FAULT SPACING ENHANCED BY SEDIMENTATION AT THE ANDAMAN SEA SPREADING CENTER

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TECTONICS INFLUENCED BY SURFACE PROCESSES?

• At **subaerial plate boundaries**: **surface reworking processes** (erosion, sedimentation) are shown to **enhance strain localization** onto a few long-lived faults (e.g. Masek and Duncan 1998; Willett, 1999 for orogens, Olive et al., 2014; Andrés-Martínez et al., 2019; Theunissen and Huismans, 2019 for continental rifts)

• However, the impact of surface processes is **hard to assess unequivocally** for **lack of reference systems** (no moutains without erosion for example); whereas **underwater plate boundaries** provide this opportunity

 Here, we study the impact of seafloor sediment deposition on fault longevity at the Andaman Sea Spreading Center by comparing it to unsedimented spreading centers of commensurate spreading rates

ANDAMAN SEA SPREADING CENTER: CONTEXT



- Spreading segment in the
 backarc area of the Sumatra subduction
 - Opening since 4Ma, full
- ^{11°} opening rate of 38 mm/yr since
 - 2Ma => slow spreading rate
 - Terrigenous sediment
- ^{10°} **deposition** from the Irawaddy river averaging 0.5 mm/yr

SEAFLOOR SPREADING IN THE ANDAMAN SEA

- Little seafloor relief beyond axial valley. Notable symmetry.
- 10-km thick crust, mostly igneous (sills), comprising 1-2 km of sediment.
- Major inward-facing normal faults 8–15 km apart, dips ~30°.



AN UNUSUAL MODE OF SEAFLOOR SPREADING

- Like other spreading centers: **sequential on-axis faulting** followed by **off-axis fault abandonment**
- Here, however, faults are progressively blanketed as they grow



AN UNUSUAL MODE OF SEAFLOOR SPREADING

ASSC: more widely spaced faults with lower dips compared to spreading centers of commensurate spreading rate.



Potential feedbacks between sedimentation and normal faulting?

NUMERICAL MODEL SETUP: FAULTS VS. MAGMA

- Hybrid finite-element / finite-difference technique (FLAC).
- Conservation of mass, momentum and energy in visco-elasto-plastic medium.



80% MAGMATIC EXTENSION (NO SEDIMENTATION)

Map of irreversible strain after 5Ma:



Characteristic fault lifespan ~ 200 kyrs, **fault spacing 4-5 km**. Fault rotation down to ~ 40° .

CONTROLS ON FAULT LIFESPAN AND SPACING

- Normal faults remain active as long as it takes less force to <u>slip + flex</u> <u>adjacent blocks + grow **topography**</u> than to break a new fault on-axis.
- The energy cost of sustaining fault slip increases with increasing offset, **drastically so in thick lithosphere**.

Force required to sustain fault activity:





CONTROLS ON FAULT LIFESPAN AND SPACING

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Greater on-axis magma injection rates push faults off-axis more quickly, resulting in more closely-spaced faults with shorter offsets.



MAGMATISM DECREASES FAULT LIFESPAN



Andaman Sea Spreading Center has **high fault spacing in spite of relatively high magma supply** (10-km thick crust, M > 0.65).

MODEL: FAULTS VS. MAGMA VS. SEDIMENTS

• Tectono-magmatic model fully-coupled with simple seafloor evolution rule representing sediment deposition:



IMPLEMENTATION OF SEDIMENT DEPOSITION



80% MAGMATIC, SEDIMENTATION RATE 0.5 MM/YR

Map of irreversible strain after 5Ma:



Characteristic fault lifespan ~ 300 kyrs, **fault spacing ~9 km**. Fault rotation down to ~ 30° .

POSSIBLE EFFECTS OF SEDIMENT DEPOSITION

- Loading increases on-axis normal stress -> increases F_{BREAK}
- Warms up lithosphere through thermal blanketing -> decreases ∂F_{EXT} / ∂ extension
- Alleviates the cost of topography build-up by leveling relief & reducing effective density contrast ("faulting in an ocean of sediments") -> decreases ∂F_{EXT} / ∂ extension

-> increases fault lifespan & spacing



EFFECT OF SEDIMENTATION ON FAULT LIFESPAN



• The decrease of fault lifespan with increasing M holds true for all tested sedimentation rates

For M ≥ 0.7, sedimentation
 can increase fault lifespan
 up to 50%

 For less magmatic cases, we find no significant effect of sediment deposition on fault lifespan

EFFECT OF SEDIMENTATION ON FAULT SPACING



Sedimentation: decreases the energy cost of topography build-up

5 Magma injection: increases the energy cost of fault growth

MODULATION BY M OF SYSTEM SENSITIVITY

- Less magmatic extension seems to reduce the sensitivity of fault lifespan and spacing to sediment deposition
- Hypothesis: competition between sediment deposition and fault-induced topography
- Faster slipping faults (associated with low M) builds tectonic relief faster, which is harder to bury, therefore reducing the efficiency of sediment blanketing
- To test this hypothesis, we define Ψ as follows :



MODULATION BY M OF SYSTEM SENSITIVITY



(here fault lifespan is normalized by the lifespan of cases without sedimentation)

MODULATION BY M OF SYSTEM SENSITIVITY



 The results fall within an envelope of increasing lifespan for increasing Ψ
 To first order, our non dimensionalization corrects the

effect of M on sediment blanketing efficiency

• However, **results still cluster by M value**

=> **other non-elucidated control** of M on fault lifespan

For M = 0.6 sedimentation seems
to reduce fault lifespan, which we do not yet understand

CONCLUSIONS

• Heavily-sedimented Andaman Sea Spreading Center features more widely spaced faults with lower dips compared to mid-ocean ridges of commensurate spreading rate.

- Thick igneous crust suggests that high spacing is unlikely to result from subdued magma supply.
- Models suggest that sedimentation enhances tectonic strain localization on a few major faults by alleviating the energy cost of topography build-up.
- Unusual faulting styles & greater fault rotation consistent with sedimentenhanced fault lifespan in the Andaman Sea.
- A straightforward illustration of feedbacks between tectonics and surface processes, in a submarine (and magmatic!) environment.