Fault Branching

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References – Fault Branching

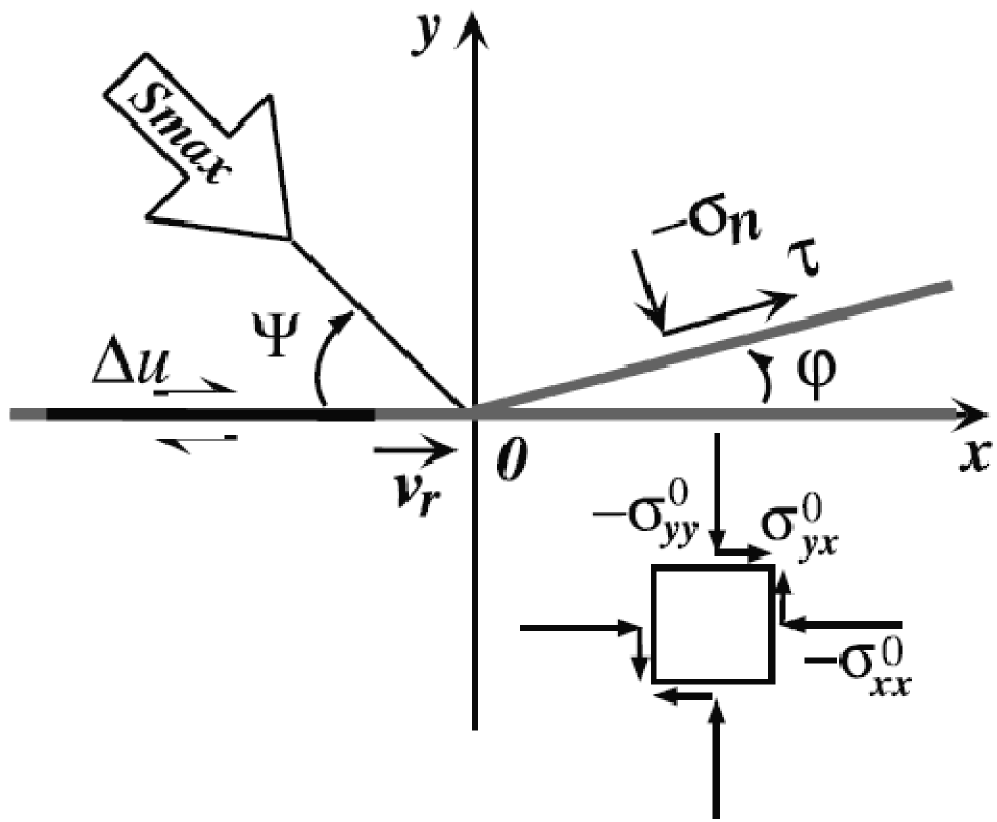
- Kame, N. and T. Yamashita (1999). Simulation of spontaneous growth of dynamic crack without constraints on the crack tip path. Geophys. J. Int. 139, 349-358.

- Kame, N., J.R. Rice and R. Dmowska (2003). Effects of prestress state and rupture velocity on dynamic fault branching. J. Geophys. Res. 108, ESE 13-1 – 13-21.

Fault Branching Model

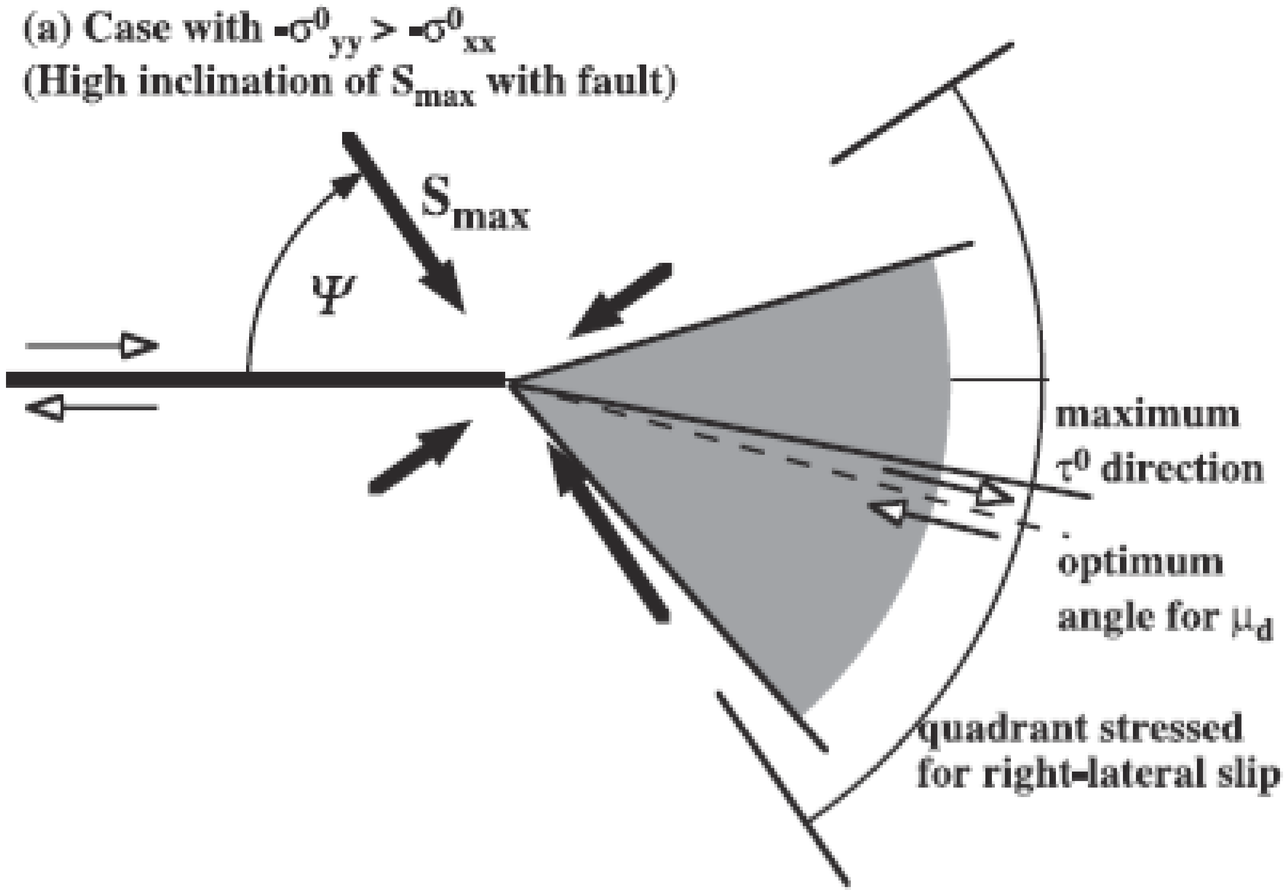
- Dynamic rupture modeling of strike-slip faulting shows that the rupture prefers to bend than to run straight (Kame and Yamashita, 1999)
- On pre-existing strike-slip faults with branches (Kame et al., 2003), the rupture mode depends on
- Ψ = angle between the direction of maximum compressive stress (Smax) and the fault strike
- φ = angle between the main fault and the branch fault
- vr = rupture velocity (expressed as a fraction of the shear wave velocity cs)

Configuration of a preexisting branched fault system and prestress state



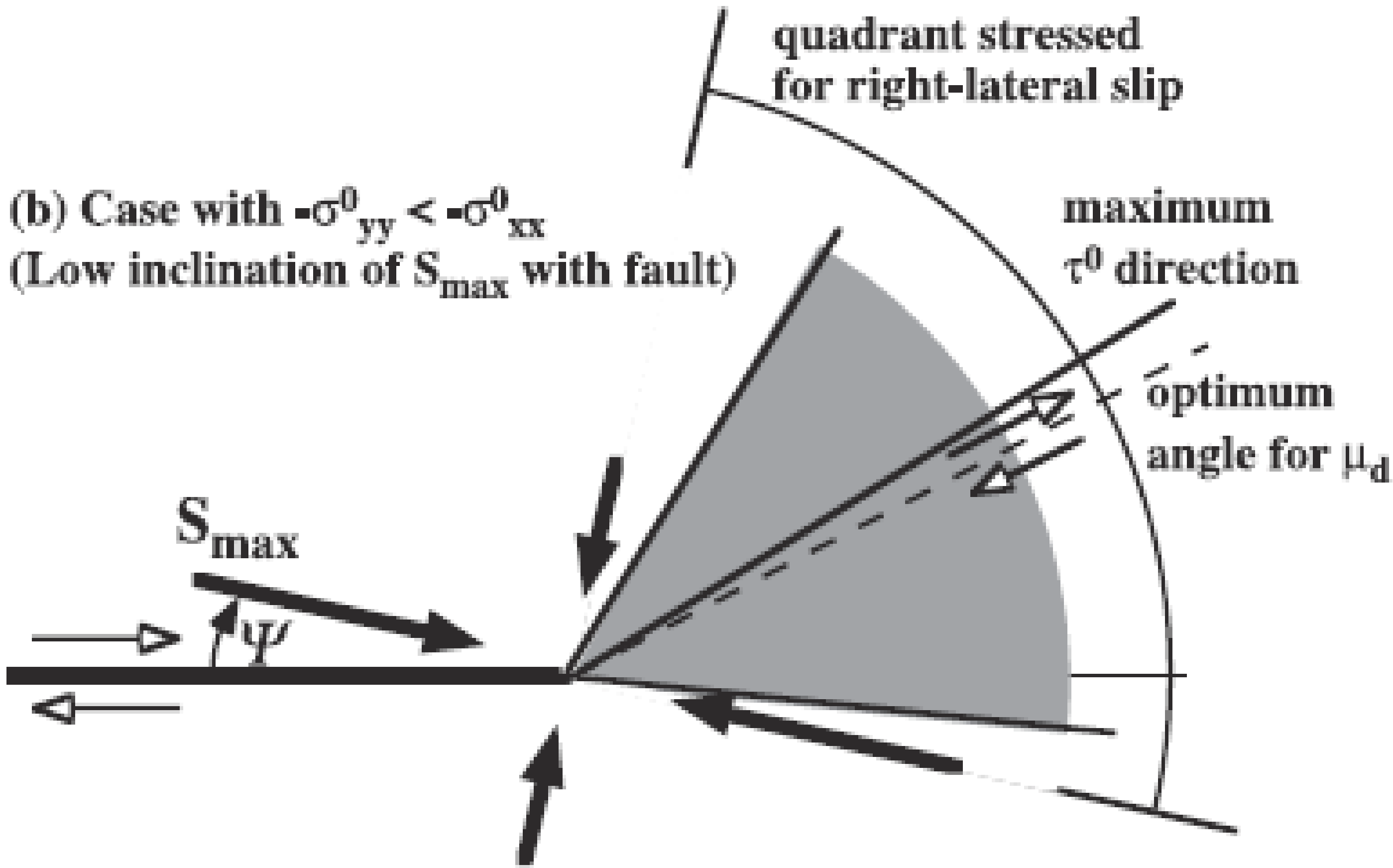
Fault-normal precompression is dominant, Ψ > 45°, allowing rupture to continue along bend paths

primarily to the extensional side



Fault-parallel precompression is dominant, Ψ < 45°, allowing rupture to continue along bend paths

primarily to the compressional side

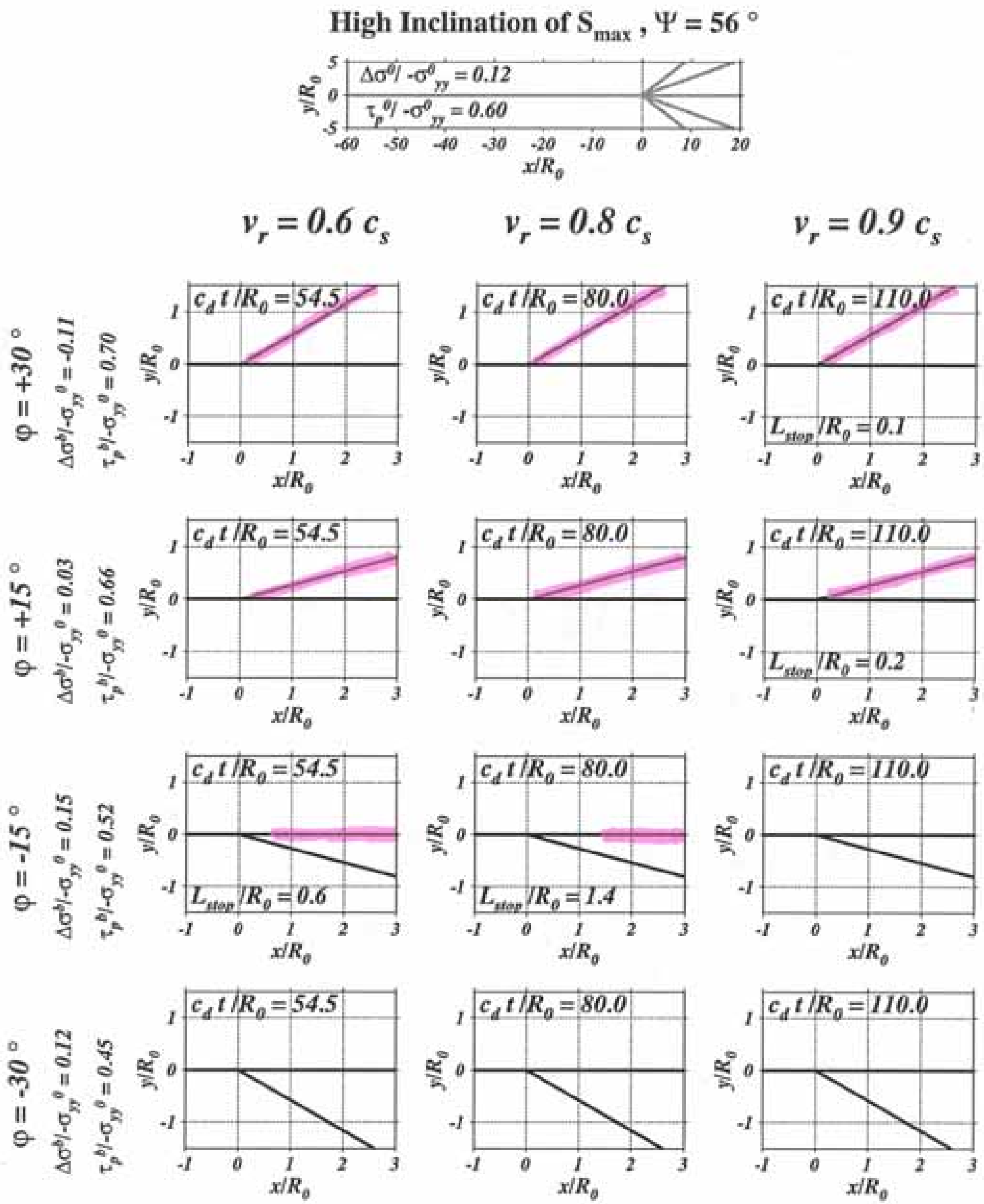


Rupture Modes

Mode	Description	Examples
1	Rupture on both main fault and branch fault	1979 Imperial Valley 1995 Kobe 1992 Landers
2	Rupture only on branch fault	1990 Luzon 2002 Denali
3	Rupture only on main fault	2001 Kokoxili (Kunlunshan)

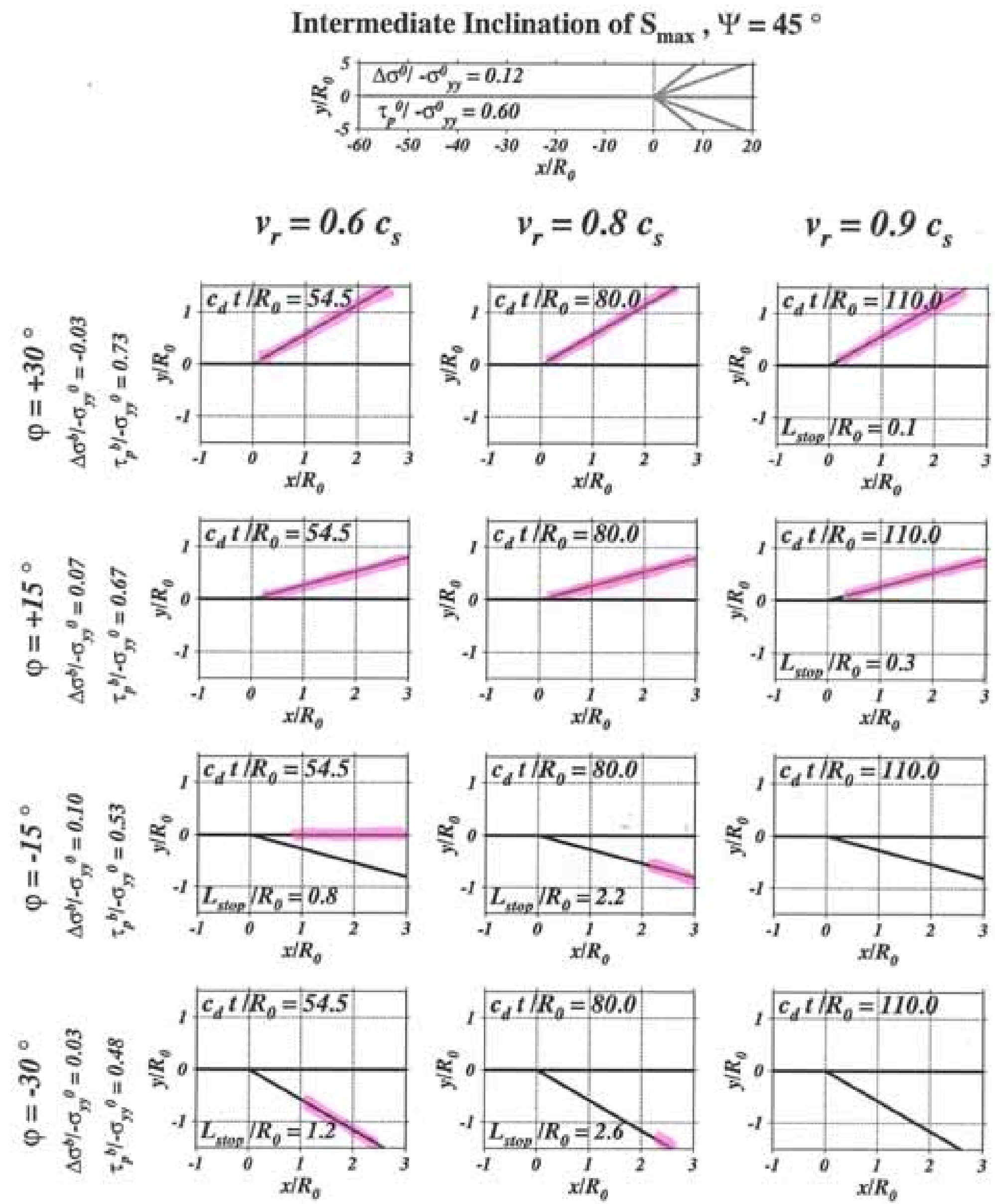
Case Histories of Earthquakes on Branched Faults

EVENT	MAIN FAULT	BRANCH FAULT	REFERENCE
1979 Imperial Valley	**Imperial**	**Brawley**	Kame et al., 2003
1990 Luzon	Philippine	**Digdig**	Rantucci, 1994
1995 Kobe	**Suwayama (Gosukebashi)**	**Okamoto**	Sekiguchi et al., 2000
1992 Landers	**Johnson**	**Kickapoo**	Kame et al., 2003
2001 Kokoxili (Kunlunshan)	**Kunlun**	Kitadan	Bhat et al., 2007
2002 Denali	Denali	**Totschunda**	Bhat et al., 2004



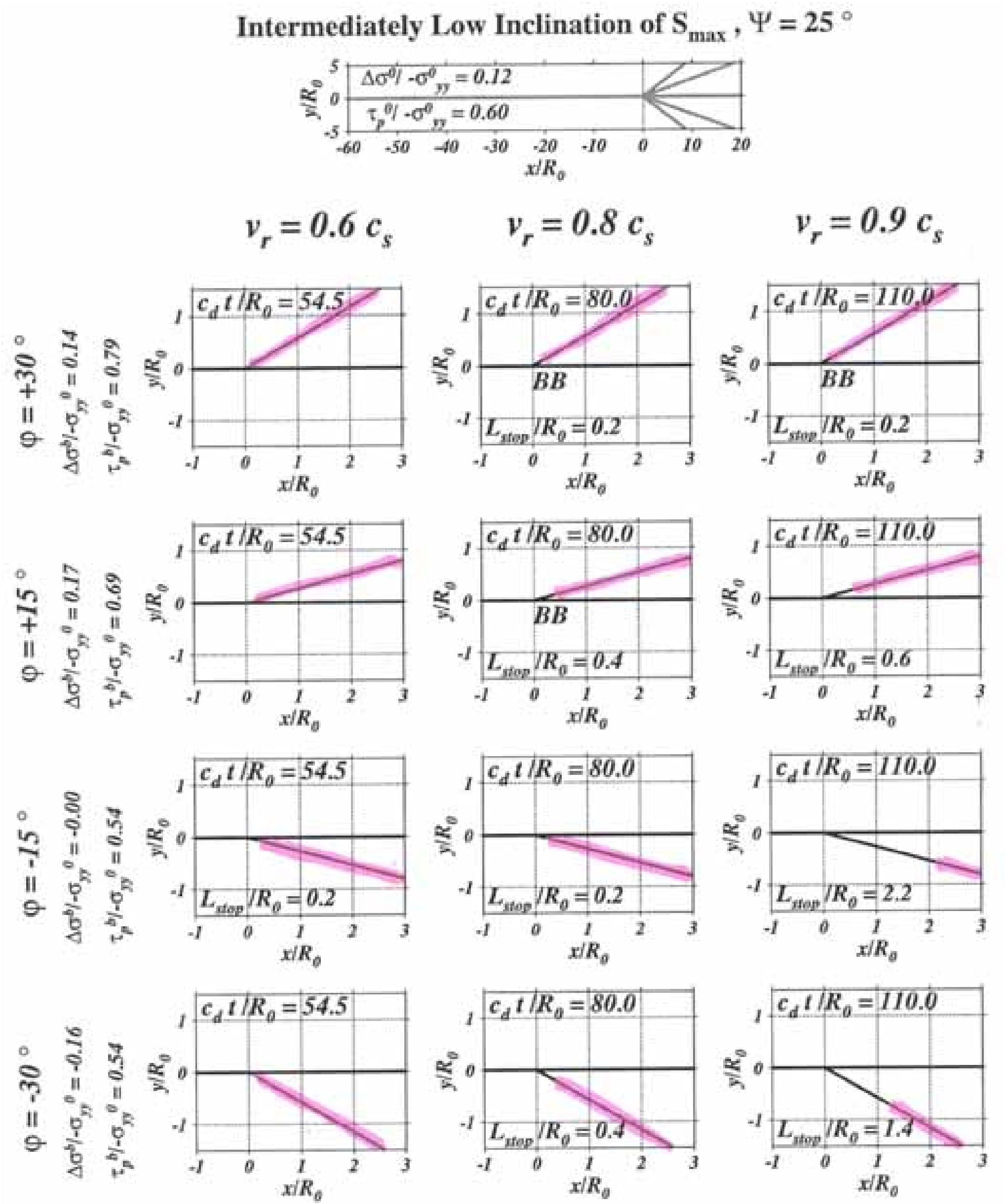
2002 Denali

1992 Landers

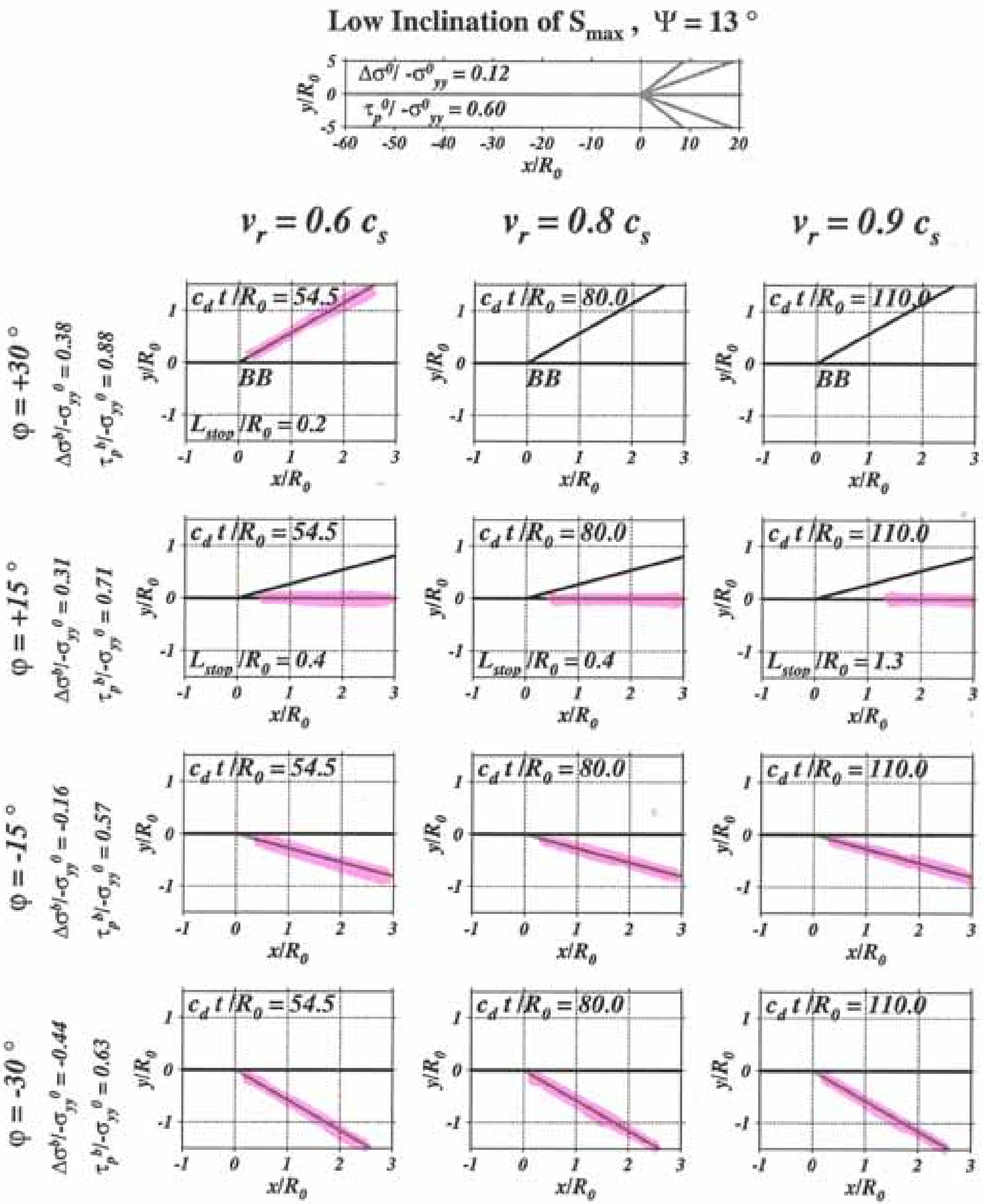


1995 Kobe

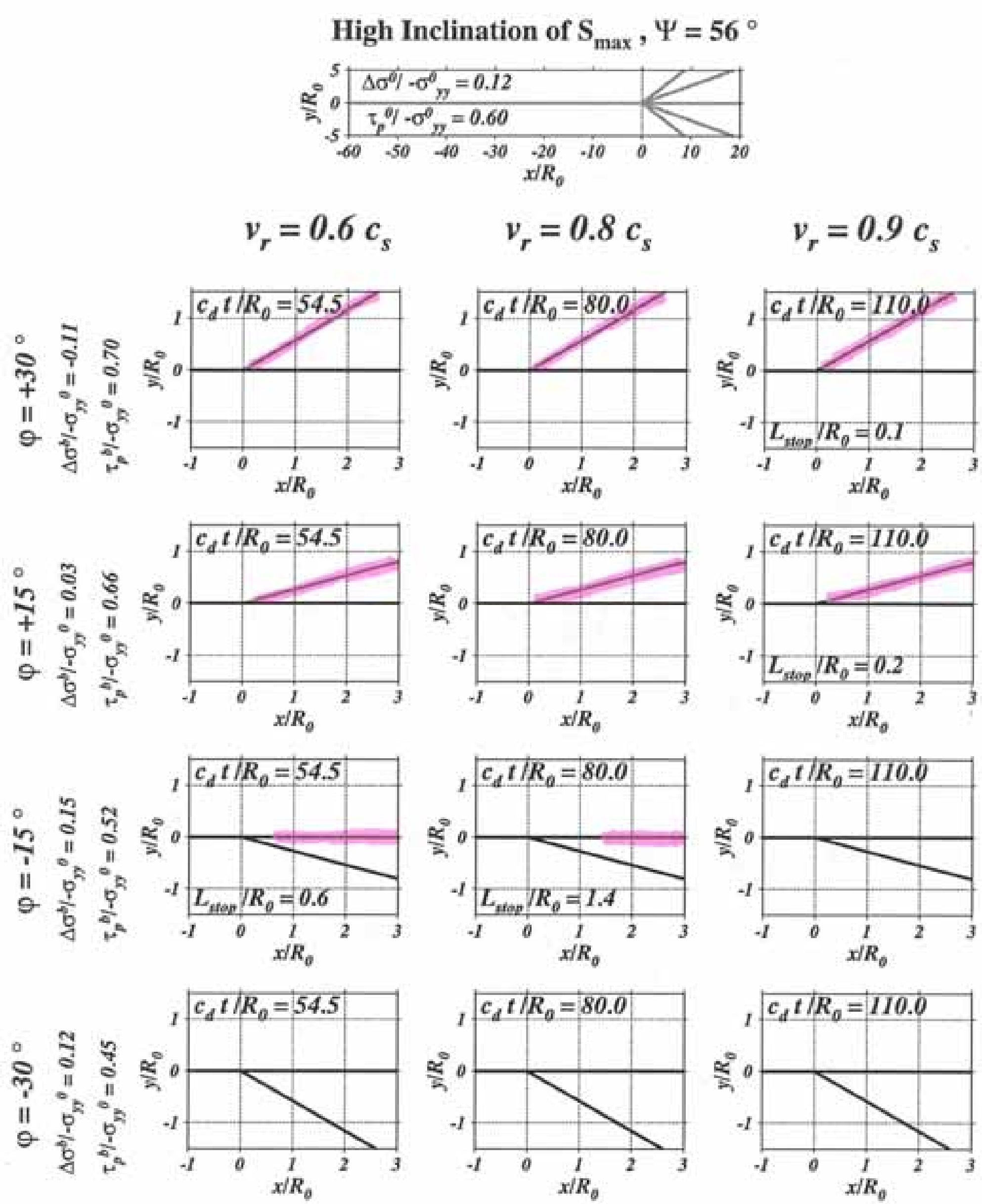
1979 Imperial Valley



2001 Kokoxili?


Low Inclination of S_{max} , $\Psi = 13°$
$\Delta\sigma^0 / -\sigma^0_{yy} = 0.12$
$\tau_p^0 / -\sigma^0_{yy} = 0.60$
$v_r = 0.6\ c_s$
$v_r = 0.8\ c_s$
$v_r = 0.9\ c_s$
$\varphi = +30°$
$\Delta\sigma^b / -\sigma_{yy}^0 = 0.38$
$\tau_p^b / -\sigma_{yy}^0 = 0.88$
$\varphi = +15°$
$\Delta\sigma^b / -\sigma_{yy}^0 = 0.31$
$\tau_p^b / -\sigma_{yy}^0 = 0.71$
$\varphi = -15°$
$\Delta\sigma^b / -\sigma_{yy}^0 = -0.16$
$\tau_p^b / -\sigma_{yy}^0 = 0.57$
$\varphi = -30°$
$\Delta\sigma^b / -\sigma_{yy}^0 = -0.44$
$\tau_p^b / -\sigma_{yy}^0 = 0.63$
$c_d\ t / R_0 = 54.5$
$c_d\ t / R_0 = 80.0$
$c_d\ t / R_0 = 110.0$
BB
$L_{stop} / R_0 = 0.2$
$L_{stop} / R_0 = 0.4$
$L_{stop} / R_0 = 1.3$
x/R_0
y/R_0

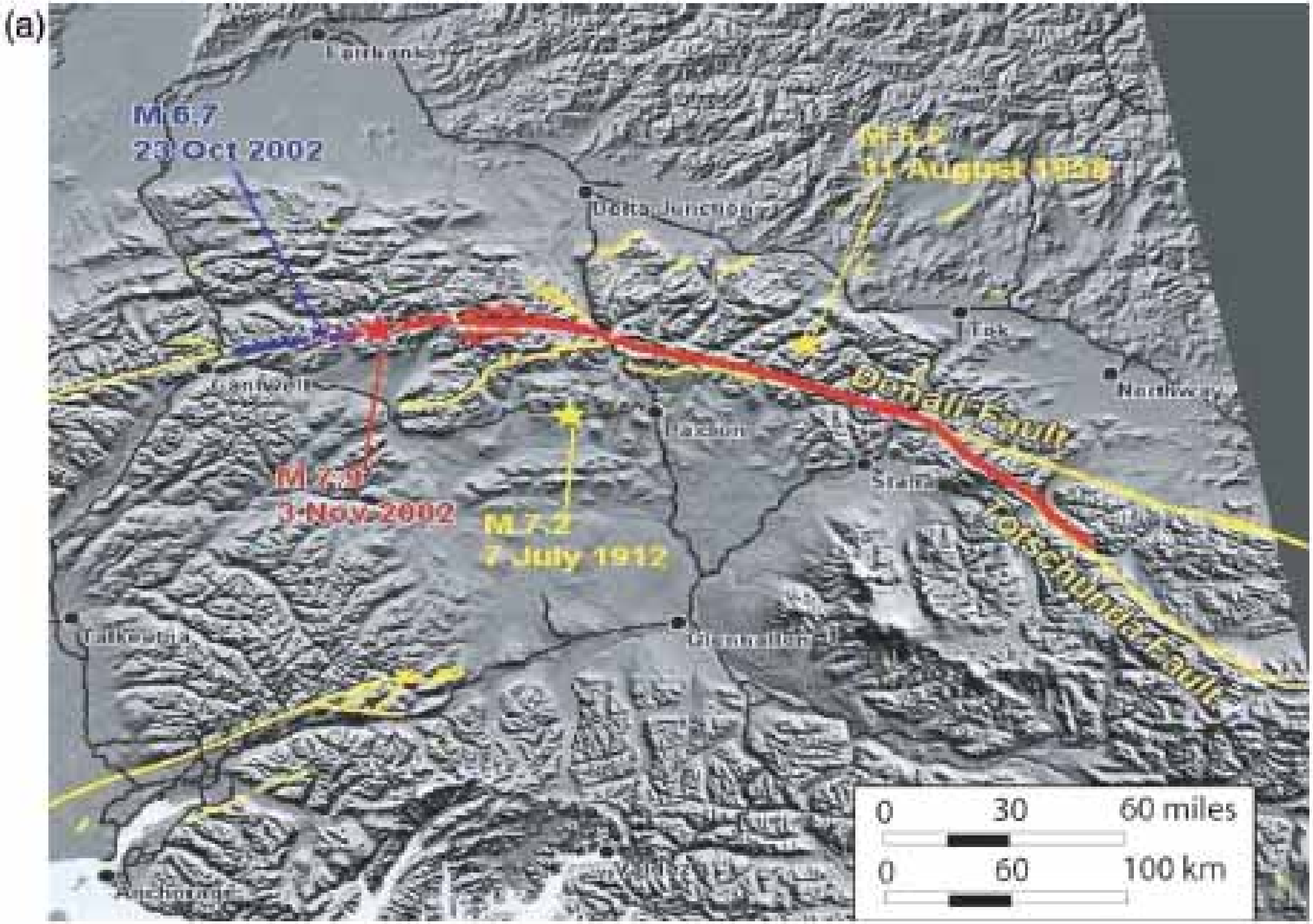
1990 Luzon?



2002 Denali

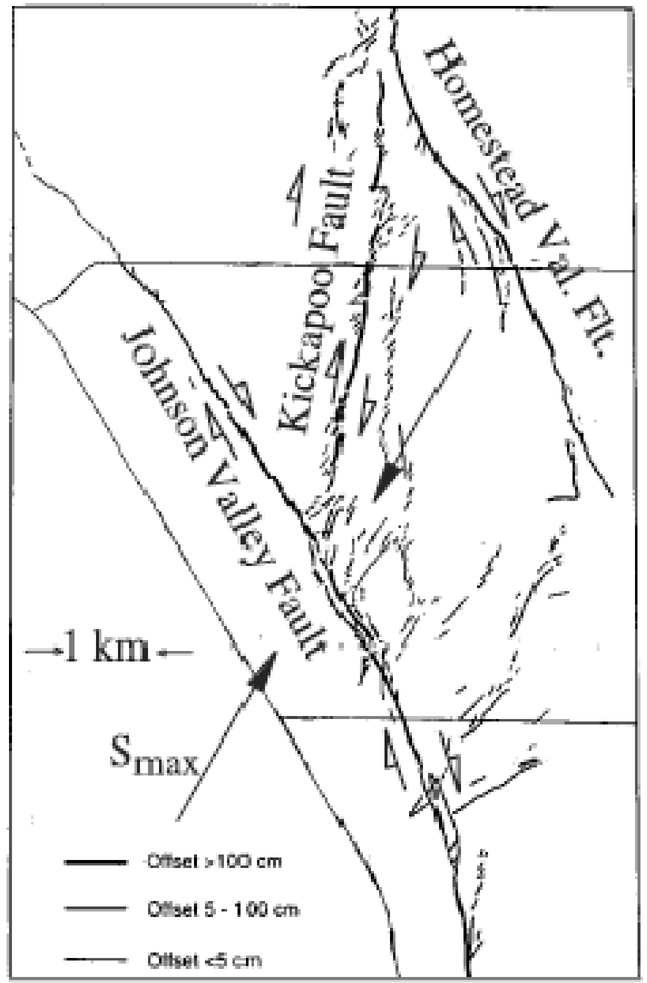
1992 Landers

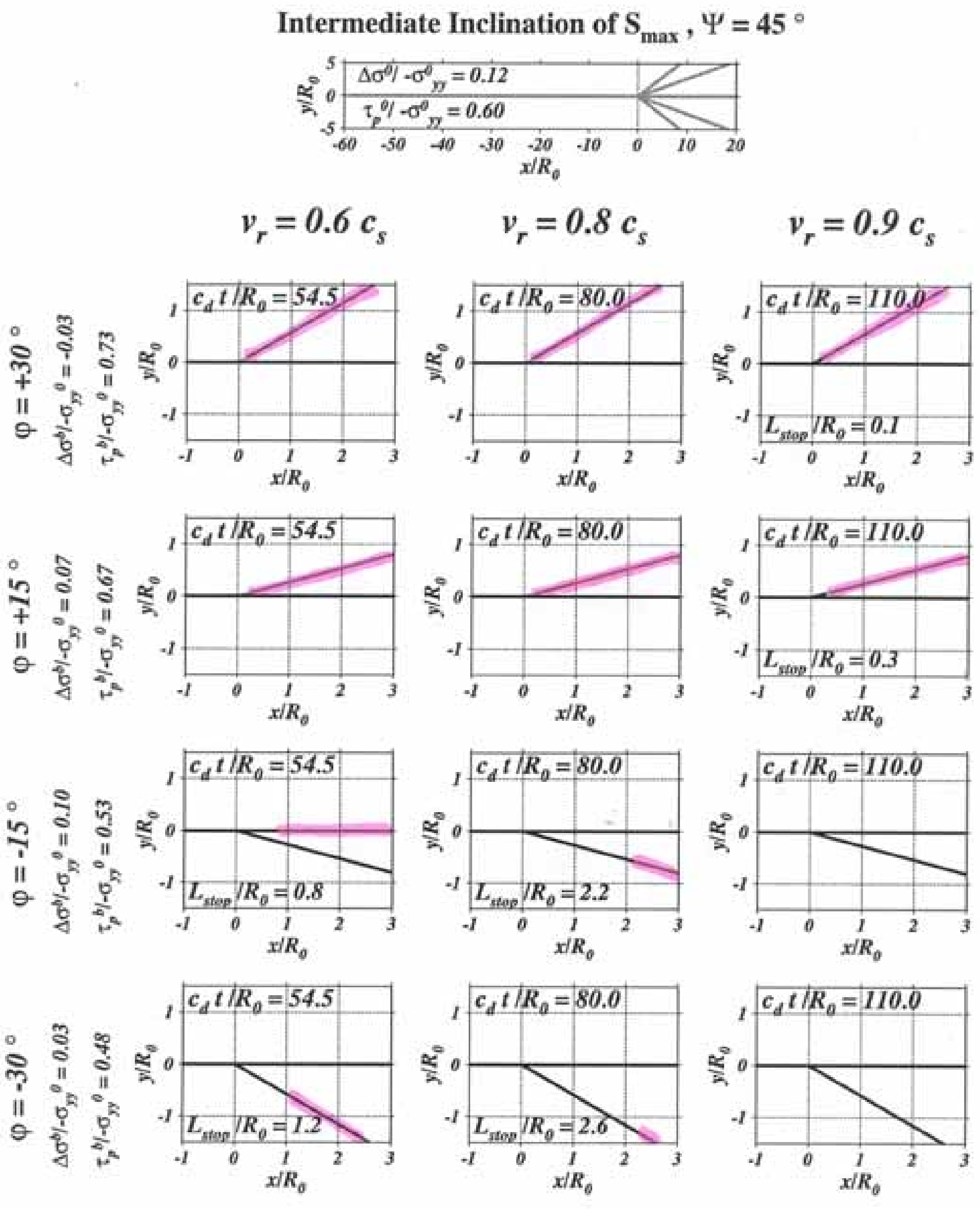
Denali


(a)
Fairbanks
M 6.7
23 Oct 2002
Delta Junction
Tok
Denali Fault
M 7.9
3-Nov-2002
M 7.2
7 July 1912
Totschunda Fault
Anchorage
0 30 60 miles
0 60 100 km

Landers

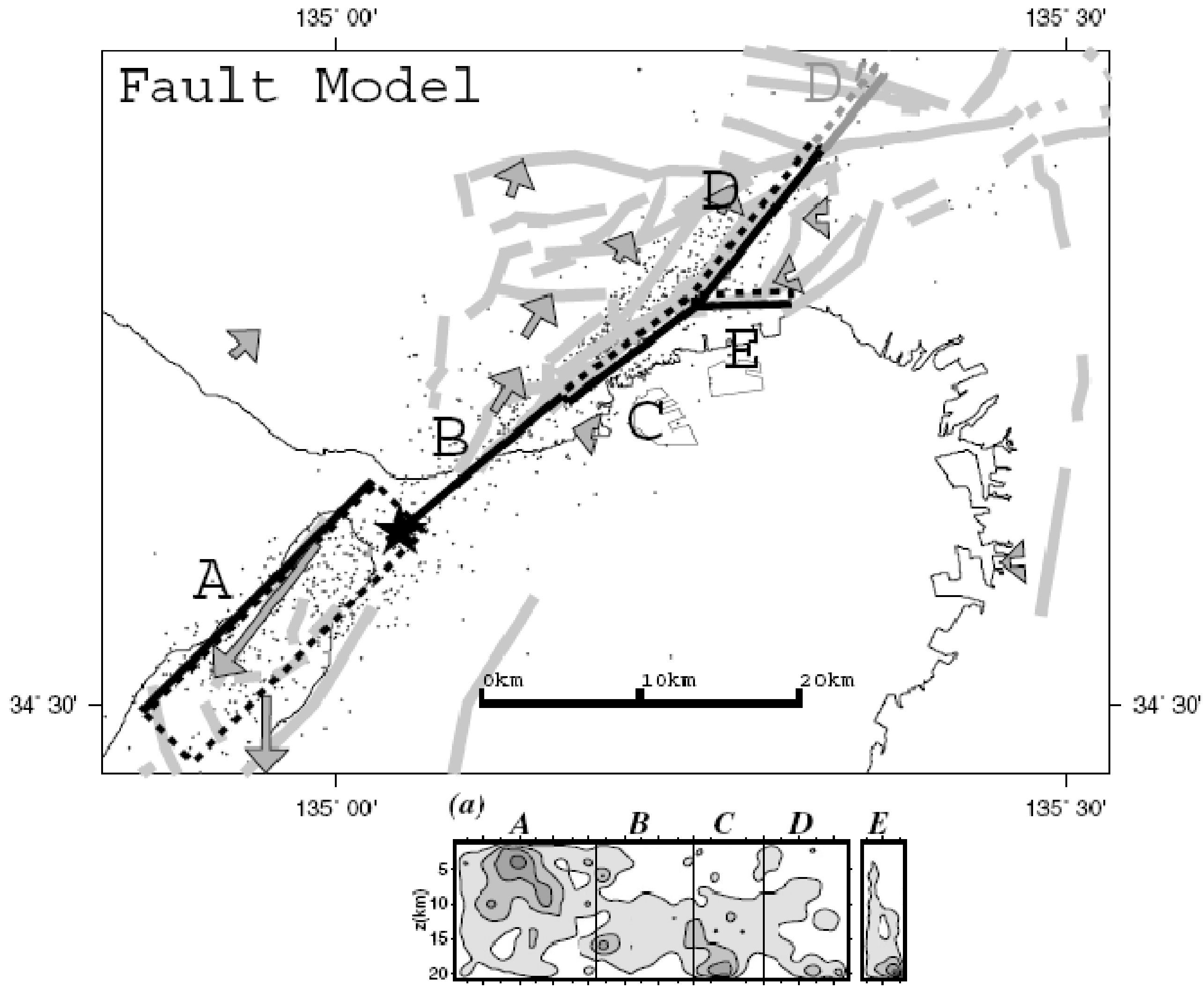
Landers 1992





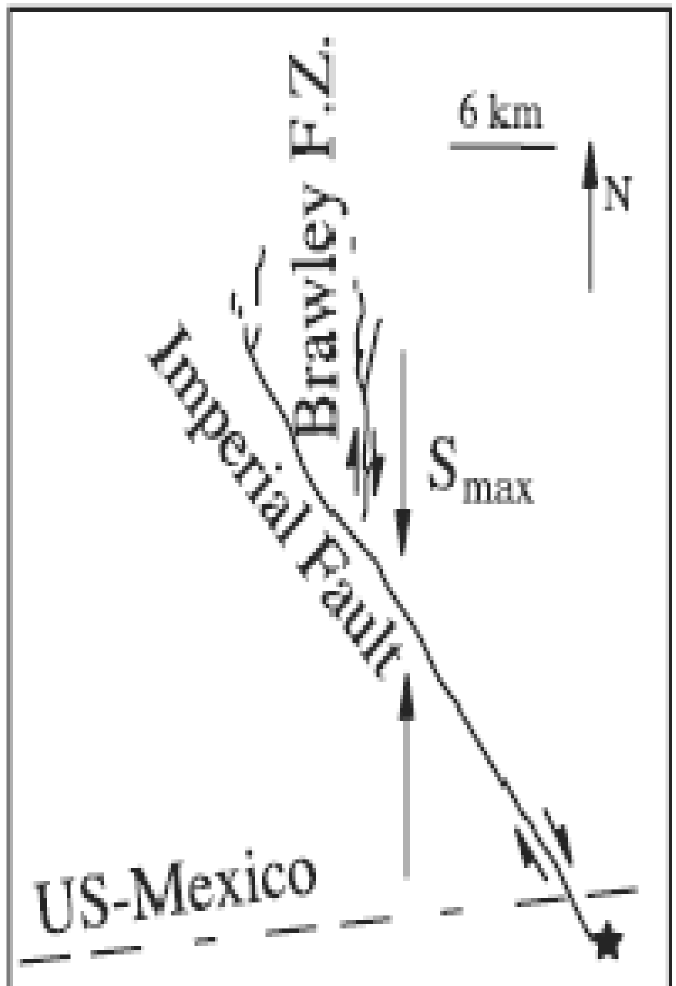
1995 Kobe
1979 Imperial Valley

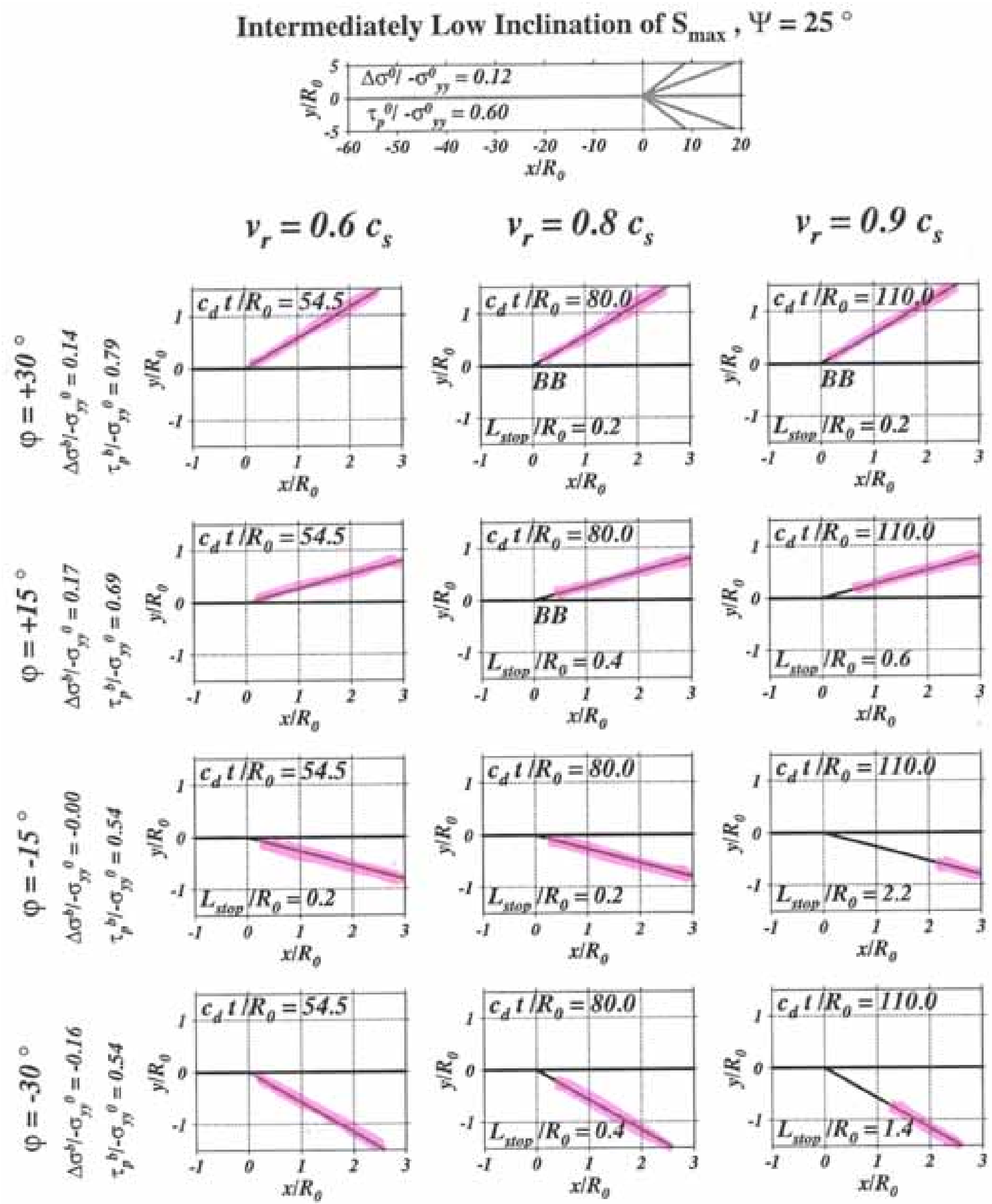
Kobe



Fault Model
135° 00'
135° 30'
34° 30'
A
B
C
D
D
E
0km
10km
20km
(a)
A
B
C
D
E
z(km)
5
10
15
20

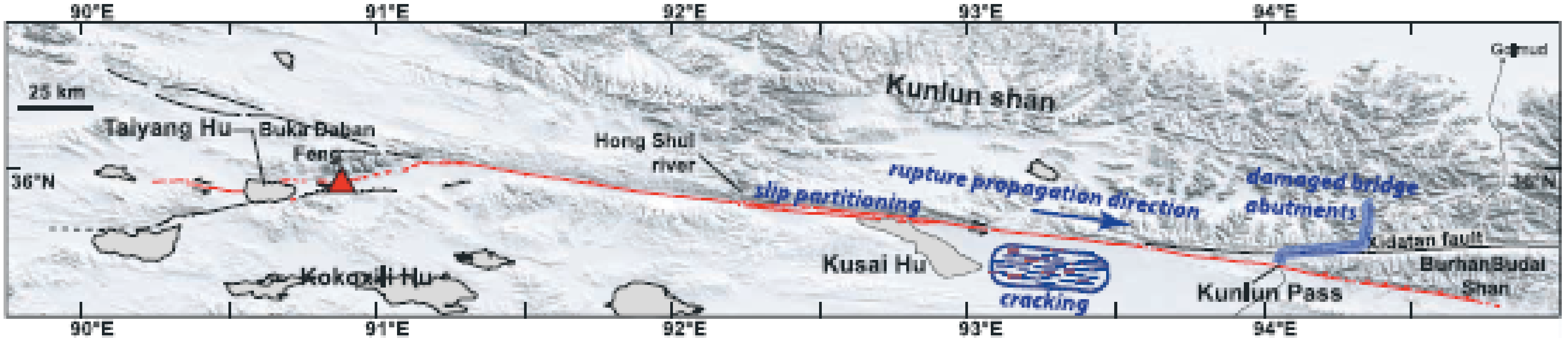
1979 Imperial Valley



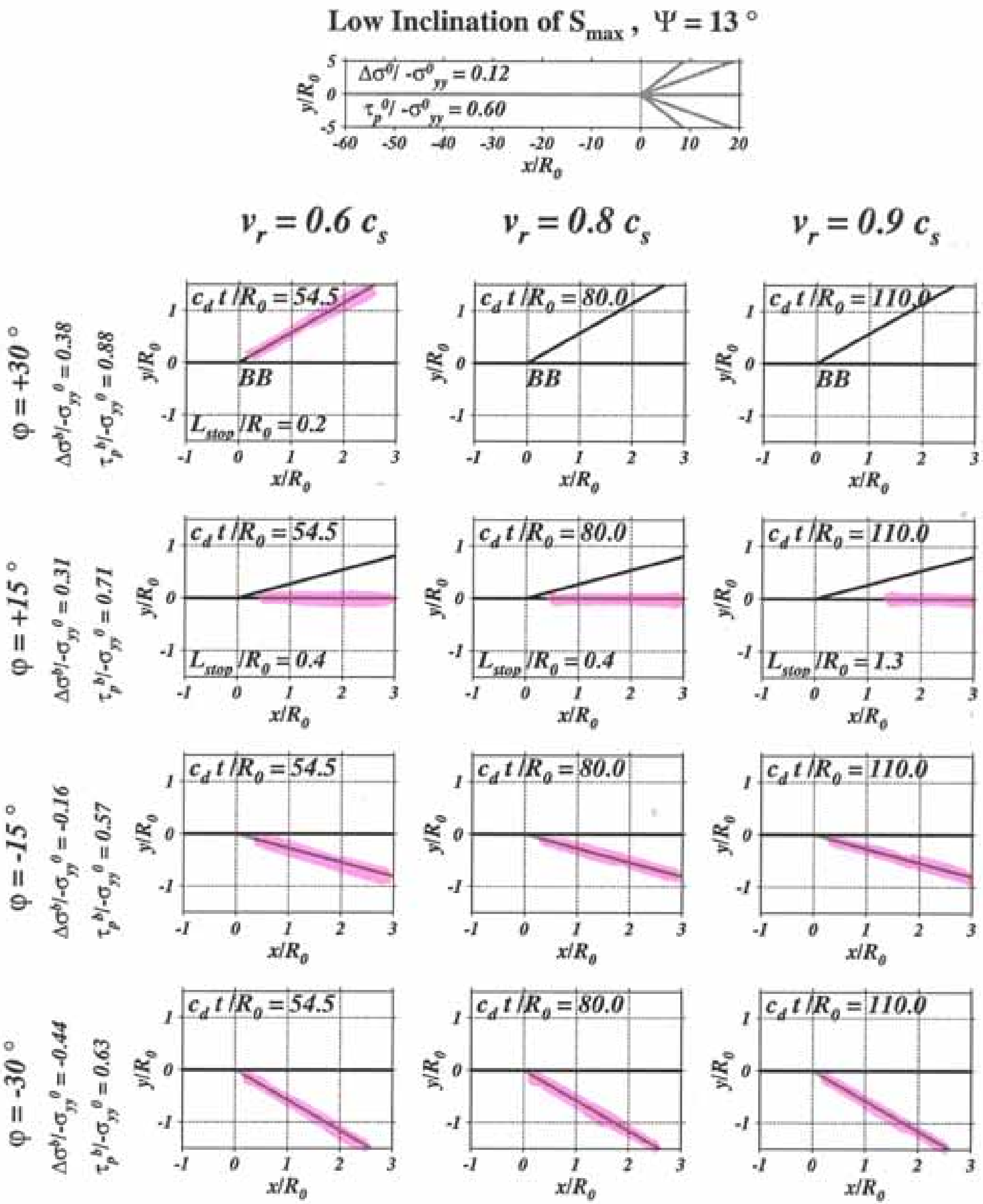


2001 Kokoxili?

Kokoxili



90°E
91°E
92°E
93°E
94°E
25 km
Taiyang Hu
Bukadaban Feng
Hong Shui river
Kunlun shan
rupture propagation direction
slip partitioning
damaged bridge abutments
Golmud
36°N
Xidatan fault
Kusai Hu
Kokoxili Hu
cracking
Kunlun Pass
BurhanBudai Shan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x/R_0
y/R_0

1990 Luzon?

Luzon

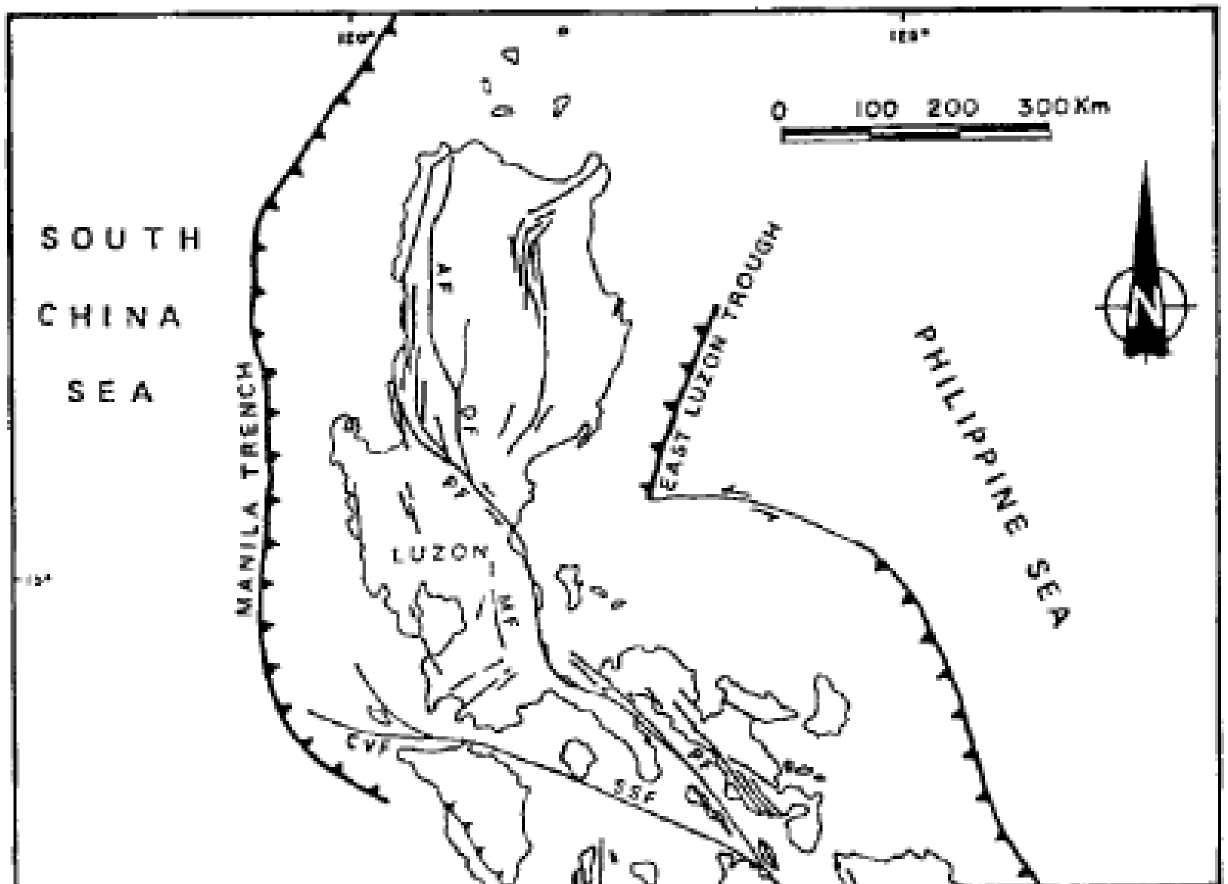

Fig. 4.8 - *Major tectonic lineaments in Luzon (PF = Philippine Fault, DF = Digdig Fault, AF = Abra Fault, MF = Manila Fault), from Punongbayan and Umbal (1990).*

Luzon

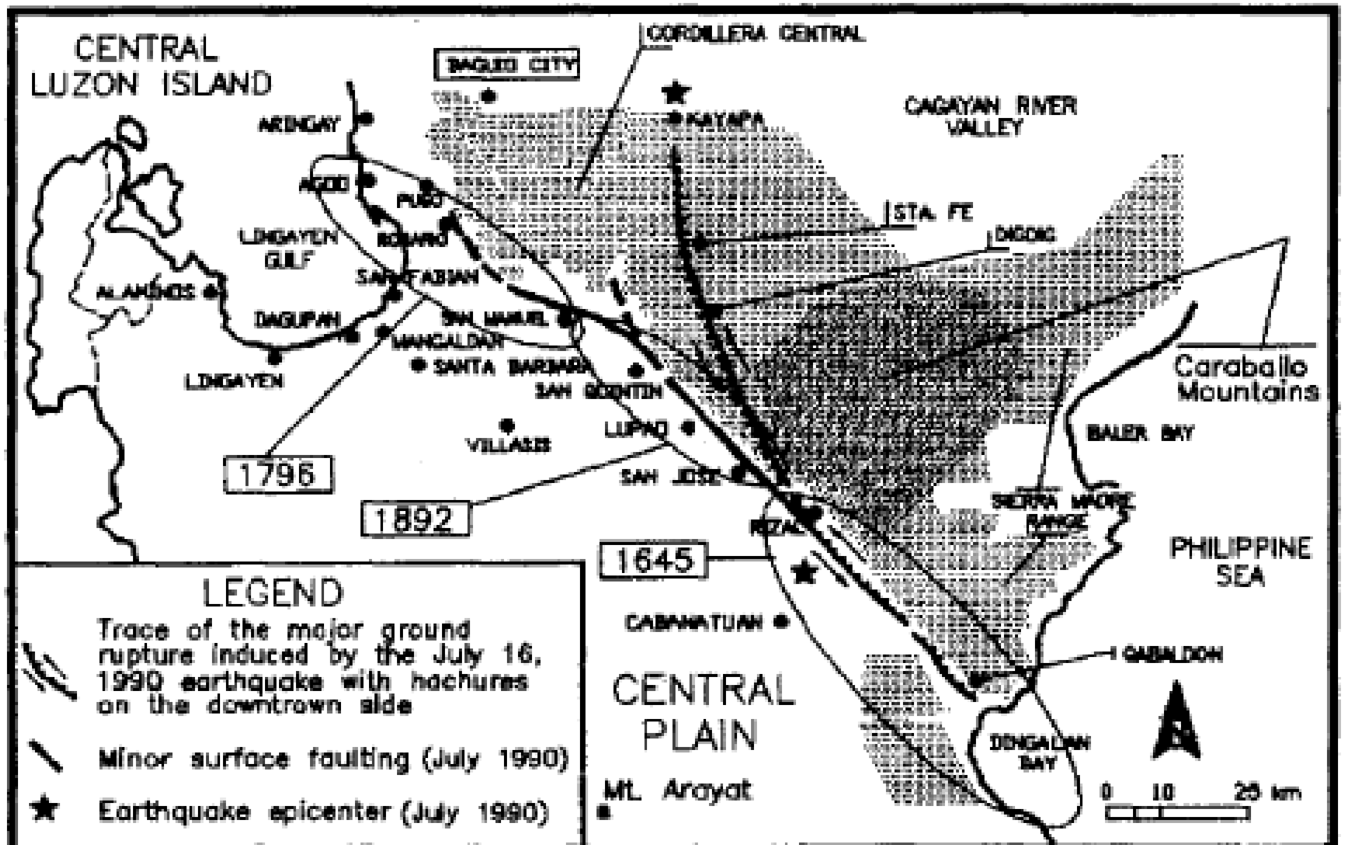

Fig. 4.9 – *Location of the Major Ground Rupture and minor surface faultings in Central Luzon associated with the July 1990 earthquake and the areas affected by the 1645, 1796, 1892 earthquakes.*

Conclusions

- We have analyzed six events involving rupture on branched faults which represent three possible modes of fault branching behavior.
- In three cases, including the 1979 Imperial Valley, 1995 Kobe, and 1992 Landers earthquakes, such rupture occurred on both the main fault and the branch fault, all consistent with Kame et al. (2003).
- In the 1990 Luzon and 2002 Denali earthquakes, rupture proceeded onto the branch fault but stopped on the main fault at the branch point.
  - The Denali earthquake observations are consistent with Kame et al.
  - The Luzon earthquake observations are potentially consistent, but the uncertainty in the stress field orientation renders this inconclusive with current data.
- In the 2001 Kokoxili (Kunlunshan) earthquake, the main fault continued to rupture without branching onto the Kitadan fault. The Kokoxili earthquake observations are potentially consistent with Kame et al., but the uncertainty in the stress field orientation renders this inconclusive with current data.