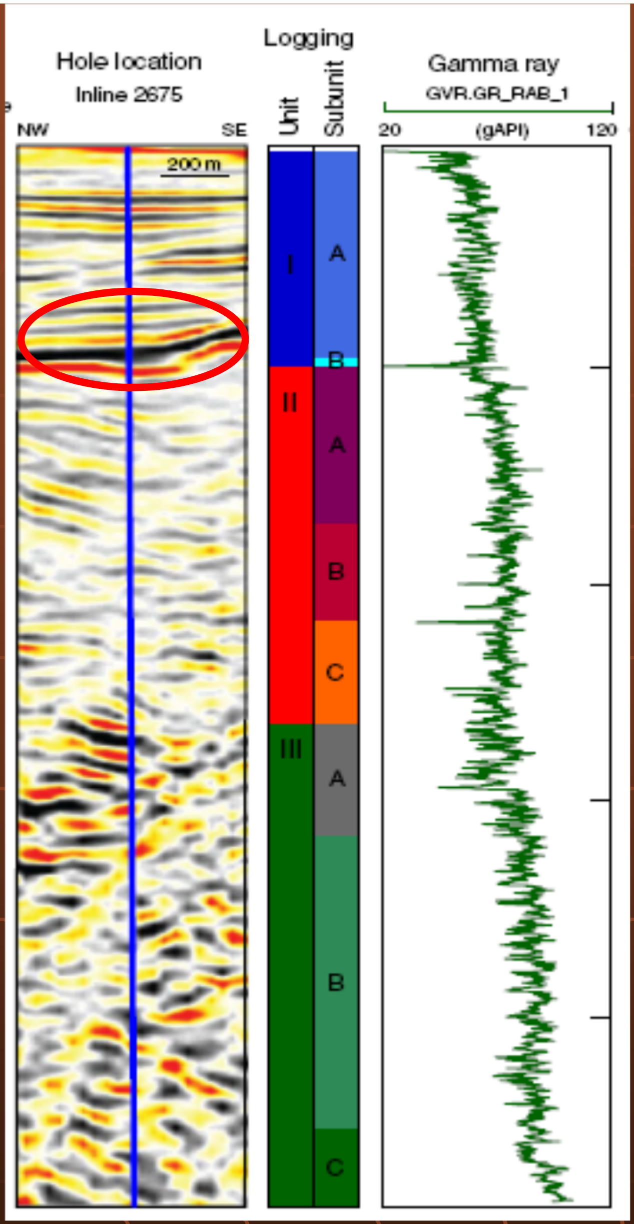
  (Ito and Obara, 2005)

- Structural interpretations and infers for seismogeneseis.
  (Moore et al., 2007, Park et al., 2010)

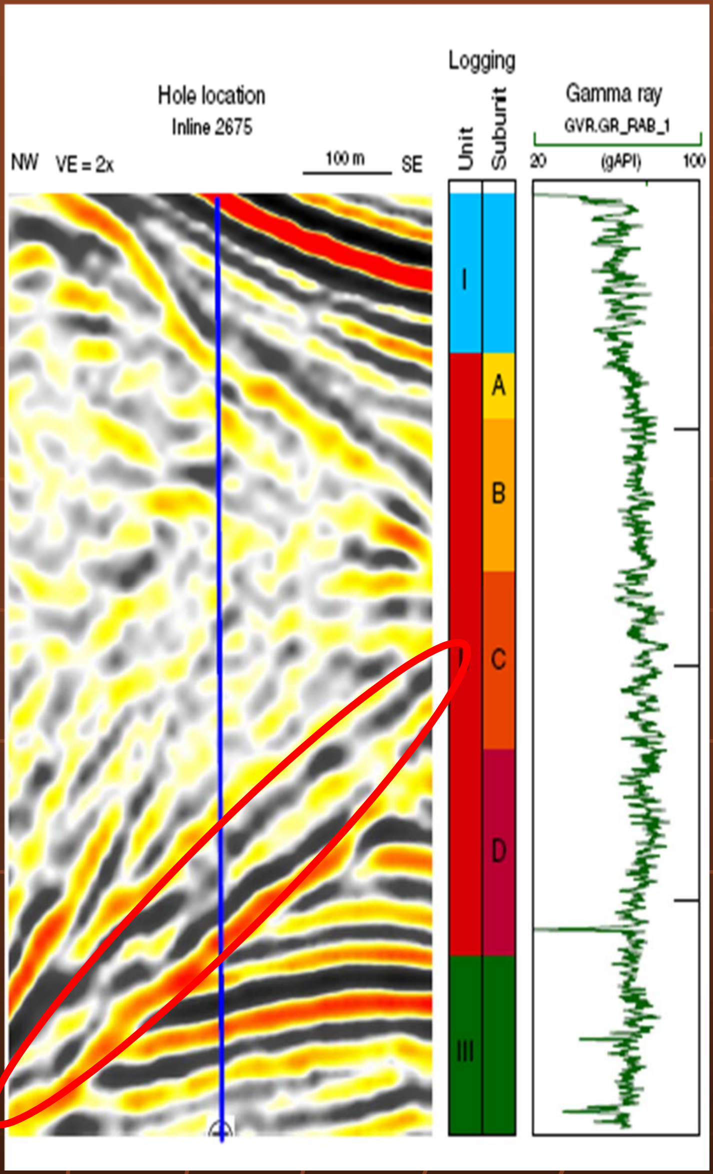
Interpretation of one strong reflector cutting through the drill site C0001 based on the seismic image is ambiguous.



Prestack time migrated section of inline 2681

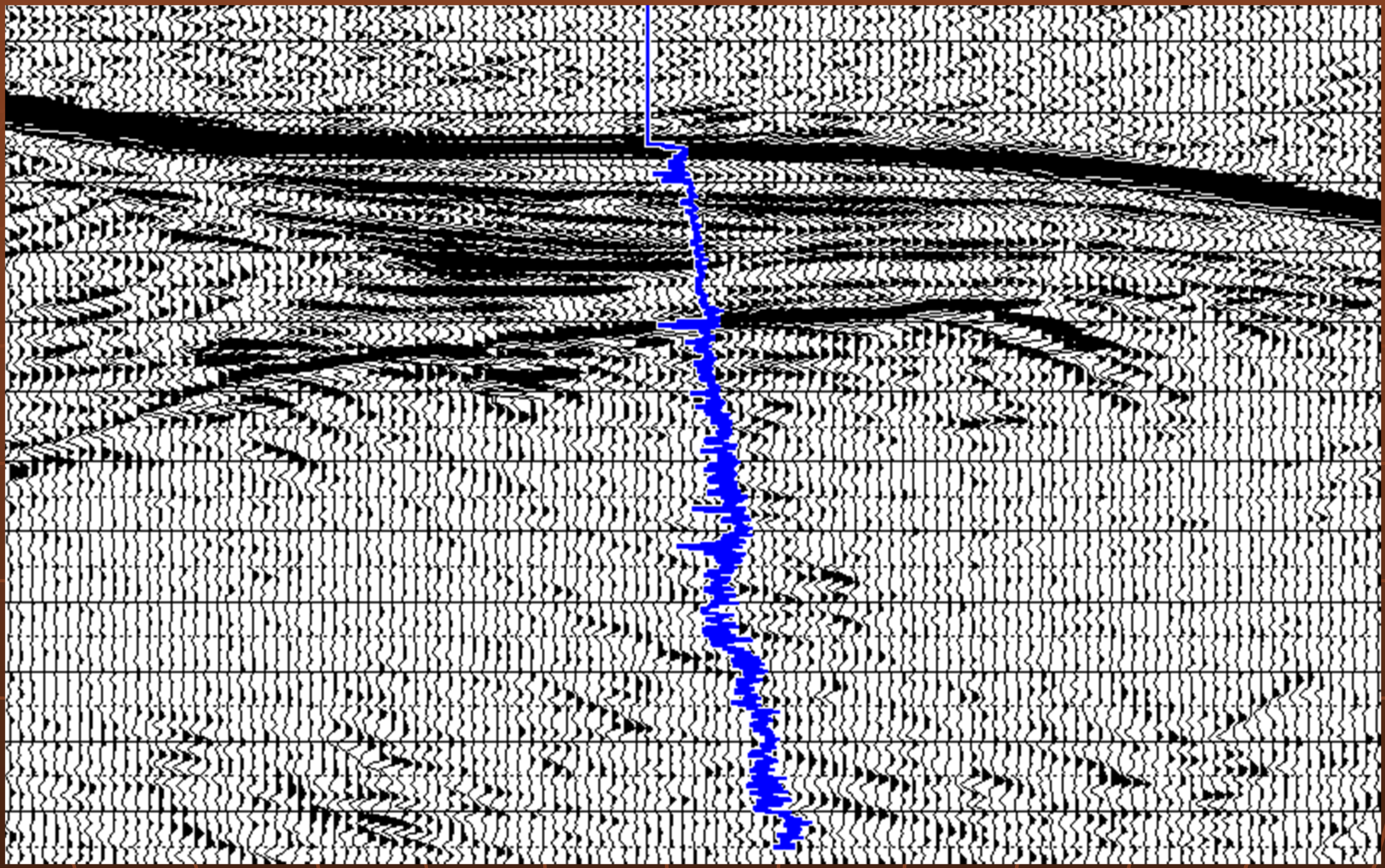


C0001D

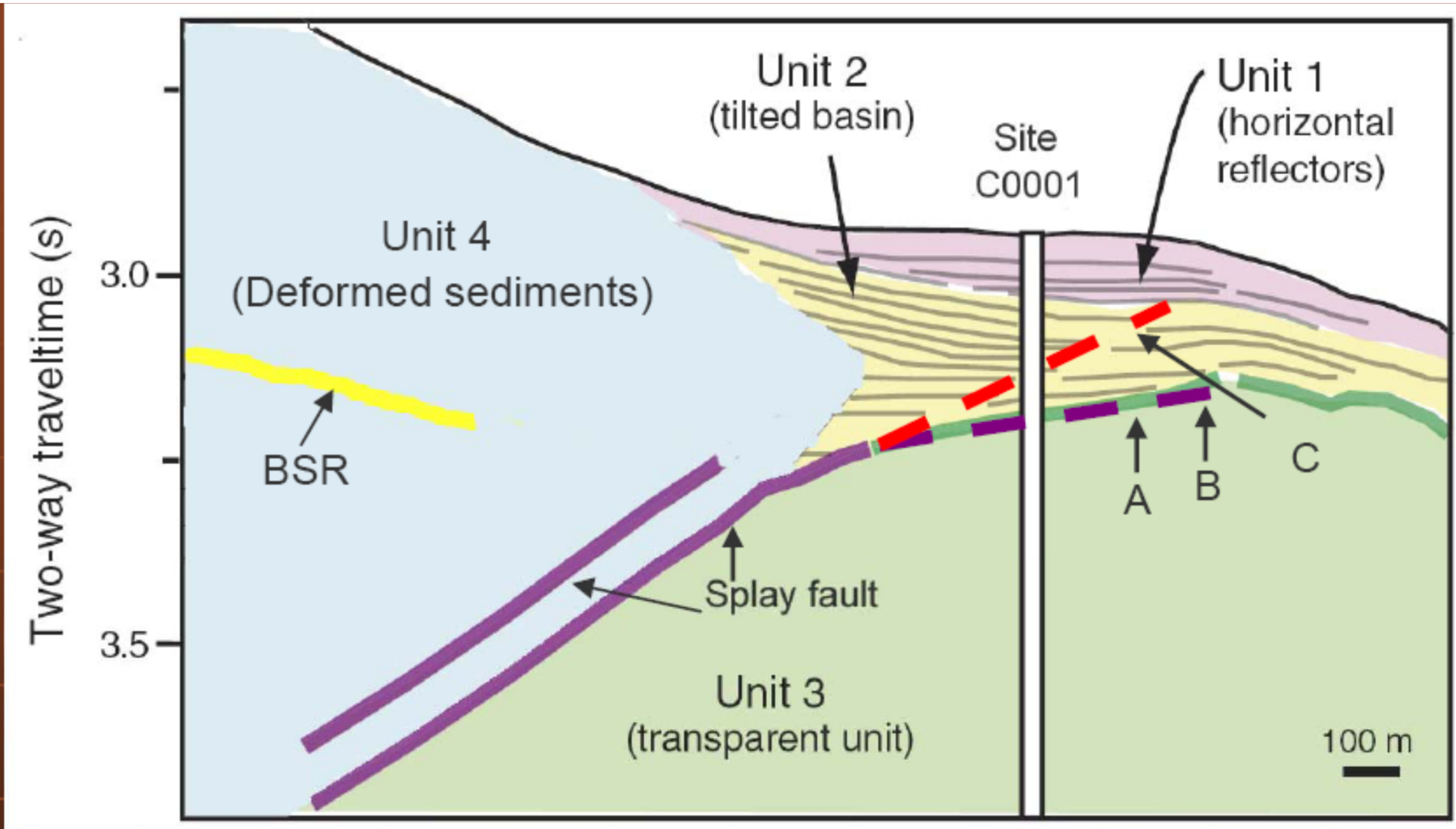


C0004B

From IODP Leg 314 report



Before the strong reflector, seismic data and well logs generally match very well. After that, seismic data are reflection free.



Three possible models that could explain the bright reflector (modified from Ashi et al, 2007).

A (green line): sedimentary unit;

B (purple line): splay fault;

C (red line): sedimentary unit but the splay fault extends upper.

Which model is better?

- Answering this question is of local tectonic significance to understand the local strain partitioning, the splay fault properties and the development of the accretionary prism.

Reprocessing seismic data

- Data was processed by CGG.
- We reprocessed the data with noise attenuation, and residual velocity picking.
- 3-D prestack time migration.

Inversion method

- Use 3-D time migrated angle gathers

- Model based inversion to get elastic parameters: P-impedance, S-impedance, and density

(1-D or trace by trace approach, forward problem is solved by linearized Zoeppritz equation)

- Wavelet estimated first statistically from seismic data and then correlated with well log data

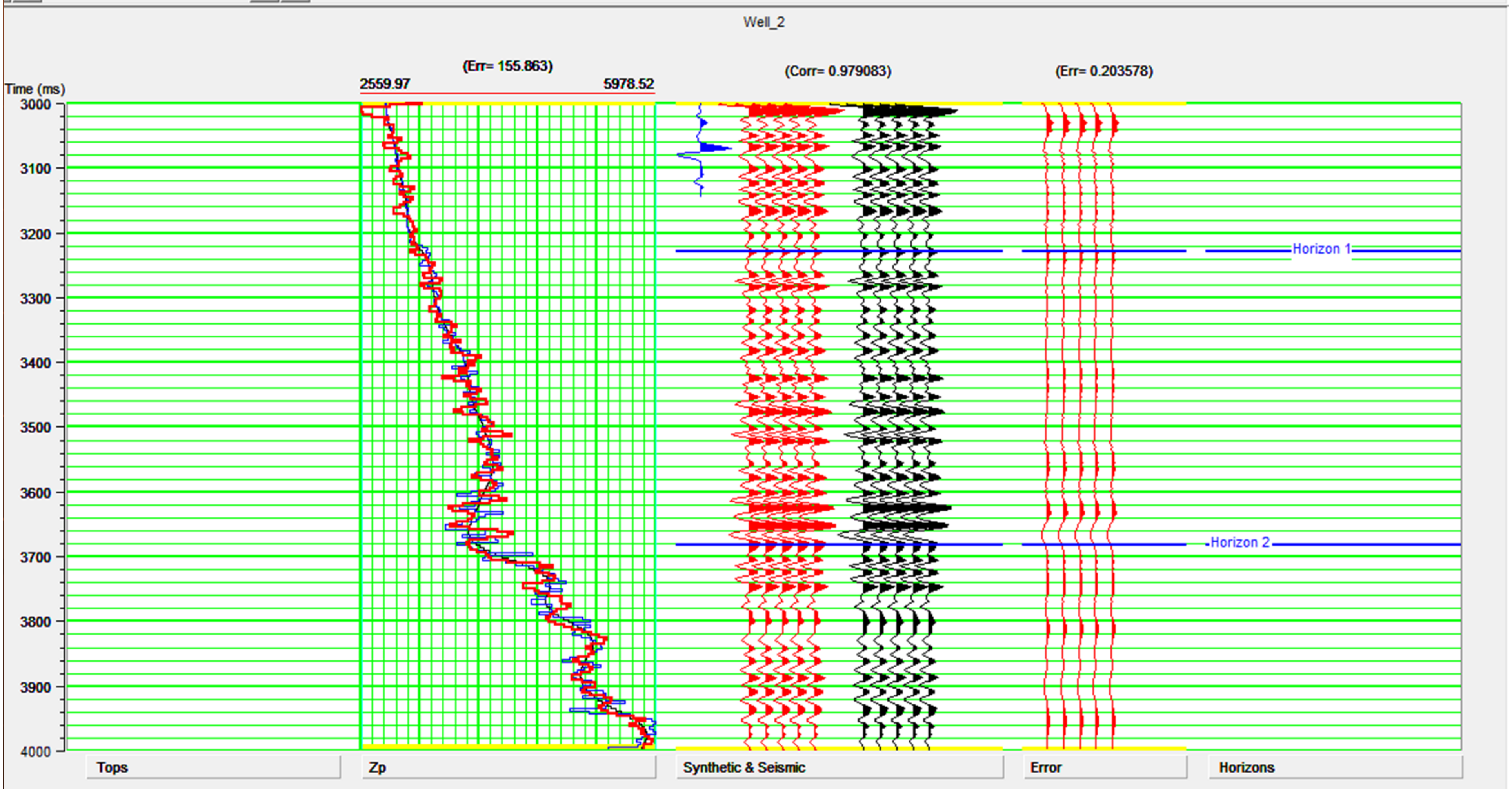
Inversion method

- Pseudo well log generated by Gardner's equation

 (Piecewisely fit the coefficients of one well log and then apply it to another based lithological interpretation).

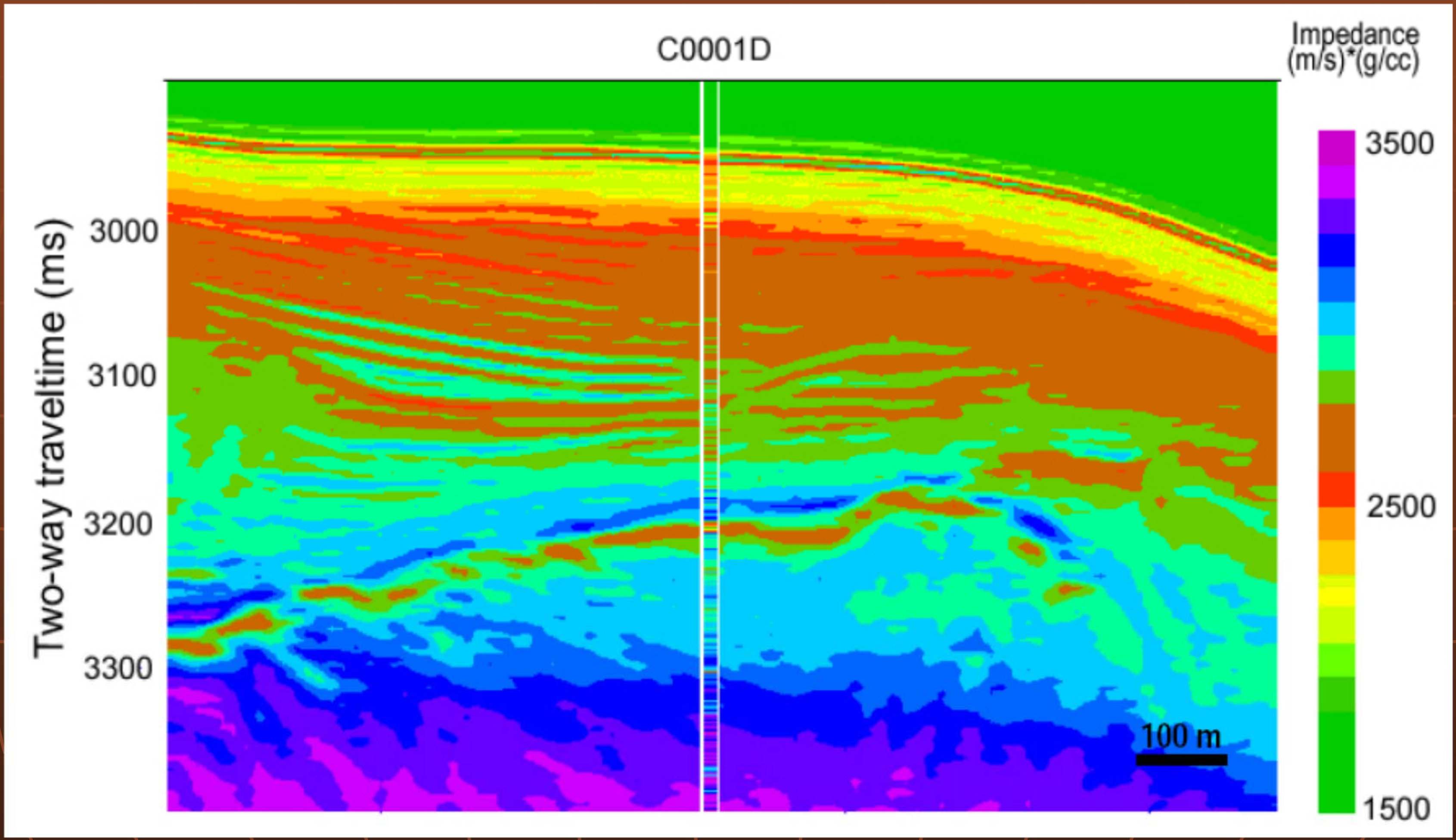
- Low frequency starting model of Zp, Zs and density from well logs and then extrapolate it to the whole region with the help of horizons.

- Porosity estimated statistically by a neural network approach.

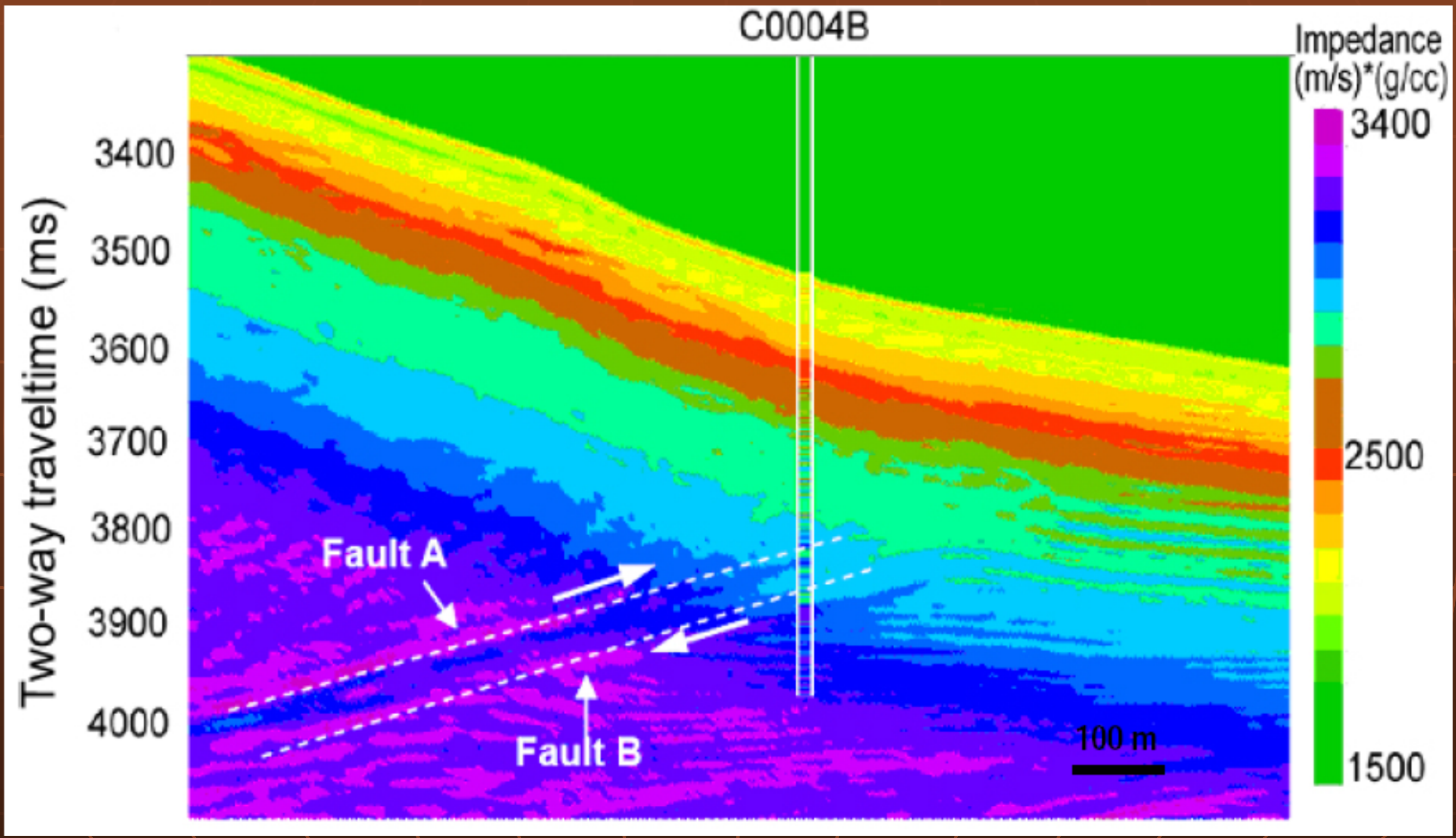


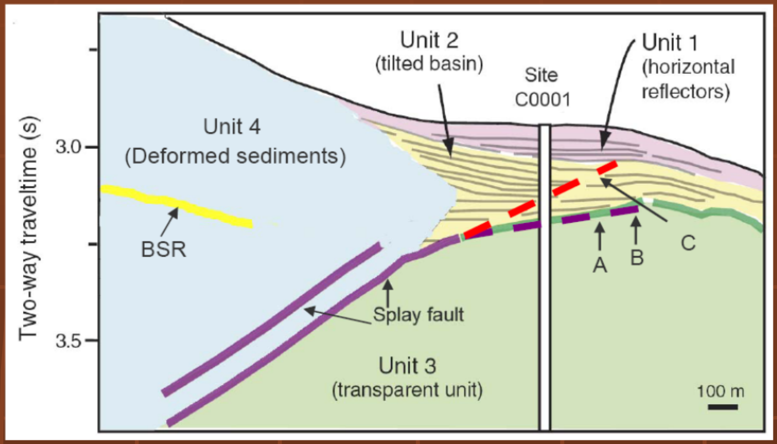
Well_2
(Err= 155.863)
(Corr= 0.979083)
(Err= 0.203578)
Time (ms)
2559.97
5978.52
3000
3100
3200
3300
3400
3500
3600
3700
3800
3900
4000
Horizon 1
Horizon 2
Tops
Zp
Synthetic & Seismic
Error
Horizons

Inverted P-impedance at well C0001D



Inverted P-impedance at well C0004B





A (green line): sedimentary unit;

B (purple line): splay fault;

C (red line): sedimentary unit but the splay fault extends upper.

We interpret the bright reflector as a splay fault because:

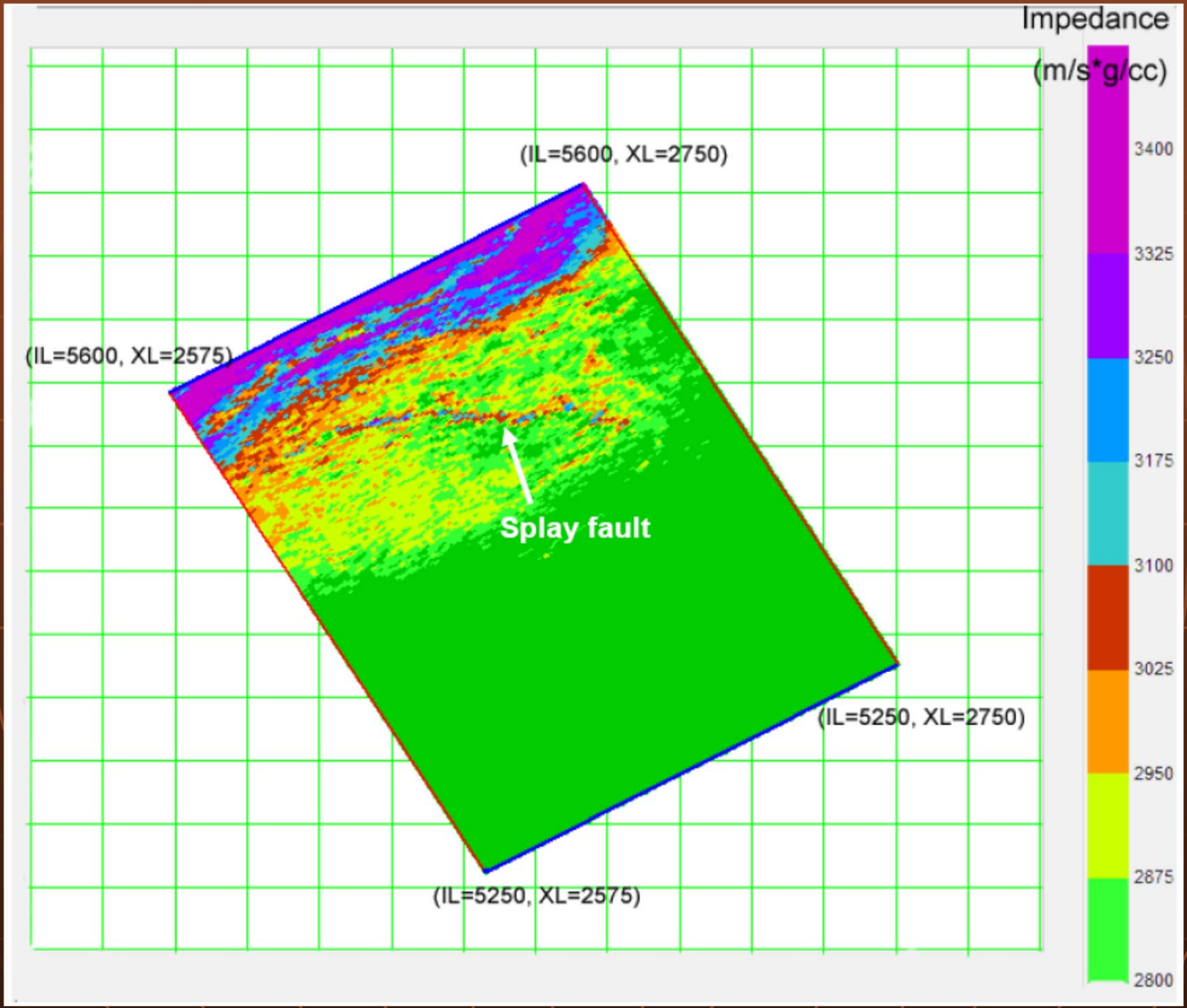
The reflector at well C0001 shows very similar results for the two branches of the splay faults at C0004:

(1) Similar high impedance with a low impedance layer beneath it.

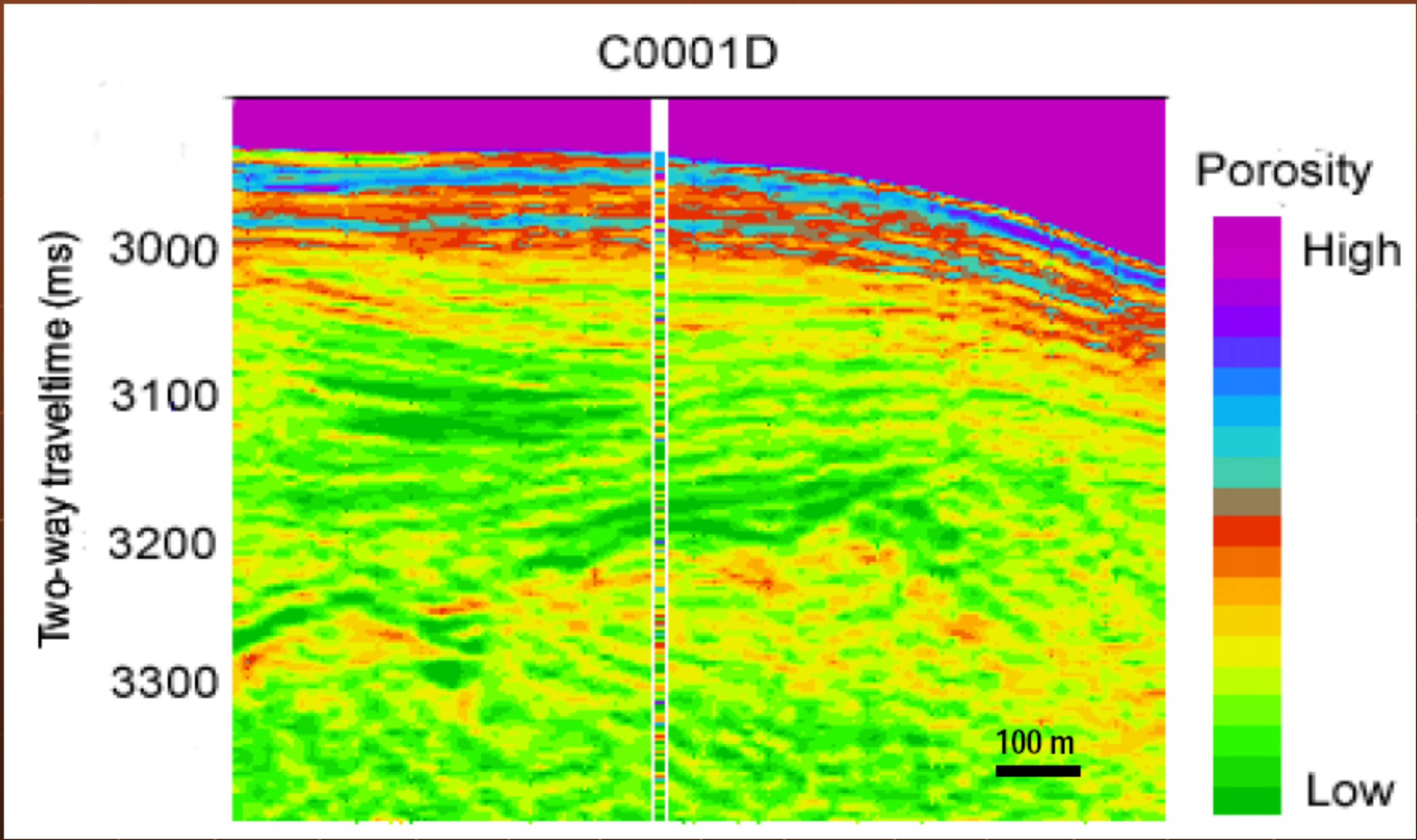
(2) Similar tilted structure.

(3) Similar impedance amplitude near the borehole.

3-D time slice of the inverted result.



Estimated porosity at well C0001D



Conclusions

- We applied seismic inversion at Nankai Trough to derive elastic properties and porosity of the splay fault system.
- Our results show that the upper splay faults are characterized by high impedance with a low impedance layer underneath.
- We interpret the “bright” reflector as the upper limit of a splay fault.

Future work

- Apply my full waveform inversion code (where the forward problem is wave equation solved by finite difference) to this or other datasets.

Special Thanks to our Sponsors

Thank you !