The Eastern Romanche ridge-transform intersection (Equatorial Atlantic): slow spreading under extreme low mantle temperatures. Preliminary results of the SMARTIES cruise.

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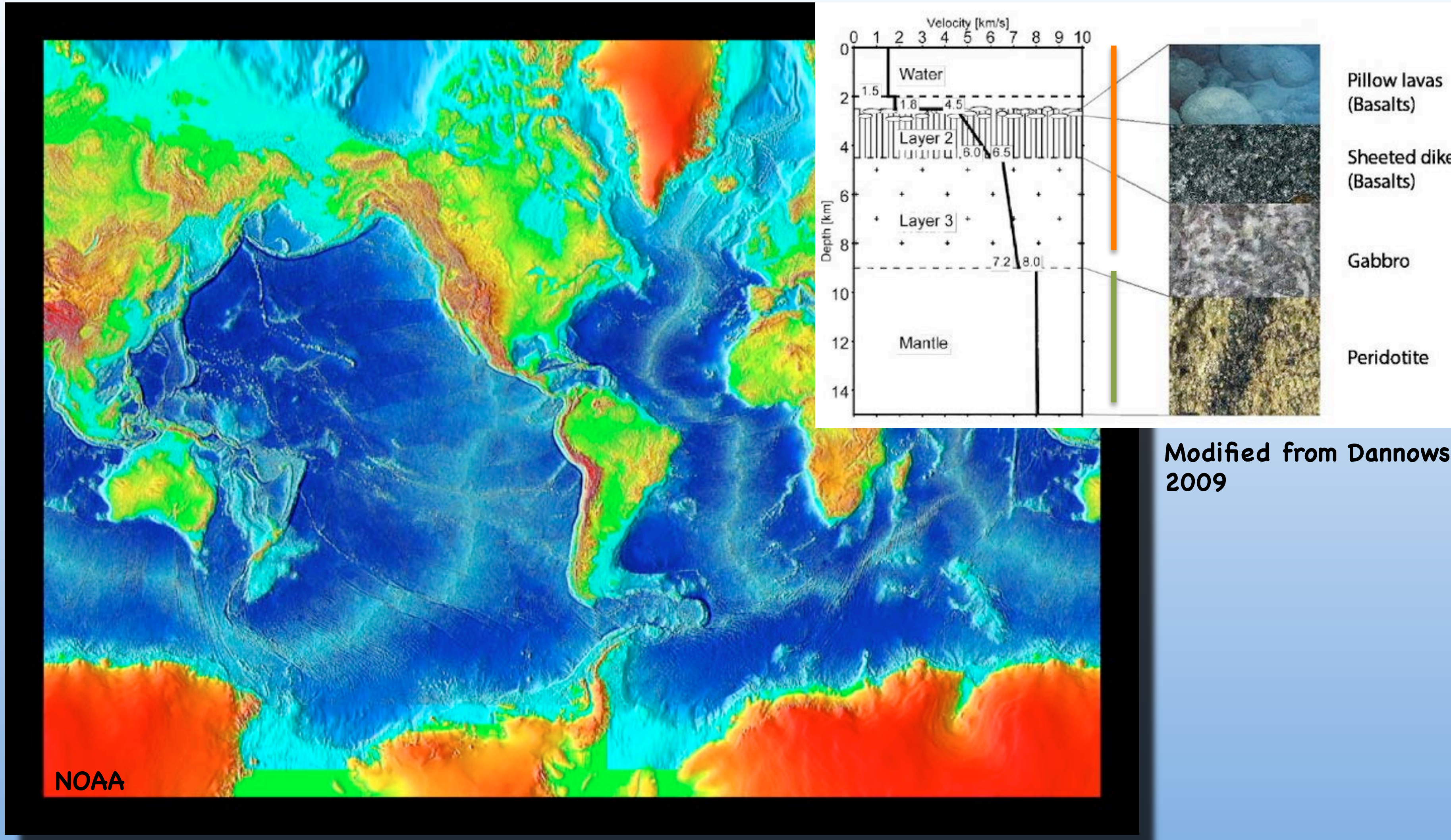
SMARTIES CRUISE Mindelo, July 12 - August 24, 2019

SMARTIES: **SM**ooth regions at the **M**id-**A**tlantic **R**idge **T**ransform-**I**ntersections under **E**xtreme thermal gradient**S**

Mid oceanic ridges: the building of new oceanic lithosphere

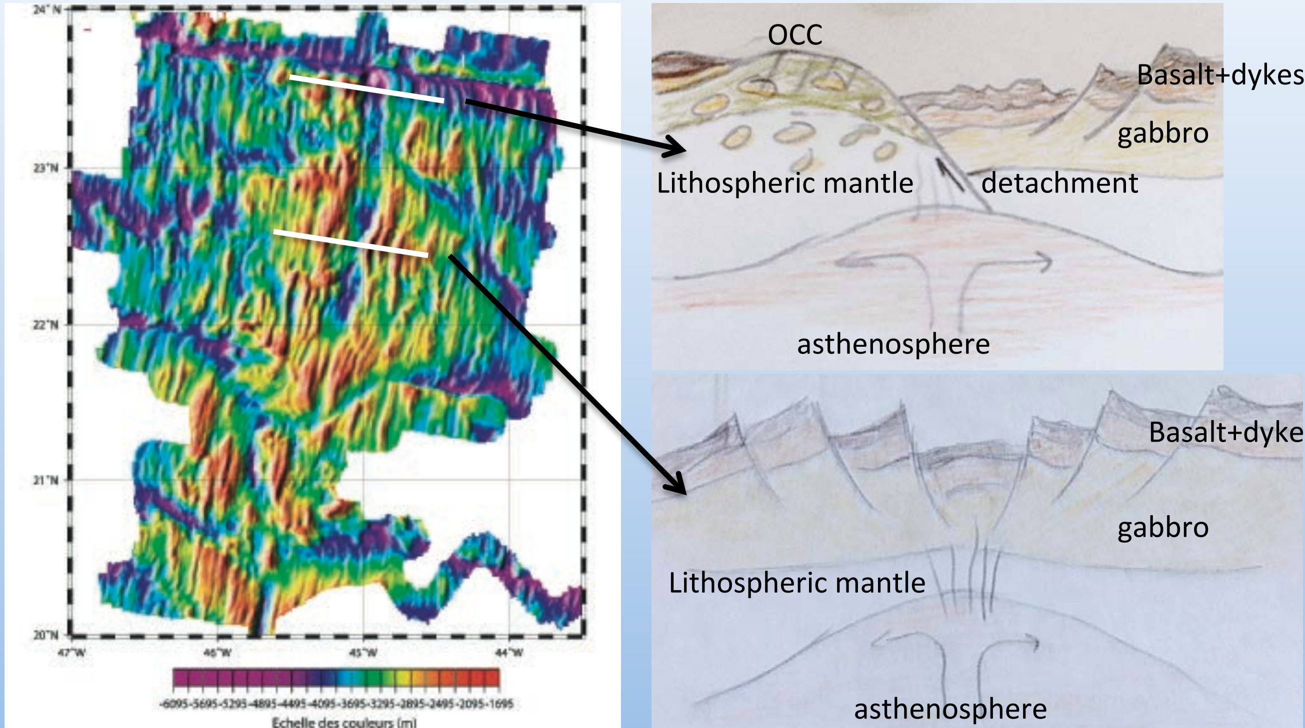


Modified from Dannowski 2009

MOR: formation of the oceanic lithosphere (crust + mantle)
Largest volcanic system on Earth

The structure of the oceanic lithosphere at slow and ultra-slow spreading rates is highly variable

At slow spreading rates: Mid-Atlantic Ridge



Maia & Gente, 1990

Segments ends(near to discontinuities): thin or near-absent crust

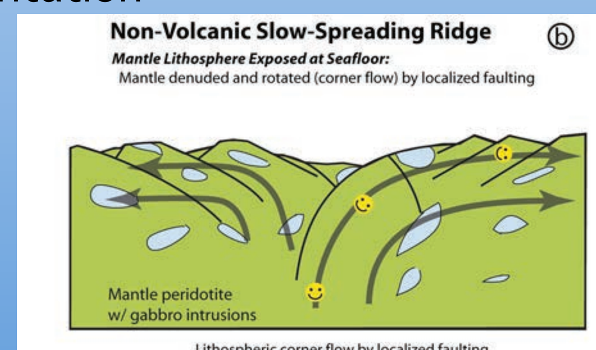
– detachment faults form Oceanic Core complexes (OCC)

Center of ridge segments: thick crust (6 to 9 km)

Highly variable lithospheric structure, linked to the axial segmentation

At ultra-slow spreading rates: South West Indian Ridge

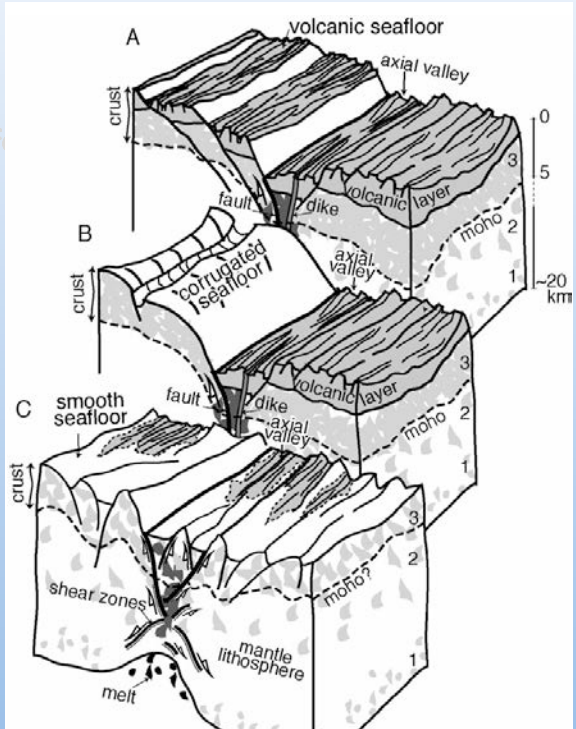
Large areas of mantle outcrops on the ocean floor exhumed through detachment faults (Smooth seafloor morphology)



Schroëder et al, 2006

It depends on the ratio between magmatic and tectonic accomodation of the spreading (M)…

OBSERVATIONS

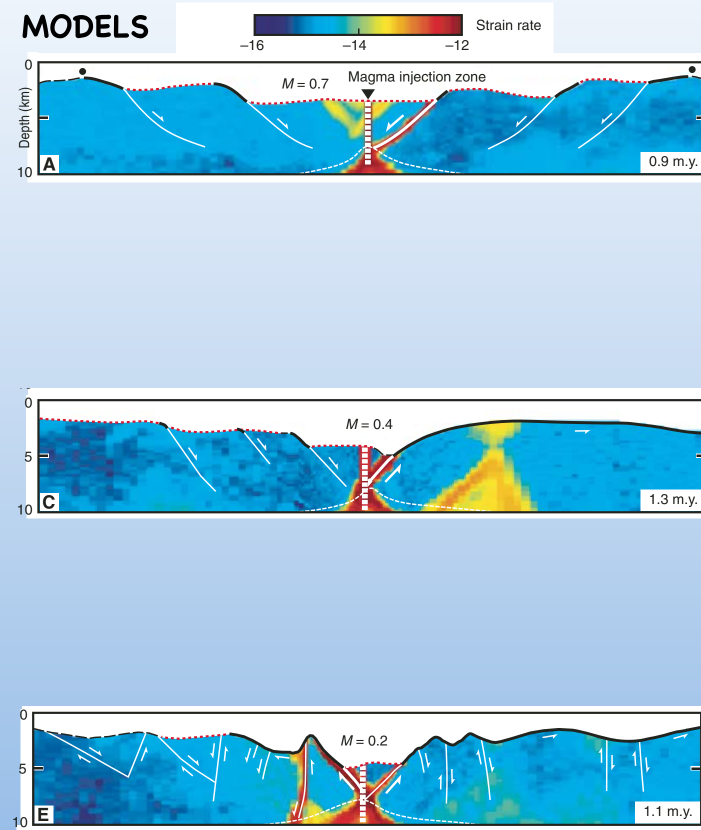


Cannat et al., 2006

Hotter, more magmatic and volcanic

Colder, less magmatic, more mantle outcrops

MODELS



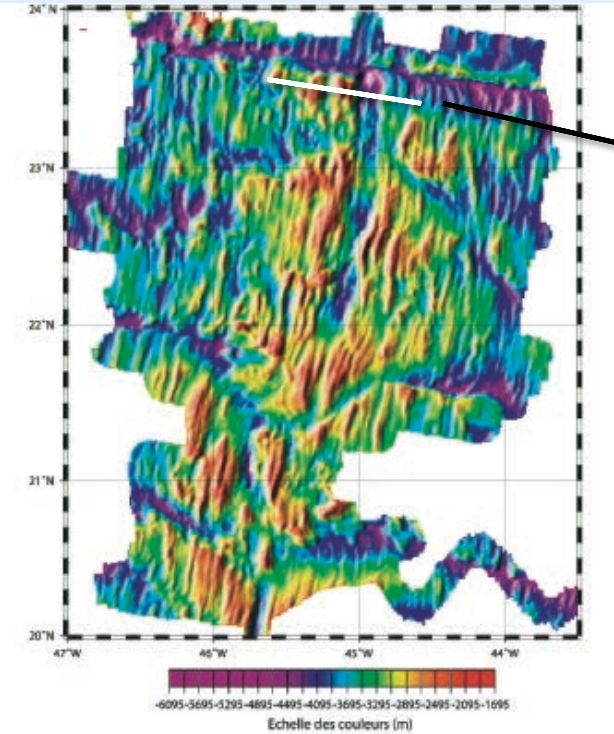
Modified from Tucholke et al., 2008

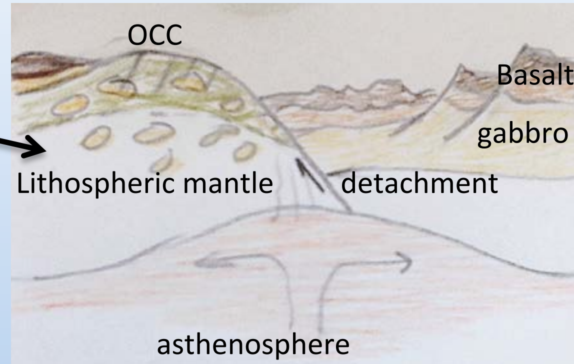
If spreading is highly magmatic (M close to 1) then few large normal faults will form because they will not be able to be active for long periods of time

If spreading is nearly amagmatic (M = 0 or very close to it) then spreading will be nearly fully tectonically accomodated and large normal faults will develop. In time, these fault surfaces will be ruptured by other normal faults that may eventually take on the main spreading.

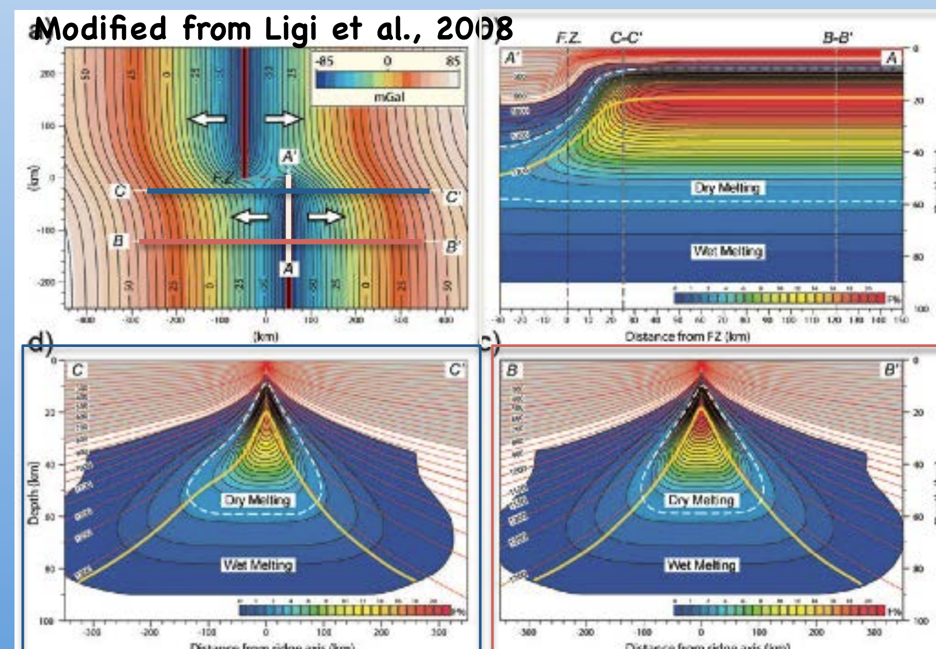
The role of transform faults on the structure of the oceanic lithosphere

Transform faults, as ridge axial discontinuities contribute to lower the mantle temperature (cold edge effect) and induce asymmetric spreading and gabbro and peridotite exhumation





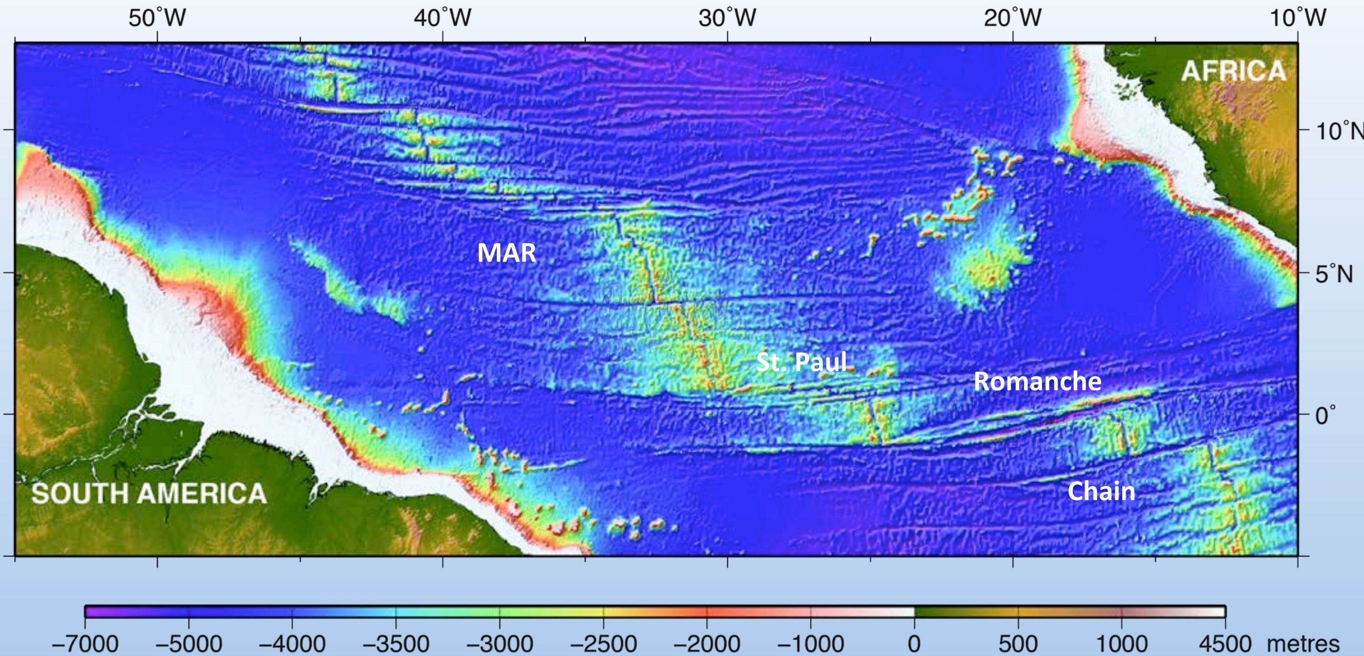
Numerical model results for a 100 km long offset transform fault. Degree of mantle melting (%) is shown along the ridge axis and on two across axis profiles at different distances from the transform.



Numerical models show the impact of the transform fault on the passive flow structure and on the mantle temperature and on the percent of melt generated below the ridge axis.

Larger offsets will induce stronger temperature and melt gradients

The Equatorial Atlantic large offset transforms: a unique area of the slow spreading Mid-Atlantic Ridge



Why?

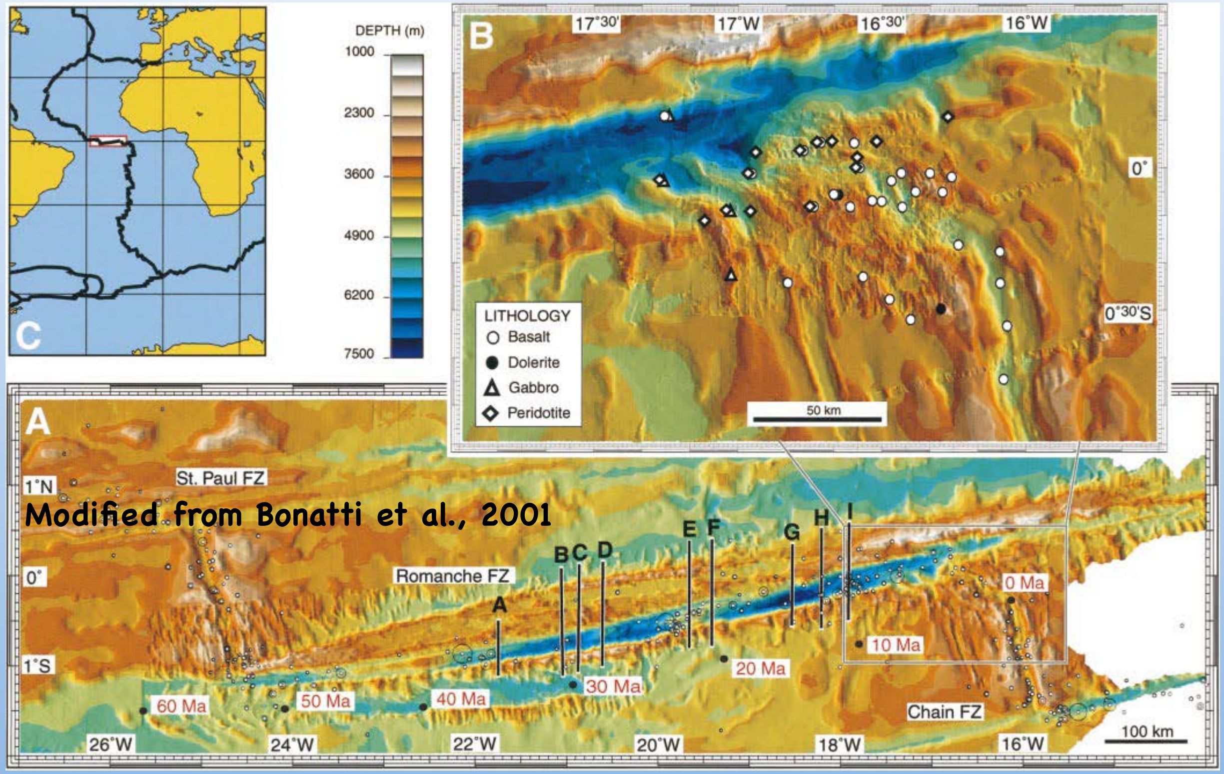
Large offset (and often complex) transform faults: St. Paul, Romanche, Chain
Very deep ridge axis (below 4000 m)
High peridotite/basalt ratio (islets formed of deformed peridotite – St. Peter & Paul's islets)
Estimated low melting rates from rock chemistry
Complex temporal evolution of the largest transform systems, such as St. Paul and Romanche

What are the effects of these large transform faults on the structure of the oceanic lithosphere? Specifically, what could be the effect of the Romanche mega-transform?

A few studies on the Equatorial Atlantic: Bonatti, 1990; Bonatti et al., 1993; 1994; 1996; Schilling et al., 1995; Seyler and Bonatti, 1997; Hékinian et al., 2000; Bonatti et al., 2001, Ligi et al., 2002; Ligi et al., 2008; Maia et al., 2016; Brunelli et al., 2019

The Romanche mega-transform fault and its Eastern intersection with the Mid-Atlantic Ridge

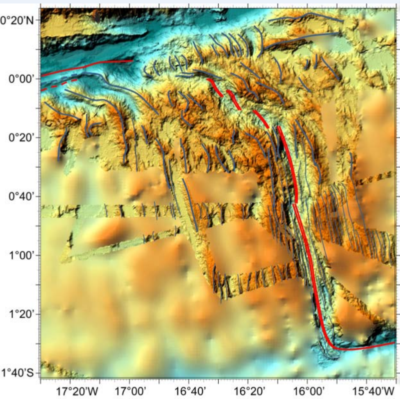
The Romanche mega-transform fault is the largest of the Atlantic and possibly the largest active transform fault in the oceans. It offsets the ridge axis for more than 900 km and corresponds to an age offset > 50 my.

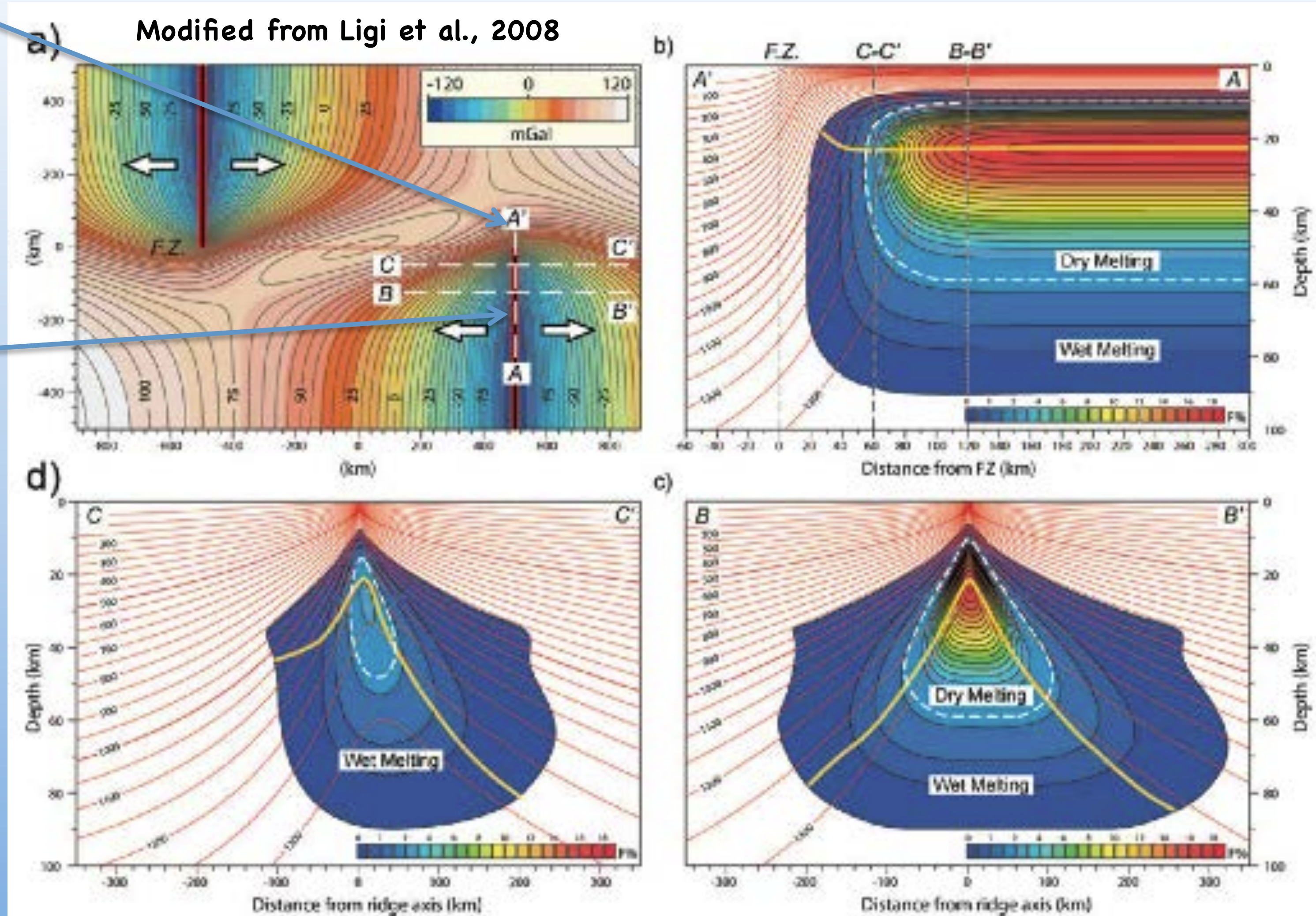


Previous cruises (e.g. Bonatti et al., 1994; 1996, Bonatti et al., 2001) revealed:

highly complex morphology of the tranform fault: lens-shaped slice of lithosphere, double fault…
ridge-transform intersection has a very anomalous morphology – oblique zones, heavily faulted surfaces
peridotites (and some gabbros) dredged over a large portion of the south flank of the transform (about 20 km-wide stretch)

The Romanche mega-transform fault and its Eastern intersection with the Mid-Atlantic Ridge





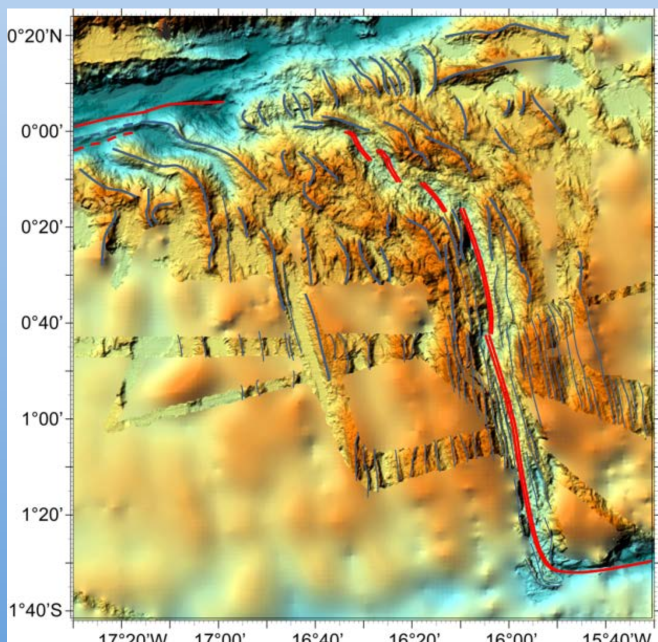
Models of the cold edge effect induced by the very large offset of the Romanche transform (Ligi et al., 2005)

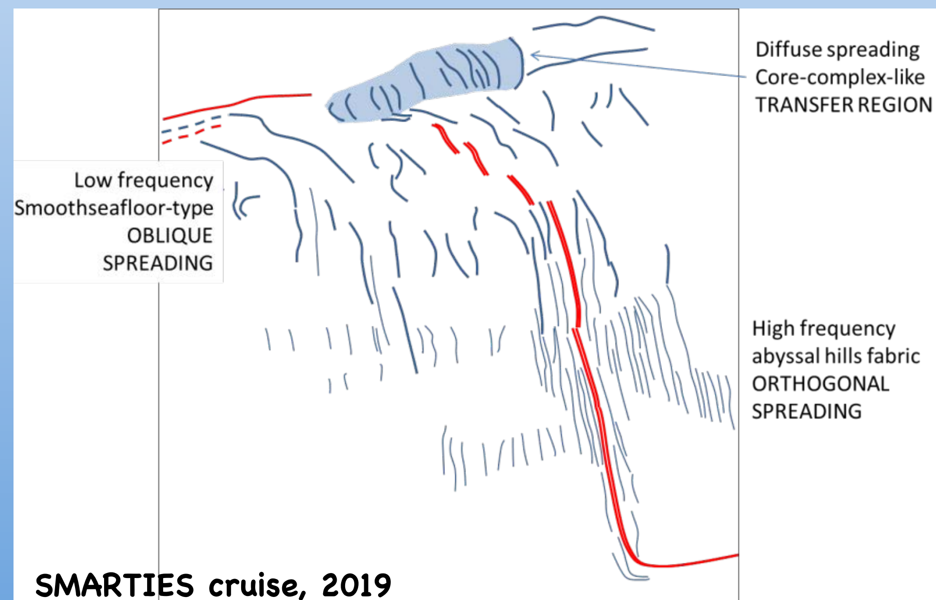
- extremely low melt rates at the axis, tectonically dominated spreading

The Romanche mega-transform fault and its Eastern intersection with the Mid-Atlantic Ridge: the SMARTIES cruise (2019)

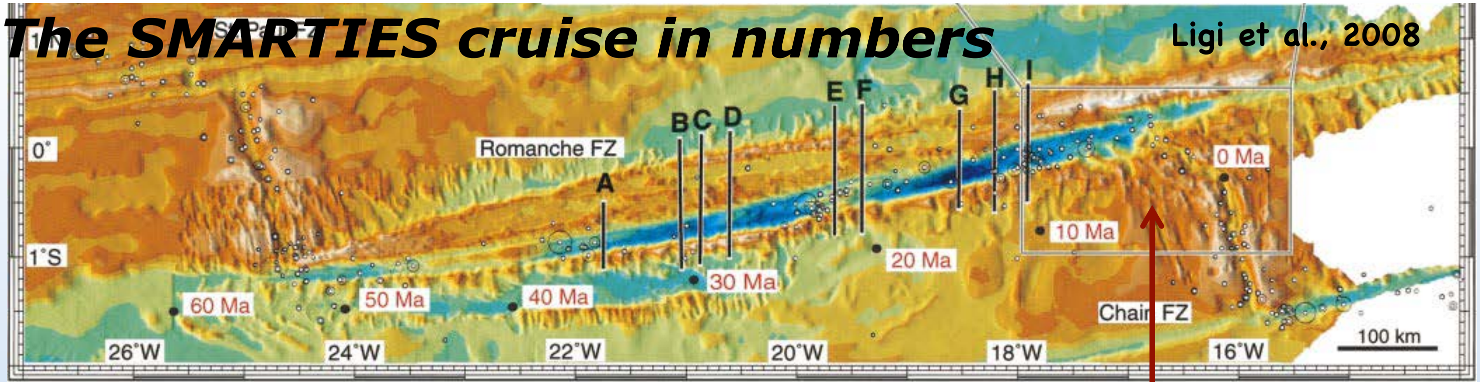
Objectives

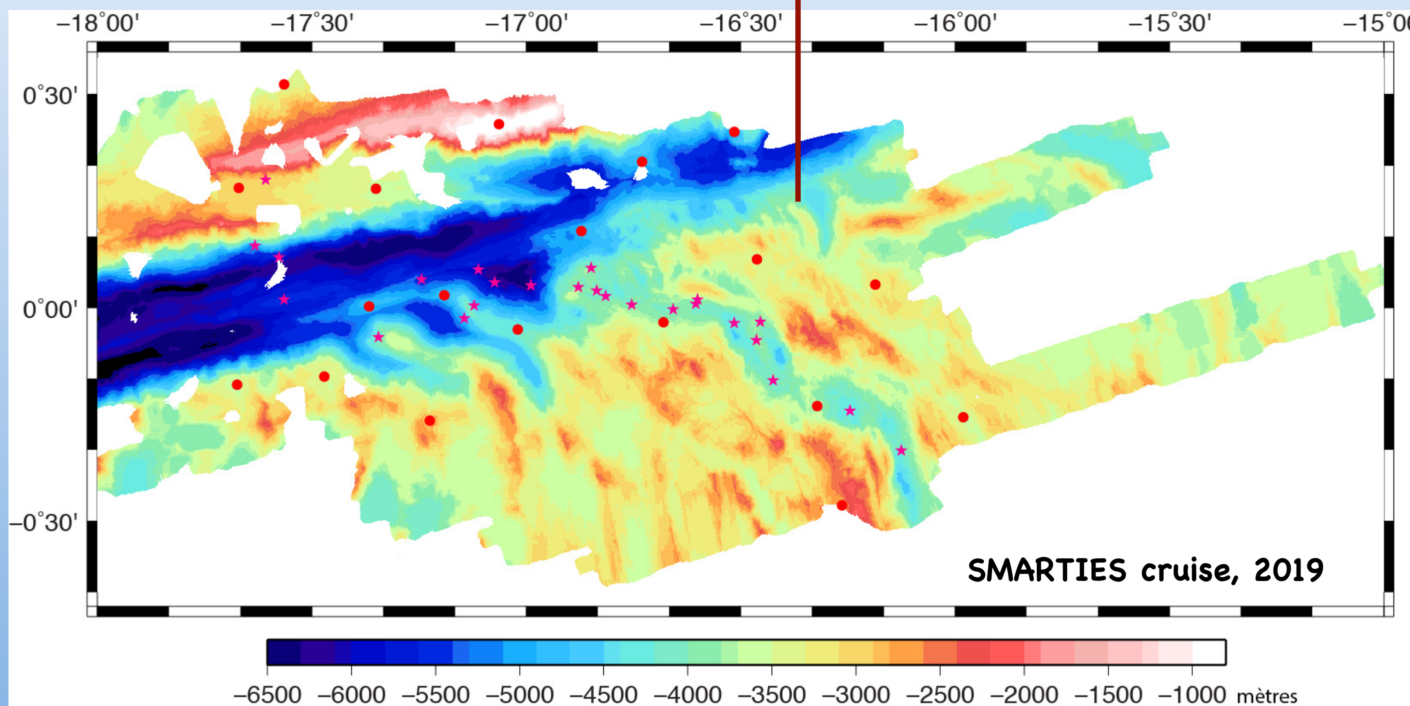
- To understand and quantify the influence of a strong thermal gradient on the spreading processes
    - Origin of the particular topography of the Ridge-Transform Intersection;
    - Origin of the alkali basalts previously sampled at the ridge axis;
    - Links between axial obliquity and magma supply;
    - Distribution and style of the axial volcanism and tectonics;
    - Hydrothermal processes: distribution and style.





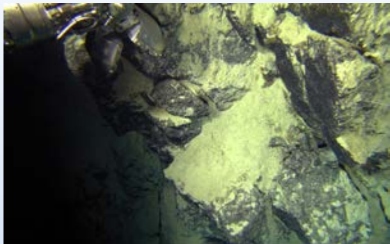
The SMARTIES cruise in numbers

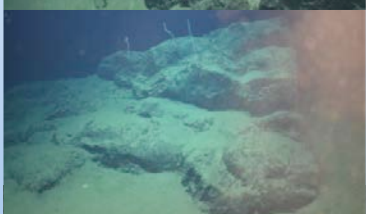


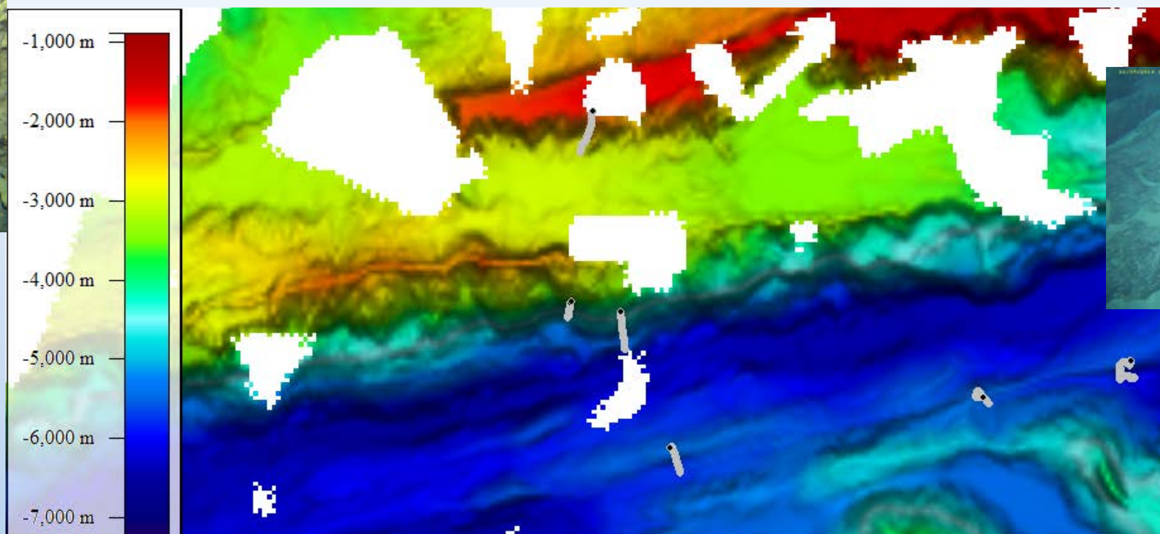


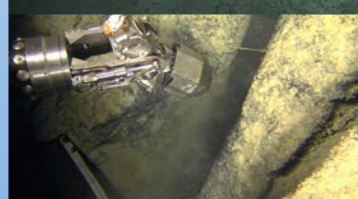
Bathymetry, gravity and magnetics: well covered area, very good resolution bathymetry
19 OBS deployed, 18 retrieved (red dots)
25 (of 23 scheduled) Nautile dives (pink stars) : 217 hours of videos and photographs, 2,2 T of rock samples
19 dives with the Nautile magnetometer

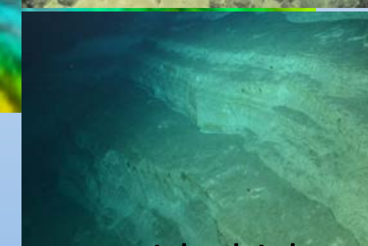
The north wall of the South-Eastern Romanche valley





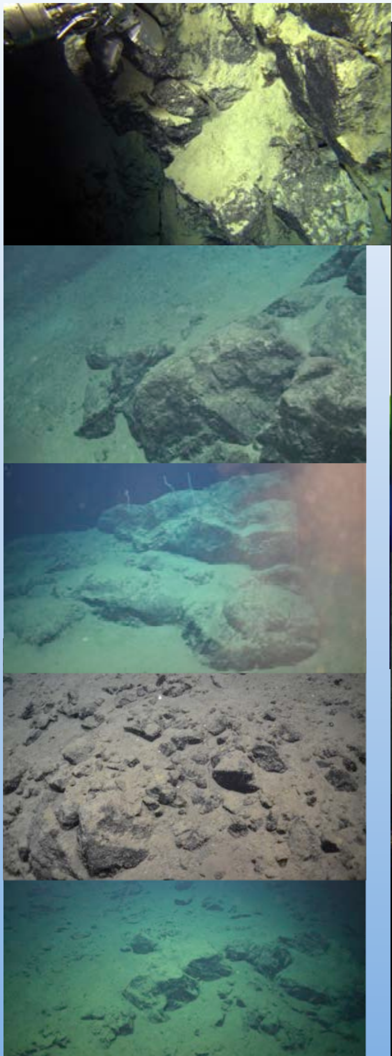


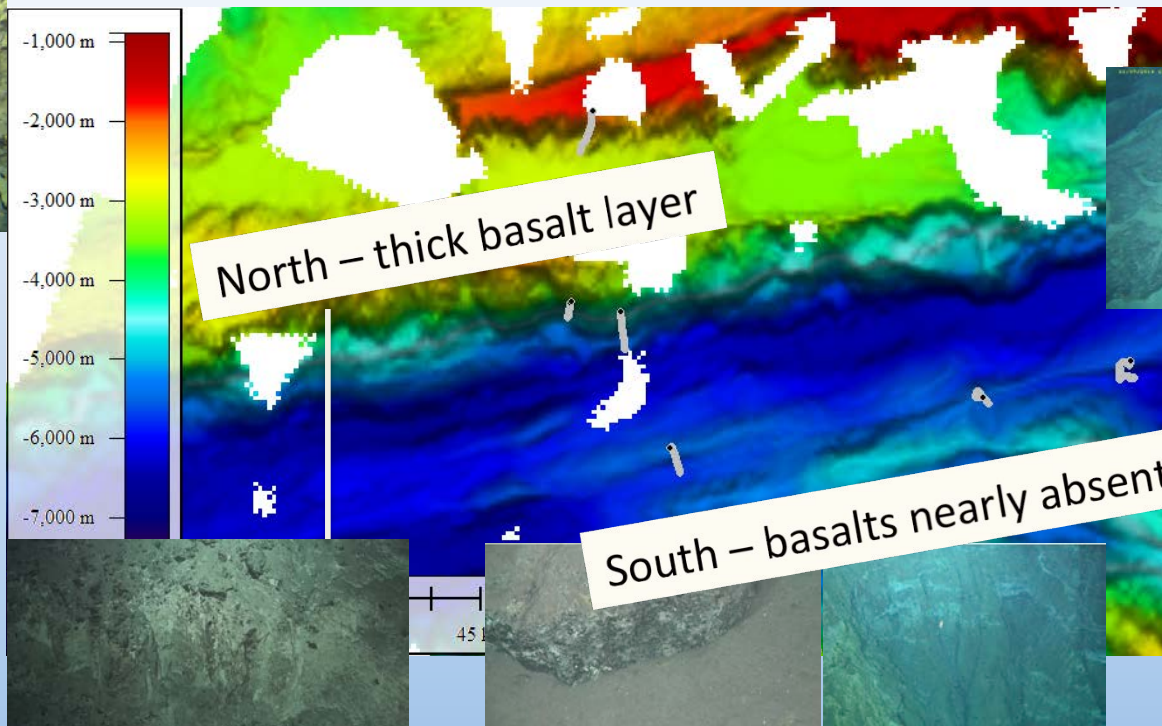


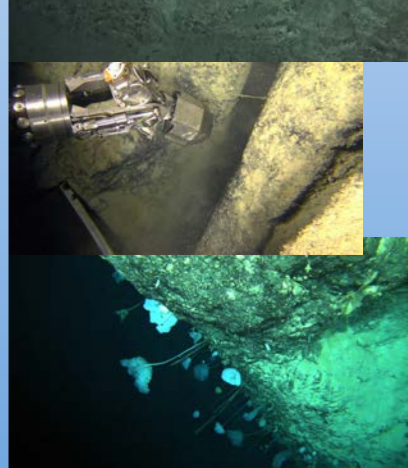


The section revealed a very magmatic crust with thick basaltic lava flows and a thick carbonate layer on top. In the nodal basin, the north and south walls are covered by a thick sediment layer and no clear outcrop was found. Samples recovered here are peridotites and gabbros.

The north wall of the South-Eastern Romanche valley

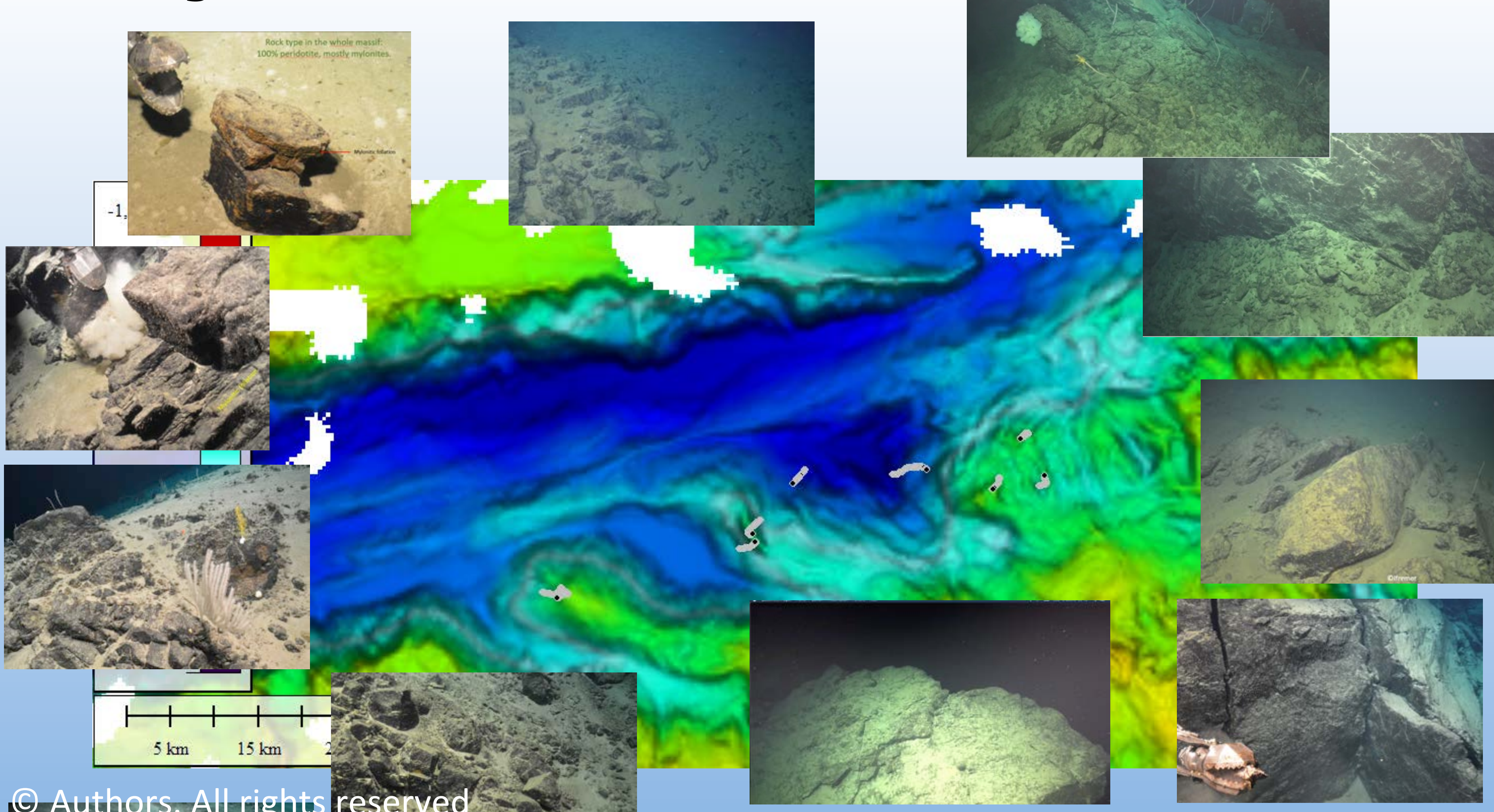


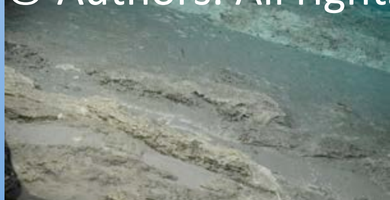




Strong asymmetry between both walls of the transform valley

The Ridge-Transform intersection area

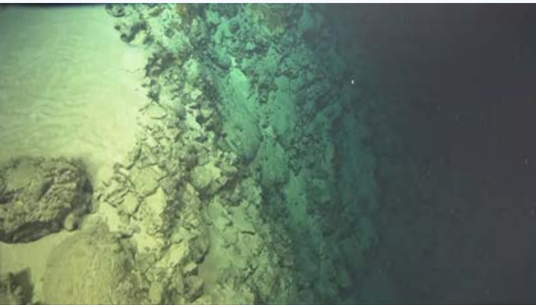


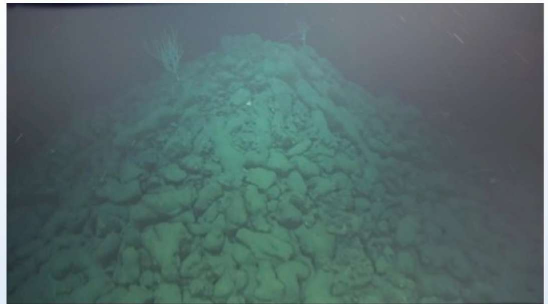


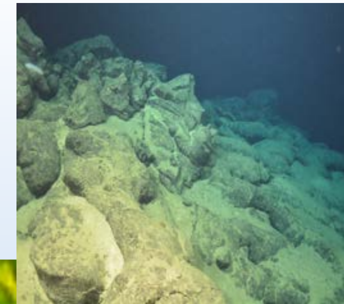
Highly deformed mylonitized peridotites
Samples from the core of one structure
No gabbros to be seen…

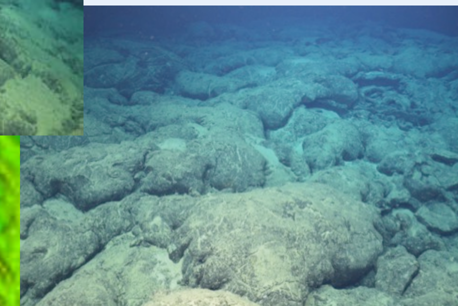
The hills mapped along the southern wall of the Romanche, as well as the highly deformed area to the East are fragments of OCCs (to the West) and a highly deformed OCC (to the East)

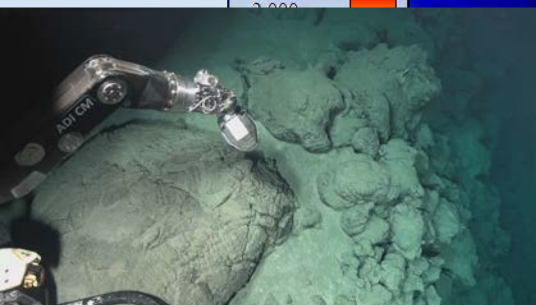
The axial area

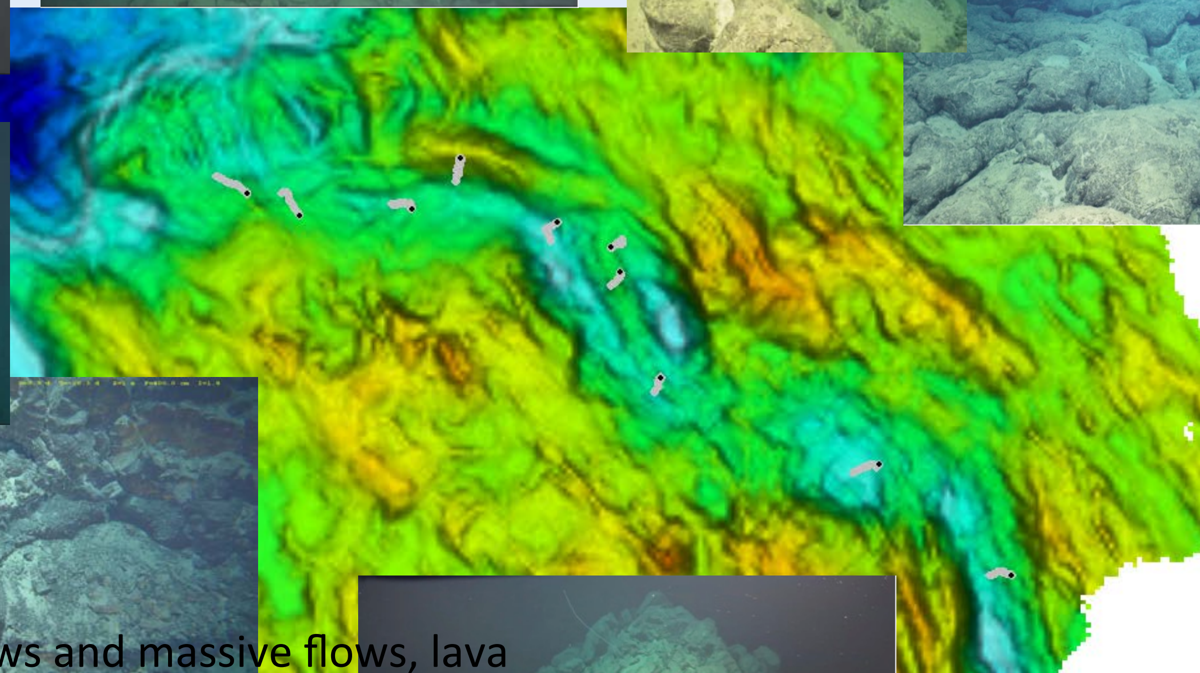


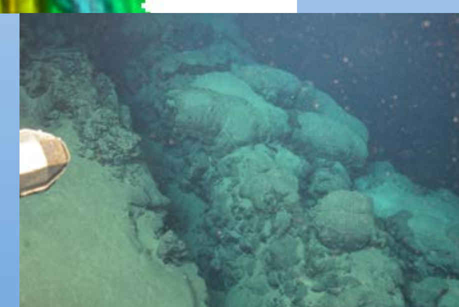












Variable morphology: pillows and massive flows, lava tubes

Very localized eruptive centers, some individual volcanoes

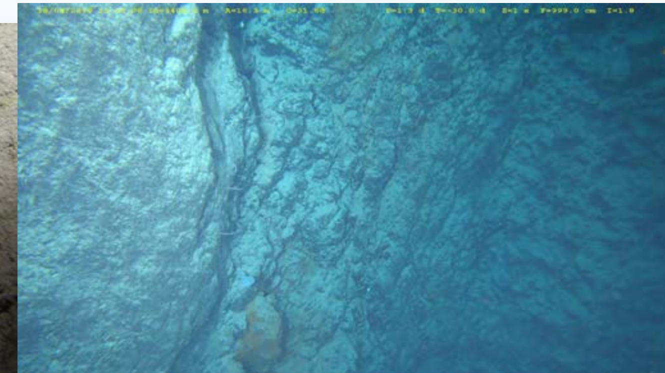
Faults and fissures cut the lava flows

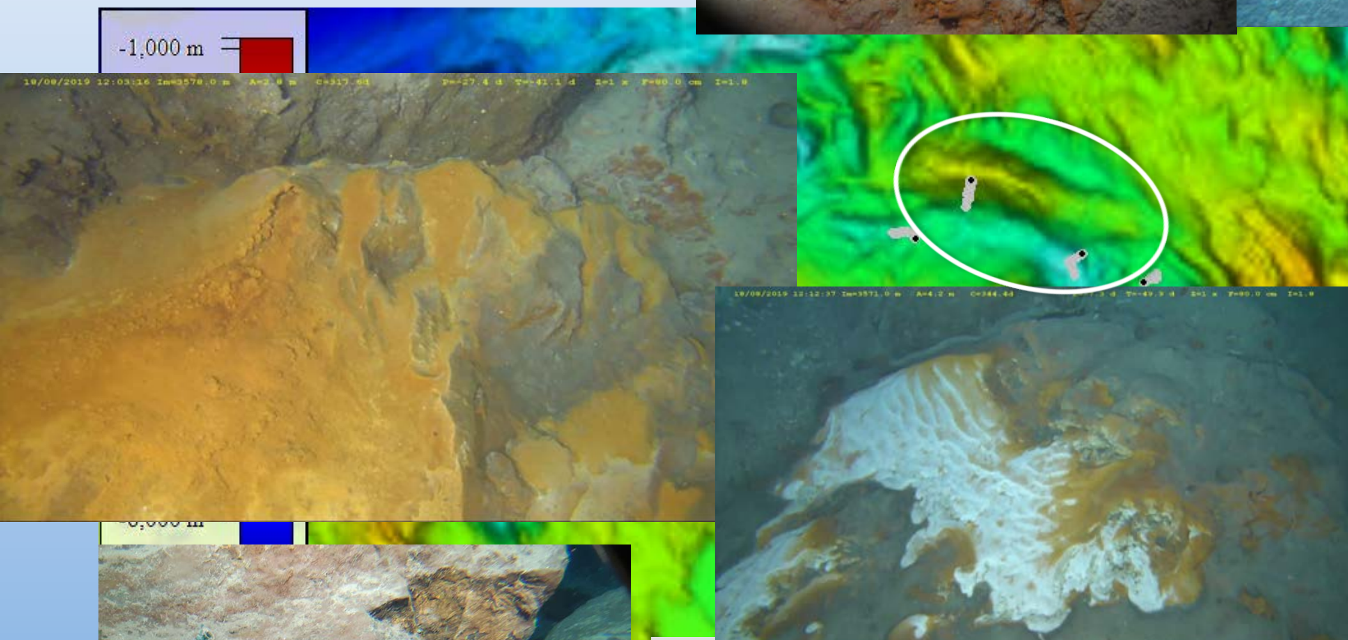
Flows overlay the faults

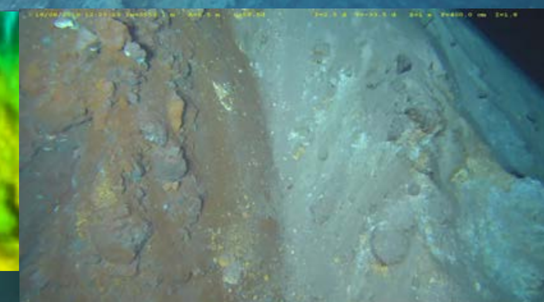
From a near normal axial area to the South to a highly oblique domain nearing the transform fault - Discontinuous and faulted neo-volcanic zone

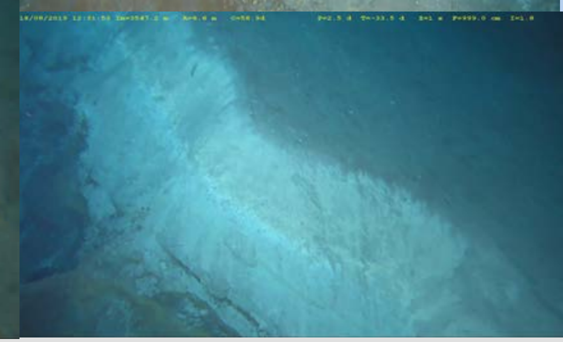
The oblique axial area and the hydrothermal area

Two old dredges: peridotites
Very high topography and an active fault on the Northeast flank
Strong obliquity









Normal fault, serpentinized peridotite.
Hydrothermal deposits in an erosional gully
Small fluid vents: low temperature fluids, residual heat? Or just from serpentinization?
Evidence of higher temperature deposits
Copper sulphides at the base of blocks

A few brief and very preliminary observations

There is clear evidence of an exceedingly low melt supply at the ridge axis south of the Romanche transform fault:

- ✓ off axis reliefs are formed by deformed peridotites (i.e. mantle) and several ruptured OCCs (different from the SWIR area…)
- ✓ axial volcanic zone highly faulted and discontinuous, forming patches of localized volcanic fields
- ✓ average depths are really… deep

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