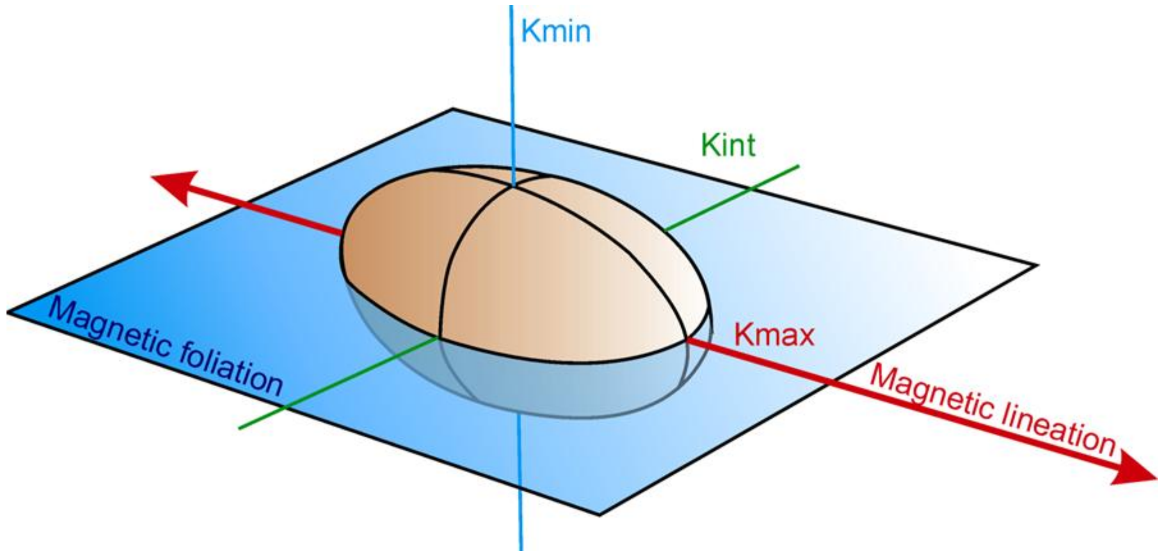
Magnetic Anisotropy of Rocks



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Literature

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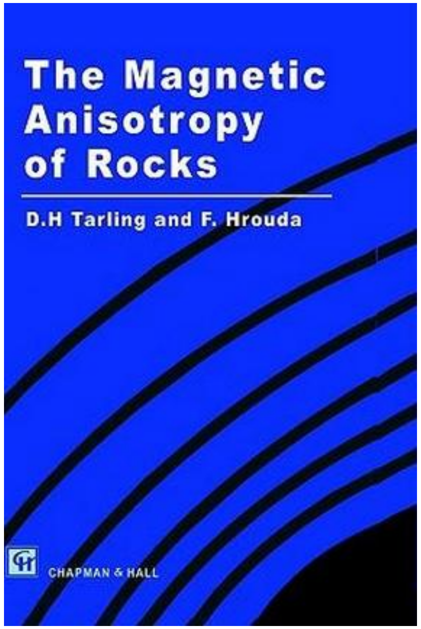

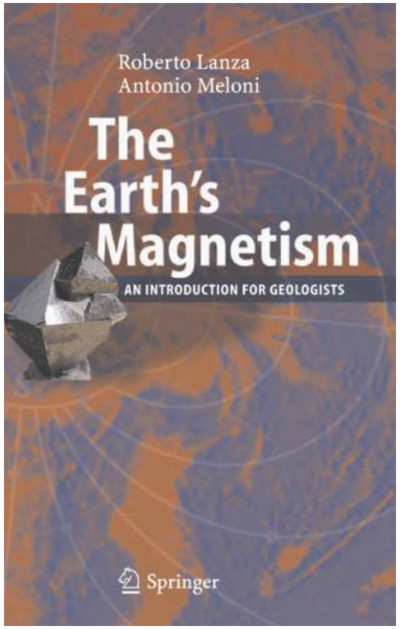

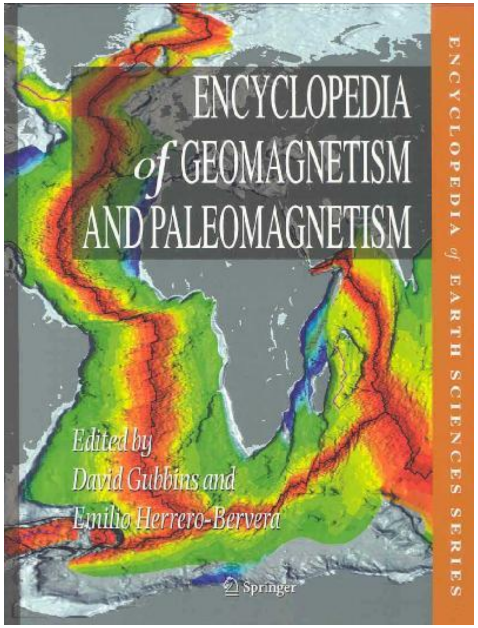

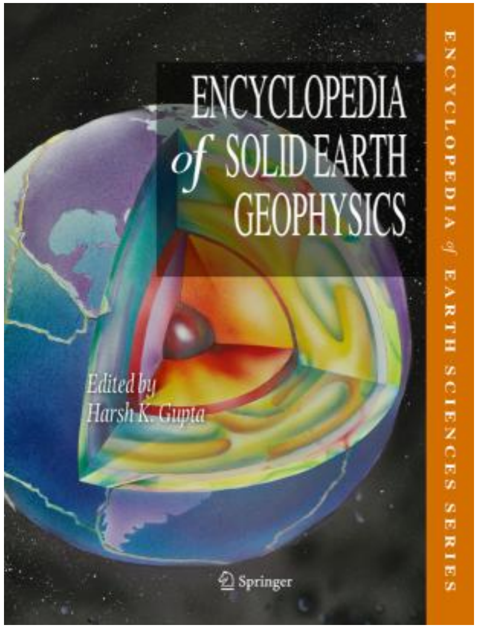

Agenda

1. Definition and application in geology
2. Magnetic anisotropy of minerals
3. Magnetic fabric vs. texture of rocks
4. Magnetic fabric of sedimentary, deformed, and metamorphosed rocks
5. Magnetic fabric of igneous rocks
6. Sampling, measurement and data processing

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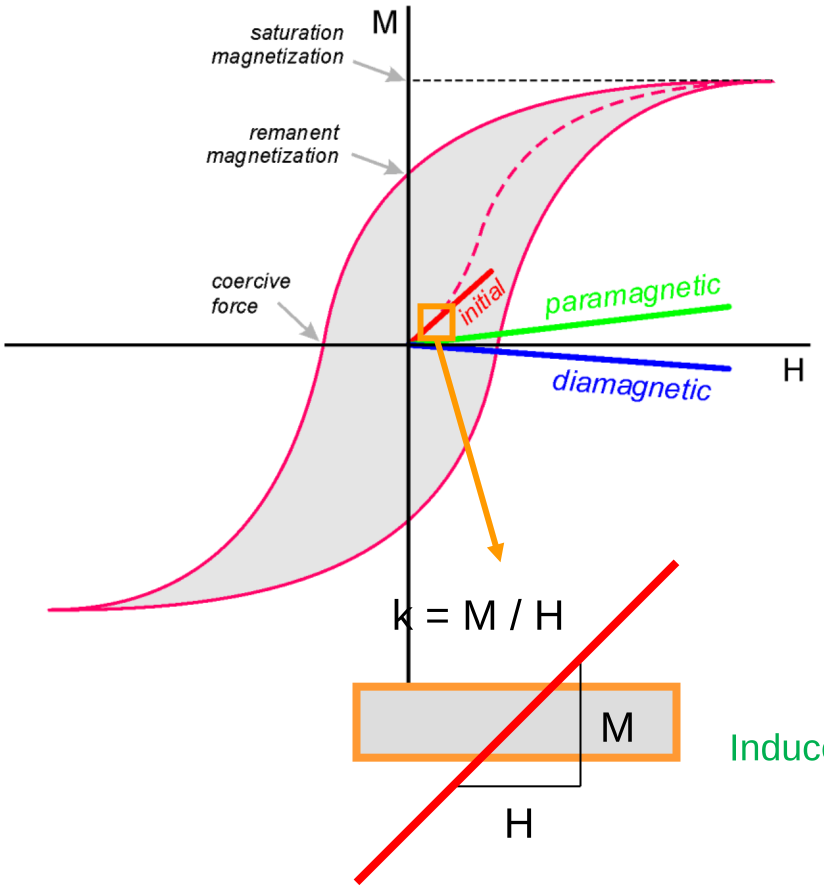
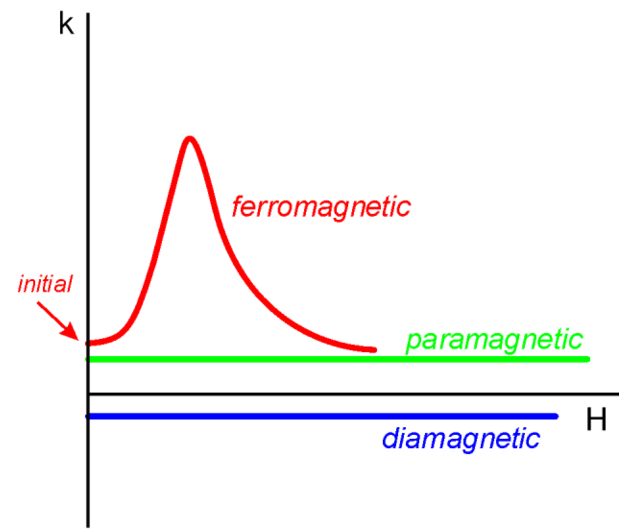
Definition

- Magnetic anisotropy is a directional variability of a certain magnetic property, usually **A**nisotropy of **M**agnetic **S**usceptibility (AMS)
- Tool to study rock texture (Petrofabric)
- Compared to the other methods of fabric analysis (U-stage, X-ray texture goniometry, neutron texture goniometry, EBSD), AMS is fast, cheap, high-resolution, non-destructive.
- It can be applied to many samples covering whole outcrops, drill cores, or geological units.
- Application in structural geology and tectonics, volcanology, sedimentology, and paleomagnetism.

- **Magnetic susceptibility** is the ability to acquire induced magnetization, i.e. ability to get magnetized





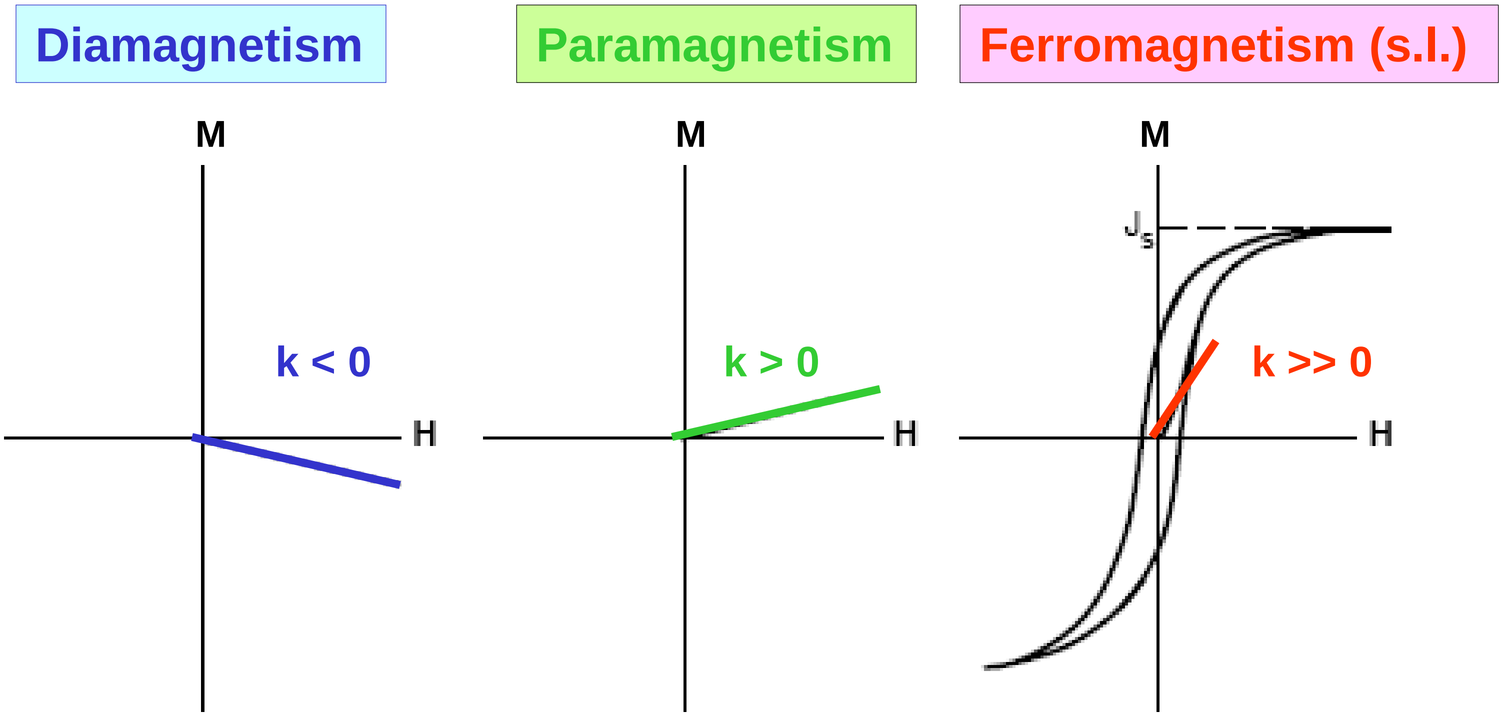
$$\mathbf{M} = \mathbf{Mi} + \mathbf{Mr}$$

Induced magnetization (Mi) — Remanent magnetization (Mr)

$$\mathbf{Mi} = k \times \mathbf{H}$$

k: Magnetic susceptibility

$$k = \mathbf{Mi} / \mathbf{H}$$

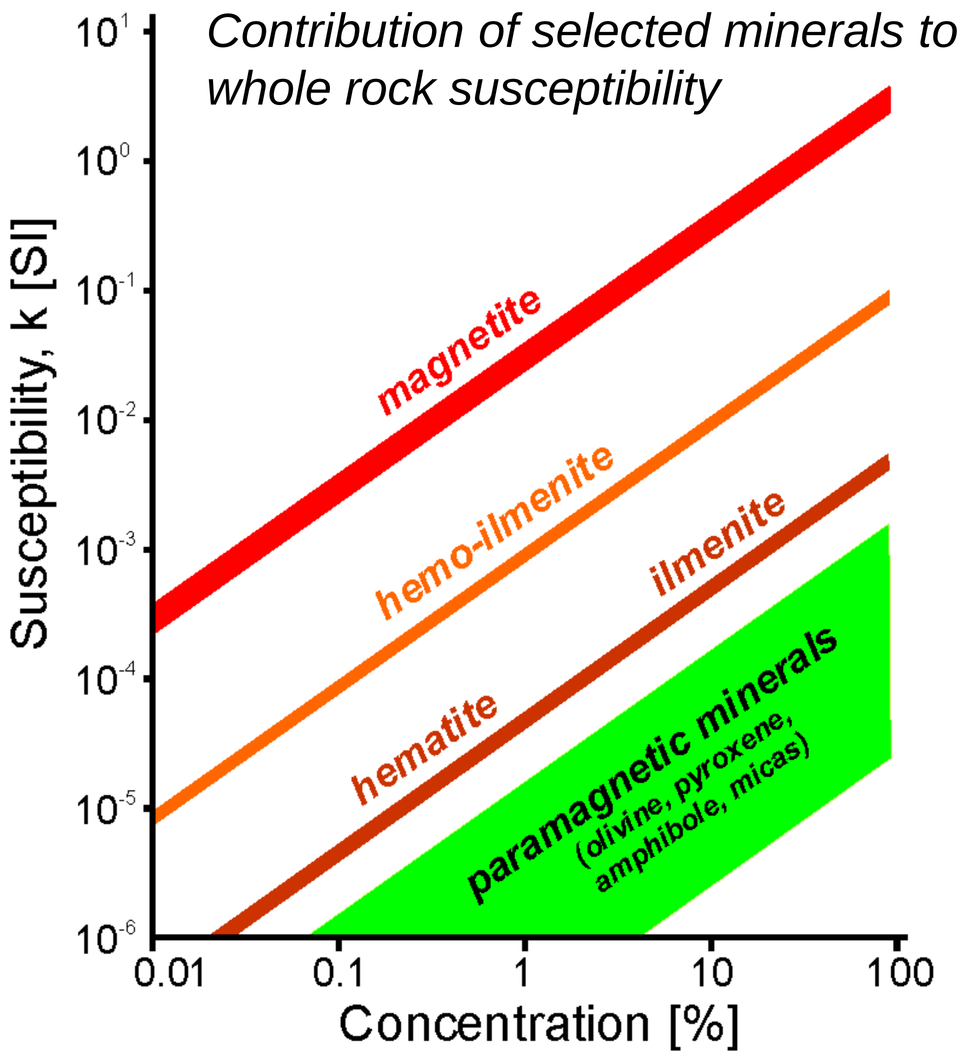


Diamagnetism	Paramagnetism	Ferromagnetism (s.l.)
Induced magnetization antiparallel to the external field	Induced magnetization parallel to the external field	Complex relationship between external field and induced magnetization: hysteresis curve
Magnetic susceptibility relatively **low** and **negative**	Magnetic susceptibility relatively **low** and **positive**	Magnetic susceptibiliy relatively **high**
No remanence	**No remanence**	**Remanent magnetization**
quartz *calcite* *aragonite*	*pyroxene* *hornblende* *olivine* *micas*	*iron* *magnetite* *hematite* *pyrrhotite*

- Magnetic susceptibility is the ability to acquire induced magnetization, i.e. ability to get magnetized

$$\mathbf{M} = k \times \mathbf{H}$$

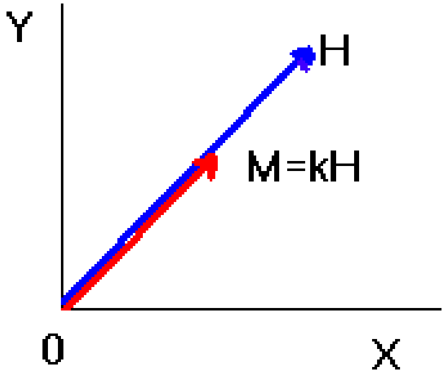
$$k = M / \mathbf{H}$$



Anisotropy magnetic susceptibility (AMS)

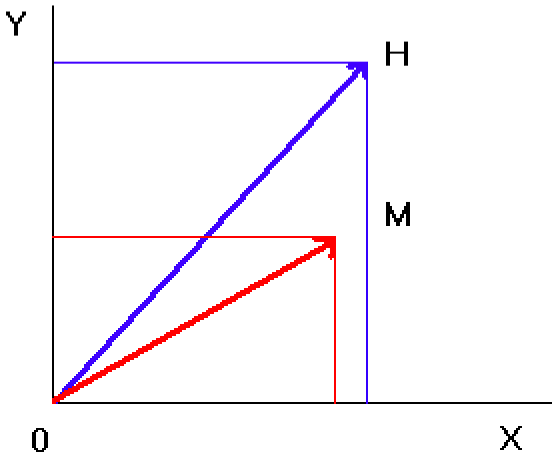
Magnetically isotropic material

$M_1 = k\, H_1$
$M_2 = k\, H_2$
$M_3 = k\, H_3$



Magnetization of anisotropic materials

$M_1 = k_{11}\, H_1 + k_{12}\, H_2 + k_{13}\, H_3$
$M_2 = k_{21}\, H_1 + k_{22}\, H_2 + k_{23}\, H_3$
$M_3 = k_{31}\, H_1 + k_{32}\, H_2 + k_{33}\, H_3$



Matrix notation

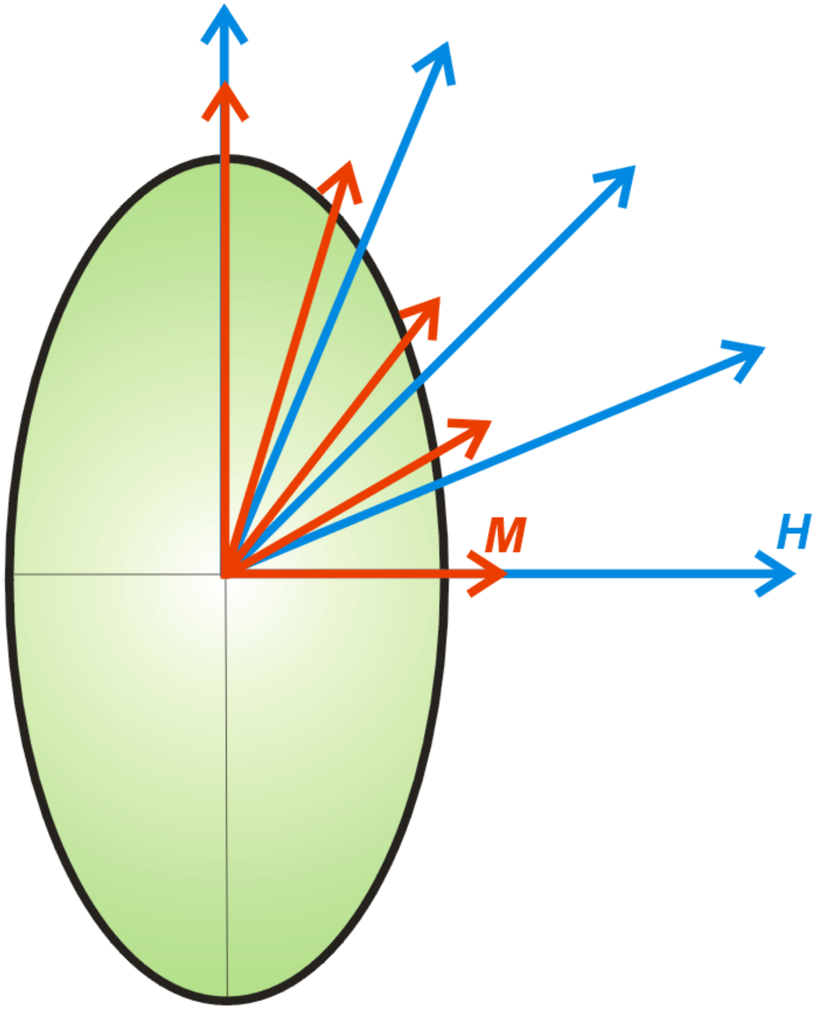
$$\begin{vmatrix} M_1 \\ M_2 \\ M_3 \end{vmatrix} = \begin{vmatrix} k_{11} & k_{12} & k_{13} \\ k_{21} & k_{22} & k_{23} \\ k_{31} & k_{32} & k_{33} \end{vmatrix} \begin{vmatrix} H_1 \\ H_2 \\ H_3 \end{vmatrix}$$

Vector of field intensity

Vector of magnetization

Susceptibility tensor

Anisotropic magnetizing ellipsoidal grain

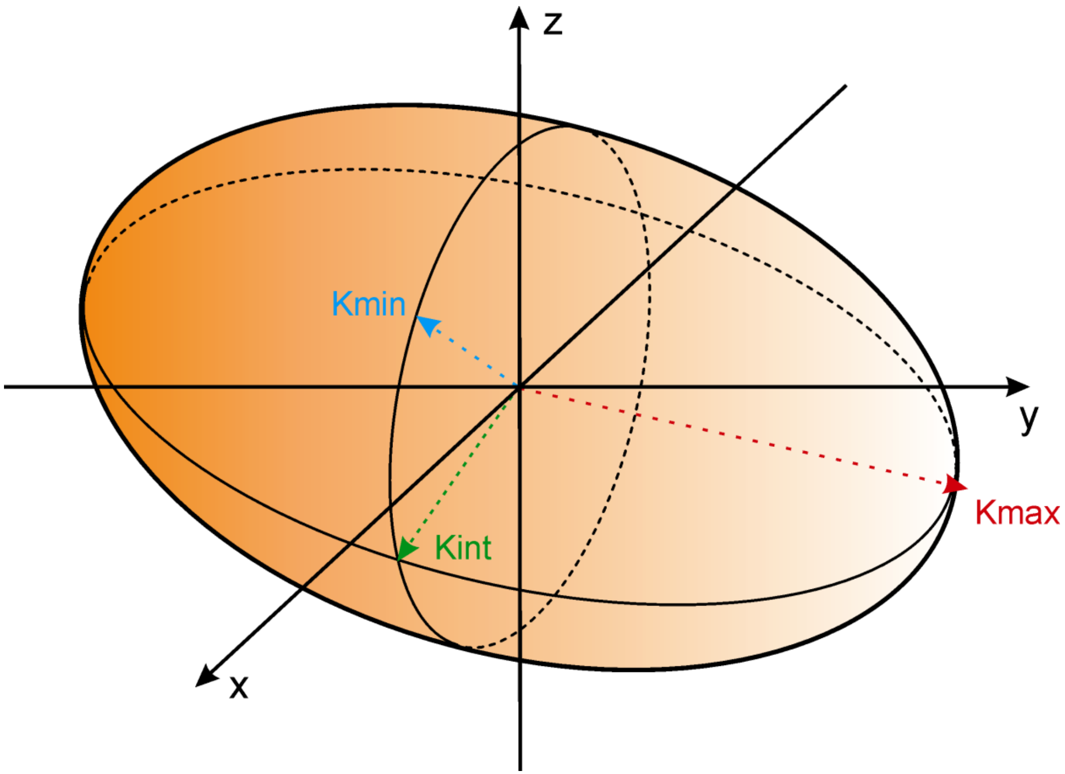


- If one magnetizes an ellipsoidal grain of magnetite and the magnetizing field is parallel to ellipsoid axes, the magnetization is parallel to the field.
- Otherwise, the magnetization deflects from the field.
- The relationship between field and magnetization is described by the susceptibility tensor.

$$\mathbf{M} = k \times \mathbf{H}$$

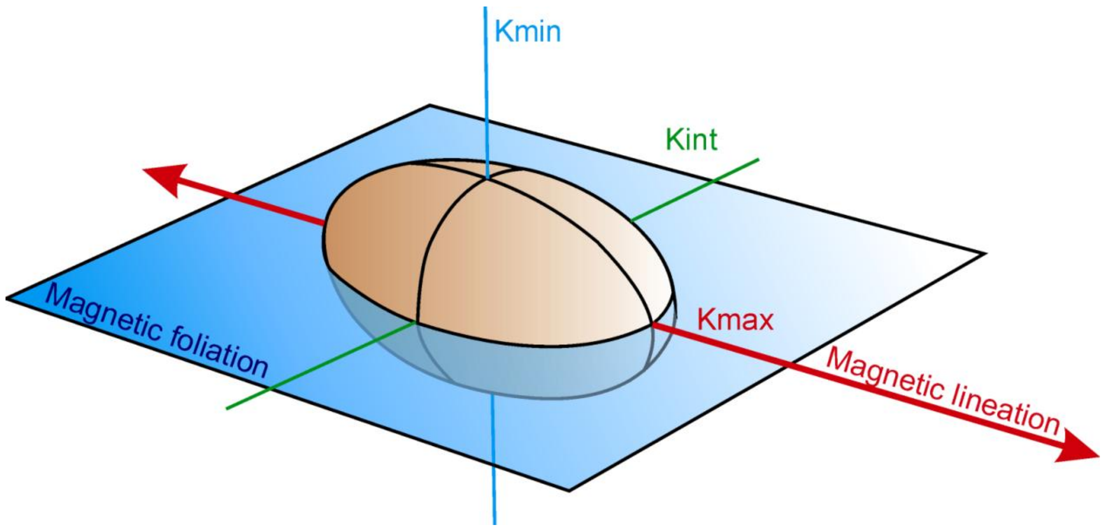
Ellipsoid as geometrical visualization of tensor

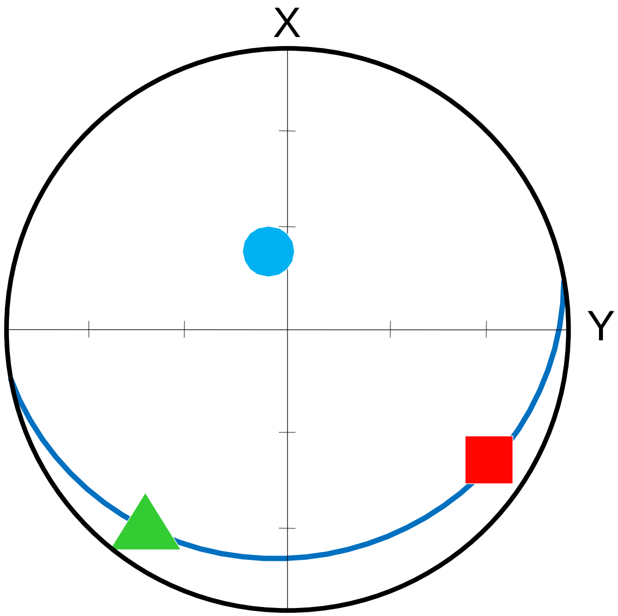
$$\begin{vmatrix} M_1 \\ M_2 \\ M_3 \end{vmatrix} \begin{matrix} = \\ = \\ = \end{matrix} \begin{vmatrix} k_{11} & k_{12} & k_{13} \\ k_{21} & k_{22} & k_{23} \\ k_{31} & k_{32} & k_{33} \end{vmatrix} \begin{vmatrix} H_1 \\ H_2 \\ H_3 \end{vmatrix}$$



Magnetic fabric

Rock fabric defined from magnetic anisotropy





Principal susceptibilities

$$k_1 \geq k_2 \geq k_3$$

Mean susceptibility

$$k_m = (k_1 + k_2 + k_3) / 3$$

Degree of anisotropy

$$P = k_1 / k_3$$

Shape parameter

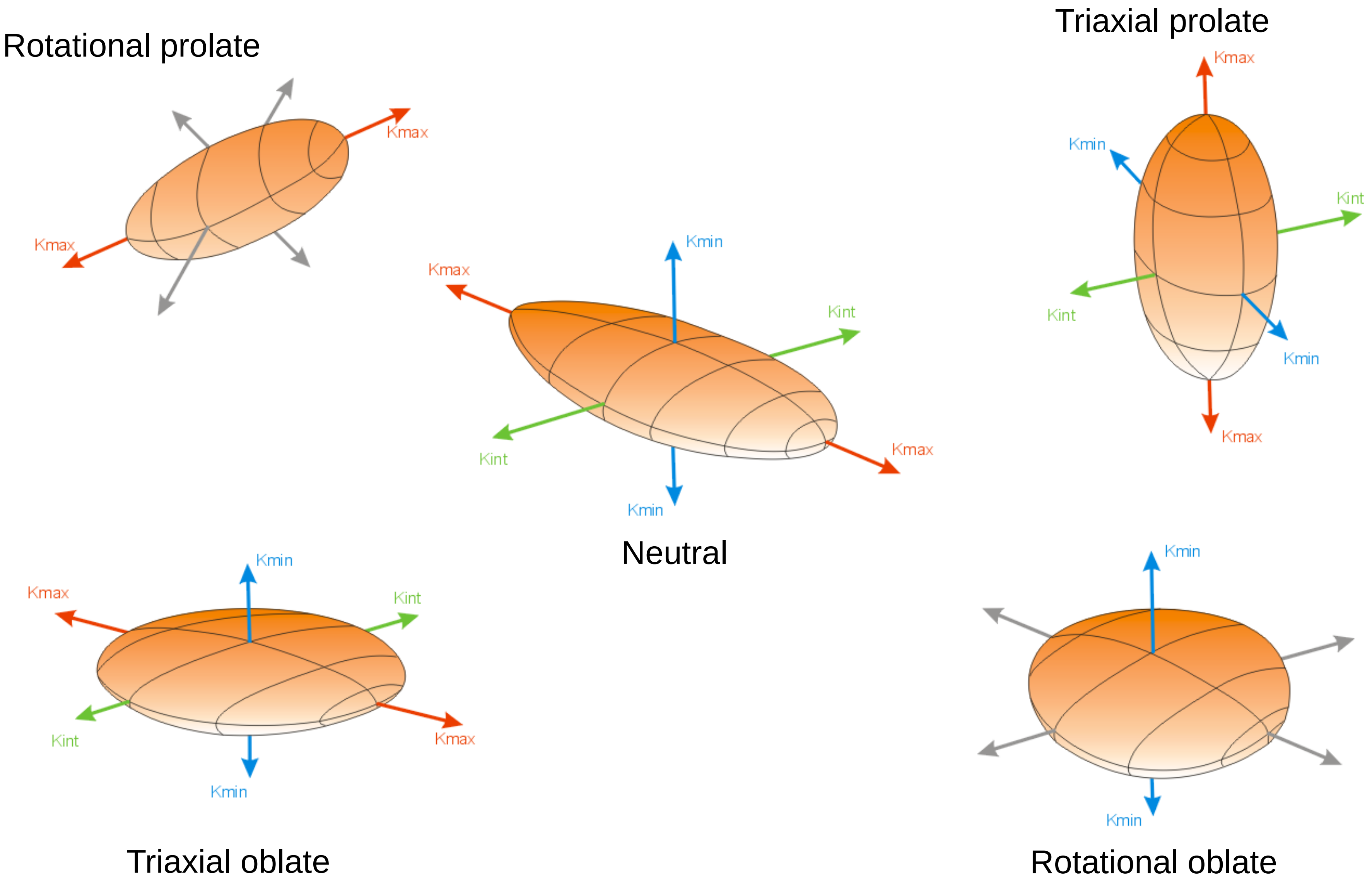
$$T = (2\eta_2 - \eta_1 - \eta_3) / (\eta_1 - \eta_3)$$

where $\eta_1 = \ln k_1$, $\eta_2 = \ln k_2$, $\eta_3 = \ln k_3$

$+1 > T > 0$ oblate (planar) fabric

$-1 < T < 0$ prolate (linear) fabric

Shapes of anisotropy ellipsoids



Quantitative parametrs of anisotropy

$k_1 \geq k_2 \geq k_3$ ← *principal susceptibilities*

$k_m = (k_1 + k_2 + k_3) / 3$ ← *mean susceptibility*

$P = k_1 / k_3$ ← *degree of anisotropy*

$L = k_1 / k_2$ ← *degree of magnetic lineation*

$F = k_2 / k_3$ ← *degree of magnetic foliation*

$T = (2\eta_2 - \eta_1 - \eta_3) / (\eta_1 - \eta_3)$ ← *shape parameter*

where $\eta_1 = \ln k_1$, $\eta_2 = \ln k_2$, $\eta_3 = \ln k_3$

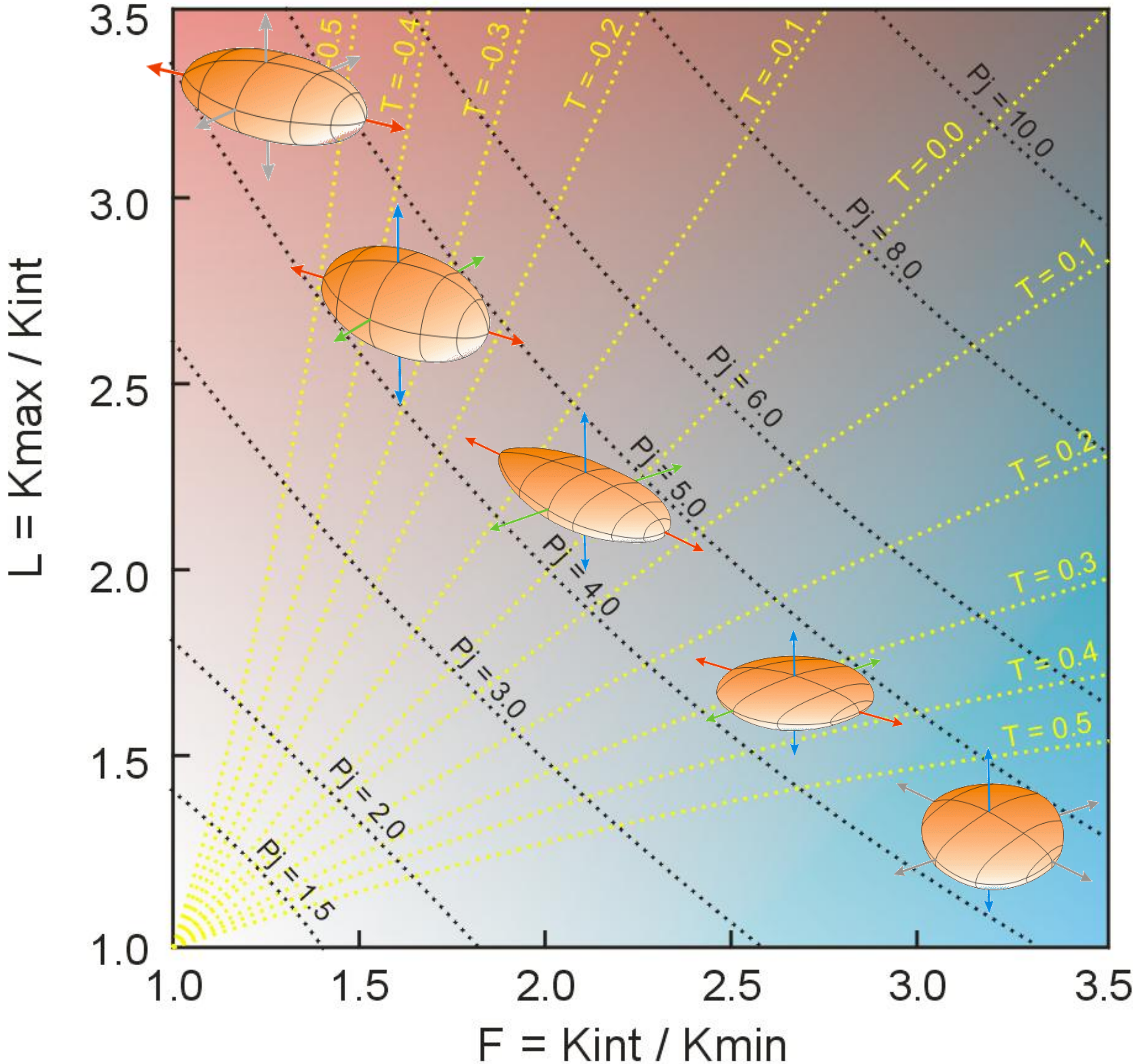
$+1 > T > 0$ *oblate (planar) ellipsoid*

$-1 < T < 0$ *prolate (linear) ellipsoid*

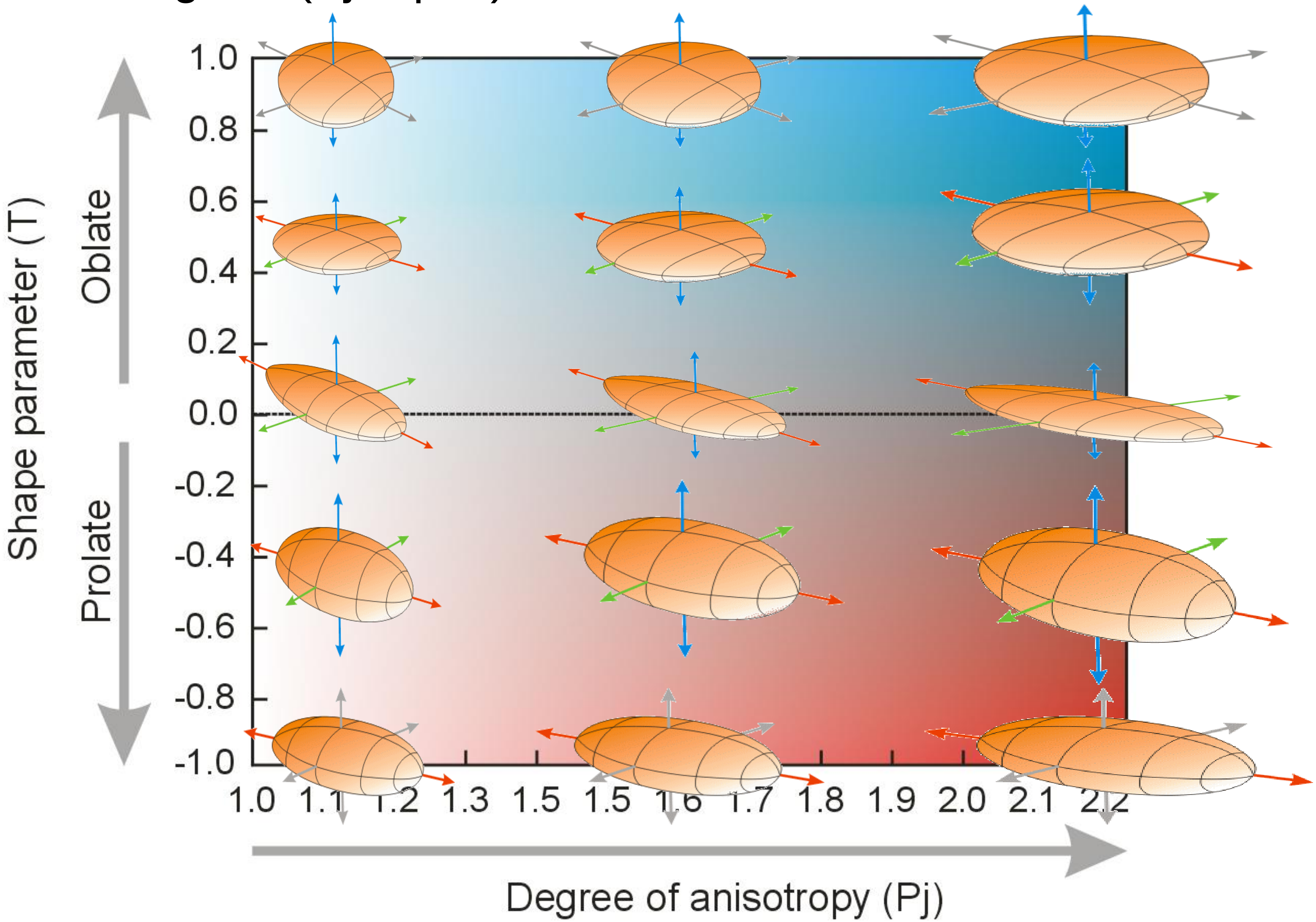
$Pj = P^a$ ← *corrected degree of anisotropy*

$a = \sqrt{(1+T^2 / 3)}$

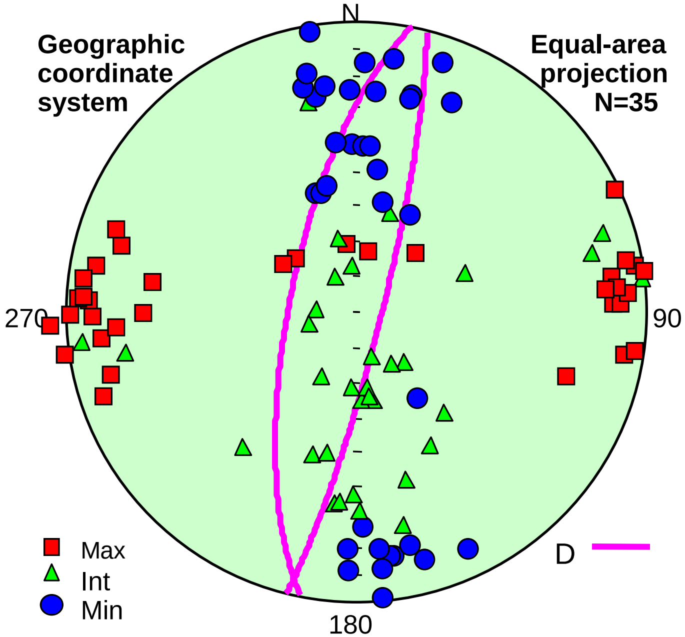
Flinn diagram (L-F plot)



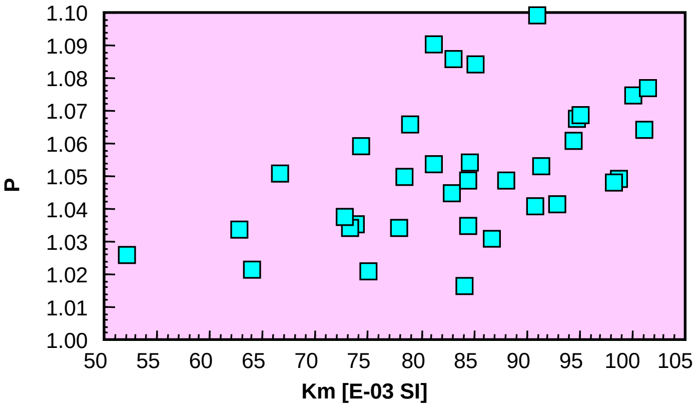
Jelinek diagram (Pj-T plot)



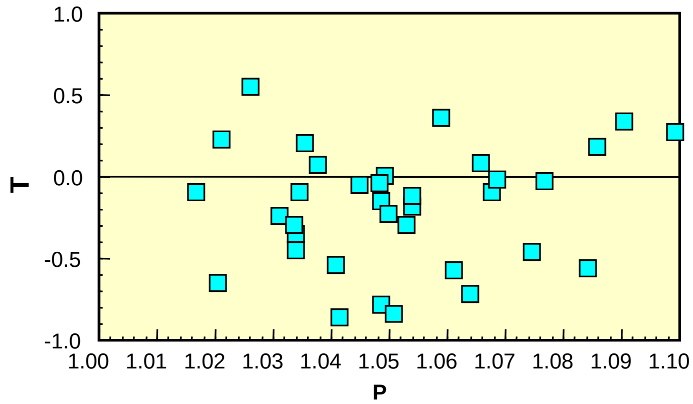
Lambert projection, Lower hemisphere



Degree of anisotropy vs. Mean susceptibility



P-T plot (Jelinek plot)



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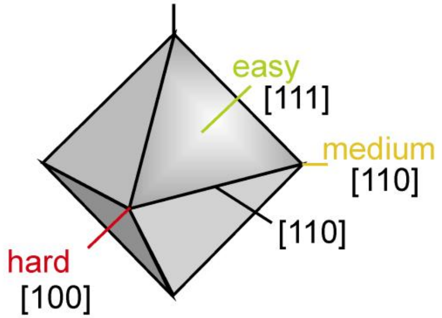
Shape anisotropy

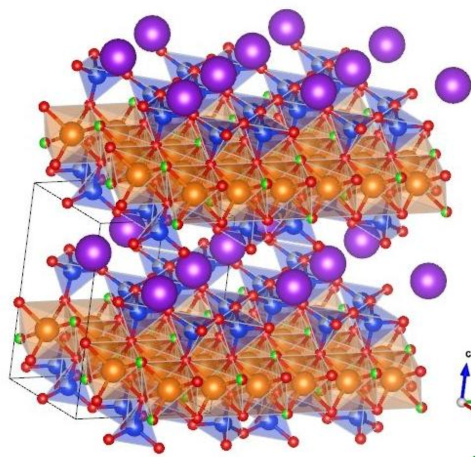
Magnetocrystalline anisotropy

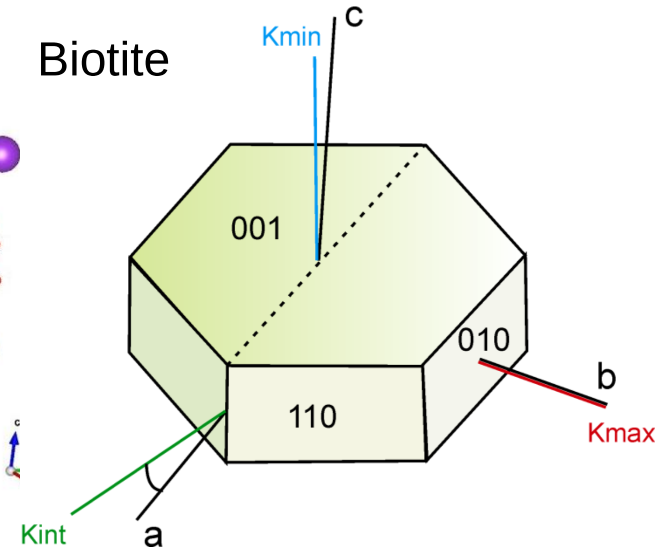
Magnetite

All other minerals

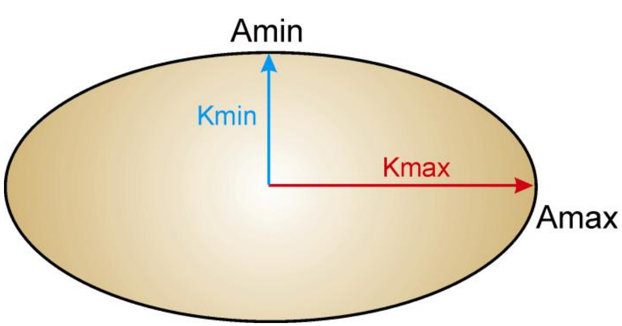
Magnetite crystal



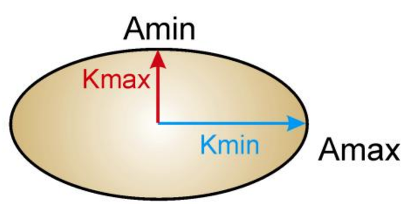


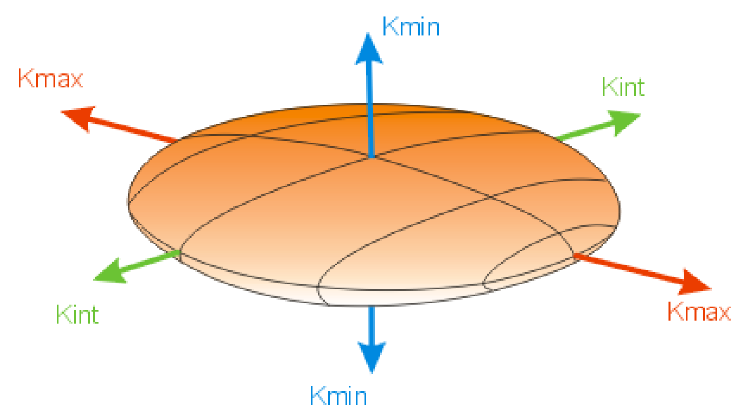


Multi-domain magnetite

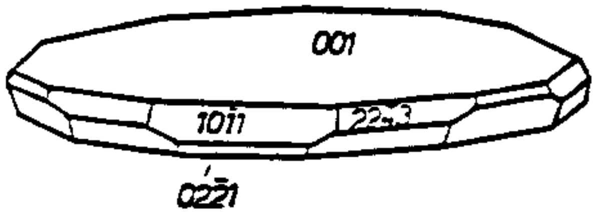


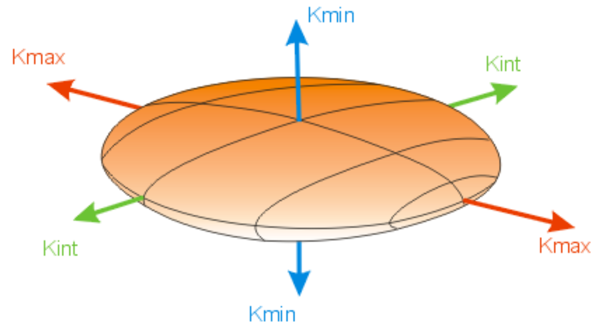
Single-domain magnetite





Magnetocrystalline anisotropy

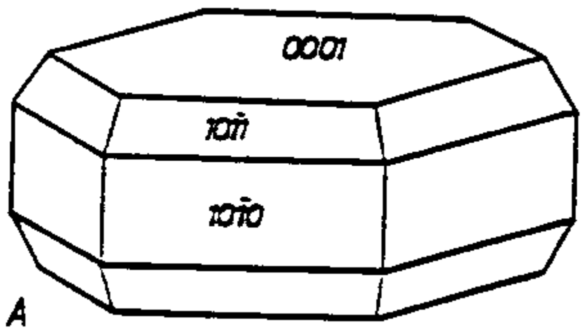


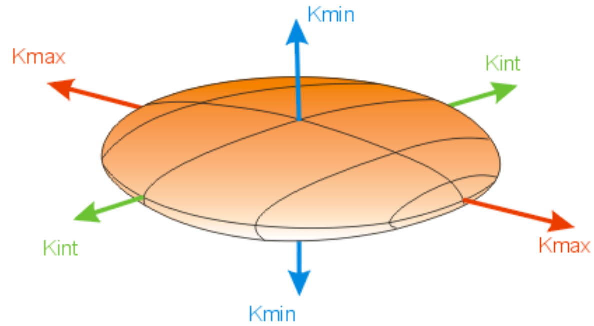


Hematite

$k_1 = k_2 >> k_3$

$P > 100$



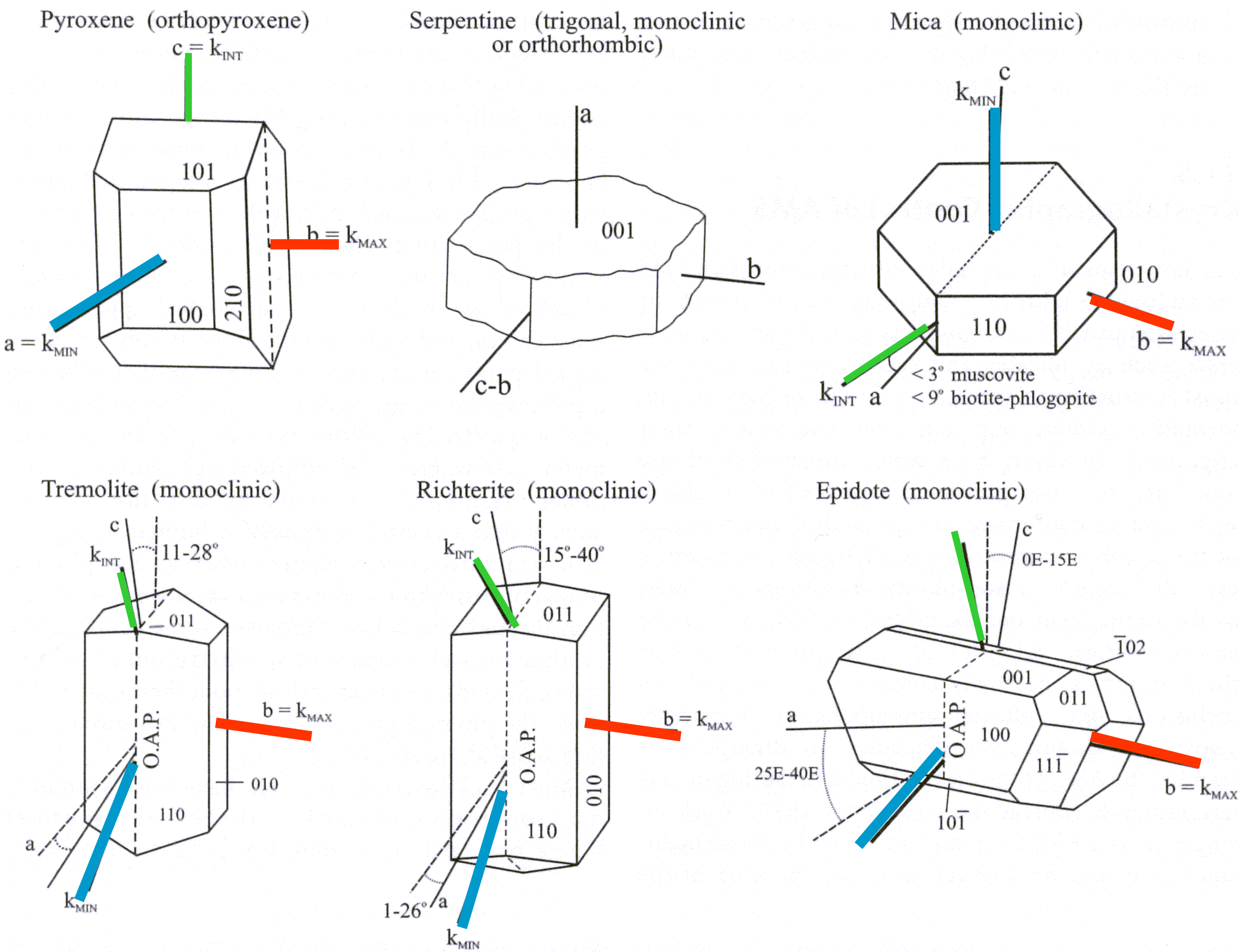


Pyrrhotite

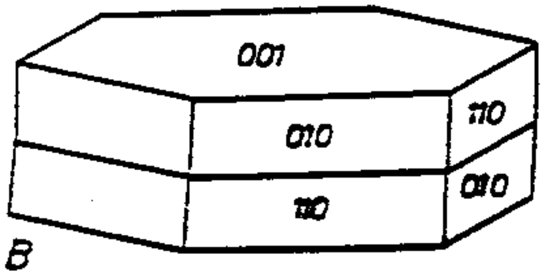
$k_1 = k_2 >> k_3$

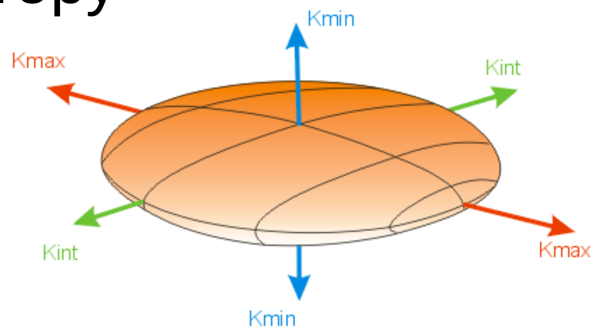
$P > 300$

Magnetocrystalline anisotropy



Magnetocrystalline anisotropy

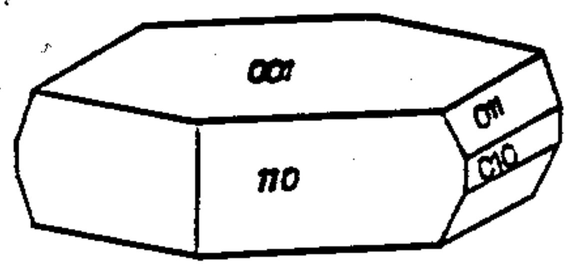


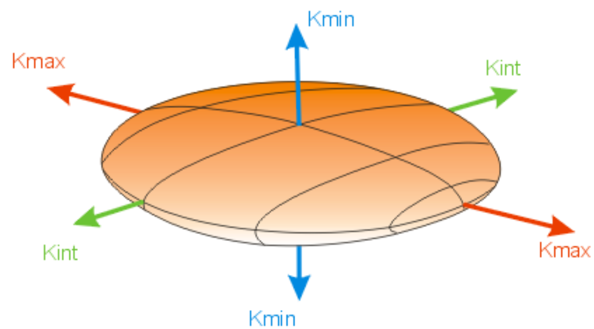


Biotite

$k_1 = k_2 > k_3$

P = 1.2-1.6

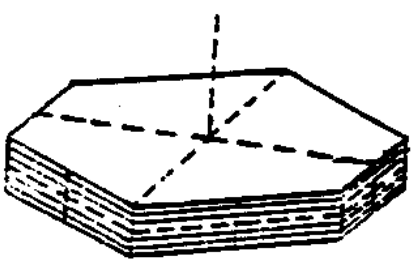


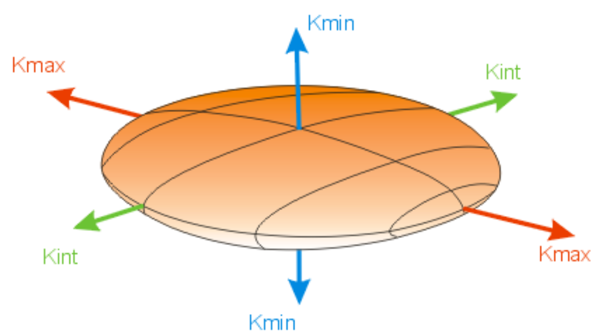


Muscovite

$k_1 = k_2 > k_3$

P = 1.3-1.4





Chlorite

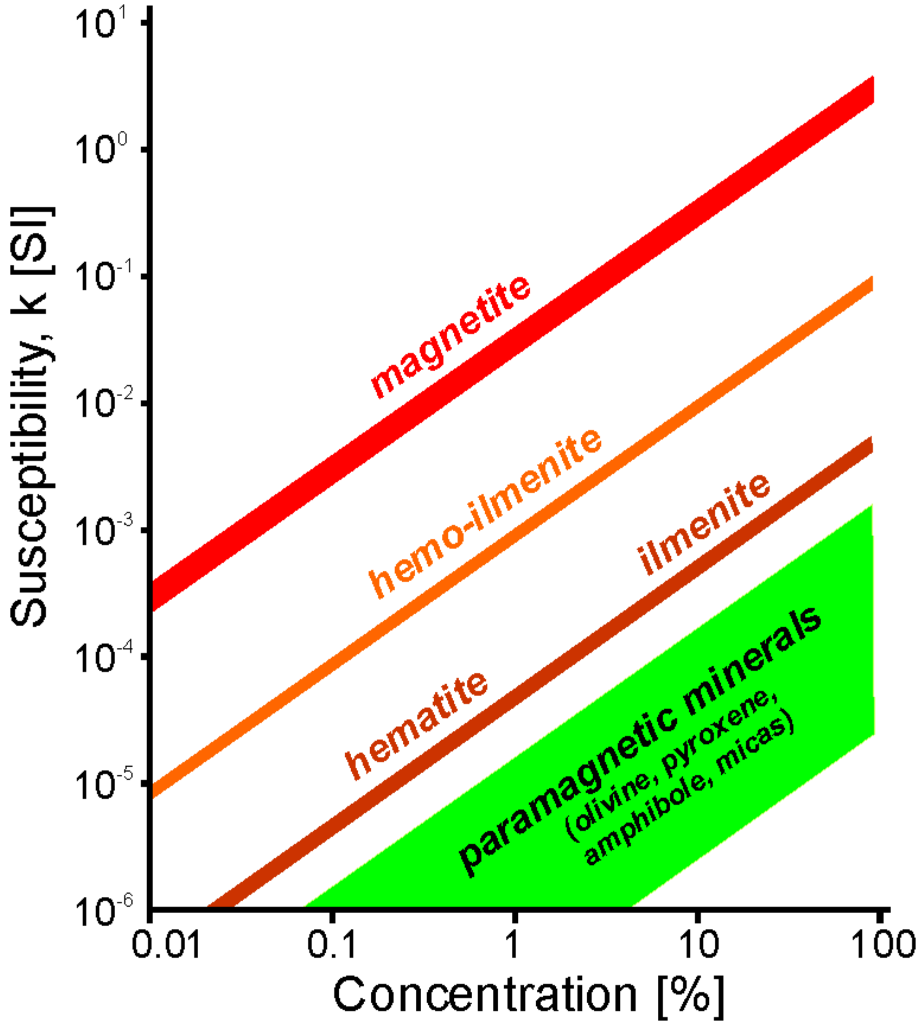
$k_1 = k_2 > k_3$

P = 1.2-1.8

Magnetic properties of selected minerals

Mineral	Susceptibility [10^{-6}]	Degree of anisotropy	Shape of anisotropy	Anisotropy type
Magnetite	3000000	1.1 to 3.0	Variable	Shape
Hematite	1300 to 7000	>100	~1.00	Magnetocrystalline
Pyrrhotite		100 to 10000	~1.00	Magnetocrystalline
Actinolite	490	1.2 to 1.2	-0.40 to 0.40	Magnetocrystalline
Hornblende	746 to 1368	1.665	-0.51	Magnetocrystalline
Glaucophane	787	1.205	0.10	Magnetocrystalline
Chlorite	70 to 1550	1.2 to 1.7	~1.00	Magnetocrystalline
Biotite	998 to 1290	1.2 to 1.6	~1.00	Magnetocrystalline
Phlogopite	1178	1.3	0.95	Magnetocrystalline
Muscovite	122 to 165	1.4	0.44	Magnetocrystalline
Quartz	-13.4 to -15.4	1.01	1.00	Magnetocrystalline
Calcite	-13.8	1.11	1.00	Magnetocrystalline
Aragonite	-15.0	1.15	0.80	Magnetocrystalline

Contribution of selected minerals to whole rock susceptibility



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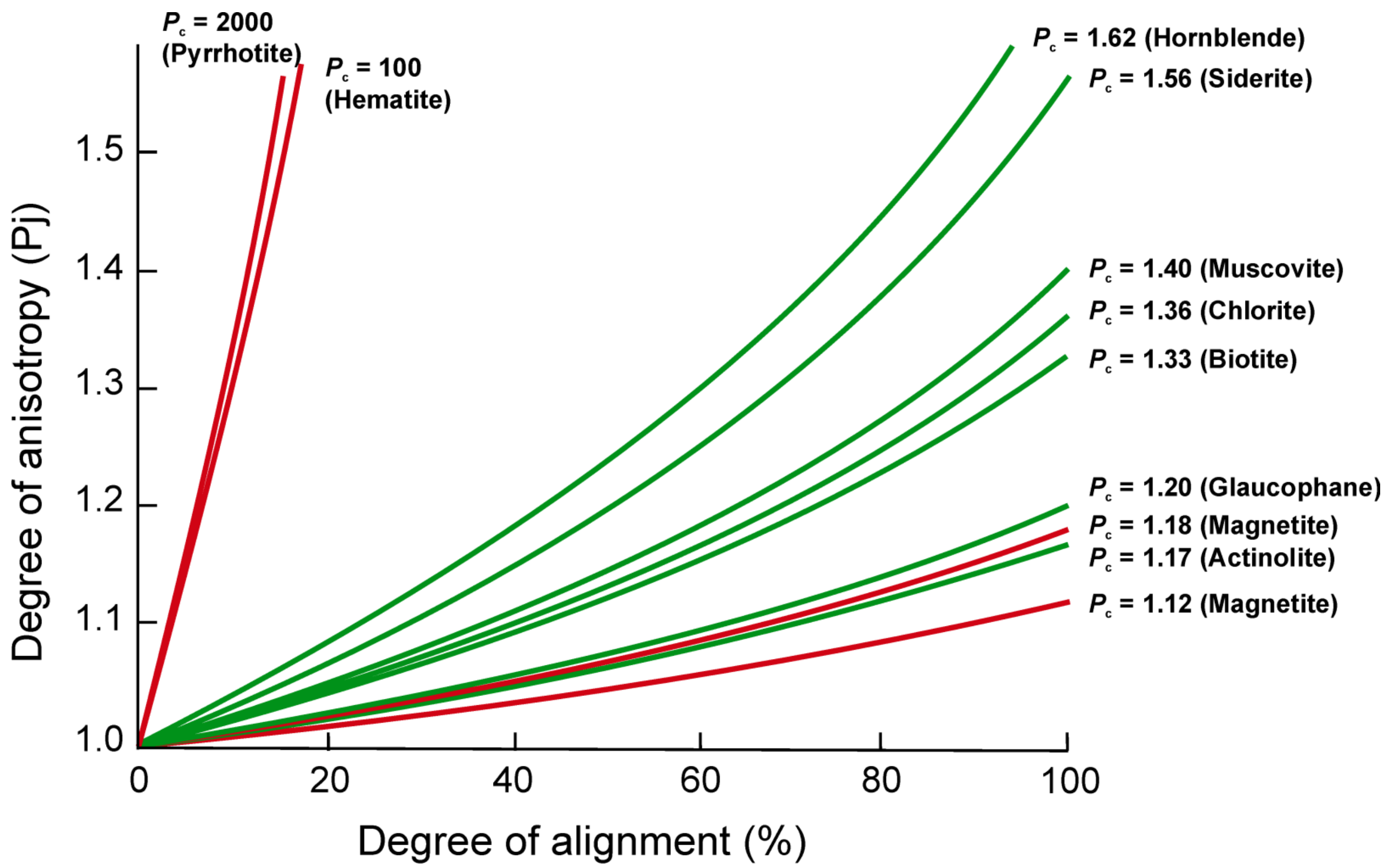
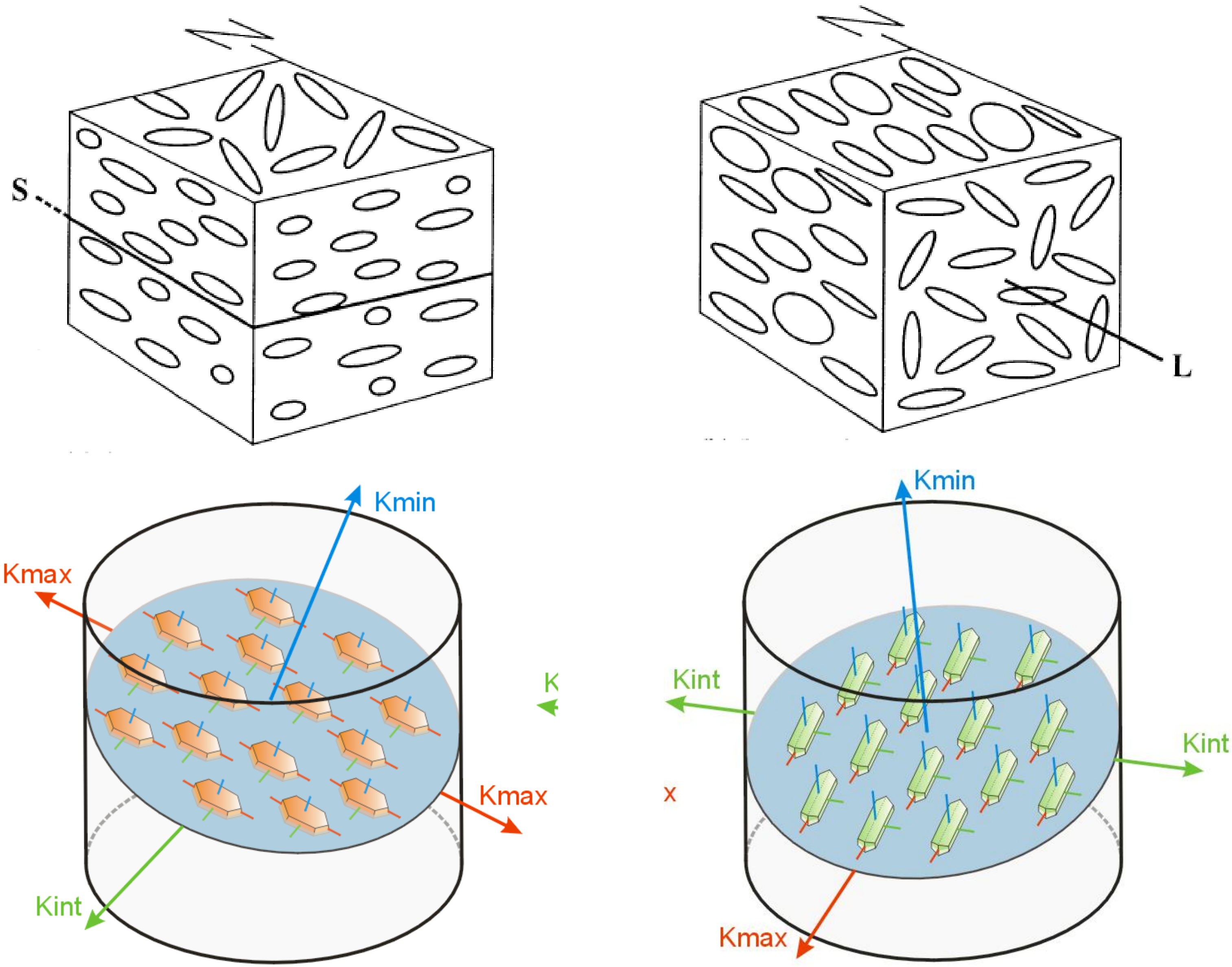
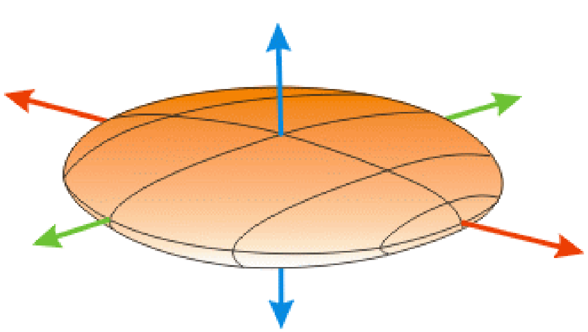
Rock anisotropy degree as a function of preferred orientation of its minerals

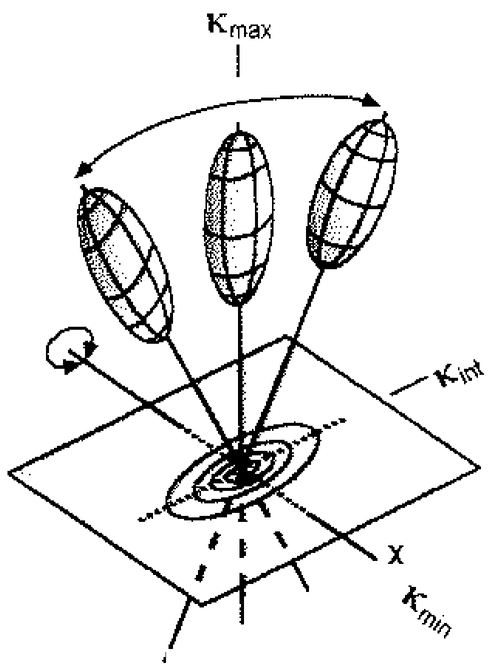


3. Magnetic fabric vs. texture of rocks

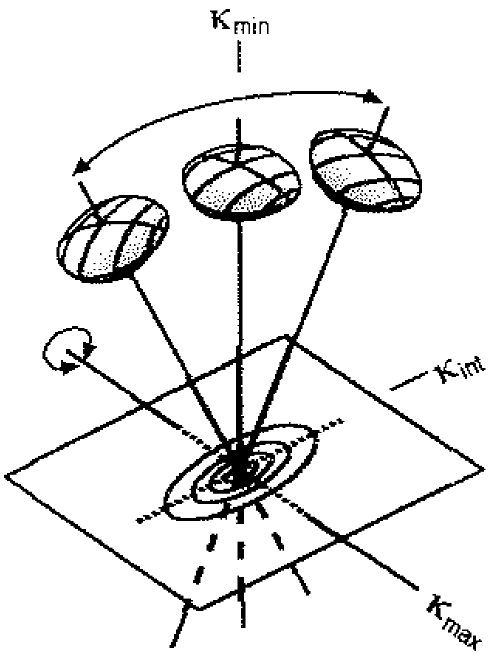


Magnetic fabrics of higher order



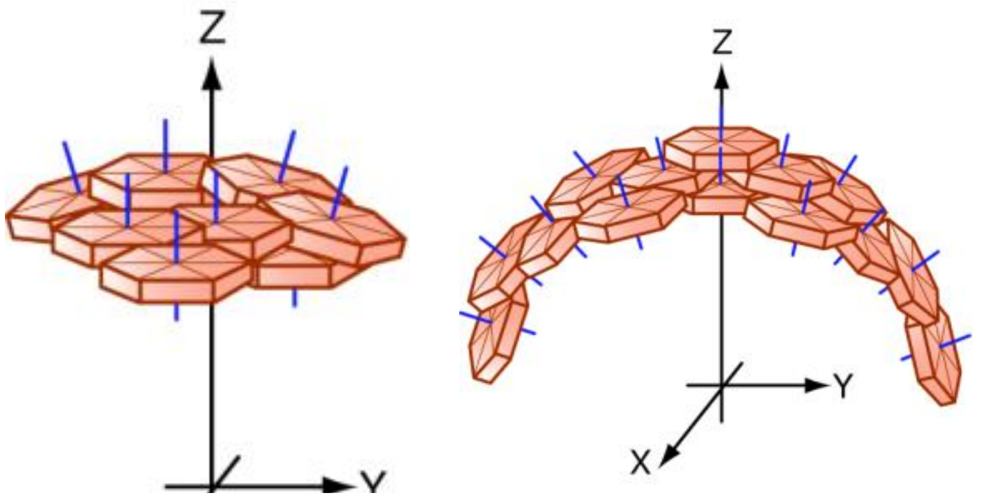


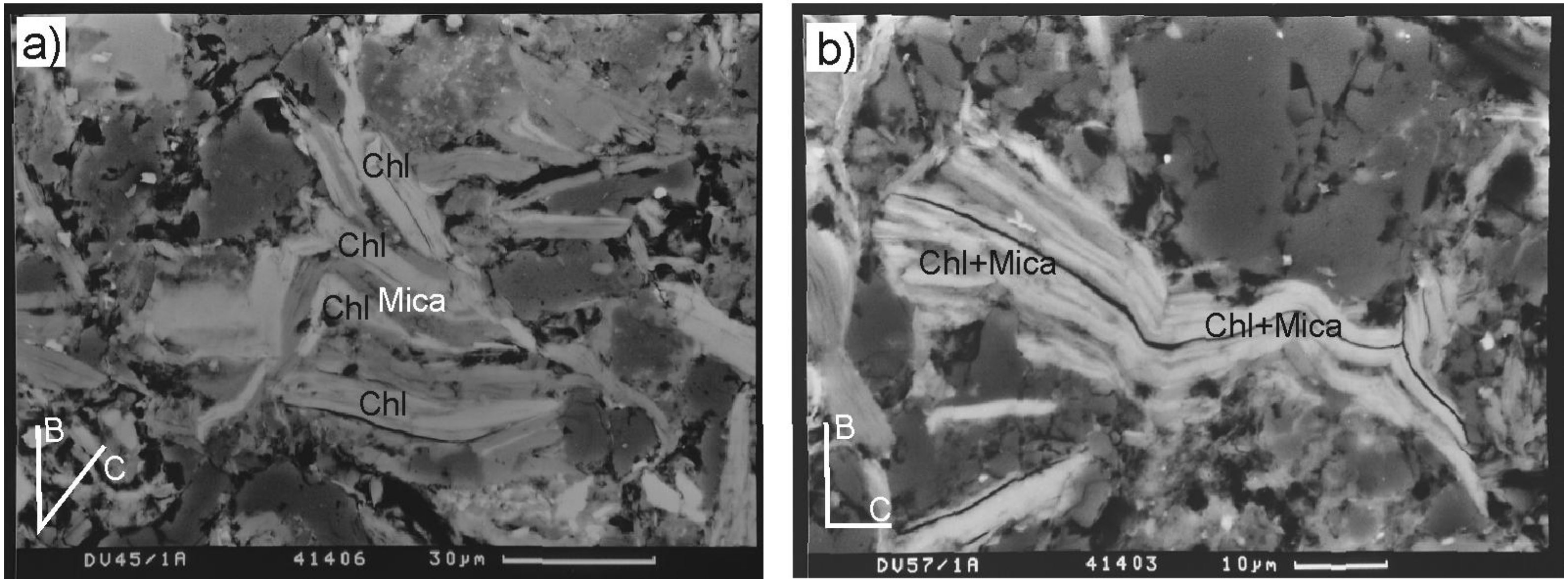
oblate fabric



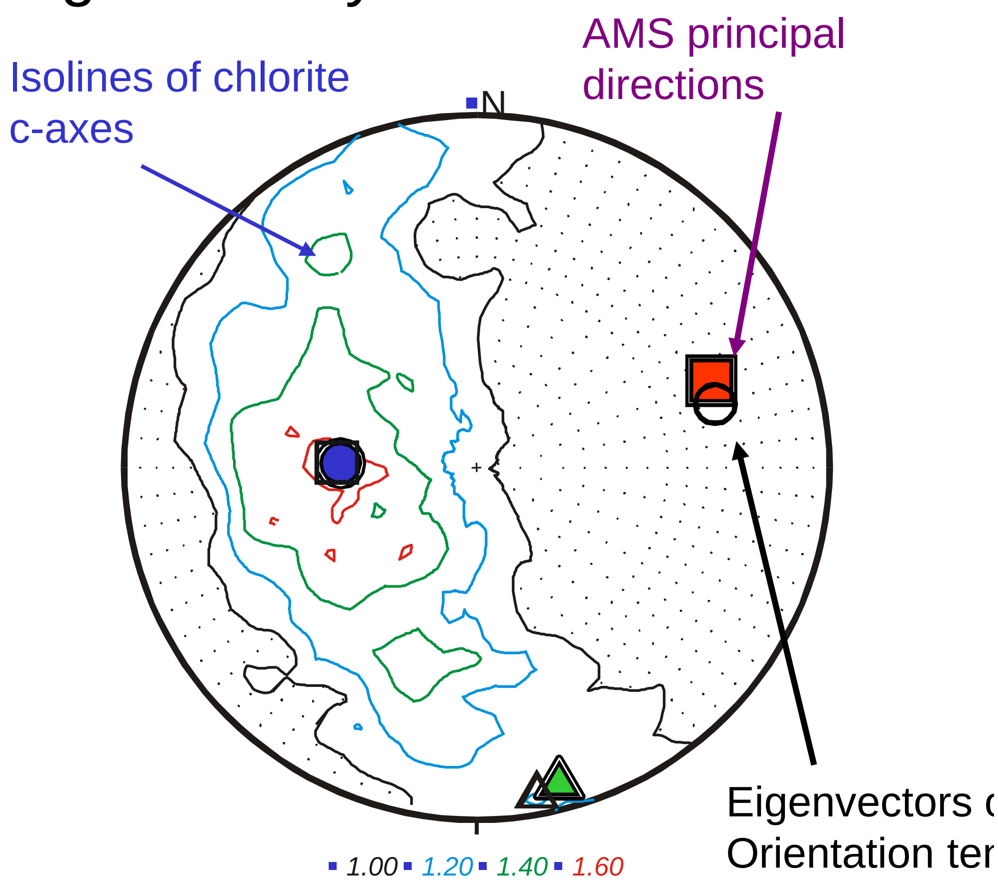
prolate fabric

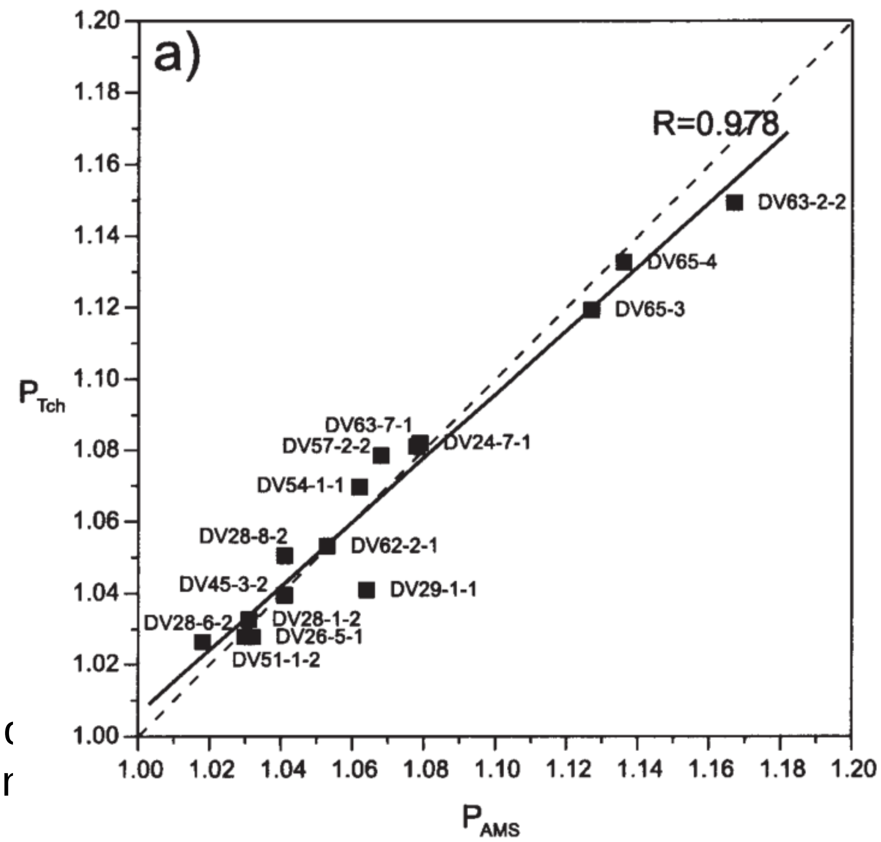
Comparison of magnetic fabric and neutron texture goniometry





Comparison of magnetic fabric and neutron texture goniometry



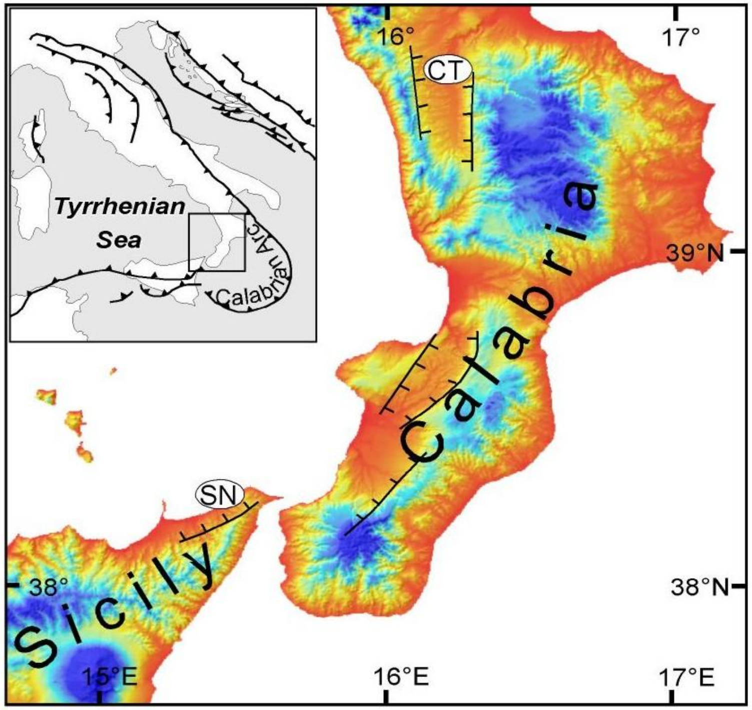


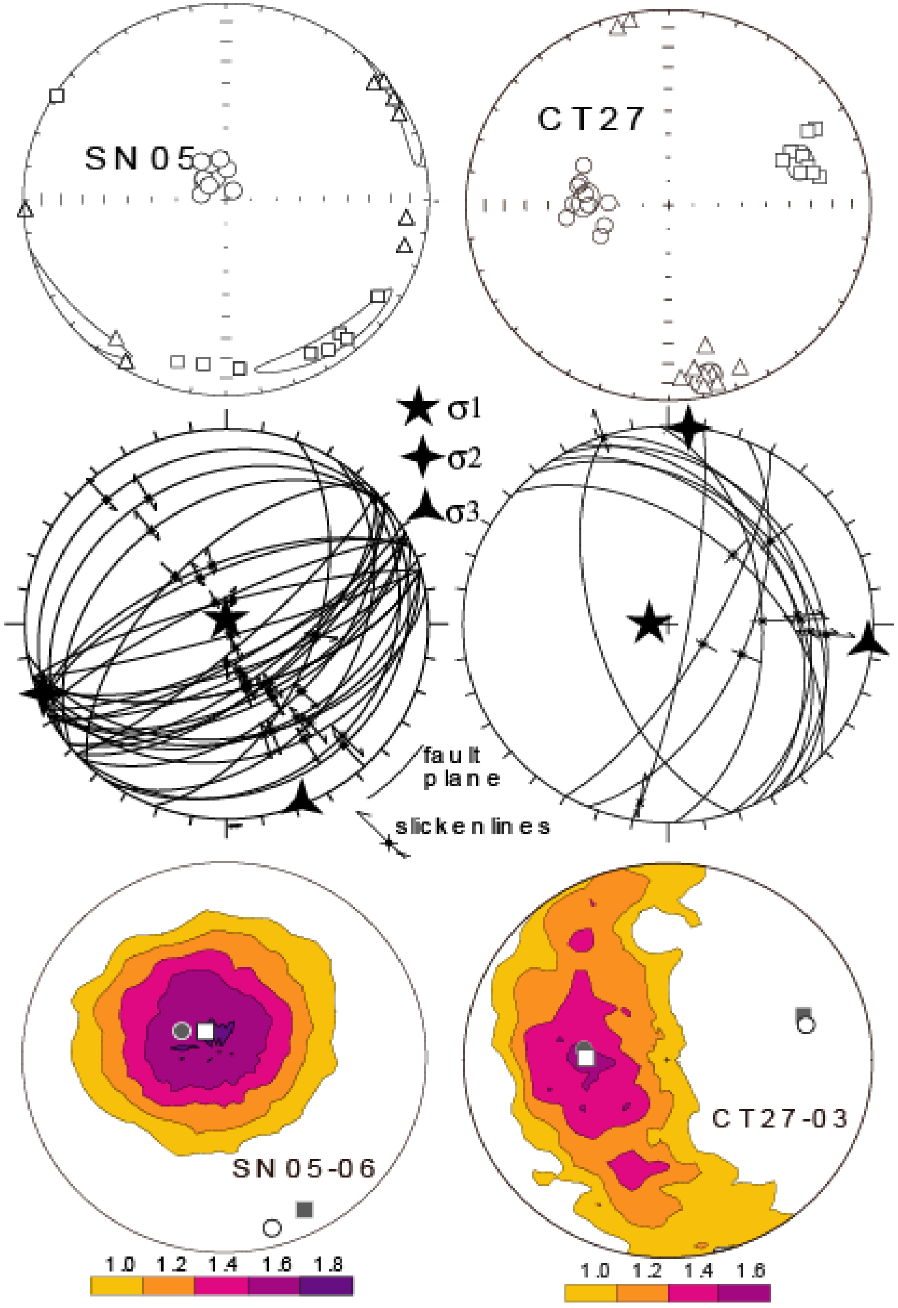
Neutron texture goniometer TEX2

GKSS Forschungszentrum Geesthacht GmbH, Germany

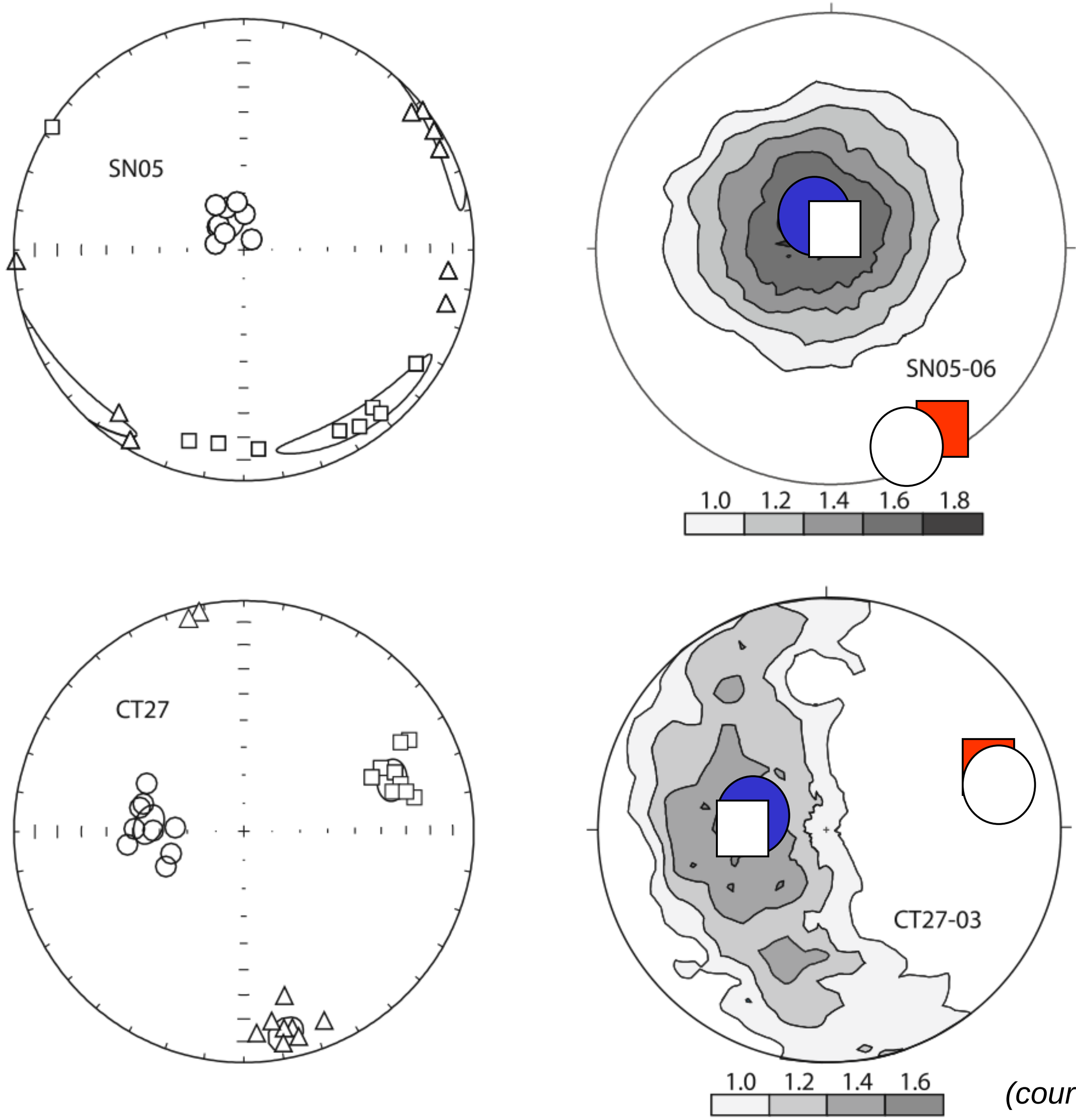
Shale, Rhenohercynian Belt, Czech Republic

3. Magnetic fabric vs. texture of rocks





Comparison of magnetic fabric and neutron texture goniometry



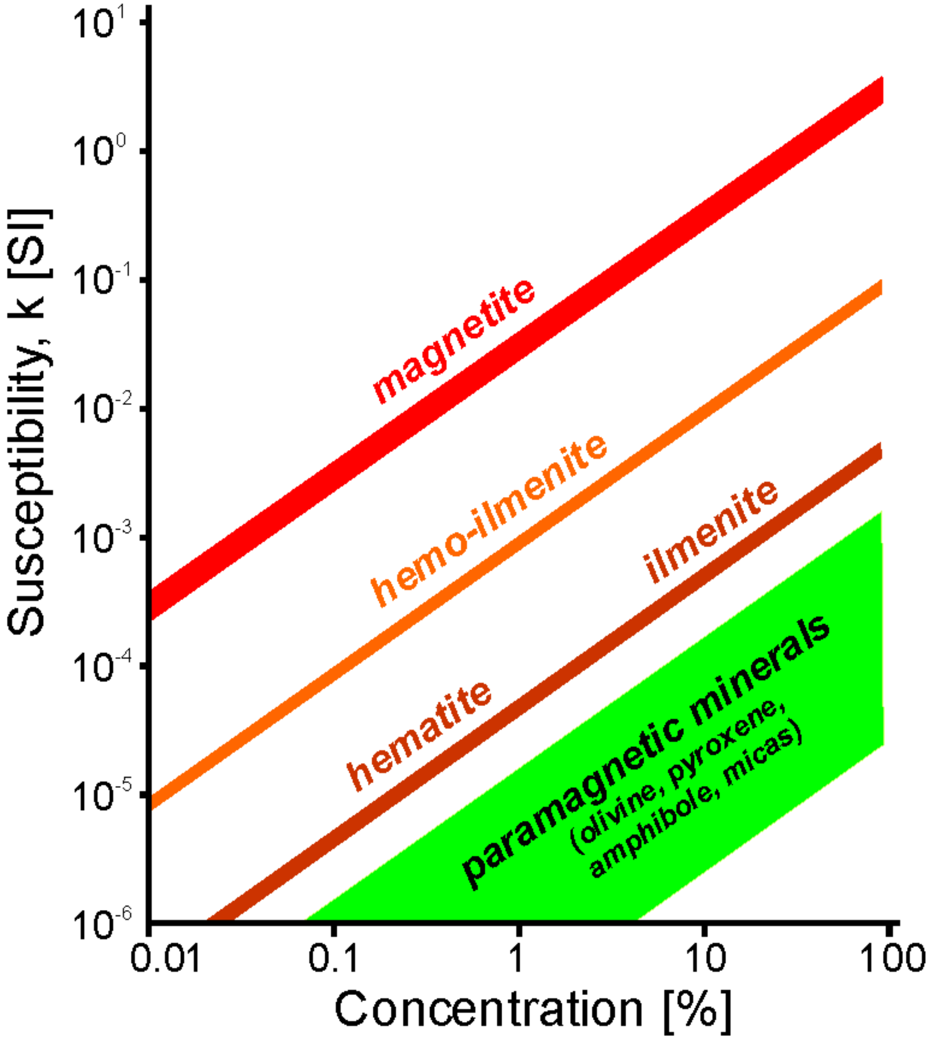
Neogene basin, Southern Italy

(courtesy F. Cifelli)

Agenda

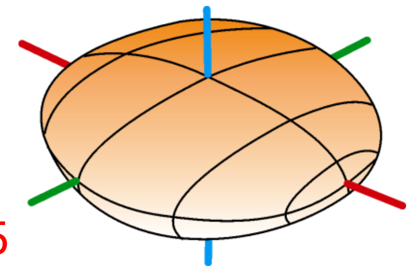
1. Definition and application in geology
2. Magnetic anisotropy of minerals
3. Magnetic fabric vs. texture of rocks
4. Magnetic fabric of sedimentary, deformed, and metamorphosed rocks
5. Magnetic fabric of igneous rocks
6. Sampling, measurement and data processing

Magnetic susceptibility usually carried by paramagnetic minerals

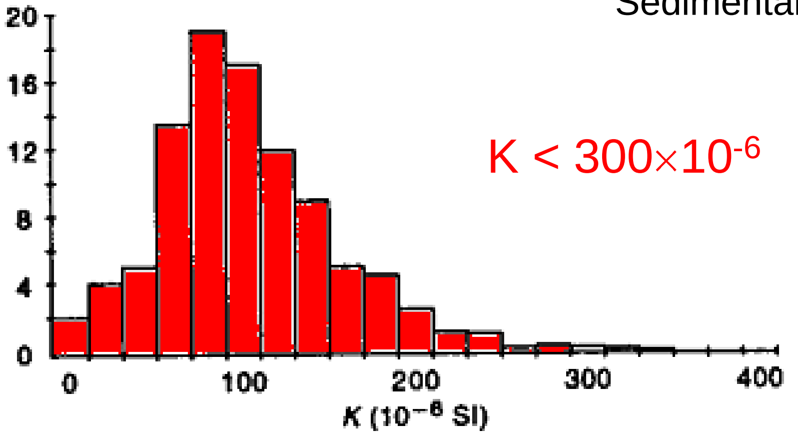


- Relatively low magnetic susceptibility

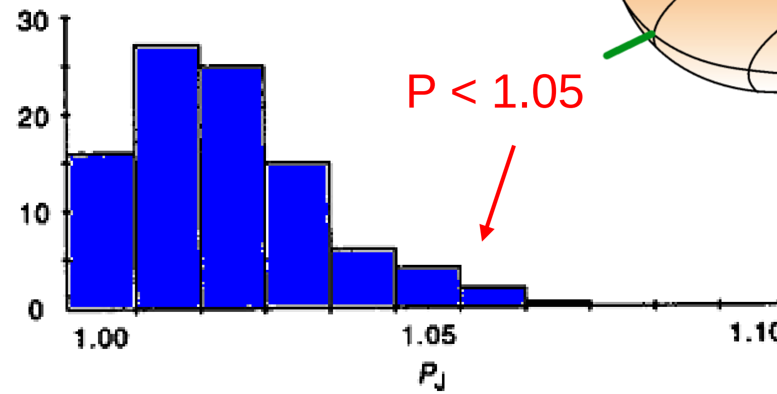
- Anisotropy degree < 5%
- Oblate fabric



Sedimentary rocks

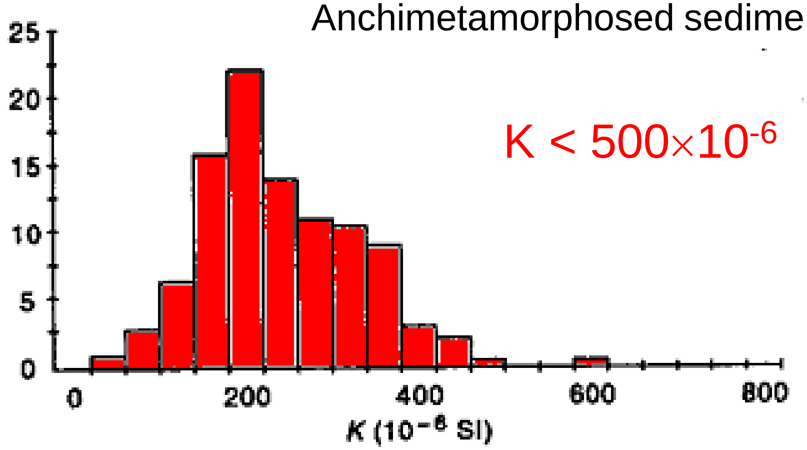


K < 300×10^{-6}

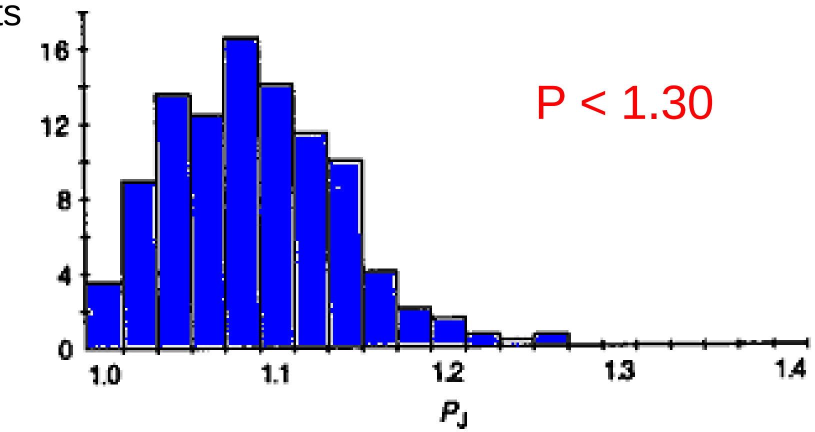


P < 1.05

Anchimetamorphosed sediments

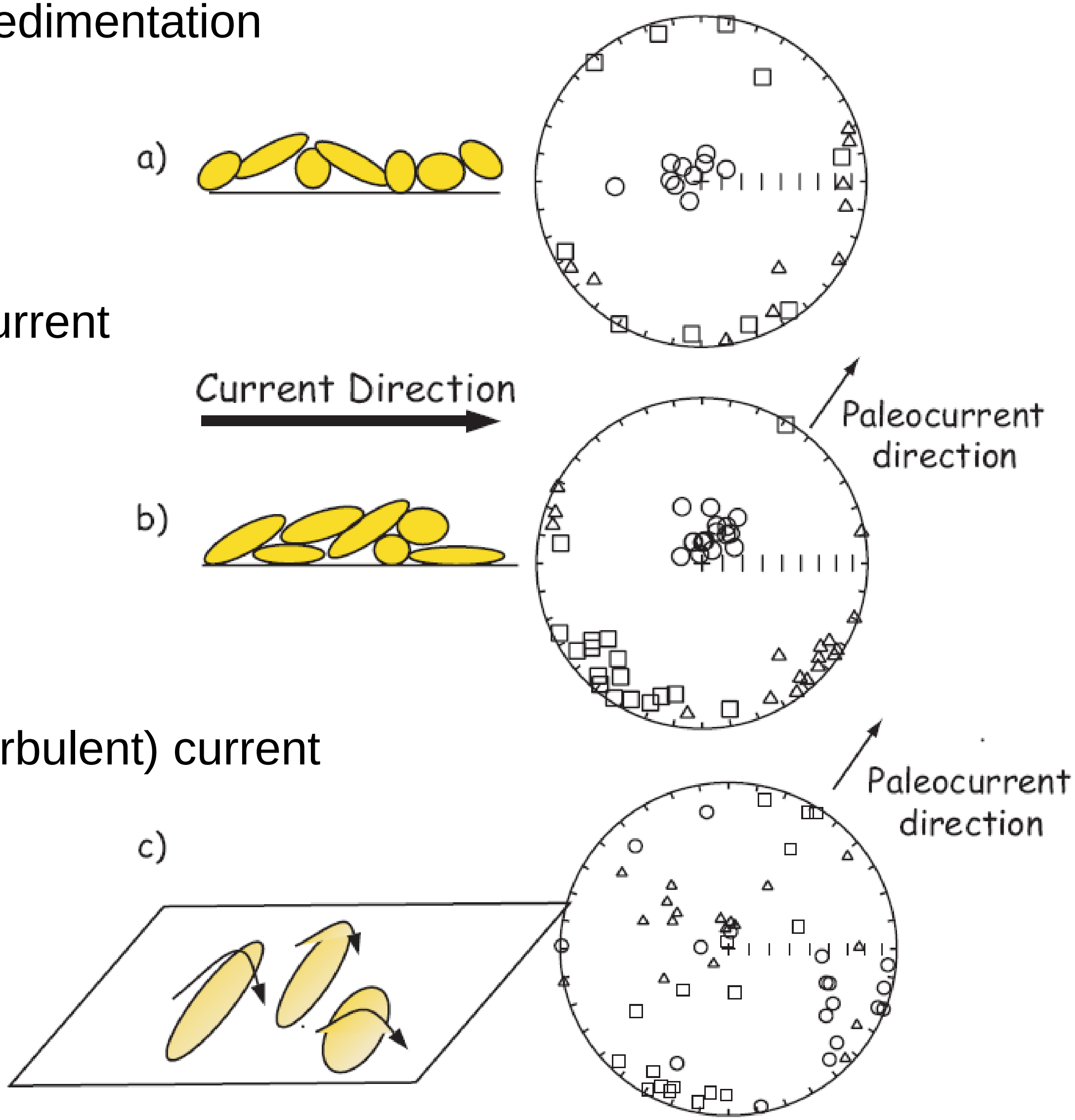


K < 500×10^{-6}



P < 1.30

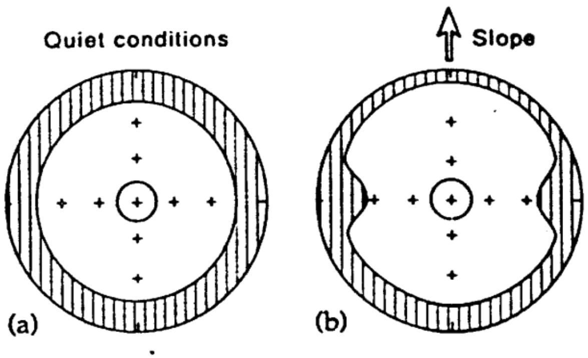
- calm sedimentation
- slow current
- fast (turbulent) current



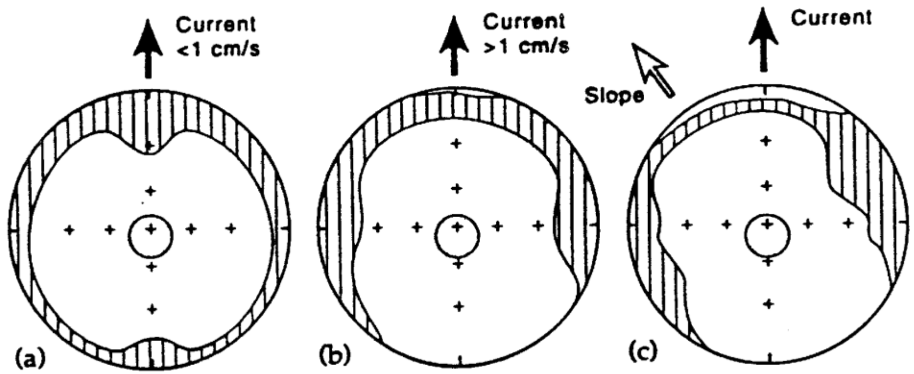
(after Tauxe 2013)

Examples of various sedimentary fabrics

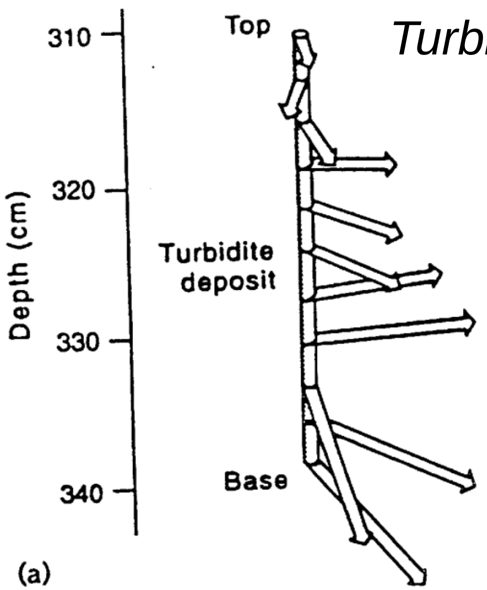
No current

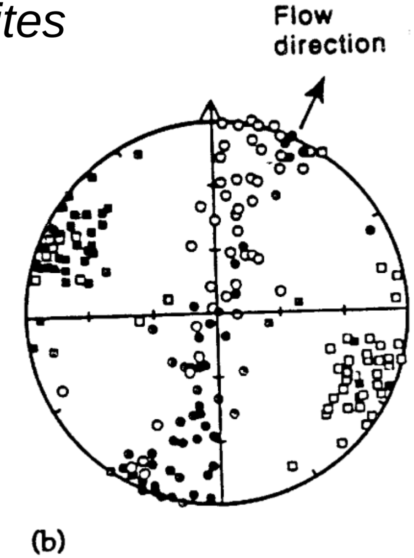


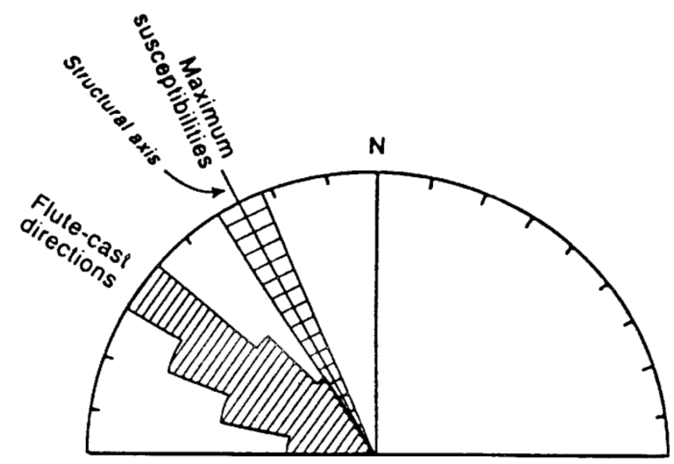
Current



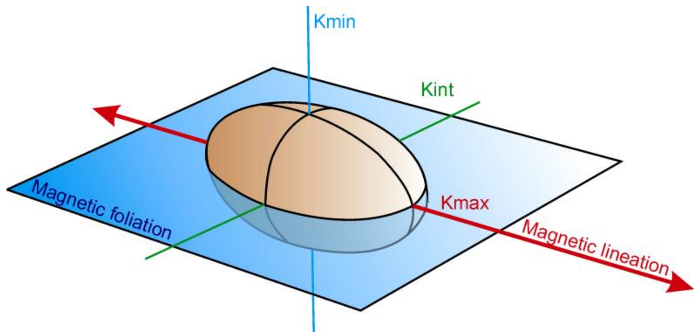
Turbidites

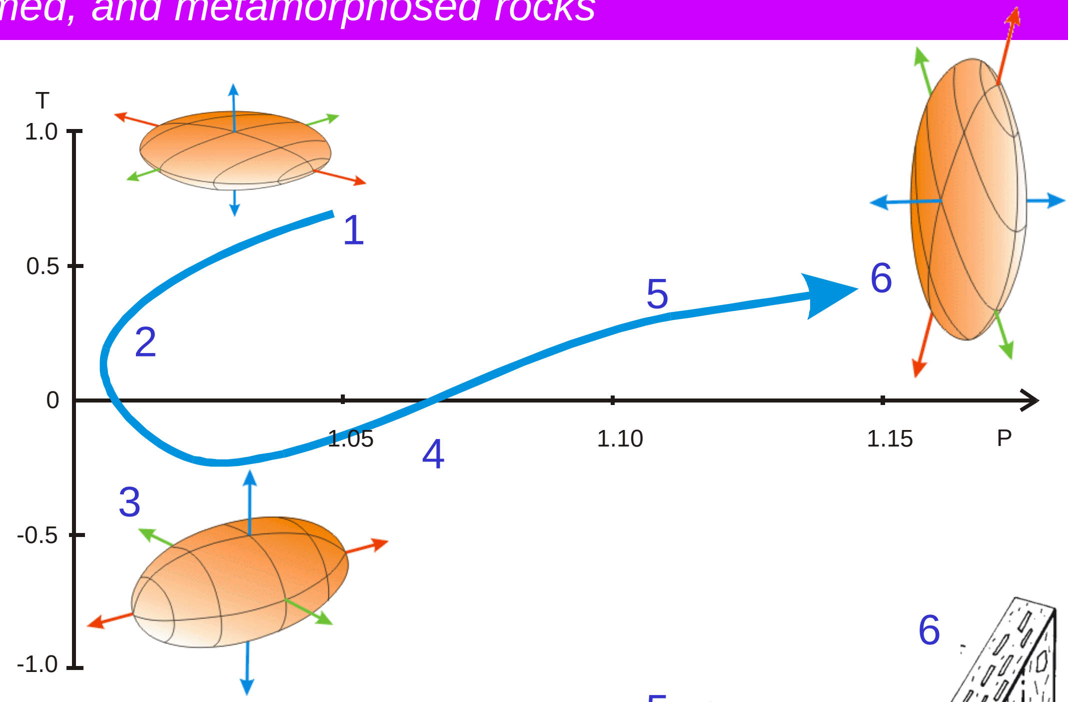


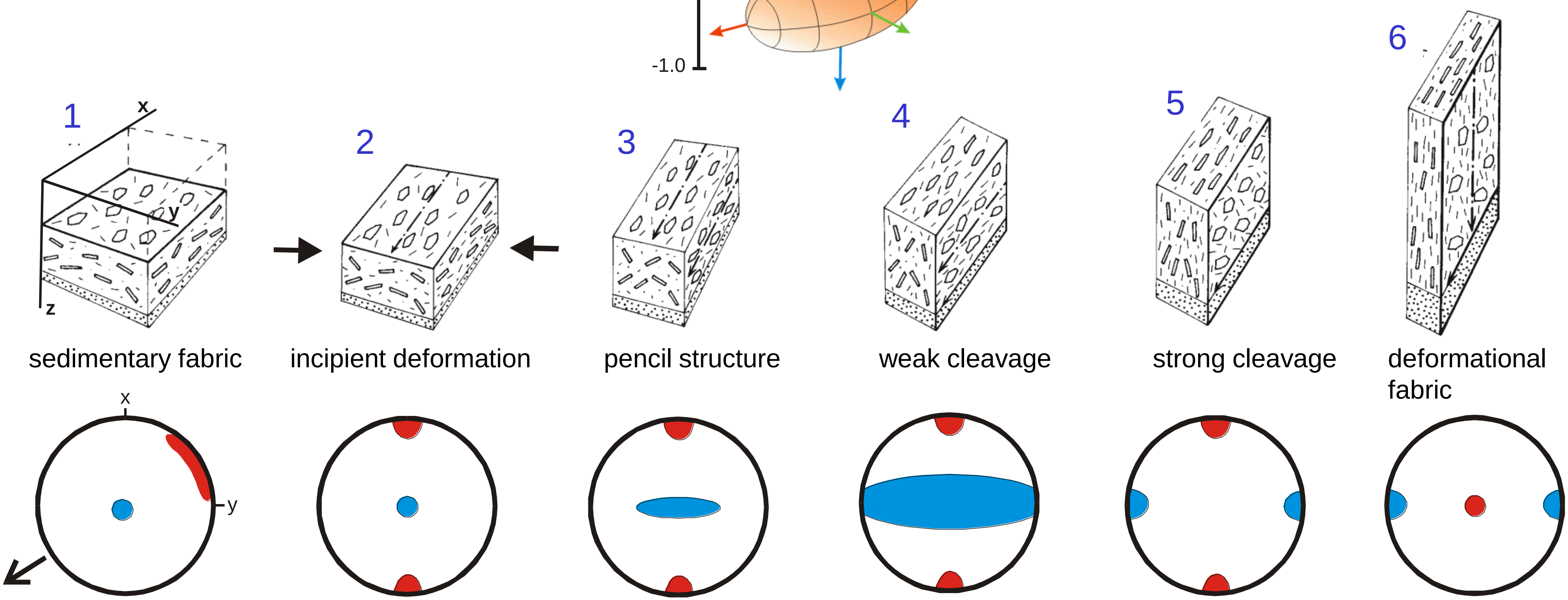




Deformation of sediments

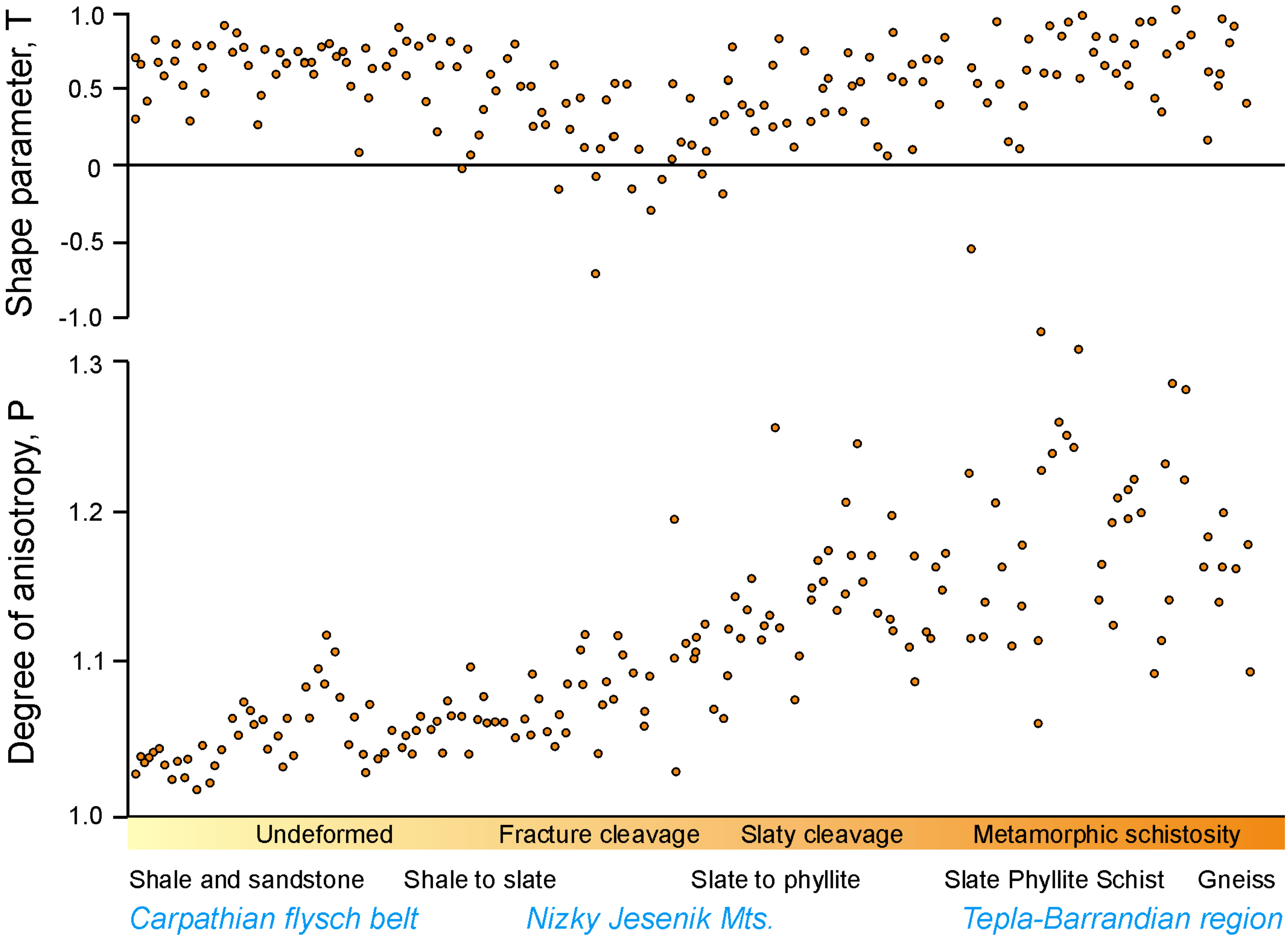




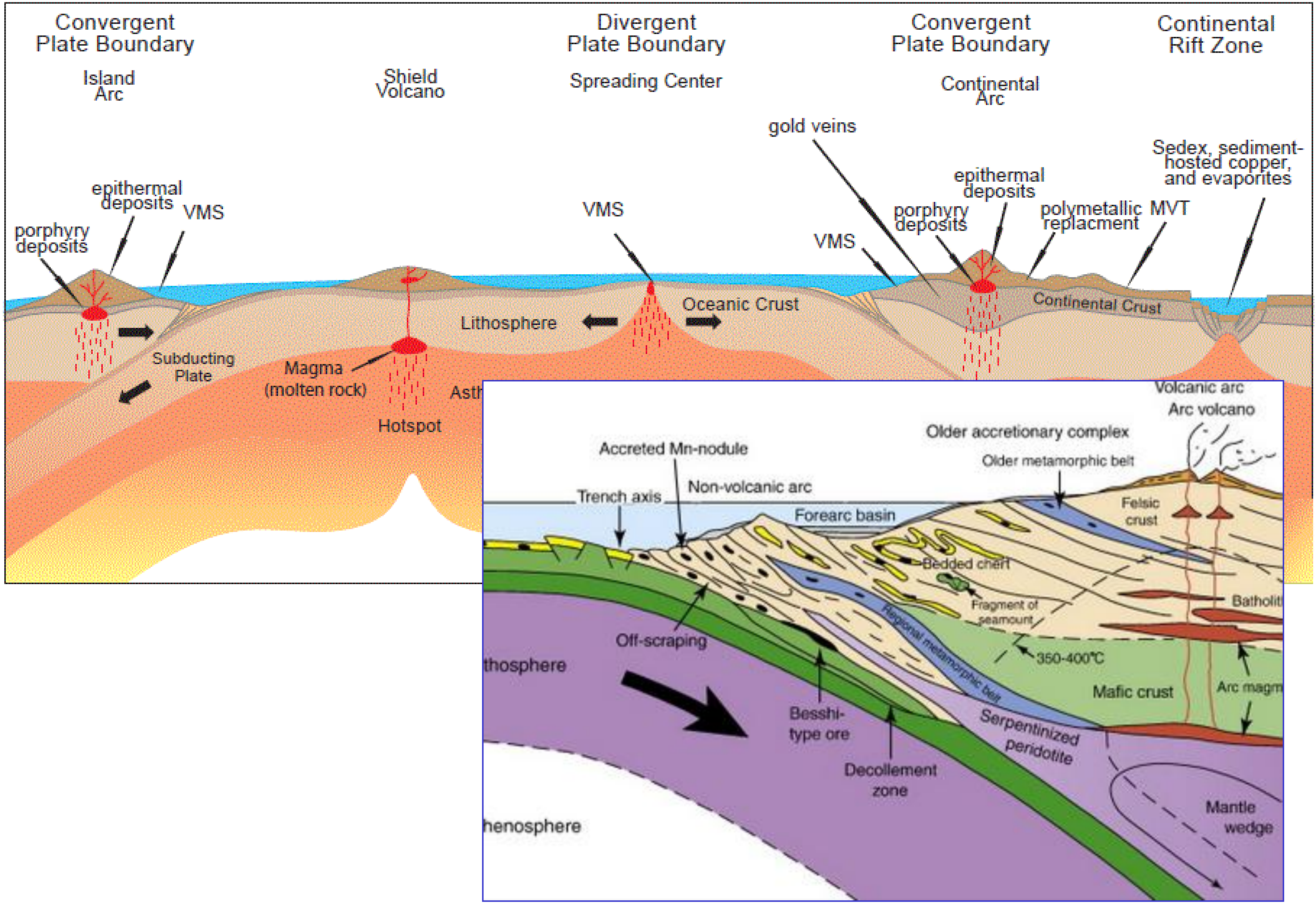


4. Magnetic fabric of sedimentary, deformed, and metamorphosed rocks

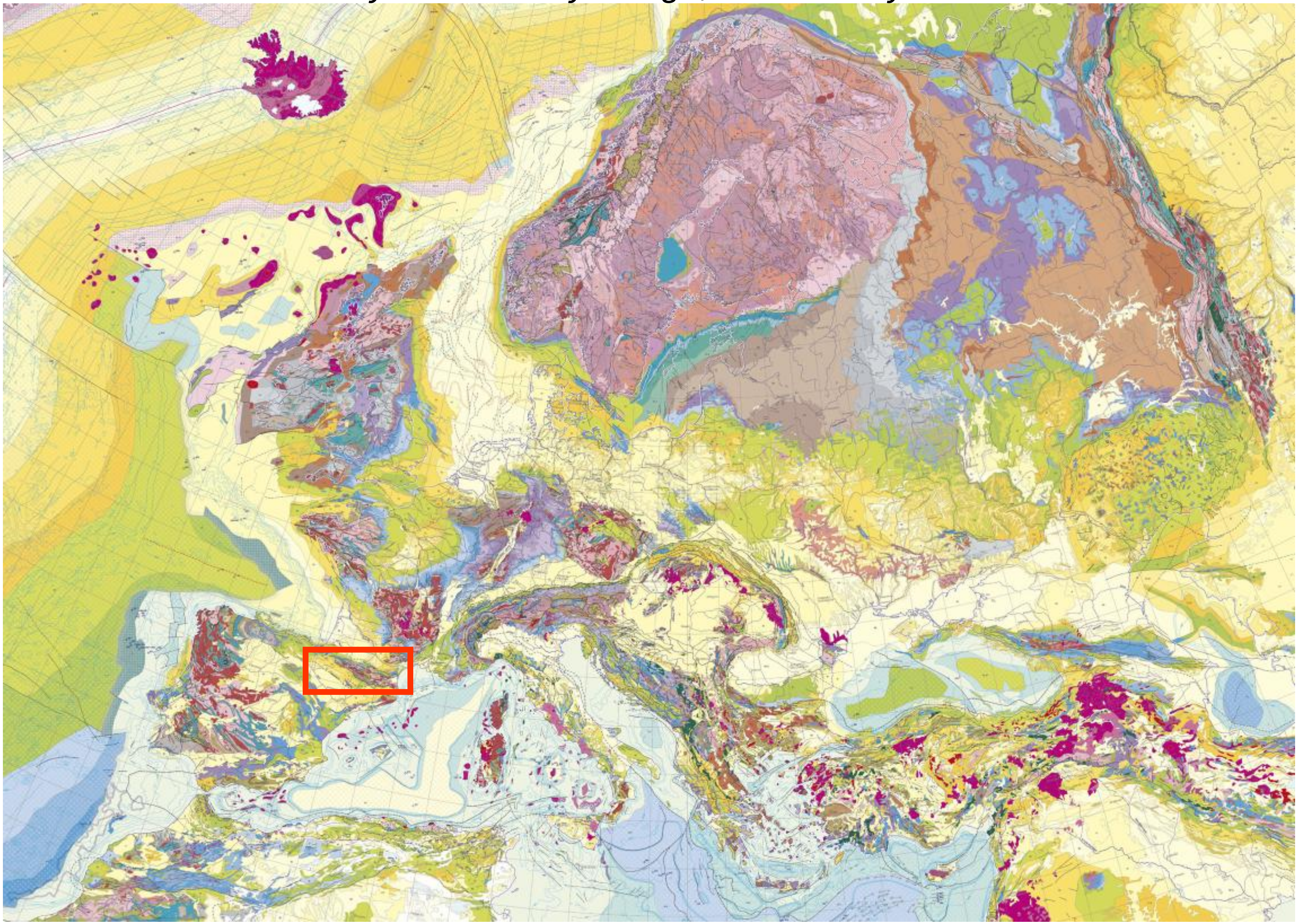
Pencil structure
(southern Pyrenees, Spain)


Shape parameter, T
1.0
0.5
0
-0.5
-1.0
Degree of anisotropy, P
1.3
1.2
1.1
1.0
Undeformed
Fracture cleavage
Slaty cleavage
Metamorphic schistosity
Shale and sandstone
Shale to slate
Slate to phyllite
Slate Phyllite Schist
Gneiss
Carpathian flysch belt
Nizky Jesenik Mts.
Tepla-Barrandian region

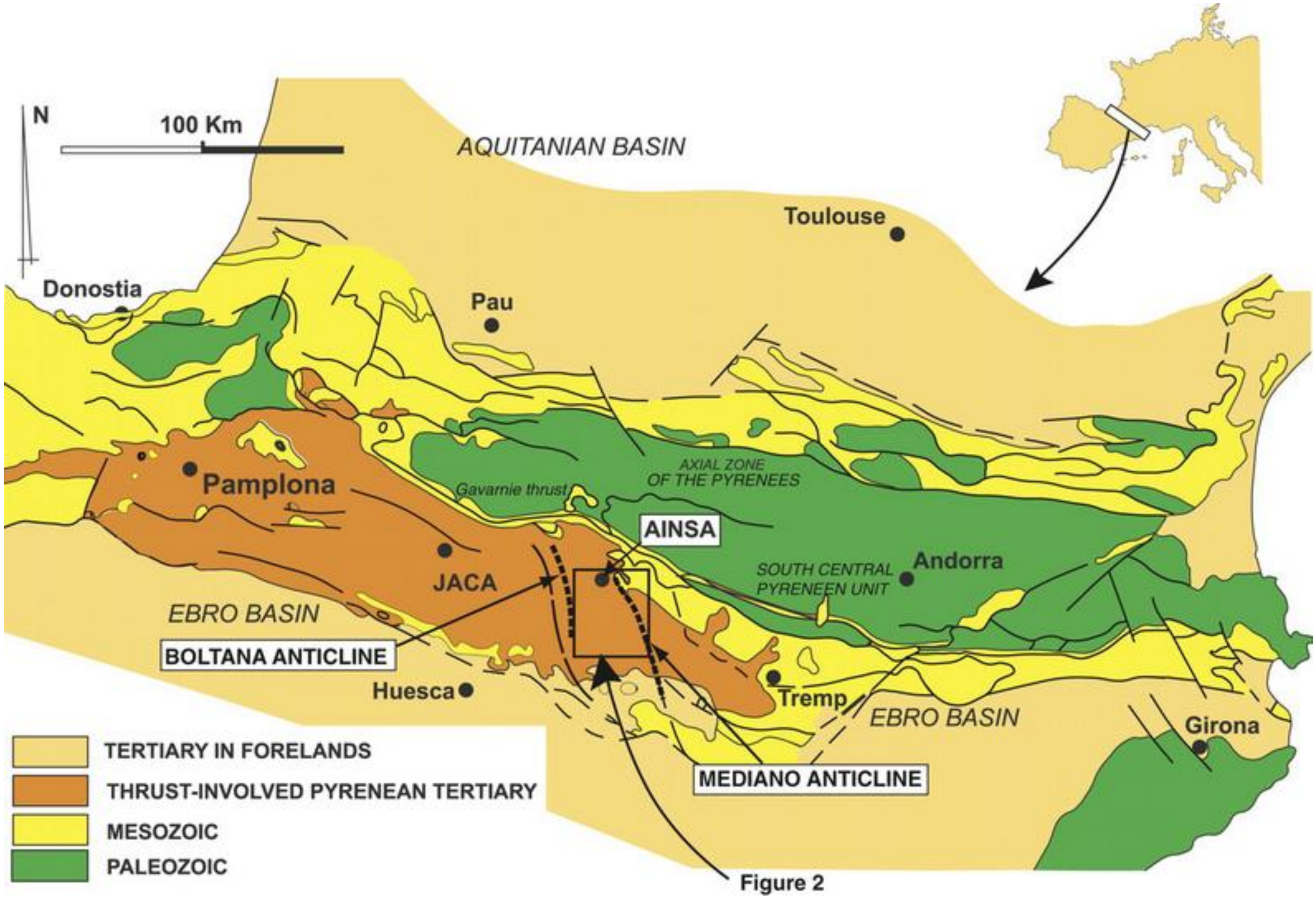
Accretionary wedge



Tertiary accretionary wedge, southern Pyrenees

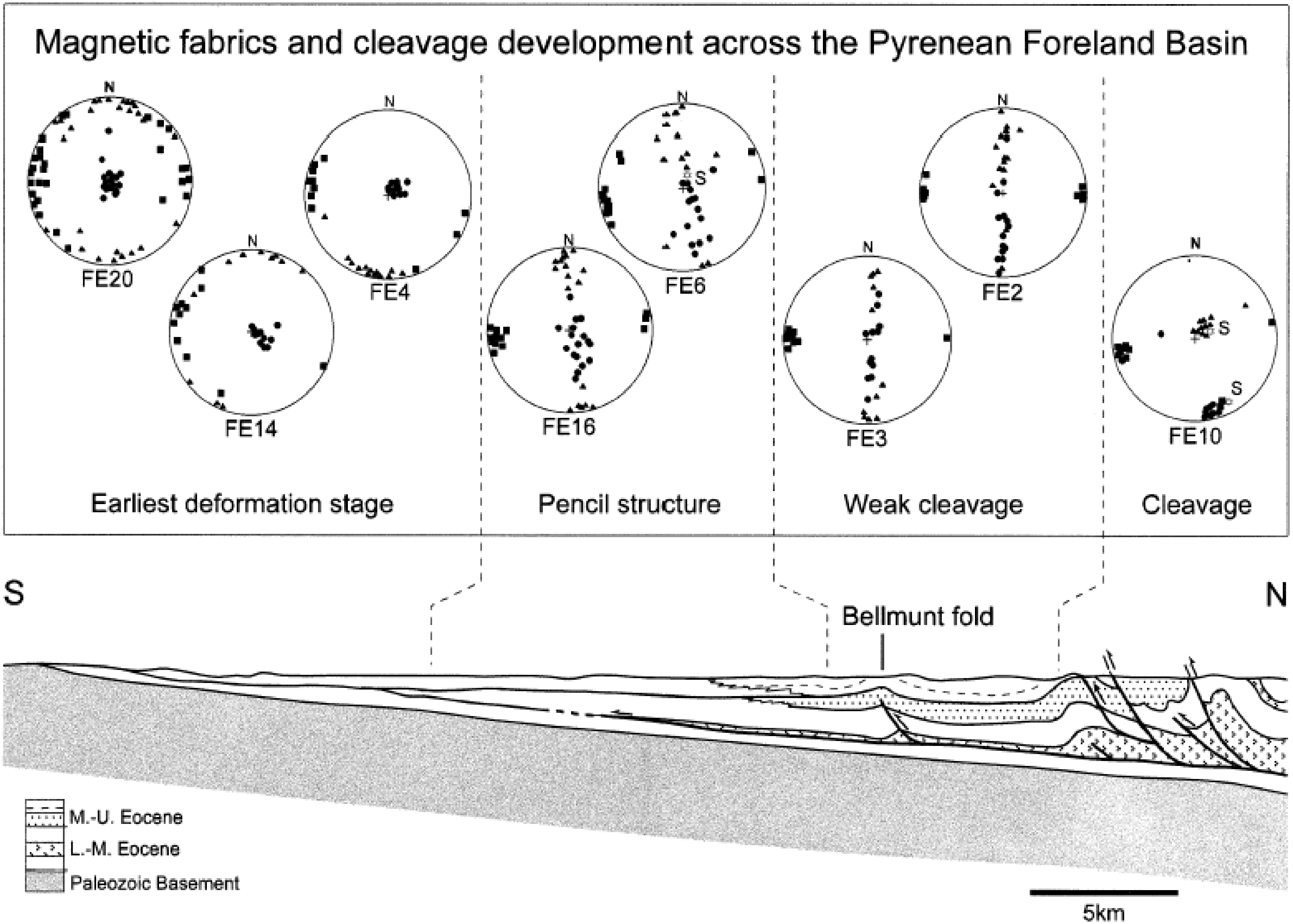


Tertiary accretionary wedge, southern Pyrenees



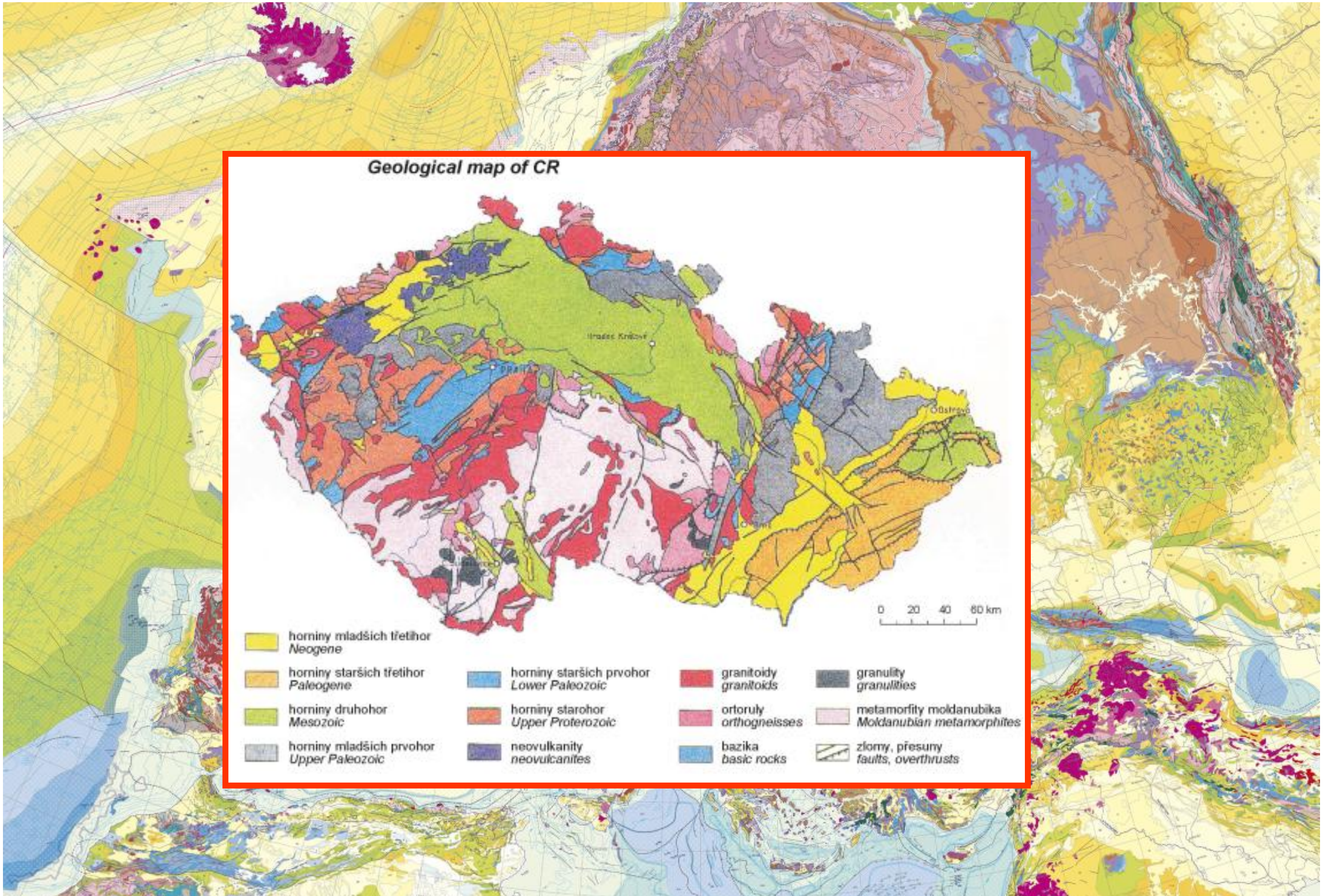
(Parés & van der Pluijm 1999)

Tertiary accretionary wedge, southern Pyrenees

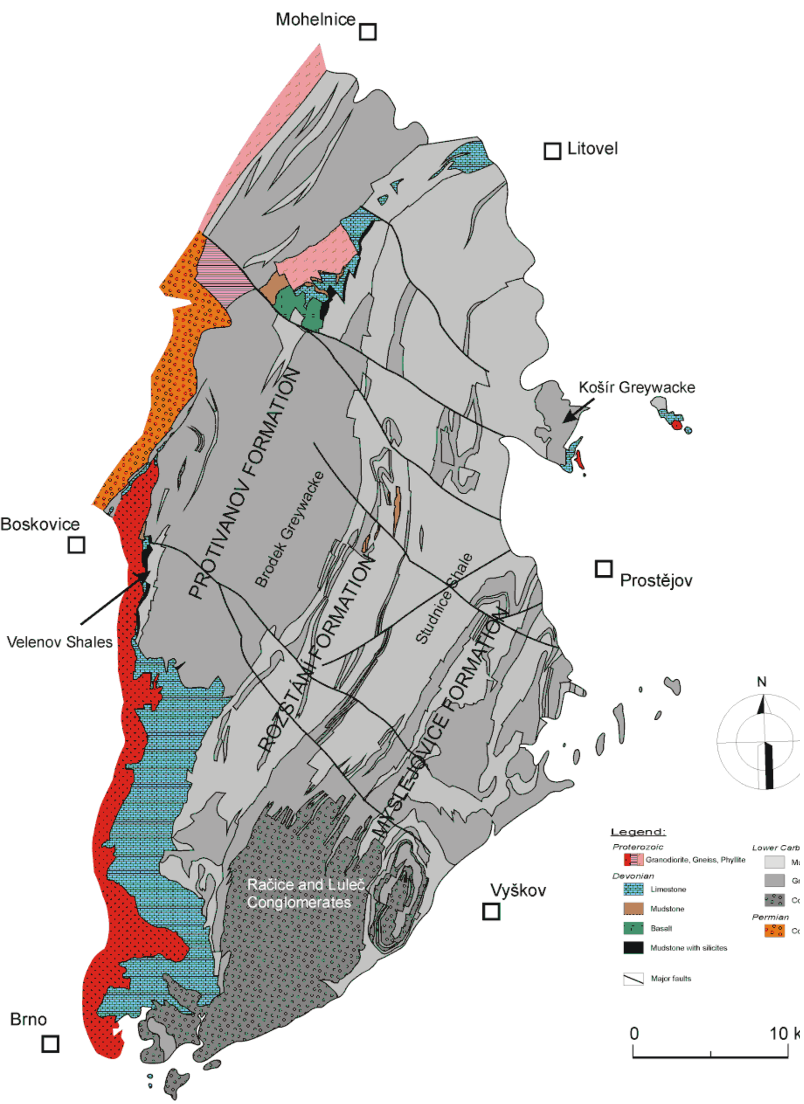


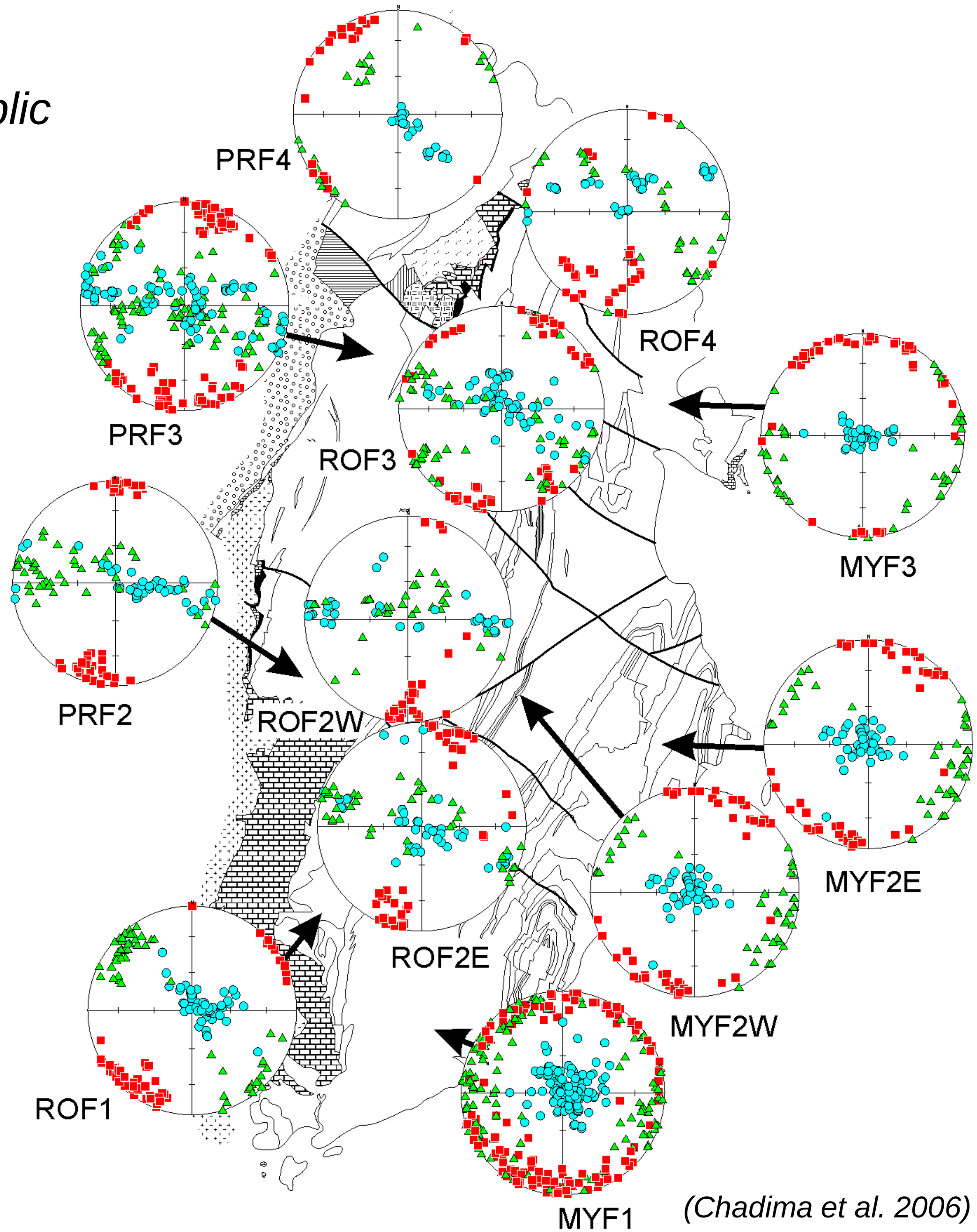
(Parés & van der Pluijm 1999)

Paleozoic accretionary wedge Rhenohercynian Belt, Czech Republic



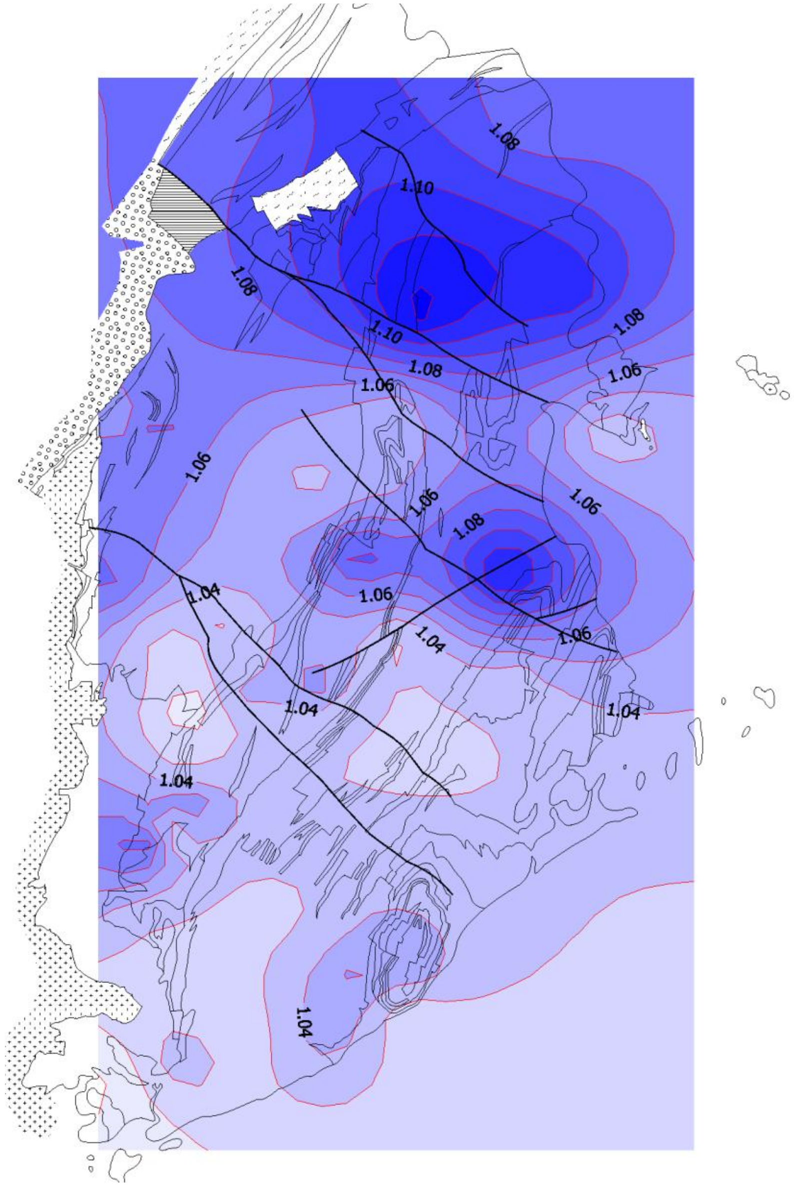
Paleozoic accretionary wedge
Rhenohercynian Belt, Czech Republic



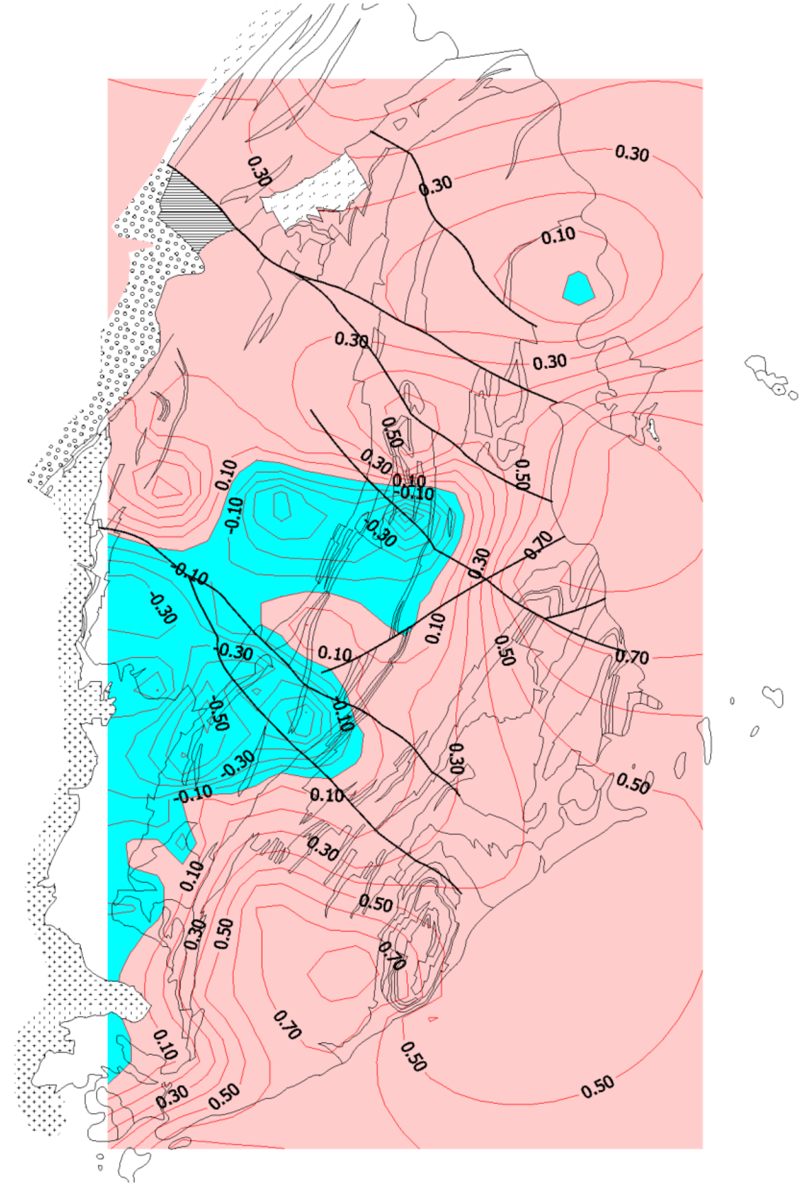


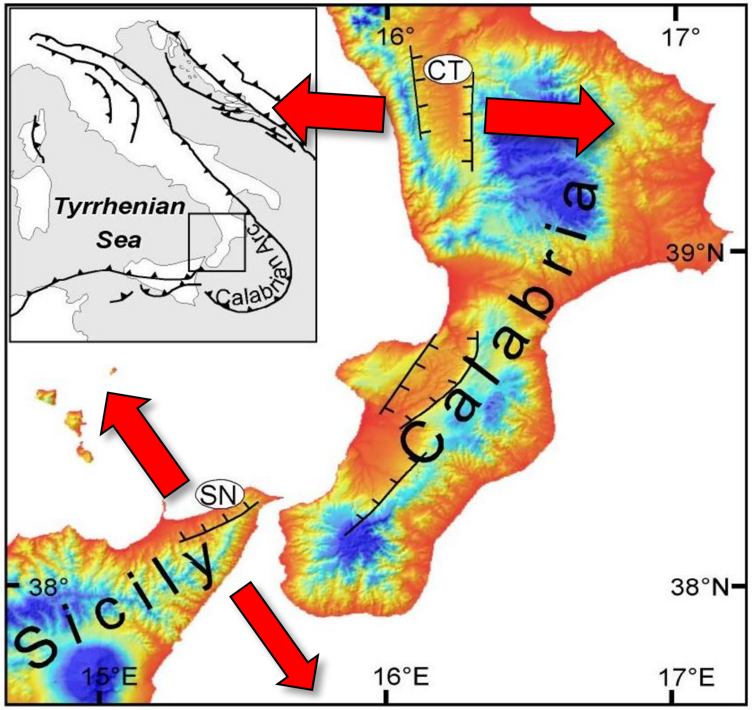
(Chadima et al. 2006)

Anisotropy degree (P)



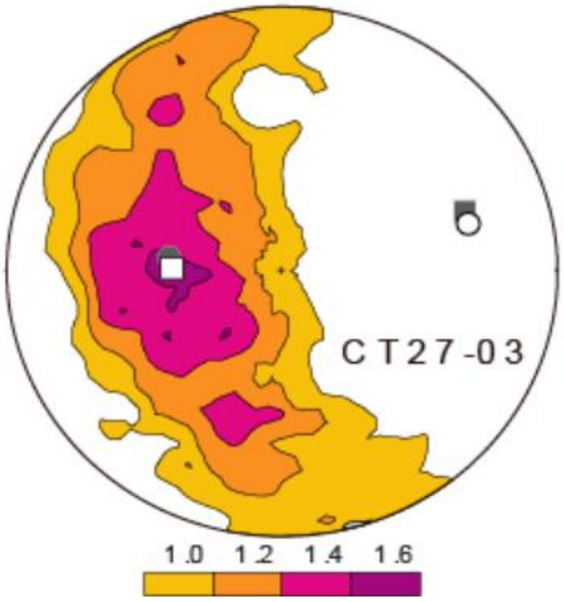
Shape parameter (T)

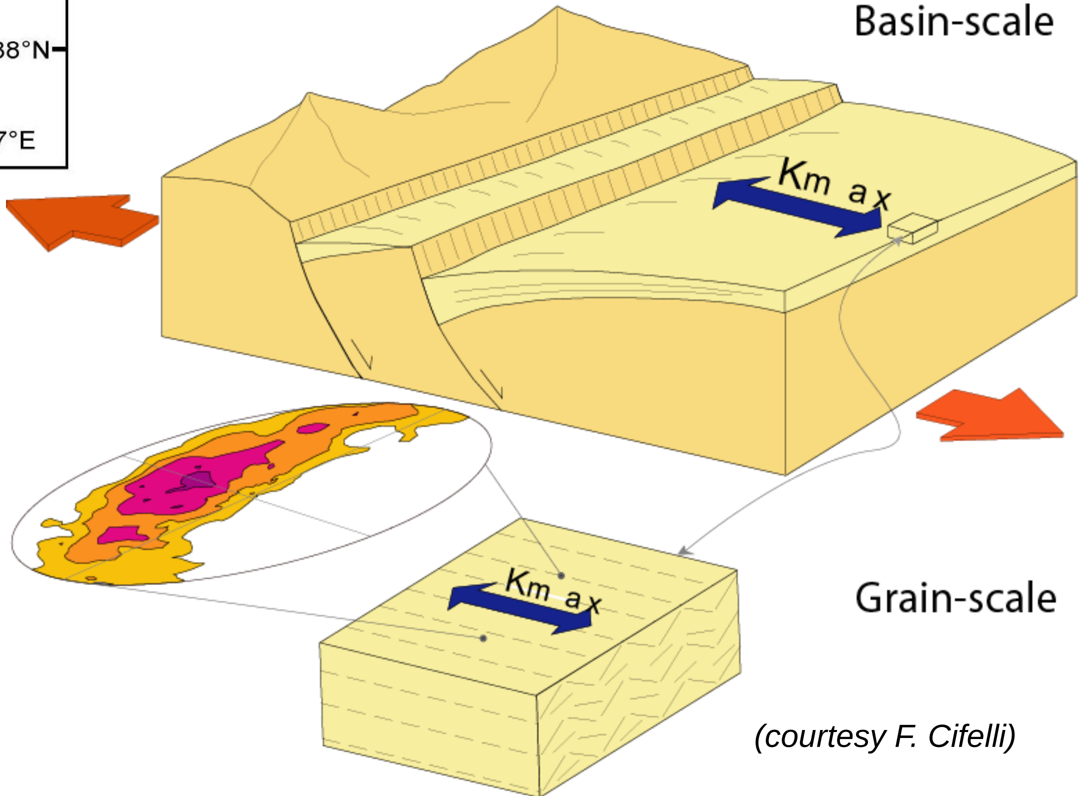




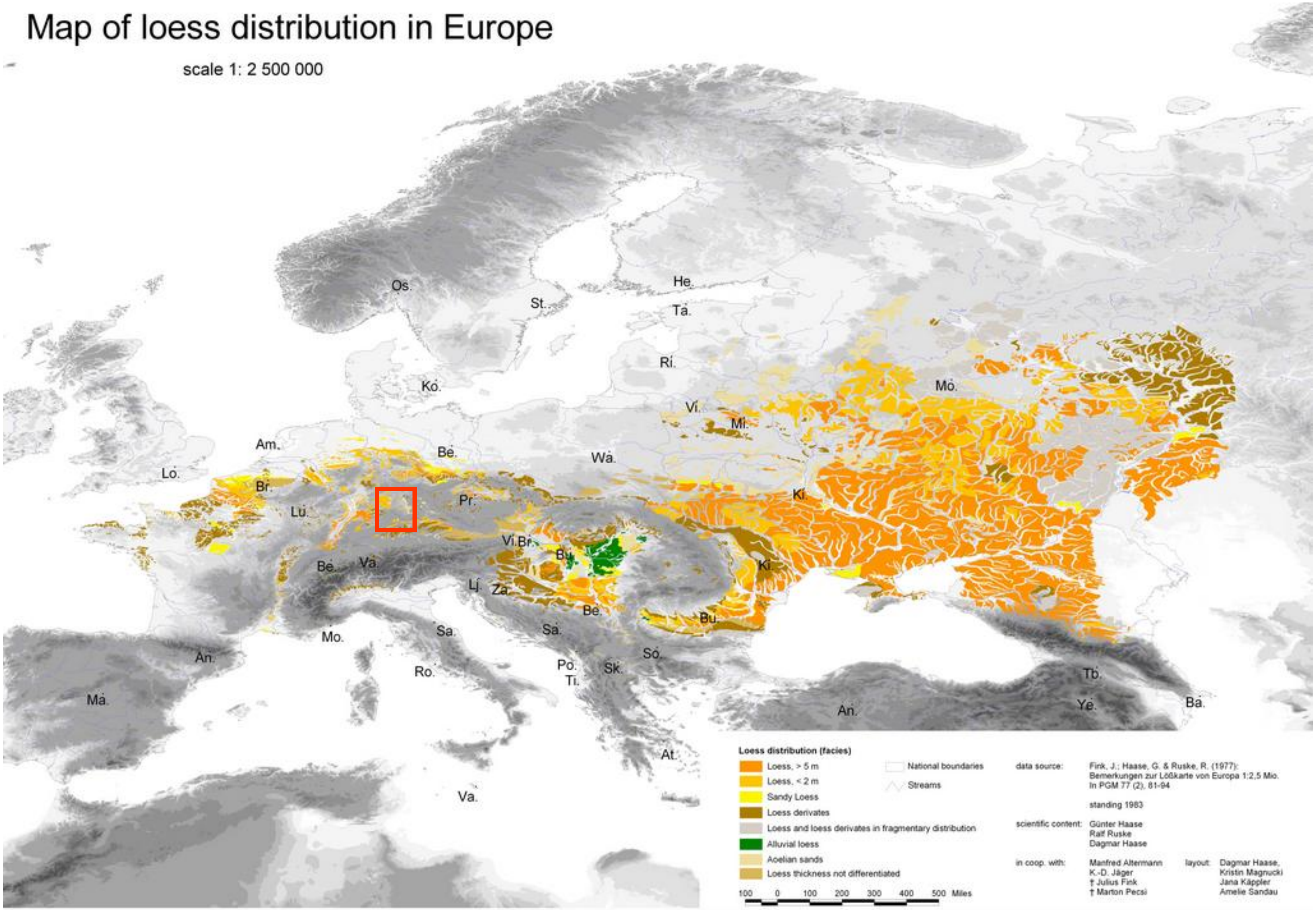
Extentional tectonic setting

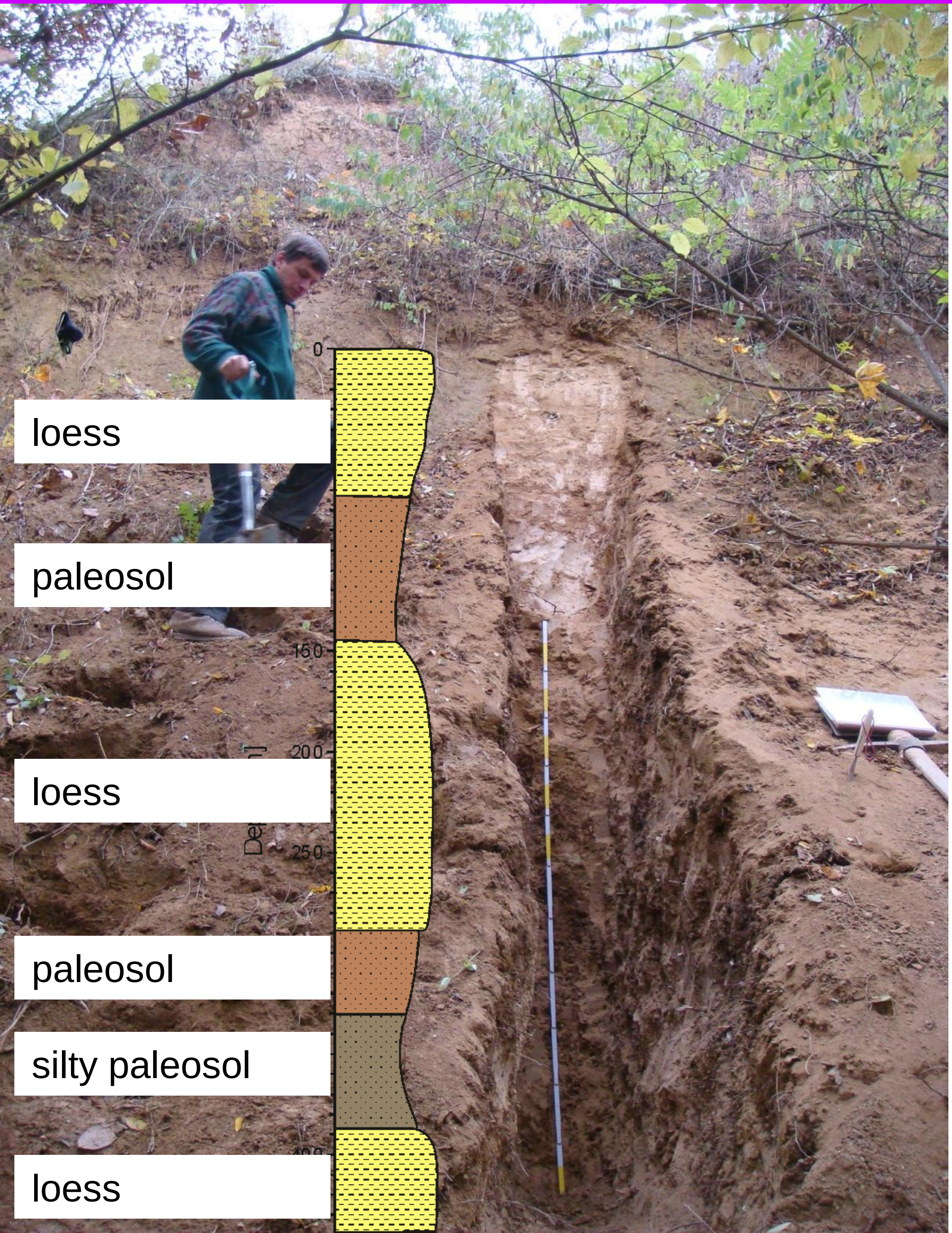
- *Extentional setting*
- *Neogene basin, southern Italy*

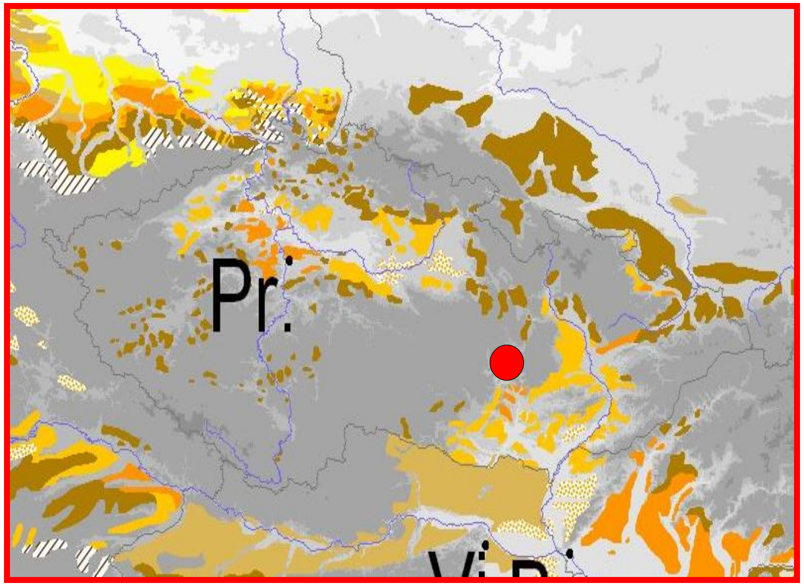




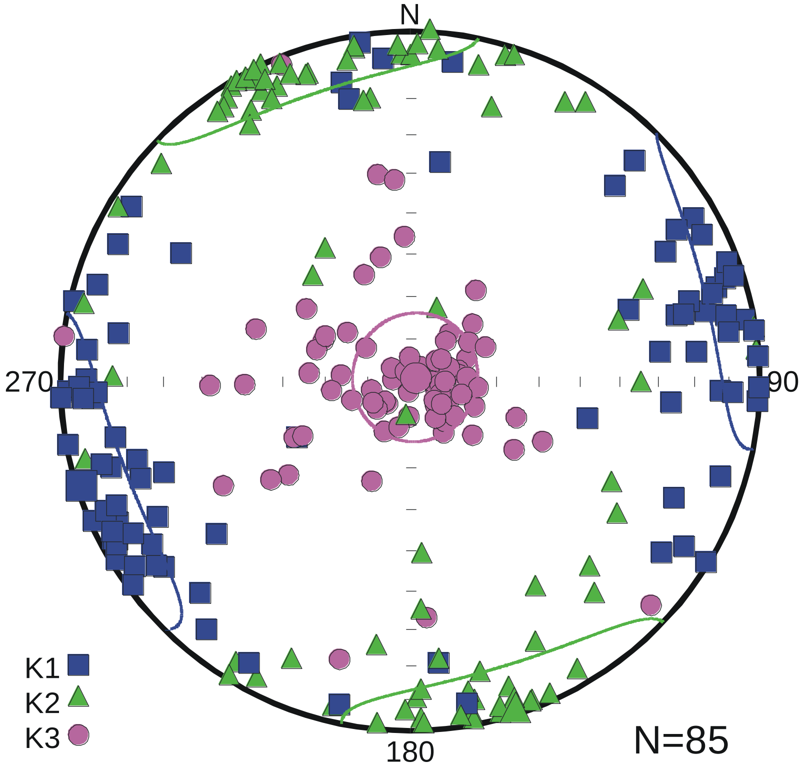
(courtesy F. Cifelli)

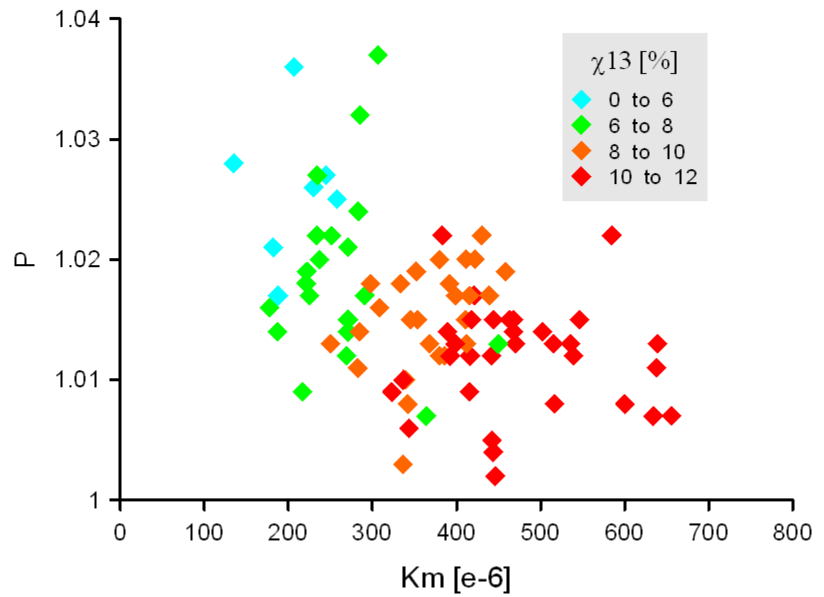

Map of loess distribution in Europe
scale 1: 2 500 000
Os.
St.
He.
Ta.
Ri.
Ko.
Mo.
Vi.
Mi.
Am.
Be.
Wa.
Lo.
Br.
Lu.
Pr.
Ki.
Vi.Br.
Bu.
Be.
Va.
Lj.
Za.
Ki.
Be.
Bu.
Sa.
Sa.
Mo.
An.
So.
Po.
Ti.
Sk.
Ro.
Tb.
Ma.
Ye.
Ba.
An.
At.
Va.
Loess distribution (facies)
Loess, > 5 m
Loess, < 2 m
Sandy Loess
Loess derivates
Loess and loess derivates in fragmentary distribution
Alluvial loess
Aoelian sands
Loess thickness not differentiated
National boundaries
Streams
100 0 100 200 300 400 500 Miles
data source:
Fink, J.; Haase, G. & Ruske, R. (1977): Bemerkungen zur Lößkarte von Europa 1:2,5 Mio. In PGM 77 (2), 81-94
standing 1983
scientific content:
Günter Haase
Ralf Ruske
Dagmar Haase
in coop. with:
Manfred Altermann
K.-D. Jäger
† Julius Fink
† Marton Pecsi
layout:
Dagmar Haase,
Kristin Magnucki
Jana Käppler
Amelie Sandau

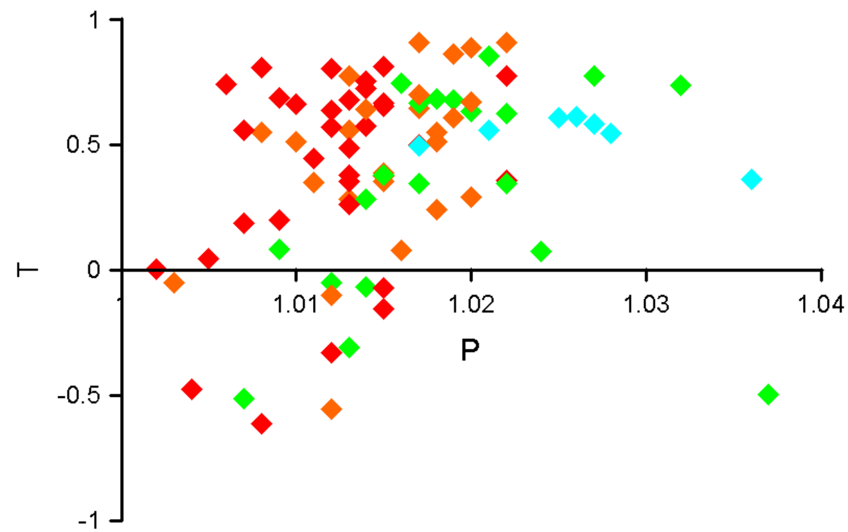

loess
paleosol
loess
paleosol
silty paleosol
loess
0
150
200
250

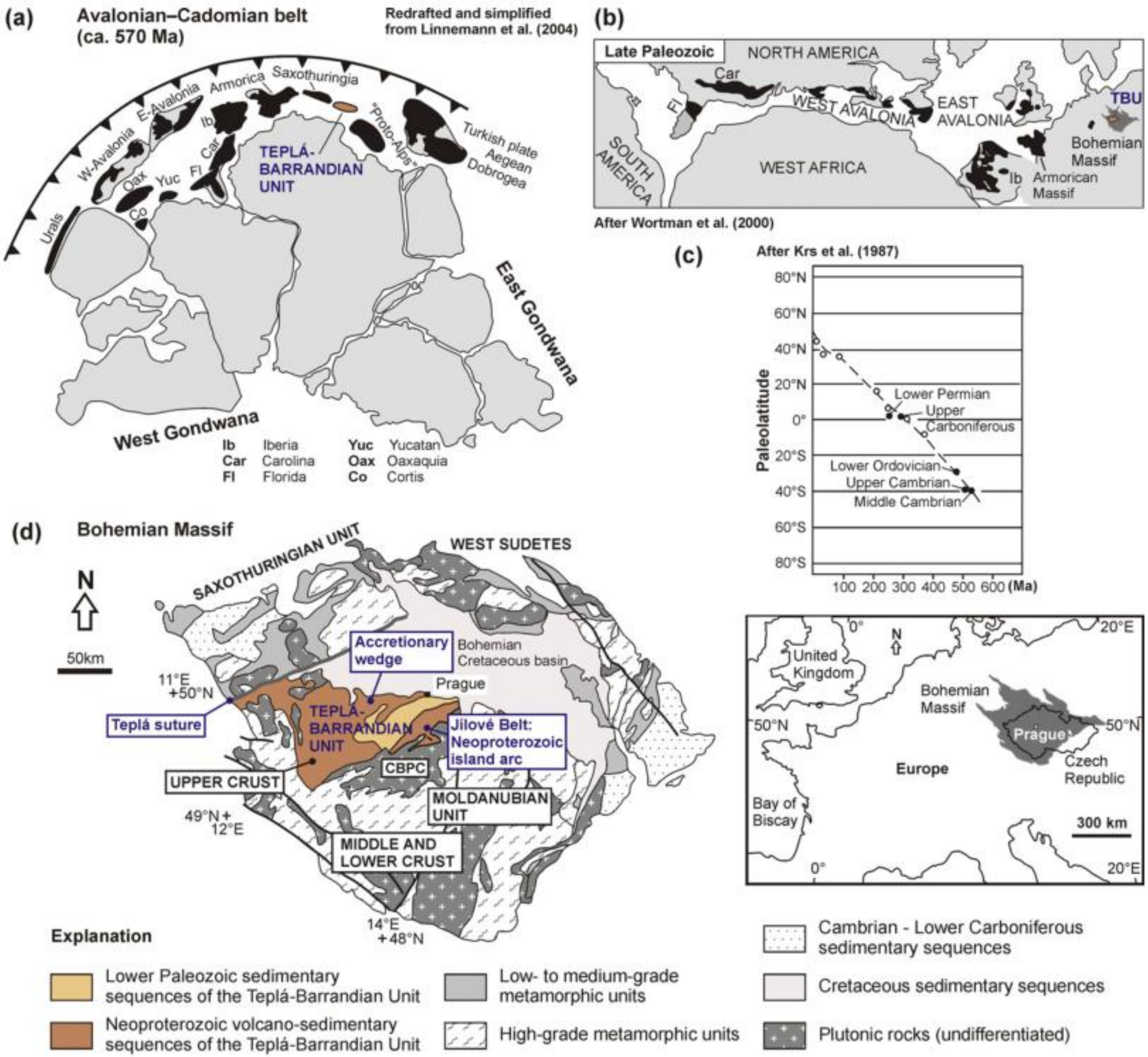

Pr.

4. Magnetic fabric of sedimentary, deformed, and metamorphosed rocks

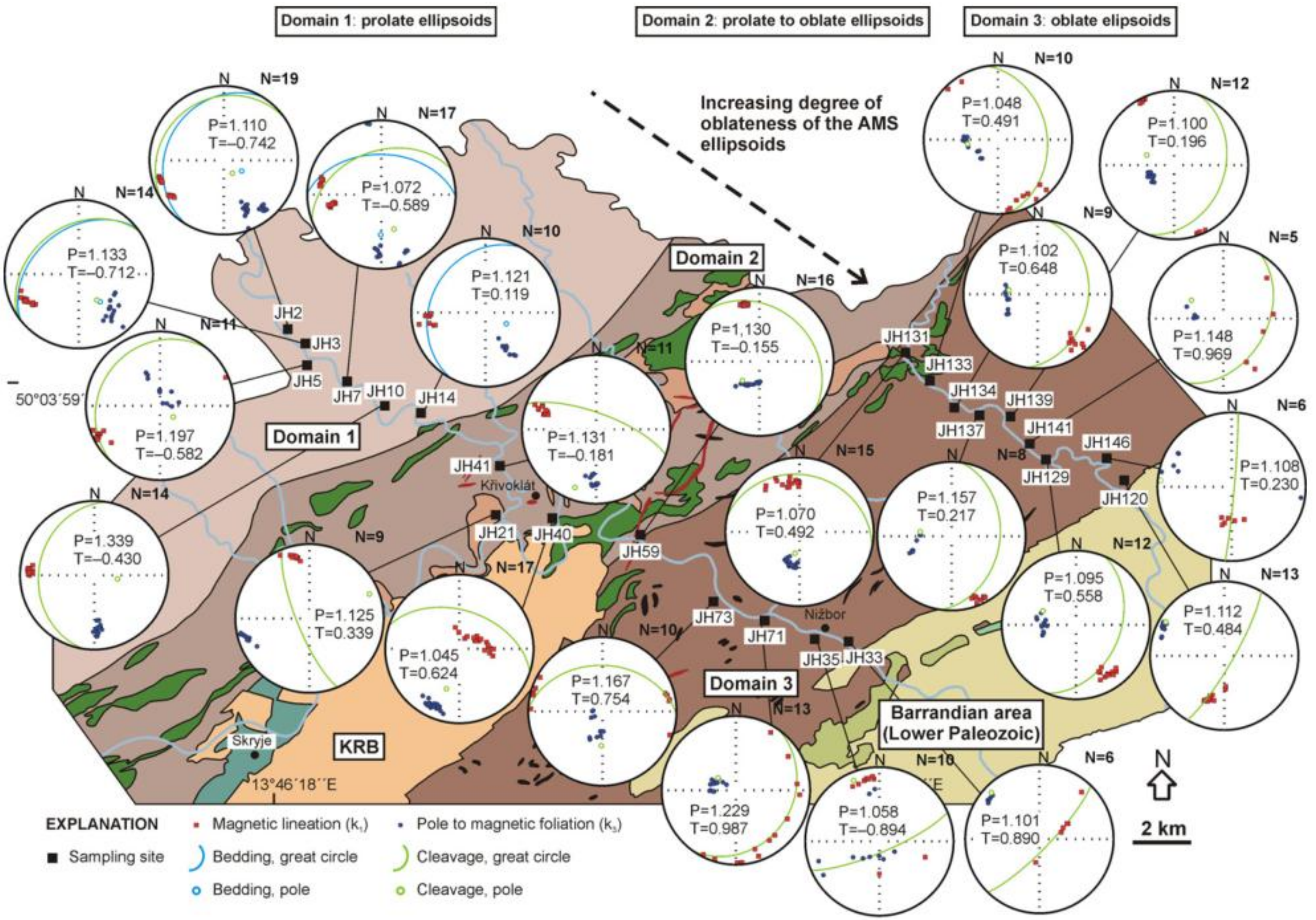




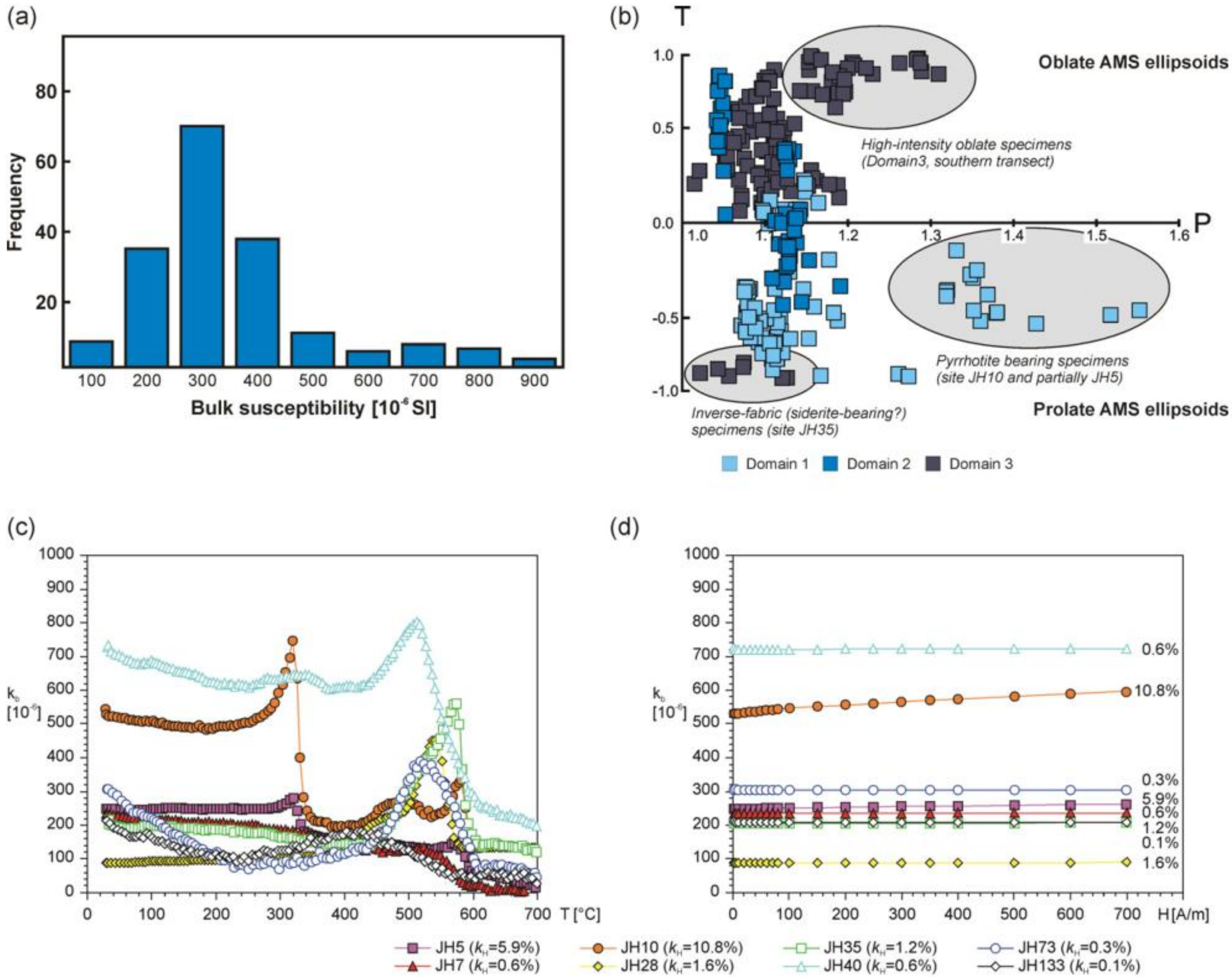




(Hajná et al. 2010)



(Hajná et al. 2010)



(Hajná et al. 2010)

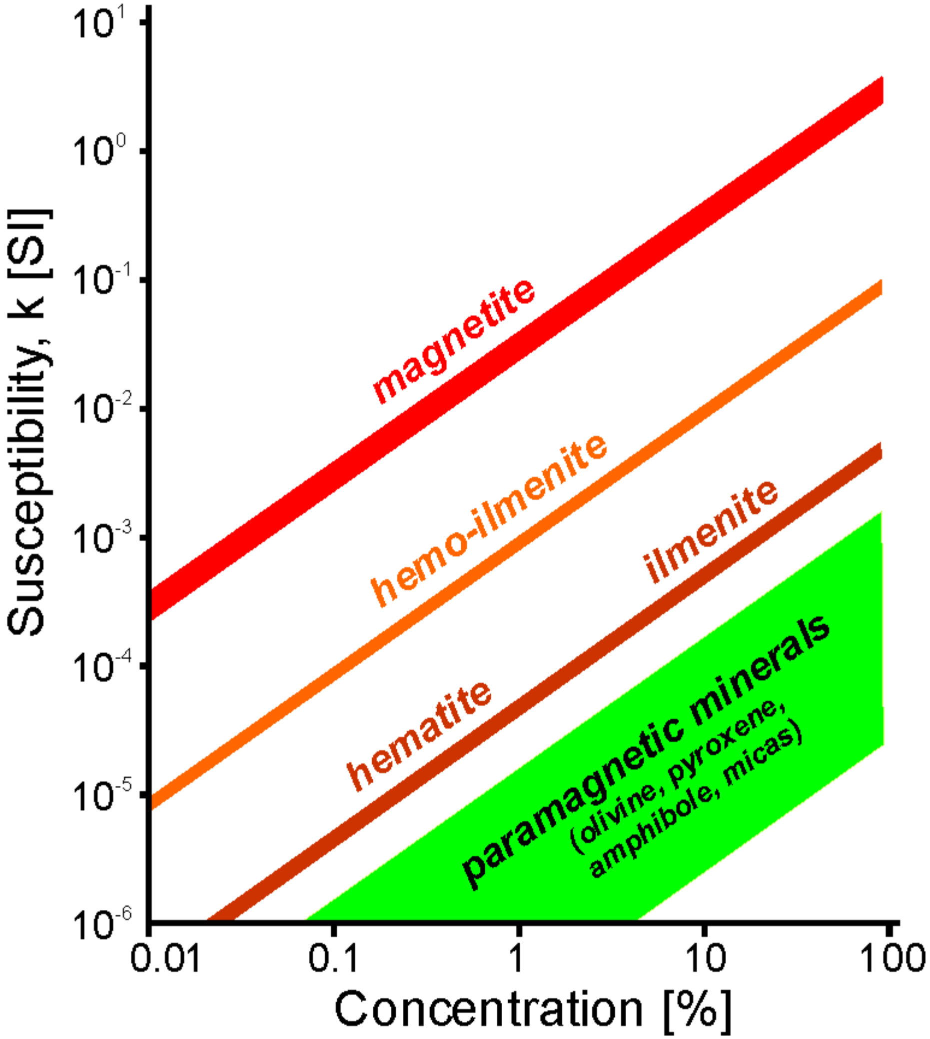
Agenda

1. **Volcanic rocks**

2. **Dikes**

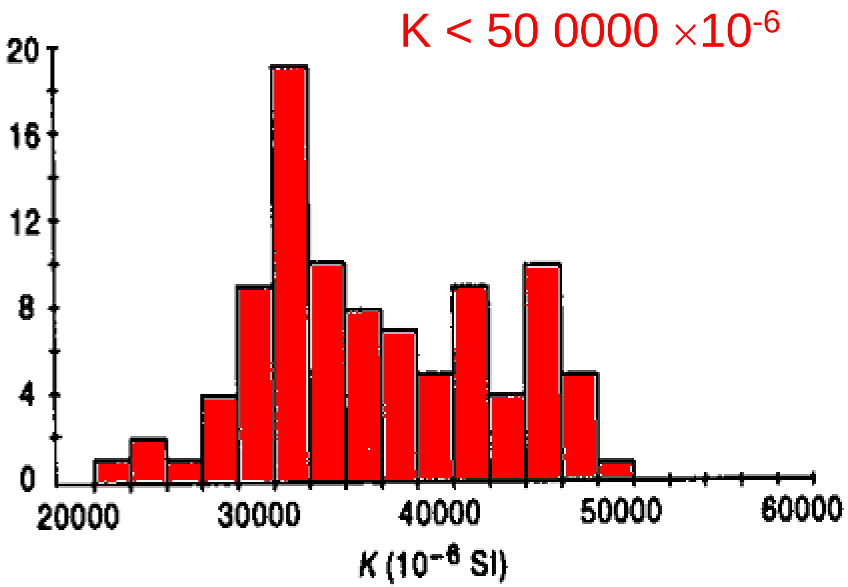
3. **Plutonic rocks**

Magnetic susceptibility dominantly carried by magnetite

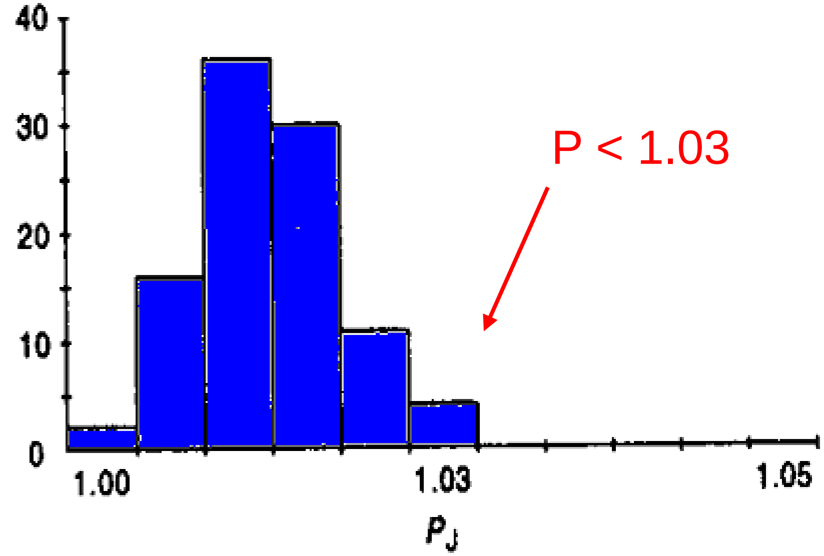


Igneous rocks

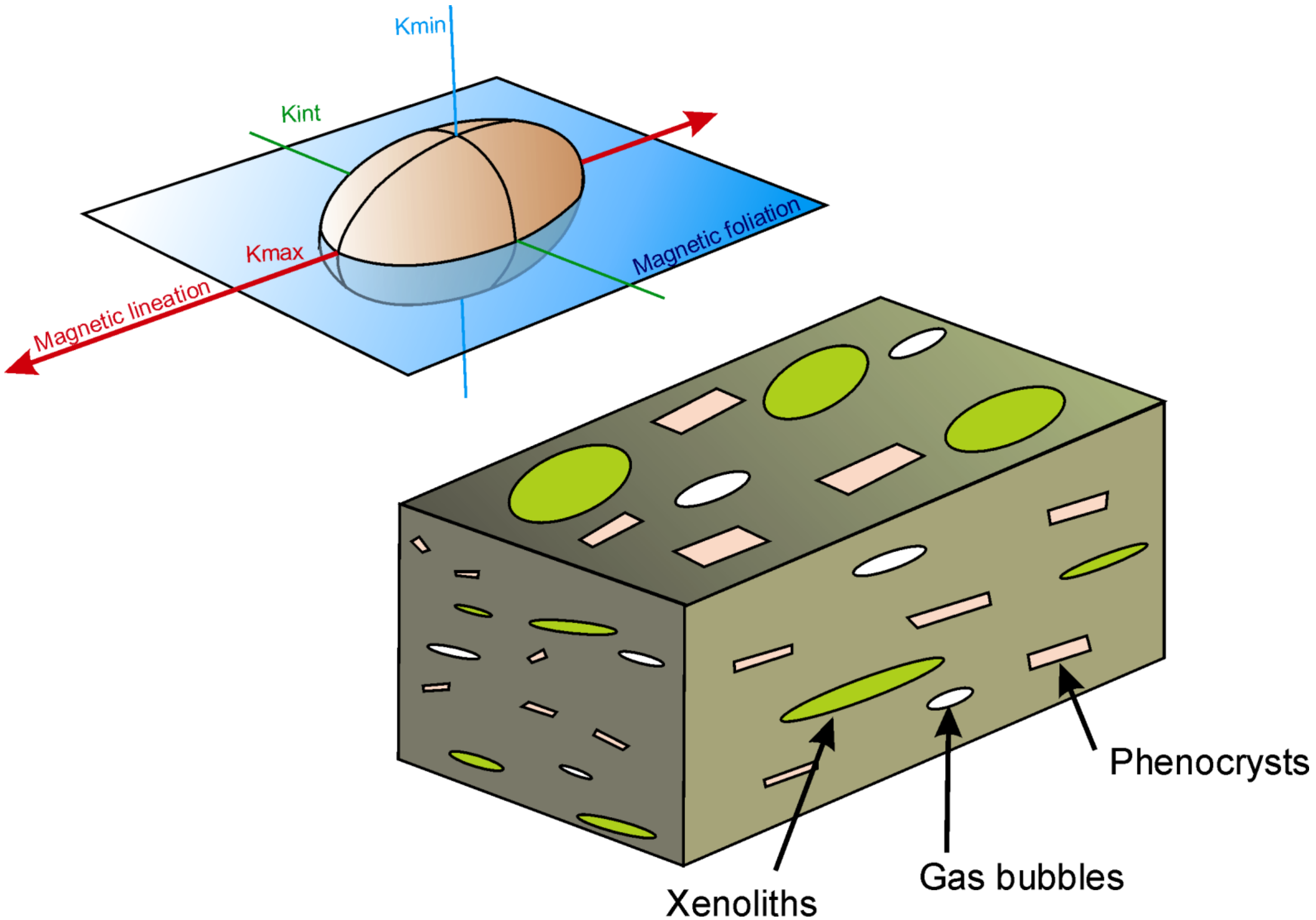
Very high magnetic susceptibility



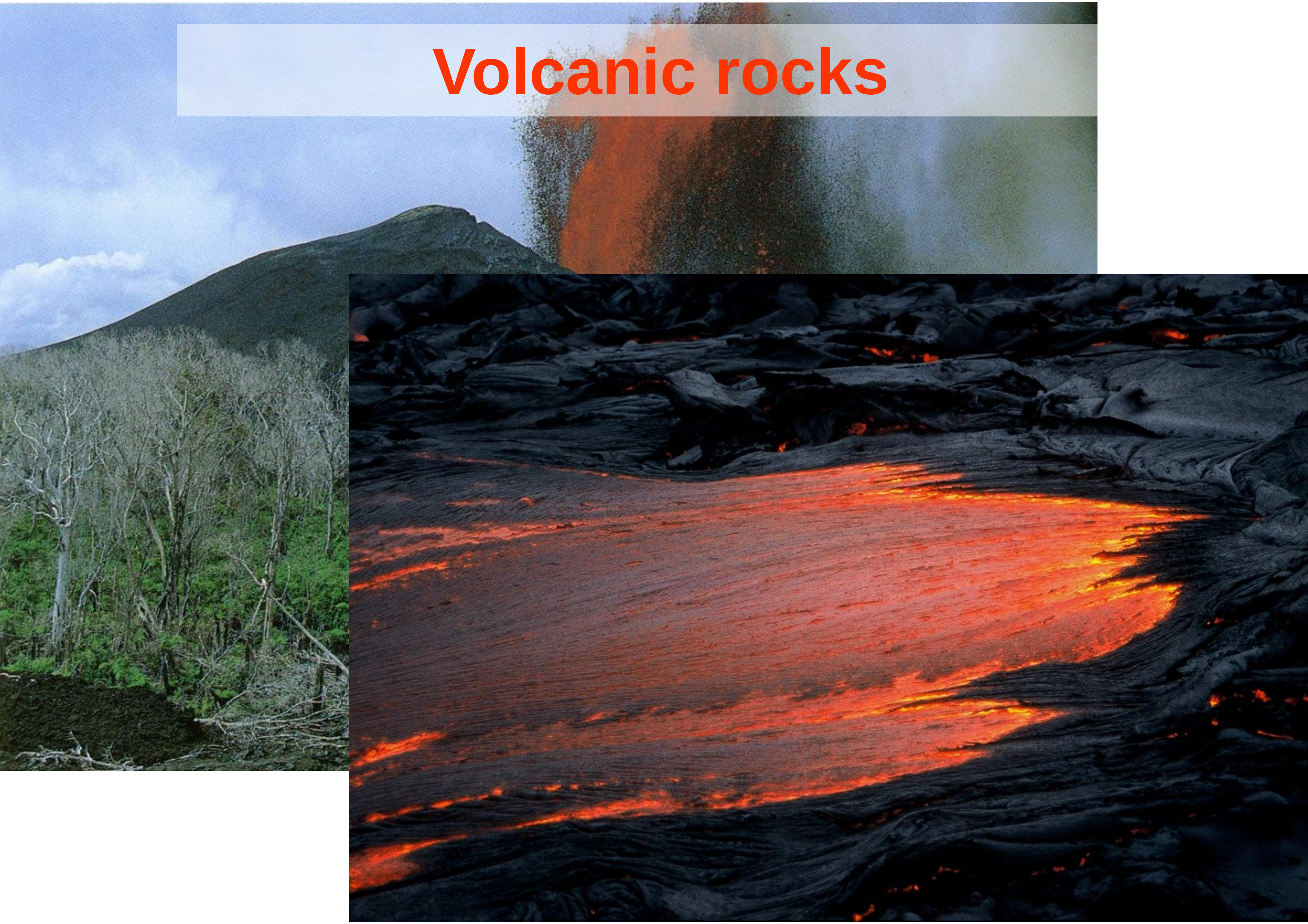
Relatively low anisotropy degree



5. Magnetic fabric of igneous rocks

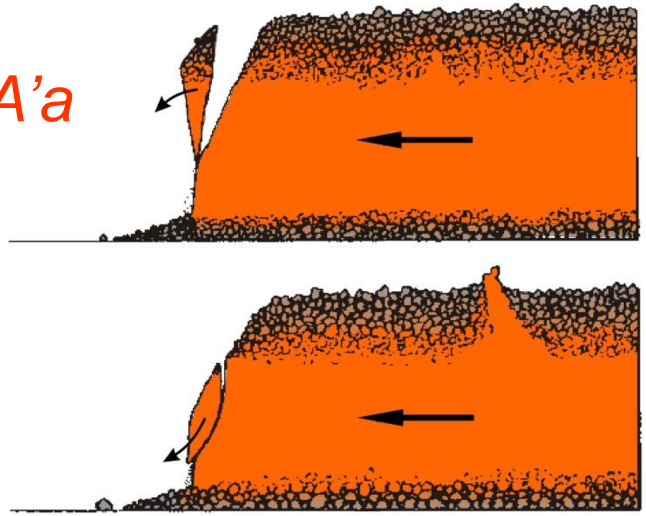


Volcanic rocks

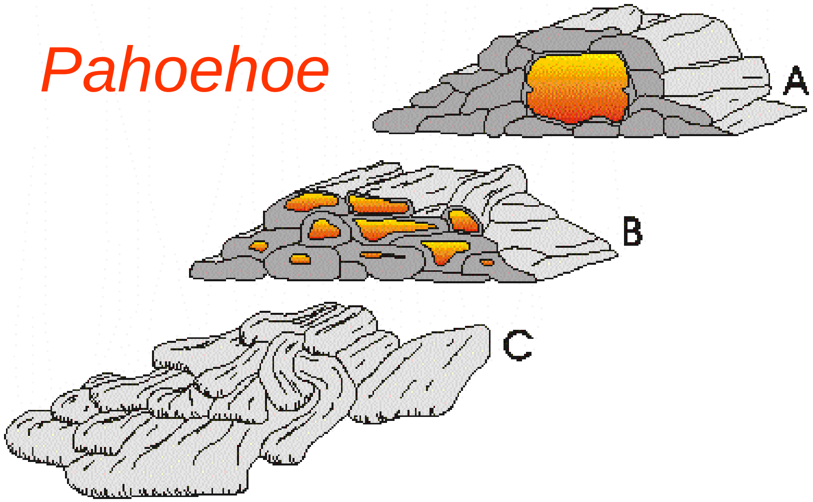


Lava flows

A'a

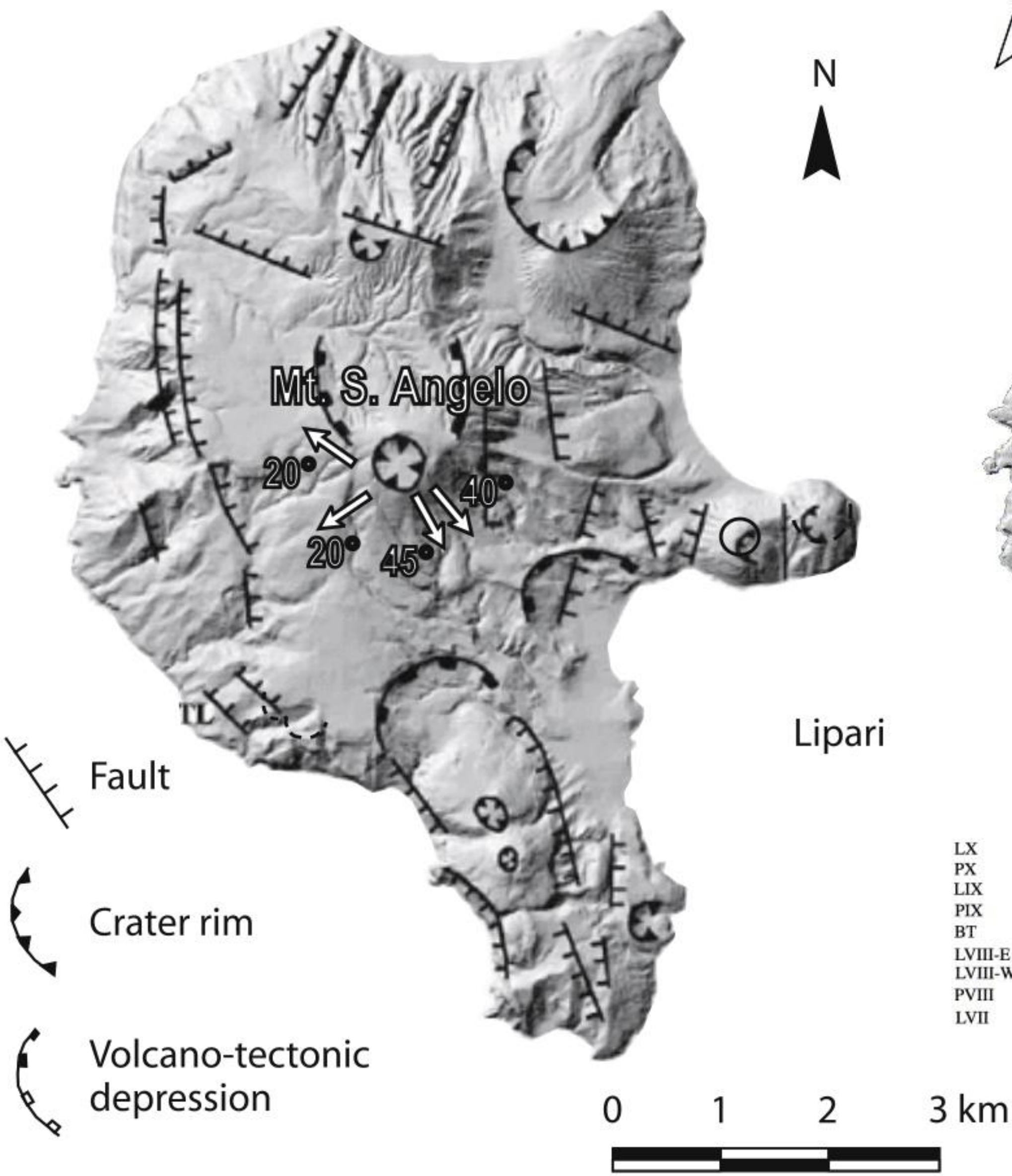


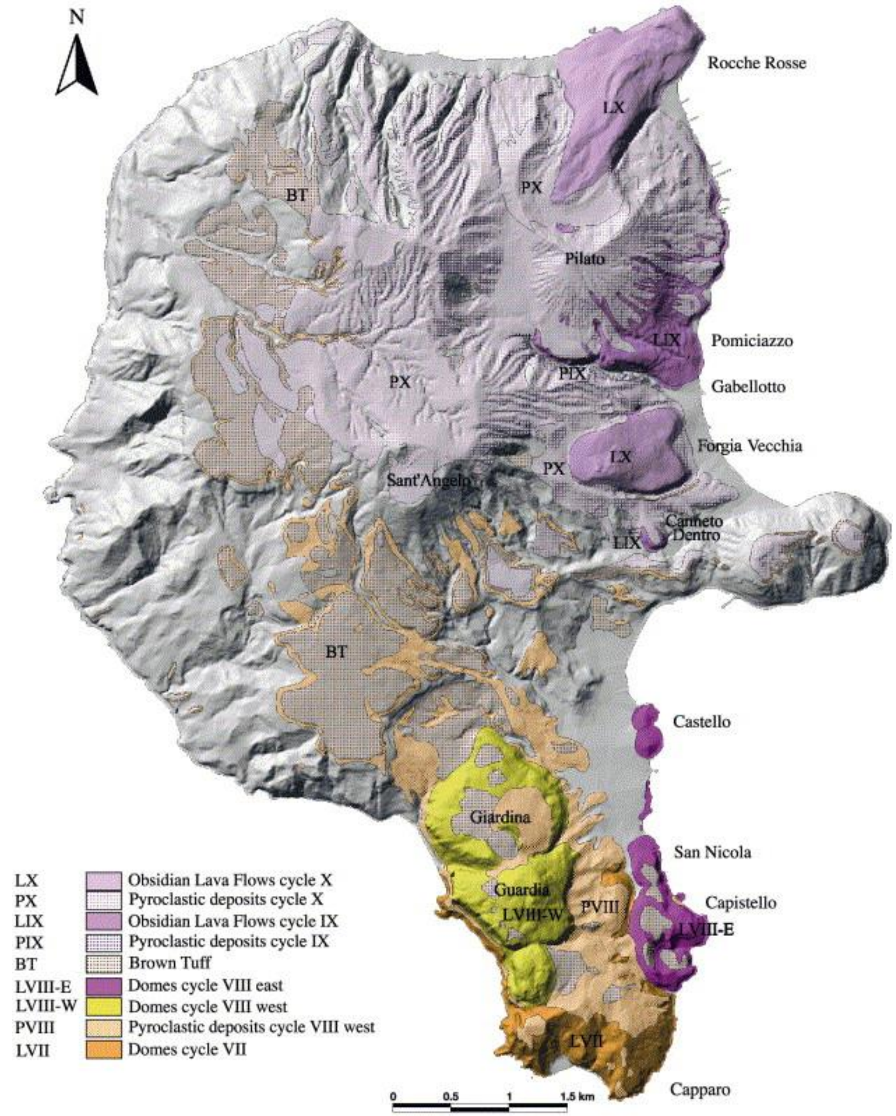
Pahoehoe



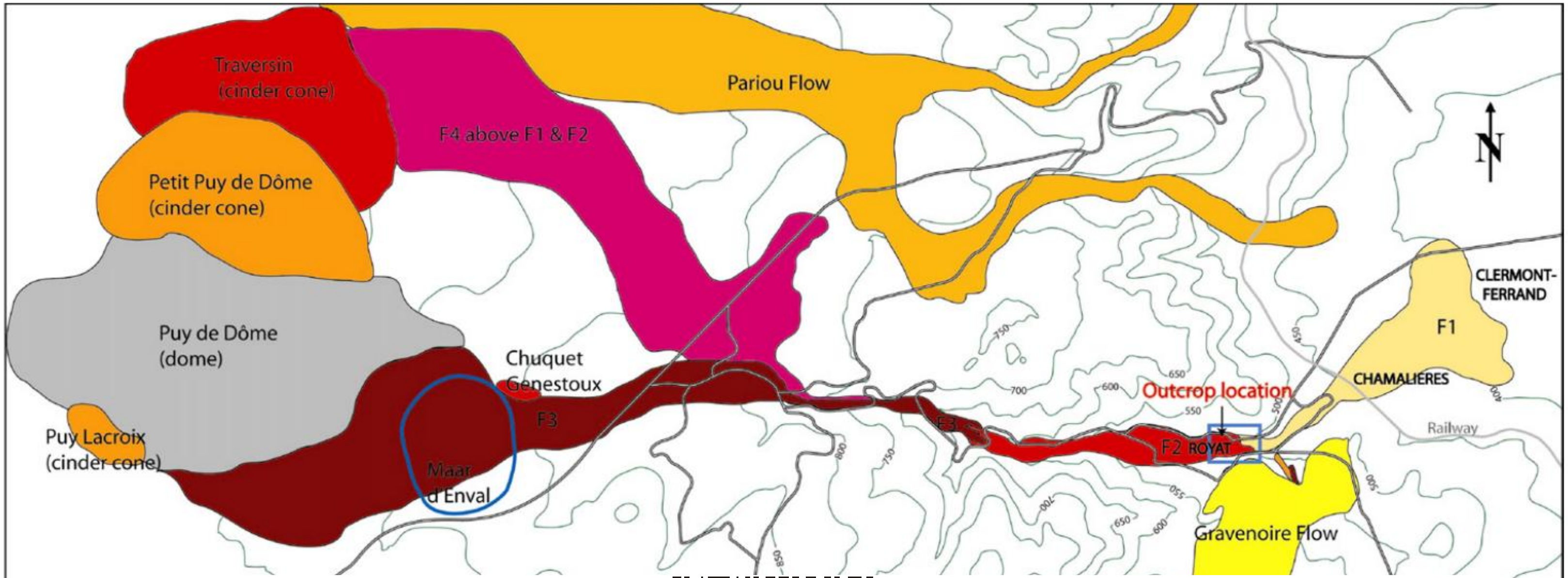
Lipari Island, Tyrrhenian Sea, Italy

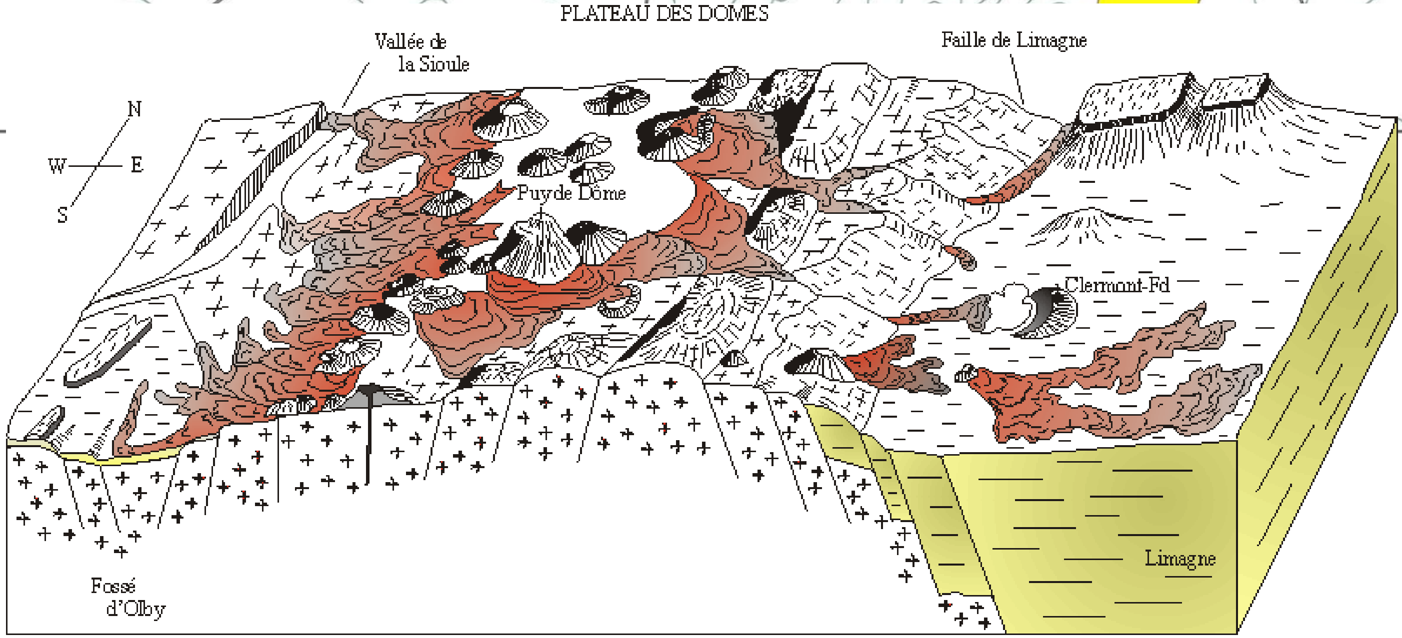
Lipari Island, Tyrrhenian Sea



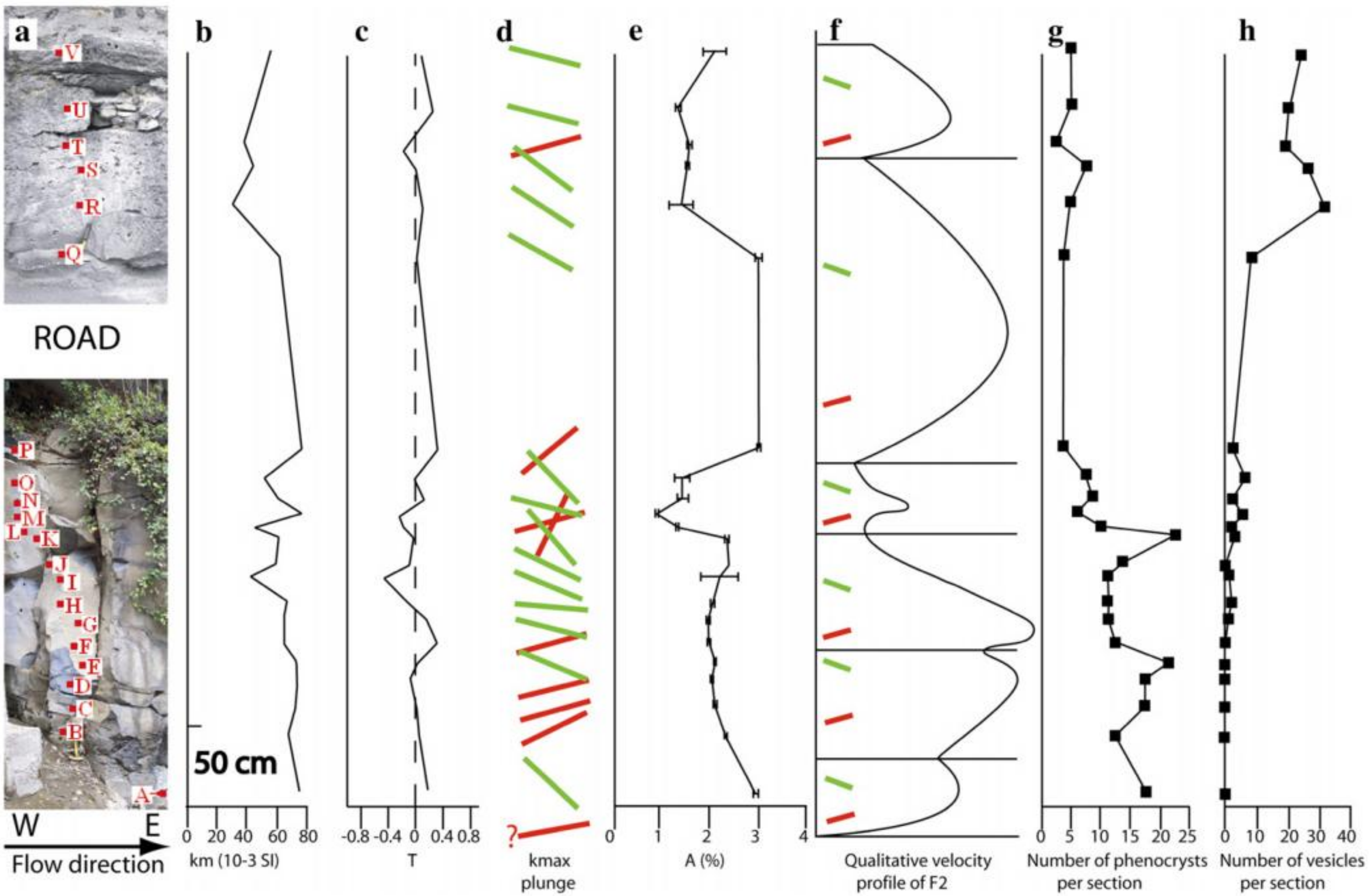


Chaîne des Puys, Massif Central, France



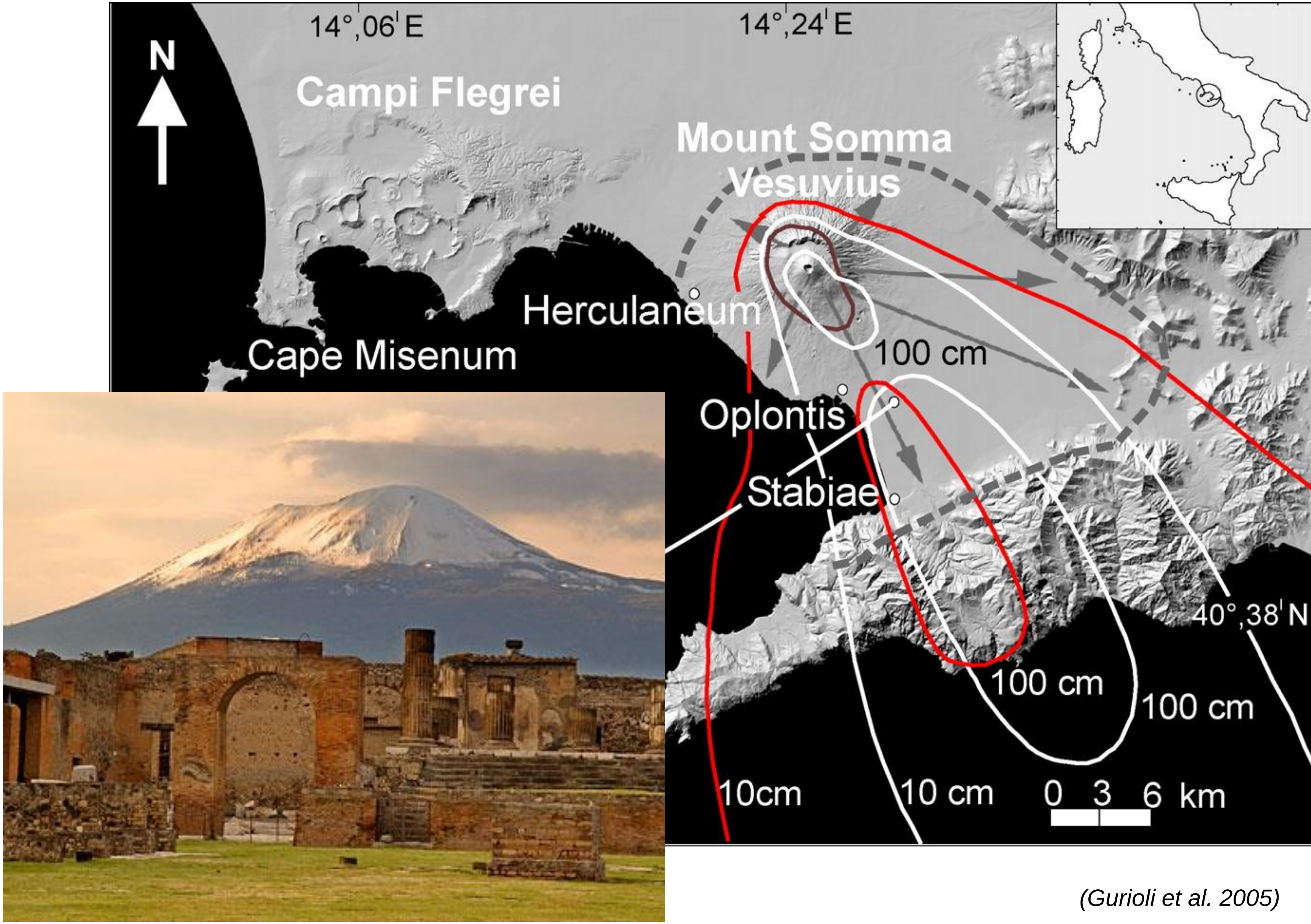


Section across lava flow

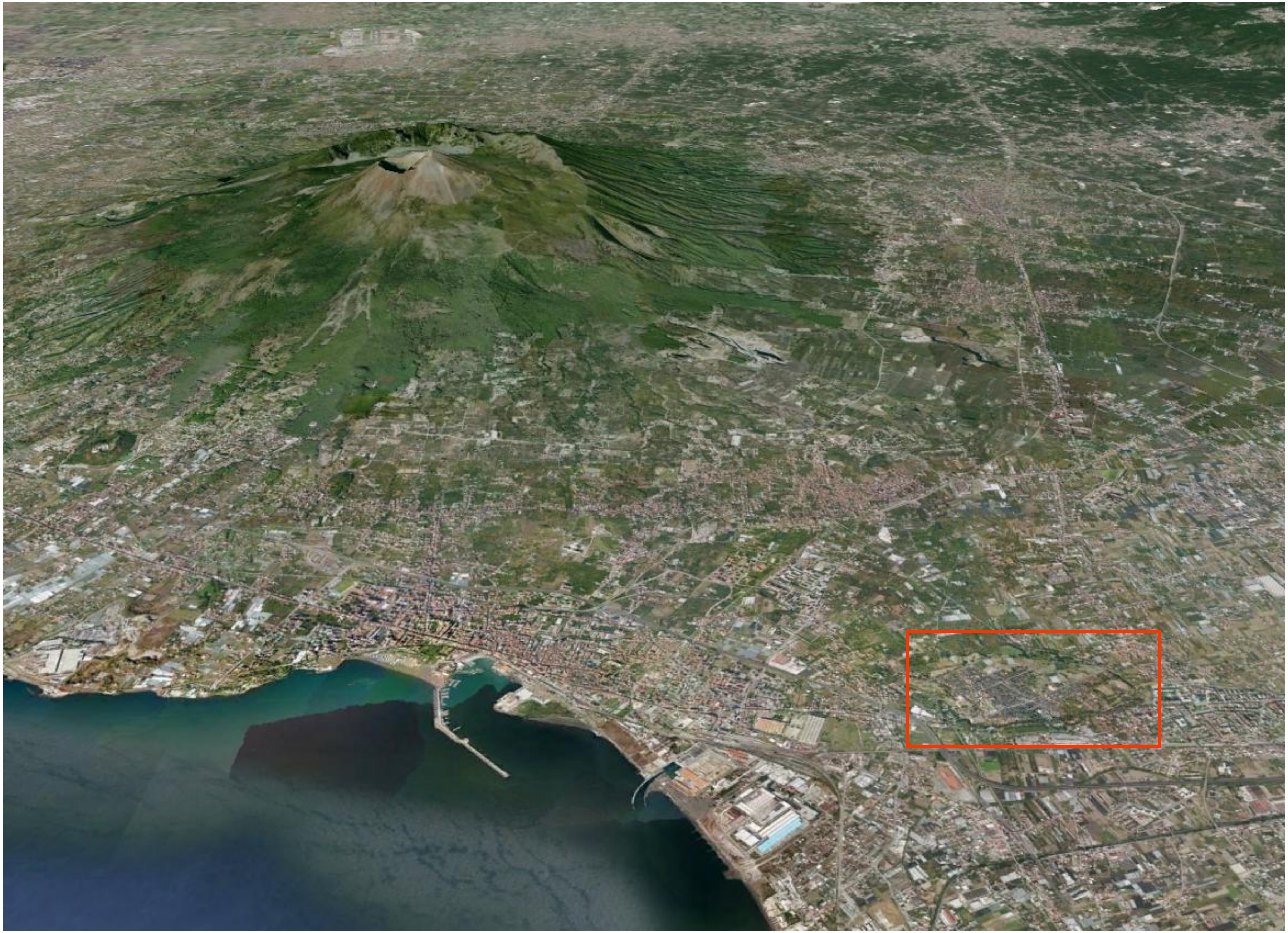


(Loock et al. 2008)

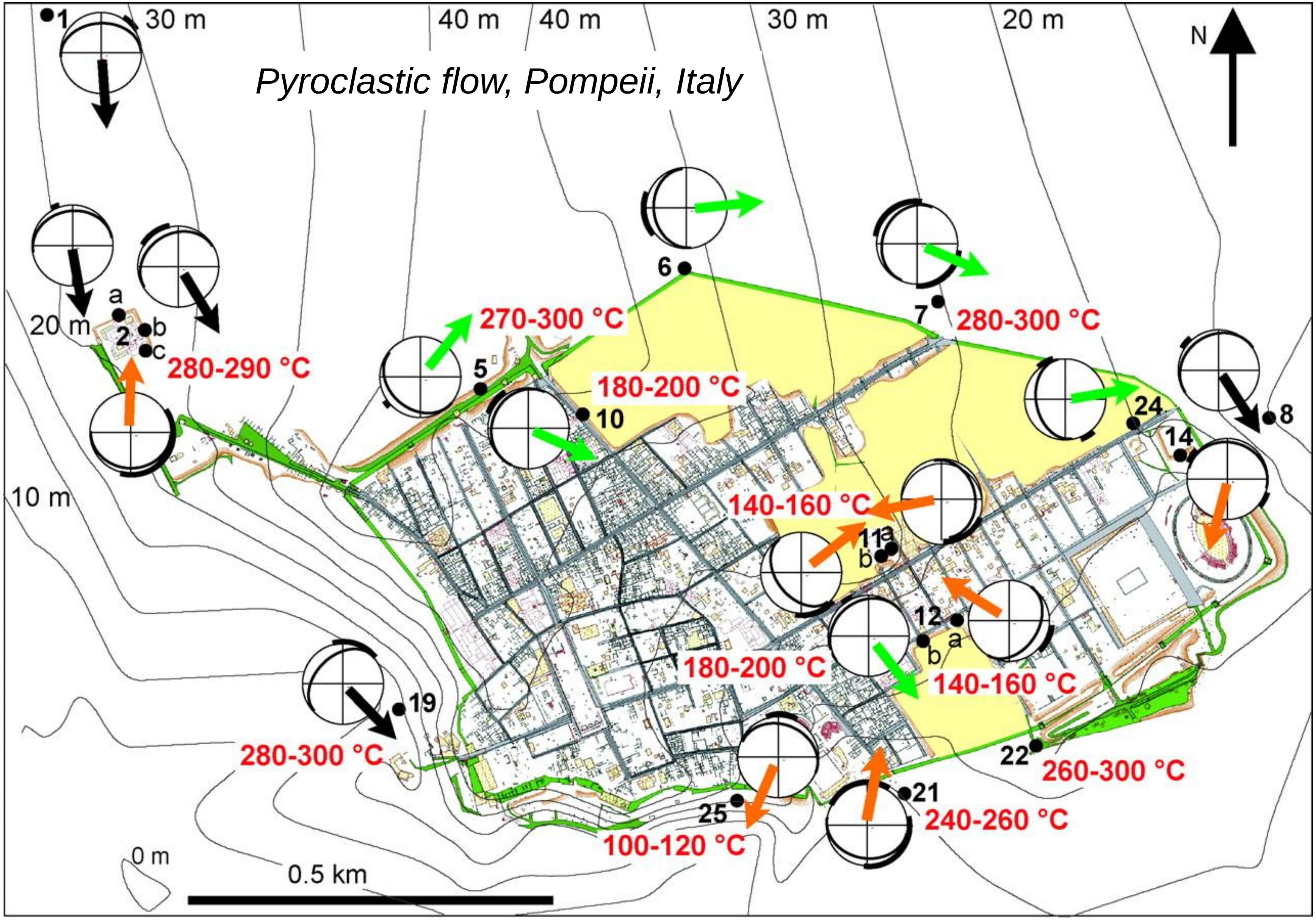
Pyroclastic flow, Pompeii, Italy



(Gurioli et al. 2005)



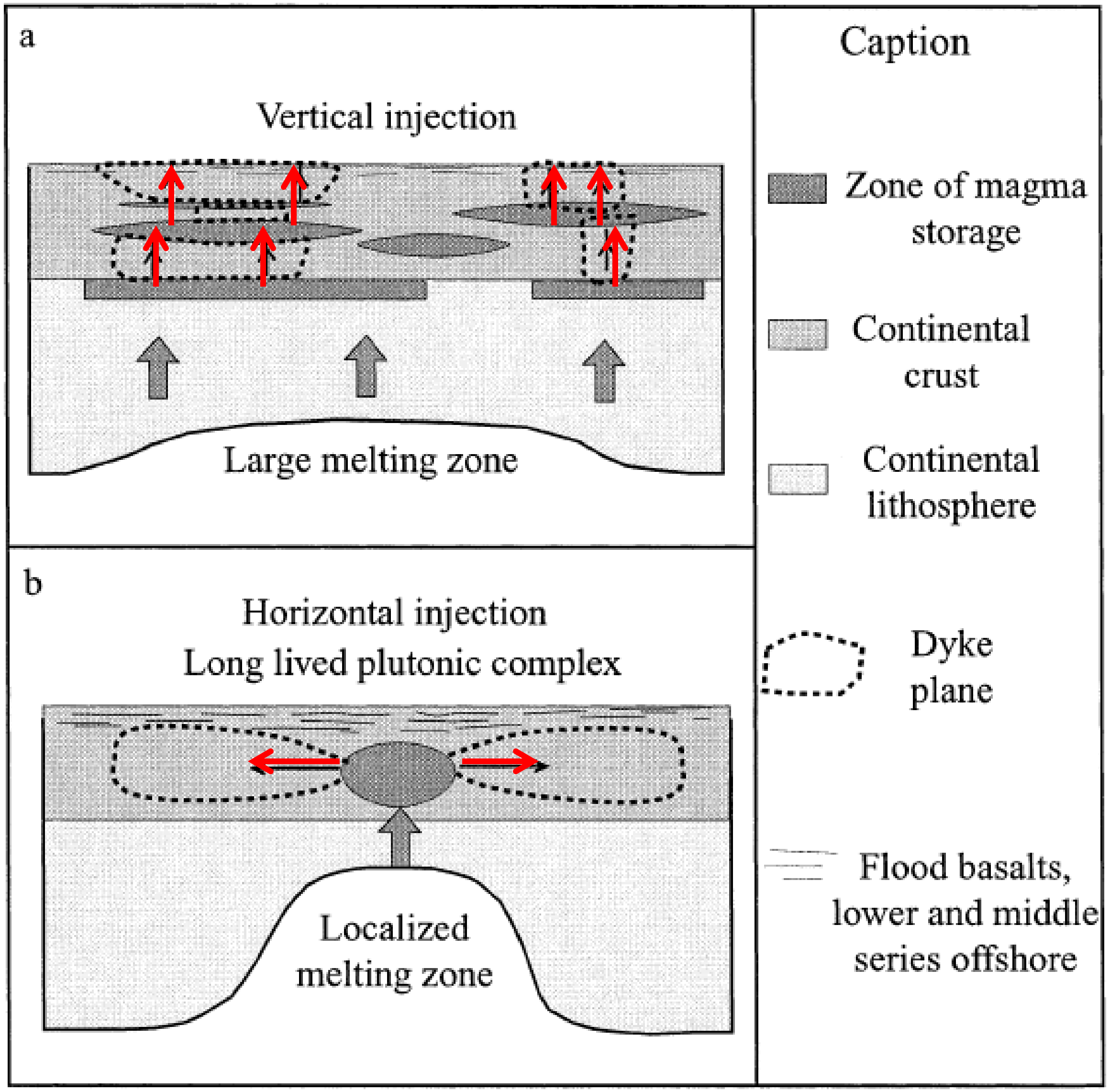
5. Magnetic fabric of igneous rocks



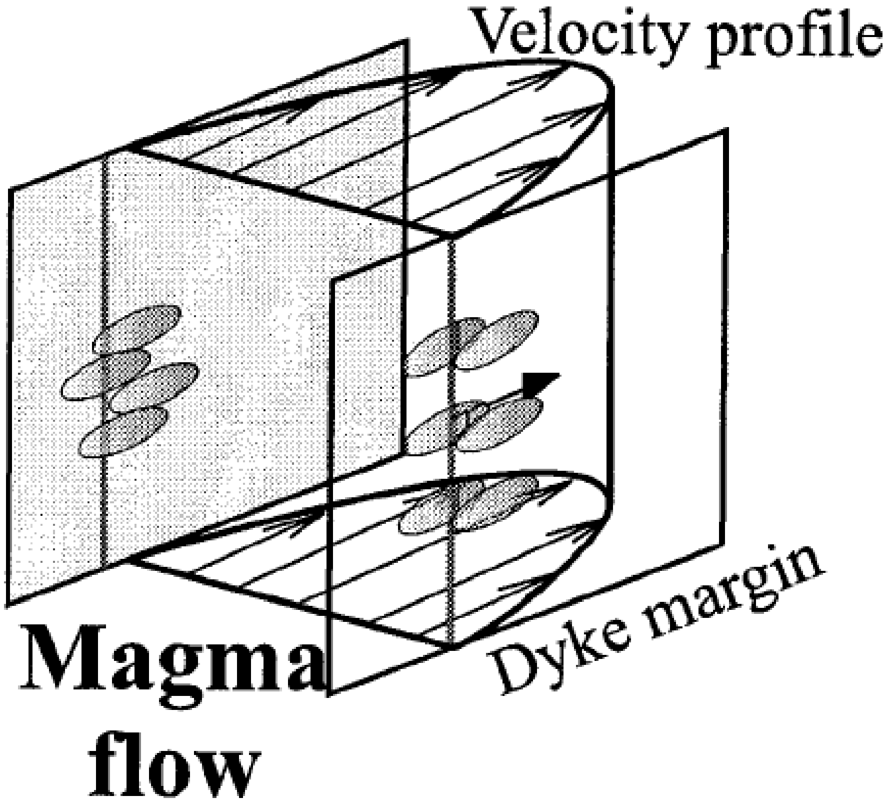
(Gurioli et al. 2005)

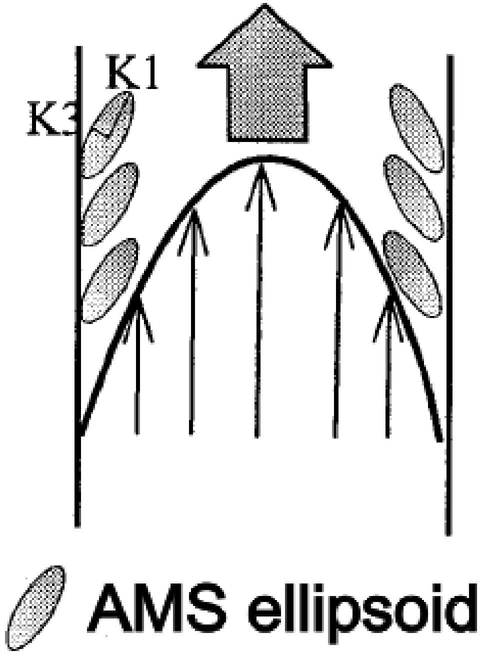
Dikes

Estimate of flow direction

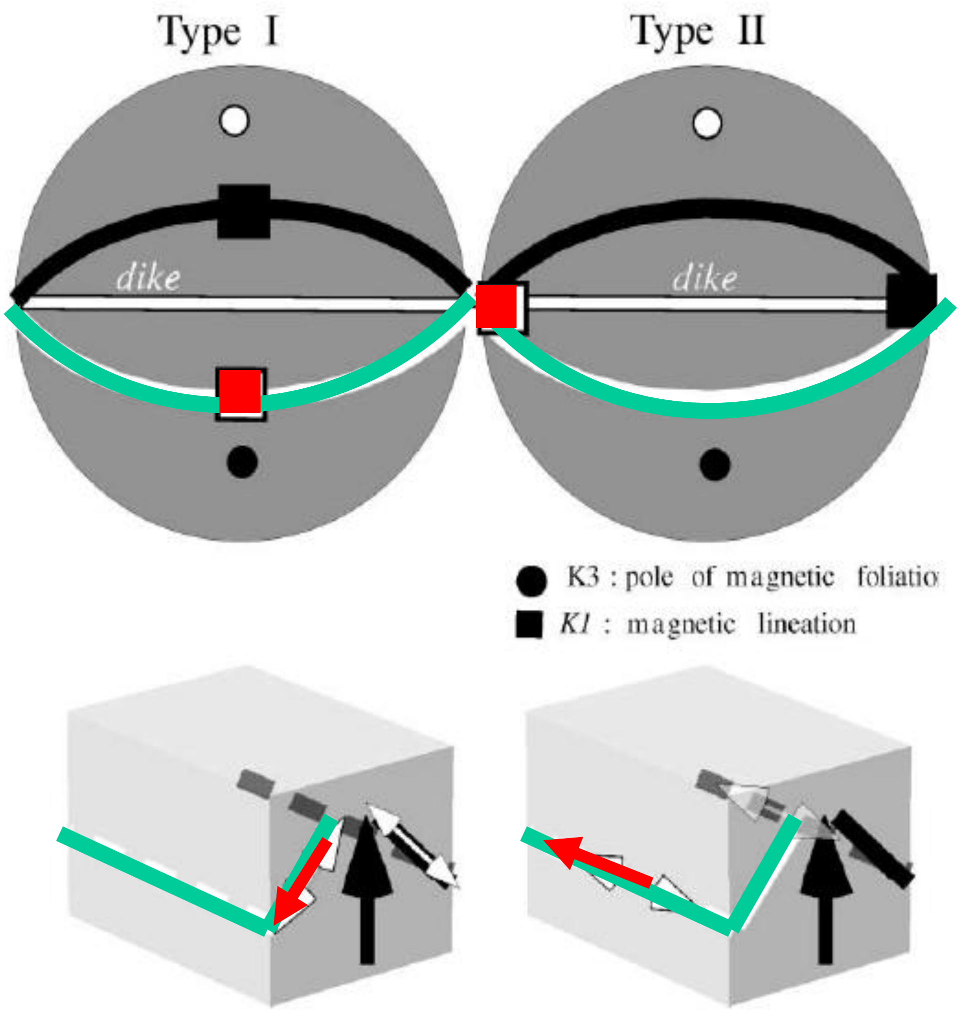


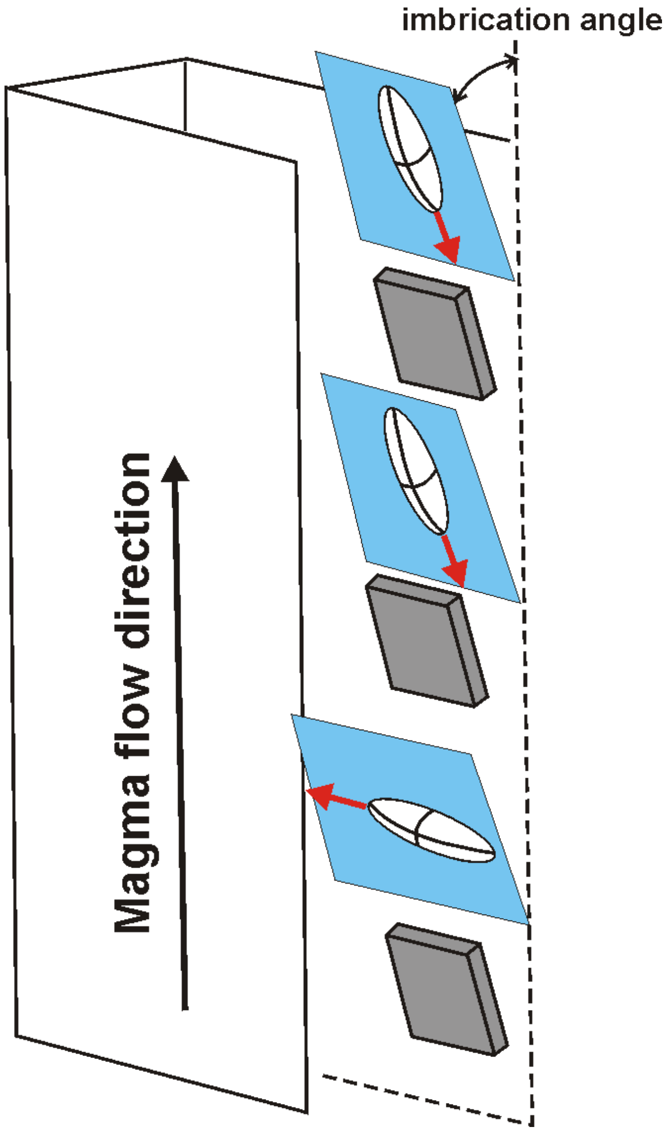
Dikes

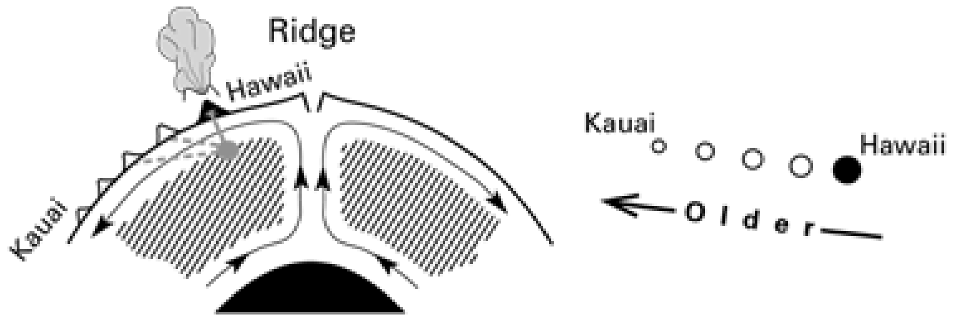

Velocity profile
Magma
flow
Dyke margin


K1
K3
AMS ellipsoid

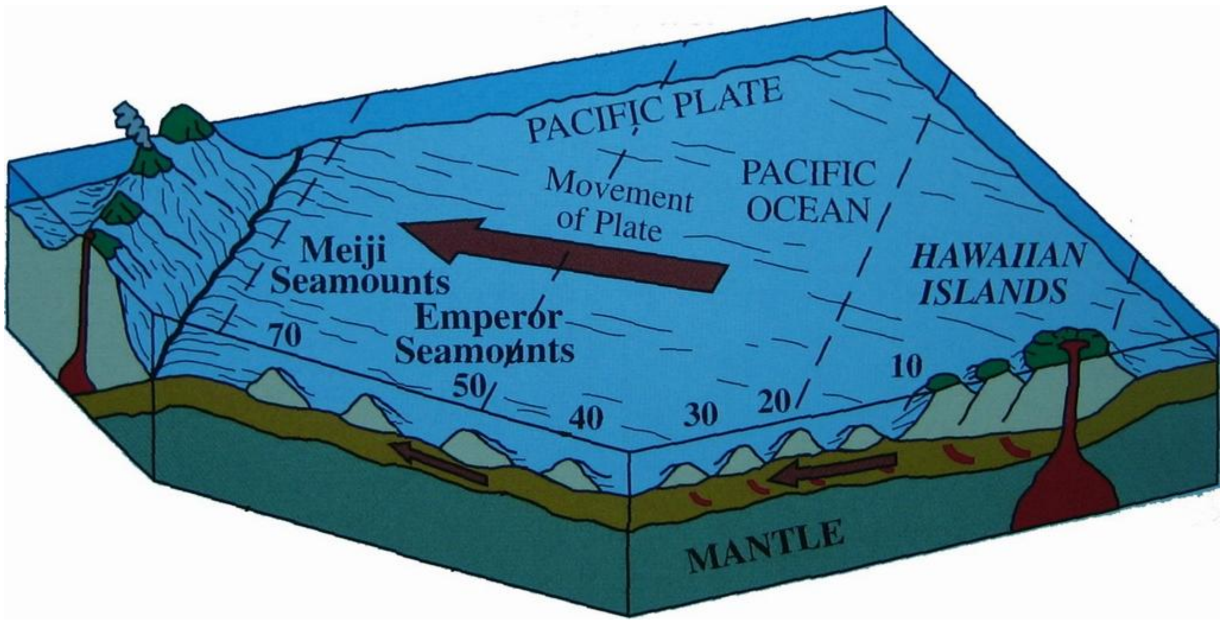
•magnetic lineation is not always parallel to flow direction
•preferably use imbrication of magnetic foliation



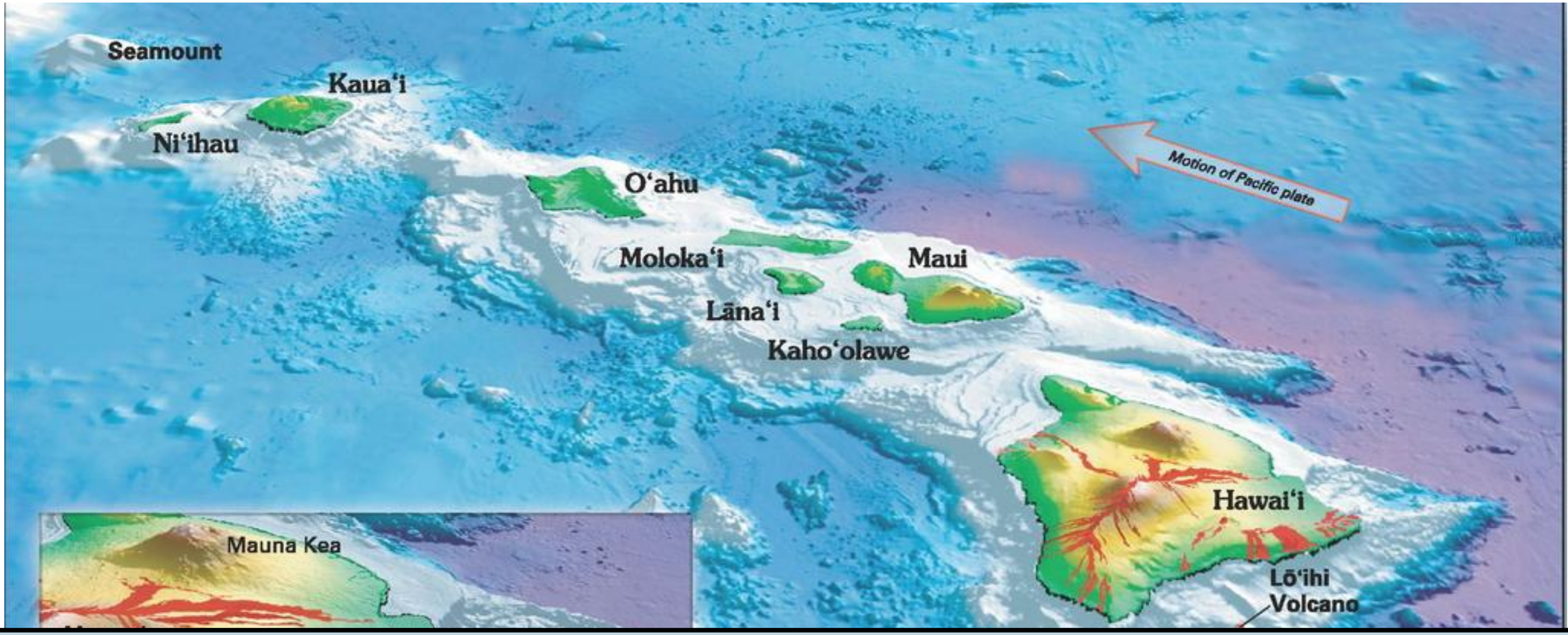


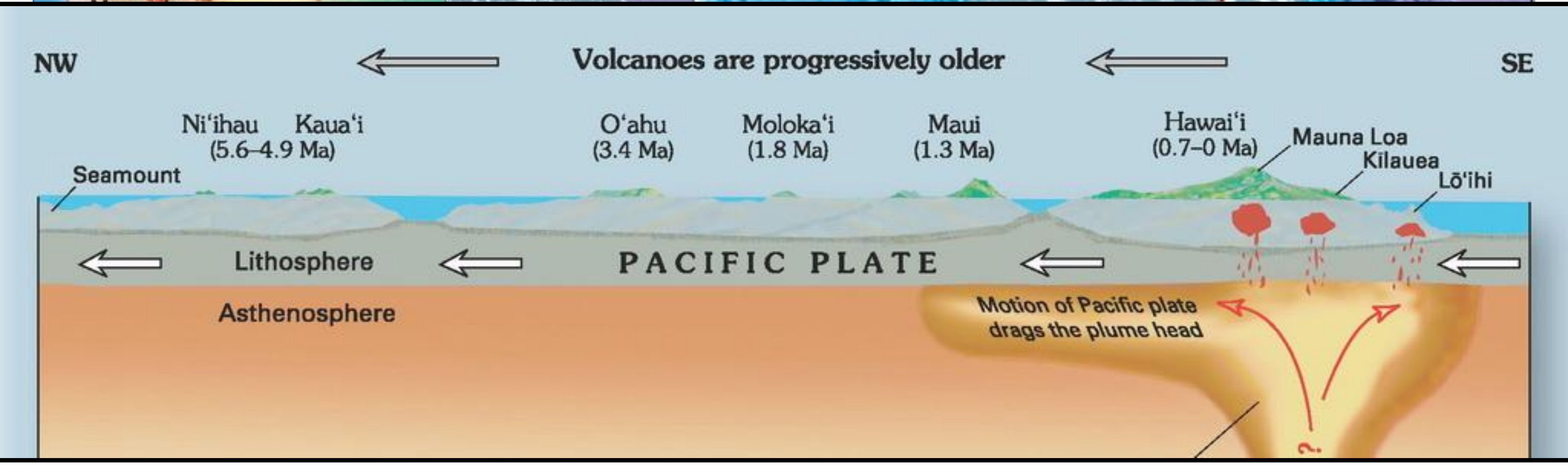


(a) Section (b) Plan

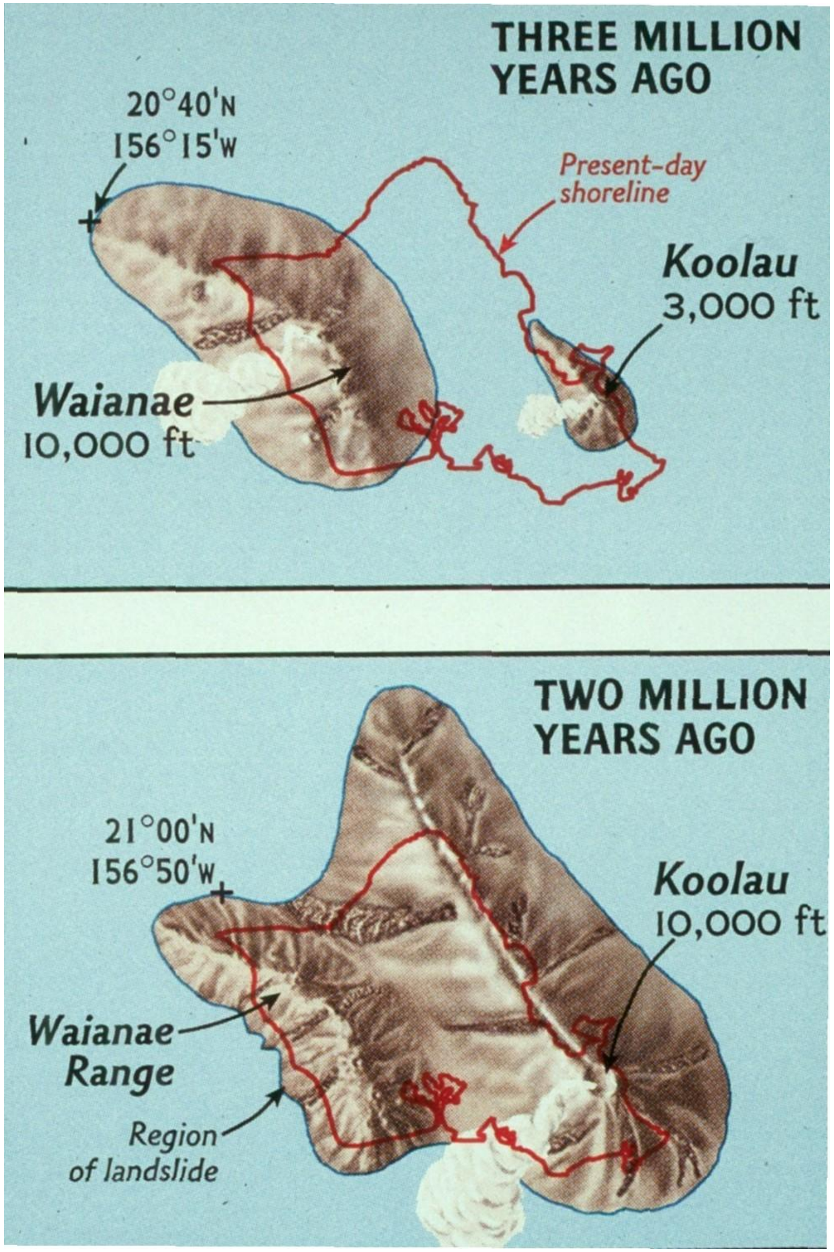


Wilson, J. T. 1963. A possible origin of the Hawaiian Islands. *Canadian Journal of Physics*, **41**, 863-670.

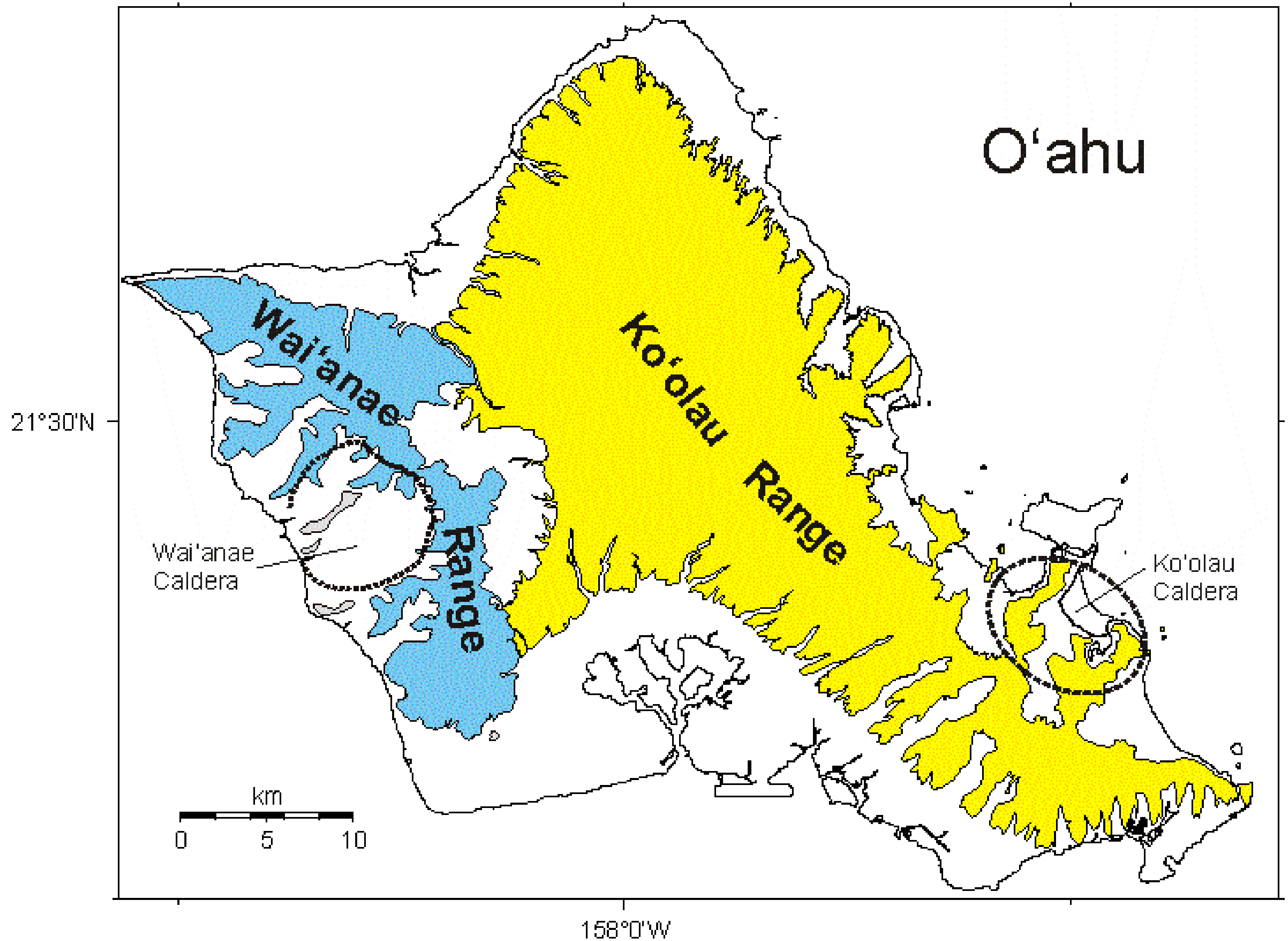

Seamount
Kaua'i
Ni'ihau
O'ahu
Moloka'i
Maui
Lāna'i
Kaho'olawe
Motion of Pacific plate
Hawai'i
Mauna Kea
Lō'ihi
Volcano


NW
Volcanoes are progressively older
SE
Ni'ihau
Kaua'i
(5.6–4.9 Ma)
O'ahu
(3.4 Ma)
Moloka'i
(1.8 Ma)
Maui
(1.3 Ma)
Hawai'i
(0.7–0 Ma)
Mauna Loa
Kīlauea
Lō'ihi
Seamount
Lithosphere
PACIFIC PLATE
Asthenosphere
Motion of Pacific plate
drags the plume head

Island of Oahu

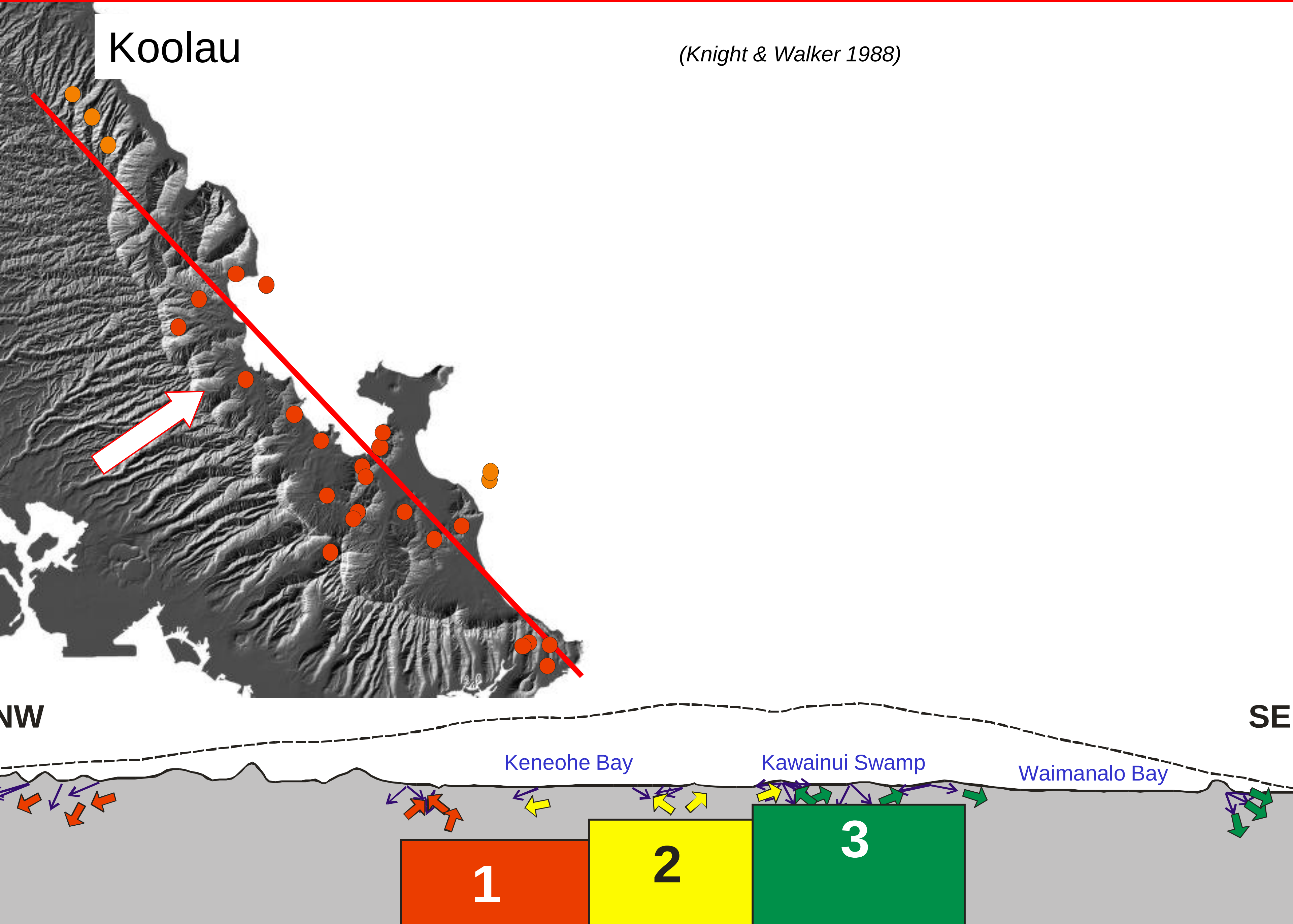


Geology of Oahu



Koolau

(Knight & Walker 1988)

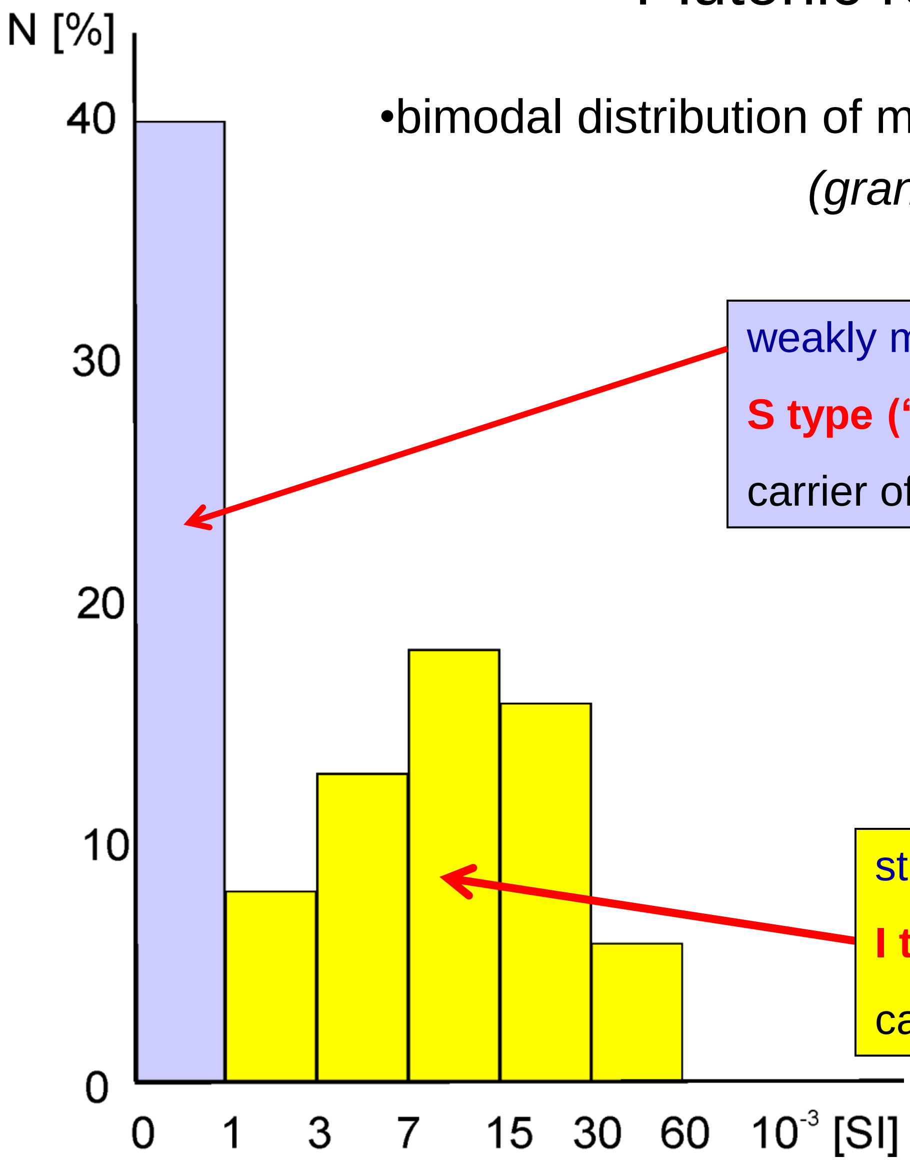



Plutonic rocks

Plutonic rocks

- bimodal distribution of magnetic susceptibility

  (granitoids of former USSR)



weakly magnetic (paramagnetic) granitoides

S type ("Sedimentary")

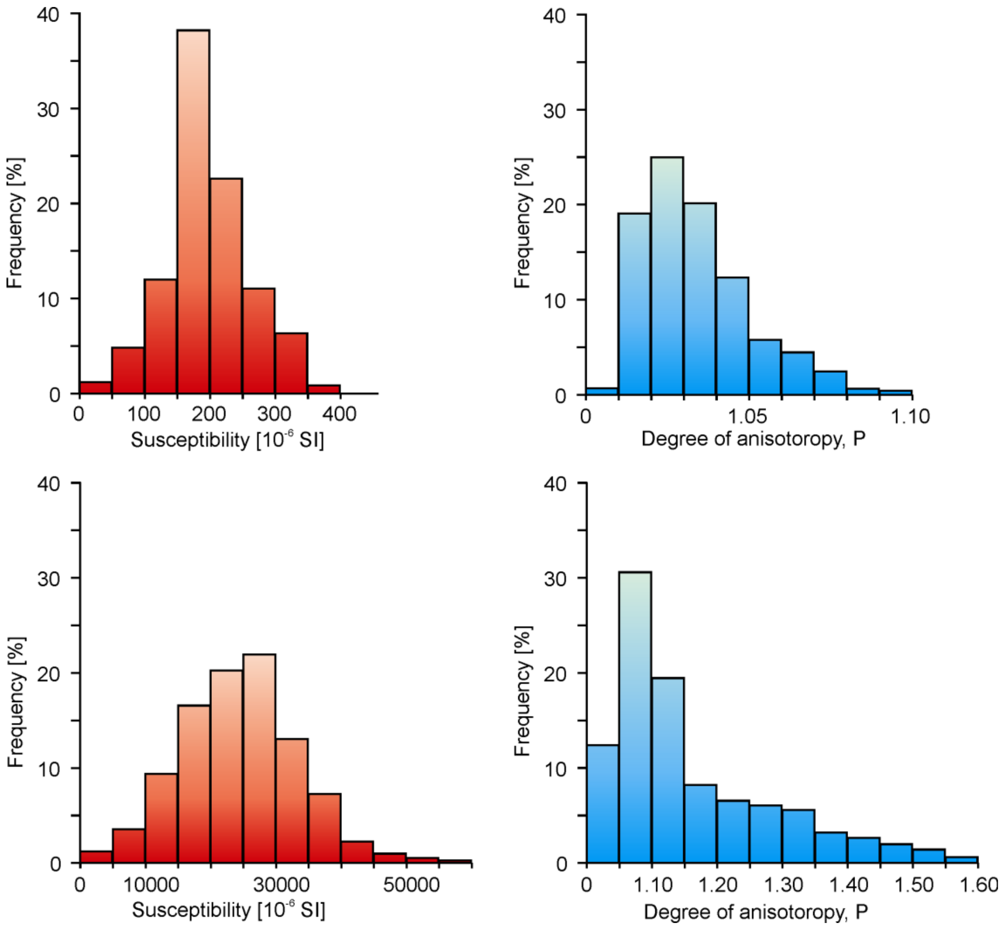
carrier of magnetization mainly **biotite (hornblende)**

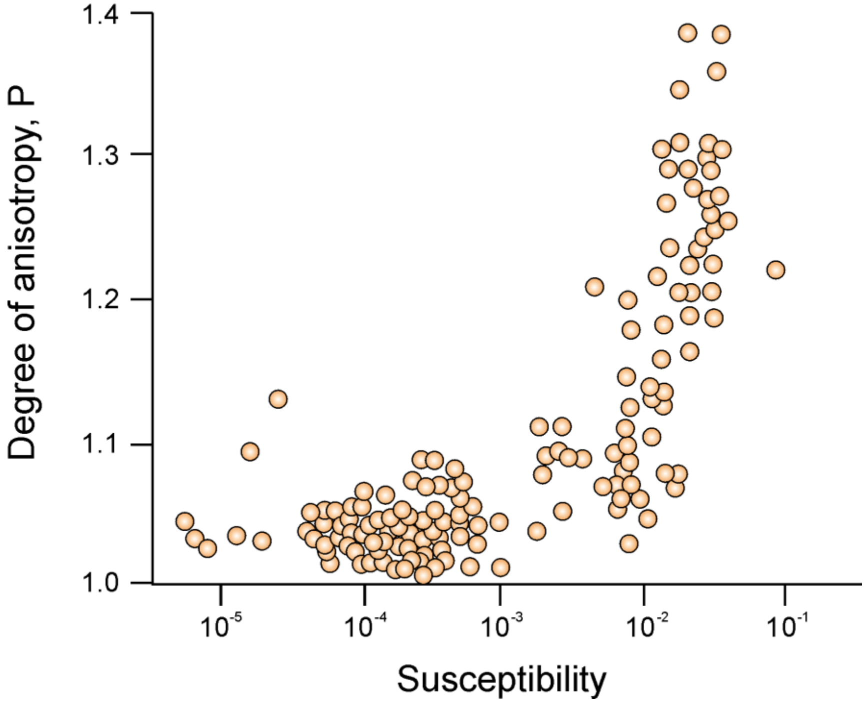
strongly magnetic (ferromagnetic) granitoides

I type (Igneous)

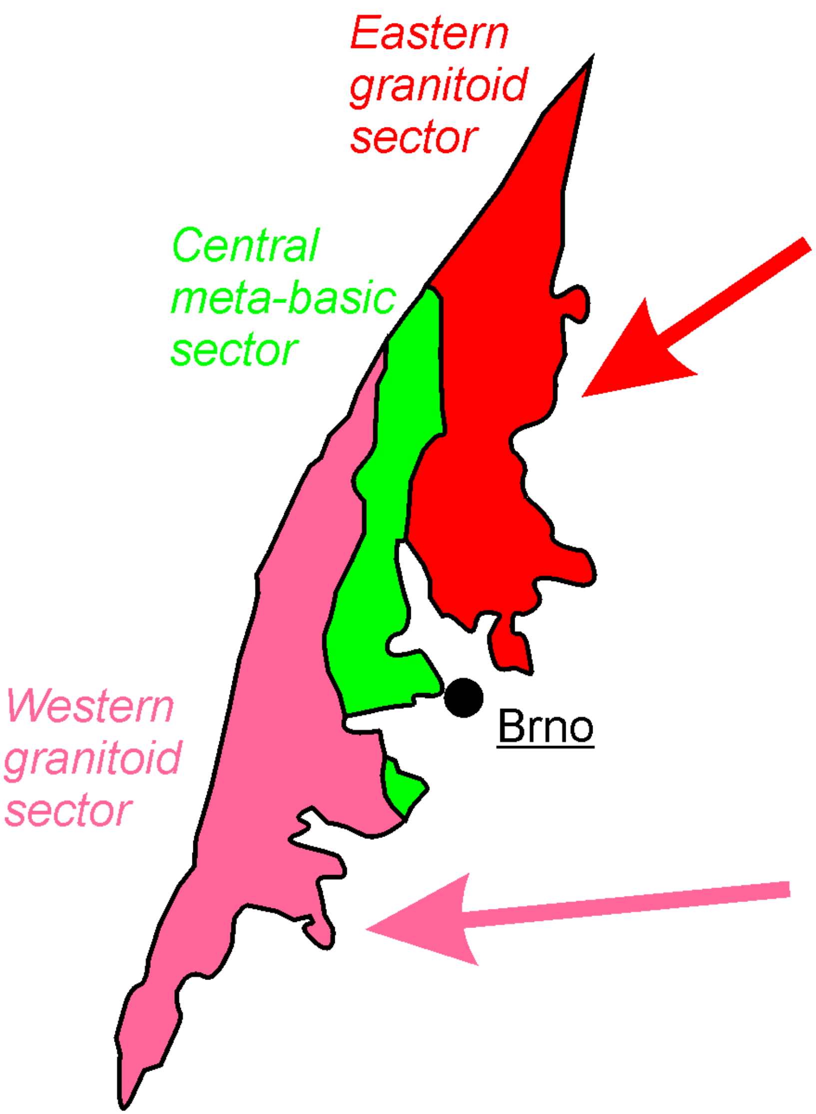
carrier of magnetization mainly **magnetite**

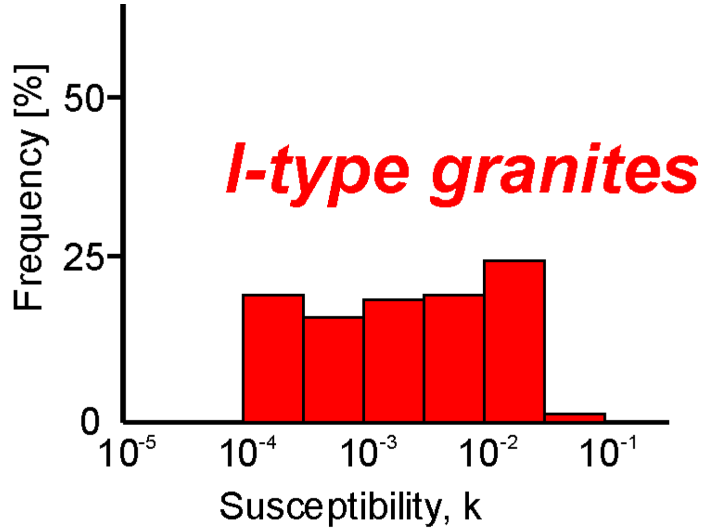
5. Magnetic fabric of igneous rocks

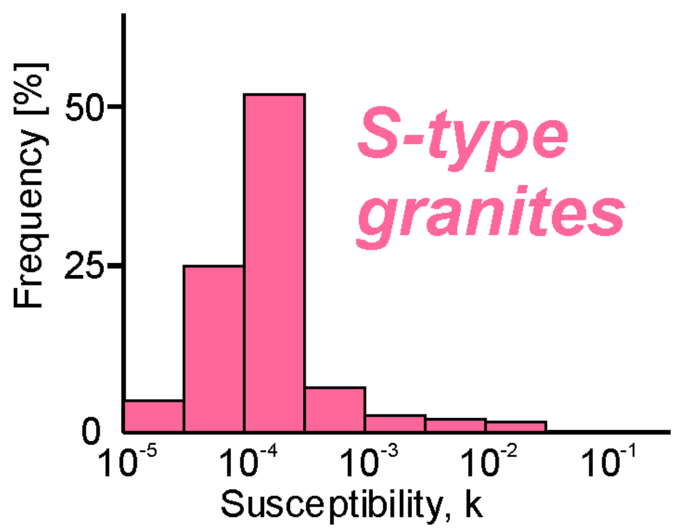




Brno Massif


Eastern
granitoid
sector
Central
meta-basic
sector
Western
granitoid
sector
Brno


I-type granites
Frequency [%]
50
25
0
10^{-5}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
Susceptibility, k


S-type
granites
Frequency [%]
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25
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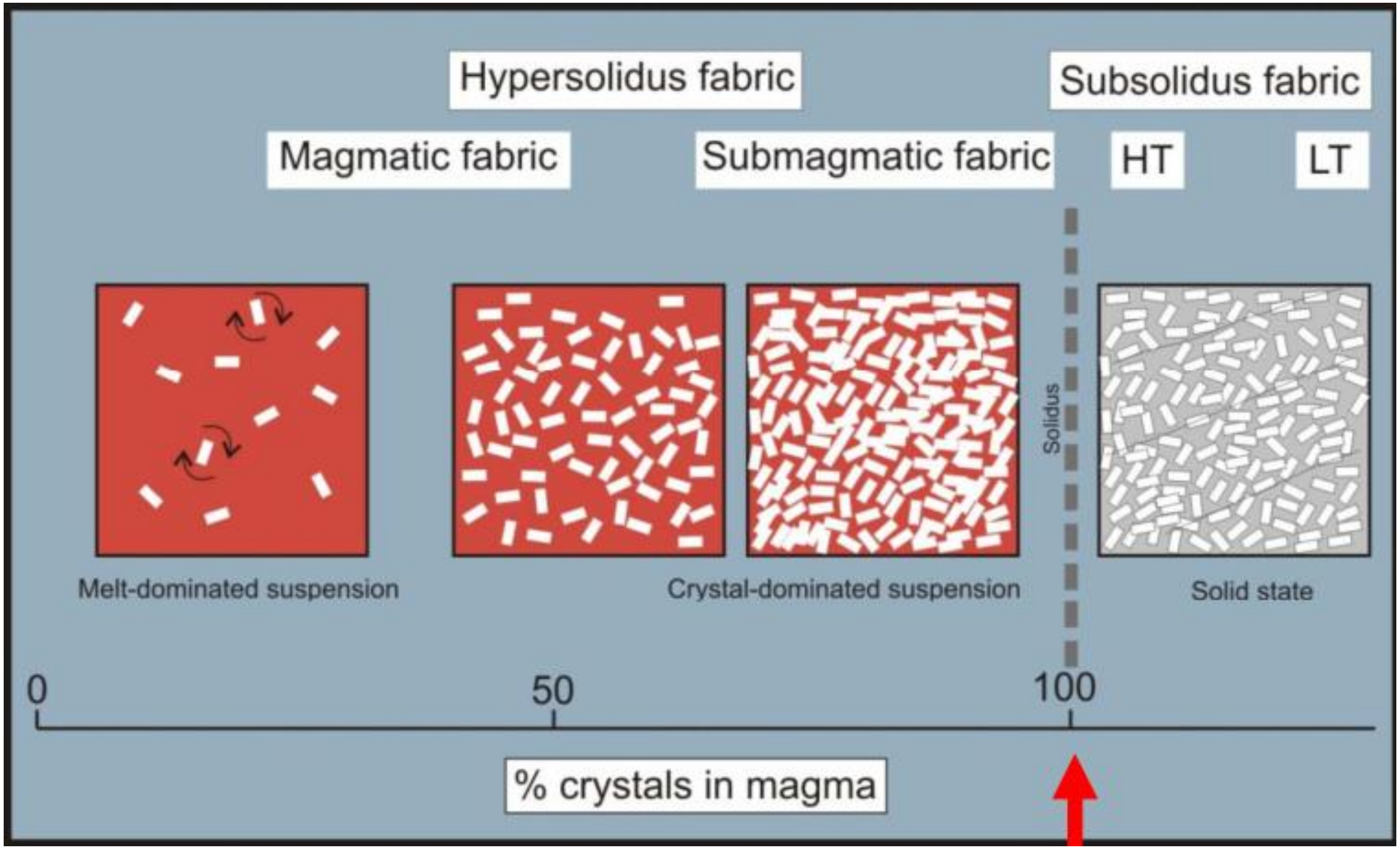
10^{-5}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
Susceptibility, k



Hypersolidus fabric
Subsolidus fabric
Magmatic fabric
Submagmatic fabric
HT
LT
Solidus
Melt-dominated suspension
Crystal-dominated suspension
Solid state
0
50
100
% crystals in magma

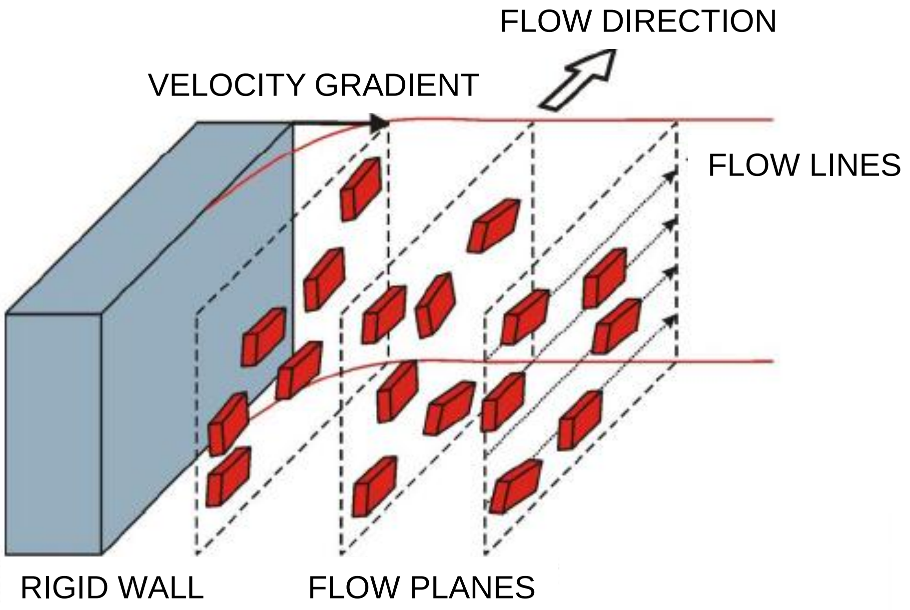
5. Magnetic fabric of igneous rocks

▪Foliations and lineations in plutons originate by magma flow

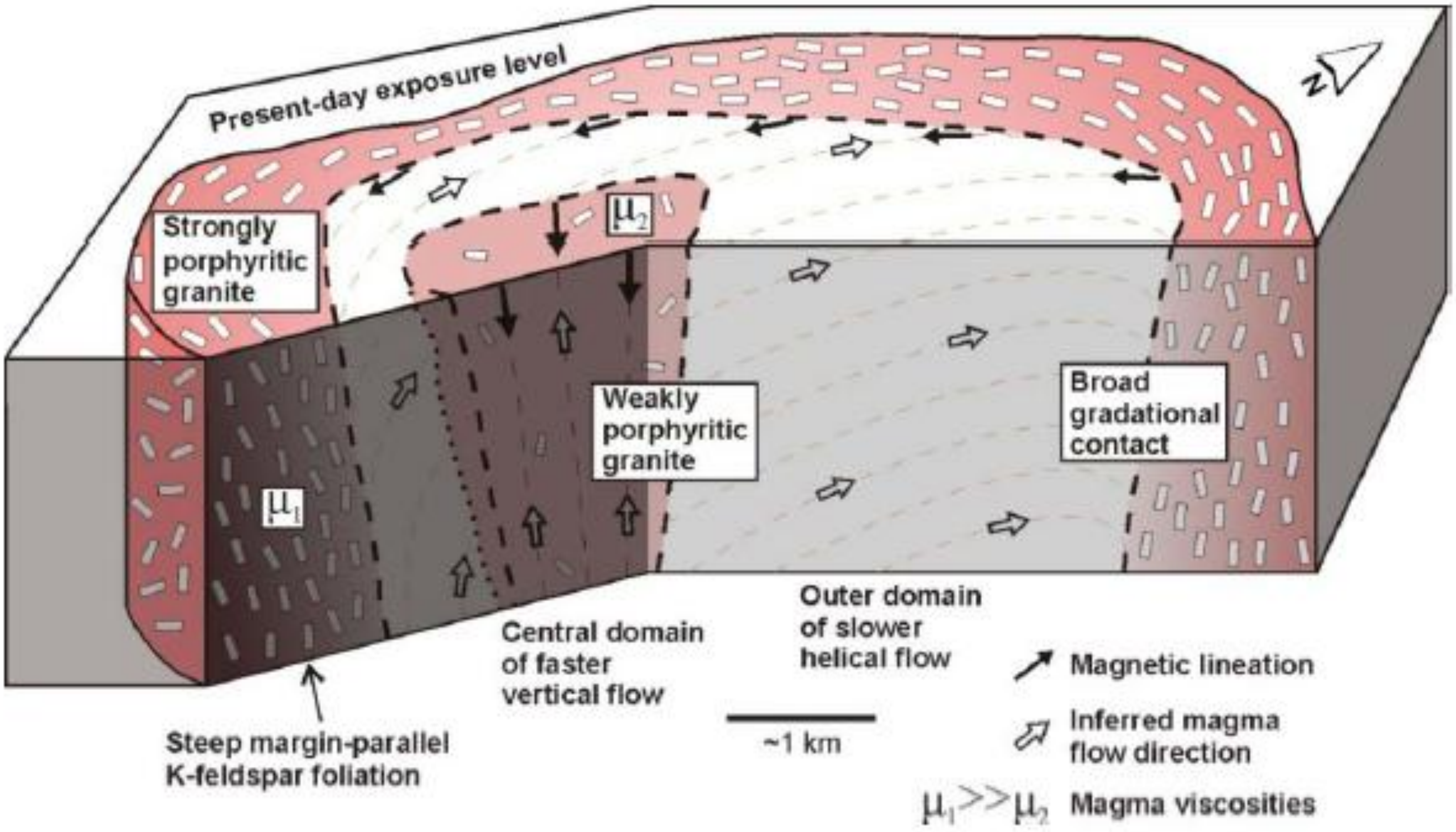
▪Magnetic foliation = magma flow plane

▪Magnetic lineation = magma flow line

▪Regional-scale investigation of magnetic fabric helps to decipher magma flow within whole pluton

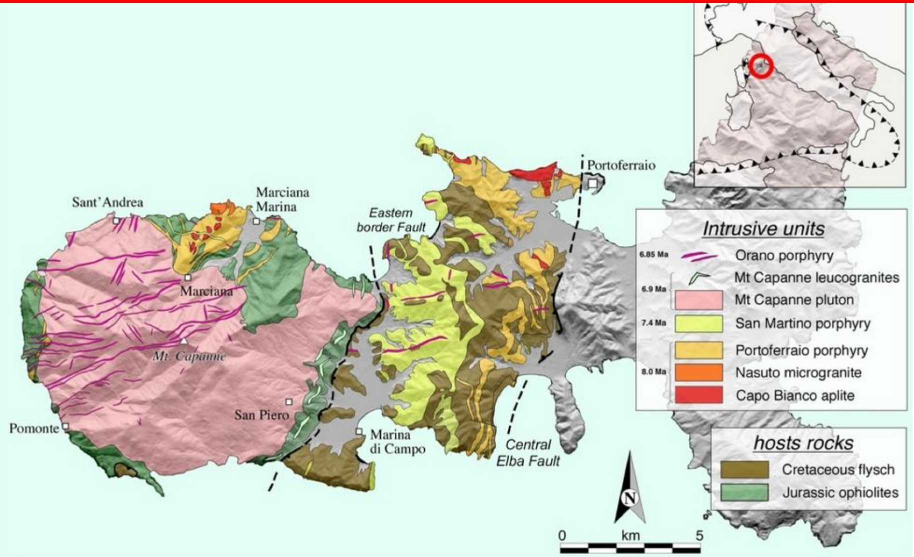


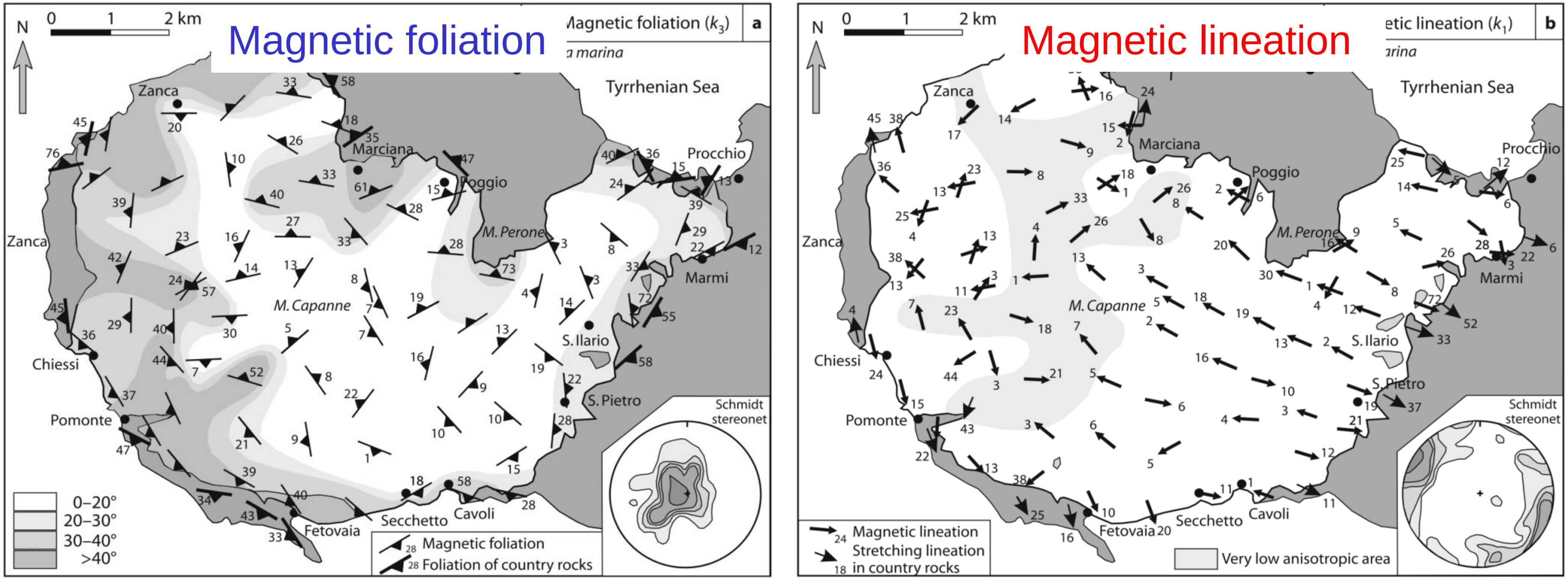
5. Magnetic fabric of igneous rocks



5. Magnetic fabric of igneous rocks

Magnetic anisotropy in pluton scale



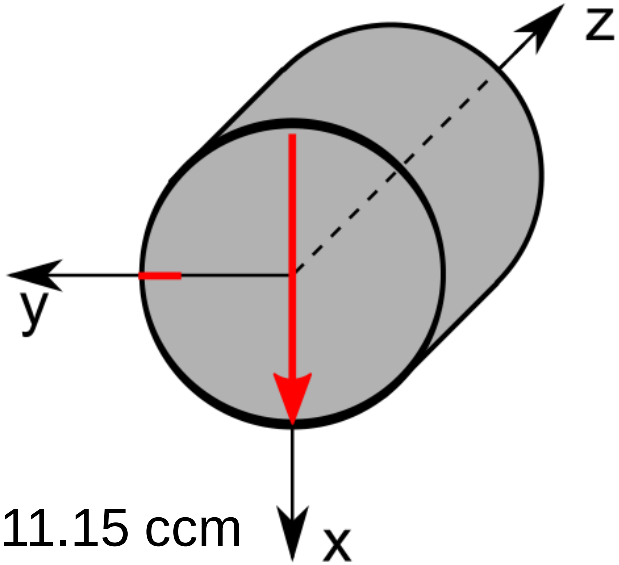


Monte Capanne granodiorite pluton (Elba Island, northern Tyrrhenian Sea, Italy)
(Bouillin et al. 1993)

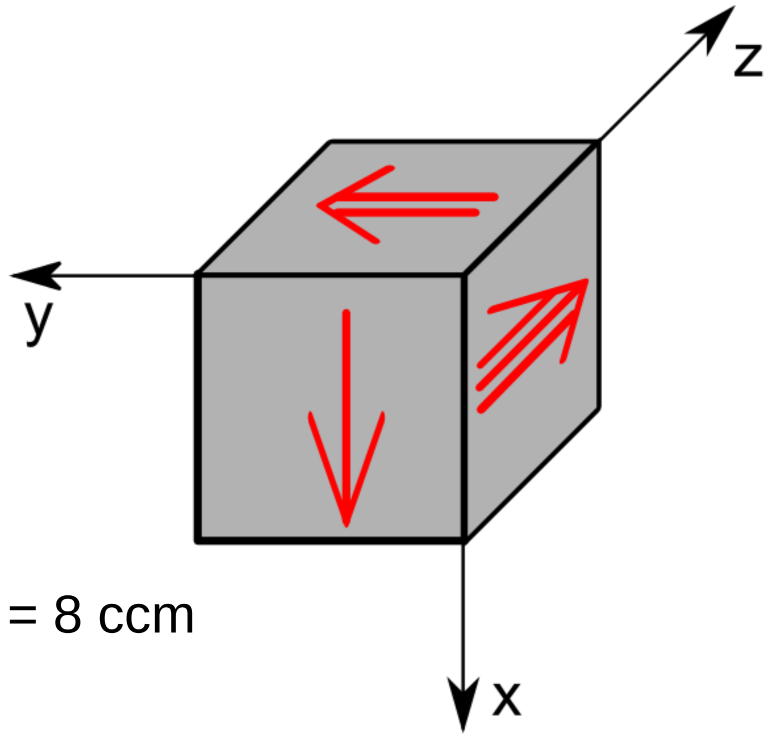
Agenda

1. Definition and application in geology
2. Magnetic anisotropy of minerals
3. Magnetic fabric vs. texture of rocks
4. Magnetic fabric of sedimentary, deformed, and metamorphosed rocks
5. Magnetic fabric of igneous rocks
6. Sampling, measurement and data processing

Oriented samples



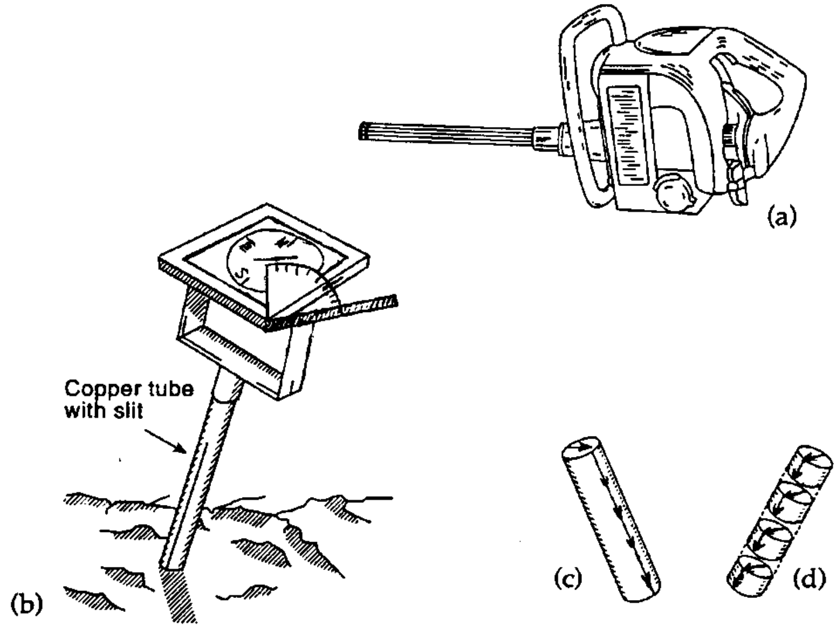
V = 11.15 ccm

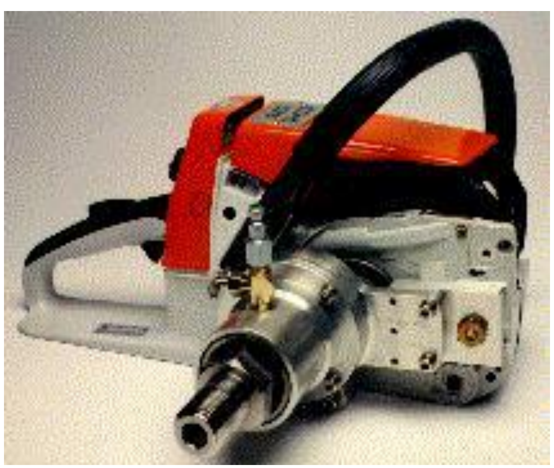


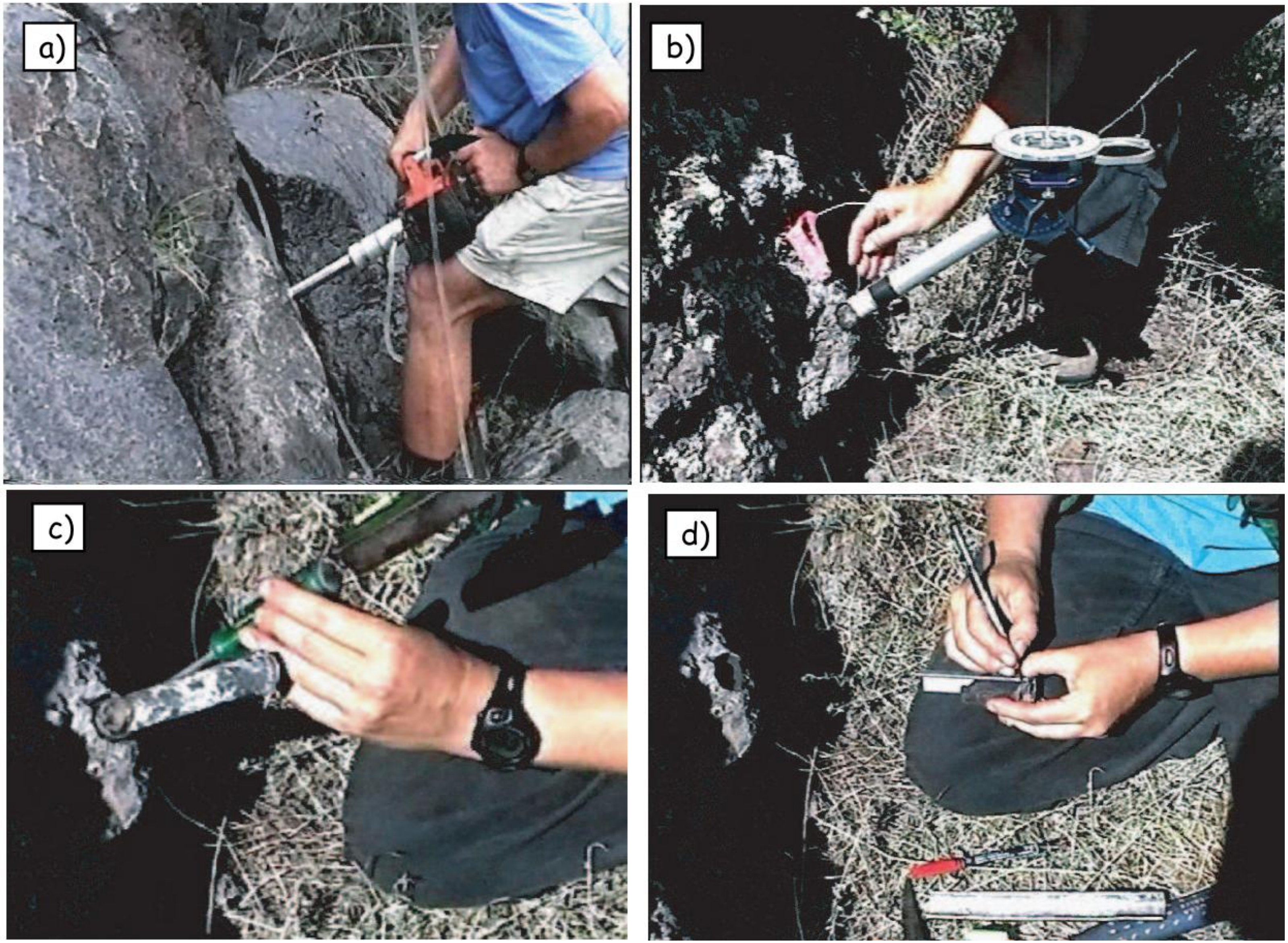
V = 8 ccm

Field Drilling Oriented Cores

Petrol powered portable drilling machine

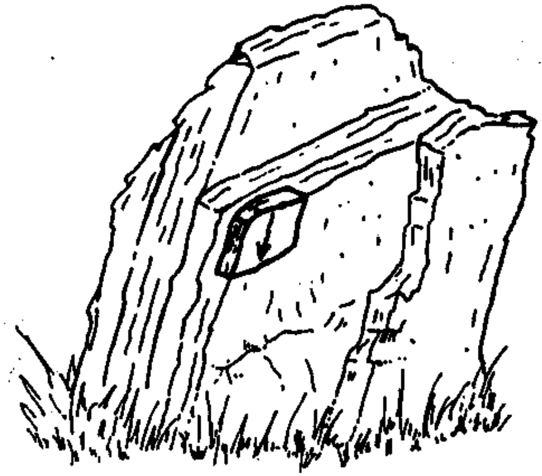


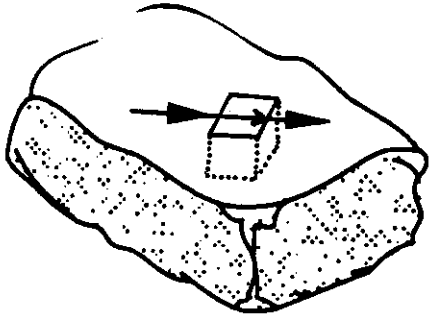


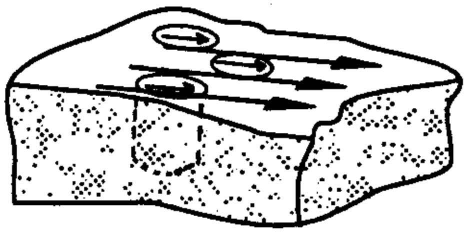


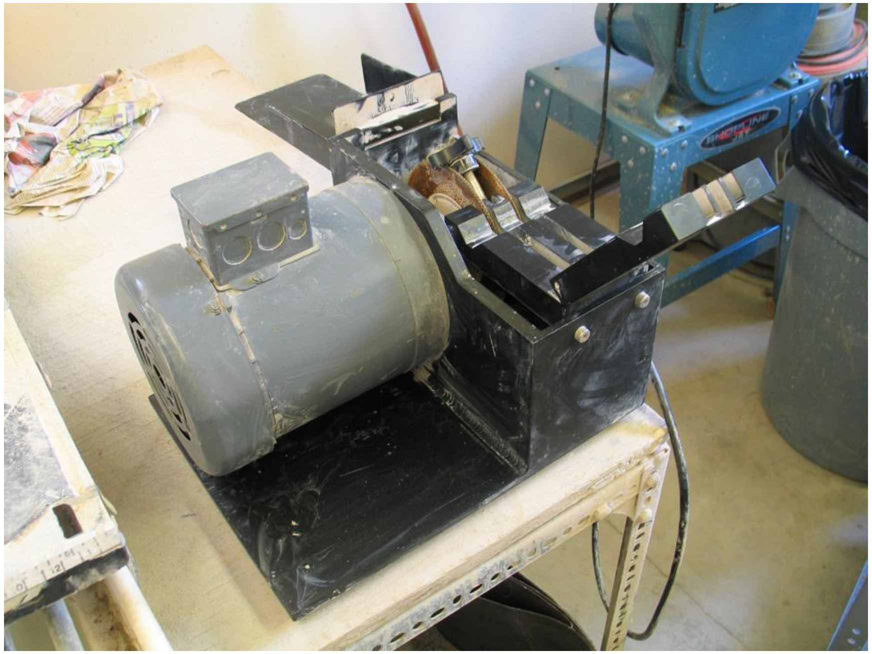
(Tauxe. 2005)

Block specimens





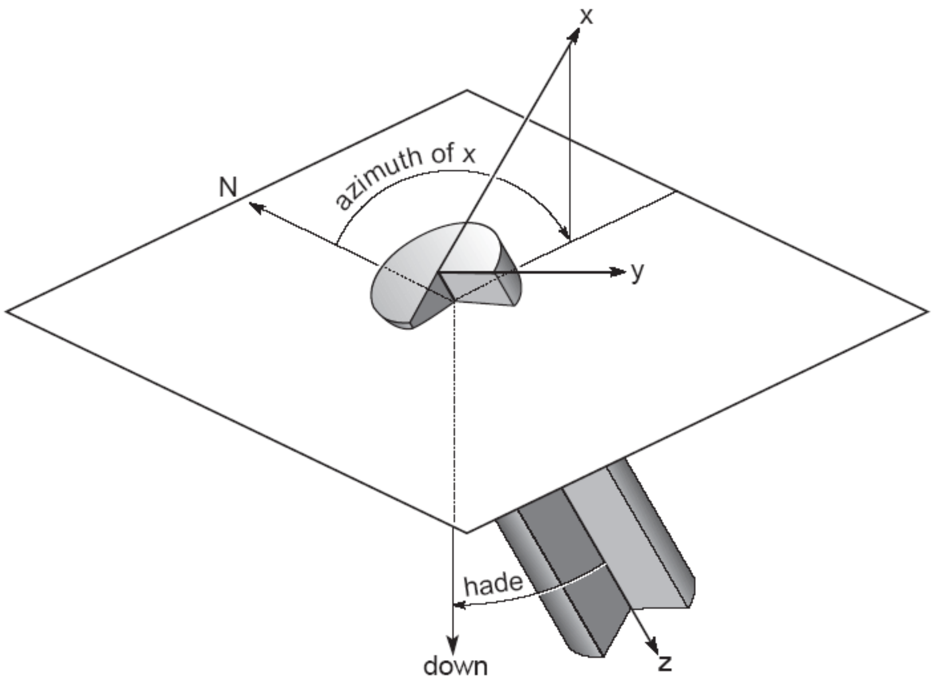




Sample to geographical coordinate system transformation

$$\mathbf{R} = \mathbf{T}\ \mathbf{r}, \qquad \mathbf{K} = \mathbf{T}\ \mathbf{k}\ \mathbf{T'},$$

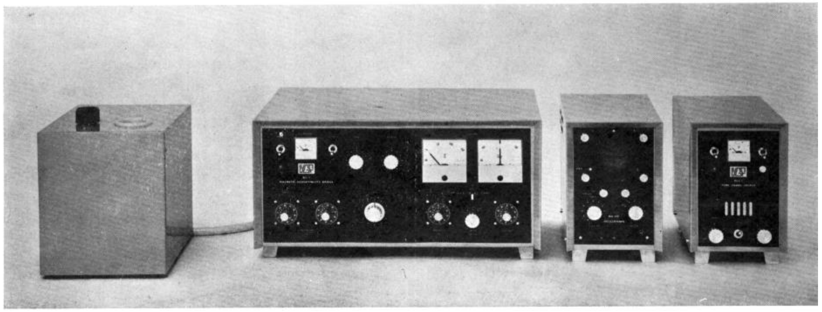
- ***r***, ***R*** *vectors in sample or geographical coordinate systems*
- ***k, K*** *tensors in sample or geographical coordinate systems*
- ***T*** *transformation matrix (**T'** transposed matrix of **T**)*



6. Sampling, measurement and data processing

Kappabridge (and PC) evolution

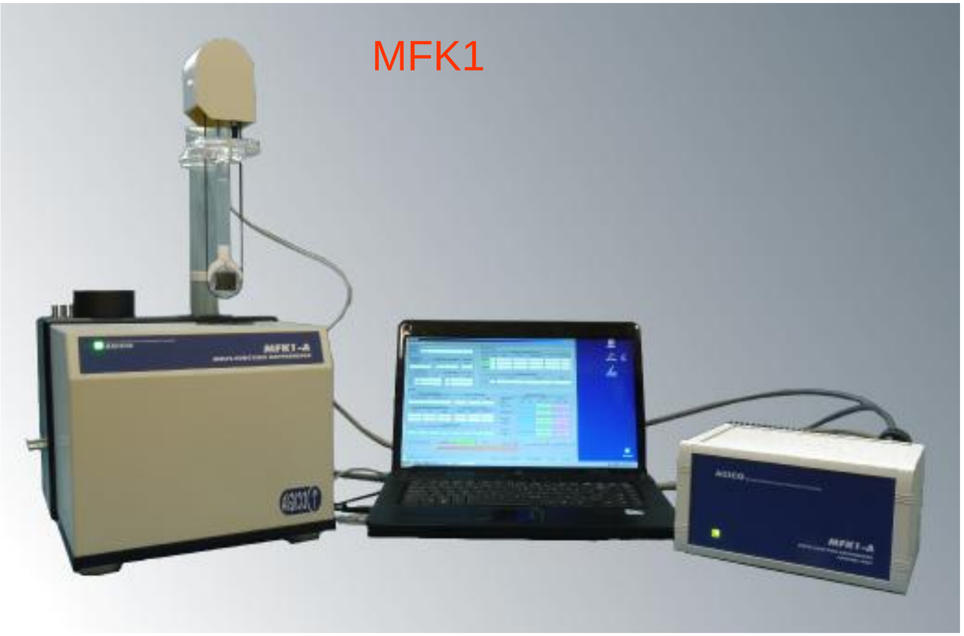
KLY-1 (1967)



KLY-2

KLY-3 & 4

MFK1

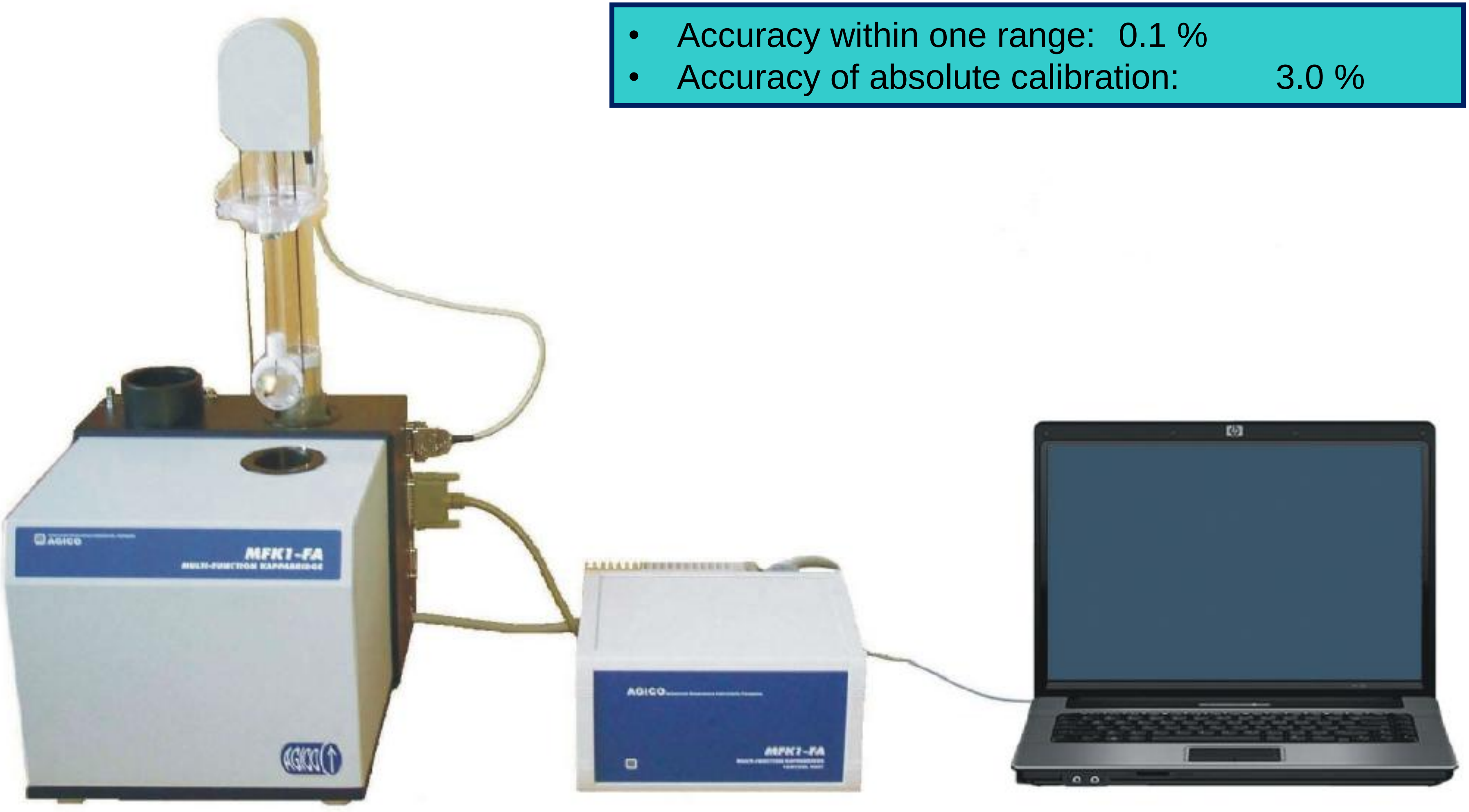


MFK1-FA

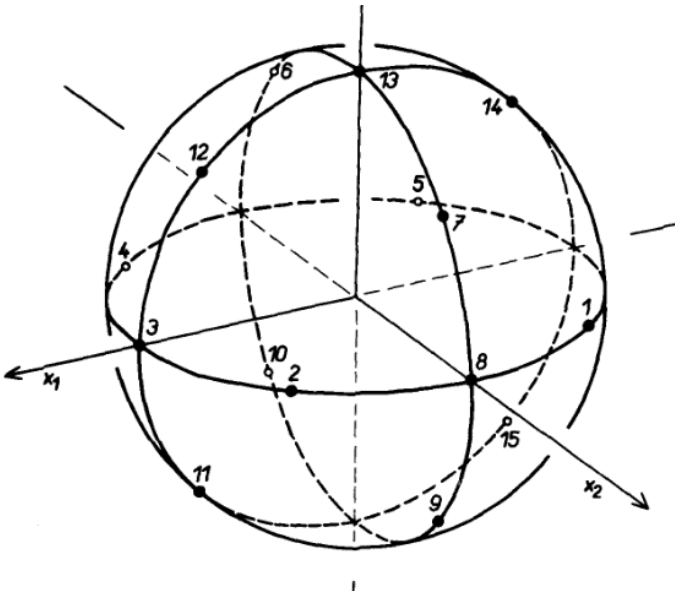
Three operating frequencies and respective field ranges (peak values):

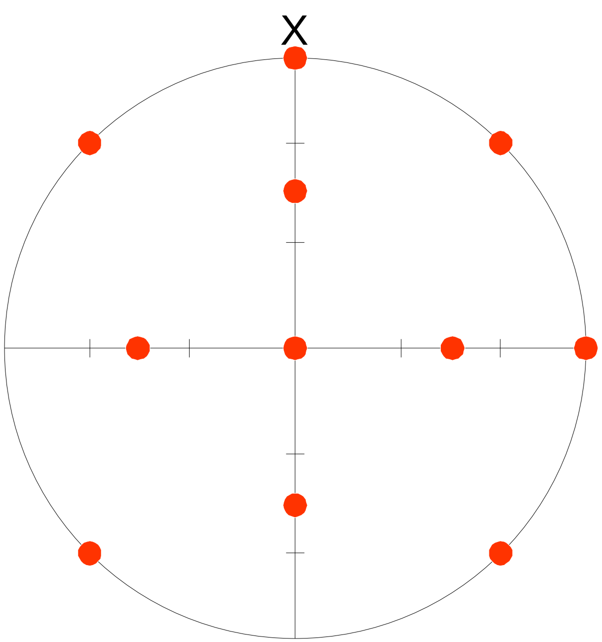
- **F1** (976 Hz): 2 - 700 A/m
- **F2** (3904 Hz): 2 - 350 A/m
- **F3** (15616 Hz): 2 - 200 A/m

- Accuracy within one range: 0.1 %
- Accuracy of absolute calibration: 3.0 %

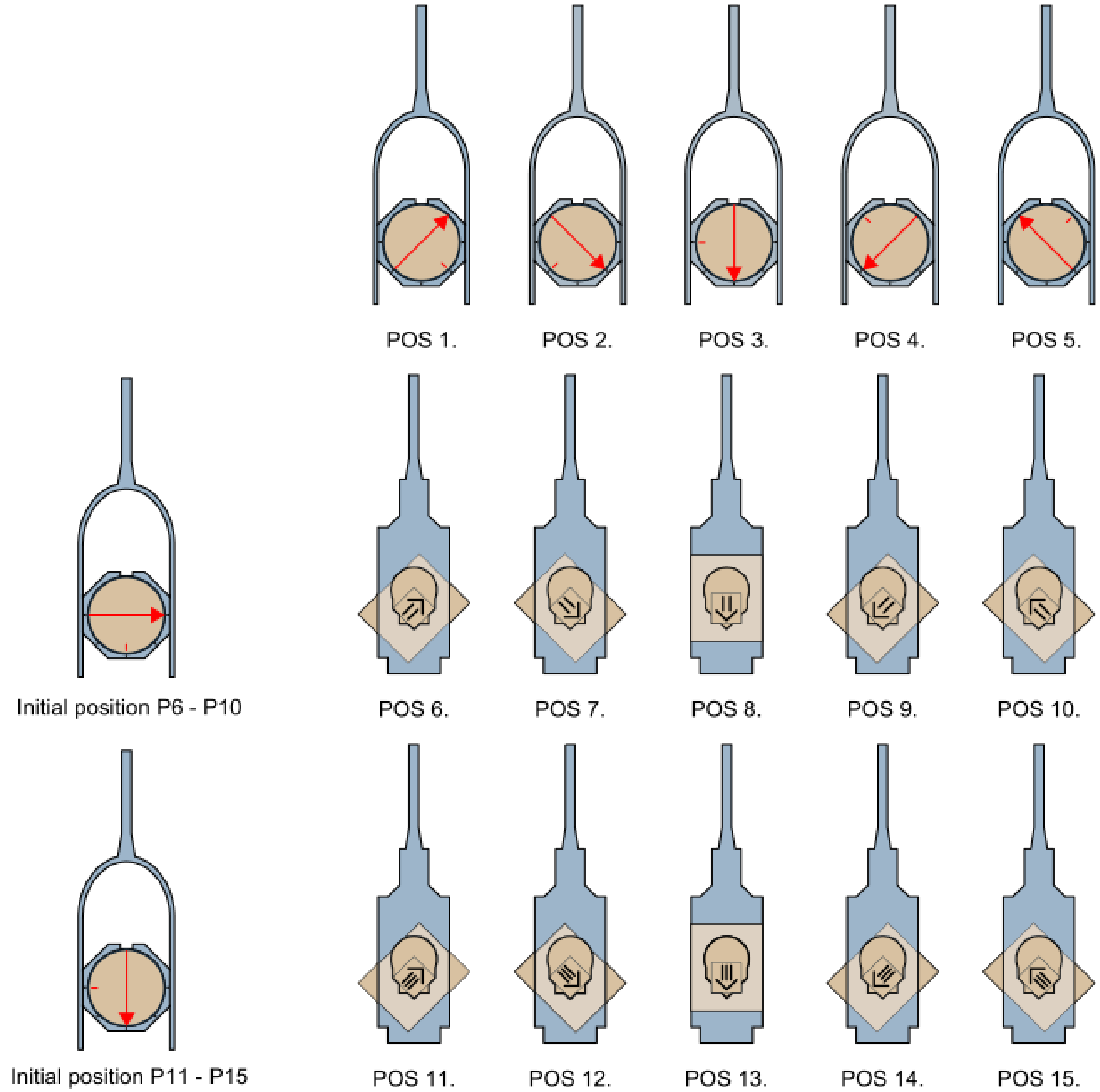


15 position design



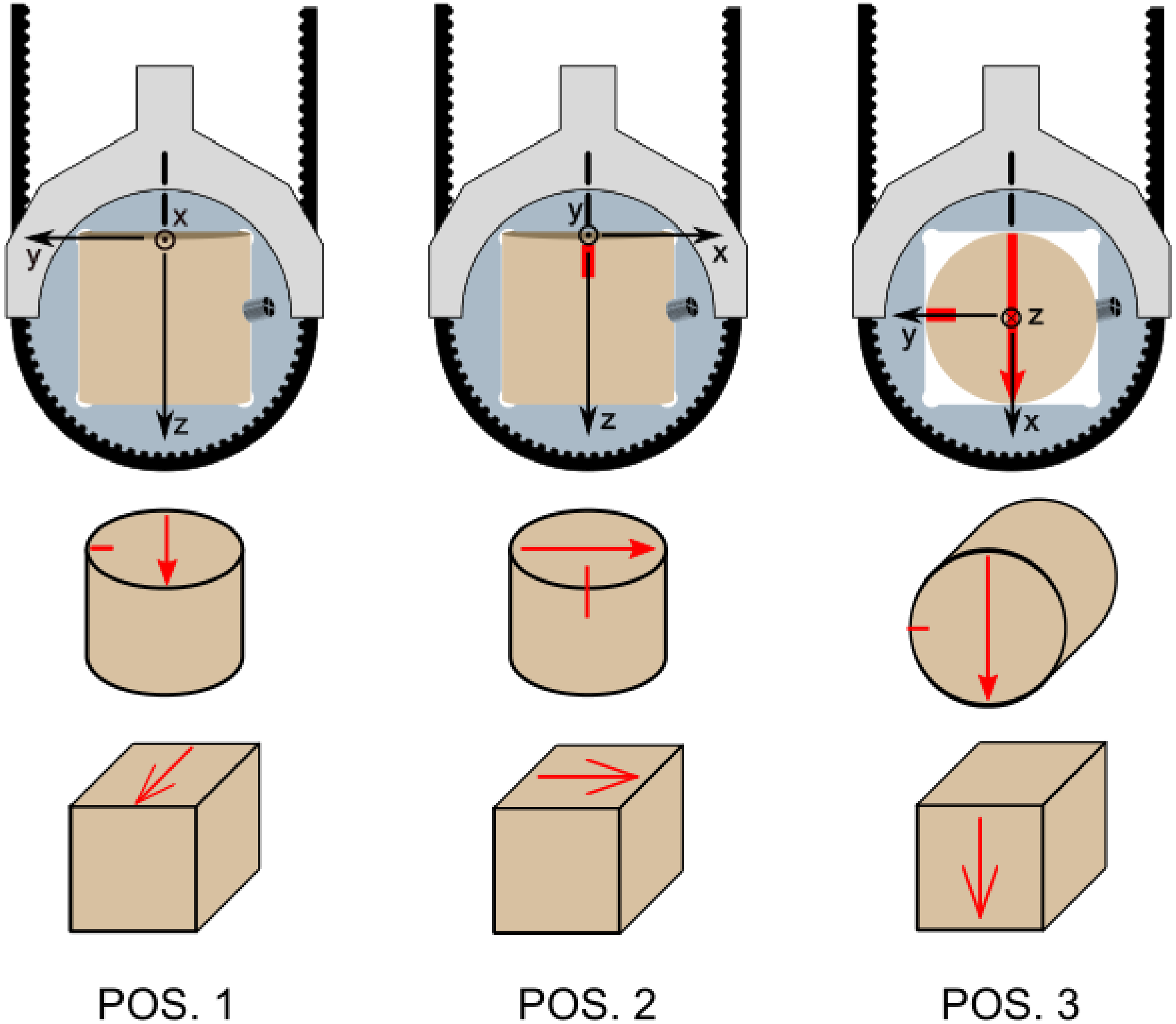


- 15 directional measurements
- Duration: ca. 9 min



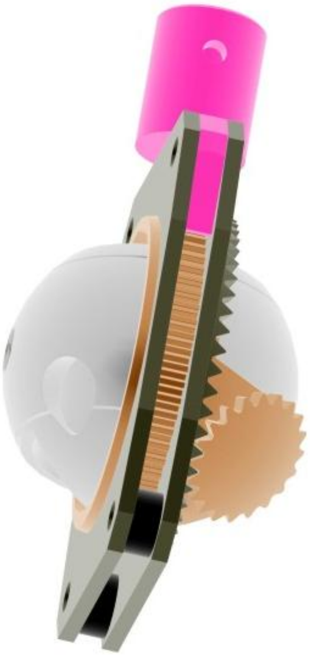
Three plane rotation

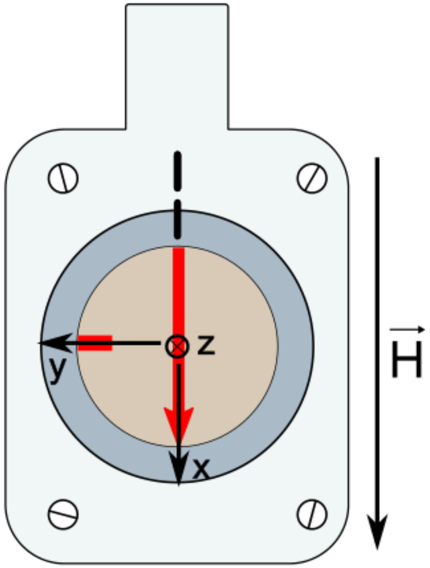
- 64 readings during each rotation
- Multiple rotations
- Duration: ca. 3-4 min

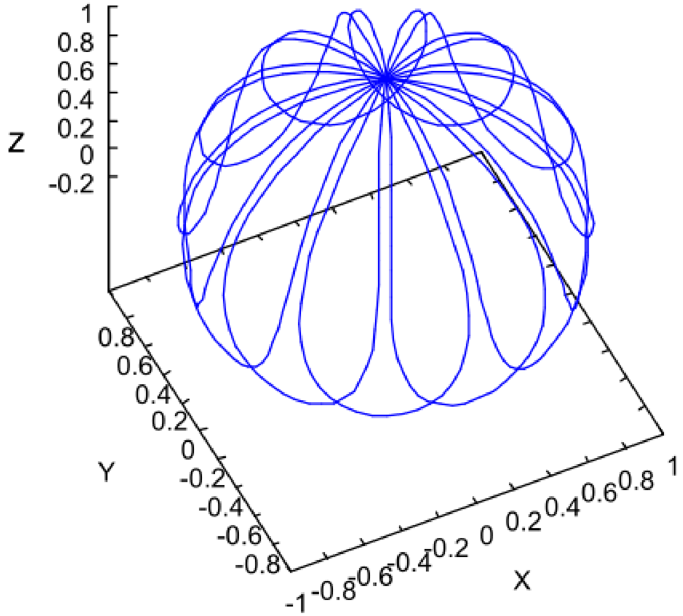


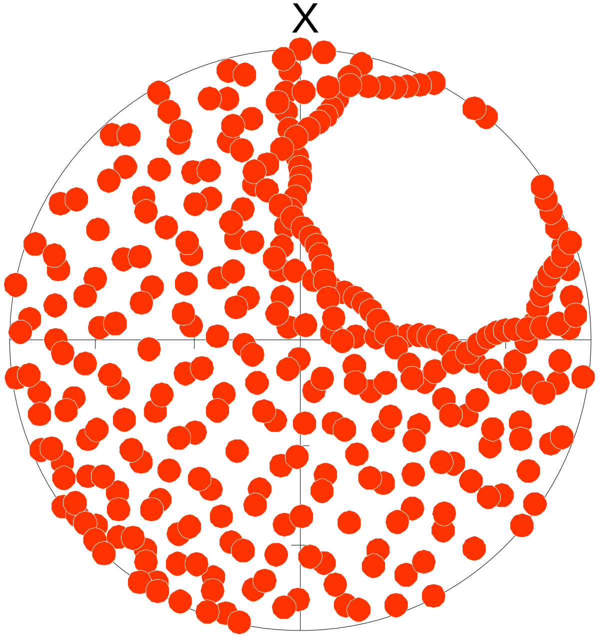
3D Rotator

- 320 readings during full rotation
- Repeated two times
- 640 directional measurements
- Duration: ca. 1.5 min

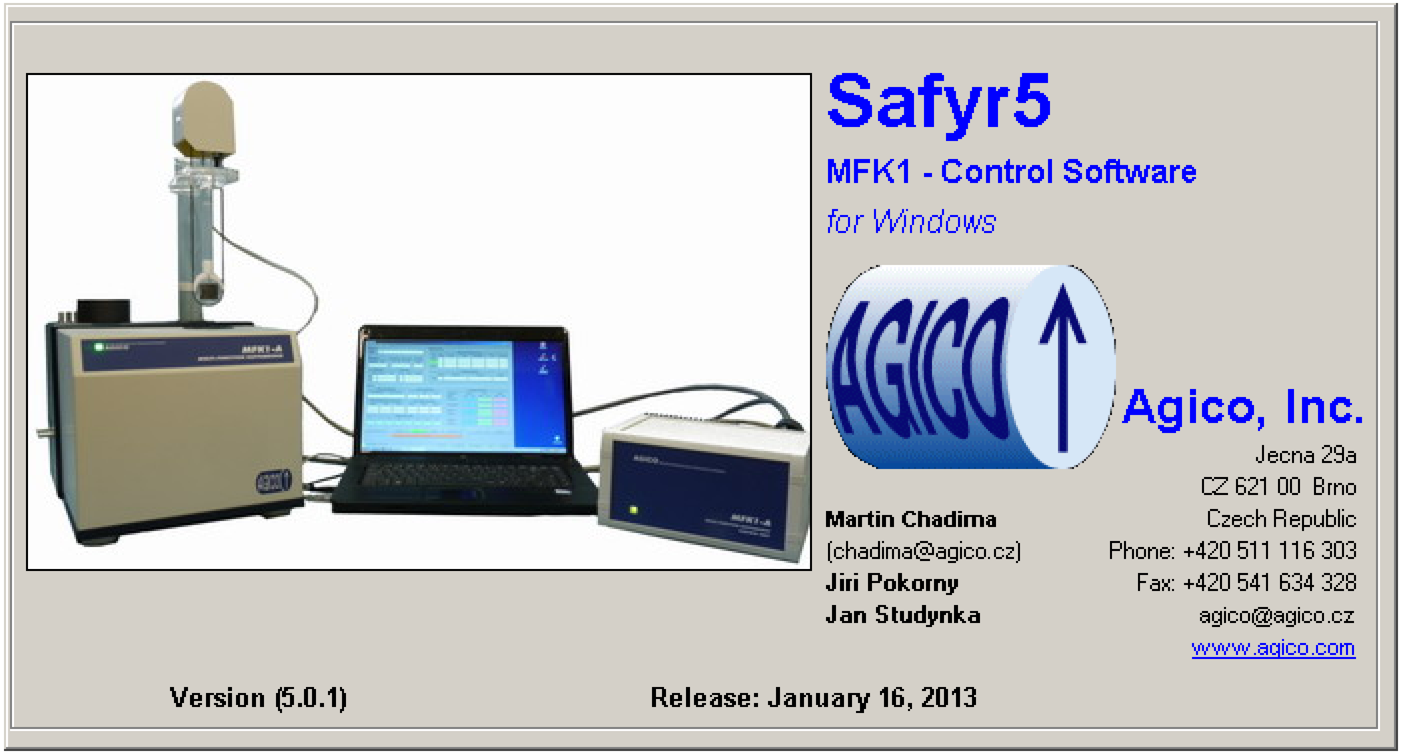


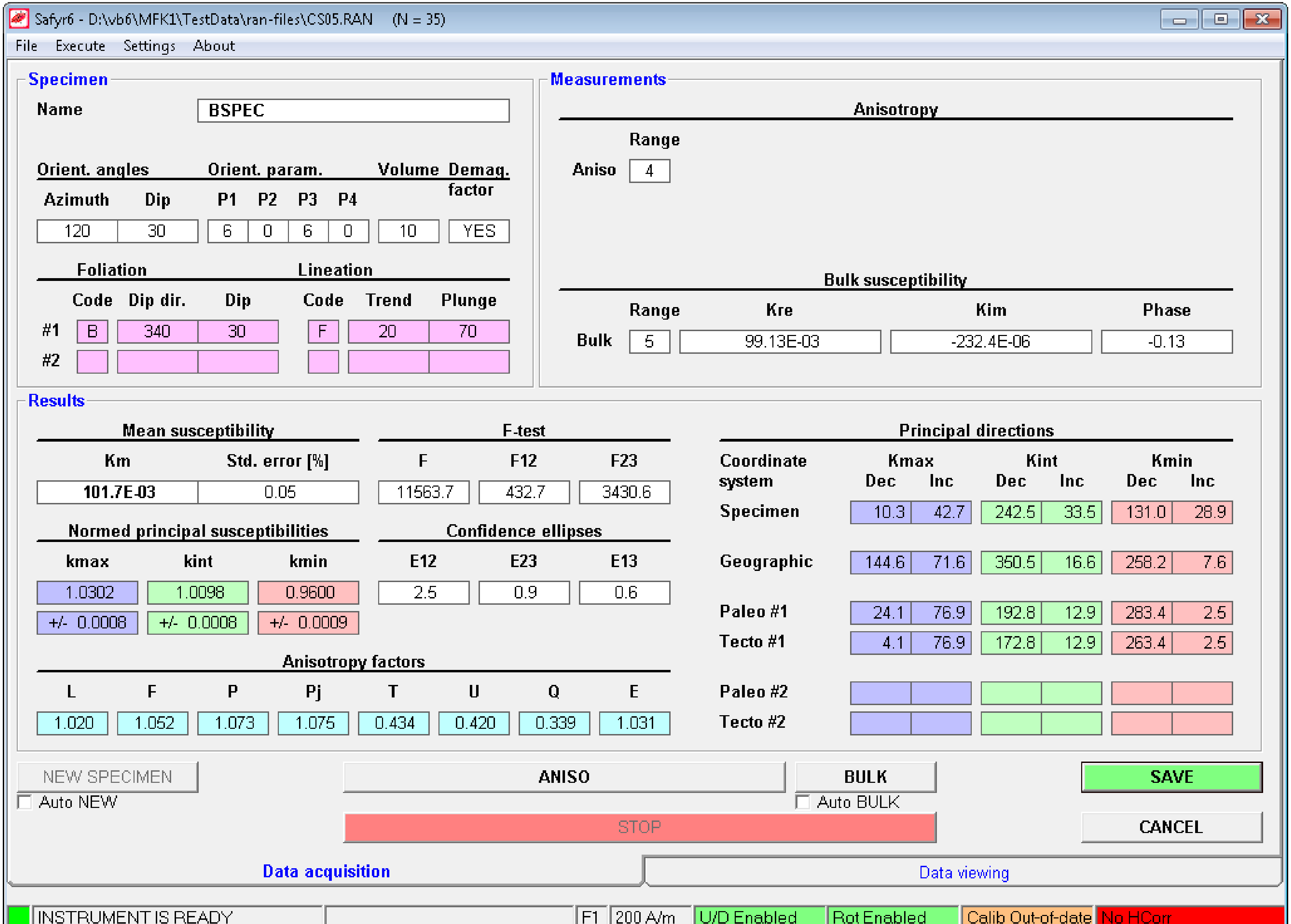


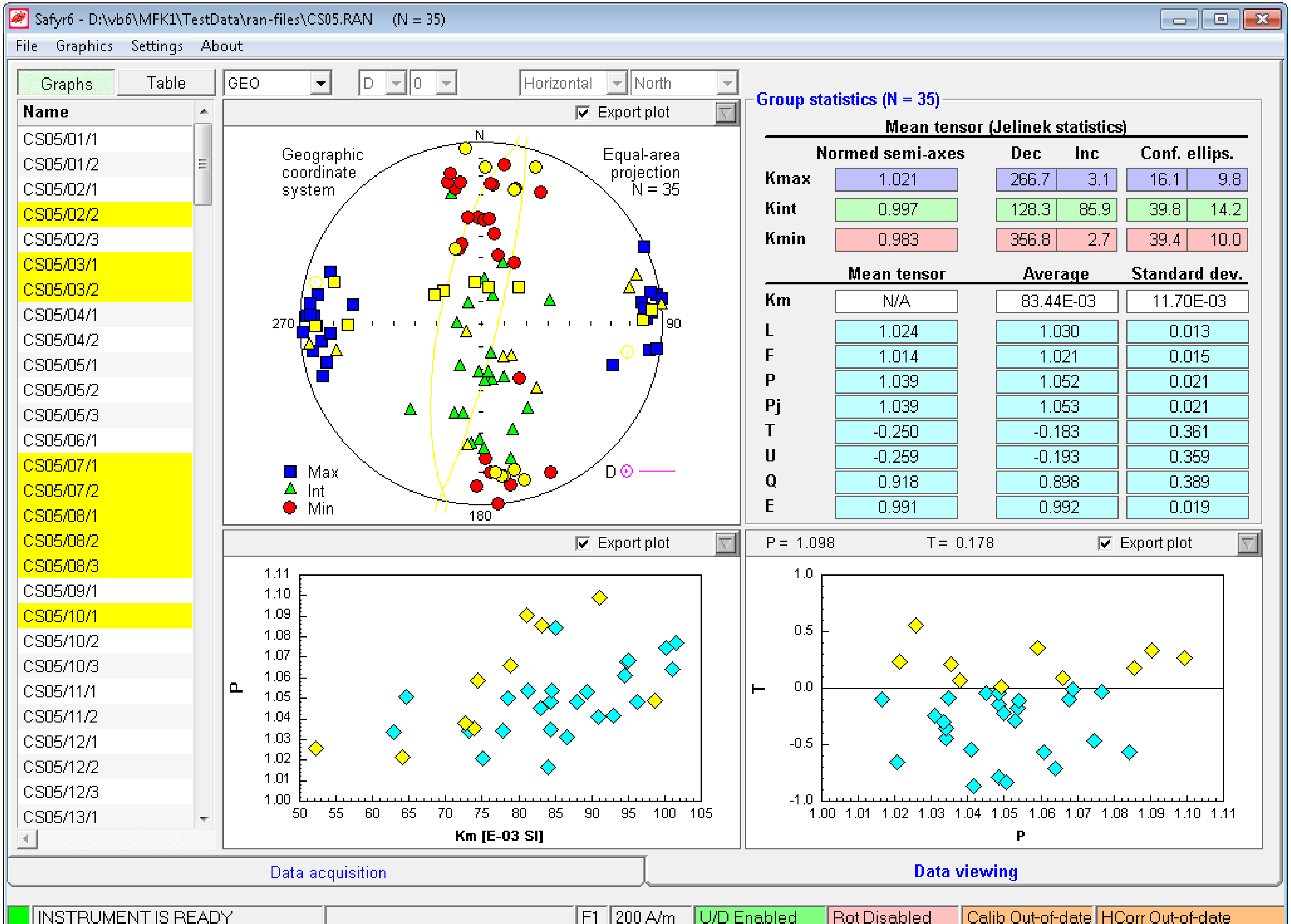




Safyr - Data acquisition software




Safyr6 - D:\vb6\MFK1\TestData\ran-files\CS05.RAN (N = 35)
File Execute Settings About
Specimen
Name BSPEC
Orient. angles Orient. param. Volume Demag. factor
Azimuth Dip P1 P2 P3 P4
120 30 6 0 6 0 10 YES
Foliation Lineation
Code Dip dir. Dip Code Trend Plunge
#1 B 340 30 F 20 70
#2
Measurements
Anisotropy
Range
Aniso 4
Bulk susceptibility
Range Kre Kim Phase
Bulk 5 99.13E-03 -232.4E-06 -0.13
Results
Mean susceptibility
Km Std. error [%]
101.7E-03 0.05
F-test
F F12 F23
11563.7 432.7 3430.6
Normed principal susceptibilities
kmax kint kmin
1.0302 1.0098 0.9600
+/- 0.0008 +/- 0.0008 +/- 0.0009
Confidence ellipses
E12 E23 E13
2.5 0.9 0.6
Anisotropy factors
L F P Pj T U Q E
1.020 1.052 1.073 1.075 0.434 0.420 0.339 1.031
Principal directions
Coordinate system Kmax Kint Kmin
Dec Inc Dec Inc Dec Inc
Specimen 10.3 42.7 242.5 33.5 131.0 28.9
Geographic 144.6 71.6 350.5 16.6 258.2 7.6
Paleo #1 24.1 76.9 192.8 12.9 283.4 2.5
Tecto #1 4.1 76.9 172.8 12.9 263.4 2.5
Paleo #2
Tecto #2
NEW SPECIMEN
Auto NEW
ANISO
BULK
Auto BULK
SAVE
STOP
CANCEL
Data acquisition
Data viewing
INSTRUMENT IS READY
F1
200 A/m
U/D Enabled
Rot Enabled
Calib Out-of-date
No HCorr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File Graphics Settings About
Graphs Table
GEO D 0 Horizontal North
Name
CS05/01/1
CS05/01/2
CS05/02/1
CS05/02/2
CS05/02/3
CS05/03/1
CS05/03/2
CS05/04/1
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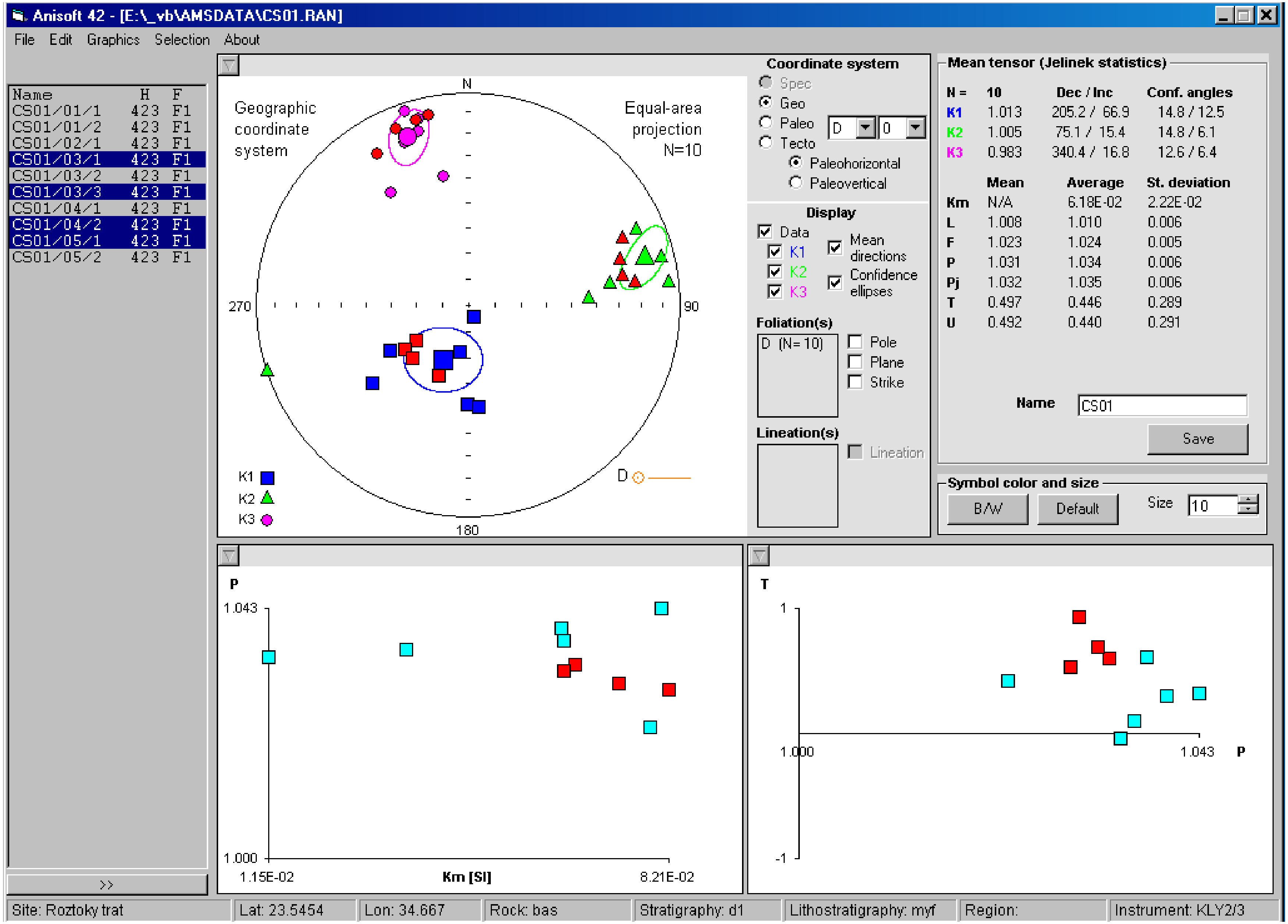
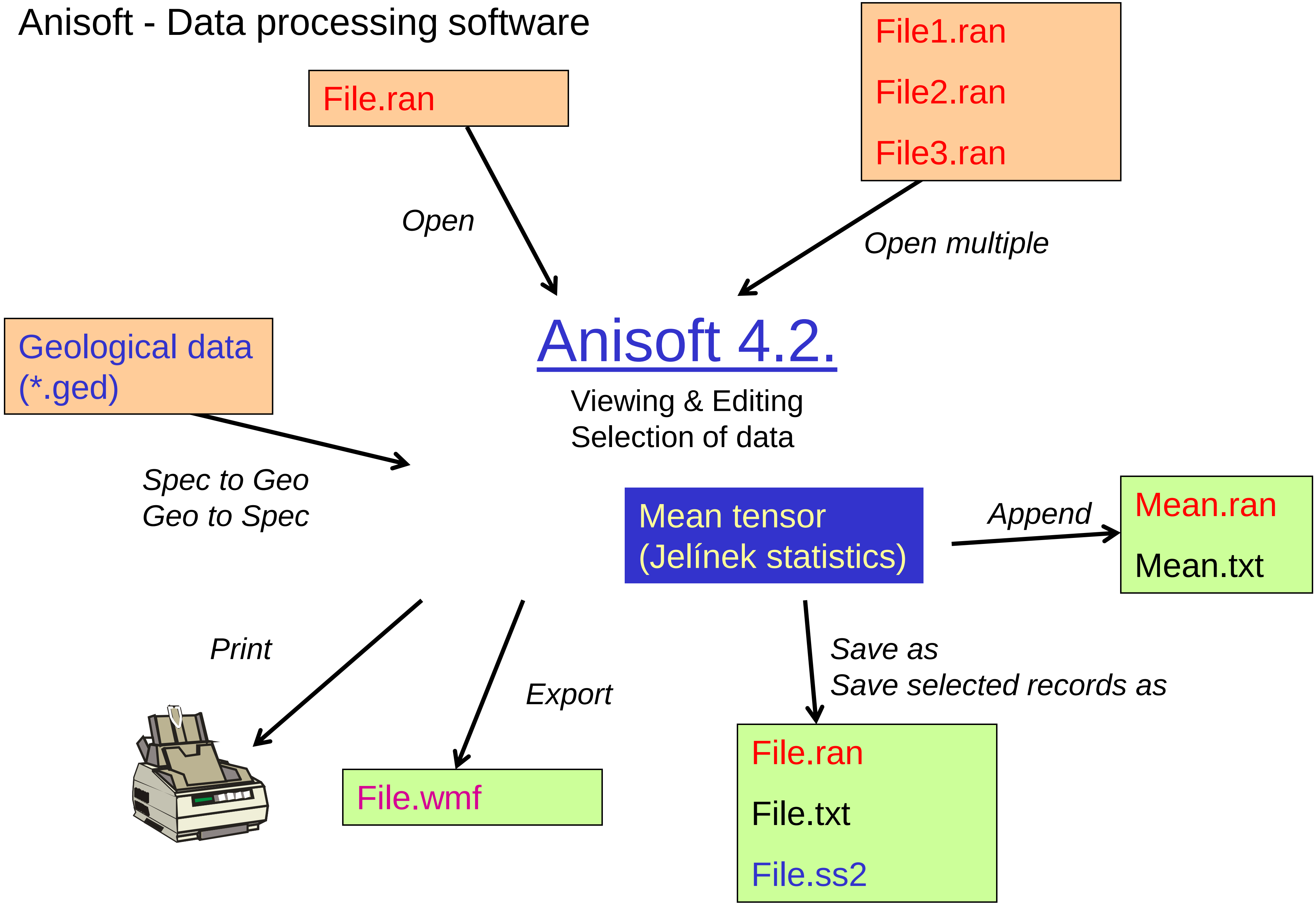
CS05/10/2
CS05/10/3
CS05/11/1
CS05/11/2
CS05/12/1
CS05/12/2
CS05/12/3
CS05/13/1
Export plot
Geographic coordinate system
Equal-area projection N = 35
N
270
90
180
Max
Int
Min
D
Group statistics (N = 35)
Mean tensor (Jelinek statistics)
Normed semi-axes Dec Inc Conf. ellips.
Kmax 1.021 266.7 3.1 16.1 9.8
Kint 0.997 128.3 85.9 39.8 14.2
Kmin 0.983 356.8 2.7 39.4 10.0
Mean tensor Average Standard dev.
Km N/A 83.44E-03 11.70E-03
L 1.024 1.030 0.013
F 1.014 1.021 0.015
P 1.039 1.052 0.021
Pj 1.039 1.053 0.021
T -0.250 -0.183 0.361
U -0.259 -0.193 0.359
Q 0.918 0.898 0.389
E 0.991 0.992 0.019
Export plot
P
Km [E-03 SI]
P = 1.098 T = 0.178 Export plot
T
P
Data acquisition
Data viewing
INSTRUMENT IS READY
F1
200 A/m
U/D Enabled
Rot Disabled
Calib Out-of-date
HCorr Out-of-date

Anisoft - Data processing software

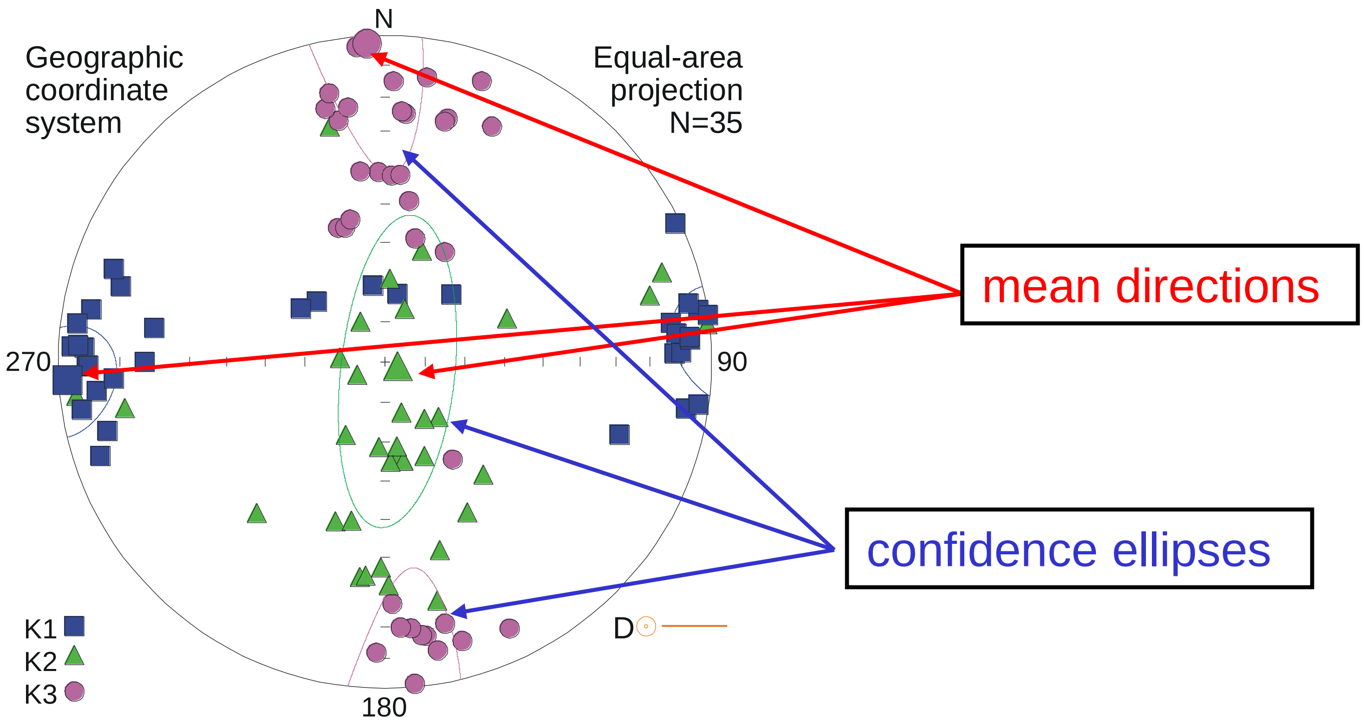


Anisoft - Data processing software

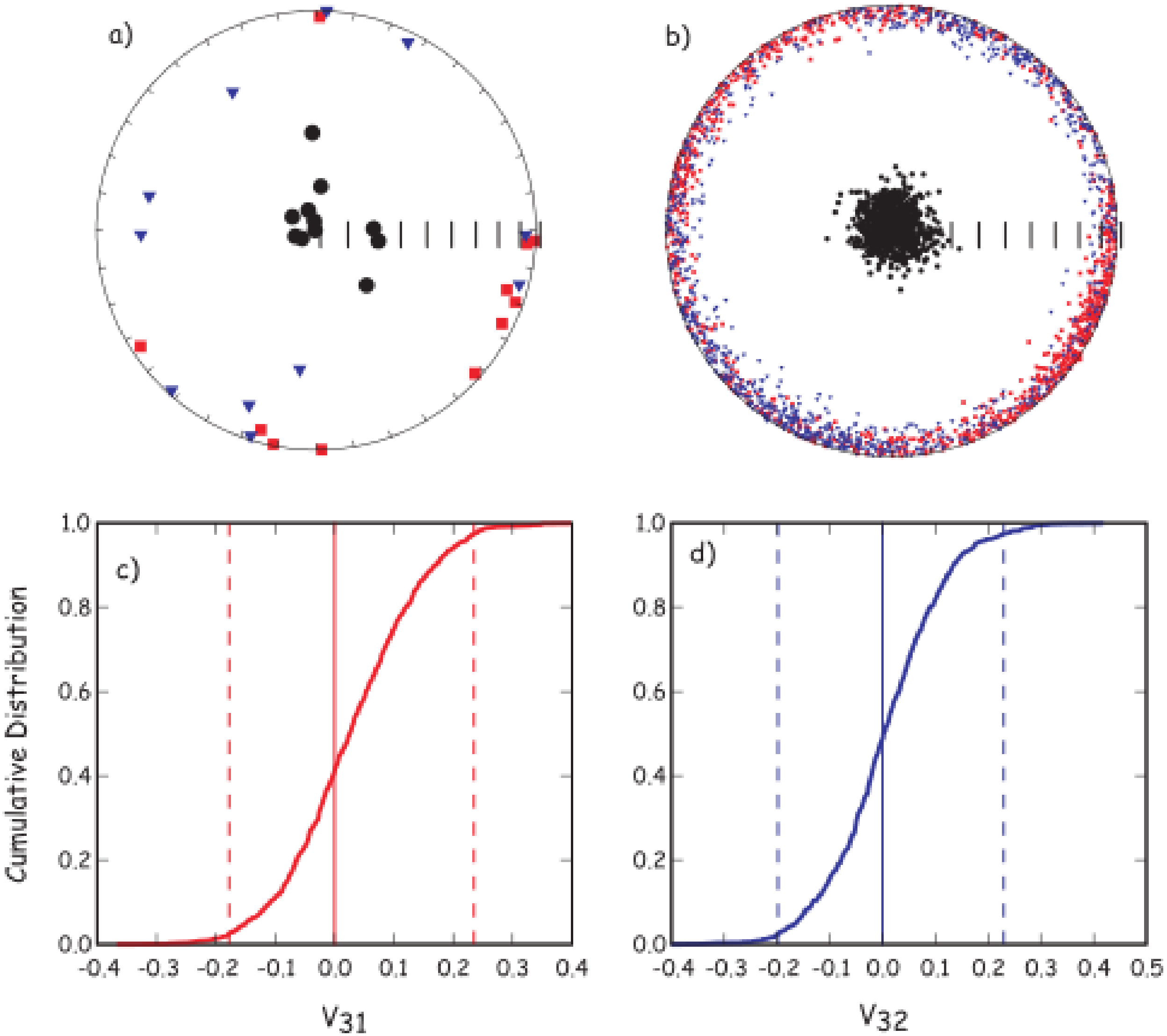


Mean tensor (Jelinek 1978, Hext 1963)

$$\mathbf{F} = \begin{pmatrix} K_{11} & K_{12} & K_{13} \\ K_{21} & K_{22} & K_{23} \\ K_{31} & K_{32} & K_{33} \end{pmatrix} = \frac{1}{n} \begin{pmatrix} \sum_{i=1}^{n} k_{11i} & \sum_{i=1}^{n} k_{12i} & \sum_{i=1}^{n} k_{13i} \\ \sum_{i=1}^{n} k_{21i} & \sum_{i=1}^{n} k_{22i} & \sum_{i=1}^{n} k_{23i} \\ \sum_{i=1}^{n} k_{31i} & \sum_{i=1}^{n} k_{32i} & \sum_{i=1}^{n} k_{33i} \end{pmatrix} = \frac{1}{n} \sum_{i=1}^{n} \mathbf{k}_i$$

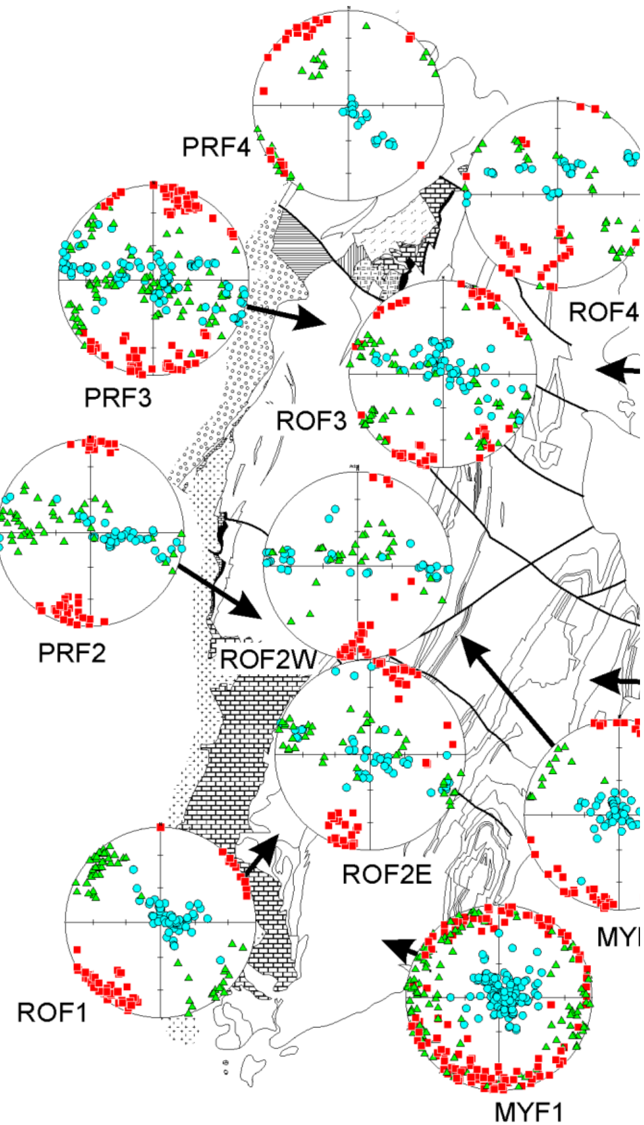


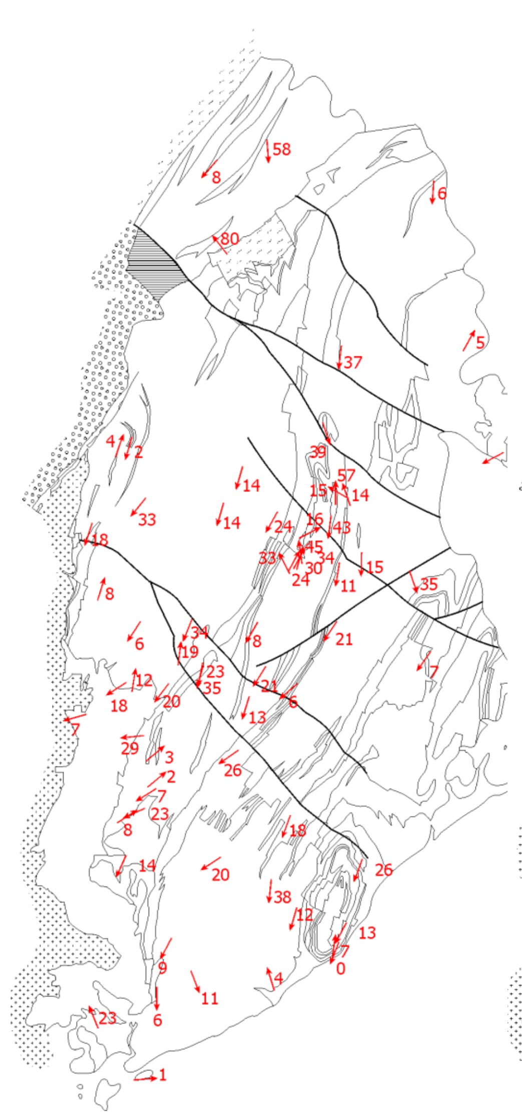
Bootstrap (Constable & Tauxe 1990)

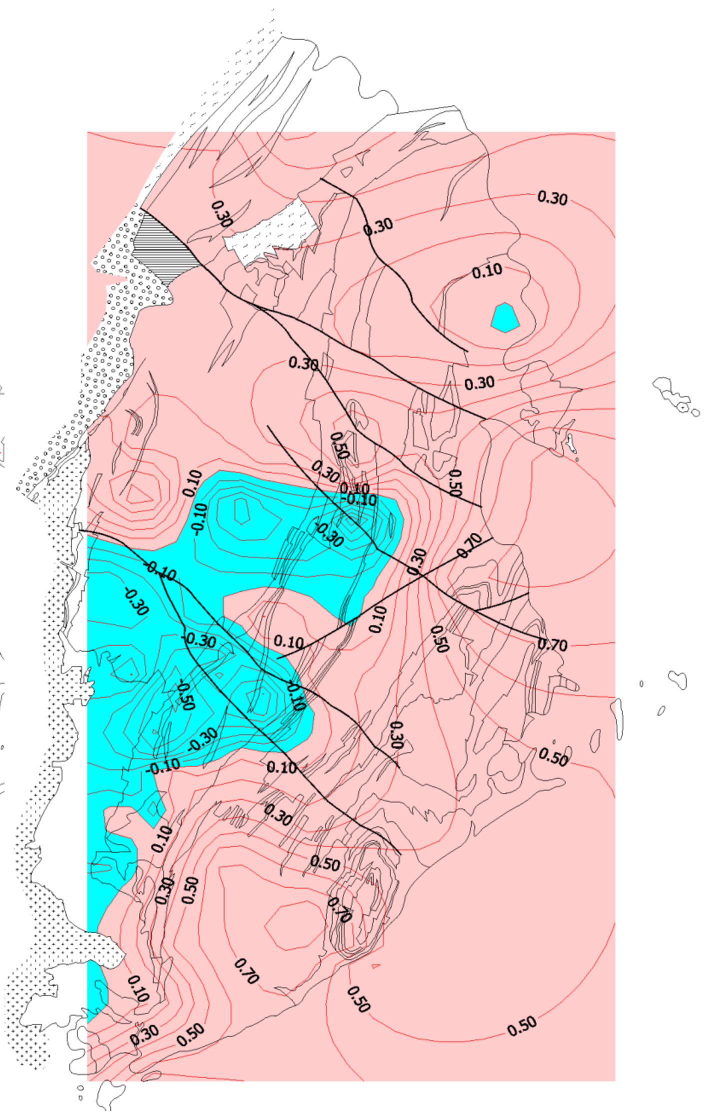


Data presentation in regional scale

- projection of mean susceptibilities
- magnetic lineation of mean tensor
- isolines of shape parameter (T)







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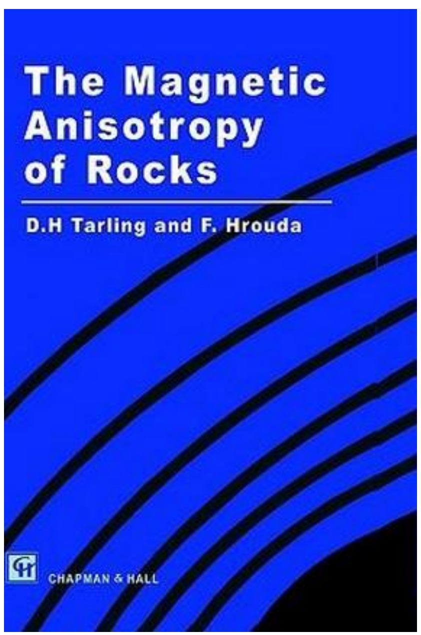
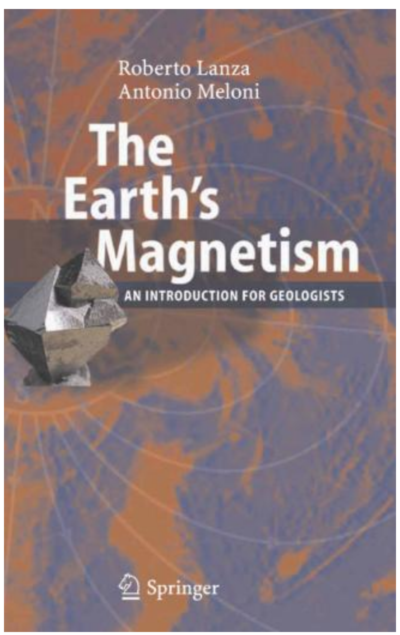
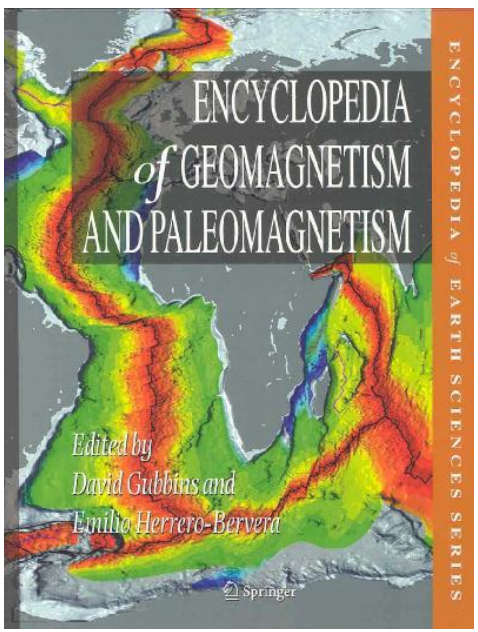
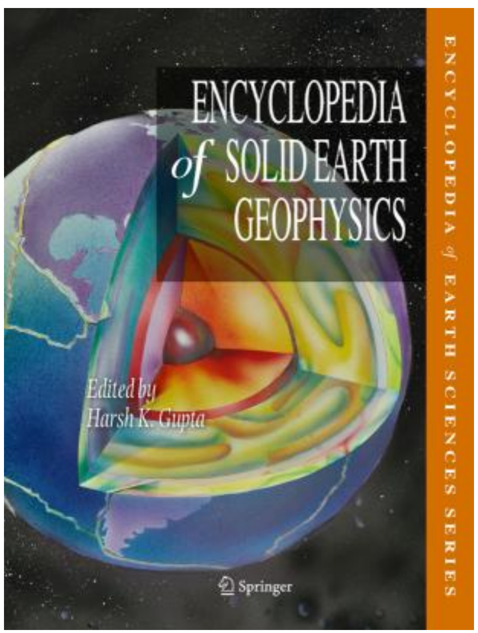
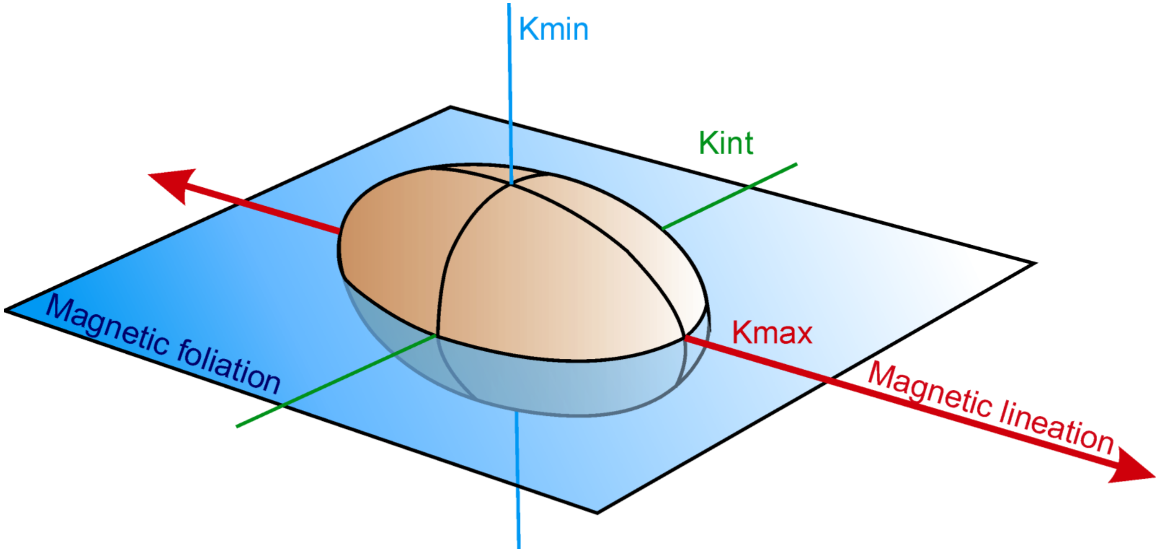








Thanks for your endurance!



ADVANCED GEOSCIENCE INSTRUMENTS COMPANY

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