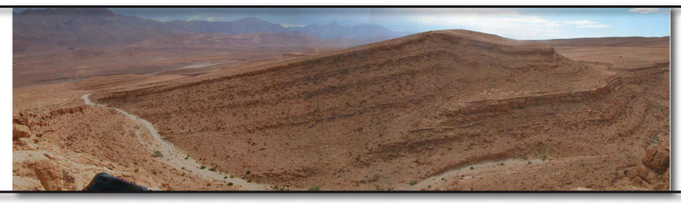
TO meeting - Nov. 2009



Predicting the Evolution of Fold-and-Thrust belt

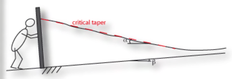
Nadaya Cubas
cubas@gps.caltech.edu

Coll. :
Y. Leroy (1), B. Maillot (2),
P. Souloumiac (1), C. Barnes (2)

(1) ENS, Paris
(2) Université Cergy-Pontoise
(3) Jussieu, Paris

J.P. Avouac (4)
(4) CalTech

Mechanical predictions



the limit analysis theory :

Comes from civil ingeneering and predicts an *upper* and a *lower* bound of the force necessary to create a rupture in a structure.

2 basic ingredients :

(1) Mechanical equilibrium
(2) The theory of maximum rock strength

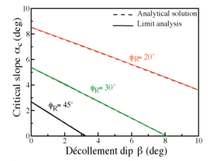
Composed of 2 approaches :

(1) The external approach : kinematical approach : Searchs for the lower upper bound of the tectonic force : *predicts positions of faults*

(2) The internal approach : static approach : Searchs for the upper lower bound of the tectonic force : *predicts stress field*

The external approach : predicting thrusting sequences

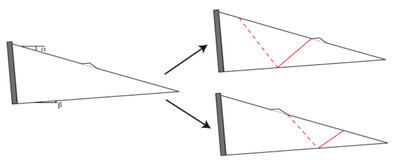
Critical taper of Dahlen et al. (JGR, 1984) properly captured :



for various ramp frictions (ϕ_R),
both approaches provide same results

➤ First validation of the theory

Effects of a small perturbation on the critical taper :



➤ Surface processes play major role on activation or abandon of faults

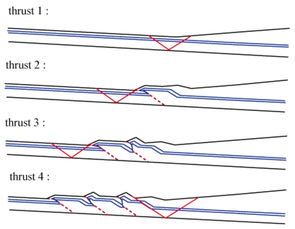
A predicted sequence of thrusts :

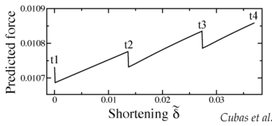
➤ New thrust always at the topographic slope break

➤ Thickening above the ramp

➤ Out-of-sequence formed to recover critical taper

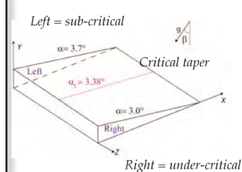
➤ Weakening accounted for by a decrease of the friction of the ramp

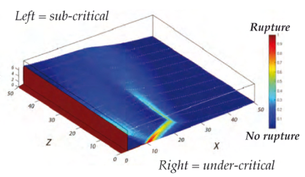


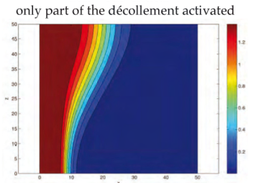


Cubas et al., JGR 08

3D predictions :





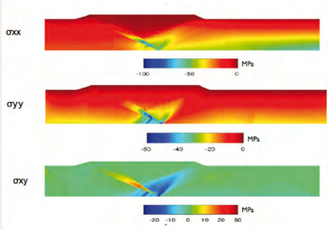


➤ 3D effects on the critical taper

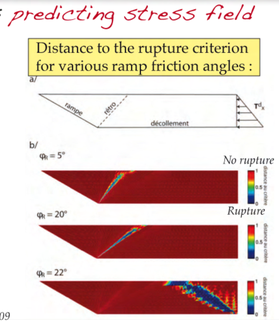
Souloumiac et al., submitted

The internal approach : predicting stress field

Optimized stress field :



Distance to the rupture criterion for various ramp friction angles :



➤ For larger ramp friction : new ramp formed at the back

Souloumiac et al., JGR 09

Analogue validation

Cadell, 1890

To validate the theory, an inverse study comparing mechanical predictions with sandbox experiments has been carried out :

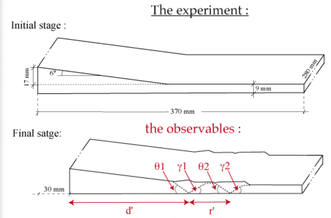
Inversion principle :

Since the theory predicts positions, dips, lifetimes and forces from the rheological parameters, inversion consists in retrieving the sand rheology from the experiments geometry.

Experimental set-up :

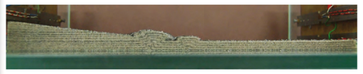
Quantitative comparison requires to determine the intrinsic variability of the experimental results. Therefore, we studied only one experiment repeated 10 times. And a statistical study has been conducted to construct the statistical models of the observables.

The experiment :

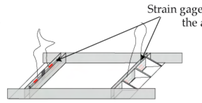


the observables :

+ force + lifetime 1st thrust

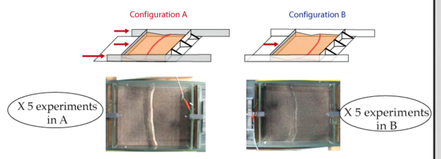


The sandbox :

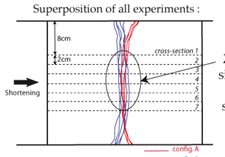


To control side walls effects :

2 configurations permitting a reversible motion of the lateral walls and thus an inversion of the lateral friction :



Superposition of all experiments :



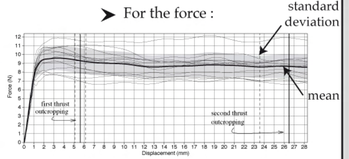
Zone devoid of side walls effects selected for statistical study

Cubas et al., subm.

Statistical results :

➤ After a complete statistical analysis, the errors bar of each observable is obtained (standard or mean deviation) :

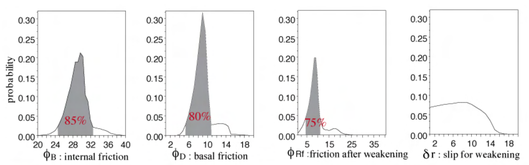
➤ For the force :



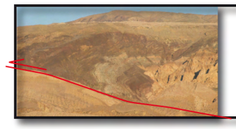
Cubas et al., subm.

Probabilities distributions :

➤ The internal and basal friction are in good accordance with independent measurements. However, the very low friction after weakening is not already explained.



Field applications

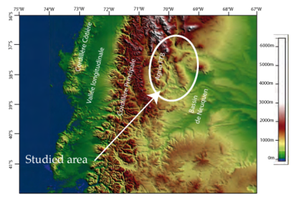


The theory can be applied in different ways :
another inverse study can be carried out to retrieve the rheology of a structure from its geometry
or the theory can be applied to provide mechanical arguments to structuralists.

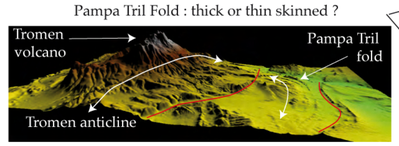
Mechanical validation of kinematical models :

The Agrio is a cretaceous fold-and-thrust belt in Argentina. Its northen area is mainly recovered by volcanic deposits and very poor information has been obtained from seismic lines. 2 differents interpretation for the Pampa Tril fold are in competition :

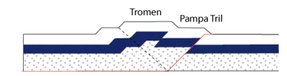
(1) in favor of a crustal fault,
(2) in favor of an intermediate décollement.



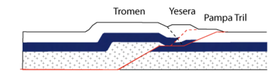
Pampa Tril Fold : thick or thin skinned ?



Thick-skinned model :



Thin-skinned model :

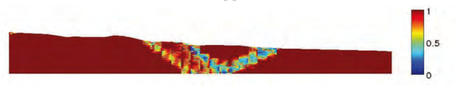


➤ By comparing the force required by each hypothesis, the intermediate décollement seems favored.

Retrieve mechanical parameters from strucural geometry :

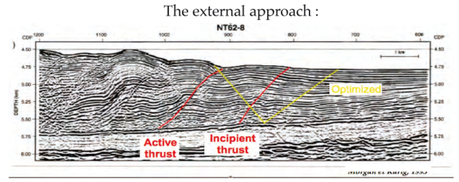
We searched for which basal and internal frictions an optimized thrust would appear near the incipient :

The internal approach :



Souloumiac et al., JGR 09

The external approach :

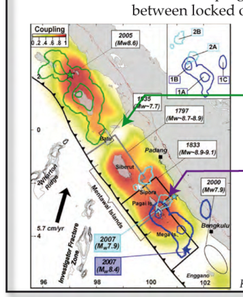


➤ Both approaches found :
9° (μ = 0.15) for the basal friction
27° (μ = 0.5) for the internal friction

Morgan and Karig, JSG 94; Cubas et al., JGR 08

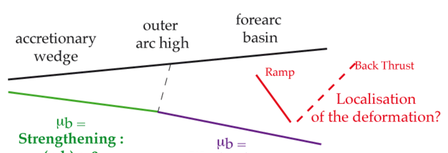
? Further studies at TO

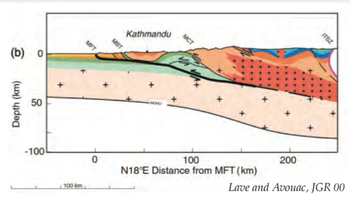
Basal friction of the Sumatra subduction :
difference between creeping or stick slip sliding regions?
between locked or coupling zone ?



Konca et al., Nature 08

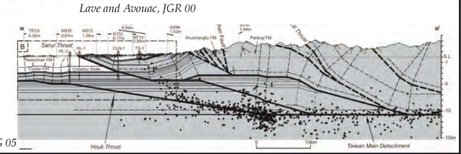
The rate- and state- dependent laws : can we applied limit analysis ?
study of the localisation of the deformation considering a décollement with weakening and strengthening areas?





Lave and Avouac, JGR 00

What about other crustal wedges?
How to explain the South Tibetan Detachment?
Taïwan wedge?



Yue et al., JSG 05

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