

Immagini e fotografie tratte da:

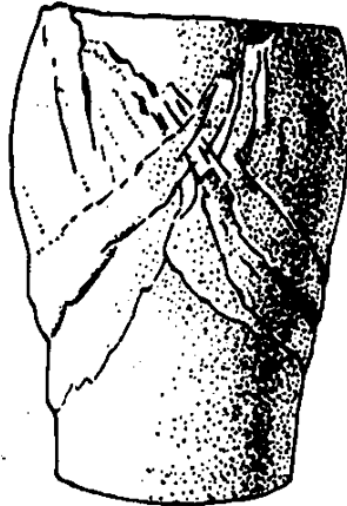
- Boccaletti M & Tortorici L., 1987. Appunti di Geologia Strutturale. Patron Editore.
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Deformazione fragile



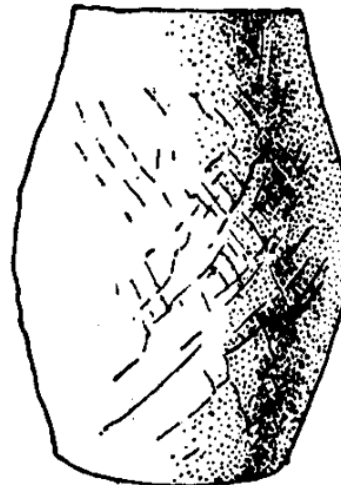
confining pressure

Deformation
20%



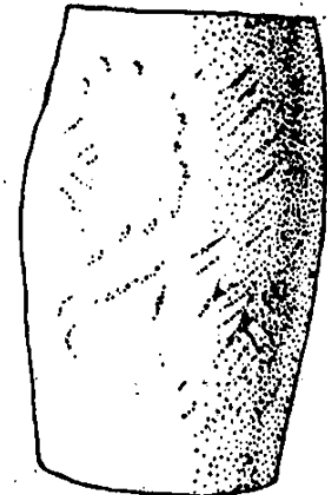
280 kg/cm²

20%



460 kg/cm²

20%



1000 kg/cm²

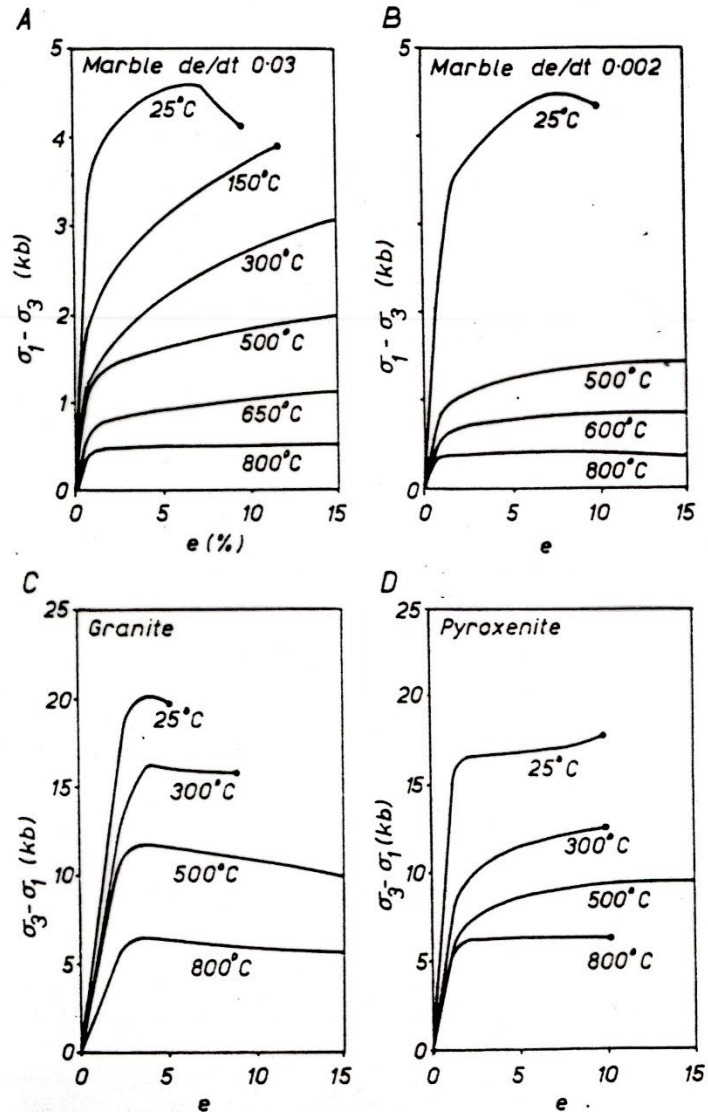
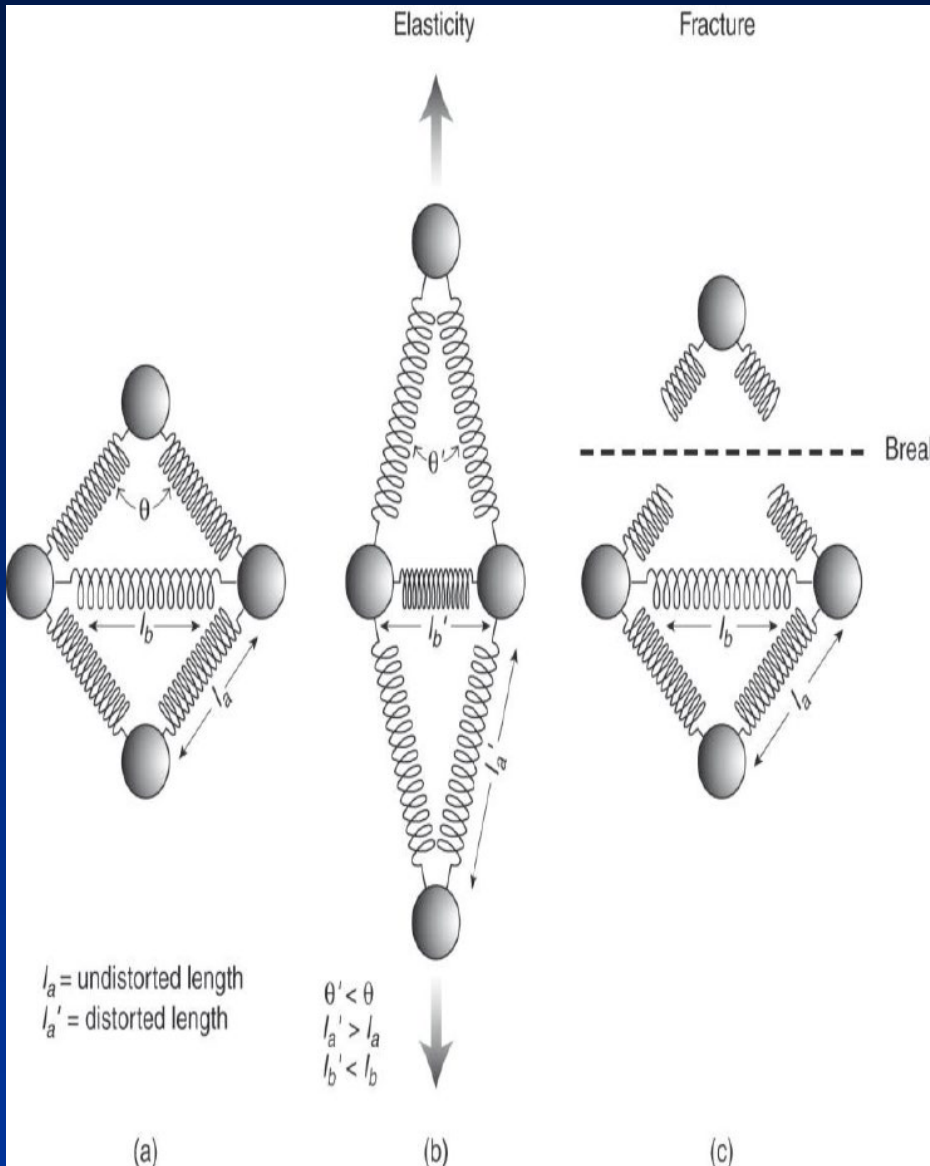
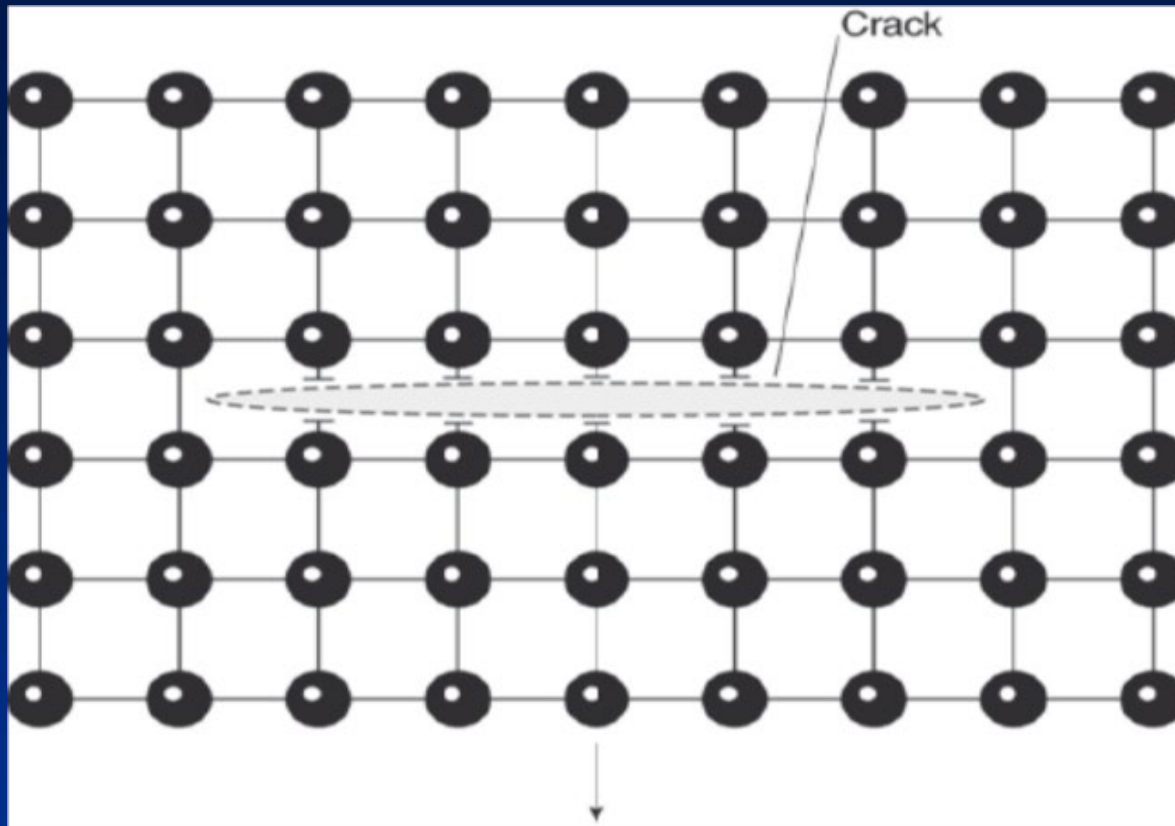


FIG 45

Stress-strain curves from triaxial tests made on various rock materials. A and B, Yule marble in extension; C, granite in compression; D, pyroxenite in compression: all with 5 kilobars confining pressure. (After Griggs, Turner, and Heard, 1960.)

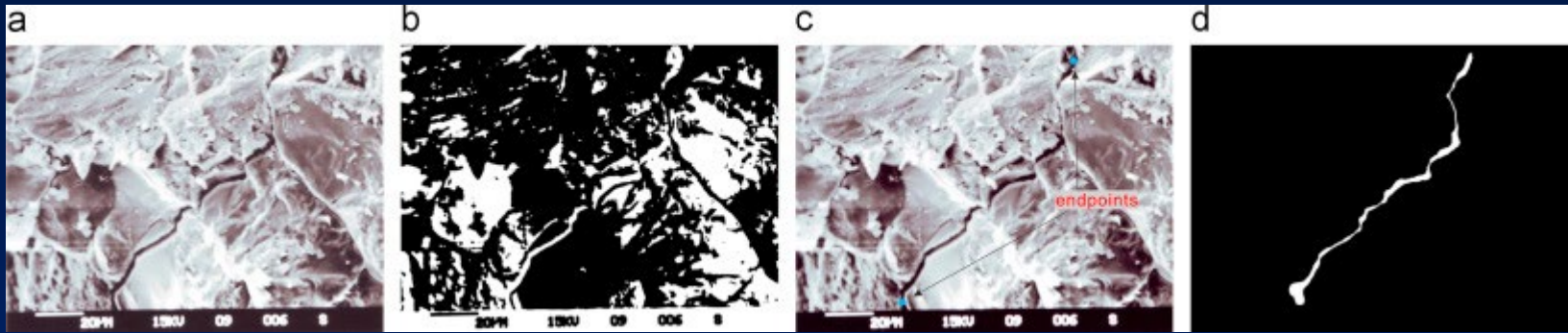


Resistenza
 “atomica”
 teorica= 100
 volte maggiore
 dell’effettiva
 resistenza alla
 deformazione
 sperimentale!

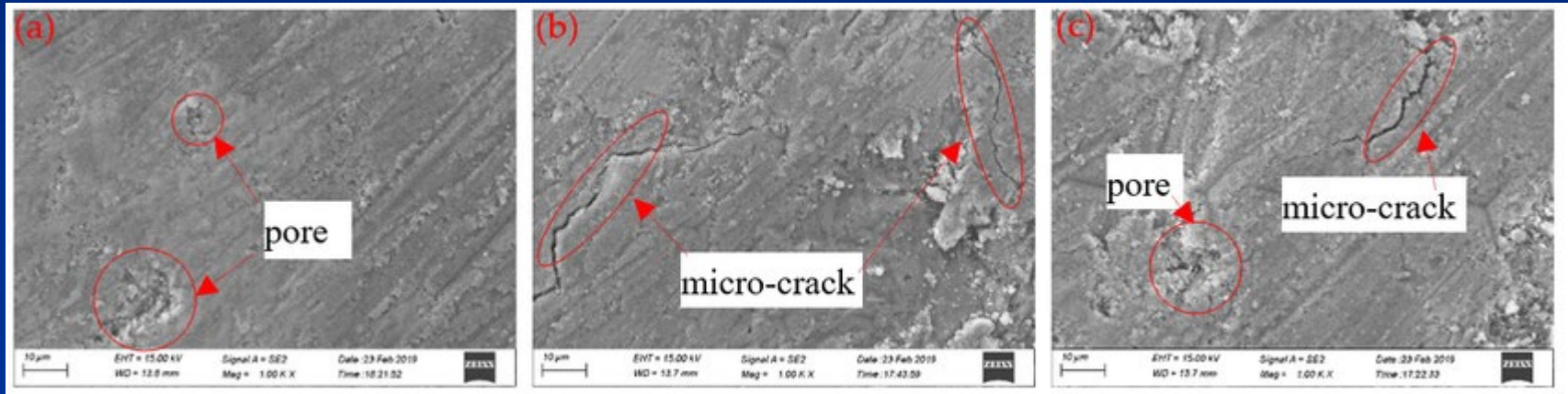


Da van der Pluijm & Marshak, 2004

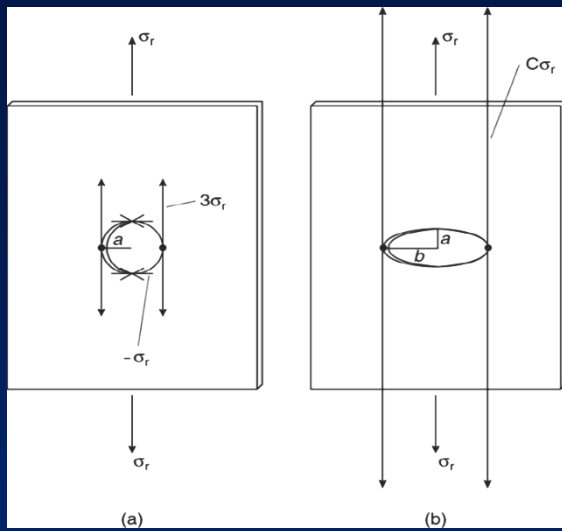
La ragione è nella presenza di
microfratture (micro crack)



Da Luo et al., 2015

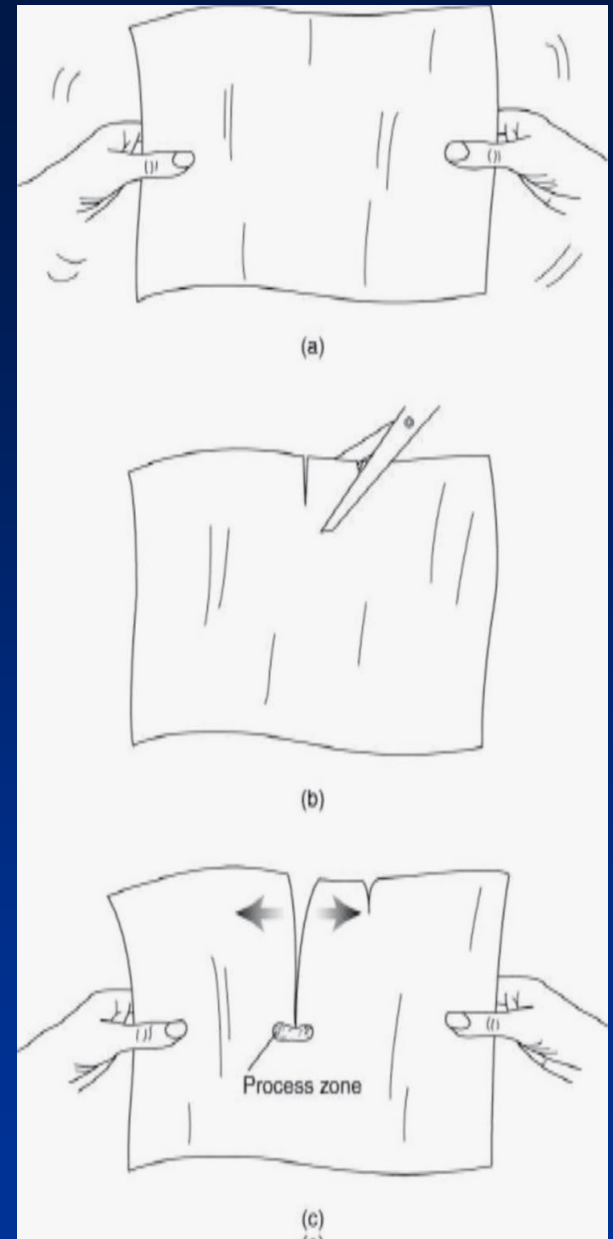


Da Sun et al., 2019

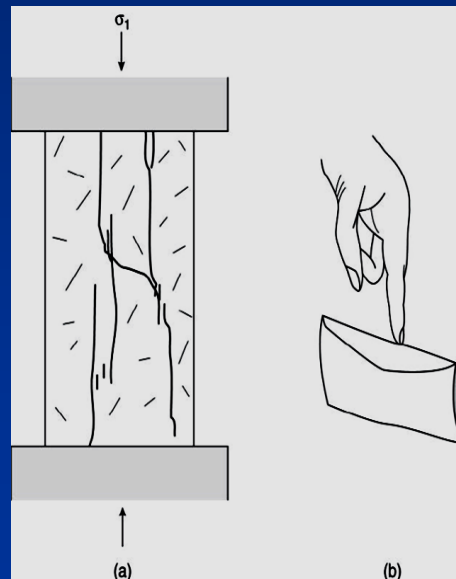
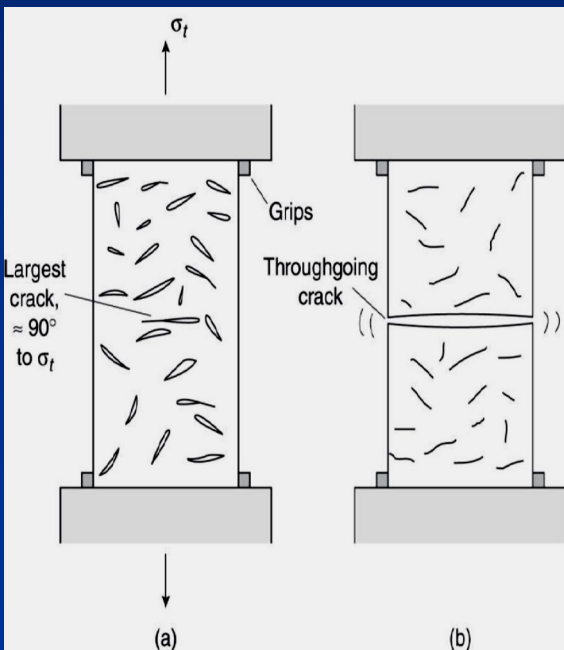


Microfratture (micro crack)

Da van der Pluijm & Marshak, 2004



Da van der Pluijm & Marshak, 2004

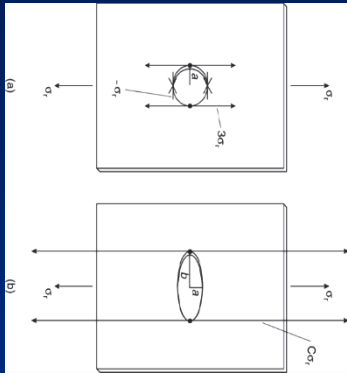


Sforzo in compressione

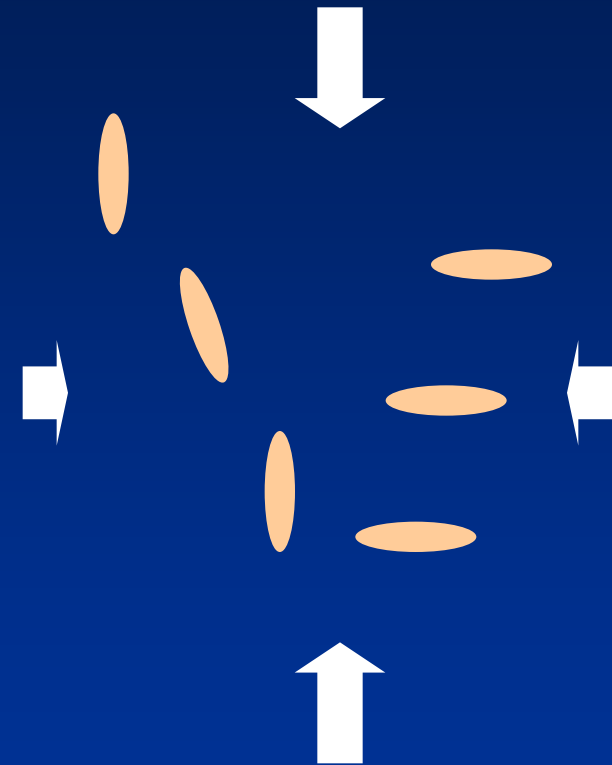
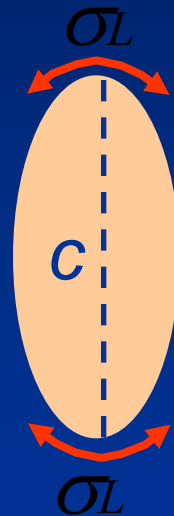
Sforzo in estensione

Perchè la rottura in trazione avviene più facilmente che in compressione?
Perché la rottura avviene (in tutte le condizioni) in ogni caso a valori che sono ben al di sotto della resistenza teorica dei materiali?

Critério di rottura di Griffith (1924)



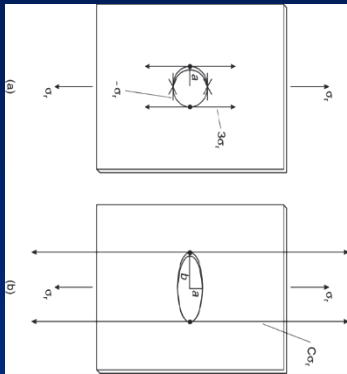
$$\sigma_L = \sigma \sqrt{\frac{c}{rm}}$$



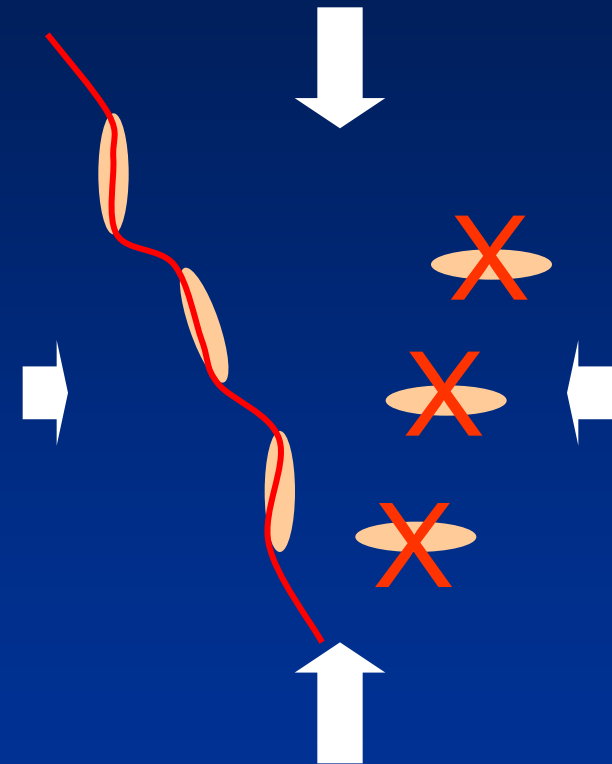
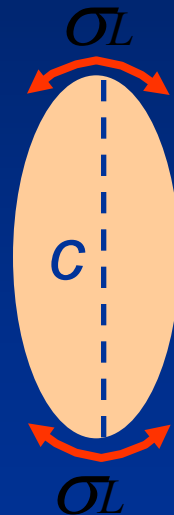
Stato di sforzo legato alla propagazione delle microfrazture
rm = raggio di curvatura dell'apice della microfrazione
c = lunghezza max della frattura

Perchè la rottura in trazione avviene più facilmente che in compressione?
 Perché la rottura avviene (in tutte le condizioni) in ogni caso a valori che sono ben al di sotto della resistenza teorica dei materiali?

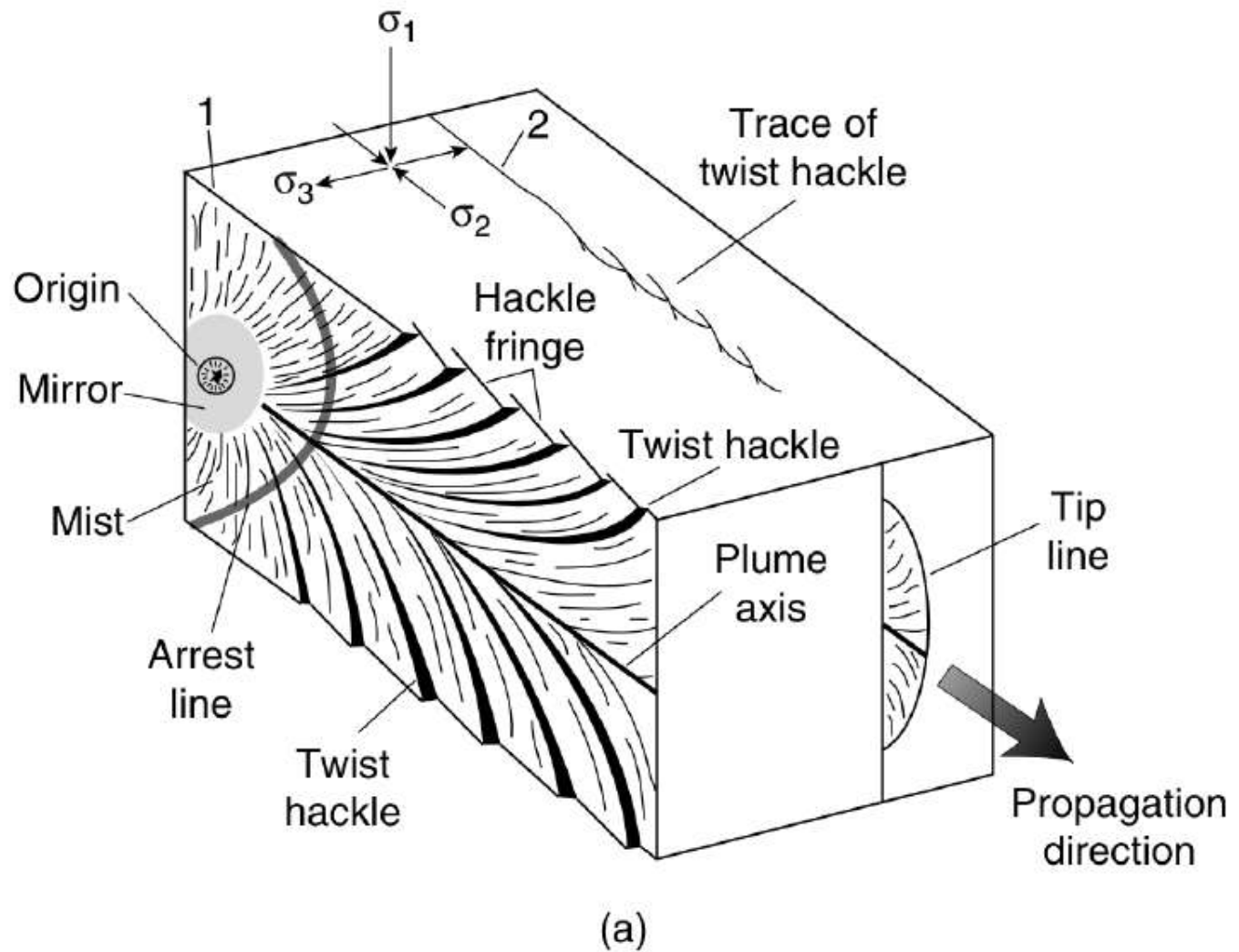
Criterio di rottura di Griffith (1924)



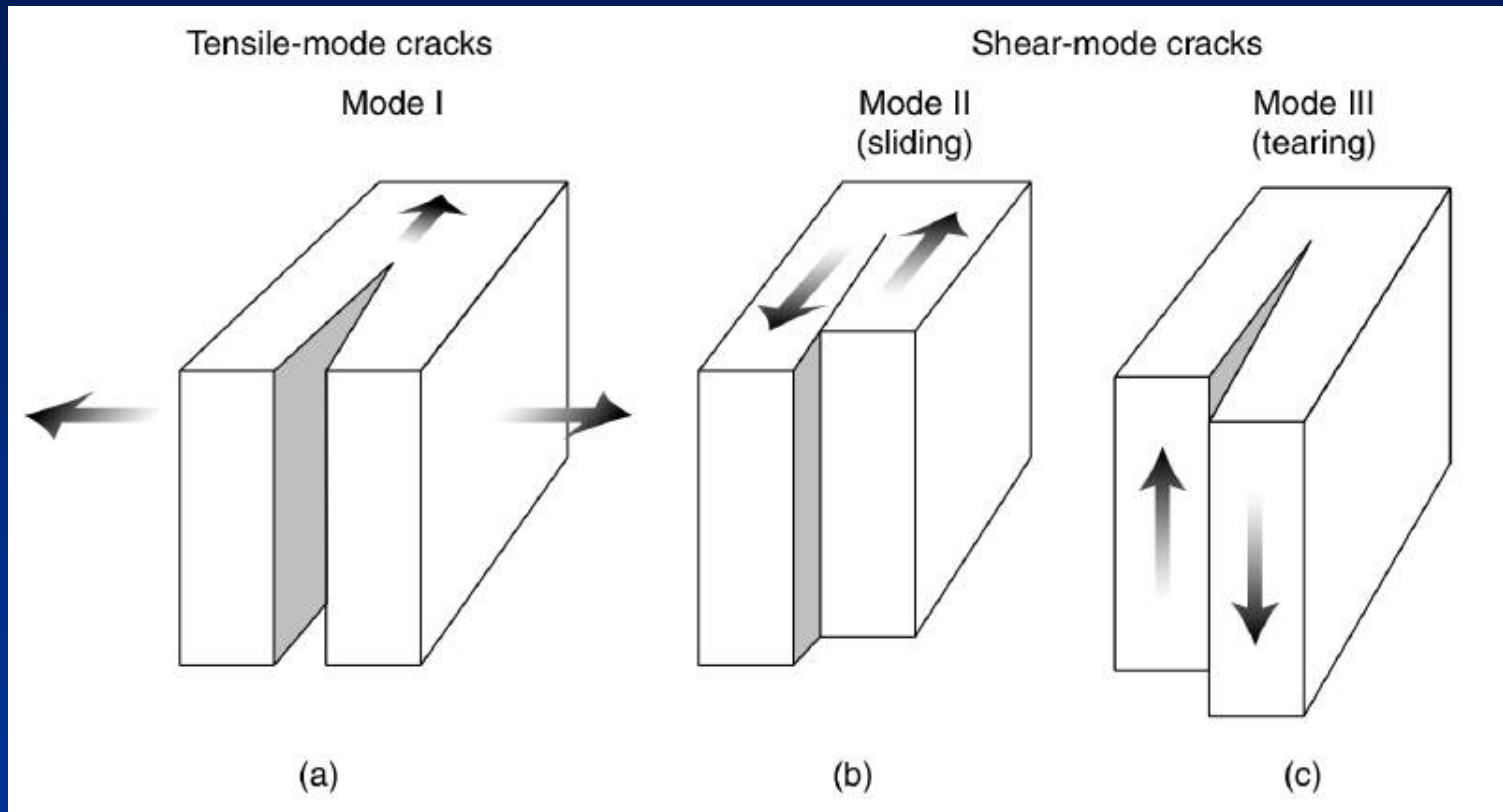
$$\sigma_L = \sigma \sqrt{\frac{c}{rm}}$$



Stato di sforzo legato alla propagazione delle microfratture
rm = raggio di curvatura dell'apice della microfrattura
c = lunghezza max della frattura



Origine delle strutture fragili: piani di discontinuità effettiva della roccia



Da van der Pluijm & Marshak, 2004

Deformazione fragile



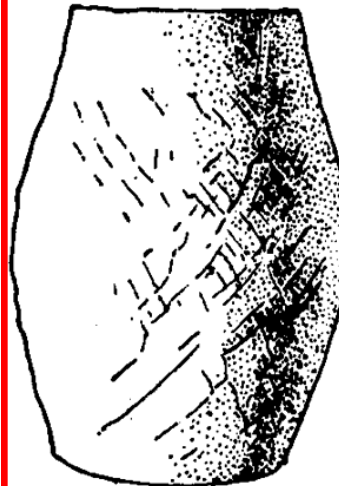
confining pressure

Deformation
20%



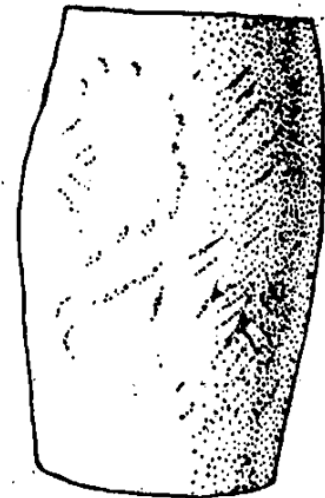
280 kg/cm²

20%



460 kg/cm²

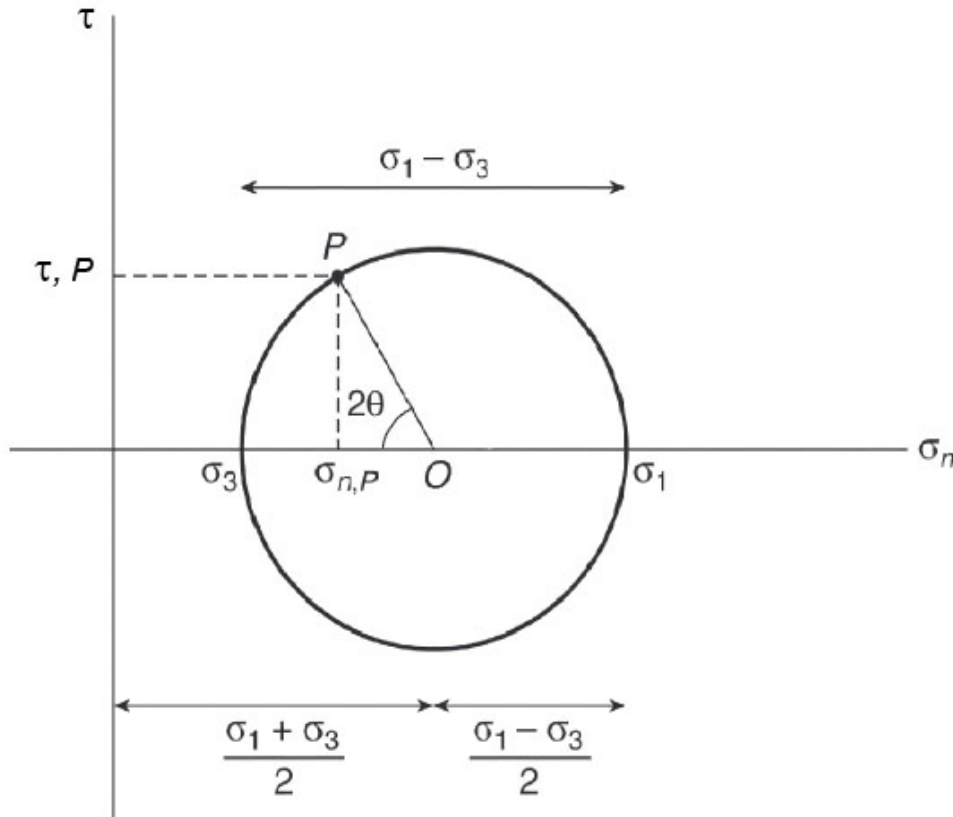
20%



1000 kg/cm²

Piani di frattura: angoli caratteristici, quali?

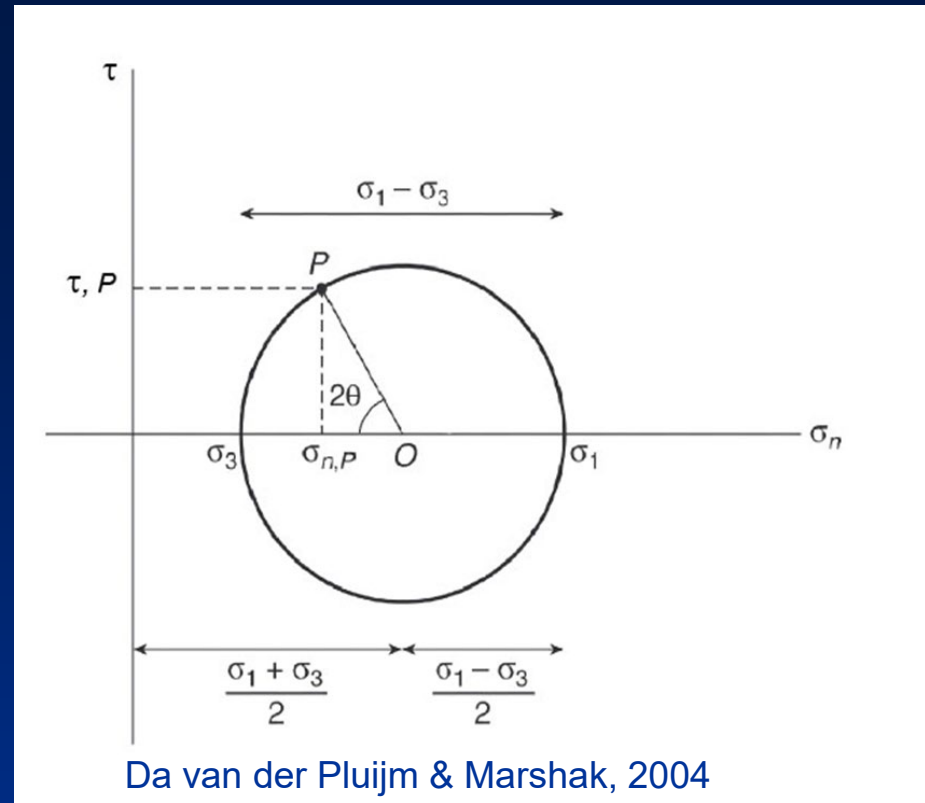
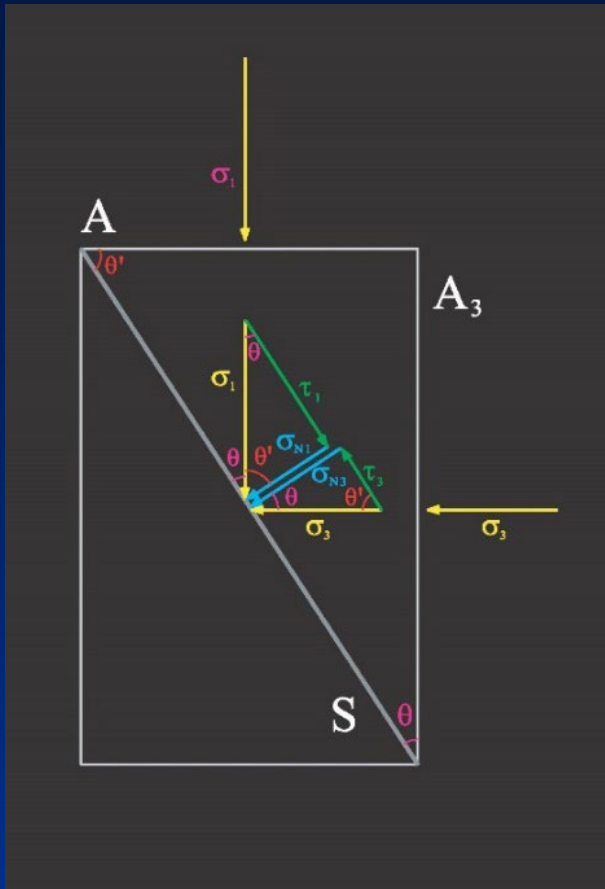
Cerchio di Mohr (NON a rottura!!!)



Da van der Pluijm & Marshak, 2004

$$\tau_R = C_0$$

Quale delle superfici all'interno del corpo
sviluppa una frattura?
Primo approccio: legge di Coulomb



$$\tau_R = C_0$$

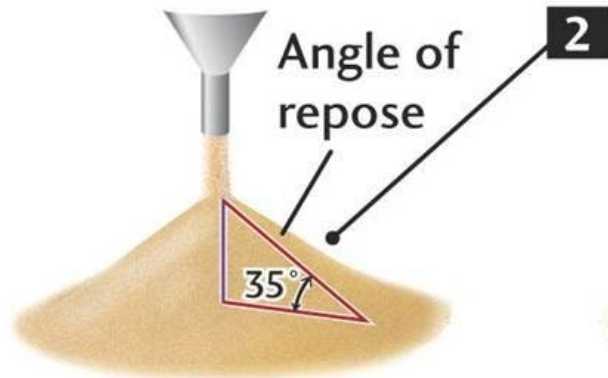
Seguendo la legge di Coulomb, la rottura dovrebbe avvenire con la condizione di τ massimo, con che angolo rispetto al σ_1 ?

$$\tau_R = C_0 + \operatorname{tg}\phi \cdot \sigma_N$$

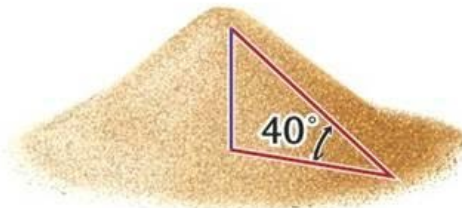
Legge di Coulomb-Navier: l'influenza dello sforzo normale sul piano di rottura potenziale, unitamente all'angolo di attrito interno (ϕ) condiziona la propagazione iniziale della frattura e **cambia gli angoli**, da 45° a circa 30° .

MASS MOVEMENT DEPENDS ON THE NATURE OF MATERIAL, WATER CONTENT, AND SLOPE STEEPNESS

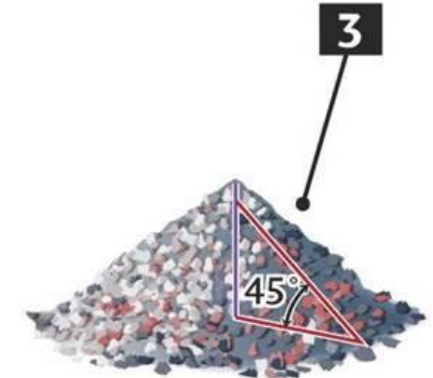
1



Fine sand

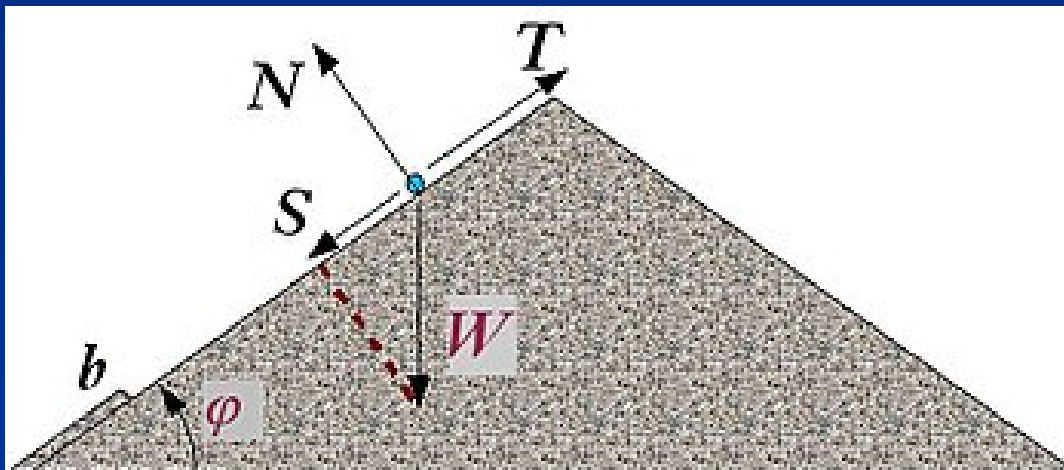


Coarse sand



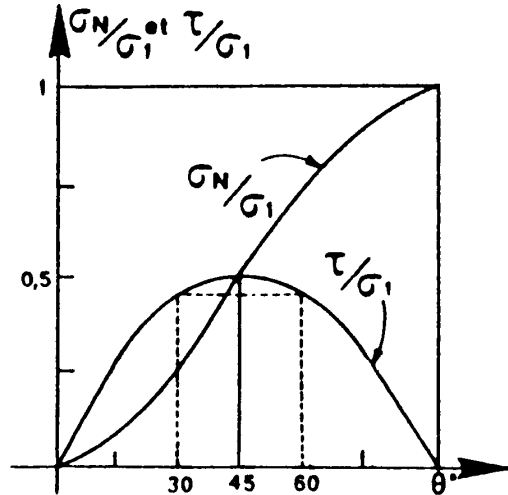
Angular pebbles

Angolo di attrito interno, ovvero angolo di scarpa(ta) o di riposo



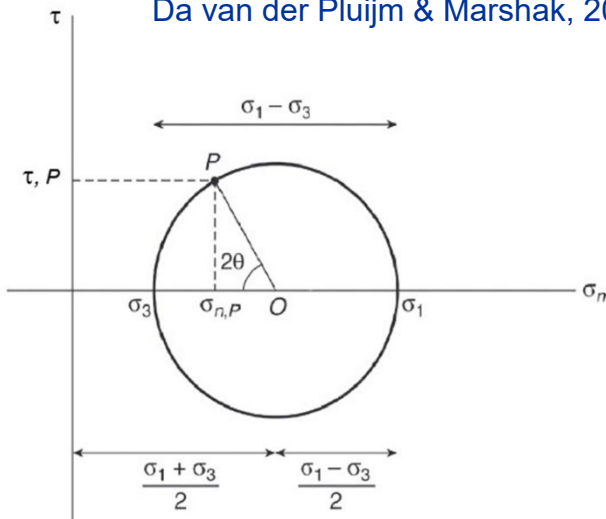


Coni di detrito, costa nord, Isola di Isfjorden, Svalbard, Norway.
Photograph taken by Mark A. Wilson (Department of Geology, The College of Wooster),
Wikipedia Public Domain.



$$\tau_R = C_0 + \operatorname{tg} \phi \cdot \sigma_N$$

Da van der Pluijm & Marshak, 2004



Legge di Coulomb-Navier: l'influenza dello sforzo normale sul piano di rottura potenziale, unitamente all'angolo di attrito interno (ϕ) condiziona la propagazione iniziale della frattura e **cambia gli angoli**, da 45° a circa 30° .

CERCHIO DI MOHR

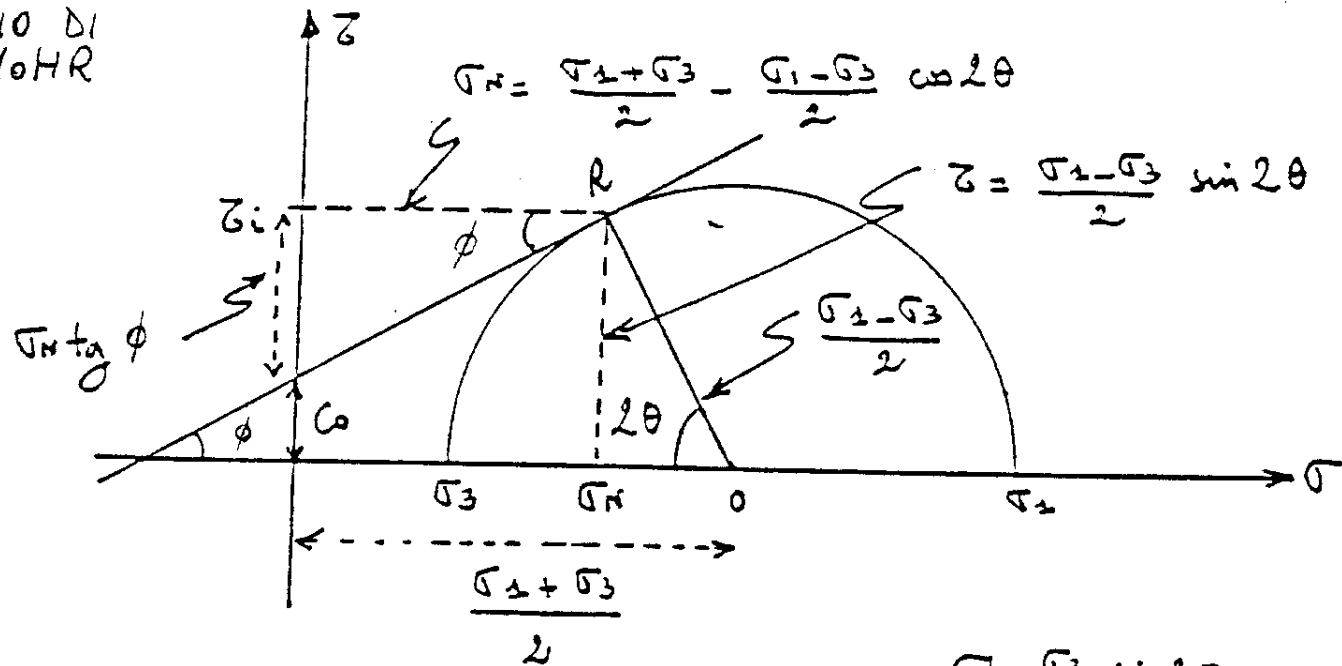


FIG. 2.9

DA HERCIER, CORSO

SEMINARIE 4
BOLOGNA, 1990

$$2\theta = 90^\circ - \phi \rightarrow$$

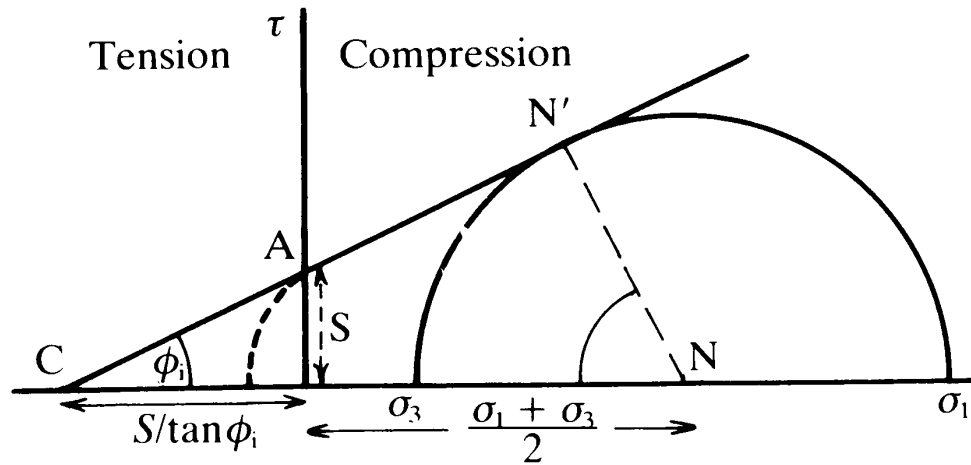
$$\tau = \frac{\sigma_1 - \sigma_3}{2} \sin 2\theta$$

$$\sigma_N = \frac{\sigma_1 + \sigma_3}{2} - \frac{\sigma_1 - \sigma_3}{2} \cos 2\theta$$

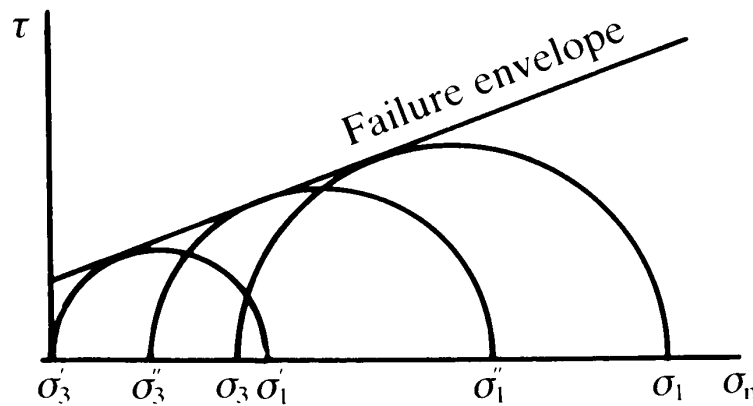
$\sigma_1 - \sigma_3 = \text{diametro del cerchio}$

$$\tau_R = C_0 + \text{tg}\phi \sigma_N$$

Cerchio di Mohr
(A ROTTURA!!!)



(a)



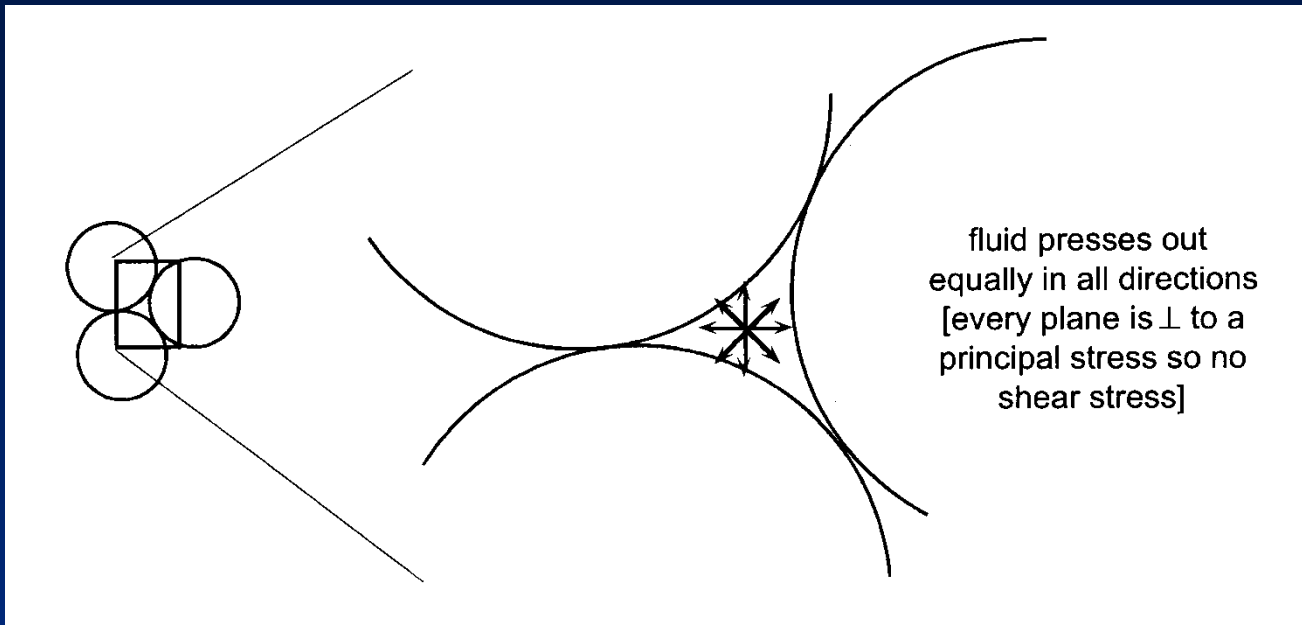
(b)

Fig. 1.51. Navier–Coulomb failure envelope (a) Failure envelope CAN' is the graphical expression of the Navier–Coulomb failure criteria (Eq. (1.59)) in which it is assumed to be valid in both tension and compression. (b) Experimentally determined failure envelope in the compressive region.

Cerchio a rottura, da singola prova (fig a) e involucro da più prove (fig. b)

Se l'involucro è una retta, l'angolo 2ϕ è costante nelle diverse condizioni dello stato di sforzo a rottura

Se l'involucro è una curva, l'angolo 2θ cambia



Pressione interstiziale dei fluidi (P_f)

Agisce in tutte le direzioni come il carico idrostatico. Non c'è sforzo di taglio perché ogni piano è ortogonale allo sforzo principale.

L'aumento di fluidi (per compattazione, metamorfismo, fusione) fa aumentare la P_f , abbassa la resistenza del materiale e favorisce la fratturazione (definendo un comportamento più fragile).

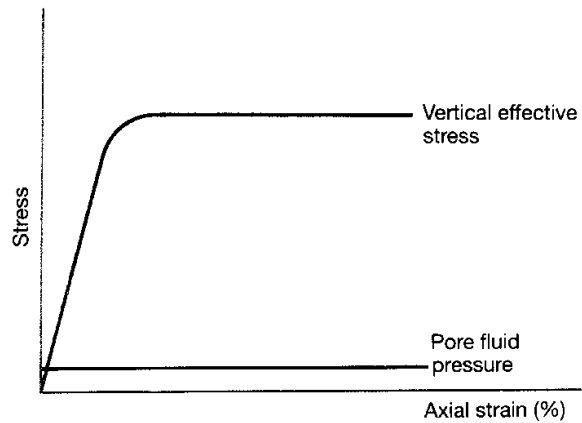
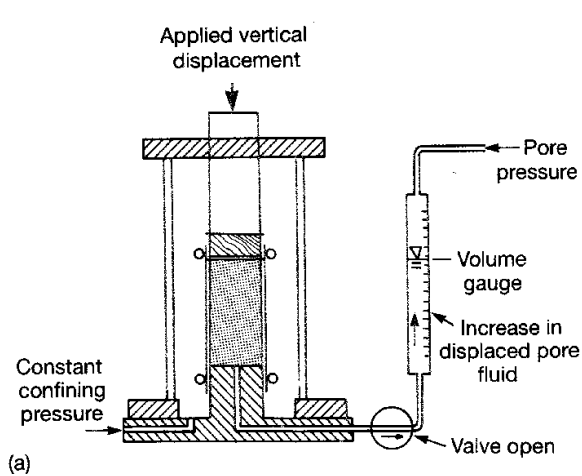


Figure 2.26 (a) Schematic representation of a drained triaxial experiment. (b) Schematic representation of an undrained triaxial experiment.

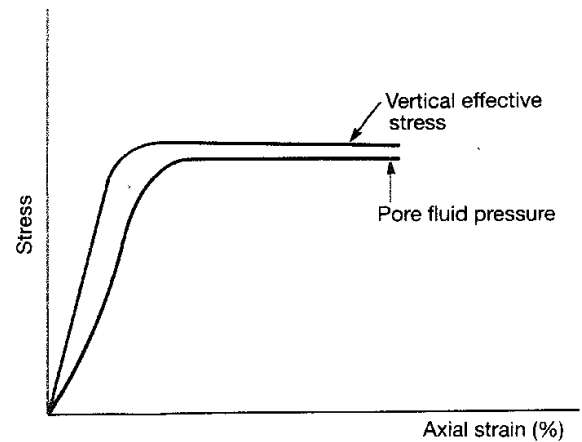
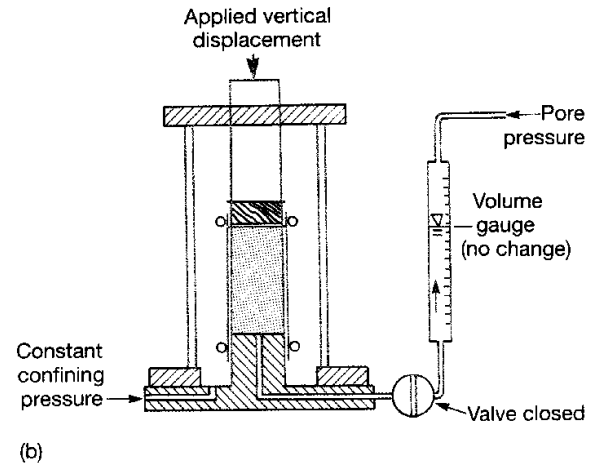
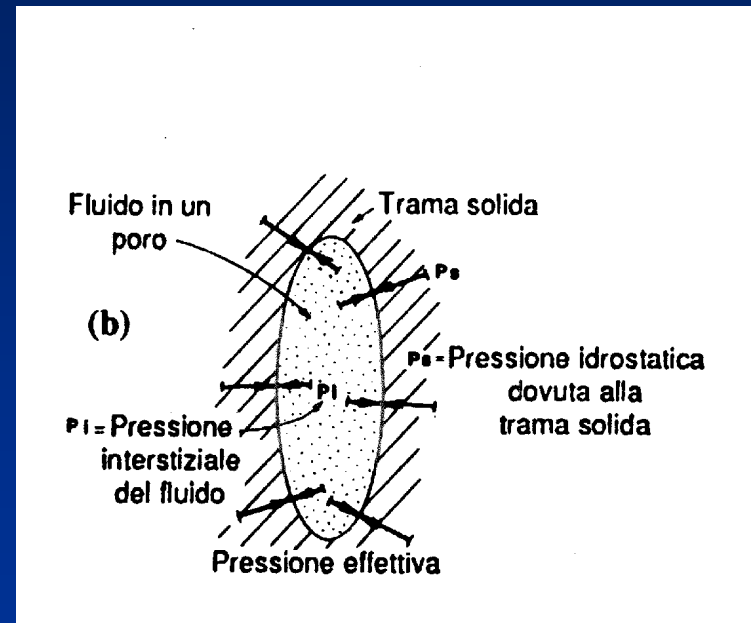


Figure 2.26 *Contd.*

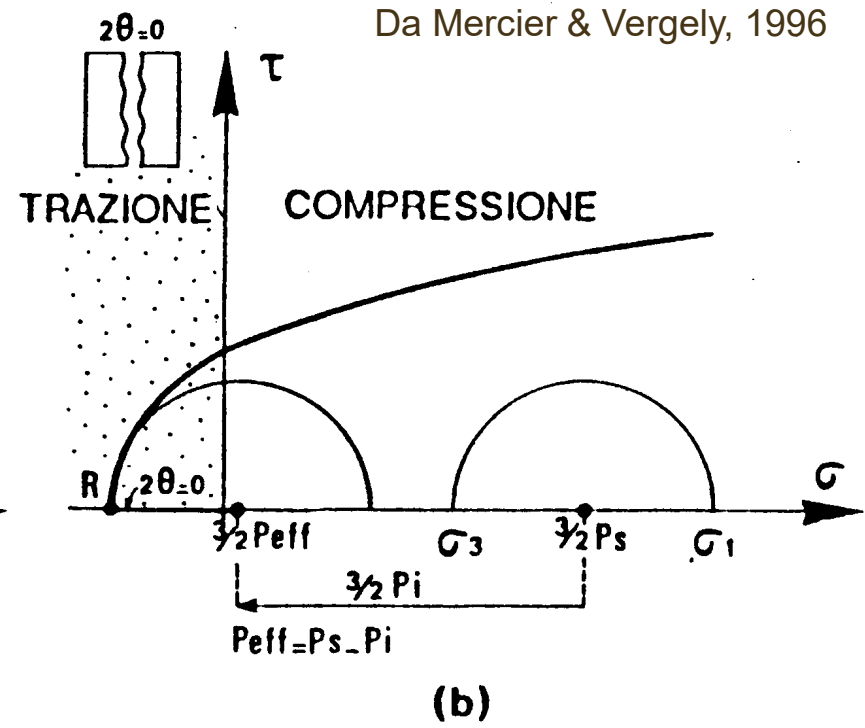
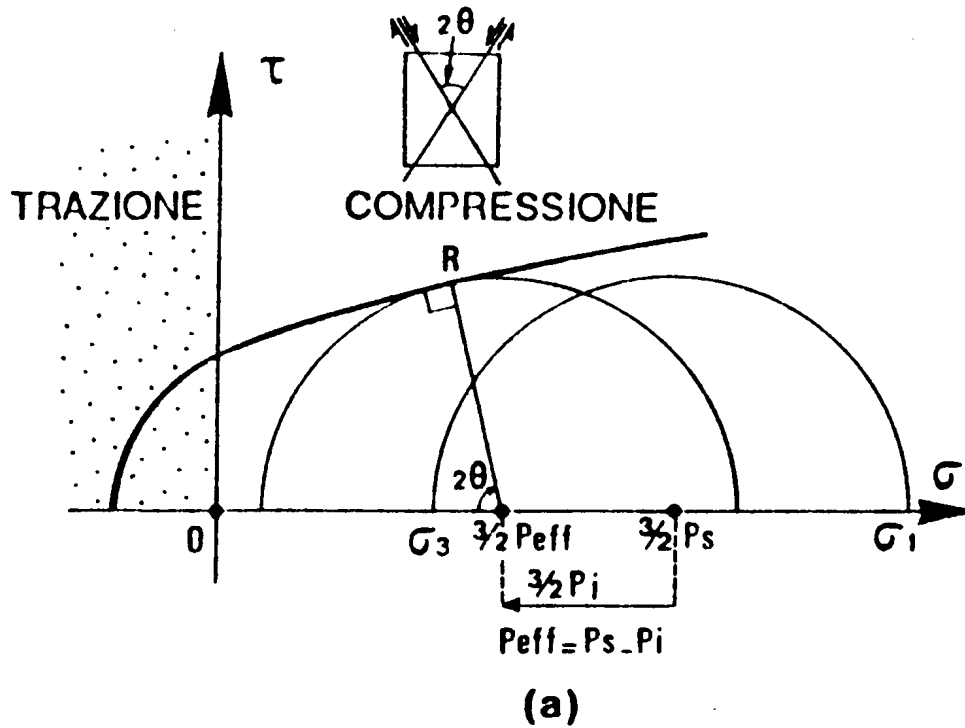
Criterio di rottura di Coulomb-Navier, modificato da Terzaghi: Influenza della pressione dei fluidi interstiziali (P_f)

$$\tau_R = C_0 + tg\phi(\sigma_N - P_f)$$



Sforzo (o pressione) efficace: $\sigma_N - P_f$

Da Mercier & Vergely, 1996

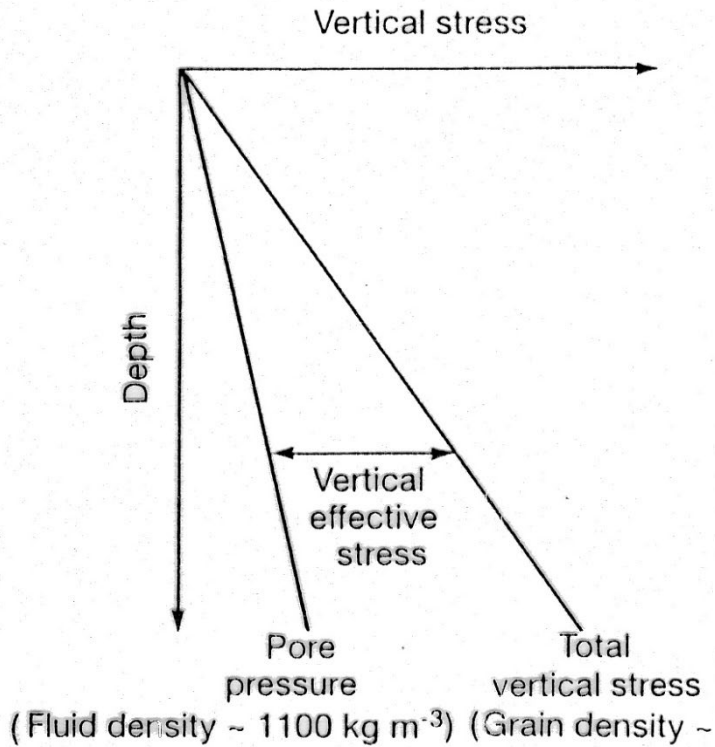


Sforzo efficace ancora
elevato (σ_3 efficace
ancora nel campo
positivo)

Sforzo efficace basso
(σ_3 negativo).

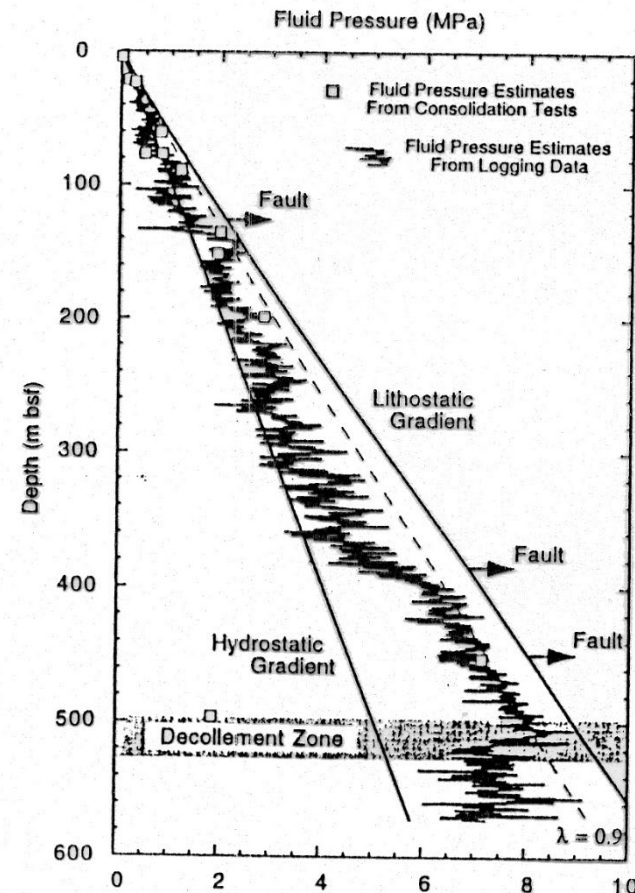
Angolo $2\theta = 0$

“idrofrazione”



Curve teoriche (di fianco) e reali (sotto) di aumento della pressione dei fluidi intestiziali con la profondità

Figure 4. Fluid-pressure curve from logging data. Note high values adjacent to and below faults. Two spikes indicate extremely high fluid-pressure values in decollement zone. Fluid-pressure estimates from consolidation tests are derived from analysis of individual samples cored at Site 671; note good agreement with log-derived fluid pressures.



Da Maltman, 1994

Da C. Moore et al., 1995, Geology

Curve reali di aumento della pressione dei fluidi interstiziali con la profondità: potenziale dei fluidi e sforzo effettivo

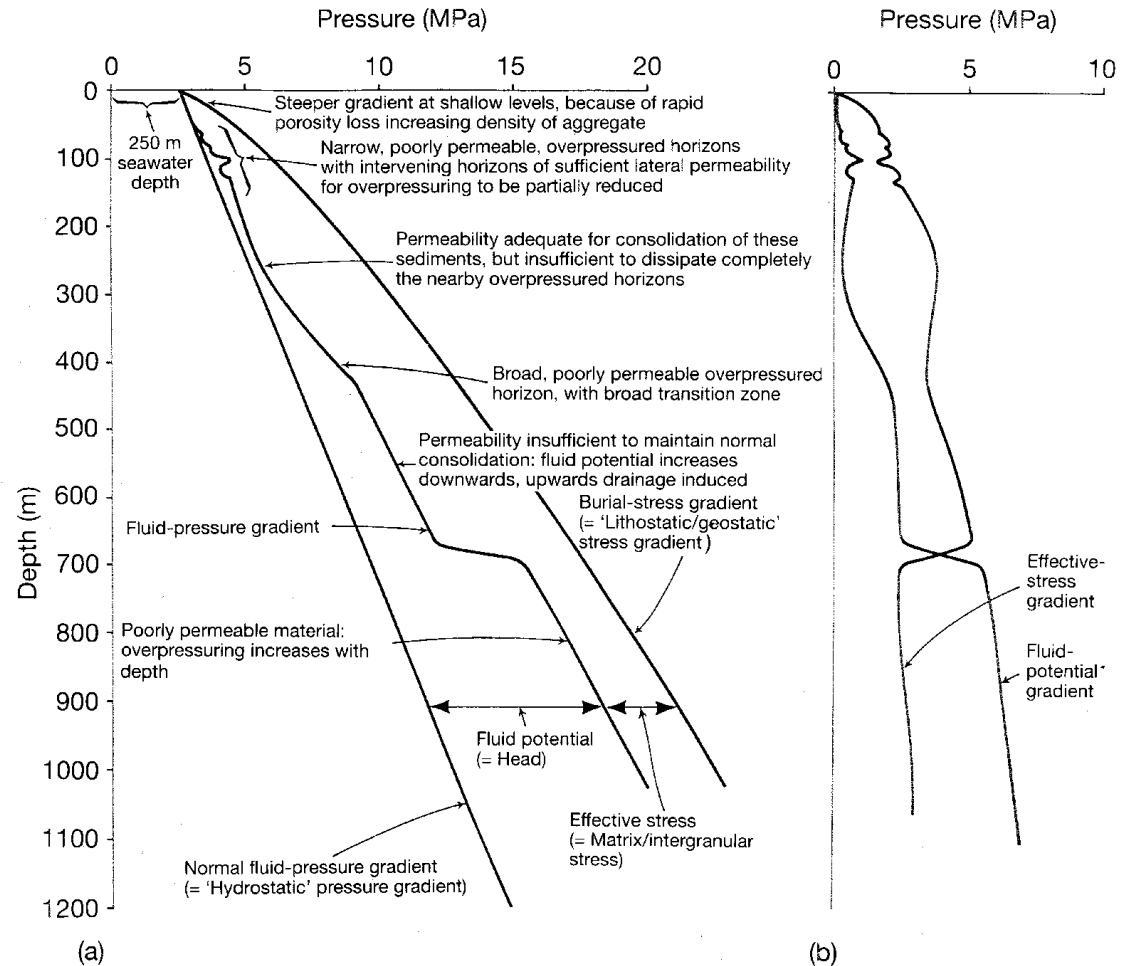


Figure 1.4 Patterns of pressure increase with depth. (a) Rates of increase of pressure and stress due to burial. The gradient for normal fluid pressure is based on an overlying seawater depth of 250 m and a constant fluid density in the entire column of 1025 kg m^{-3} . The burial-stress gradient is based on a grain density of 2650 kg m^{-3} and a porosity decrease with depth following the average values for sand-silt-clay of Einsele (1989). The hypothetical fluid-pressure gradient shown here illustrates the kinds of effects that can arise in a sequence of varied sediments. Compare with Figure 7.5. (b) Effective-stress gradient and fluid-potential gradient derived from the curves in (a). Note that the fluid potential and its gradient should properly be expressed in units of metres (the height that could be supported by a column of specified fluid, normally water or mercury) rather than pascals. The fluid potential, or total head (H), is here a pressure head (Φ), arising from the excess fluid pressure ($P_{H_2O_e}$). See Figures 7.1 and 7.2, and section 7.2 for further explanation. (From Maltman (1994) Reproduced with permission of Pergamon Press.)

Riattivazione dei piani di frattura (faglia) esistenti (comportamento elastico-frizionale)

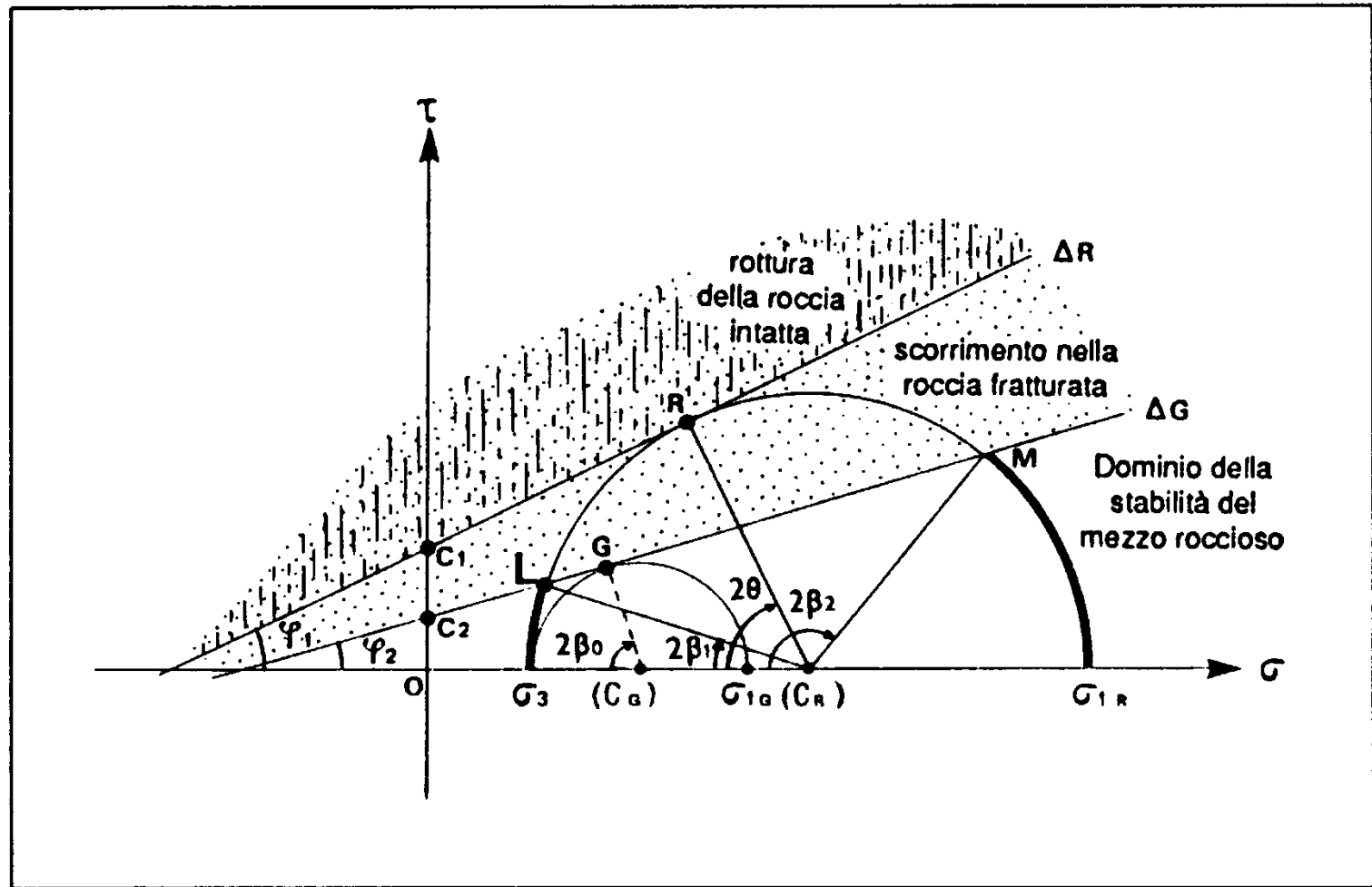
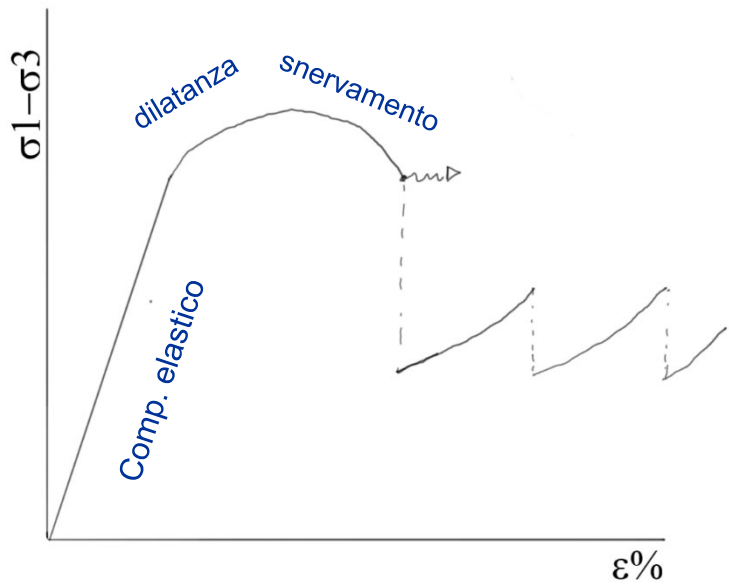
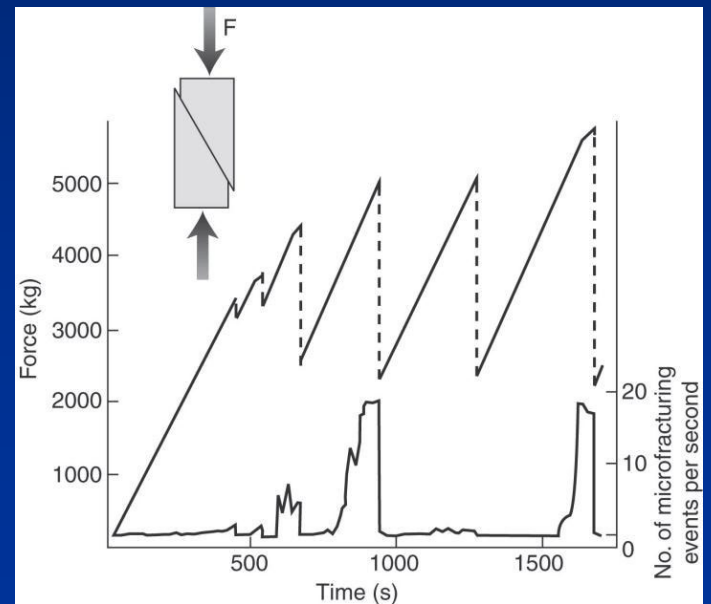


Figura 5.4. Rappresentazione mediante il cerchio e l'involuppo di Mohr delle condizioni di scorrimento lungo un piano preesistente.

Da Mercier & Vergely, 1996

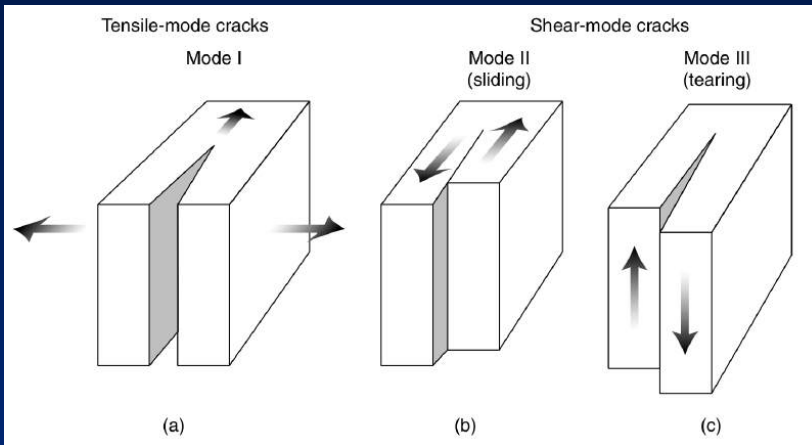


Plasticità post-fratturazione: Comportamento sismico (stick-slip)

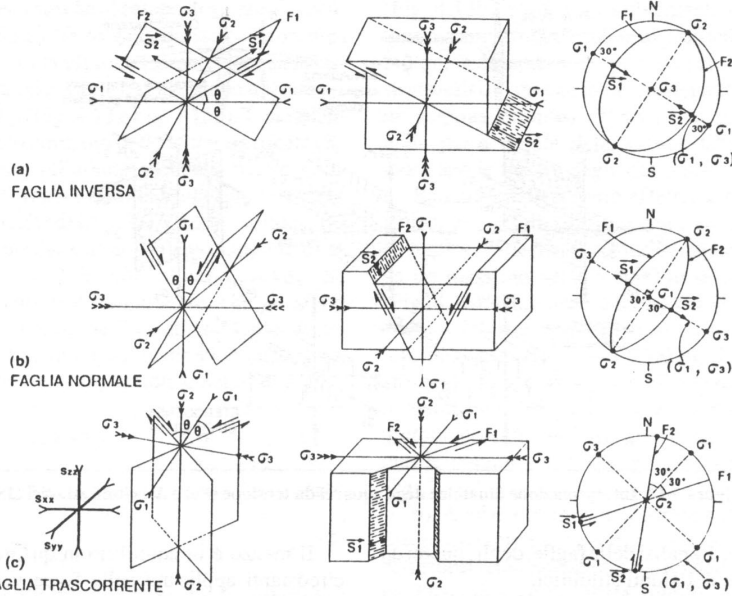


Da van der Pluijm B., Marshak S., 2004

Origine delle strutture fragili: piani di discontinuità effettiva della roccia



Da van der Pluijm B., Marshak S., 2004



Da Mercier & Vergely, 1996

E dopo?

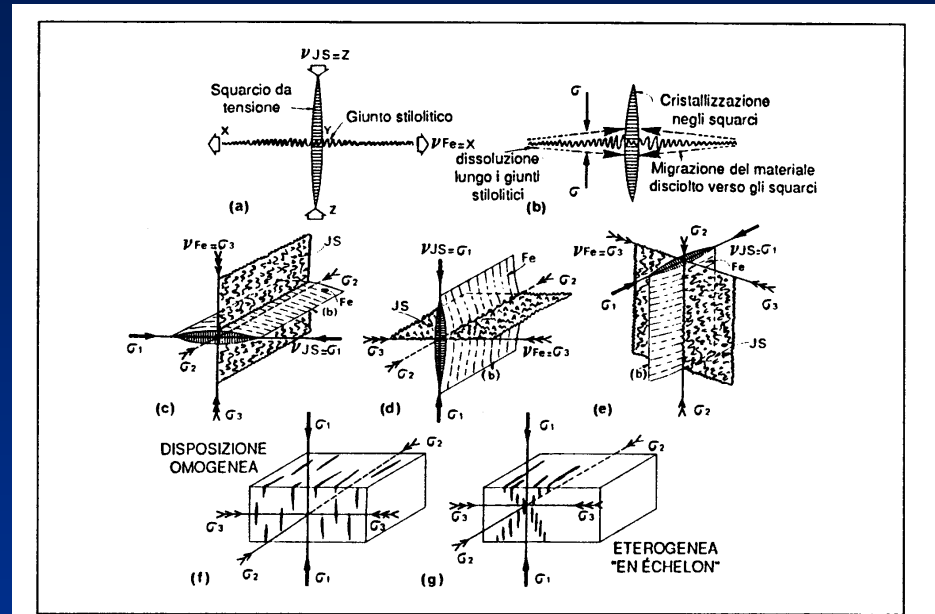


Figura 4.14. Interpretazione dinamica degli squarci da tensione (Fe) e dei giunti stilolici (JS).

Da Mercier & Vergely, 1996