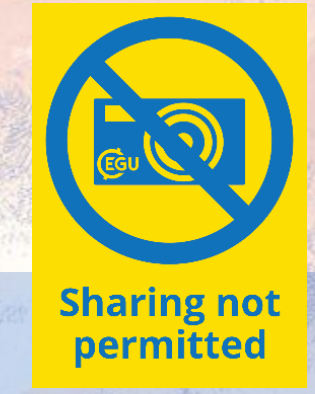
Active transpression along the Owen oceanic transform fault, India – Somalia plate boundary

Alexandre Janin[1*], Mathieu Rodriguez[1], Nicolas Chamot-Rooke[1], Alain Rabaute[2], Matthias Delescluse[1], Jérôme Dyment[3], Marc Fournier[2], Philippe Huchon[2], Jean-Arthur Olive[1], and Christophe Vigny[1]

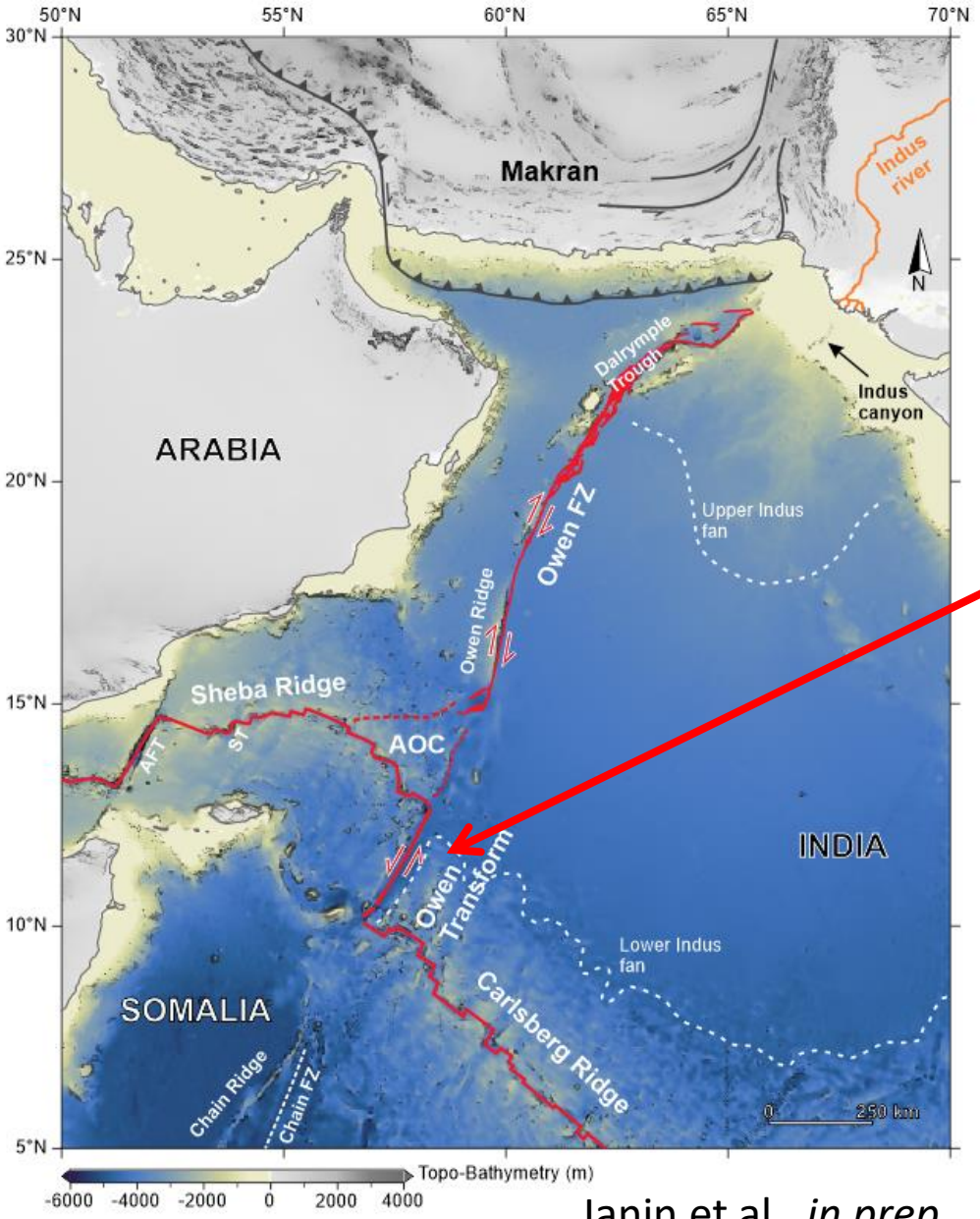
[1] Laboratoire de Géologie - CNRS UMR 8538, École Normale Supérieure - PSL University, Paris, France
[2] Sorbonne Université, CNRS-INSU, Institut des Sciences de la Terre de Paris, ISTeP UMR 7193, F-75005 Paris, France
[3] Institut de Physique du Globe de Paris, CNRS UMR 7154, Sorbonne Paris Cité, Université Paris Diderot, Paris 75005, France

[*] Corresponding author: janin@geologie.ens.fr



vEGU2021

OWEN OCEANIC TRANSFORM FAULT



Janin et al., *in prep*

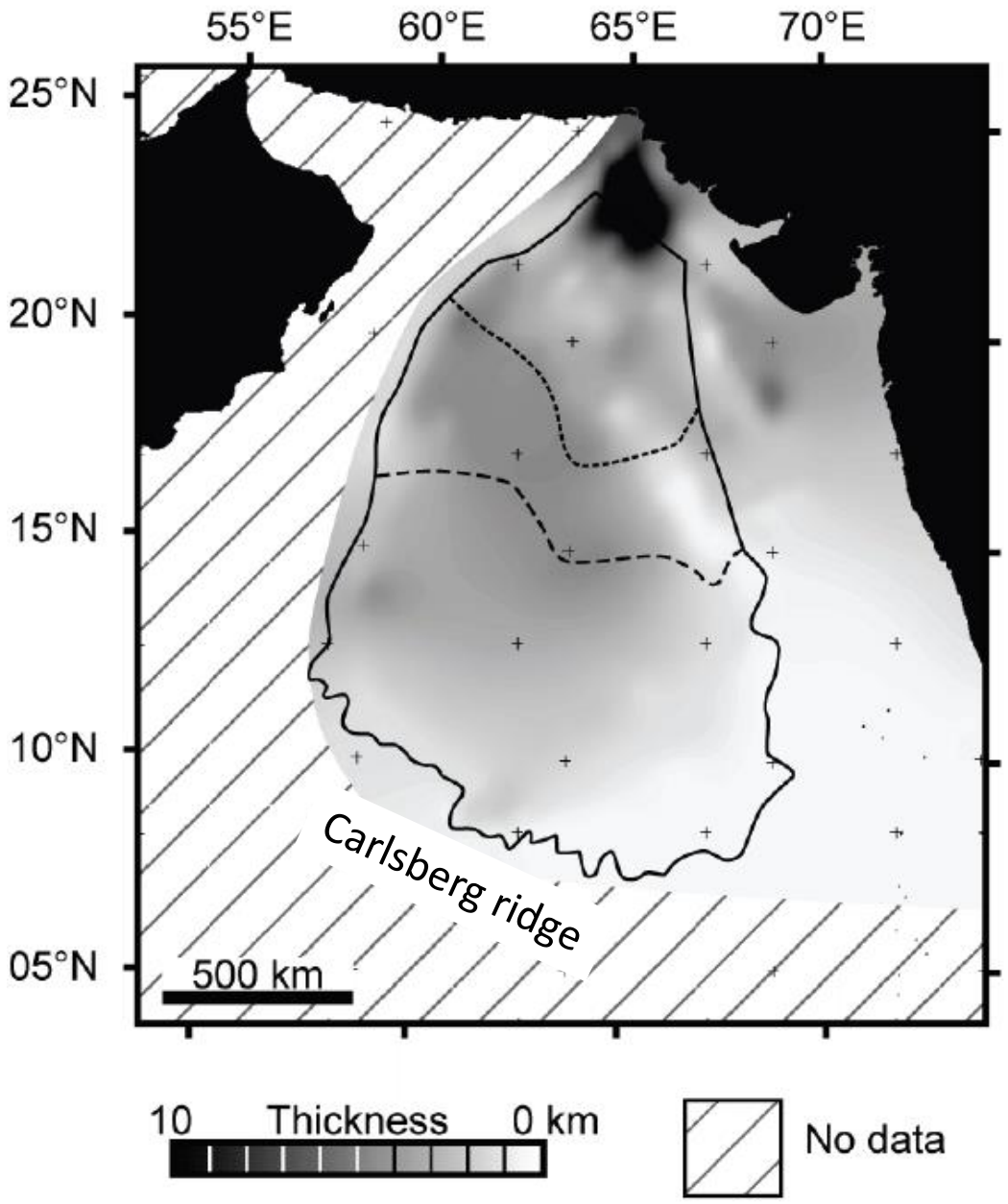
Where are we?

North-western part of the Indian Ocean (at the western termination of the Carlsberg ridge)

Owen tranform fault …

- is a 330-km-long oceanic transform fault
- is a part of the active plate boundary between India and Somalia (Wilson 1965)
- accommodates the left-lateral strike-slip motion between India and Somalia with a rate of 21.4 ± 0.6 mm. yr^{-1} (DeMets et al. 2010).

COVERED BY THE INDUS TURBIDITIC SYSTEM

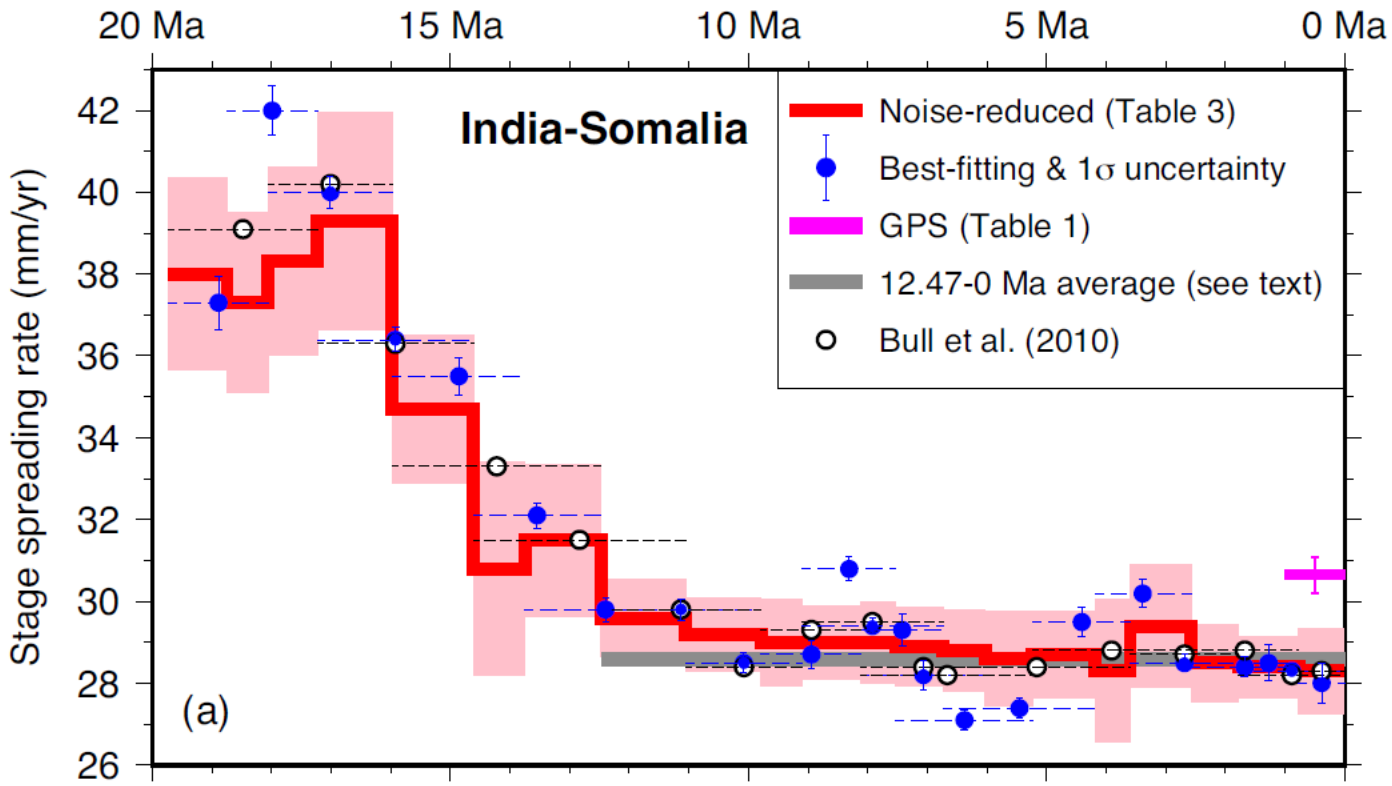


A sedimentary particularity

- The Owen transform fault is located at the distal Indus turbiditic system and captures these sediments
- The Indus fan is the second largest submarine fan with a deposit thickness up to ~ 9 km (Clift et al. 2001, Calvès 2009)
- The sedimentary cover of the Indus fan is marked by an alternance of turbidites and pelagites (avulsion of channels-levee systems)

from Calvès PhD thesis 2009,
model of Kolla and Coumes, 1987

MOTIVATIONS: STEADY KINEMATICS SINCE ~12.5 Myrs …



DeMets et al., 2020

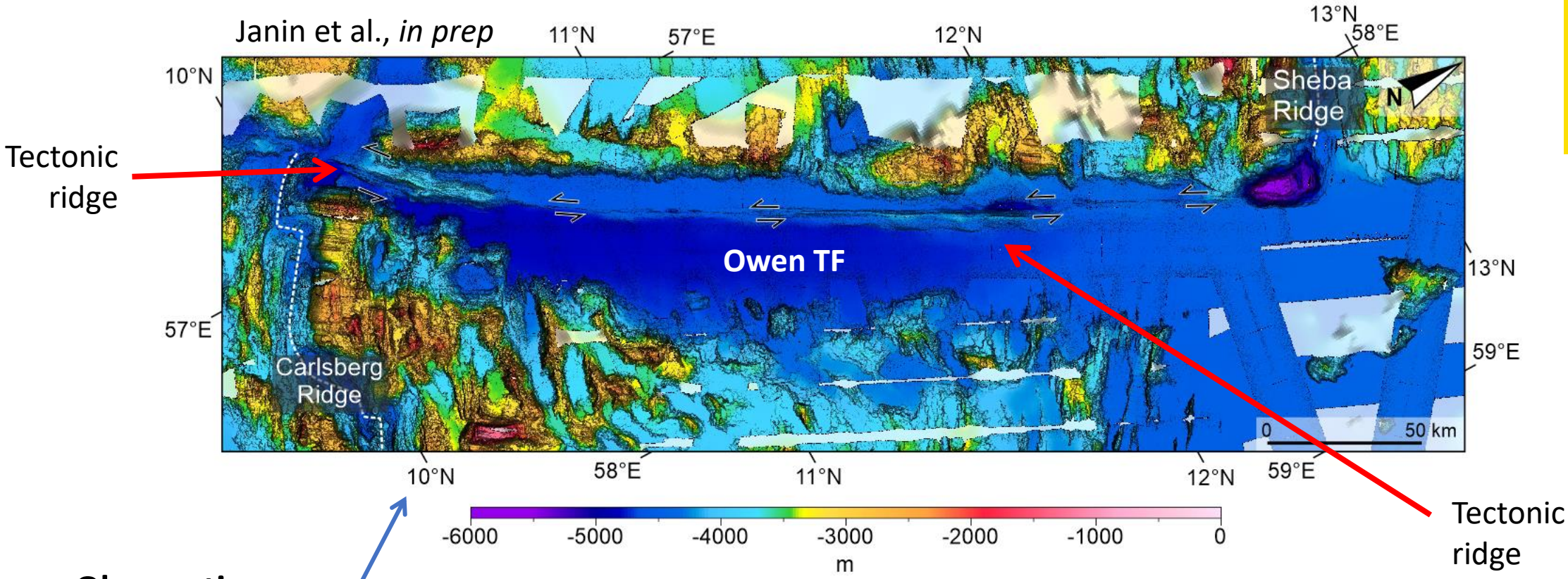
Stable relative motion

IN-SM Kinematics:

- India-Somalia relative plate motion is among the best constrained in the world thanks to the dense magnetic cover collected over the Carlsberg mid oceanic ridge (Merkouriev and DeMets 2006)
- Stability of the India – Somalia relative motion since 12.5 Myrs (Merkouriev and DeMets 2014, DeMets et al. 2020)

But …

MOTIVATIONS: …BUT TECTONIC STRUCTURES…



Observations:

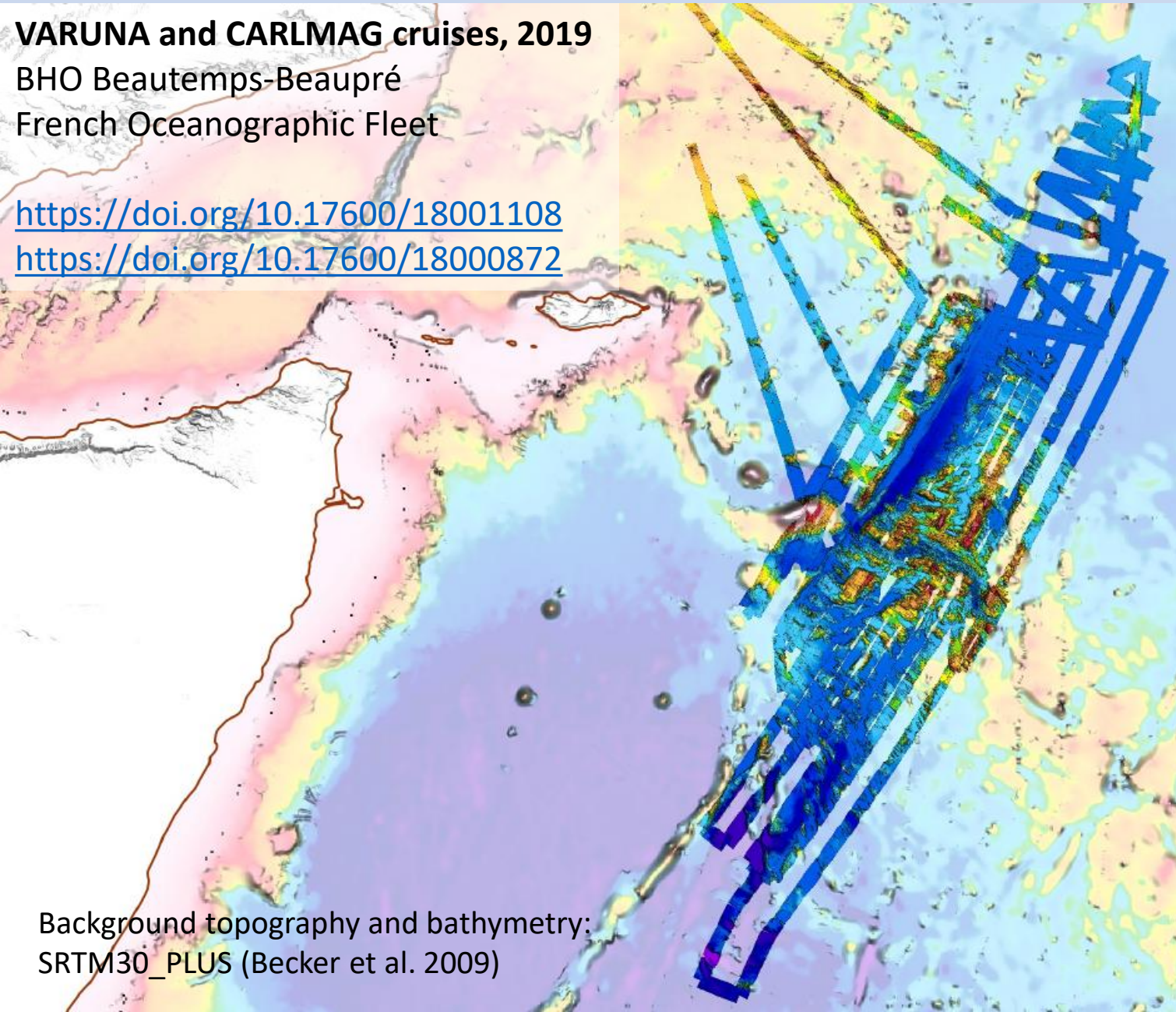
- New dataset reveals a series of **tectonic structures** along the strike of the Owen transform even on young oceanic lithosphere (< 12.47 Myrs)

What are these structures? How old are they? What do we learn about oceanic transforms?

NEW MARINE DATA

VARUNA and CARLMAG cruises, 2019
BHO Beautemps-Beaupré
French Oceanographic Fleet

https://doi.org/10.17600/18001108
https://doi.org/10.17600/18000872



Background topography and bathymetry:
SRTM30_PLUS (Becker et al. 2009)

Sharing not permitted

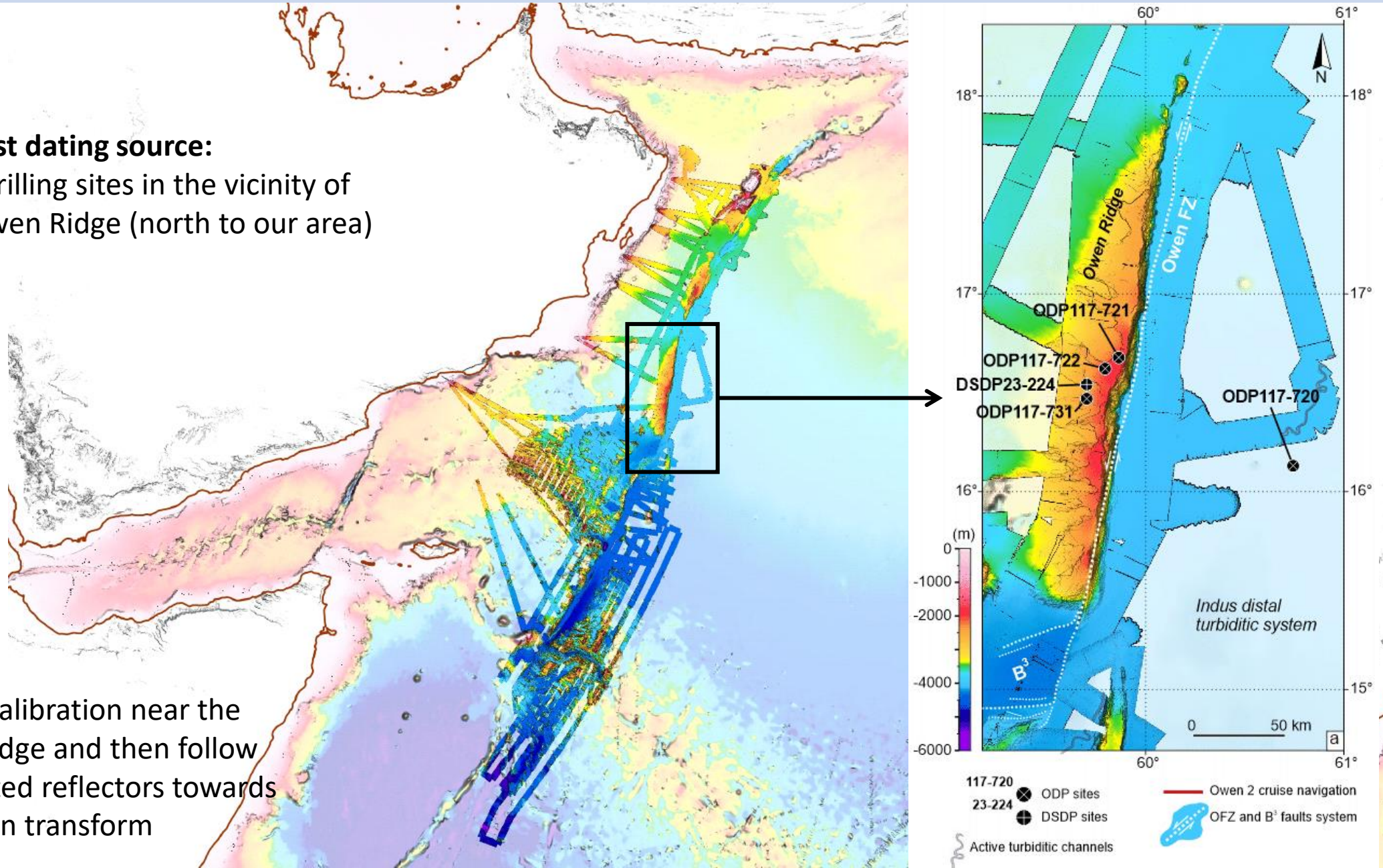
New data:

- Huge high **resolution multibeam bathymetry** cover ($\sim 2.3 \times 10^5$ km²) for a 10 to 50 meters horizontal grid interval)
- More than 5000 km of **seismic reflection profiles** (Common Mid-Point spacing of 3.125 meters)
- **Sub-Bottom seismic Profiler** (3.5 kHz)
- + geophysical measurement (gravity field and magnetic anomalies ; but not the purpose of this study)

To answer our problem: … (next slide)

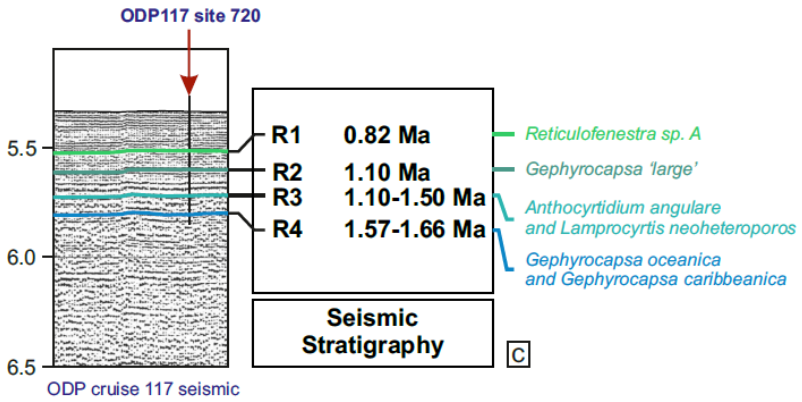
METHOD: 1.a. SEISMIC STRATIGRAPHY (drilling sites)

Nearest dating source:
ODP drilling sites in the vicinity of the Owen Ridge (north to our area)



Idea:
Build a calibration near the Owen Ridge and then follow each dated reflectors towards the Owen transform

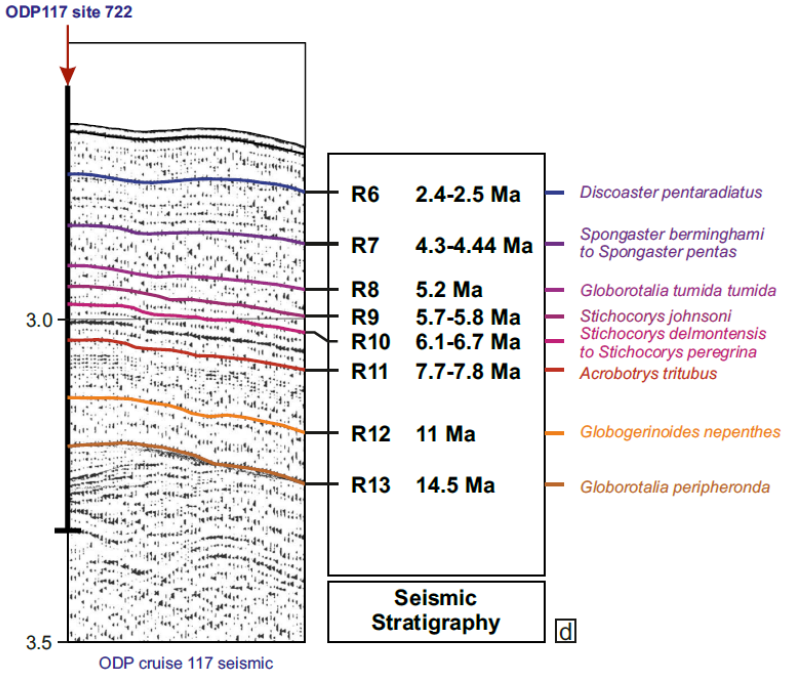
METHOD: 1.b. SEISMIC STRATIGRAPHY (calibration)

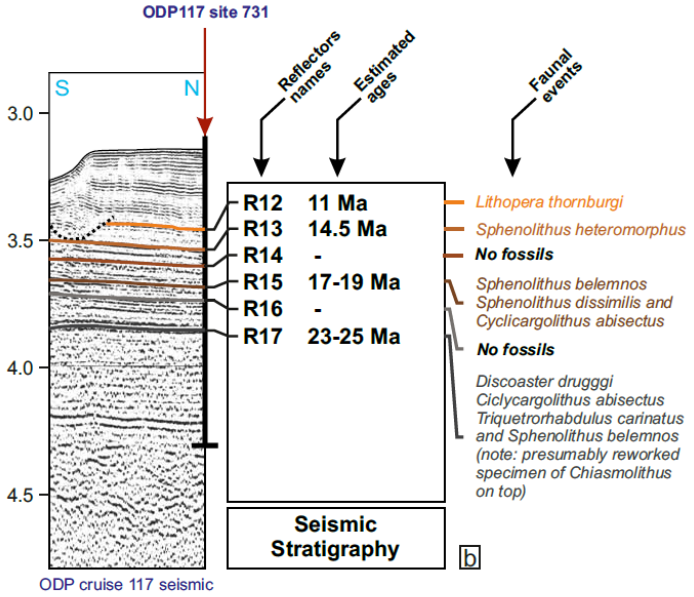


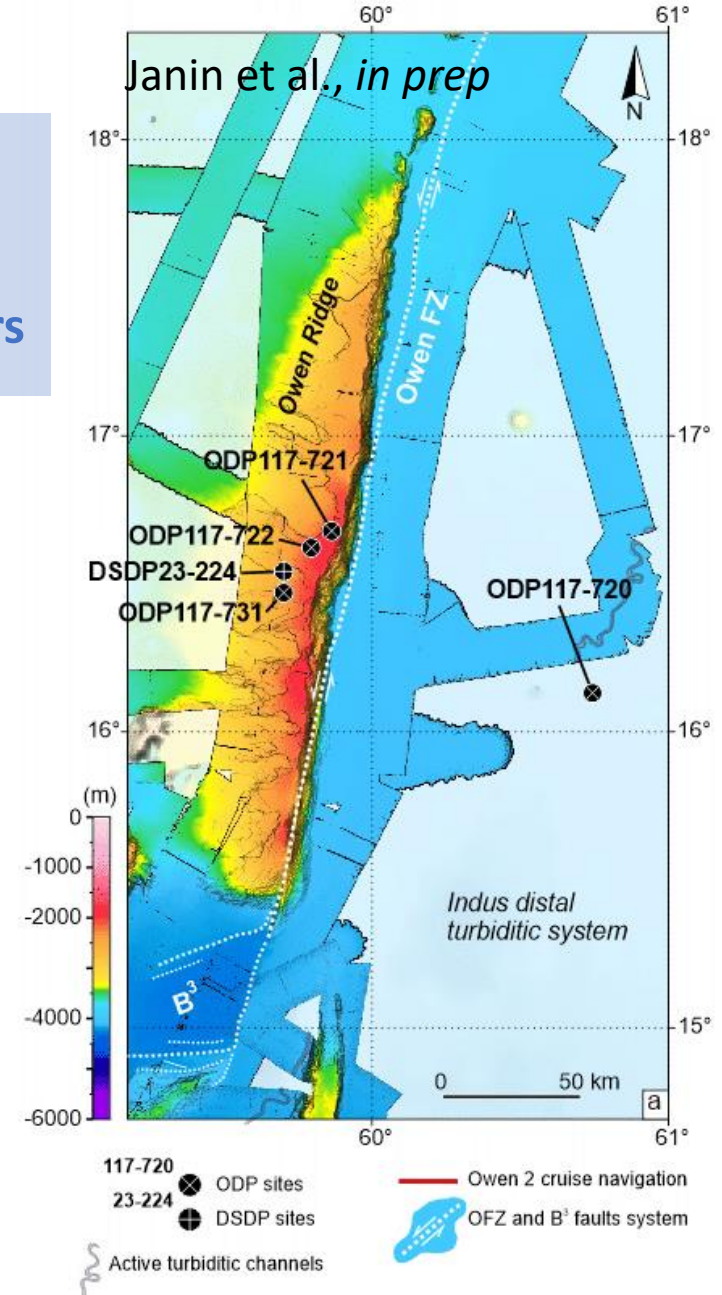
Seismic stratigraphy returns

14 dated reflectors

from 0.82 Ma to 23/25 Myrs

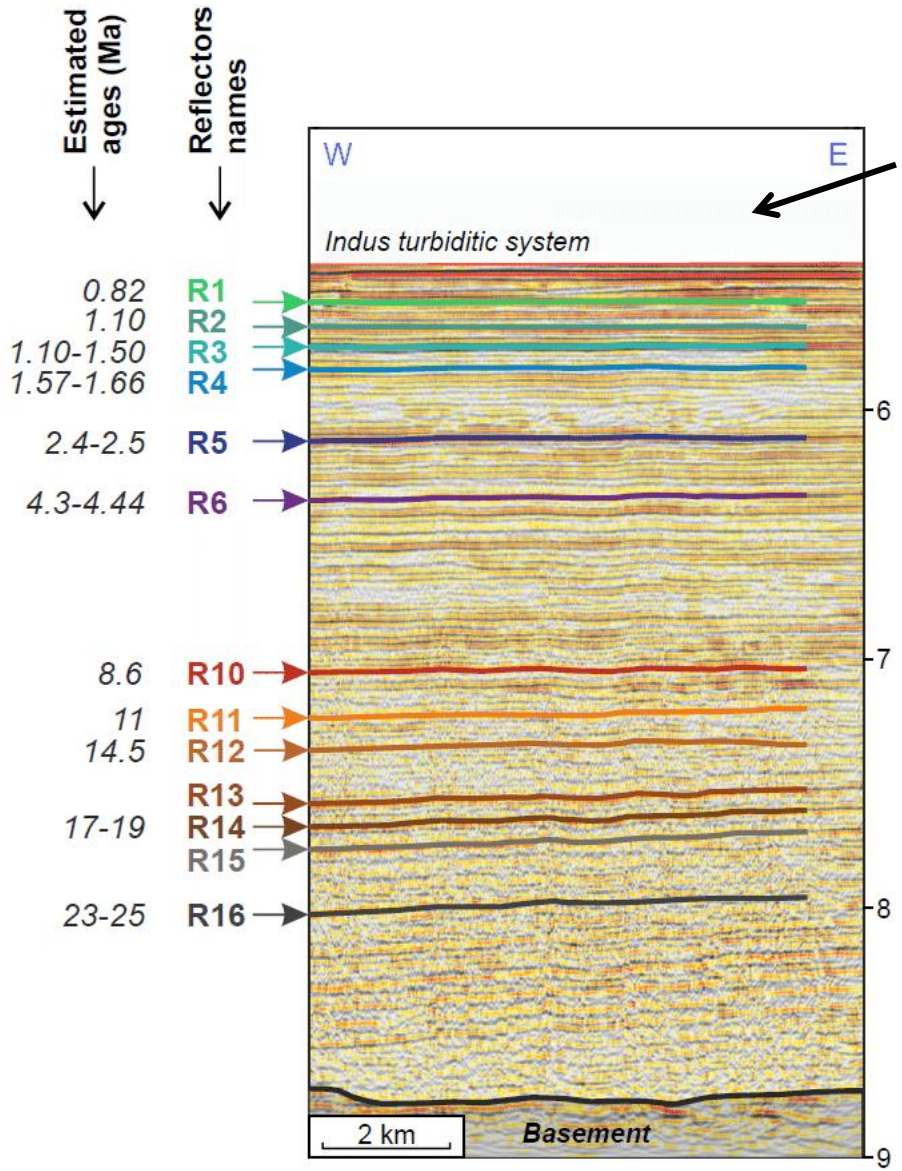






Janin et al., *in prep*

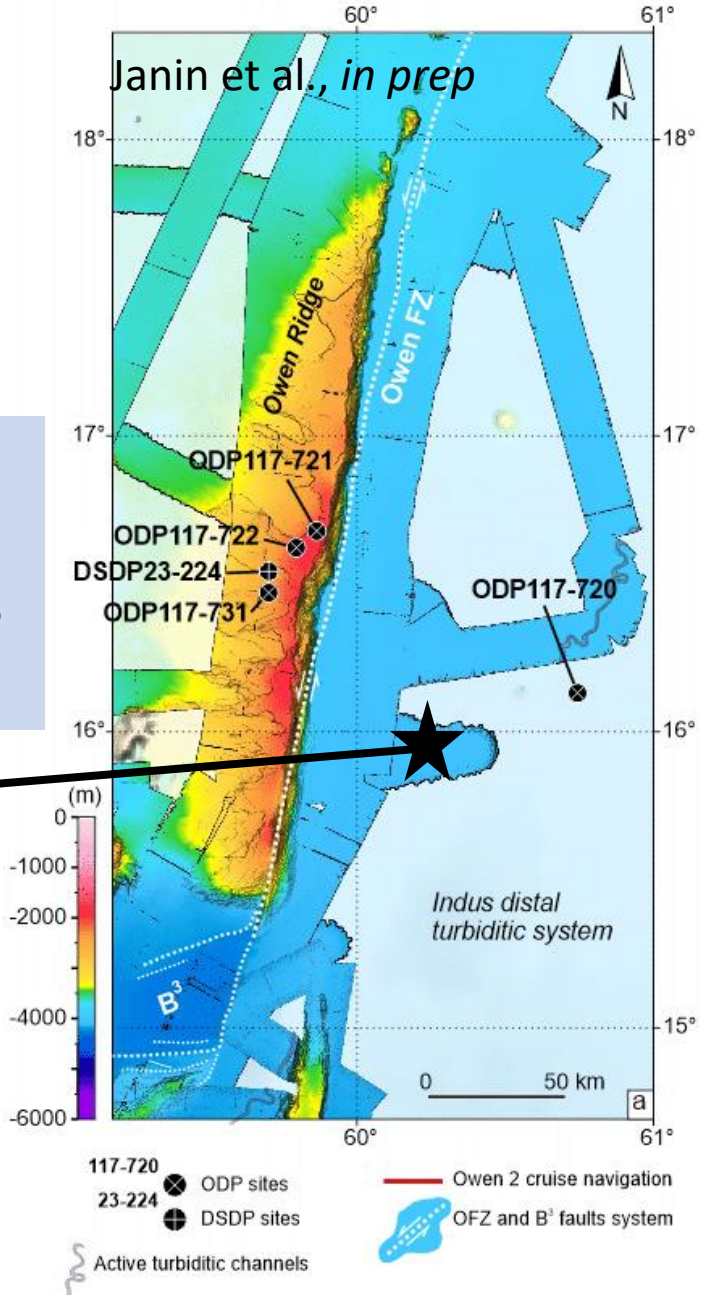
METHOD: 2. SEISMIC CORRELATIONS (gather drilling sites data)



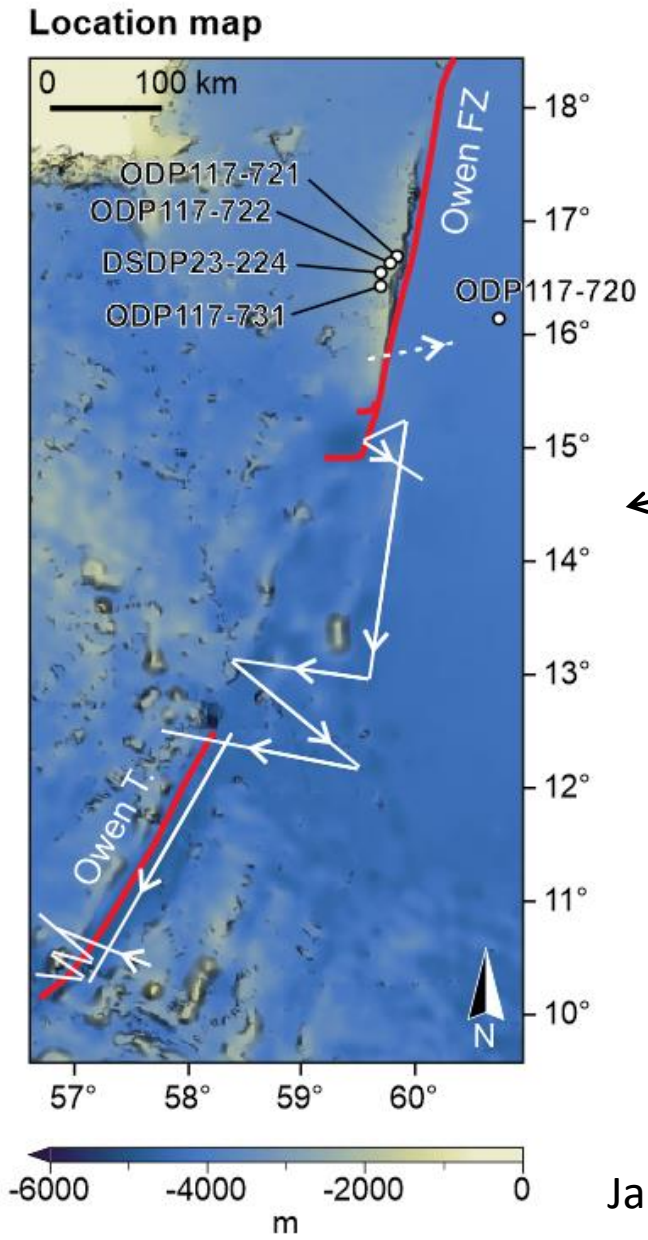
Janin et al., *in prep*

Results of the correlation between the top and the bottom of the Owen ridge

14 dated reflectors from 0.82 Ma to 23/25 Myrs in the distal Indus fan system



METHOD: 2. SEISMIC CORRELATIONS (far field correlation)



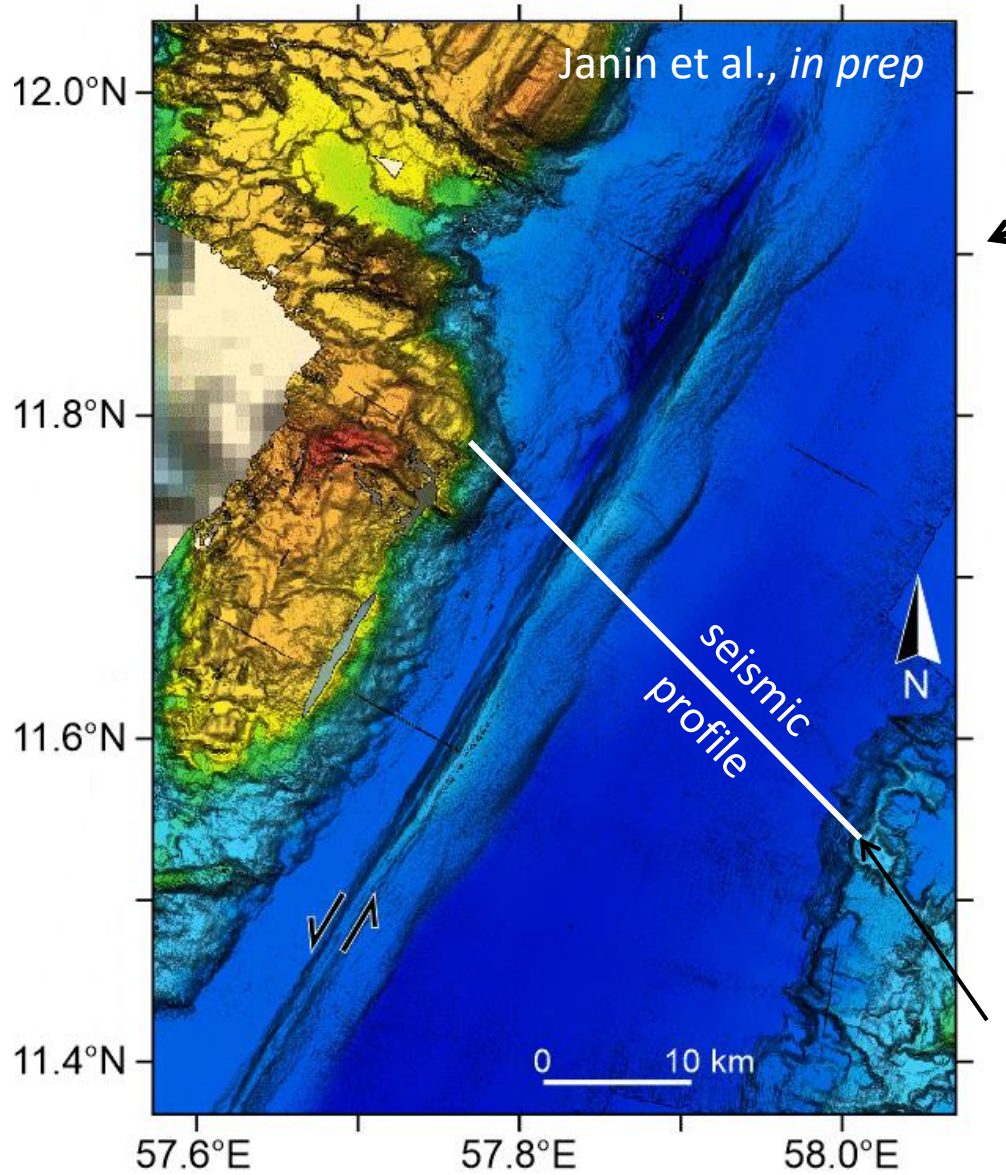
Idea (reminder):
Build a calibration near the Owen Ridge and then follow each dated reflectors towards the Owen transform

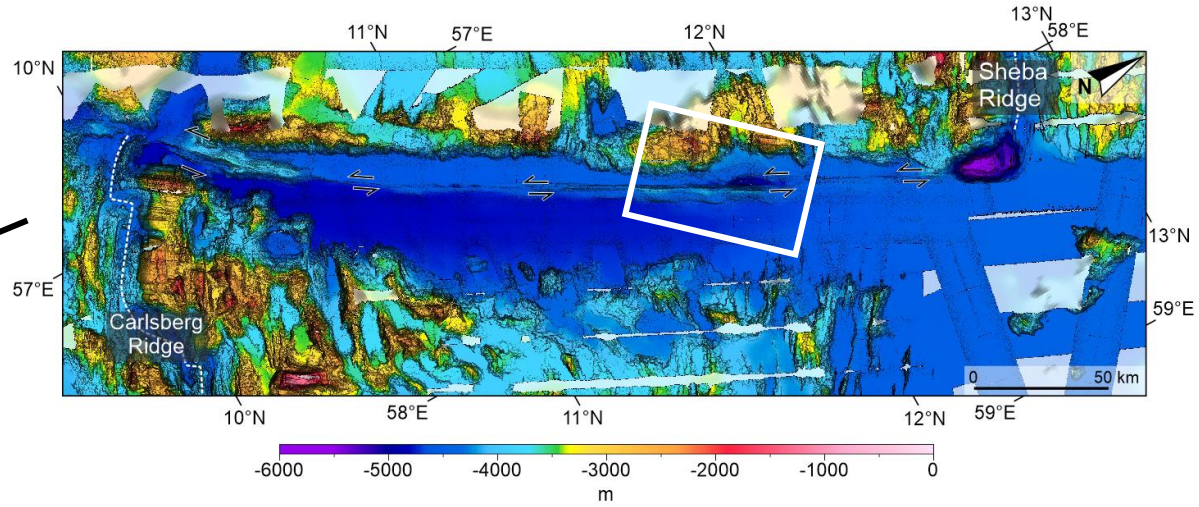
- **White dots**: Drilling sites
- **White arrows**: Correlation path used to reach sediments covering the Owen transform

Thanks to the newly acquired dense seismic profiles network we correlate towards the Carlsberg ridge (all along the Owen transform)

Janin et al., *in prep*

RESULTS: WHAT IS THE CENTRAL RIDGE?





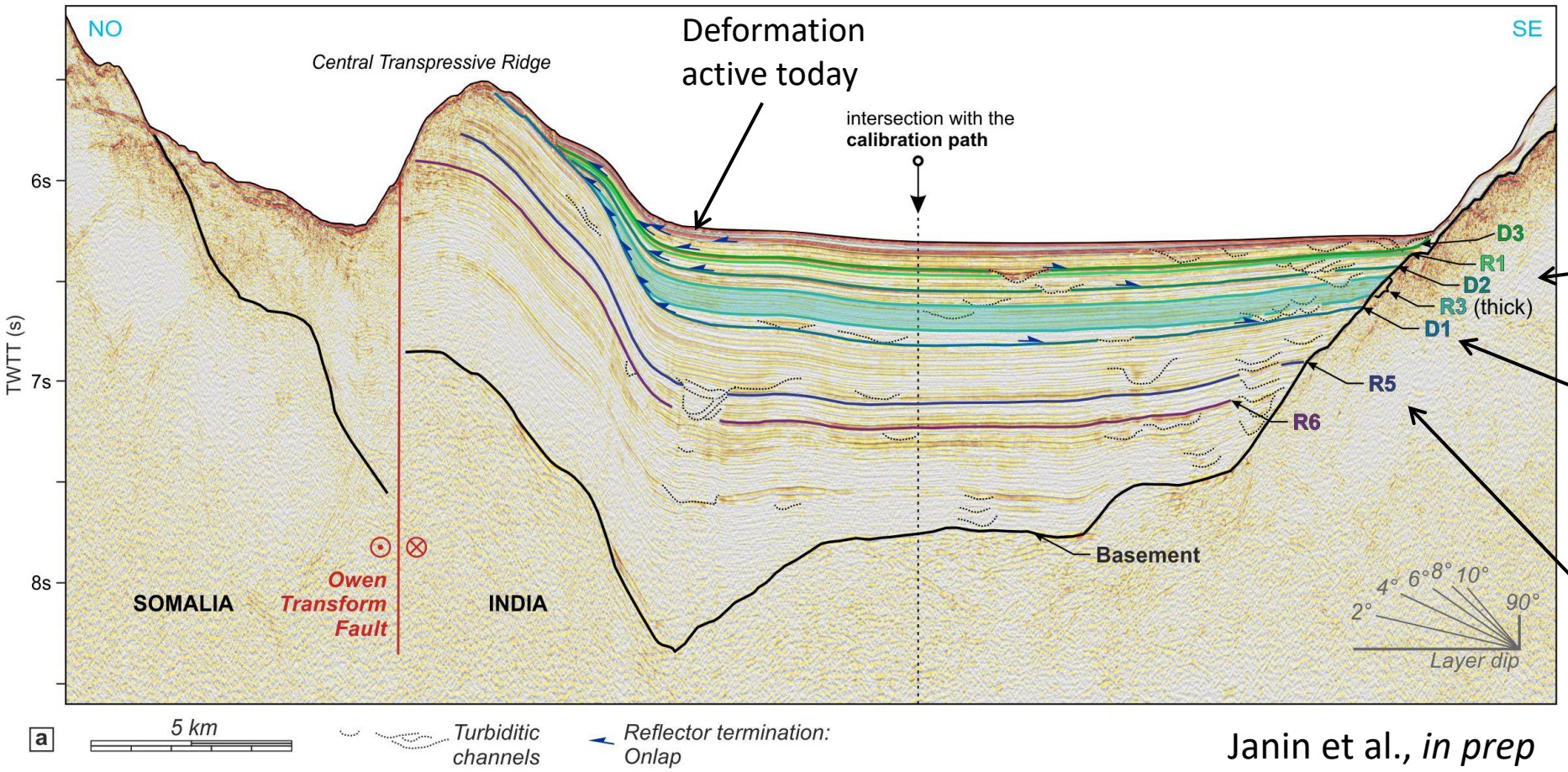
In bathymetry:

- A ridge over ~100 km and reaching 540 m high above the seafloor
- Morphology of an en échelon folds system

Location of seismic profile *(next slice)*

Seismic profile (next slice) ↓

RESULTS: WHAT IS THE CENTRAL RIDGE?



Janin et al., *in prep*

Dated reflector
1.10-1.50 Myrs

Main unconformity:
Formation of the ridge between 1.50-2.4 Myrs

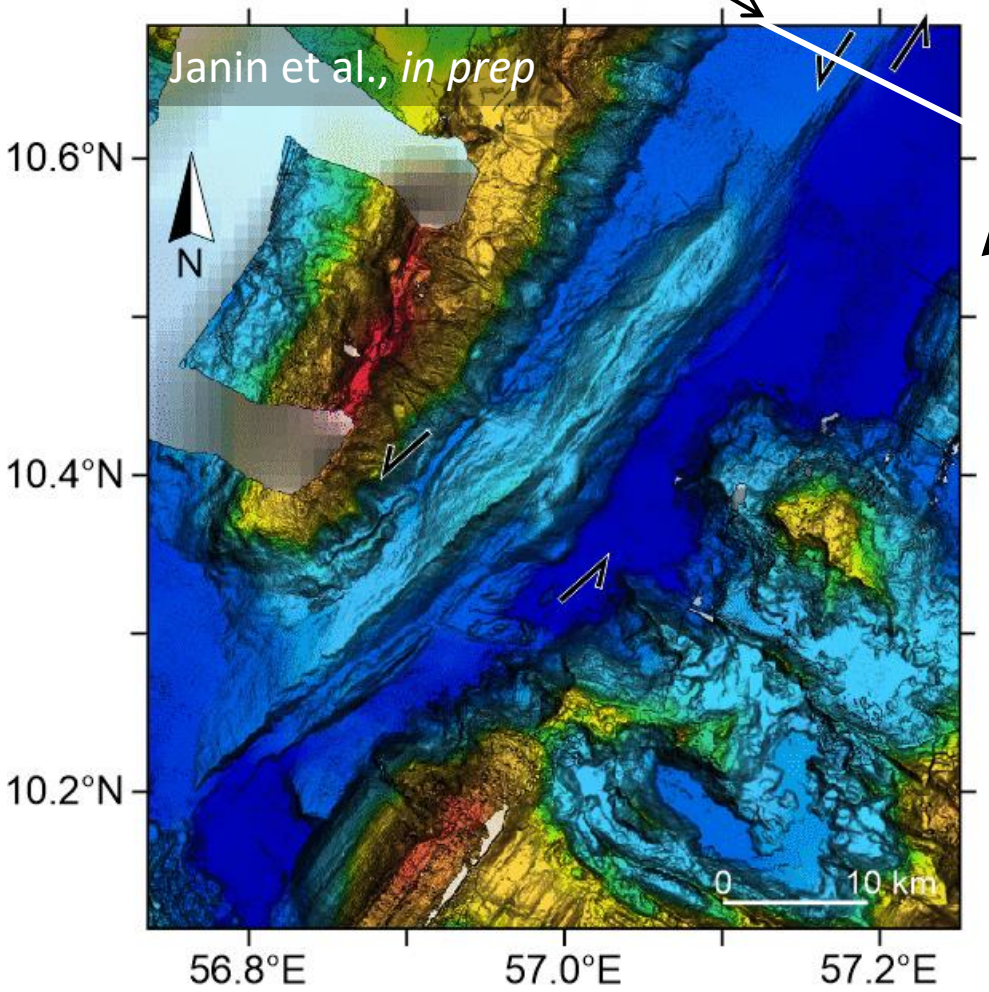
Dated reflector
2.4-2.5 Myrs

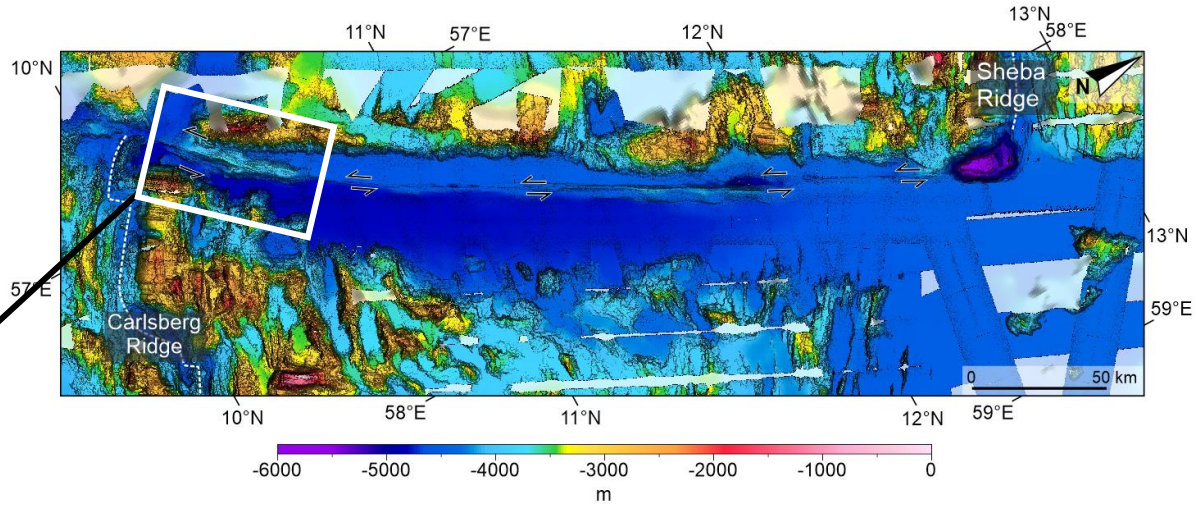
On seismic profile:

- A transpressive ridge
- Formation between 1.50 and 2.4 Myrs (seems to confirm the steady state motion between IN and SM before this recent transpression)
- Transpression active today

RESULTS: WHAT IS THE SOUTHERN RIDGE?

Location of seismic profile
(next slice)



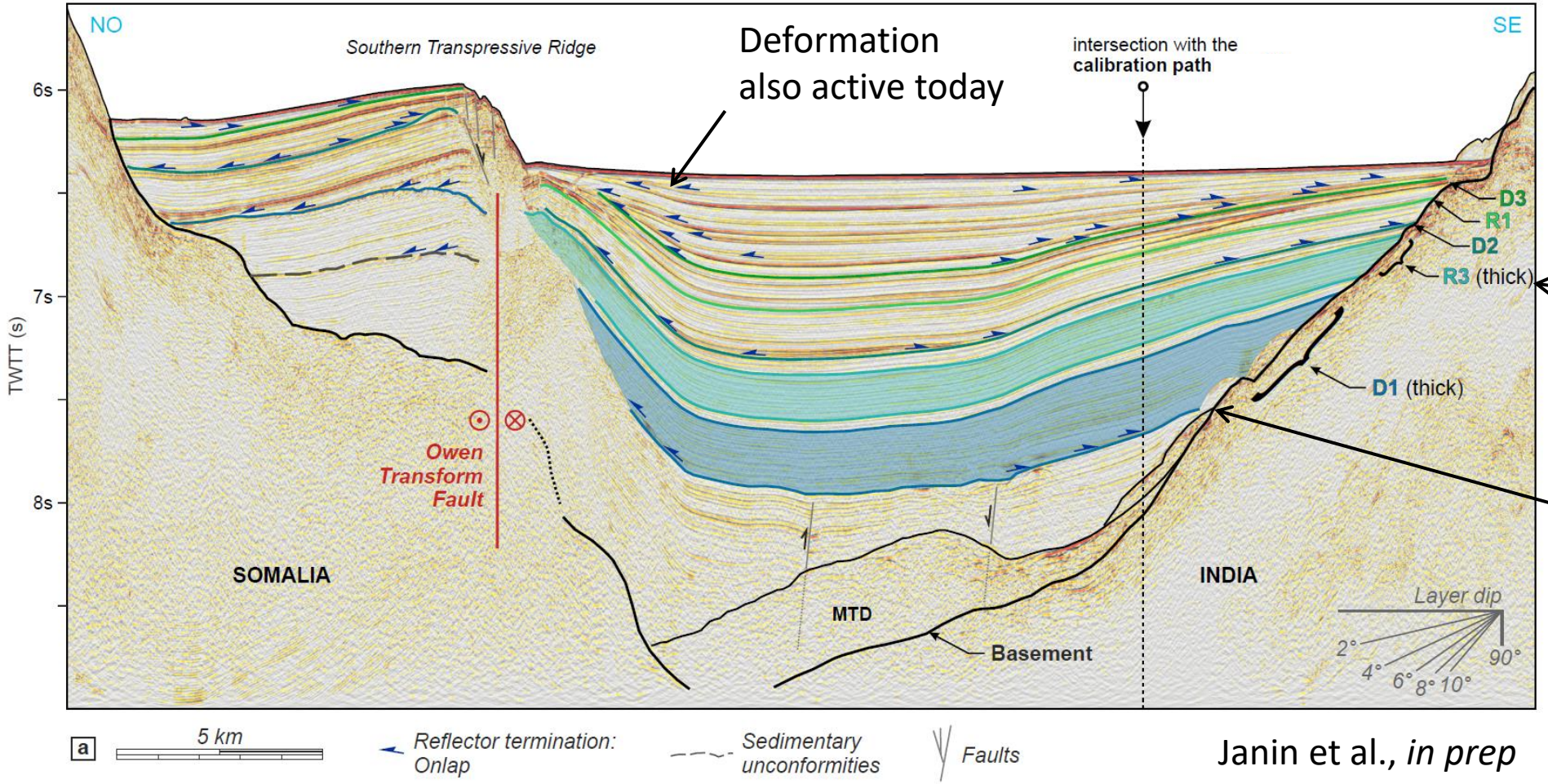


In bathymetry:

- A ridge over ~65 km and reaching 1000 m high above the seafloor
- Oblique and steep structure (up to 22°)
- Located near the Carlsberg-Owen Intersection

Seismic profile (next slide) ↓

RESULTS: WHAT IS THE SOUTHERN RIDGE?



Dated reflector
1.10-1.50 Myrs

Same main unconformity:
Formation of the ridge
between 1.50-2.4 Myrs

Janin et al., *in prep*

On seismic profile:

- Southern ridge near the Carlsberg-Owen Intersection is also a transpressive ridge
- Formation between 1.50 and 2.4 Myrs which is coeval with the formation of the central transpressive ridge (same reflector)
- Transpression also active today

CONCLUSIONS

Take-home message

- **Owen transform fault**: A long oceanic transform buried under thick distal Indus turbiditic sediments
- **New marine geophysics data** set on the Owen tranform from the VARUNA and CARLMAG cruises 2019
- Data reveal **new tectonic structures** along the Owen transform fault
- These structures were formed after a common **transpressive event** affecting the Owen transform in its all length (creates locally impressive transpressive structures)
- **Precise stratigraphy** work allows to date distal Indus turbiditic sediments up to the Carlsberg ridge
- Recent event: Beginning of the transpression **between 1.50 Myrs and 2.4 Myrs**
- Transpression **active today** all along the transform

REFERENCES

Wilson JT. Transform faults, oceanic ridges, and magnetic anomalies southwest of vancouver island. *Science*, 150(3695):482–485, 1965.

Charles DeMets, Richard G Gordon, and Donald F Argus. Geologically current plate motions. *Geophysical Journal International*, 181(1):1–80, 2010.

Calvès G. *Tectono-stratigraphic and climatic record of the NE Arabian Sea*. PhD thesis, University of Aberdeen, 2009.

Clift P, Shimizu N, Layne GD, Blusztajn JS, Gaedicke C, Schluter H-U, Clark MK, and Amjad S. Development of the indus fan and its significance for the erosional history of the western himalaya and karakoram. *Geological Society of America Bulletin*, 113(8):1039–1051, 2001.

Kolla V and Coumes F. Morphology, internal structure, seismic stratigraphy, and sedimentation of indus fan. *AAPG Bulletin*, 71(6):650–677, 1987.

Merkouriev S and DeMets C. Constraints on indian plate motion since 20 ma from dense russian magnetic data: Implications for indian plate dynamics. *Geochemistry, Geophysics, Geosystems*, 7(2), 2006.

Merkouriev S and DeMets C. High-resolution estimates of nubia–north america plate motion: 20 ma to present. *Geophysical Journal International*, 196(3):1281–1298, 2014.

DeMets C, Merkouriev S, and Jade S. High-resolution reconstructions and gps estimates of india–eurasia and india–somalia plate motions: 20 ma to the present. *Geophysical Journal International*, 220(2):1149–1171, 2020

Becker JJ, Sandwell DT, Smith WHF, Braud J, Binder B, Depner JL, Fabre D, Factor J, Ingalls S, Kim SH, et al. Global bathymetry and elevation data at 30 arc seconds resolution: Srtm30_plus. *Marine Geodesy*, 32(4):355–371, 2009.