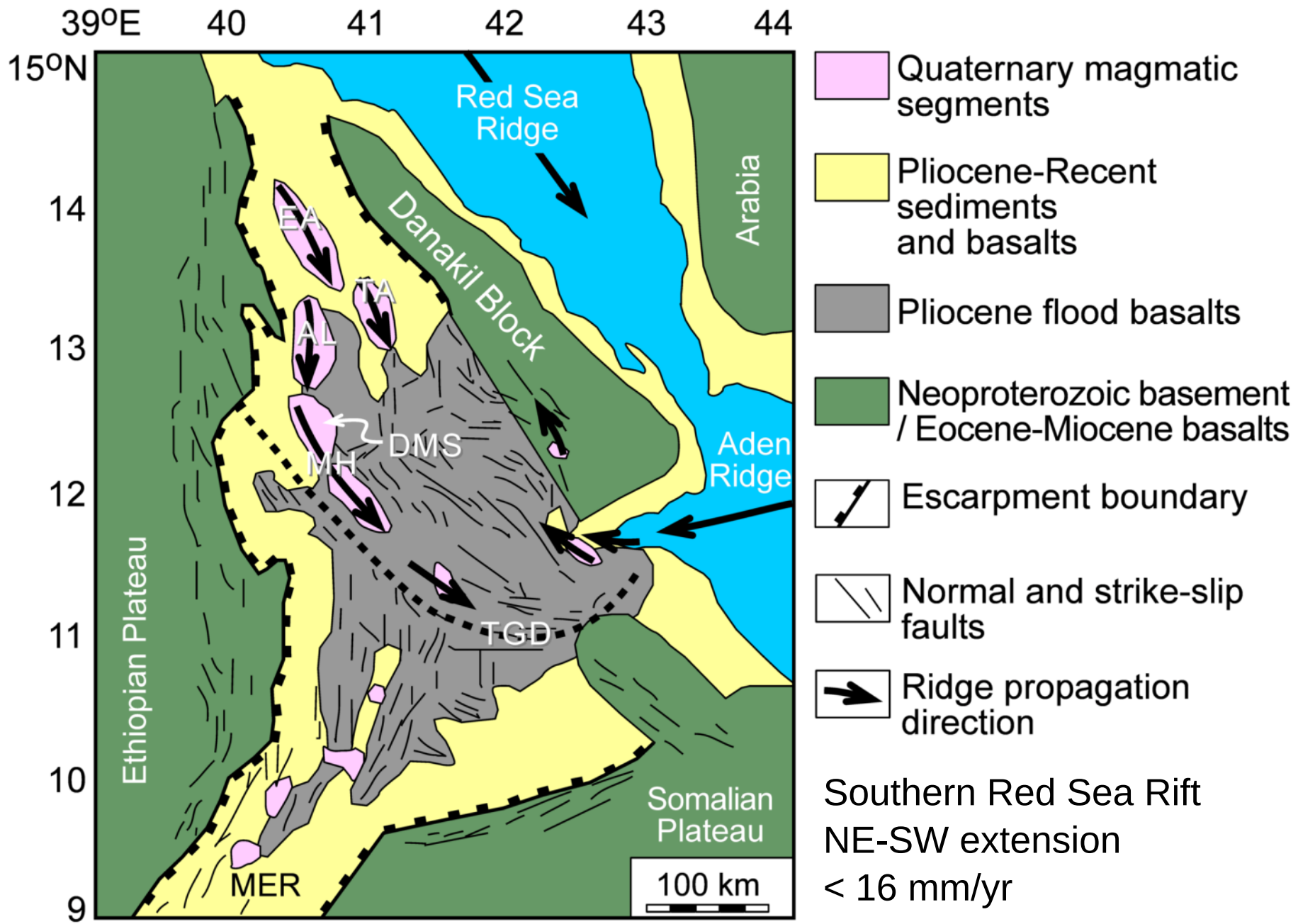
Counterclockwise Block Rotation Linked to Southward Right-Stepping Propagation And Overlap of The Red Sea Rift Segments at The Nascent Passive Margin, Afar Depression; Insight From Paleomagnetism.

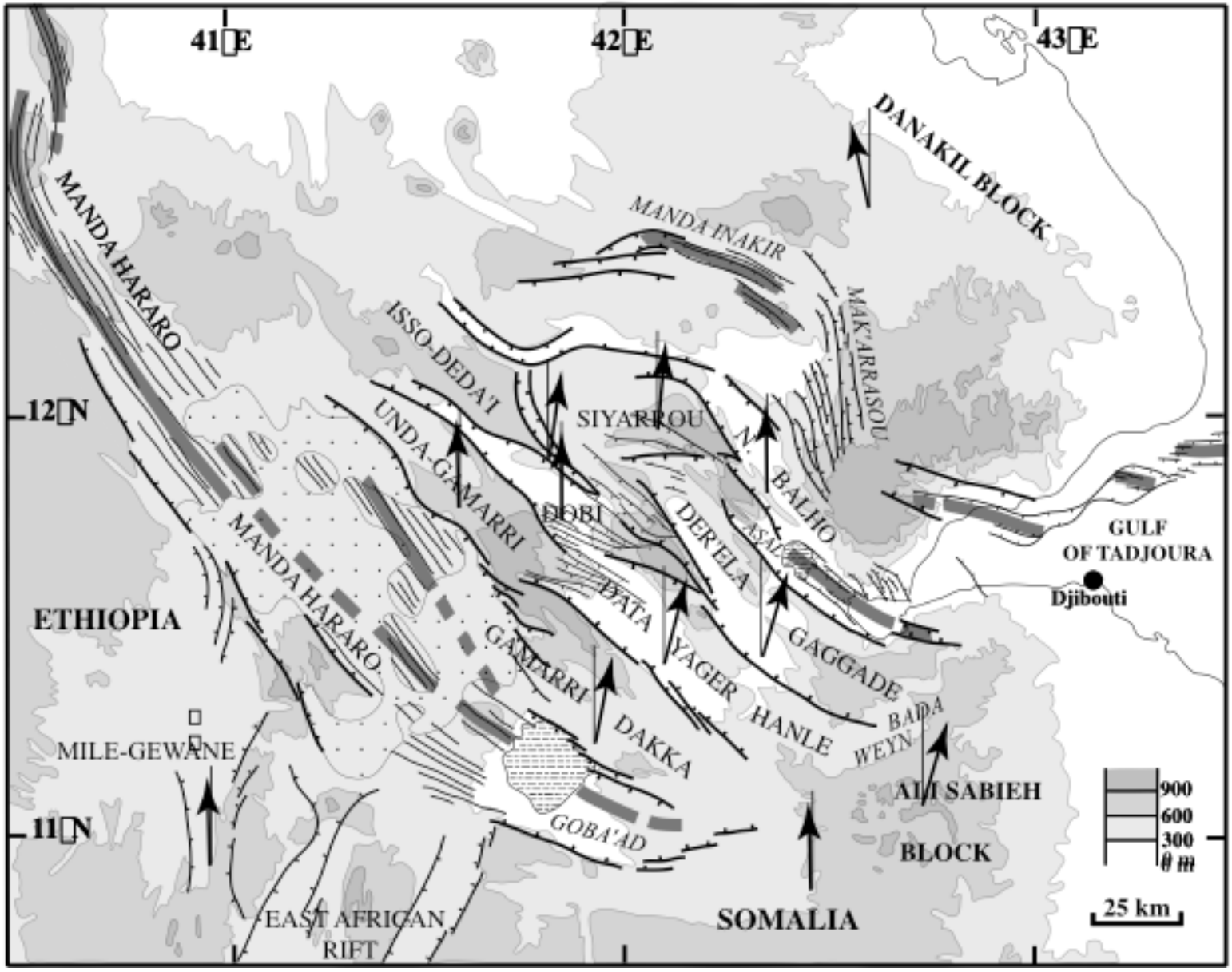
Tesfaye Kidane, Amha Atnafu, and Julie Rowland

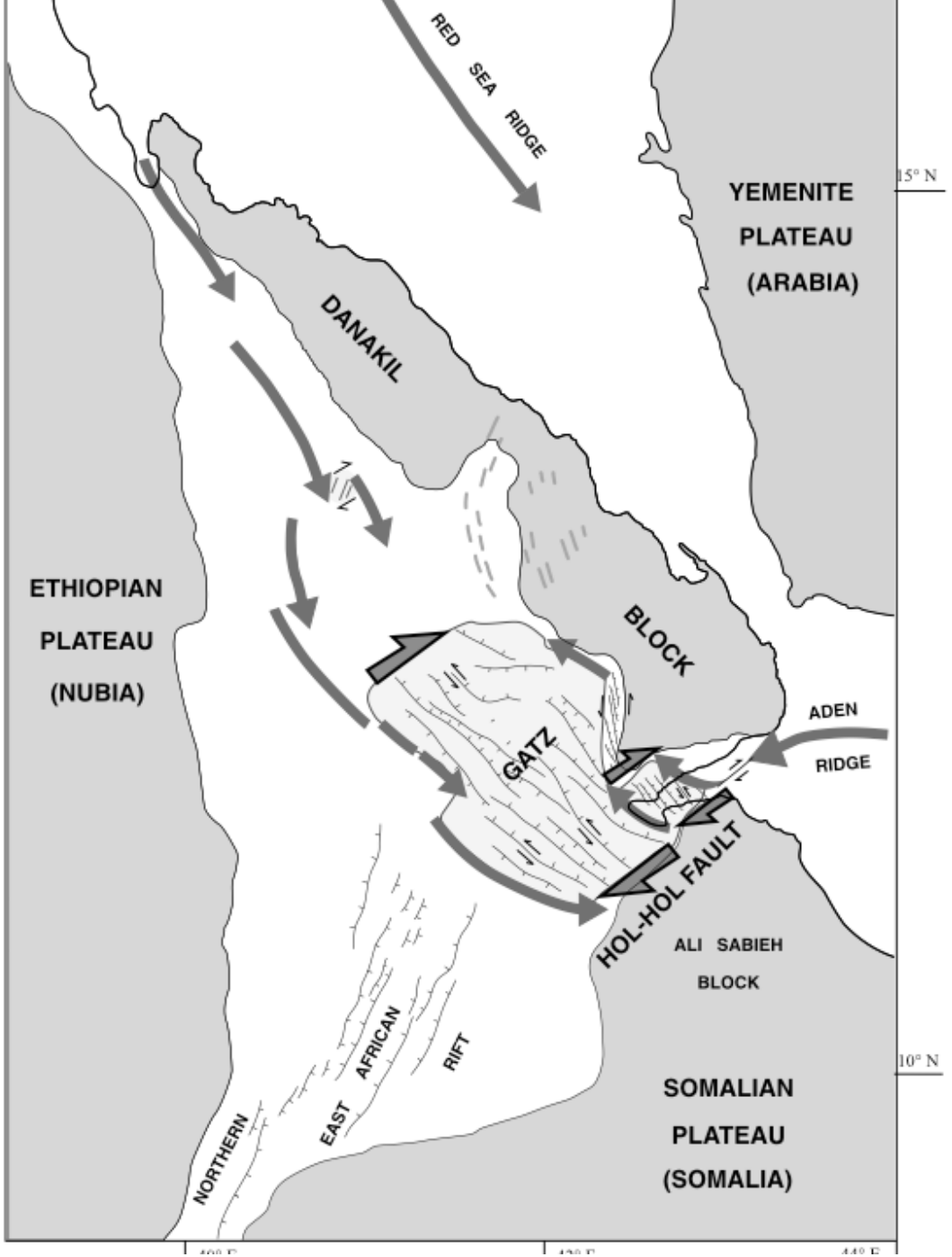
MVAR-Conference, January 12, 2012, A.A. Ethiopia

Presentation Outline

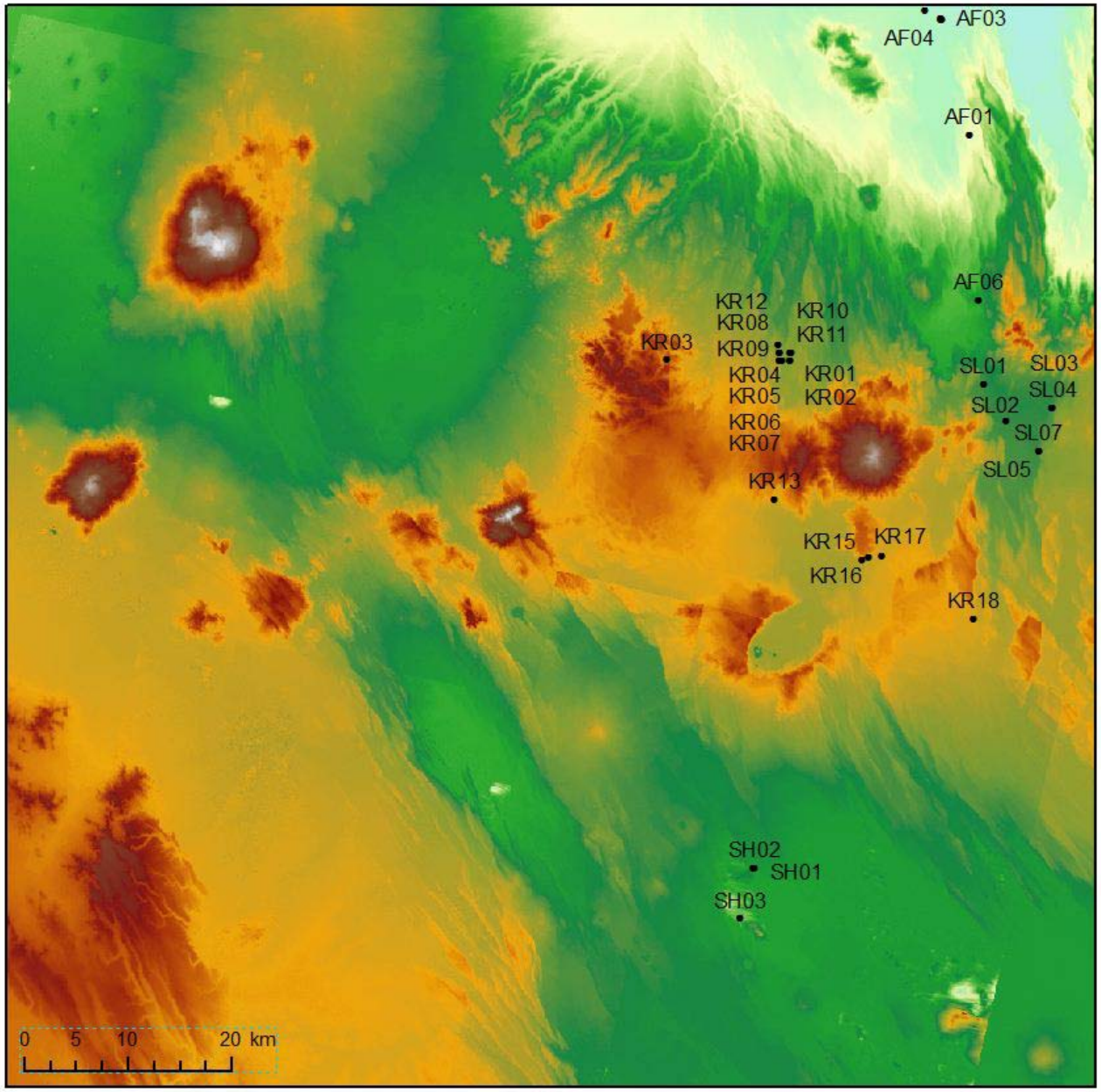
- Background Information
- Paleomagnetic Sample Collection
- Laboratory data acquisition
- Results
- Preliminary Interpretation & Conclusion


39°E
40
41
42
43
44
15°N
14
13
12
11
10
9
Red Sea Ridge
Danakil Block
Arabia
Aden Ridge
Ethiopian Plateau
Somalian Plateau
EA
TA
AL
MH
DMS
TGD
MER
100 km
Quaternary magmatic segments
Pliocene-Recent sediments and basalts
Pliocene flood basalts
Neoproterozoic basement / Eocene-Miocene basalts
Escarpment boundary
Normal and strike-slip faults
Ridge propagation direction
Southern Red Sea Rift
NE-SW extension
< 16 mm/yr


41°E
42°E
43°E
12°N
11°N
DANAKIL BLOCK
MANDA HARARO
MANDA-INAKIR
MAK'ARRASOU
ISSO-DEDA'I
SIYARROU
N. BALHO
UNDA-GAMARRI
DOBI
DER'ELA
ASAL
GULF
OF TADJOURA
Djibouti
ETHIOPIA
MANDA HARARO
DATA
YAGER
GAGGADE
GAMARRI
DAKKA
HANLE
BADA
WEYN
MILE-GEWANE
ALI SABIEH
BLOCK
GOBA'AD
900
600
300
m
25 km
EAST AFRICAN
RIFT
SOMALIA


RED SEA RIDGE
15° N
YEMENITE
PLATEAU
(ARABIA)
DANAKIL
ETHIOPIAN
PLATEAU
(NUBIA)
BLOCK
ADEN
RIDGE
GATZ
HOL-HOL FAULT
ALI SABIEH
BLOCK
10° N
EAST AFRICAN RIFT
NORTHERN
SOMALIAN
PLATEAU
(SOMALIA)

34 cooling units (paleomagnetic sites sampled)




A paleomagnetic site, > 1 site here

A paleomagnetic site, > 1 site here

Sediments in b/n paleomagnetic site

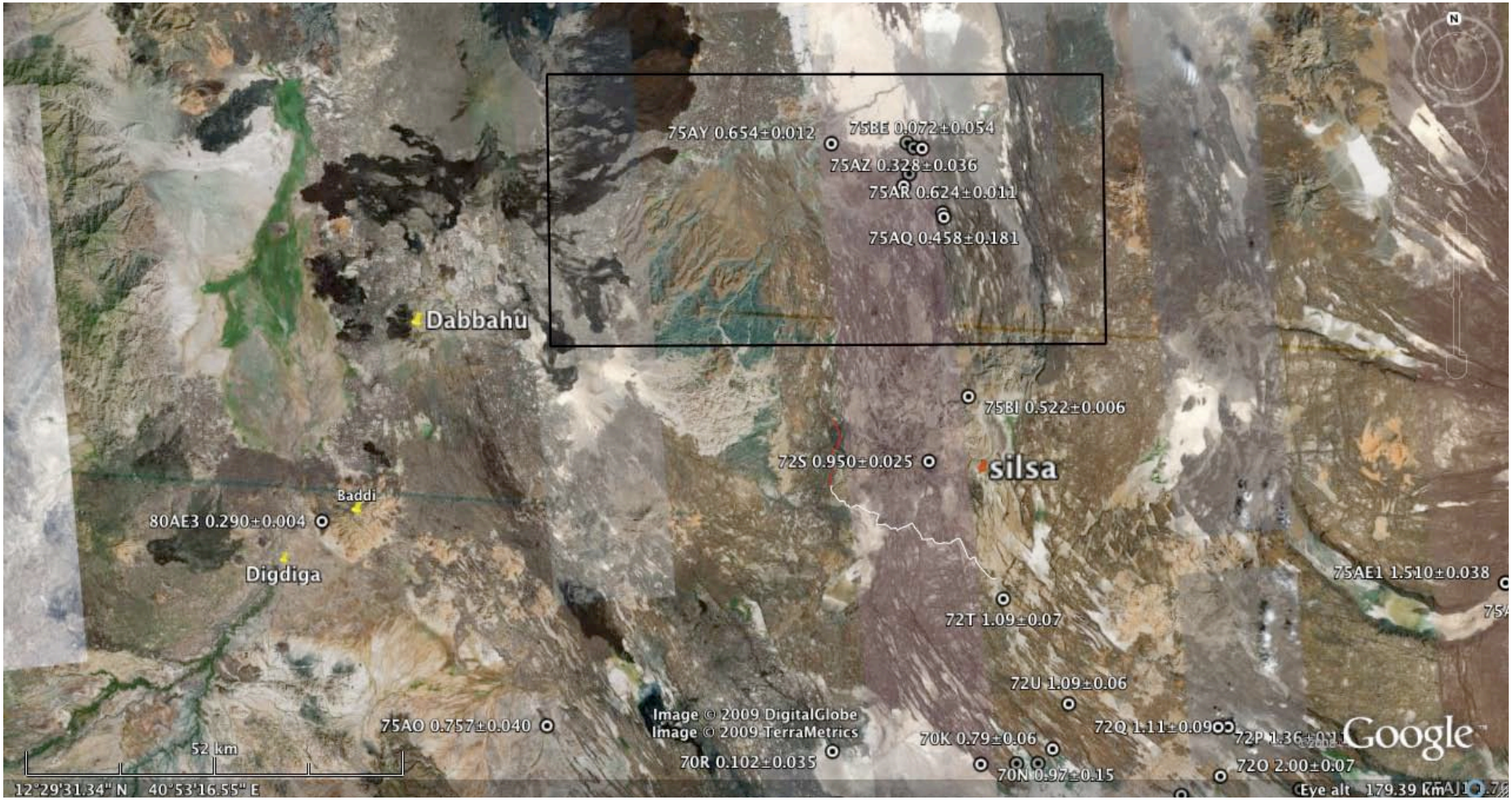

A paleomagnetic site, > 1 site here

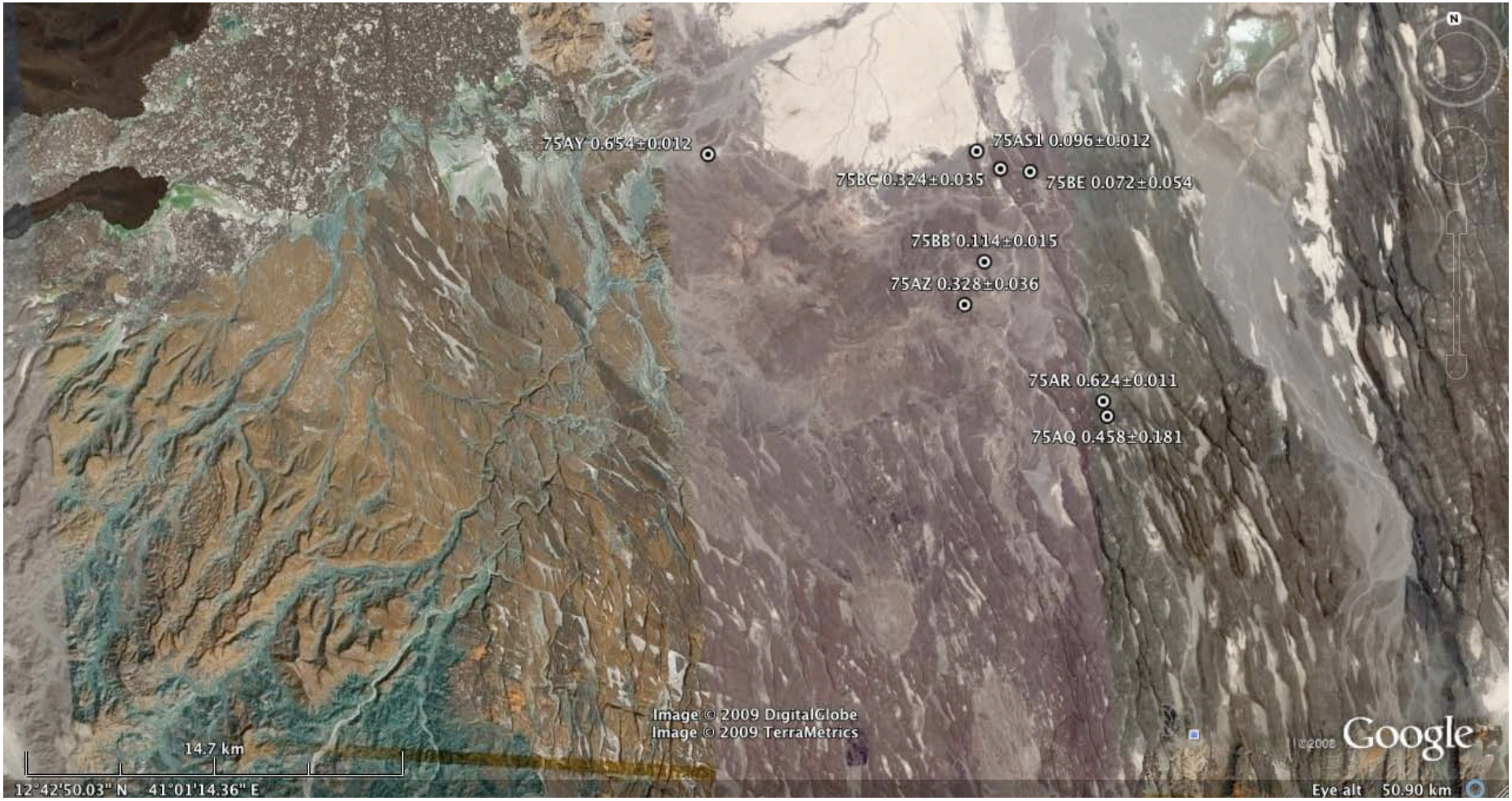

Sediments in b/n paleomagnetic site


More than 7 paleomagnetic site here

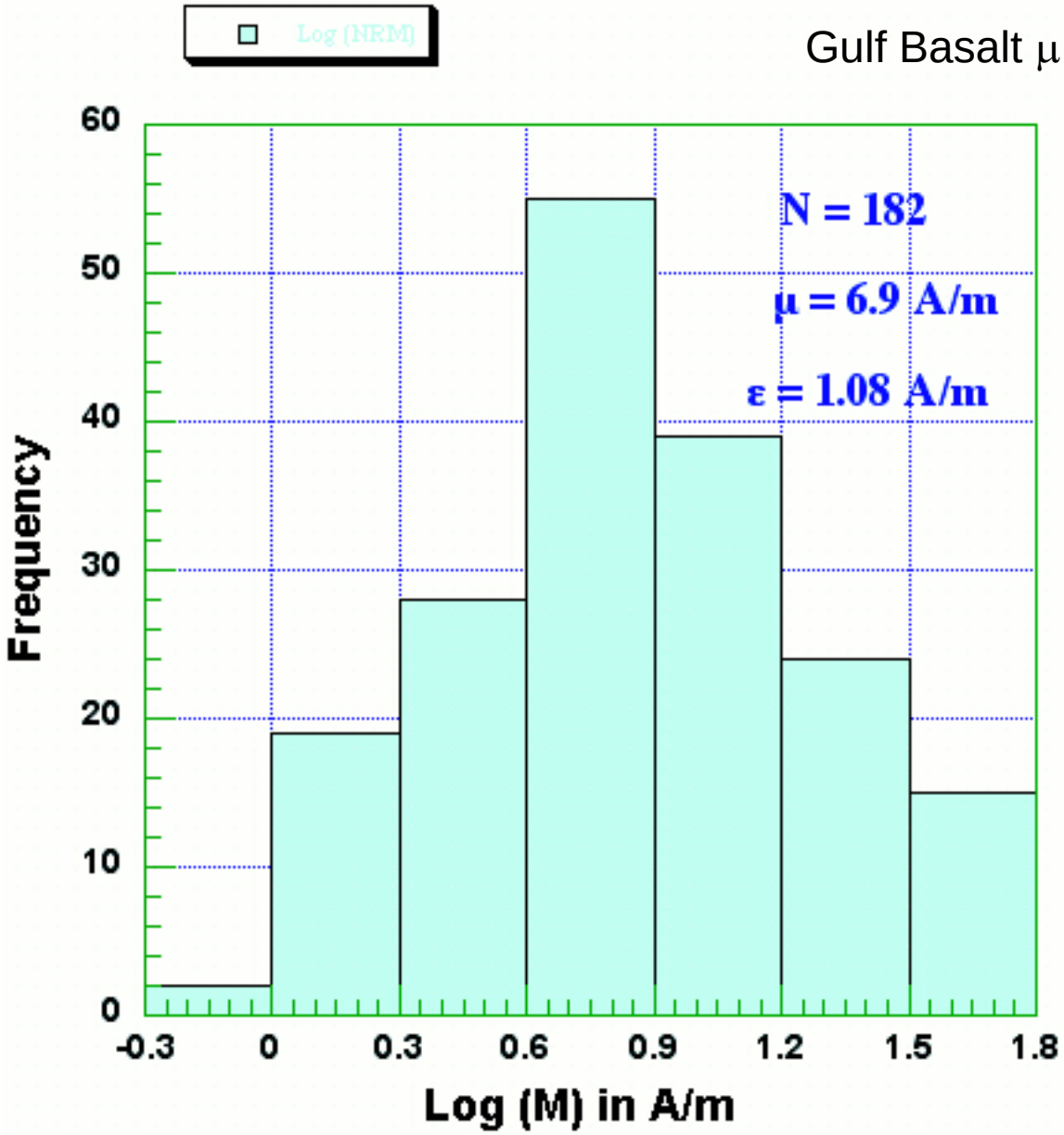

7 – 12 core
samples/site

The basalts studied are of Pleistocene – Holocene age (1.1 Ma - .07 Ma)
Lahitte et al. 2001

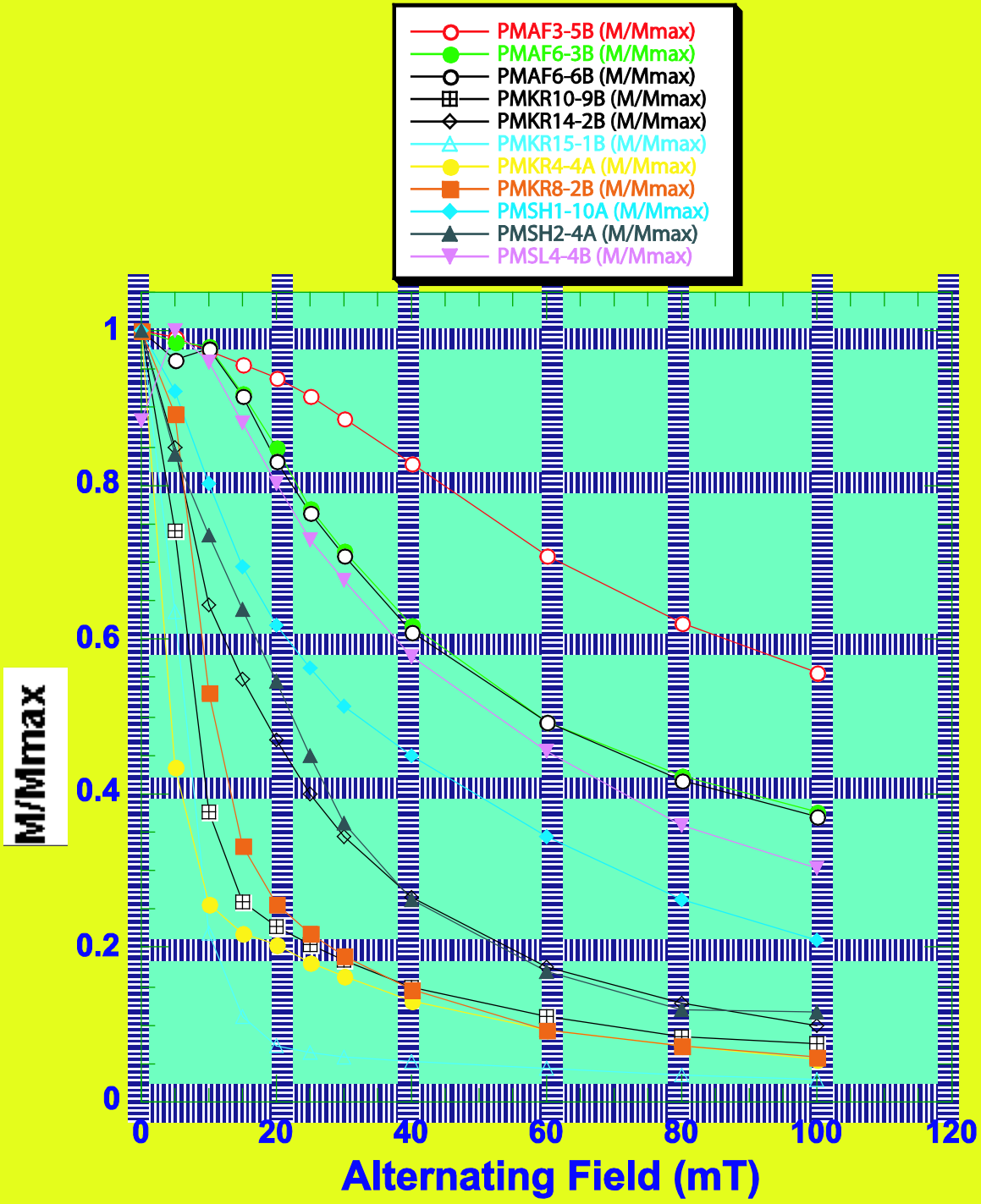



75AY 0.654±0.012
75AS1 0.096±0.012
75BC 0.324±0.035
75BE 0.072±0.054
75BB 0.114±0.015
75AZ 0.328±0.036
75AR 0.624±0.011
75AQ 0.458±0.181
Image © 2009 DigitalGlobe
Image © 2009 TerraMetrics
14.7 km
12°42'50.03" N 41°01'14.36" E
Eye alt 50.90 km
Google

Gulf Basalt μ = 5.68 A/m (s=-4.2/+16.6)

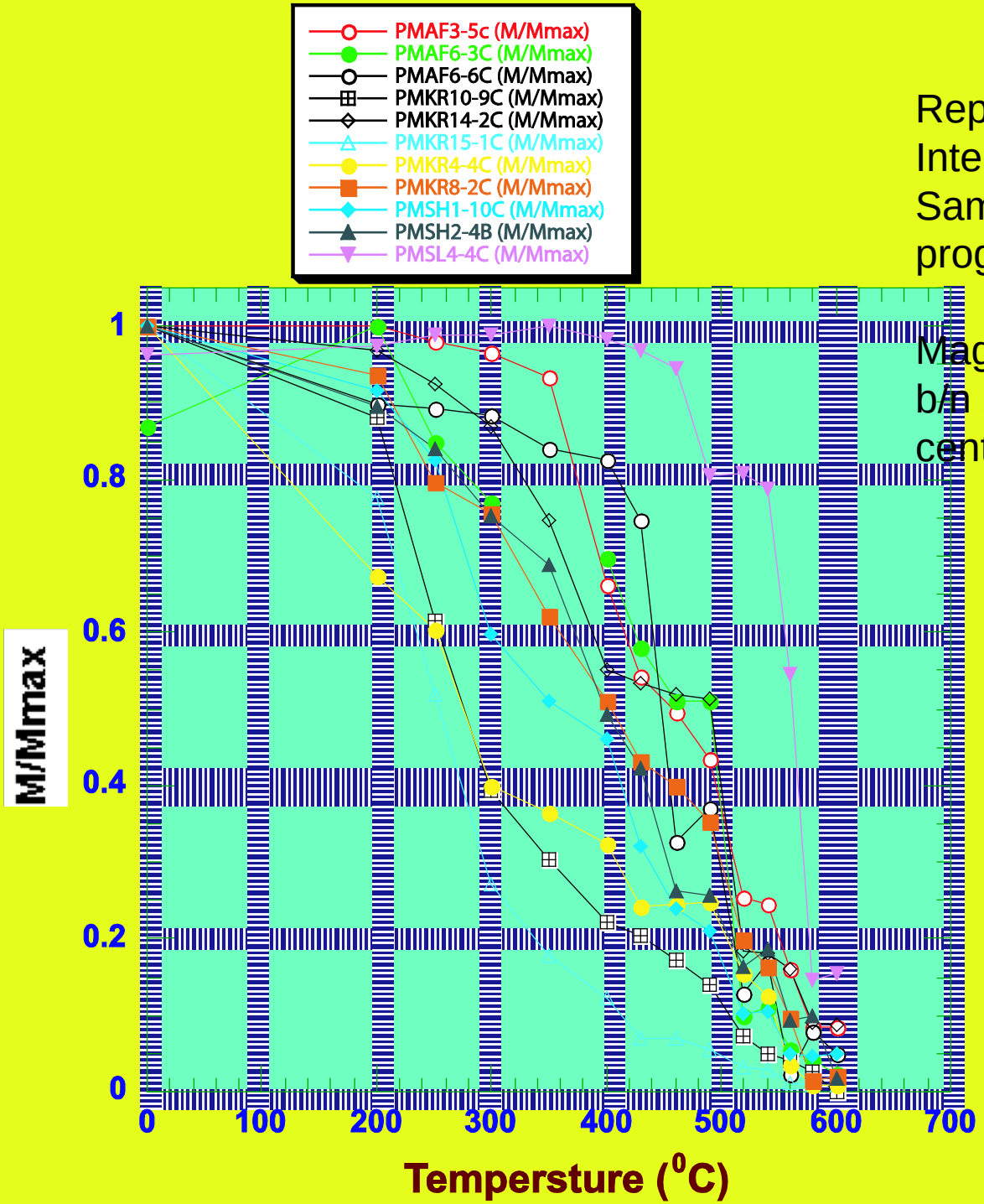


- NRM directions are random & cluster either 20 mT AF
  - 300 degree C



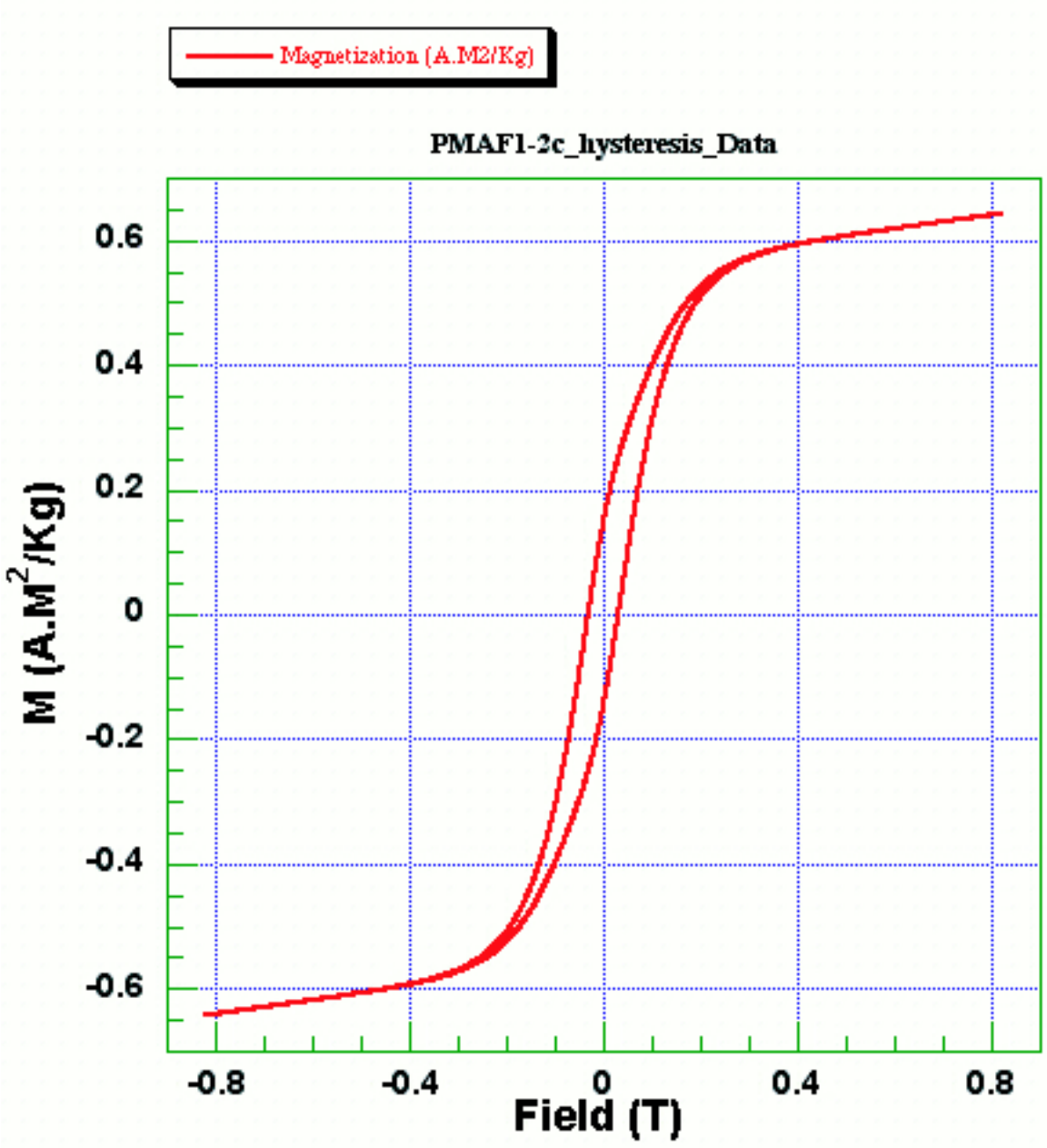
Representative normalized Intensity decay curves for Samples treated with progressive AF

MDF 5 – 60 & > 100m T



Representative normalized Intensity decay curves for Samples treated with progressive thermal demag.

Mag decays to 50% of NRM b/n 250 – 580 degree centigrade



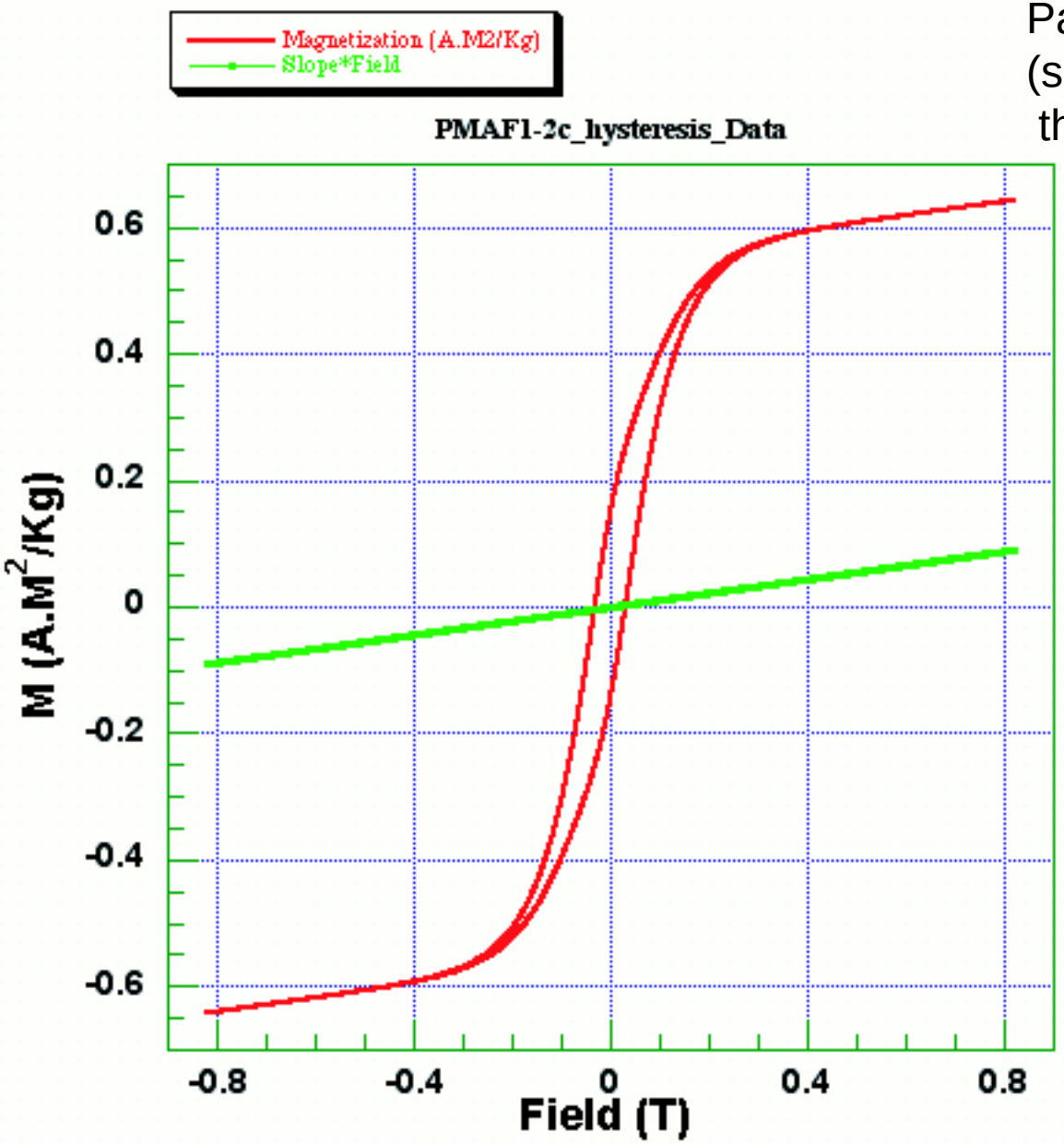
❖ In order to characterize magnetic Materials, rock – magnetic experiments were carried out using the most sophisticated & most commonly used instruments at the LMU, lab facility, Germany.

❖ Variable Field Translation Balance (MM VFTB) & Alternating Gradient Force Magnetometer.

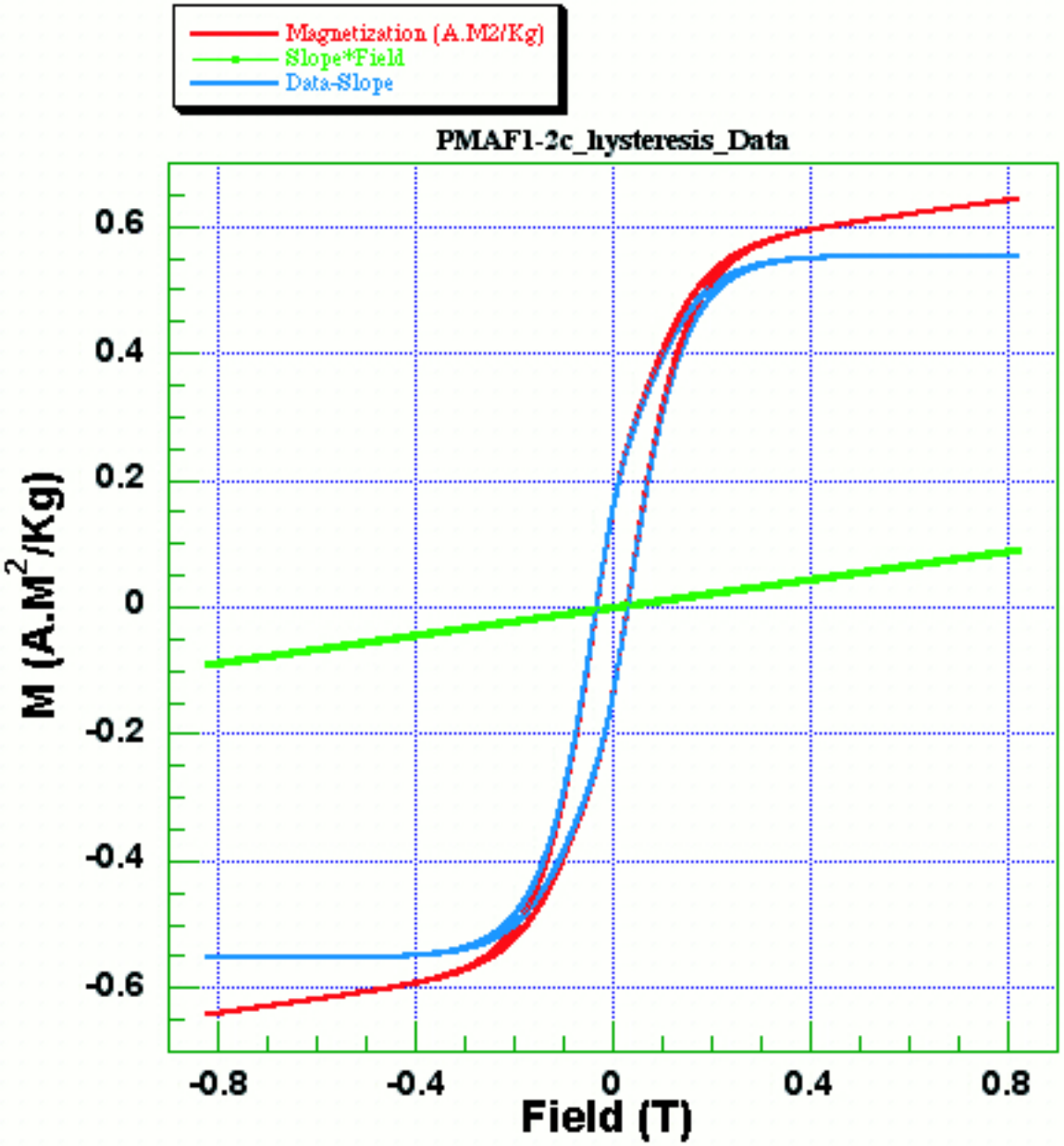
❖ IRM acquisition & associated back Field curves, as well as hysteresis loops, & thermomagnetic curves are measured.

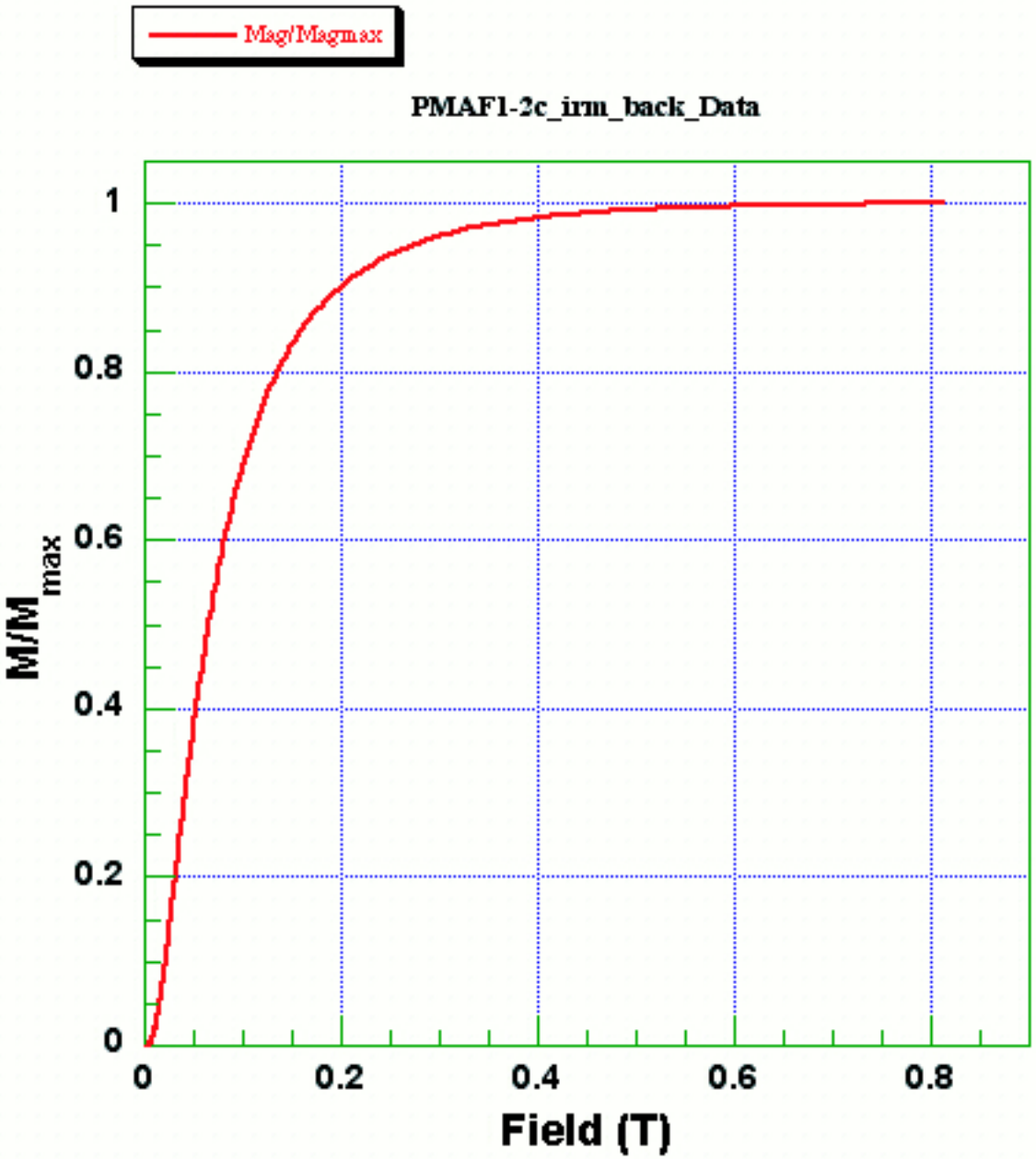
❖The RockMag Analyser 1. software by Leonhardt, 2006 was used throughout.

❖10 representative samples measured



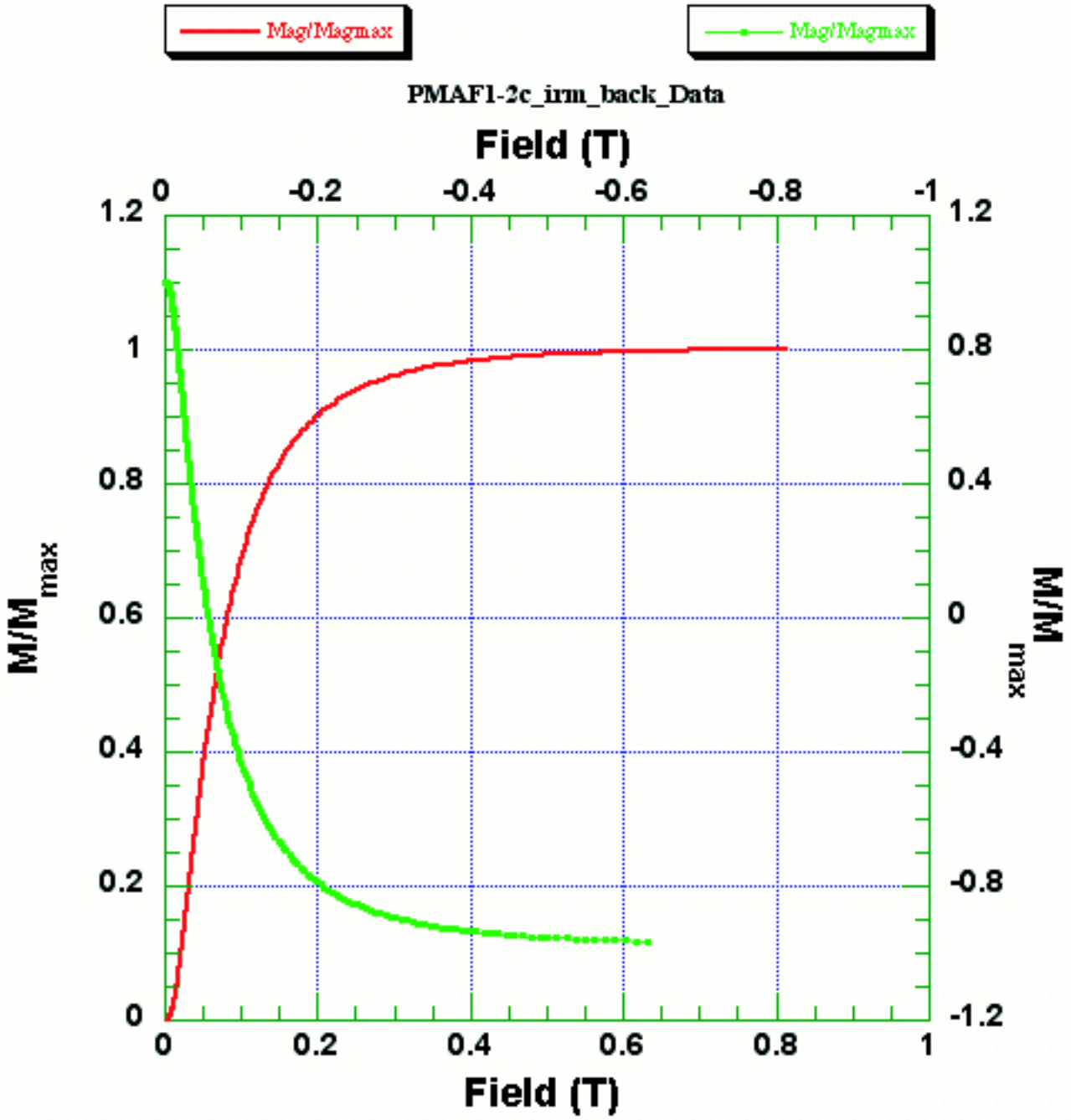
Paramagnetic contribution (slope) is subtracted to get the true ferromagnetic signal

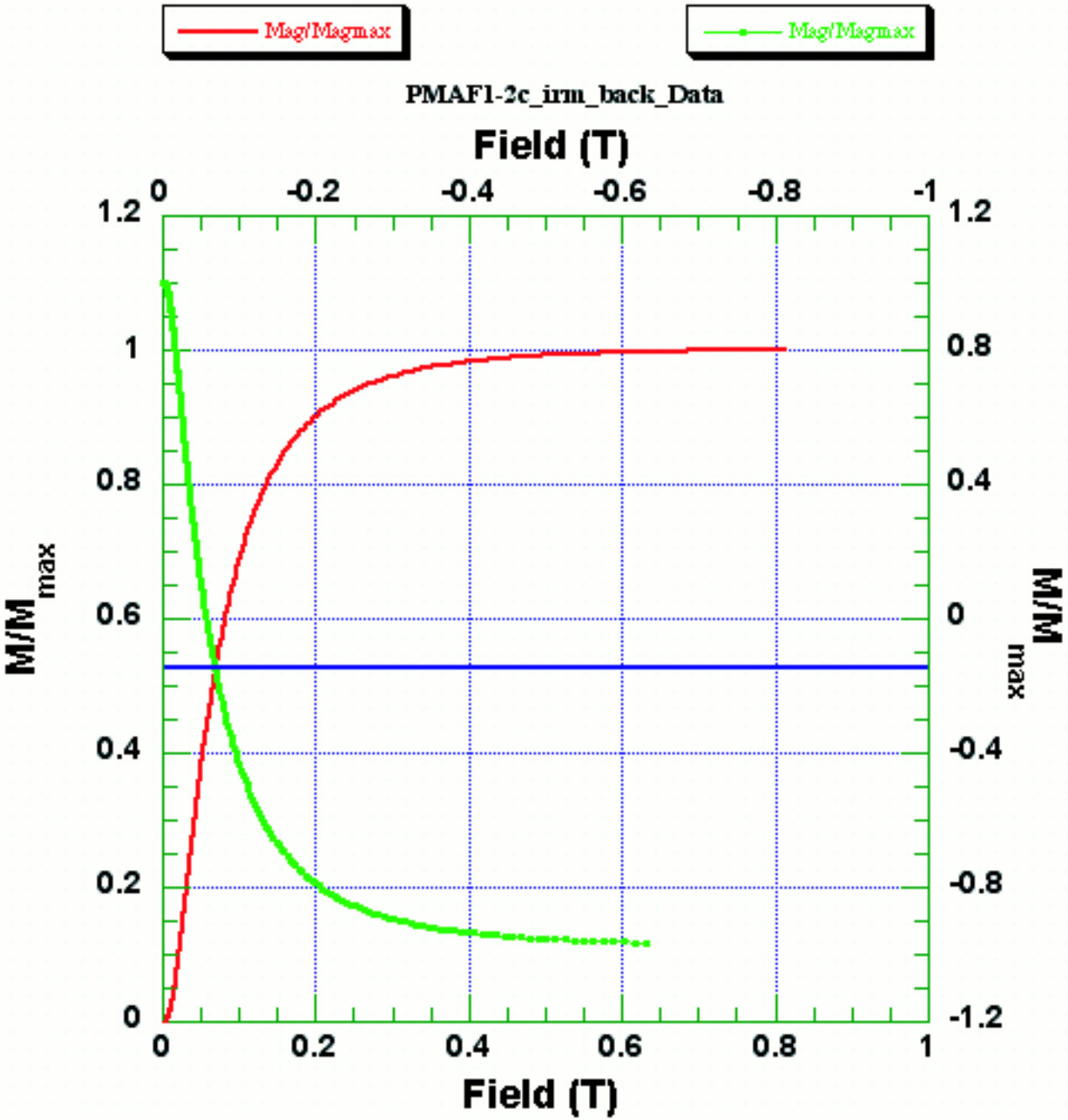

Magnetization (A.M2/Kg)
Slope*Field
Data-Slope
PMAF1-2c_hysteresis_Data
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
M (A.M2/Kg)
-0.8
-0.4
0
0.4
0.8
Field (T)



IRM acquisition curve rise Steeply and reaches its Saturation before .5T.

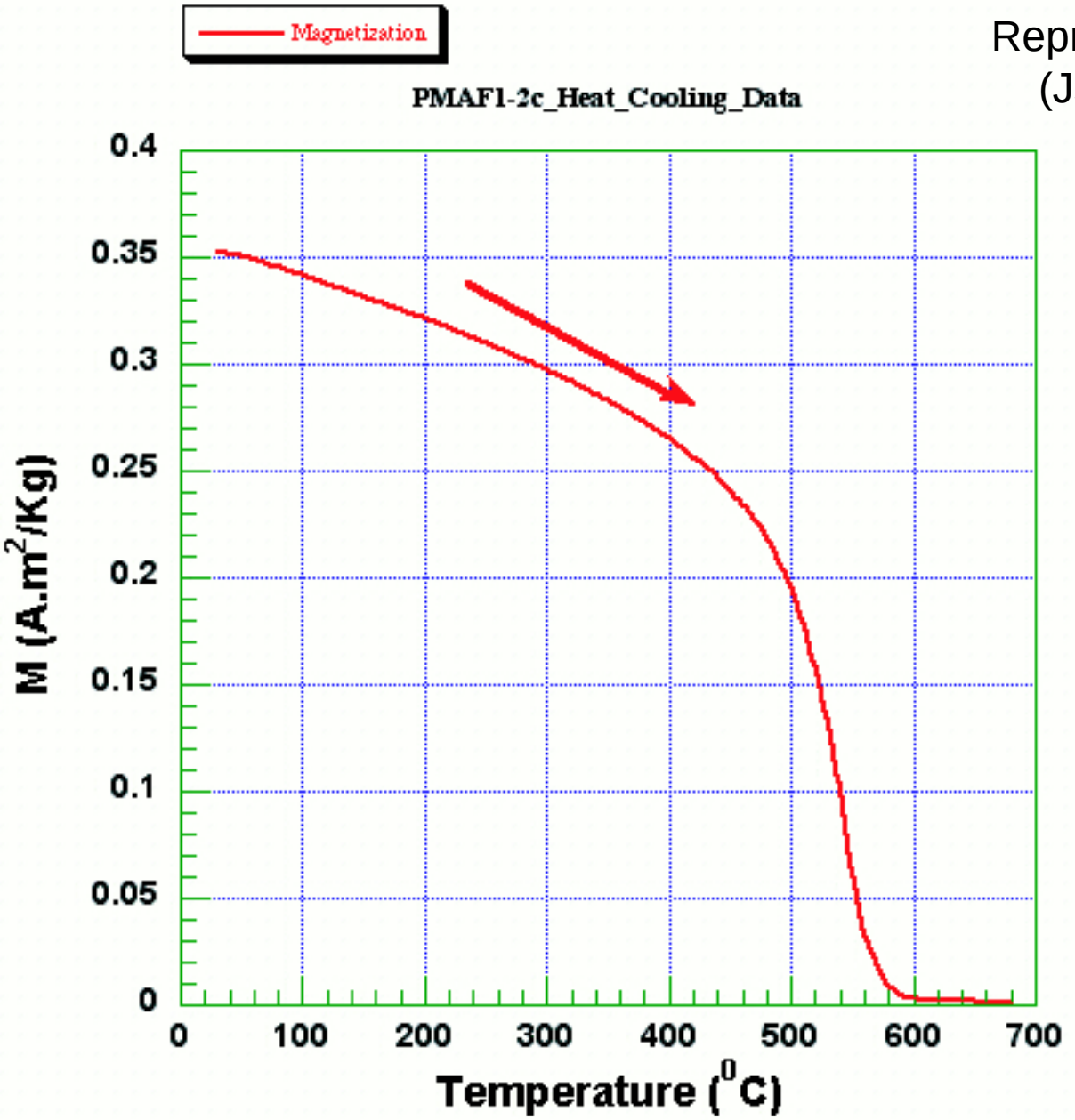
No contribution from Hematite


Mag/Magmax
Mag/Magmax
PMAF1-2c_irm_back_Data
Field (T)
0
-0.2
-0.4
-0.6
-0.8
-1
1.2
1
0.8
0.6
0.4
0.2
0
M/M max
M/M max
0.4
0
-0.4
-0.8
-1.2
0
0.2
0.4
0.6
0.8
1
Field (T)



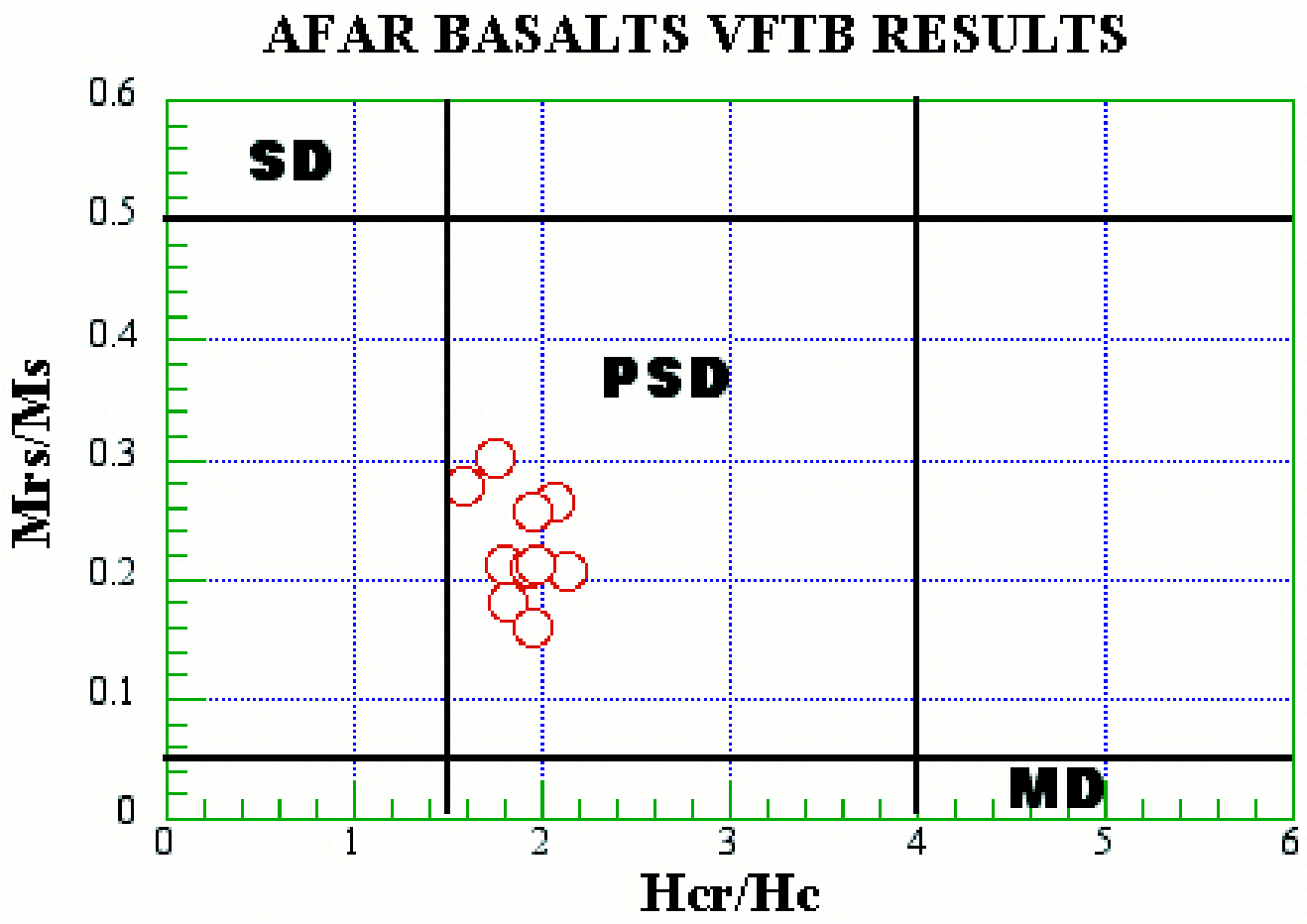
The crossover point of the IRM acquisition and back field curves range 0.5 – 0.55 indicating little or no interaction.

This value indicate grain size ranges from single Domain to Pseudo-single Domain (Johnson et al. 1975).

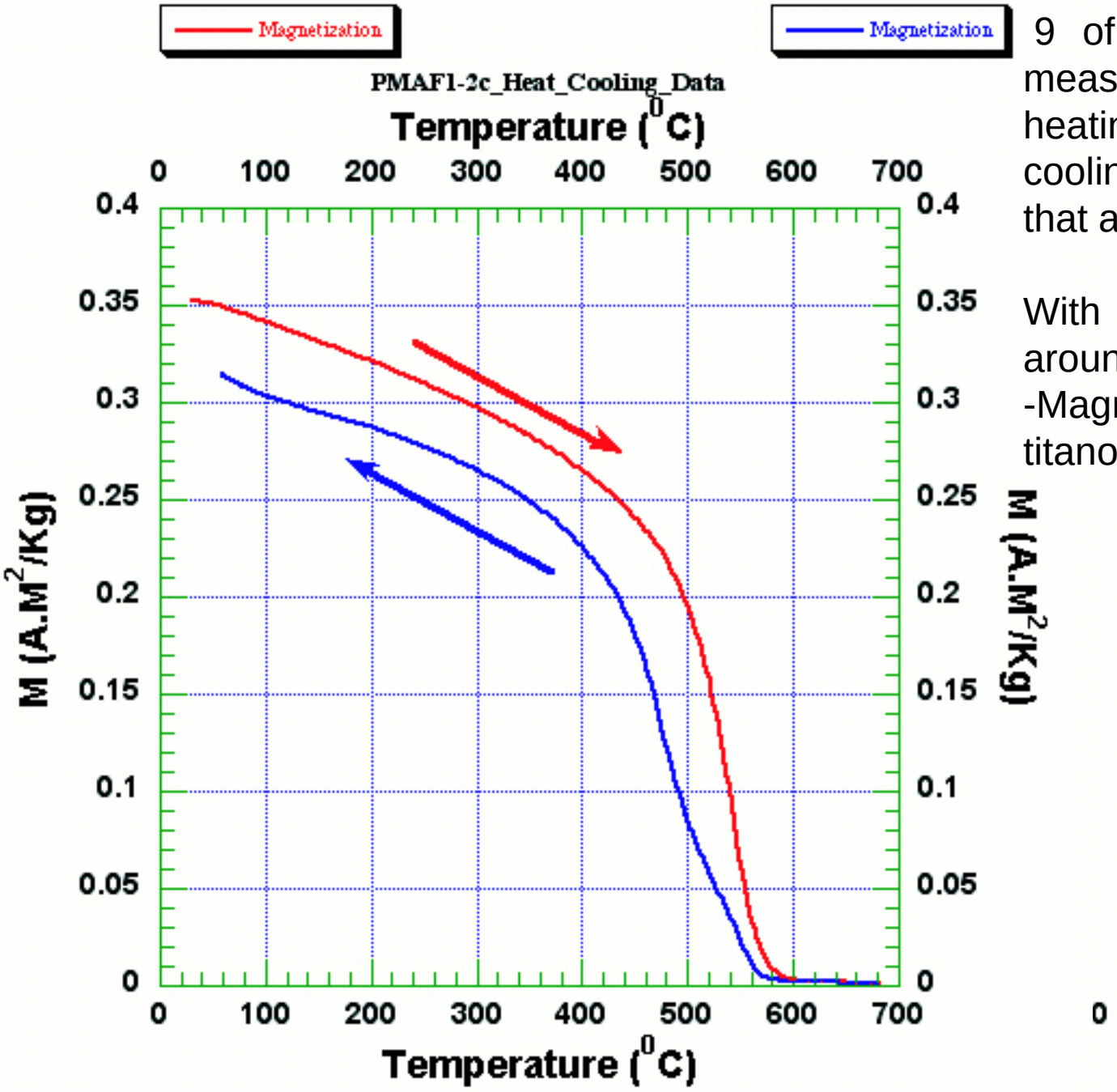


Representative thermomagnetic (Js-T) curves.

Day plot (Day et al. 1977) for the 10 samples

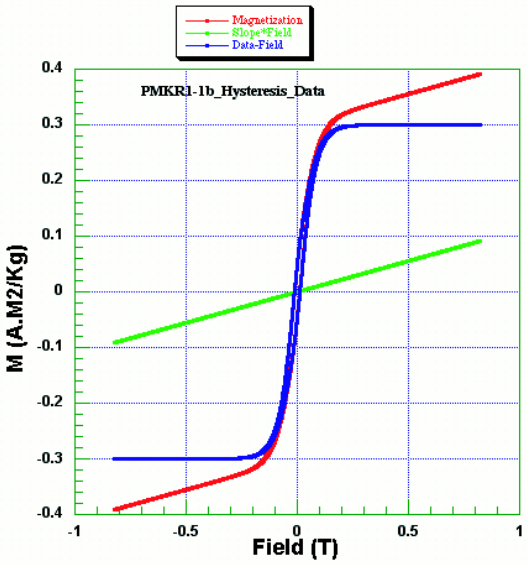


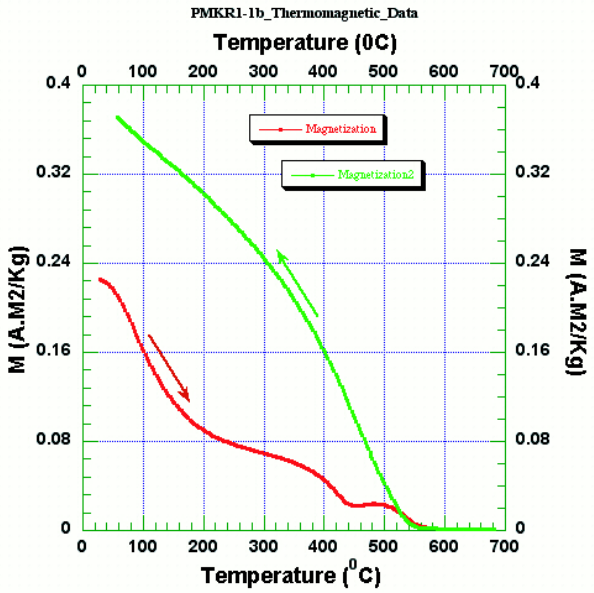
Grain size dependence of the hysteresis parameters

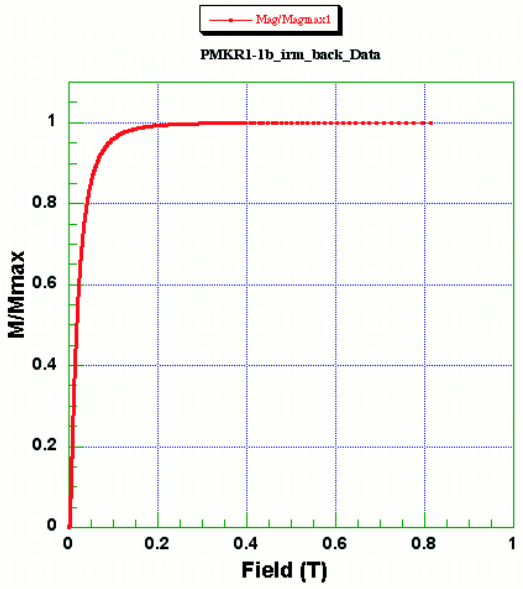


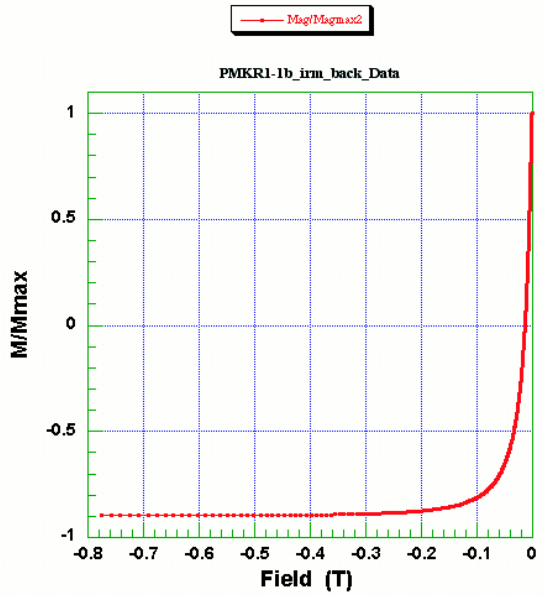
9 of 10 samples measured show heating and cooling curves that are reversible

With a curie point around 580 degree -Magntetite or titano-magnetite





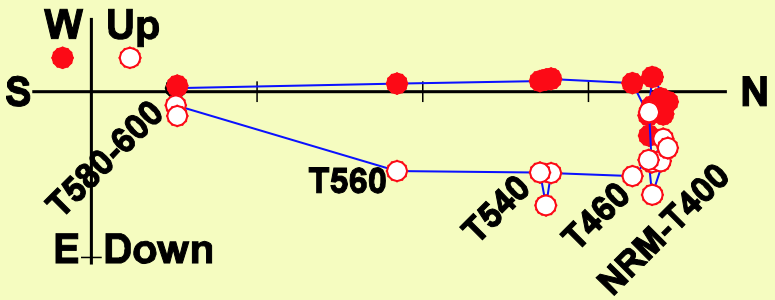




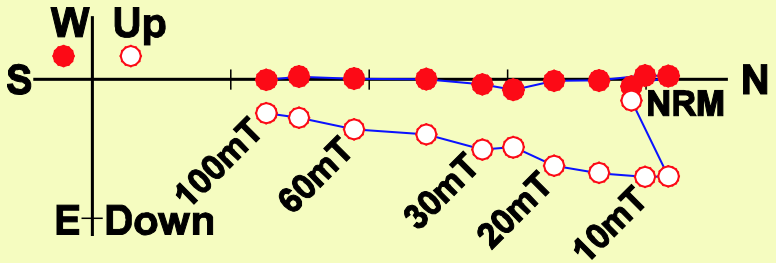
Only 1 sample show Heating and cooling Curves that are irreversible.

In the heating curve, The 1st inflection b/n Temperature 100 -200 is due to goethite and b/n 400 – 500 is due to Maghemite (Larson & Walker, 1975)

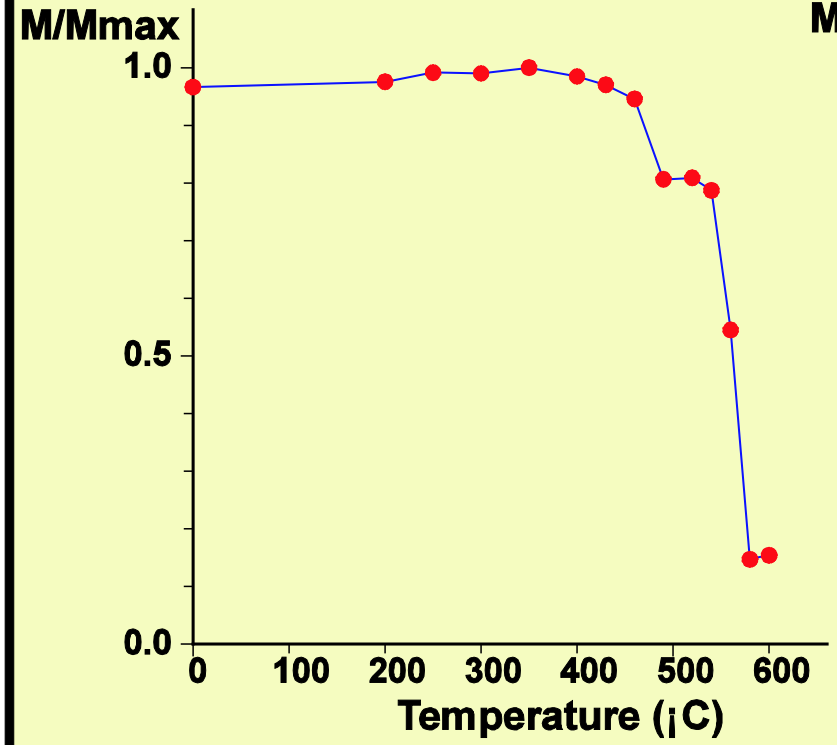
The cooling curve is characterized by large increase in Js owing to the formation of Magnetite due to the disintegration of goethite through hematite (e.g. Dekkers. 1990).



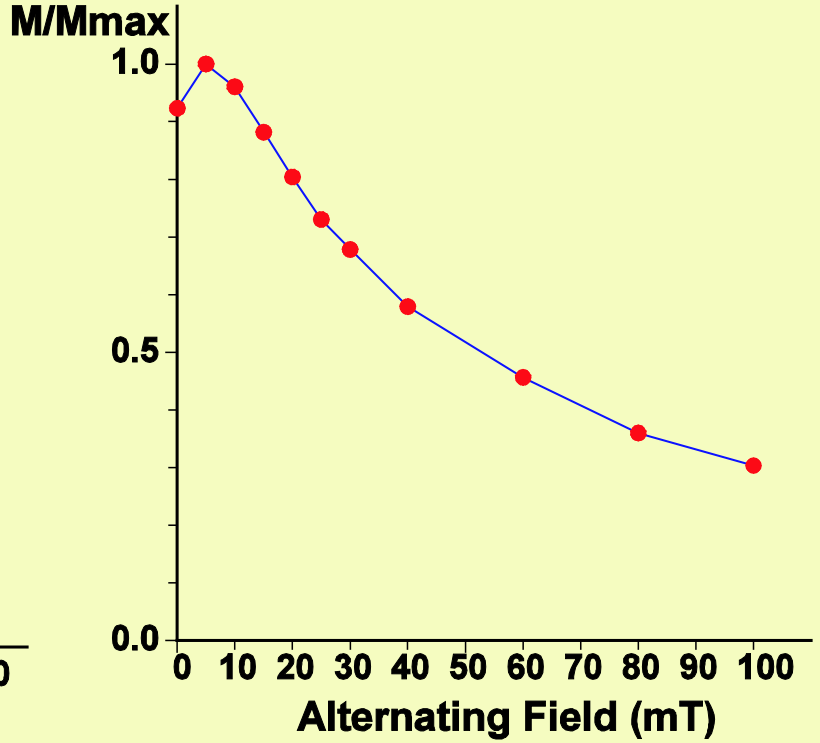
PMSL4-4C



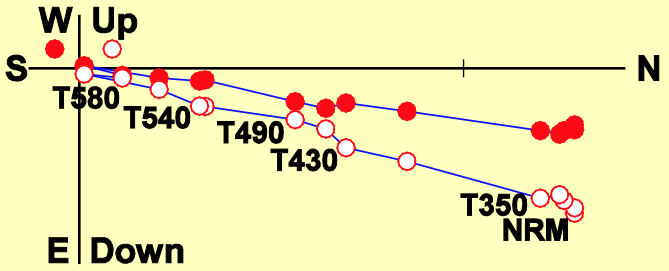
PMSL04-4B



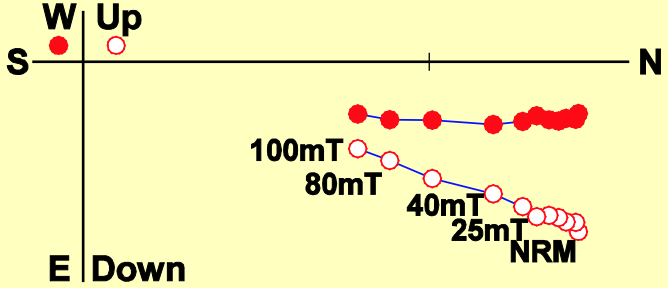
PMSL4-4C



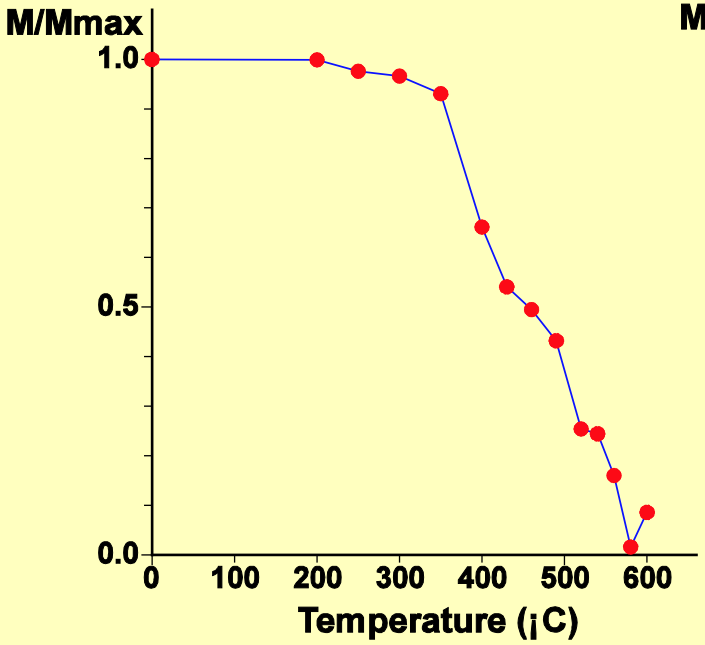
PMSL04-4B



PMAF3-5C



PMAF03-5B



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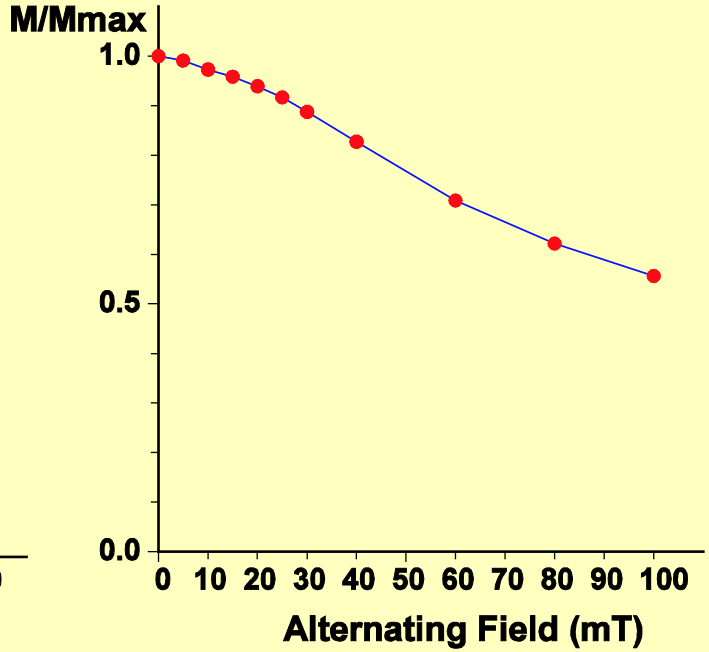

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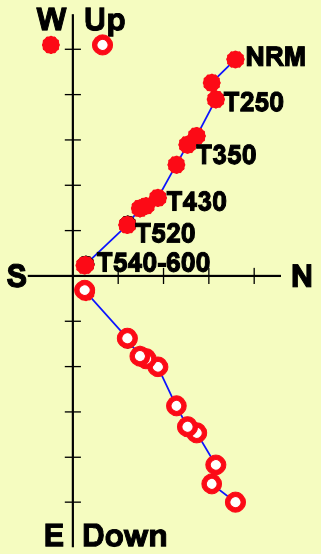

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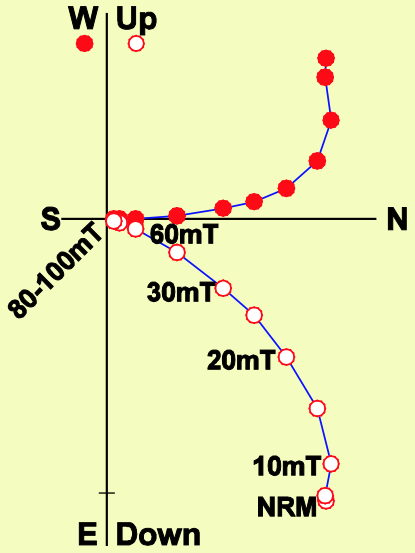

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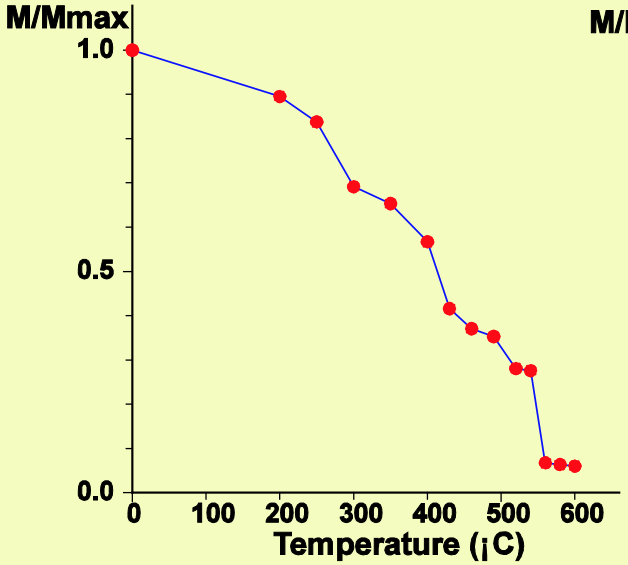

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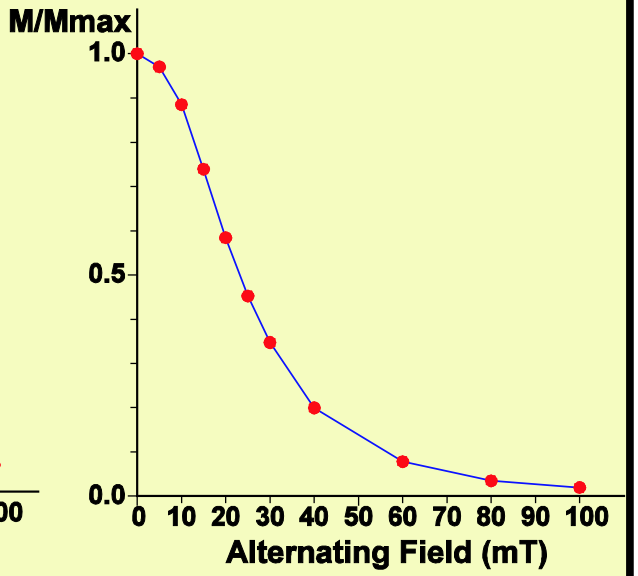

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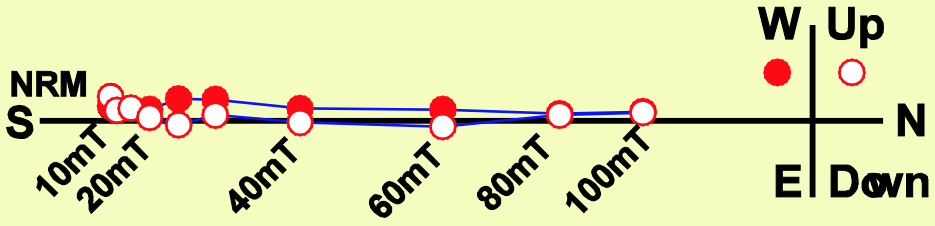

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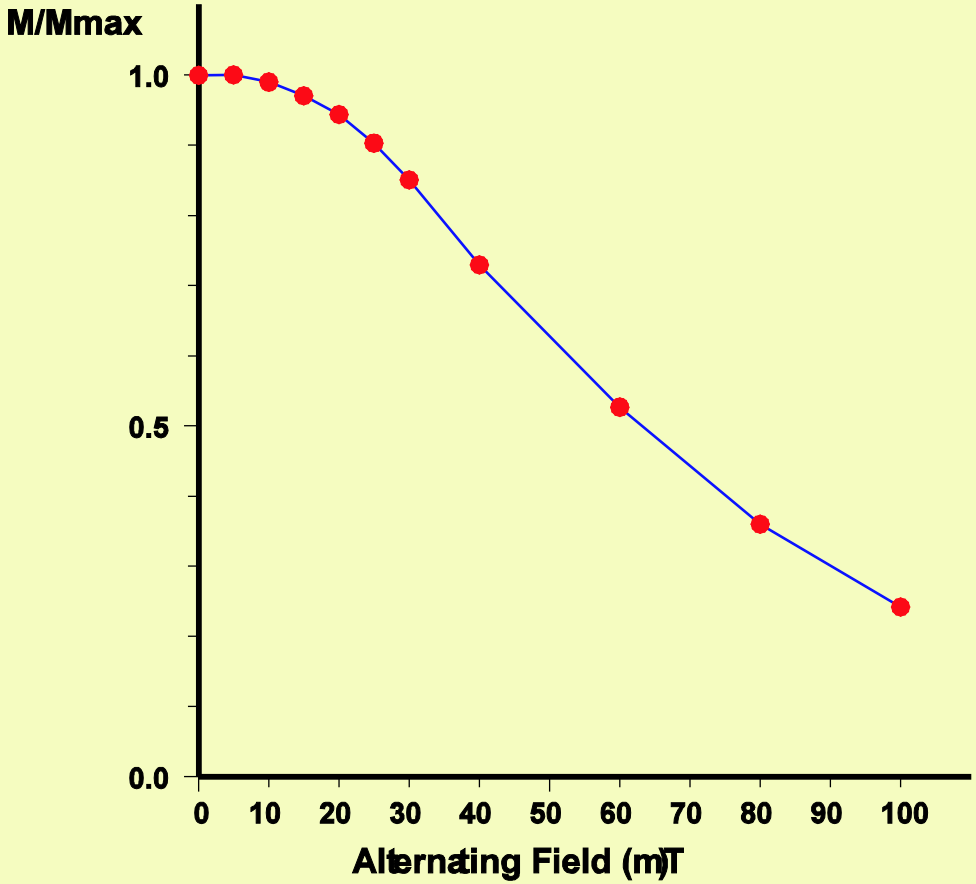

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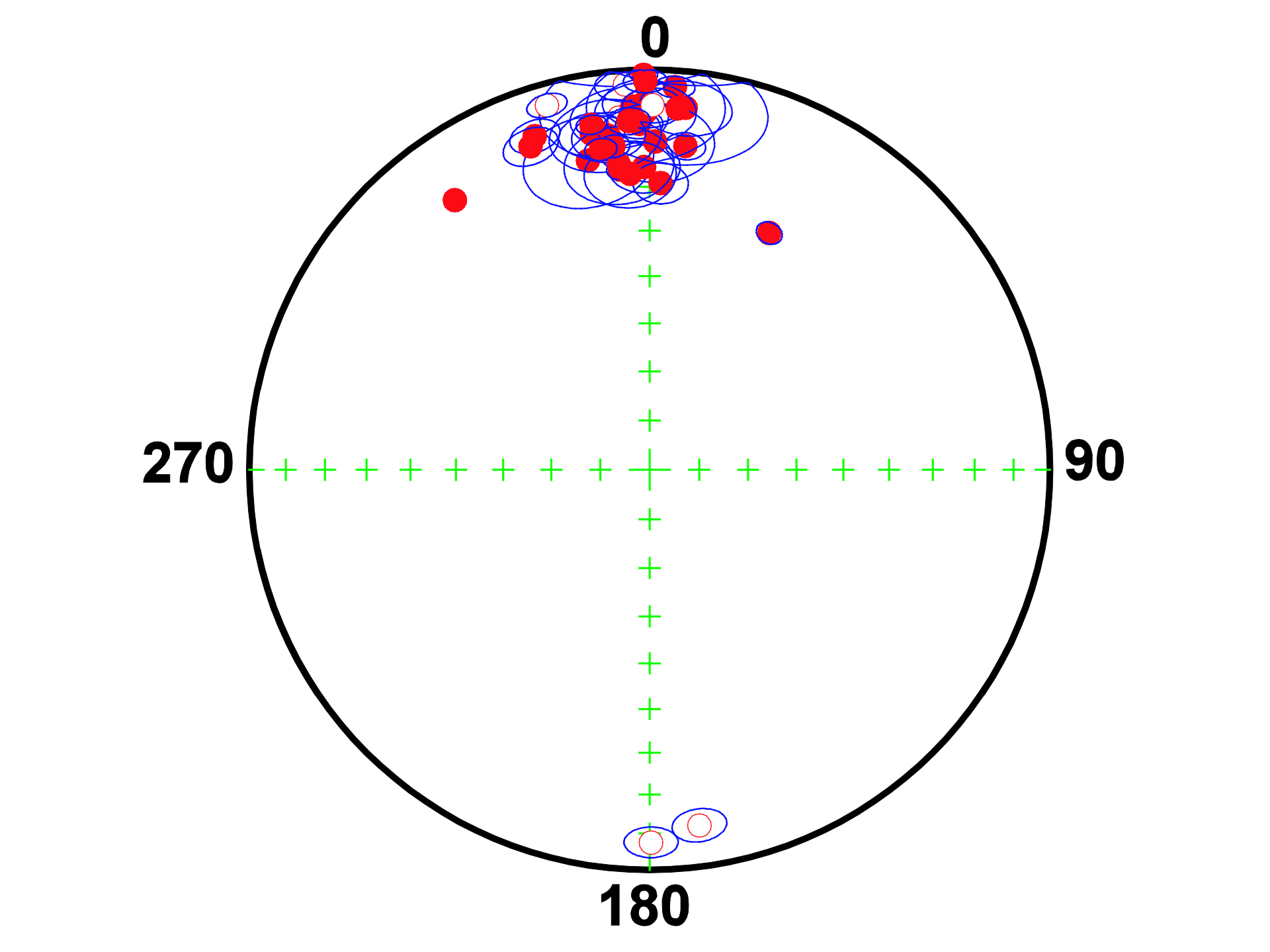
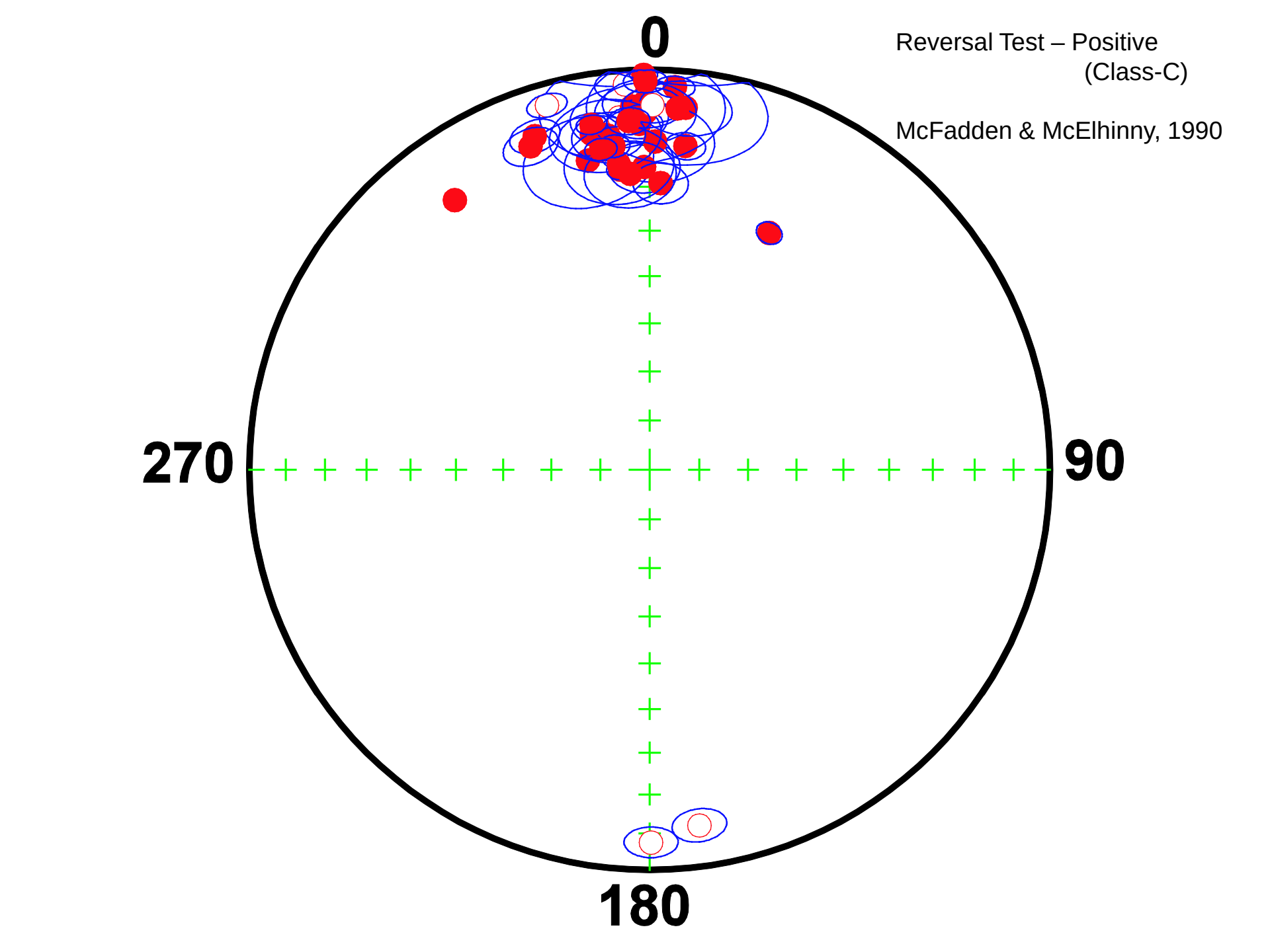
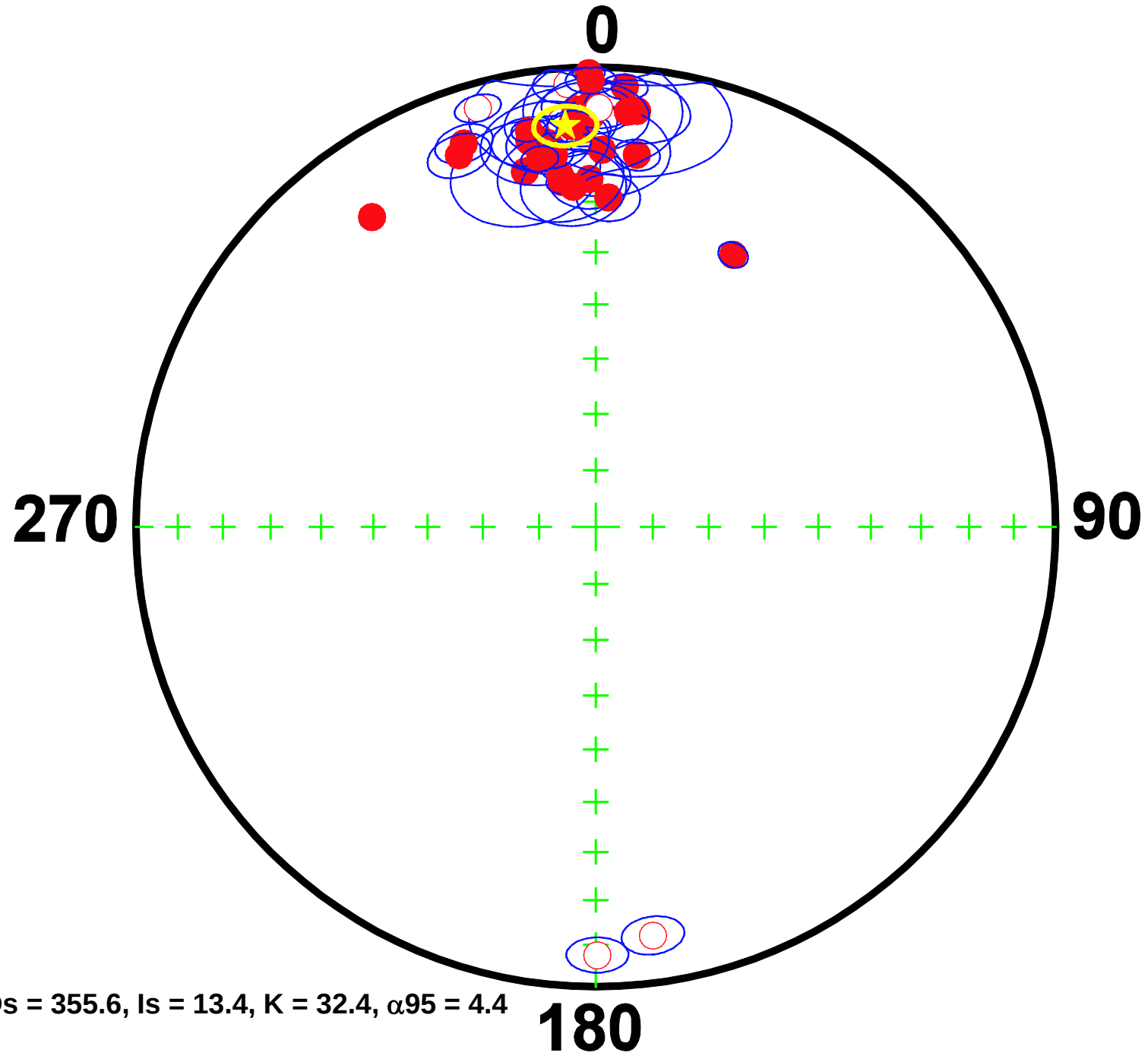
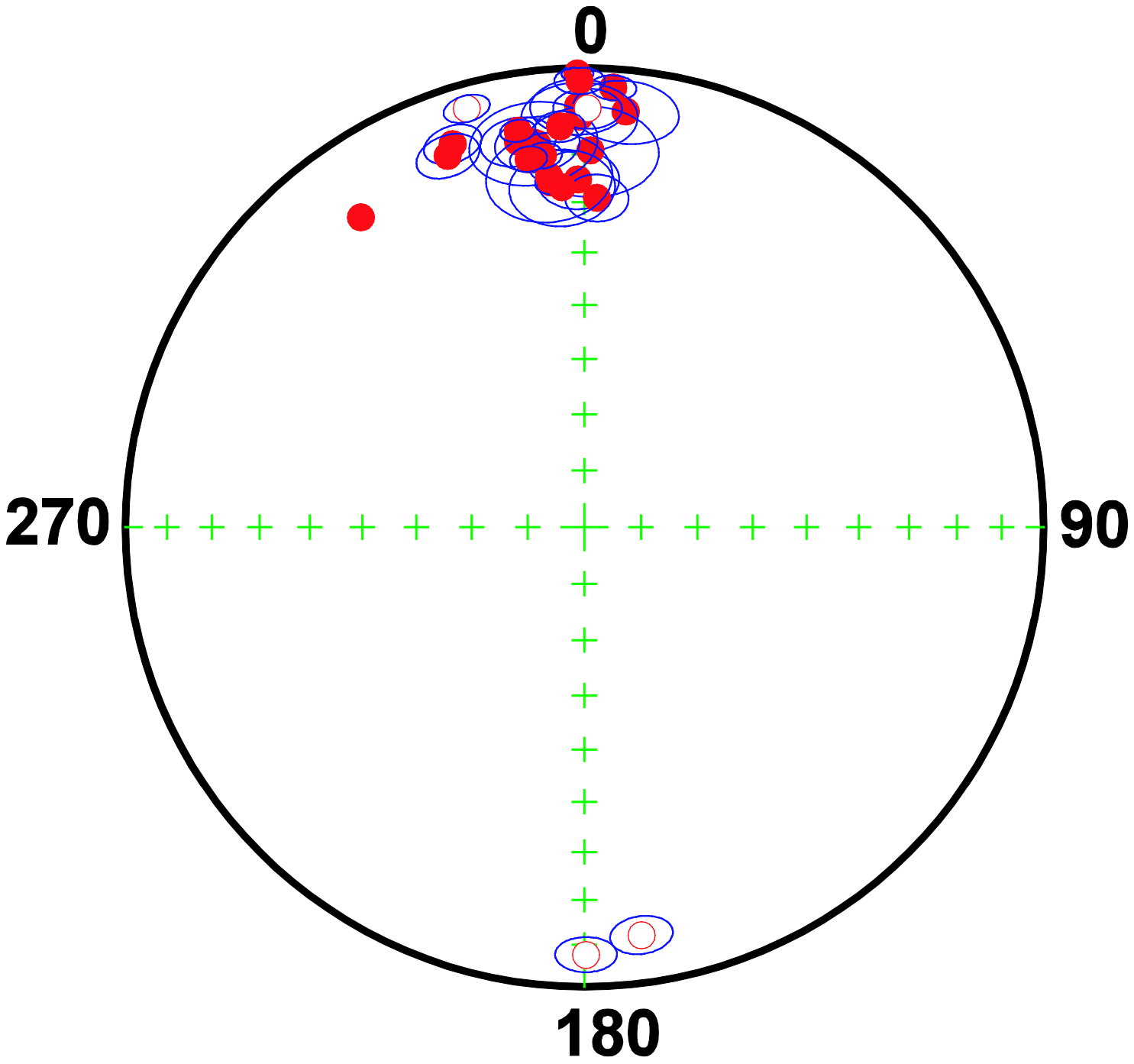

0
270
90
180


0
90
180
270
Reversal Test – Positive
(Class-C)
McFadden & McElhinny, 1990



N=34, Ds = 355.6, Is = 13.4, K = 32.4, α95 = 4.4


0
270
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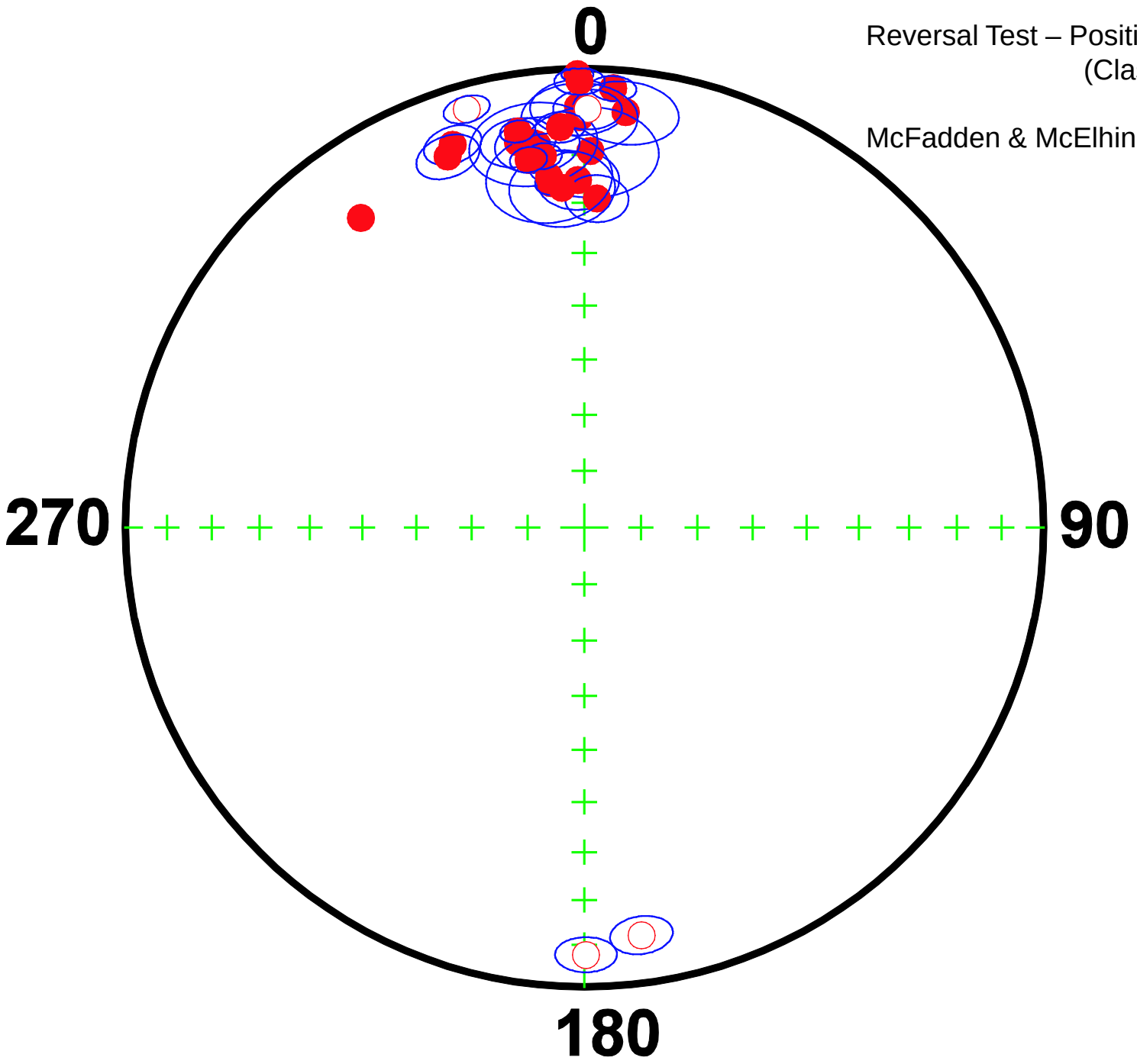
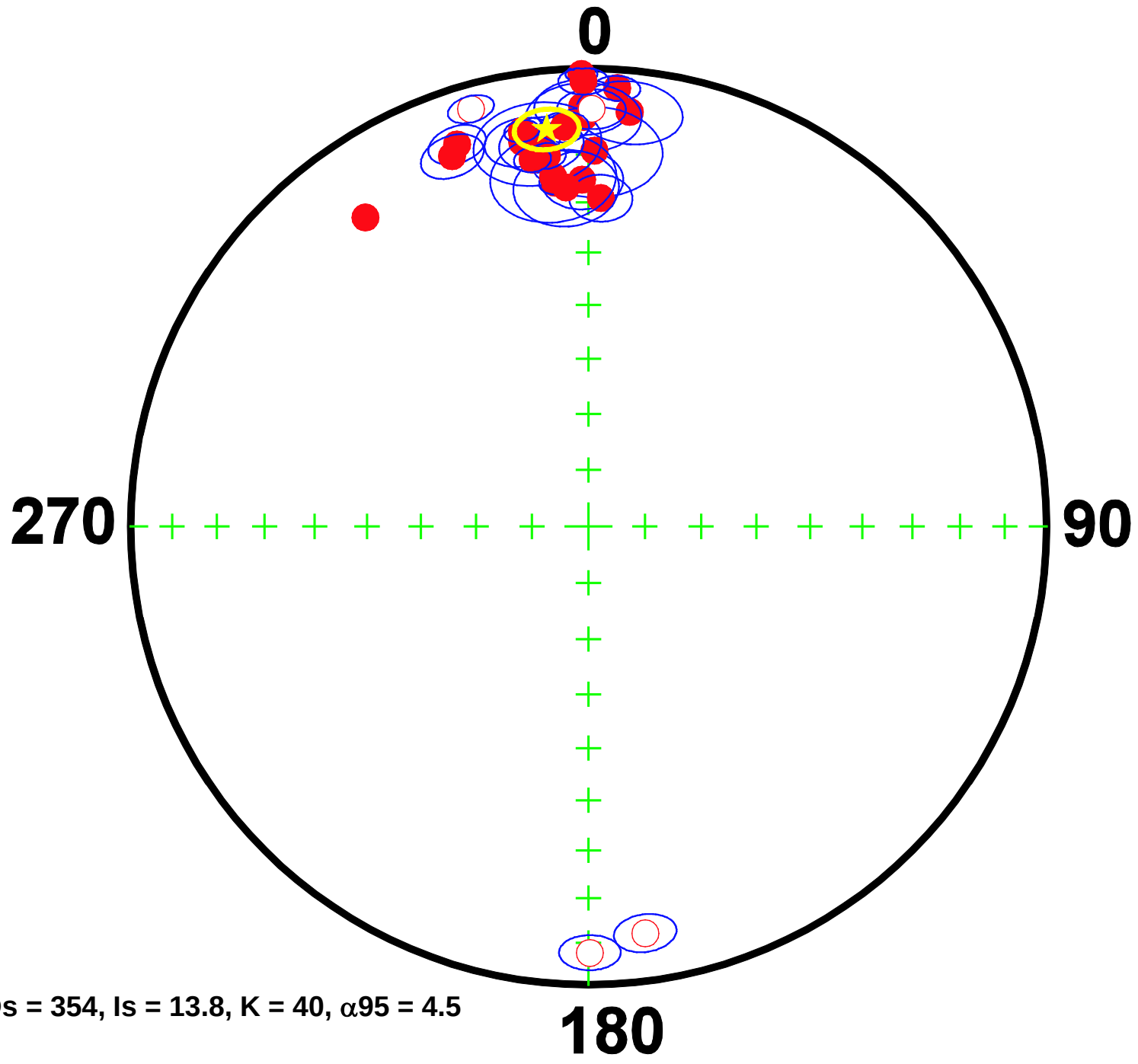
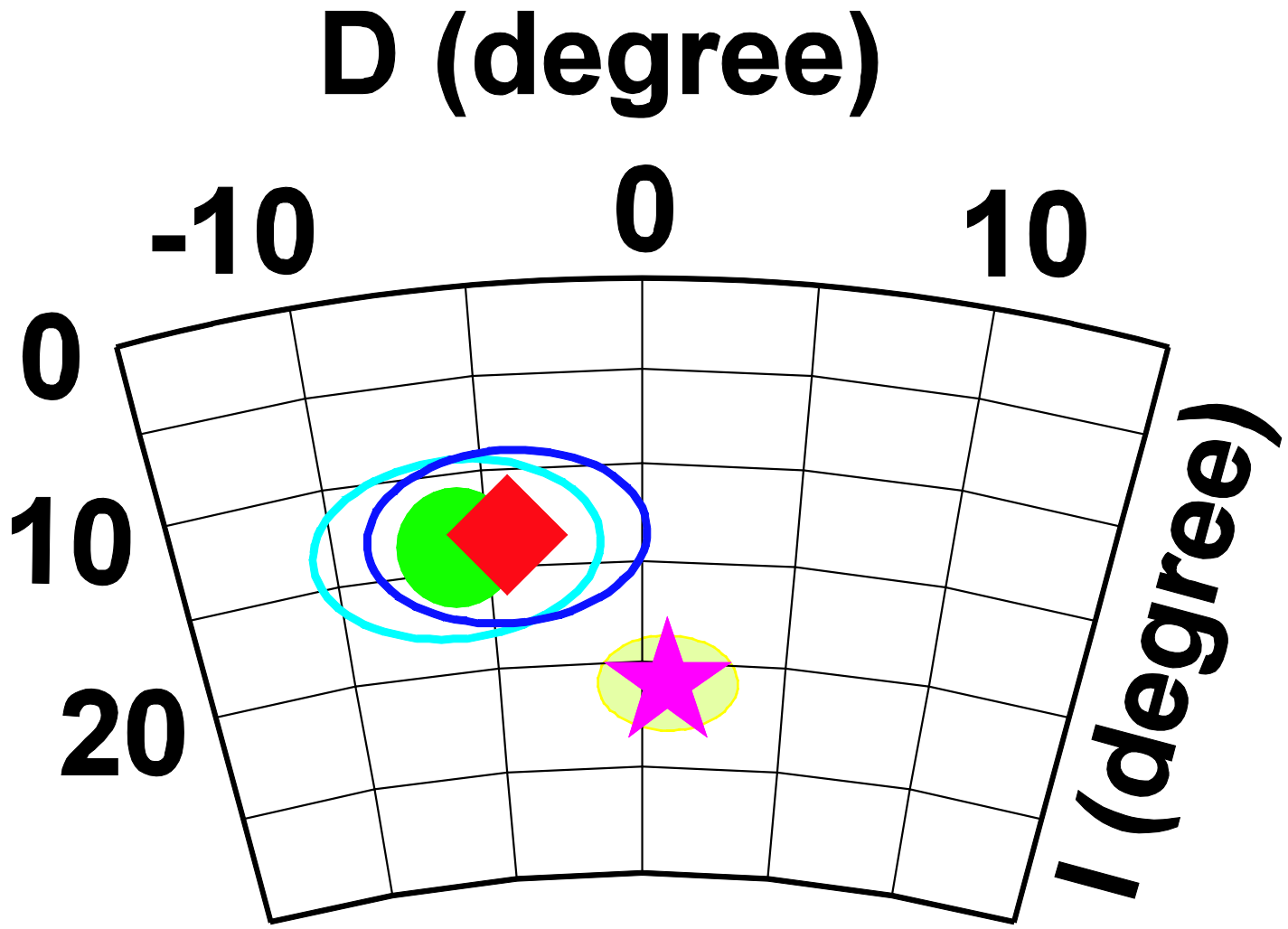


Reversal Test – Positive
(Class-C)

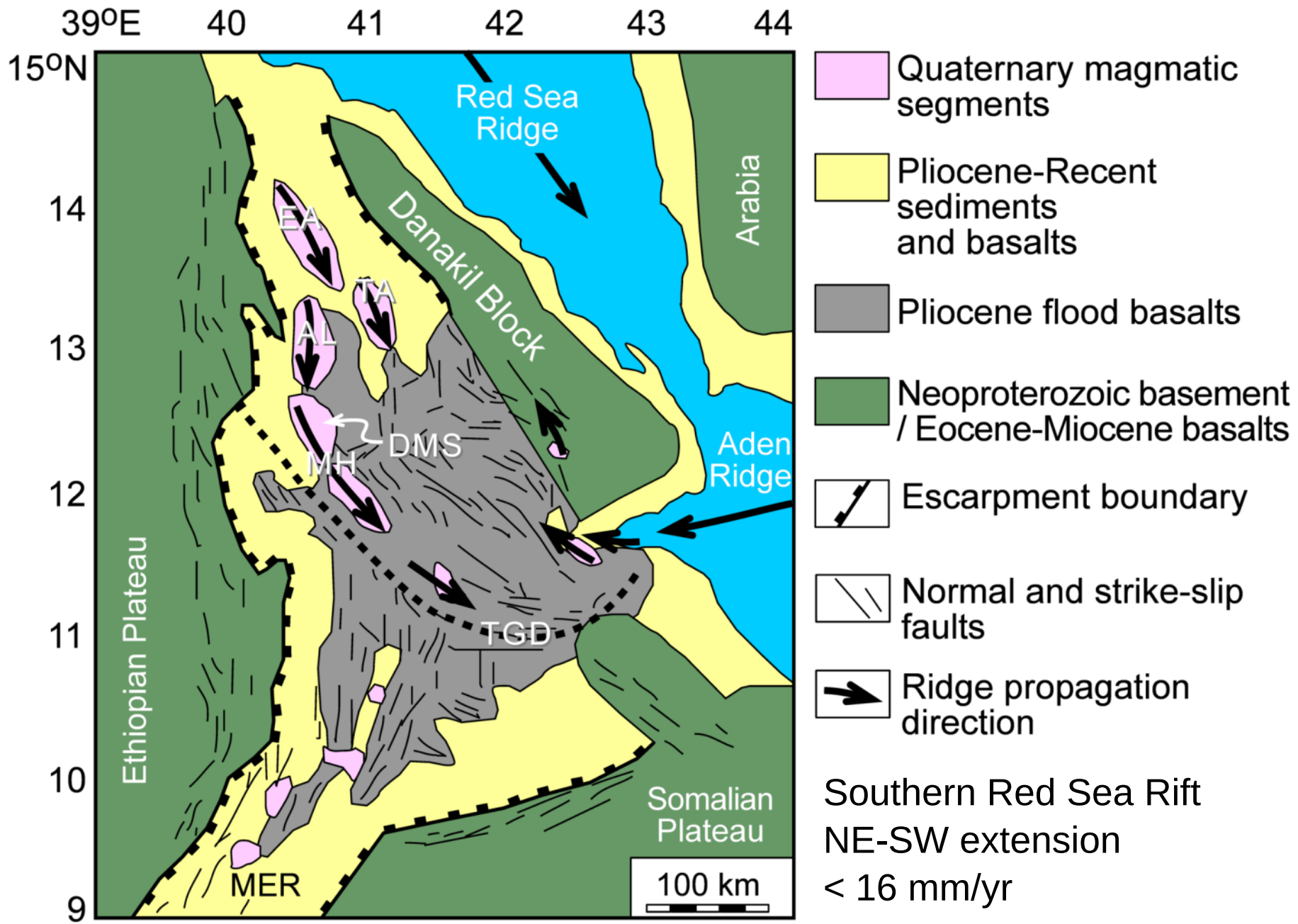
McFadden & McElhinny, 1990



N= 25, Ds = 354, Is = 13.8, K = 40, α95 = 4.5



	D	I	α95	R ± ΔR	F ± ΔF
Diploe	0.9	21	2.3		
Mean1	355.6	13.4	4.4	-5.3 ± 4.1	7.6 ± 4.0
Mean2	354.0	13.8	4.5	-6.9 ± 4.2	7.2 ± 4.2


39°E
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15°N
14
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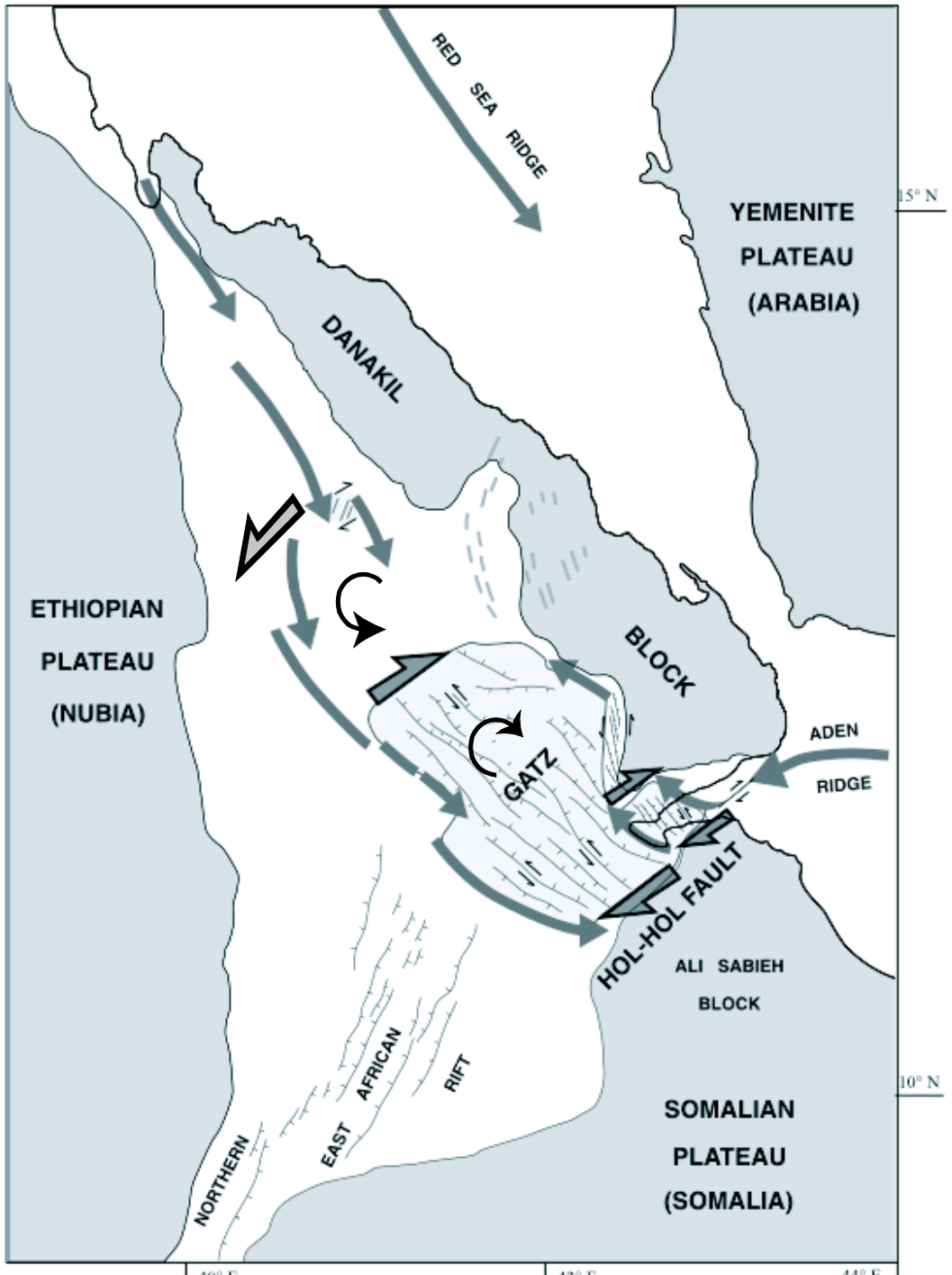
11
10
9
Red Sea Ridge
Danakil Block
Arabia
Aden Ridge
Ethiopian Plateau
Somalian Plateau
EA
TA
AL
MH
DMS
TGD
MER
100 km
Quaternary magmatic segments
Pliocene-Recent sediments and basalts
Pliocene flood basalts
Neoproterozoic basement / Eocene-Miocene basalts
Escarpment boundary
Normal and strike-slip faults
Ridge propagation direction
Southern Red Sea Rift
NE-SW extension
< 16 mm/yr


RED SEA RIDGE
YEMENITE
PLATEAU
(ARABIA)
15° N
DANAKIL
ETHIOPIAN
PLATEAU
(NUBIA)
BLOCK
GATZ
ADEN
RIDGE
HOL-HOL FAULT
ALI SABIEH
BLOCK
10° N
SOMALIAN
PLATEAU
(SOMALIA)
NORTHERN
EAST AFRICAN
RIFT

Conclusion

- After rigorous paleomagnetic procedures, the dominant magnetic minerals carrying magnetizations are magnetite and titanomagnetite with subordinate goethite/Maghemite in some samples .
- The magnetic grain sizes are all within PSD.
- The age of the samples analysed ranges between 1.1 Ma and .07 Ma, which exceeds the typical Secular variations.
- The observed rotation could not be due to the major overlap b/n Southern Red sea rifts and Gulf of Aden Ridges.
- The observed counterclockwise rotation could probably be due to the right stepping and overlap of the southward propagating Red Sea rifts.

THANK YOU