

Orientation of links connecting pairs of neighbour epicentres on Kamchatka: it is non-random, and varies in space and time

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The subject of the study:

HOW **SEISMICITY**

(epicenters and their space-time structure)

REFLECTS

SUBPARALLEL (en-echelon) SETS of LINEAMENTS
(\approx faults)

(1) SUBPARALLEL SETS OF

- LINEAMENTS**
- FAULTS**
- FRACTURES**
- JOINTS**

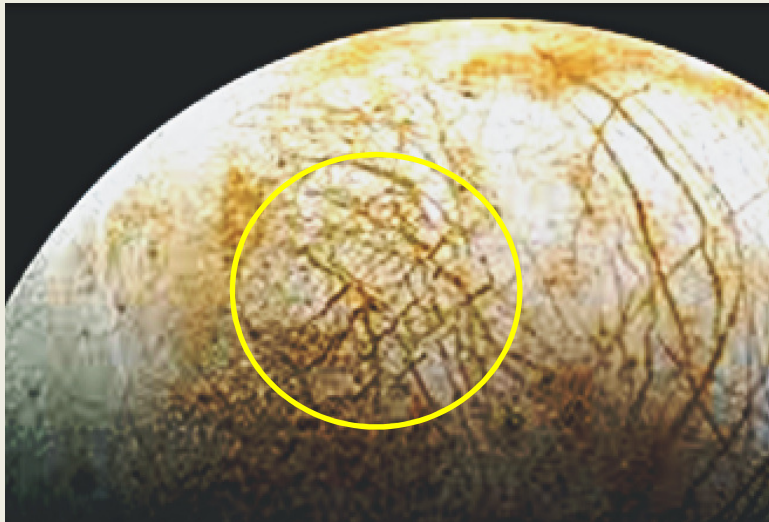


$\approx 60^\circ$



en echelon joint sets

$\approx 60^\circ$



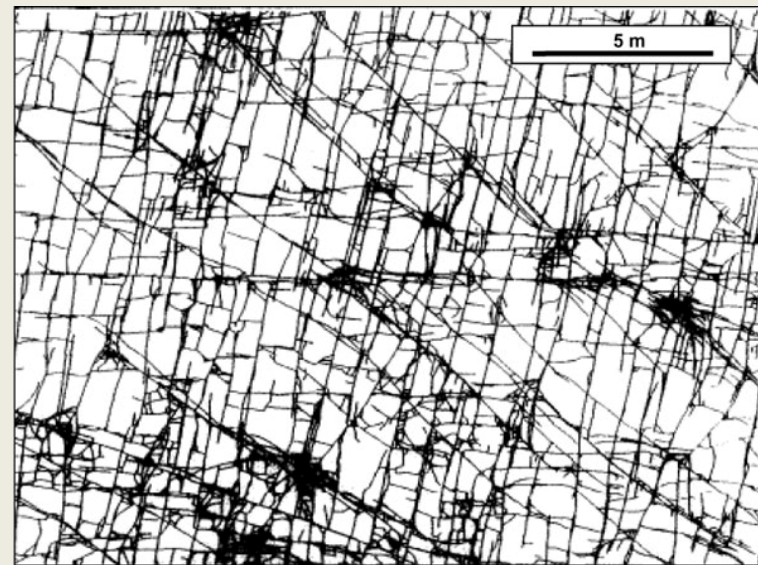
Europe



$\approx 45^\circ$



<http://maps.unomaha.edu/maher/GEOL3300/week1/joints.html>



<https://hub.globalccsinstitute.com/publications/caprock-systems-co2-geological-storage/32-faults-and-fractures>



www.e-education.psu.edu/files/geosc10_web/image/vtrips/unit9/arches3.jpg

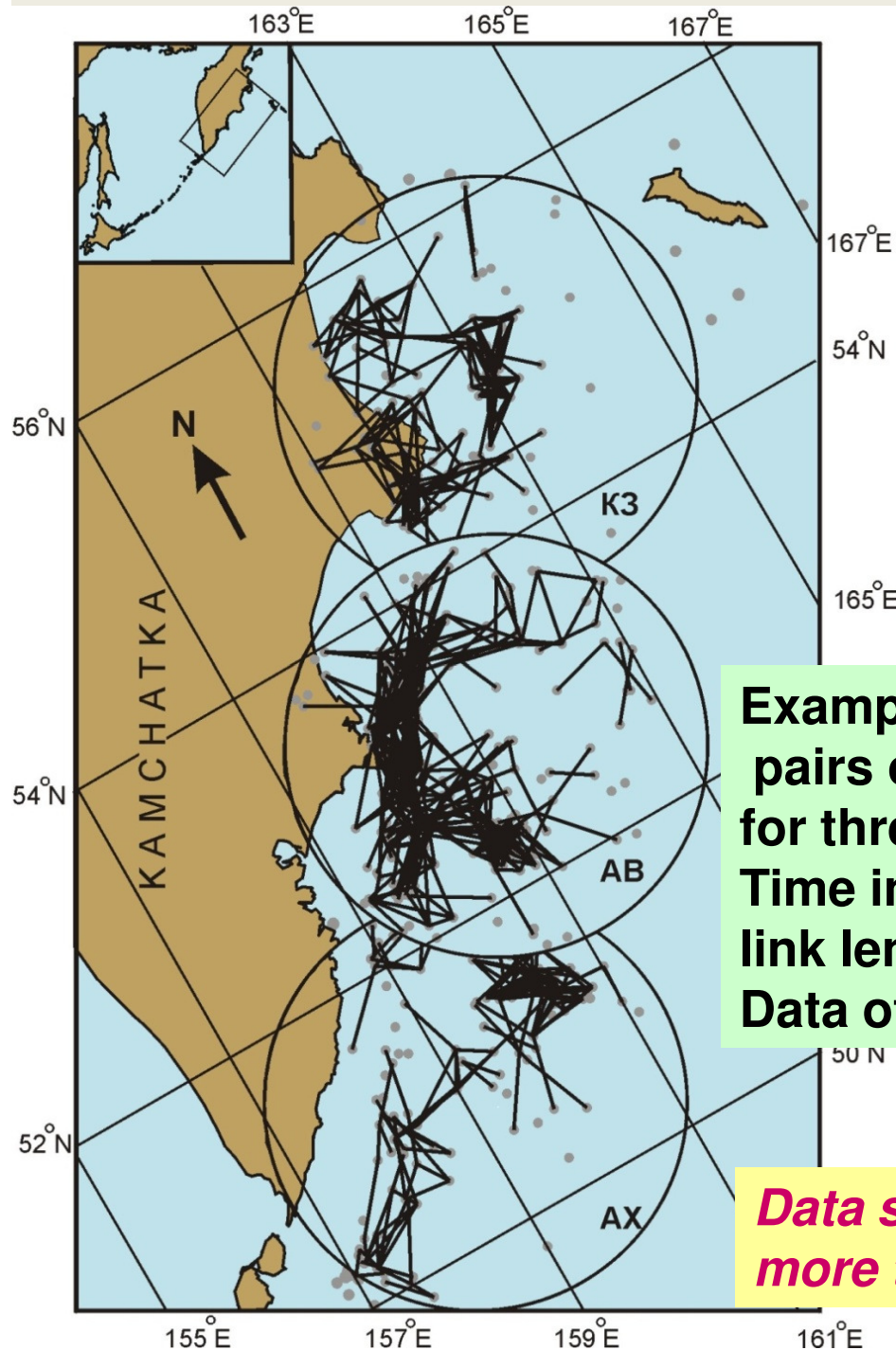


tessellated pavement at [Eaglehawk](#)

$\approx 90^\circ$



(2) Seismicity:
EPICENTERS,
their angular structure
in SPACE-TIME



«Neighbors»: epicenters
that are close
in space **AND** time

Study object: **directions**
of segments or links
that connect a pair of neighbors
in the regional
earthquake catalog
of Kamchatka

**Example: links connecting
pairs of neighbors
for three circles studied
Time interval limit: 15 days
link length: 15 to 60 km
Data of 1962**

***Data suggest en-echelon structures; is it
more than a pure imagination?***

Construction of the histogram of directions (or rose diagrams) of links

- 1. select a **subsection** of the catalog
- 2. do **thinning** (purging dense clusters)
- 3. select all pairs of neighbors by conditions

$$D1 < r_{12} < D2, \quad \Delta t_{12} < \tau$$

- 4. find **azimuths**; rotate to make
“apparent North” along island arc
- 5. make the **initial (R)** histogram/rose
- 6. construct “**normalizer**” histogram
using “non-neighbors”
- 7. make **normalized (N)** histogram
dividing R-histogram by the
“normalizer”

Parameters of the procedure

Position and radius
of the circle of selection

Beginning and end of the
time interval of selection

Neighborhood definition:
in space: $D1, D2$
in time: τ

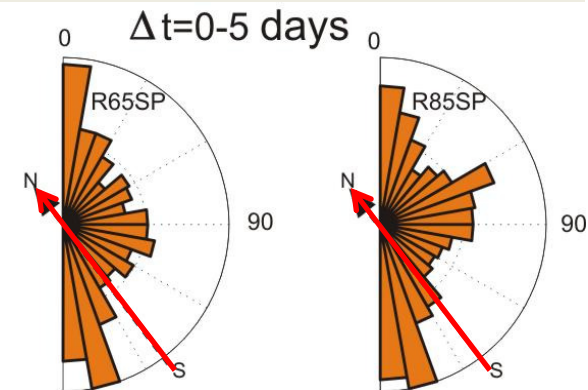
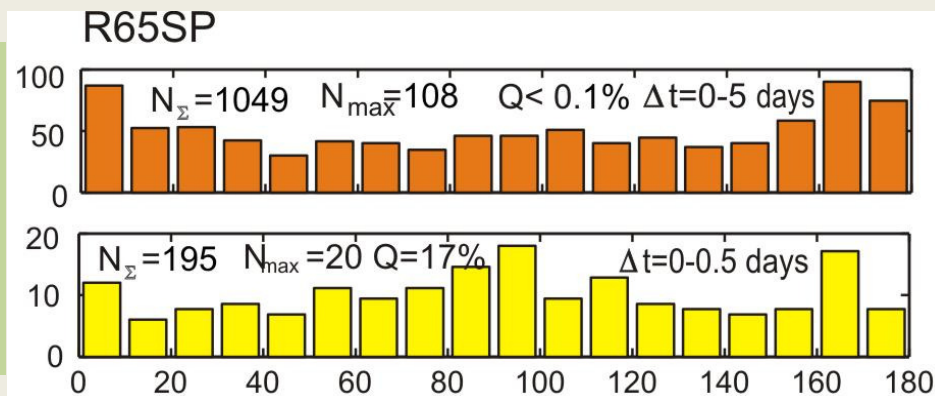
Additional parameter of
neighborhood:
difference of event numbers in
the current list

Parameters of thinning
procedure

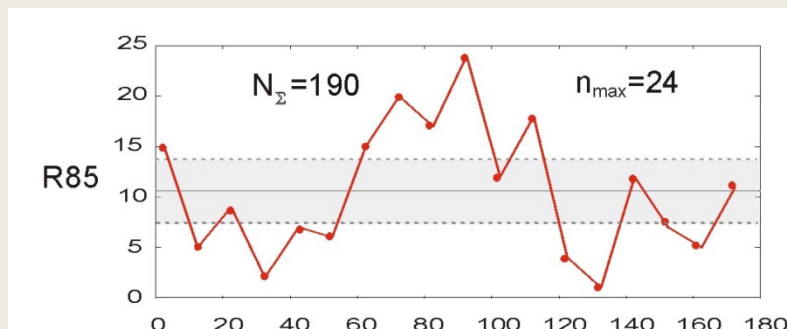
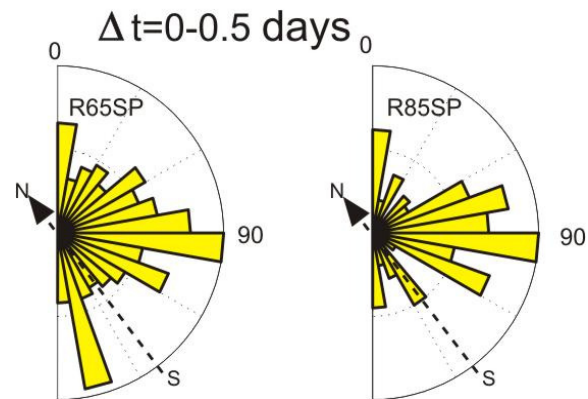
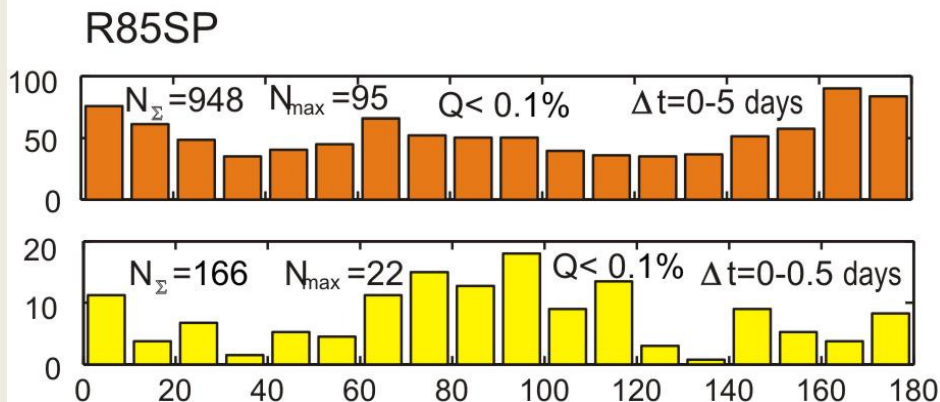
Azimuth rotation angle
(“provisional North”) $\lambda = 37^\circ$

Selecting the time limit, τ , for a pair

$\tau=5$ days
less
unusual
pictures



$\tau=0.5$ days
more
specific
pictures,
preferred



Checking the reality of the deviation
from uniform distribution over azimuth.
 Q is the confidence level against such
hypothesis. Here $Q<0.001$

Using “normalization” to suppress along-arc direction of low interest

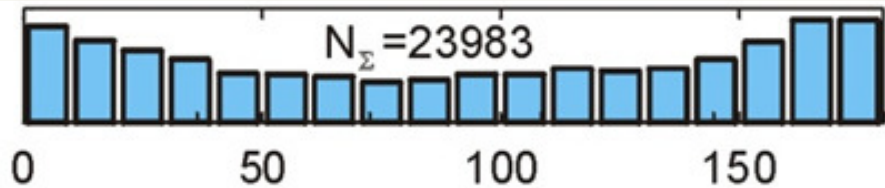
$\tau=0-0.5$ day

Initial

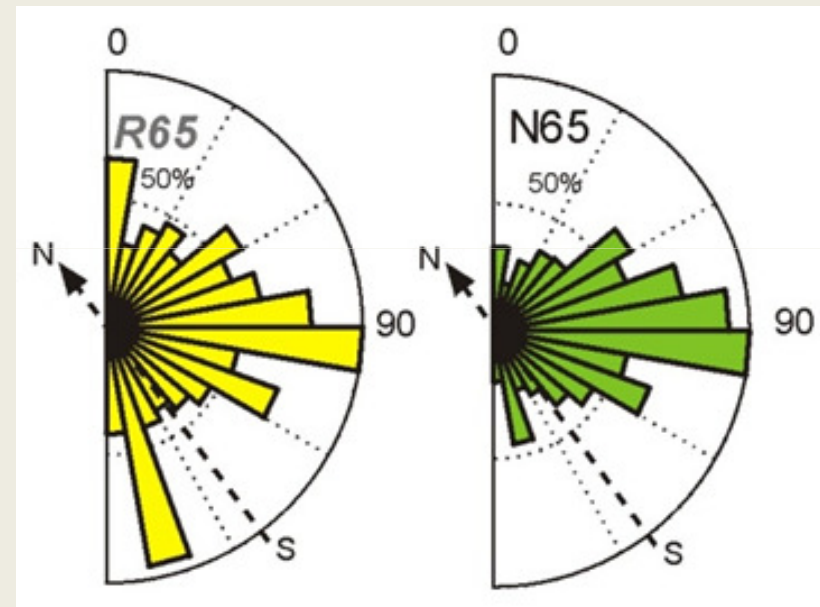
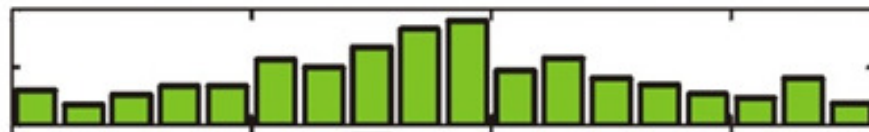


large time intervals $\Delta t_{1-2}=100-150$ days

Normalizer



Normalized



Time intervals and codes

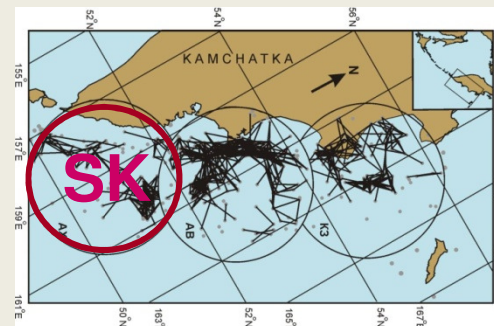
Time interval	Code	Comment
1962 - 1971.11.24	«65»	two M=7.6+ earthquakes after the end of the interval
1972-1980	«75»	
1981-1990	«85»	
1991-1997.12.05	«95»	M=7.9 earthquake after the end of the interval
1998-2010	«05»	

STATISTICS OF DIRECTIONS

Circle SK (K-K arc)

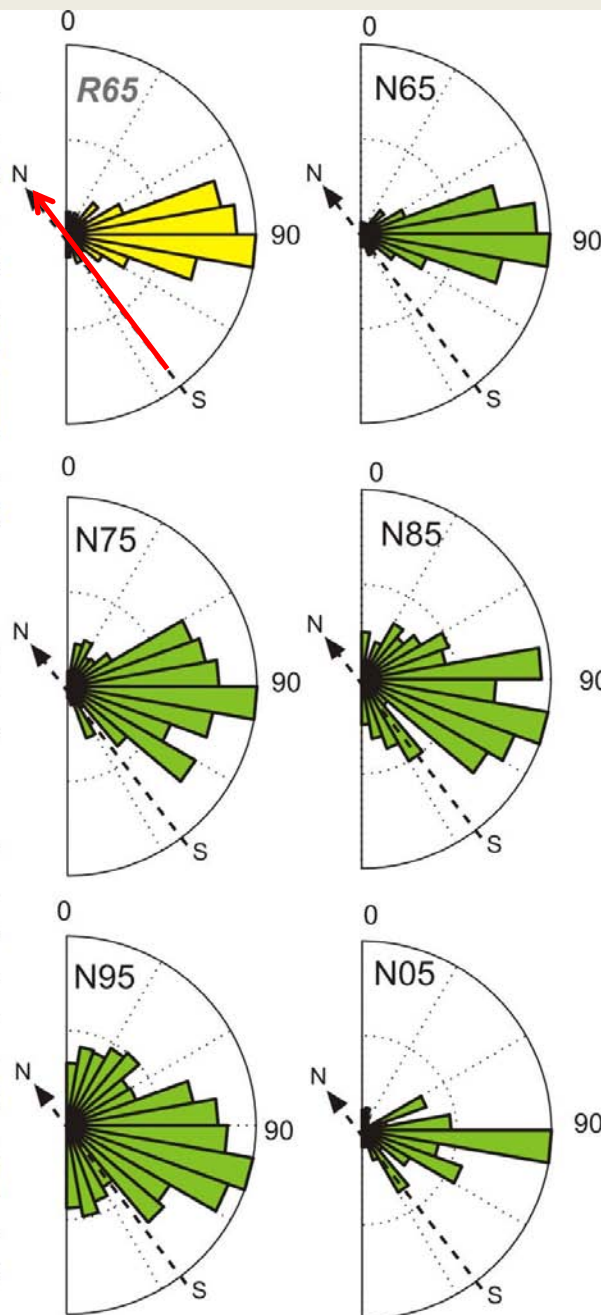
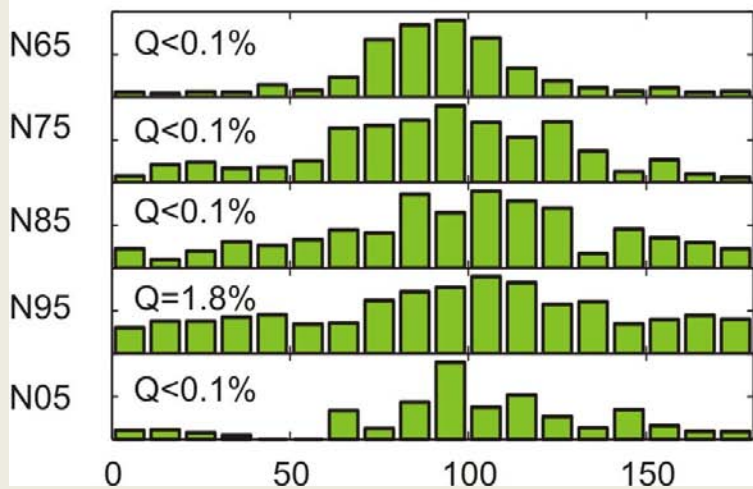
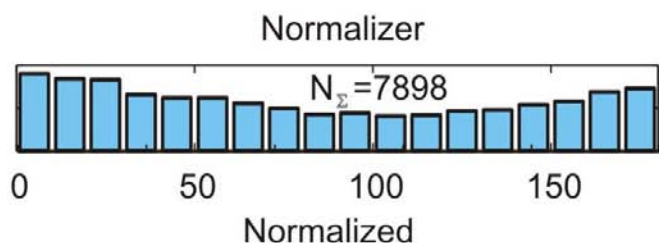
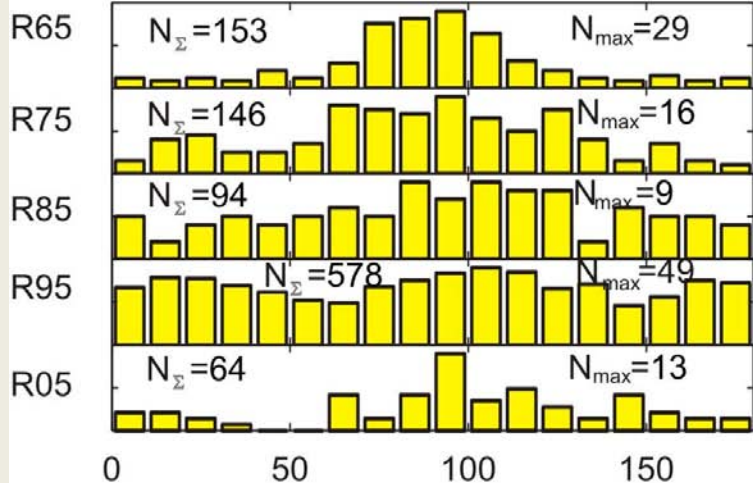
What is seen?

- (1) Petals are present
- (2) The strongest petal is at $\sim 90^\circ$,
- (3) $0-180^\circ$ also is seen
- (4) Petals at 30° , 60° , 45° : seen, not certain
- (5) Petals vary from period to period



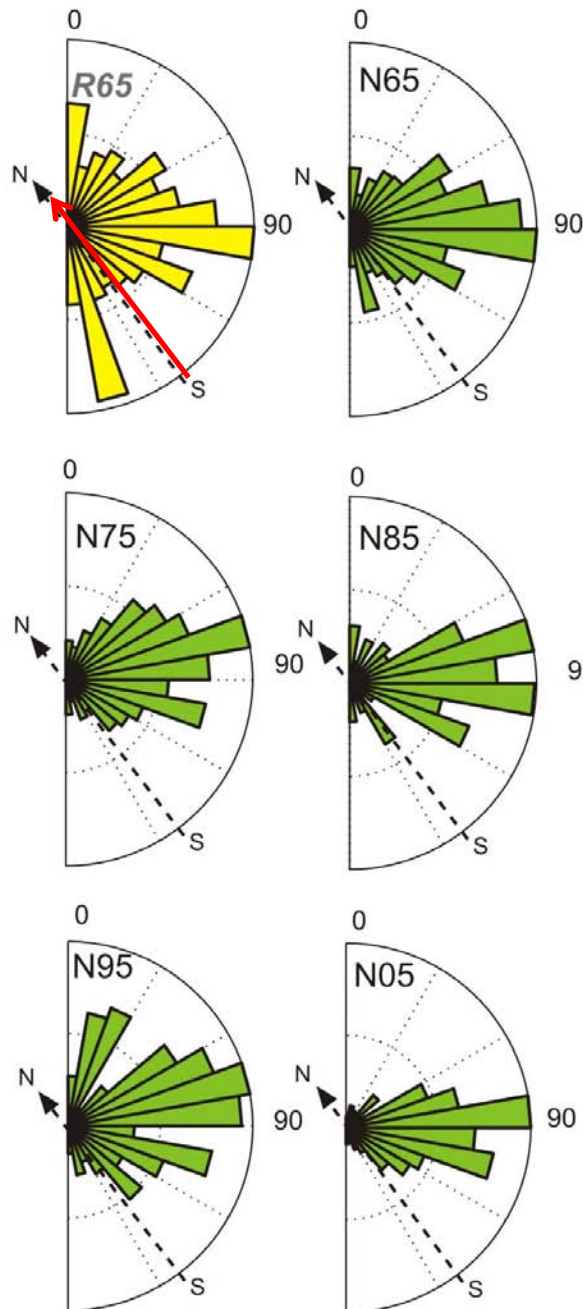
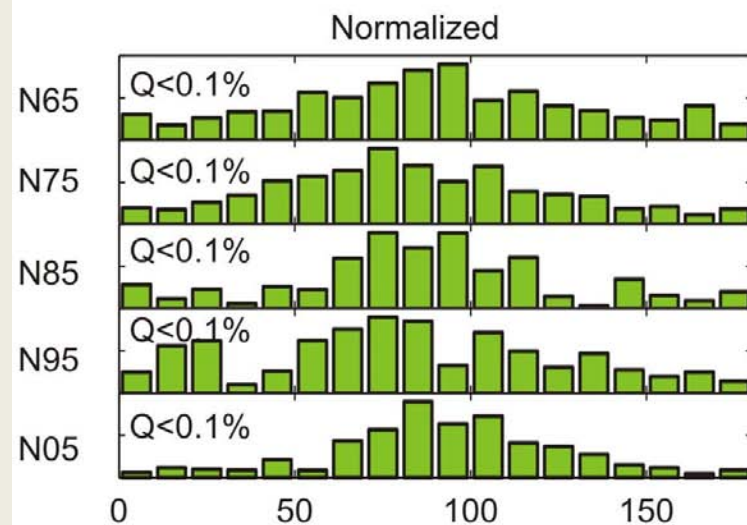
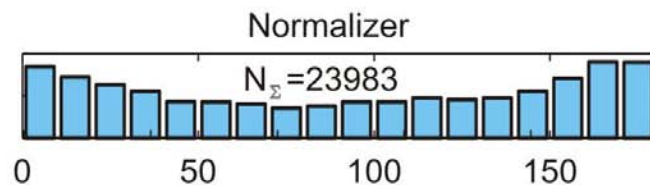
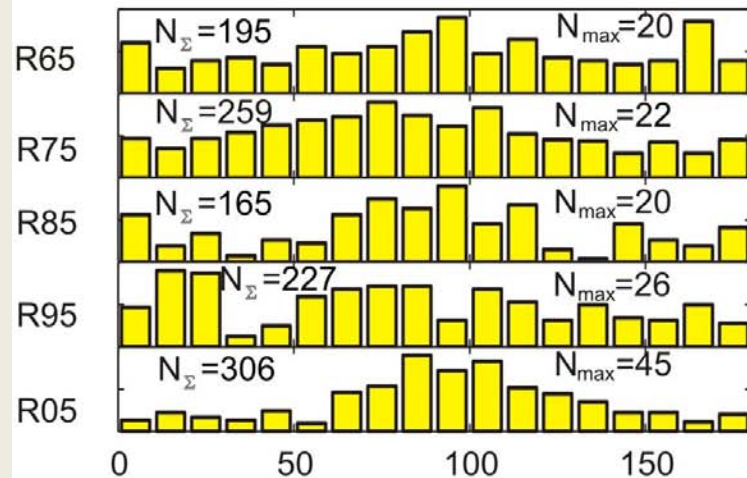
Circle **SK**

Initial



Circle SP

Initial



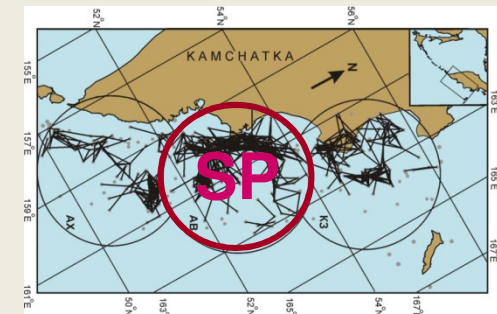
STATISTICS OF DIRECTIONS

Circle SP

(K-K arc)

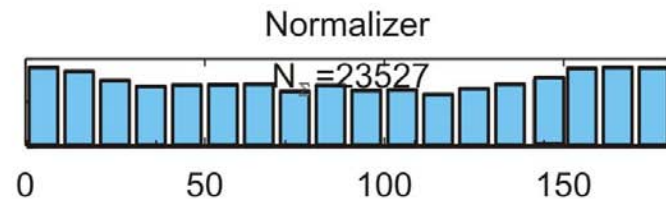
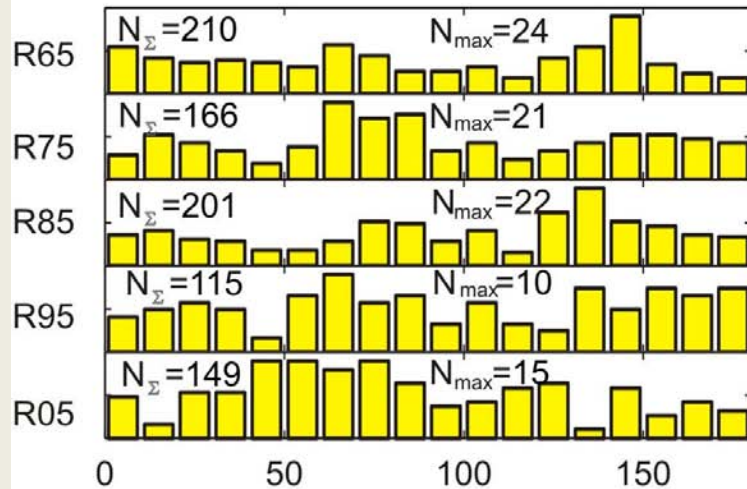
What is seen?

- (1) Petals are present
- (2) The strongest petal is at $\sim 90^\circ$,
- (3) $0-180^\circ$ also is seen
- (4) Petals at 30° , 60° , 45° : seen, not certain
- (5) Petals vary from period to period

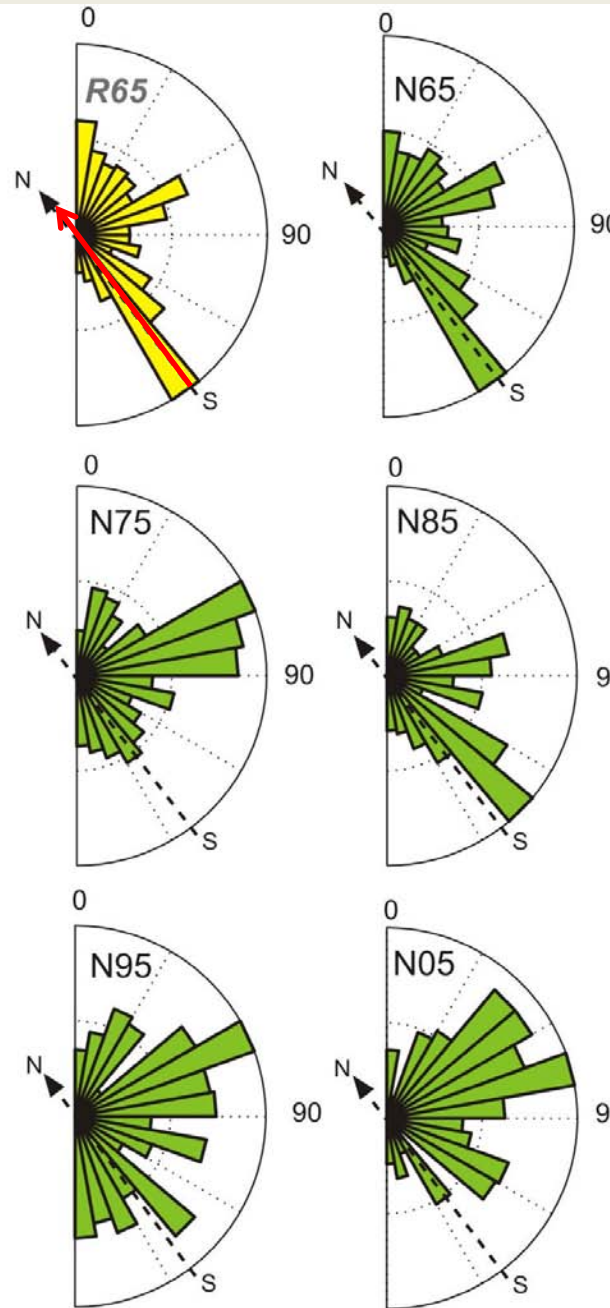
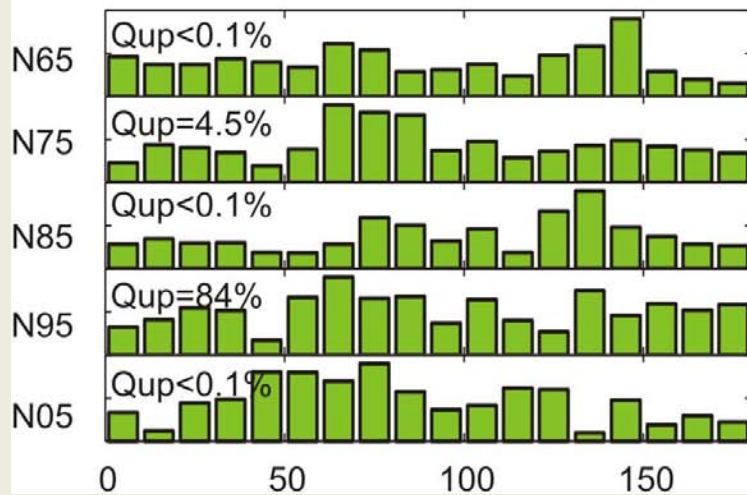


Circle KG

Initial



Normalized



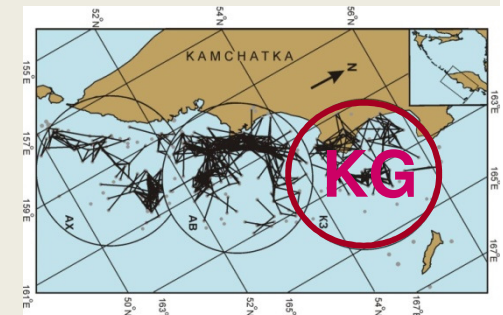
STATISTICS OF DIRECTIONS

Circle KG

(arc-arc junction)

What is seen?

- (1) Petals are present
- (2) The strongest petals are at 65° and 145°
- (3) 0-180° 120° 25° also are seen
- (4) Petals vary from period to period



How petals are formed?

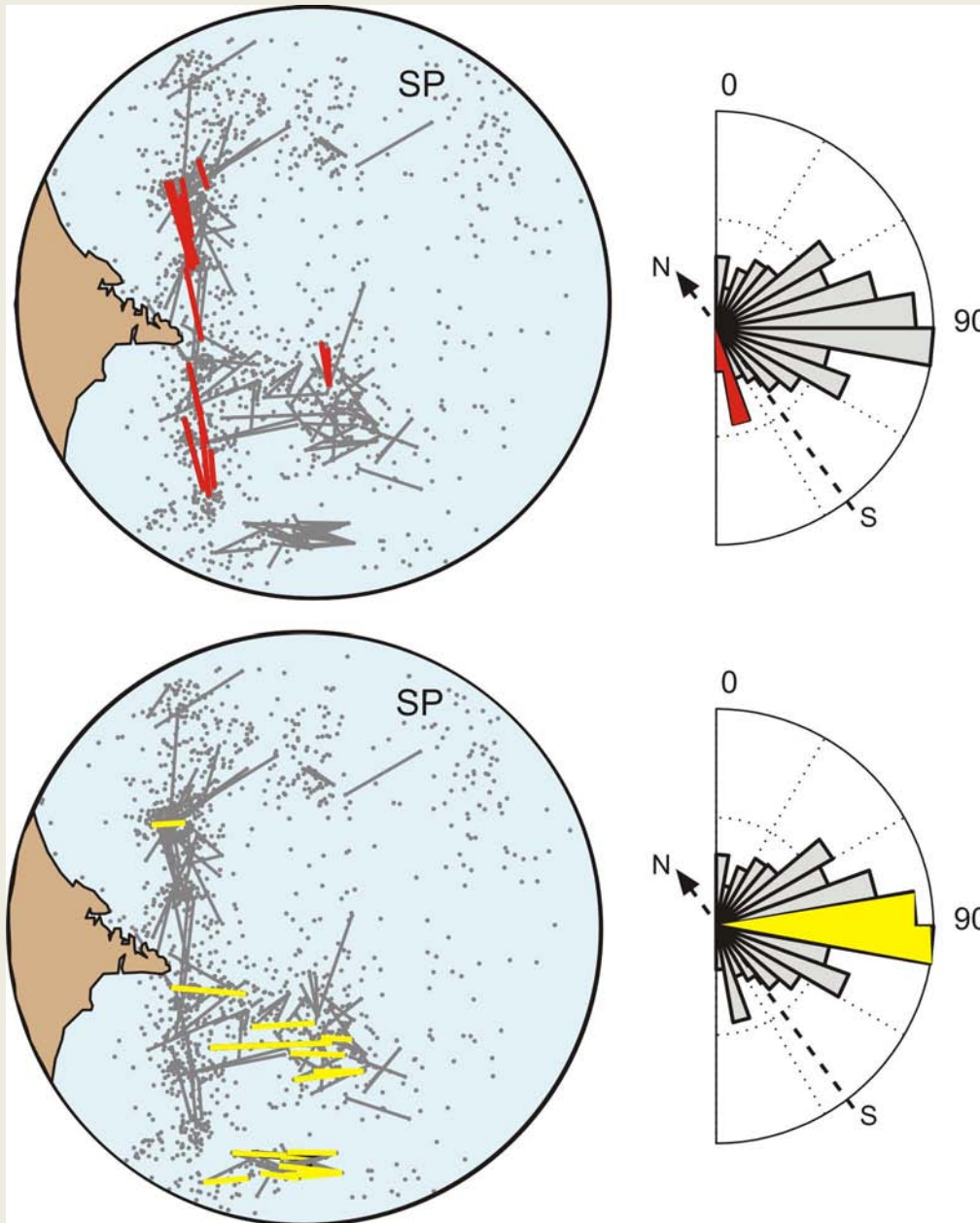
Circle **SP**, period "85".
map and rose diagram

Color: links
of a specific direction:

top: **160°-170°**,

bottom **80°-100°**

Grey: epicenters
and other links



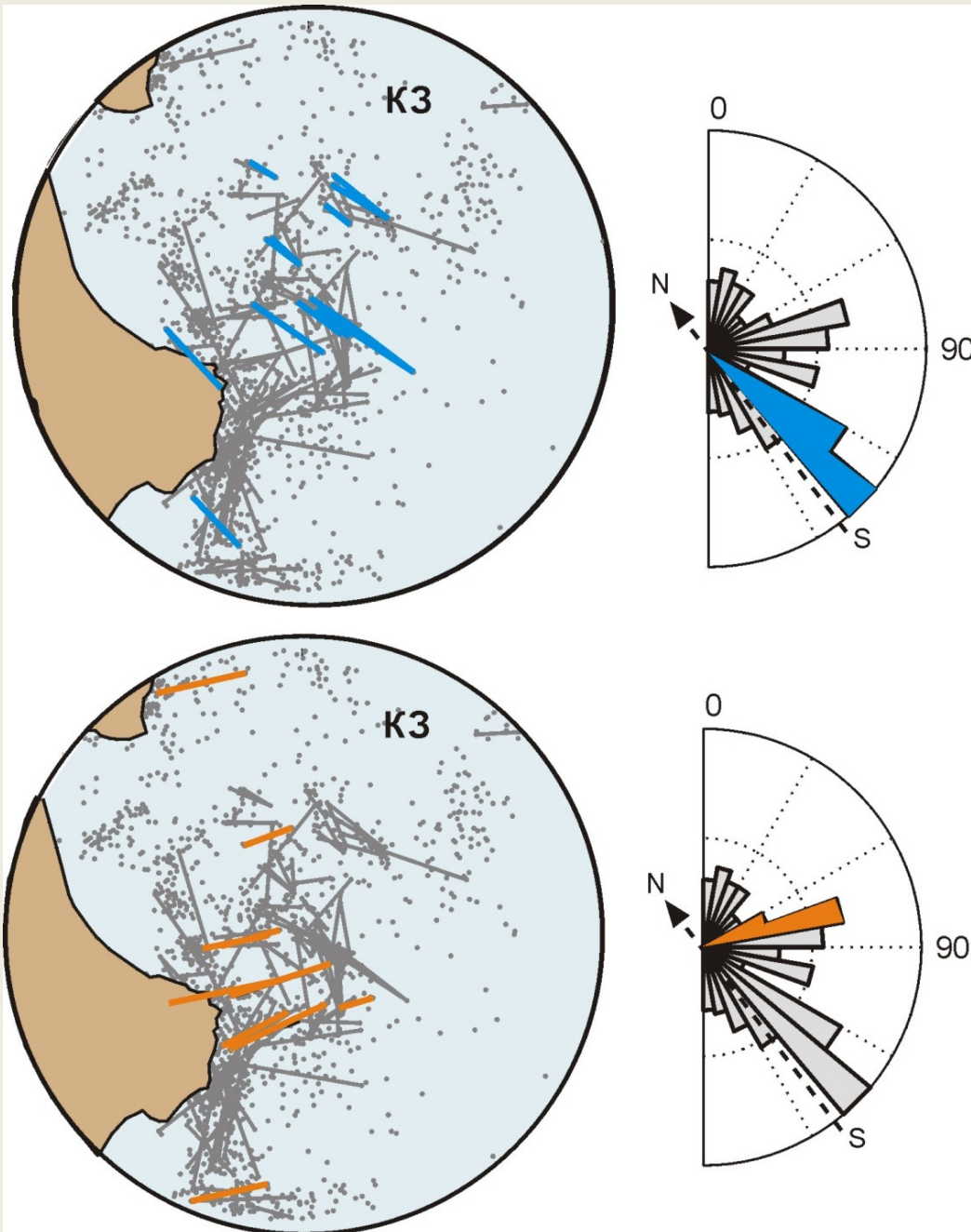
How petals are formed?

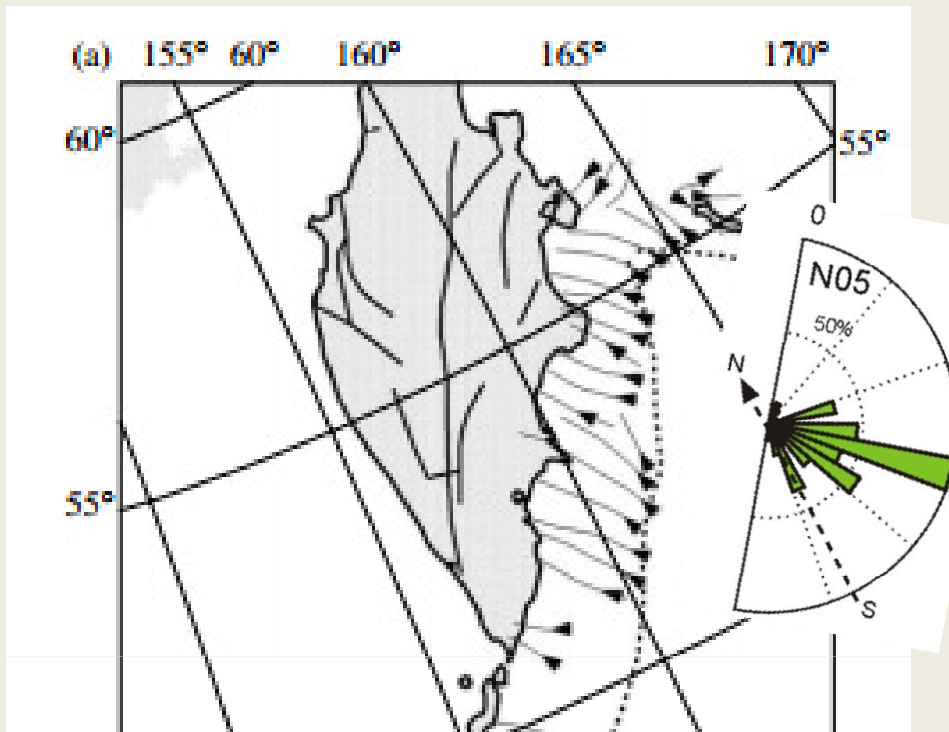
Circle **KG**, period "85".
map and rose diagram

Color: links
of a specific direction:
top: **125°-135°**,

bottom **65°-75°**

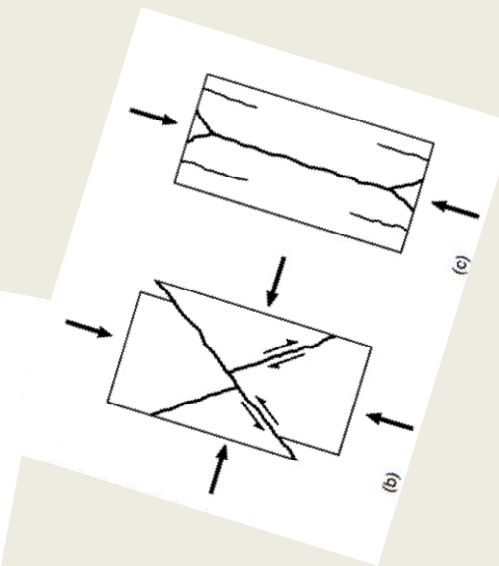
Grey: epicenters
and other links





Map: directions of the compression axis of shear stresses
(Rebetsky 2009)

Paradox: the observed 90° direction (W300N) is specific for tensile cracks at low to negative effective confining pressure



pictures from the Scholz's textbook

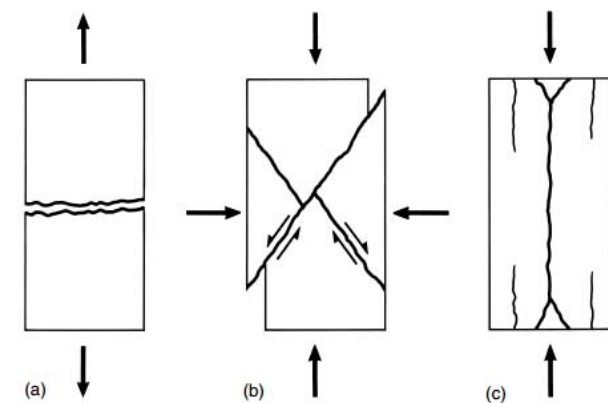


Fig. 1.12. Three modes of fracture observed in laboratory experiments: (a) tensile fracture; (b) faulting in a compression test; (c) splitting observed in a compression test at low confining pressure.

Conclusions

- A technique is developed for identifying, from small earthquake catalog data, preferred directions of motion along subparallel systems of secondary faults.
- Such directions are revealed for three segments of Kurile-Kamchatka subduction zone.
- Preferred directions are clearly observed.
- Preferred directions vary along arc.
- Preferred directions vary in time.

Thank you for
your attention