

Pressure demagnetization of synthetic Al substituted hematite and its implications for planetary studies

1/32

Zhaoxia Jiang, Pierre Rochette, Qingsong liu, Jérôme Gattacceca, Yongjae Yu, Vidal Barrón, José Torrent

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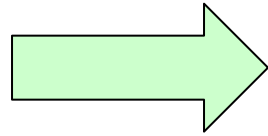
Outline

2/32

- Introduction
 - high pressure demagnetization
 - Al substituted hematite
- Experiments
- Results and discussions
- Conclusions

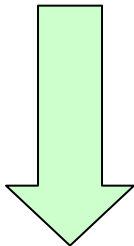
Introduction

3/32

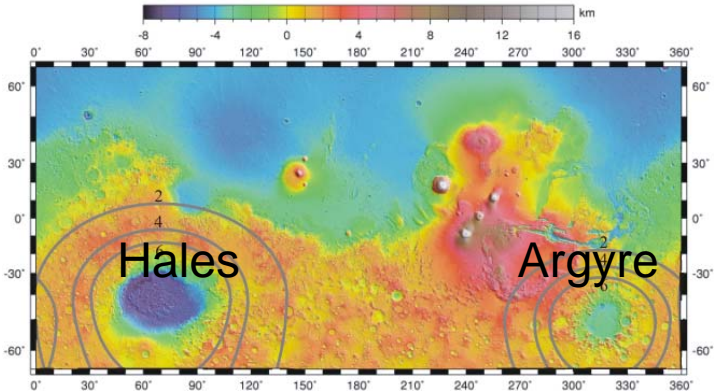
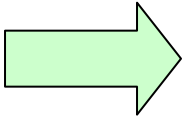
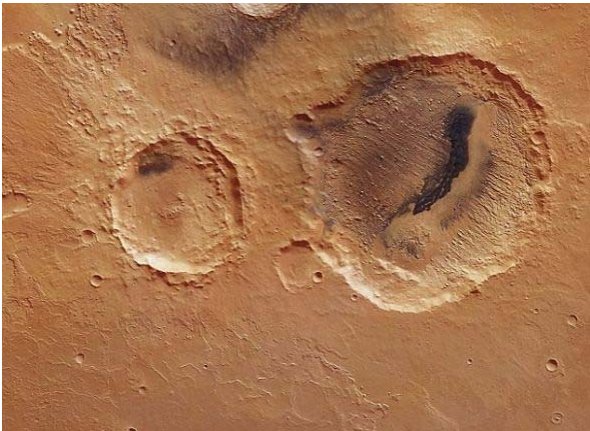


High pressure
&
high temperature

How?



demagnetization

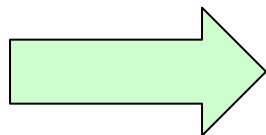


Basins on the Mars

Magnetic anomalies distribution
(Hood et al., 2003)

Introduction

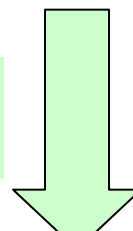
4/32



High pressure
&
high temperature

How?

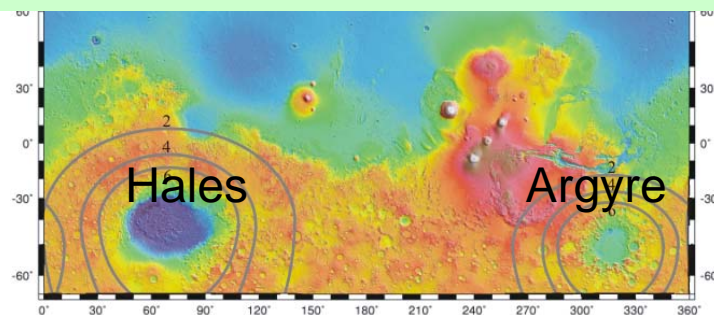
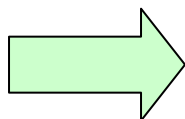
demagnetization



High pressure experiment in the lab!



Basins on the Mars



Magnetic anomalies distribution
(Hood et al., 2003)

Introduction

5/32

The main candidate magnetic minerals on Mars:

Mineral and Domain State	T_C , °C	M_s , kA/m	TRM, kA/m	Size, μm	Vol. %
SD magnetite	580	480	5–10	<0.1	0.2–0.4
SD pyrrhotite	320	≈ 100	2–4	<1.5	1 – 2
MD hematite	675	≈ 2.5	0.5–1	>15	1.5 – 3
Hemoilmenite lamellae	530–650	≤ 55	$\leq 0.5?$	<3?	≥ 3
SD hematite	675	≈ 2.5	≥ 0.2	2–15	≤ 10
SD TM60	150	125	1–2.5	<0.6	3 – 8
SD iron	765	1715	20–35	<0.025	0.05–0.1

(*Dunlop & Arkani-Hamed, 2005*)

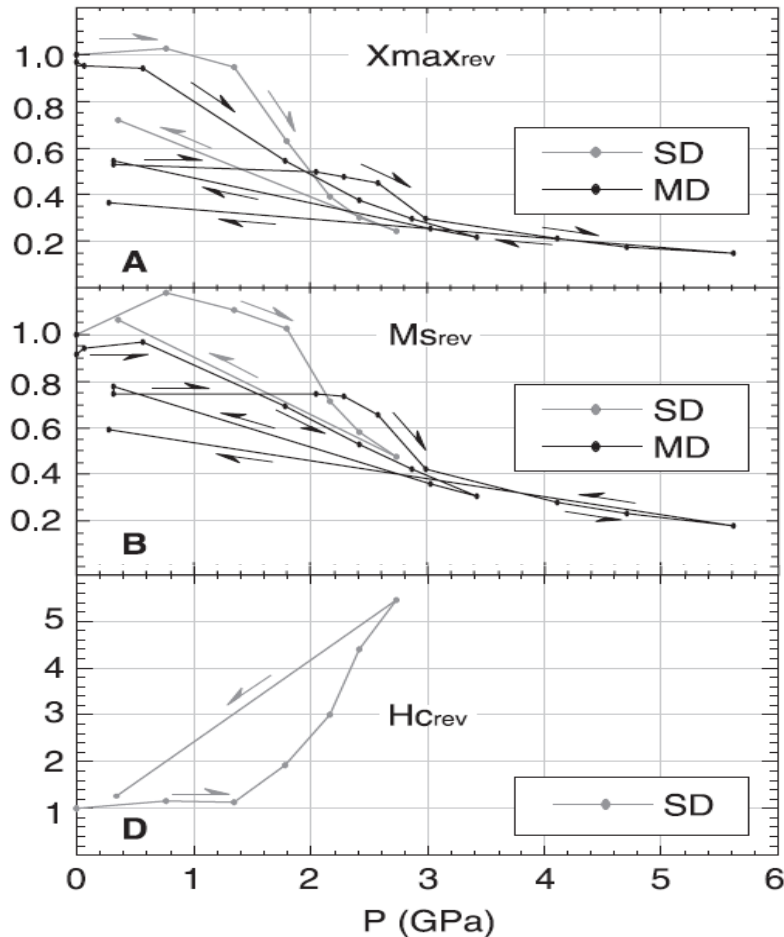
Based on the volume percentage:

Hematite > Pyrrhotite > Magnetite

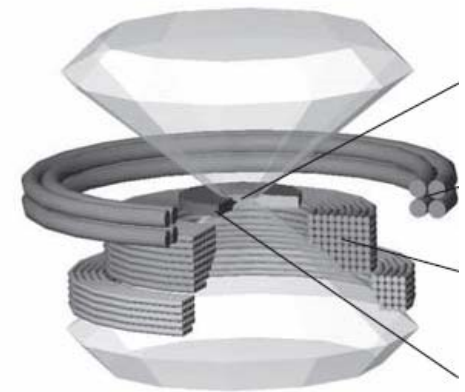
Introduction

6/32

High pressure measurement of Magnetite



Stuart Gilder



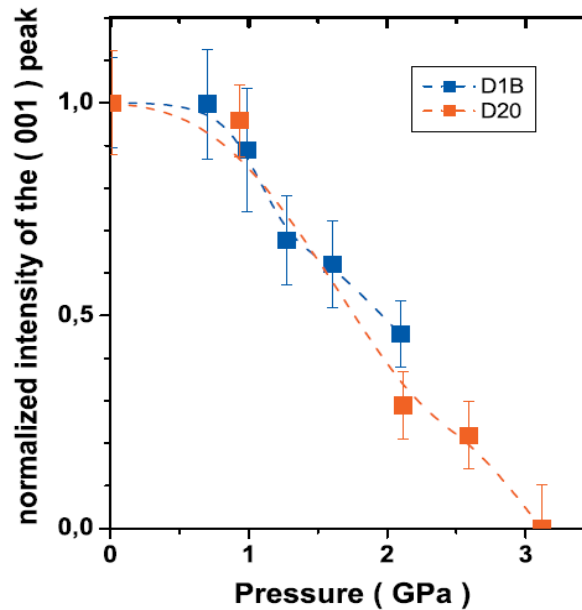
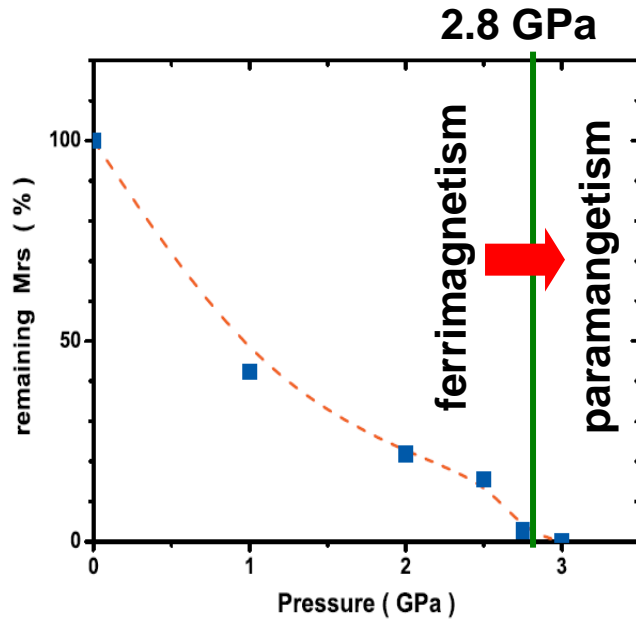
Diamond

Uniaxial pressure

Introduction

7/32

High pressure measurement of Pyrrhotite



Pierre Rochette



Karin Louzada

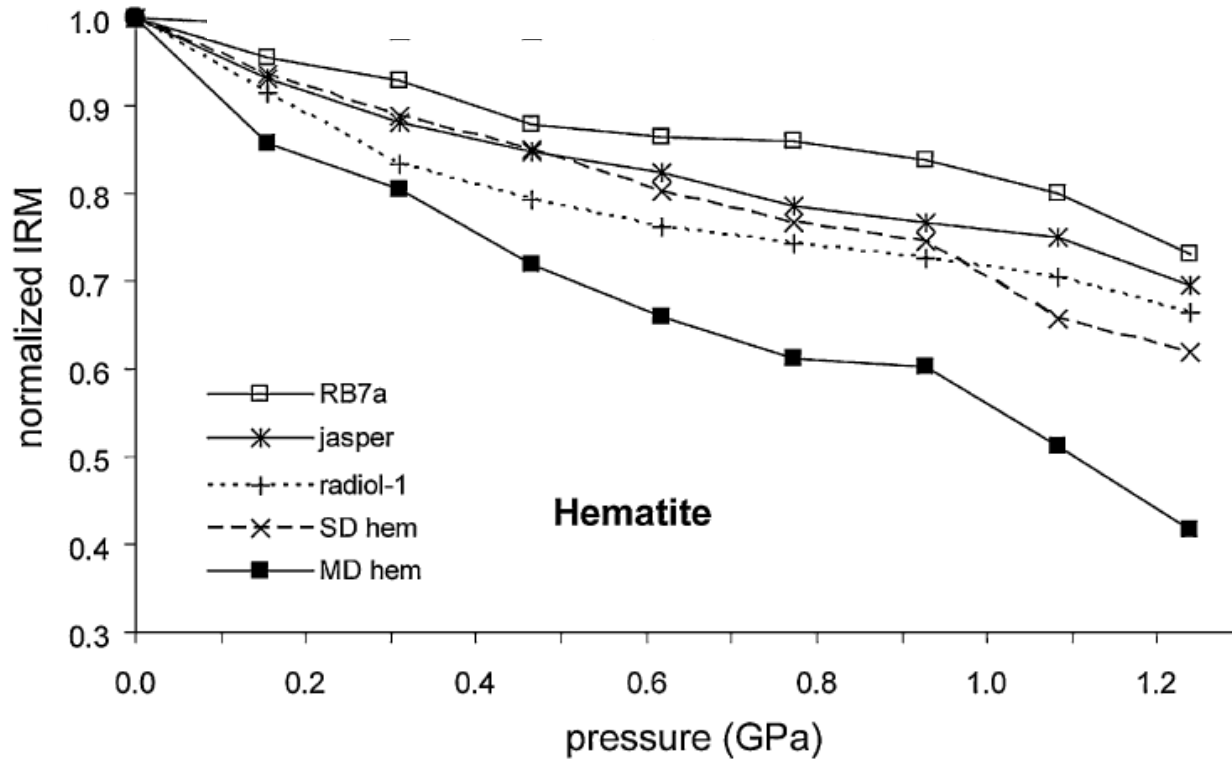
Rochette et al. (2003)

Hydrostatic pressure

Introduction

8/32

The pressure demagnetization behavior of hematite:



Bezaeva et al.(2010)

High pressure has a significant influence on the remanent of magnetic Minerals

Introduction

9/32

Al substituted hematite (Al-hematite):

soils (Schwertmann et al., 1977)

red beds (Torrent et al., 1987; Dekkers et al., 1989)

Mars (perhaps) (Hurowitz et al., 2007)

what is the behavior of the Al-hematite under pressure?

Experiments

10/32

Materials:

12 samples

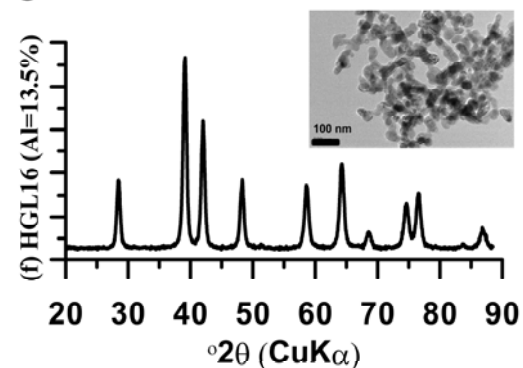
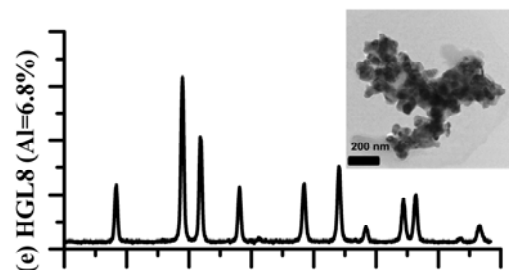
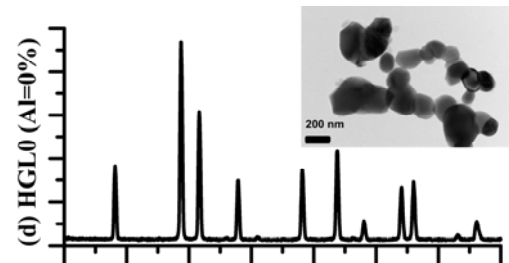
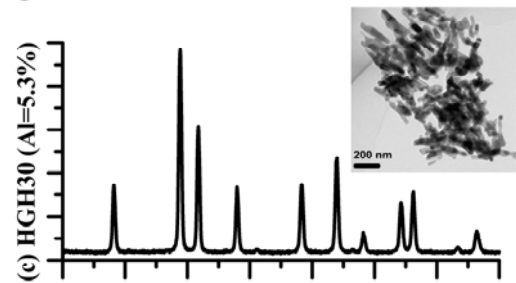
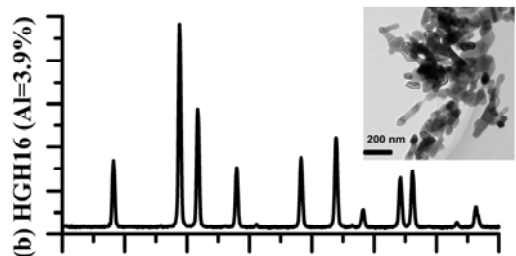
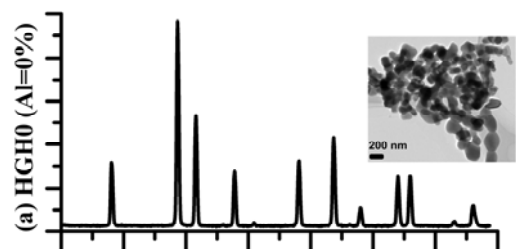
HGH* series:

HGH0, HGH2, HGH4,
HGH8, HGH16, HGH20,
HGH30

HGL* series:

HGL0, HGL4, HGL8,
HGL16, HGL20

Al content: 0~16 mol%



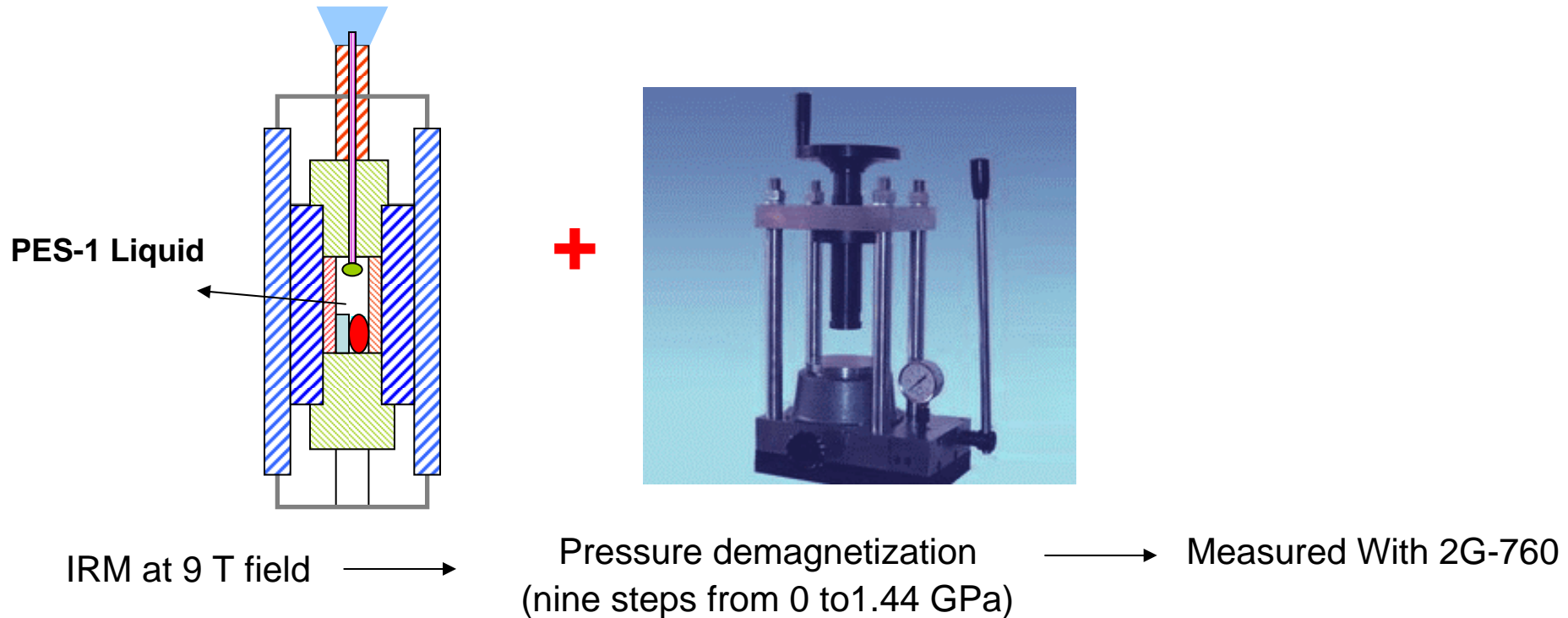
Experiments

11/32

(1) Prepare samples



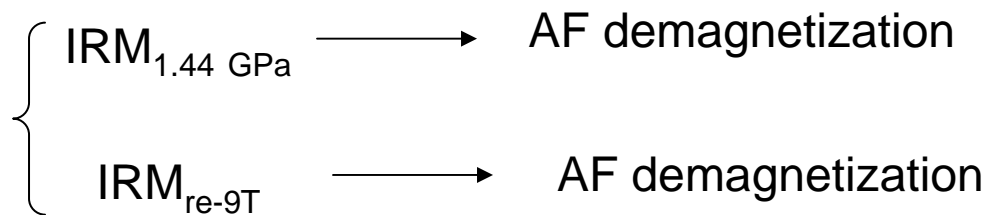
(2) Pressure demagnetization (in the shielding room)



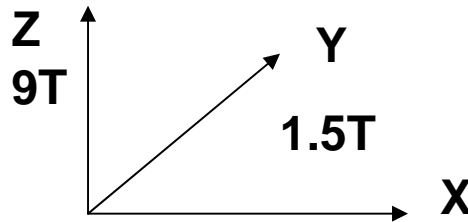
Experiments

12/32

(3) Compare with AF demagnetization



HGL4 & HGL0

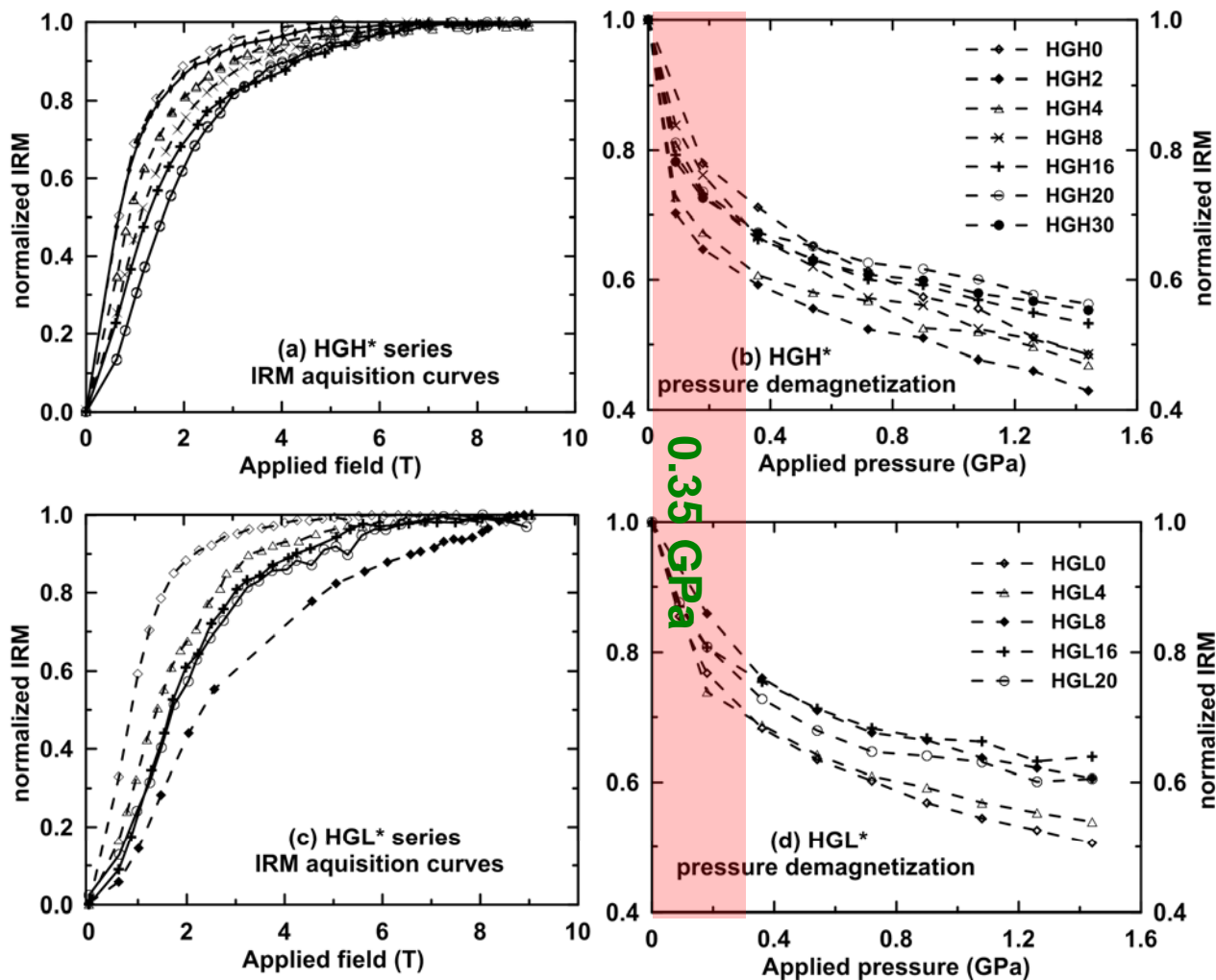


→ Pressure demagnetization

Results and discussions

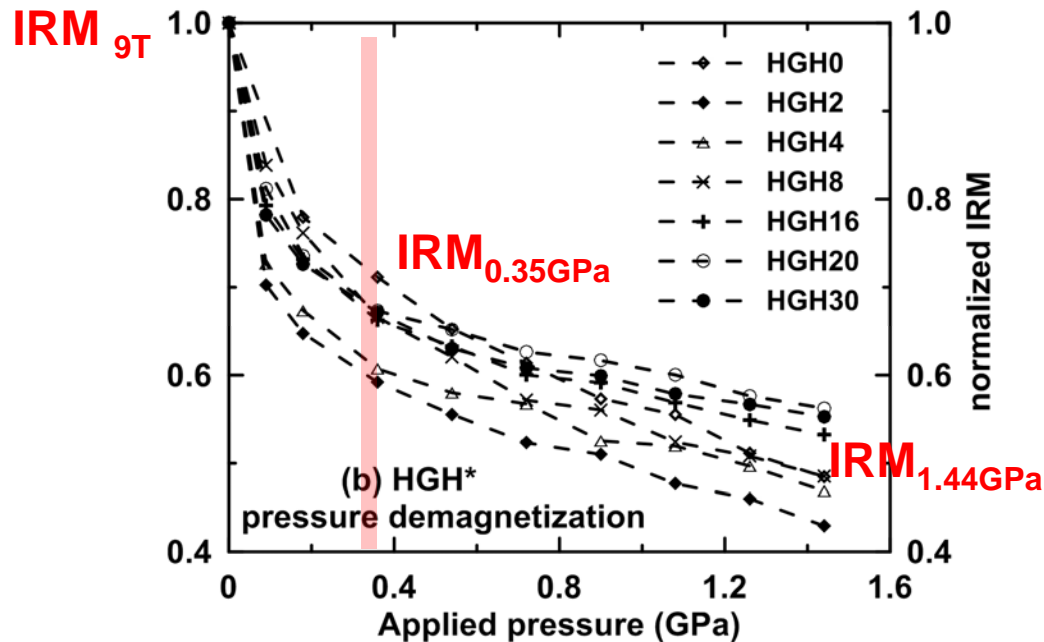
13/32

(1) pressure demagnetization of Al-hematite



Results and discussions

14/32



Pressure demagnetization degree:

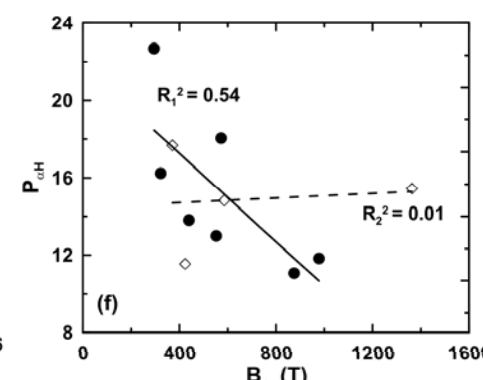
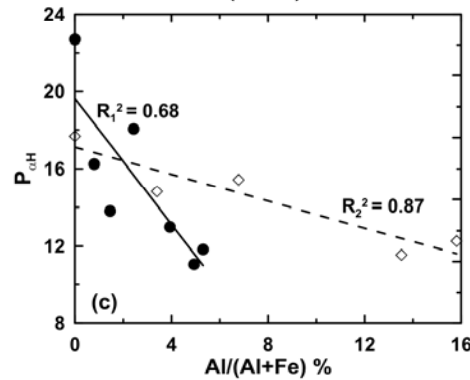
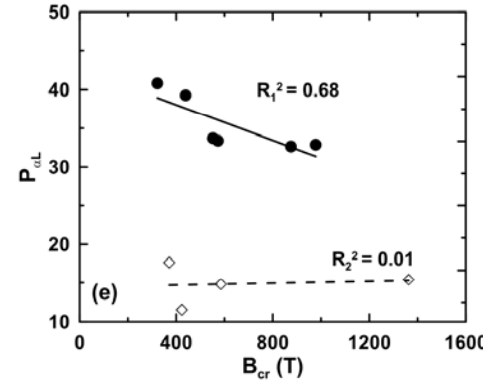
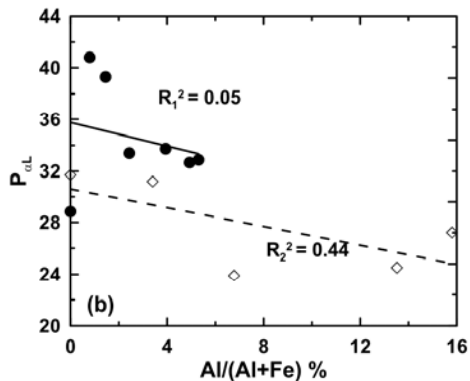
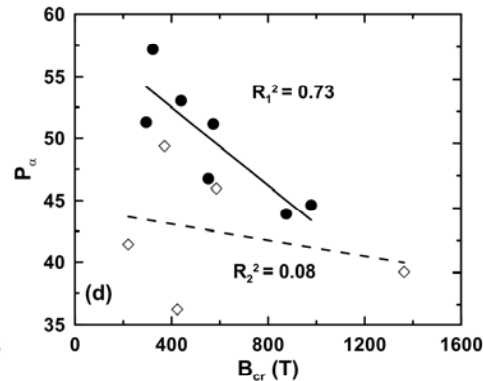
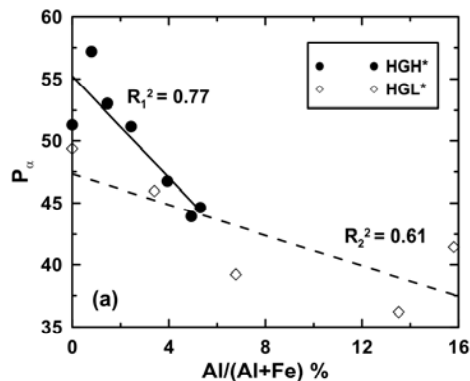
$$P_{\alpha} = 100 \times (IRM_{9T} - IRM_{1.44GPa}) / IRM_{9T} \%$$

$$P_{\alpha L} = 100 \times (IRM_{9T} - IRM_{0.35GPa}) / IRM_{9T} \%; \text{ low pressure section}$$

$$P_{\alpha H} = 100 \times (IRM_{0.35GPa} - IRM_{1.44GPa}) / IRM_{9T} \%; \text{ high pressure section}$$

Results and discussions

15/32



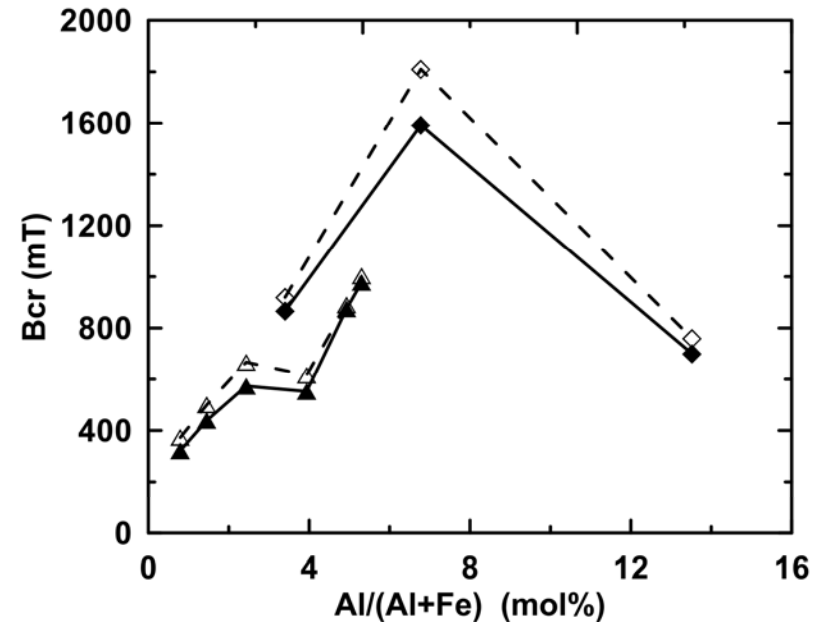
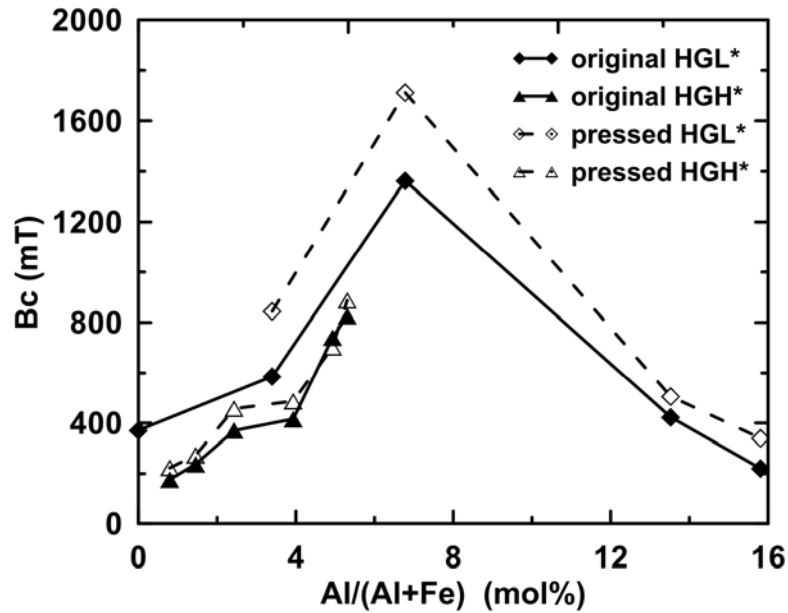
(1) P_{α} , $P_{\alpha L}$, and $P_{\alpha H}$ are linearly correlated negatively with both Al content and B_{cr} ;

(2) $P_{\alpha L}$ is sensitive to the Al content and B_{cr} ;

(3) These parameters are more correlated with Al content.

Results and discussions

16/32

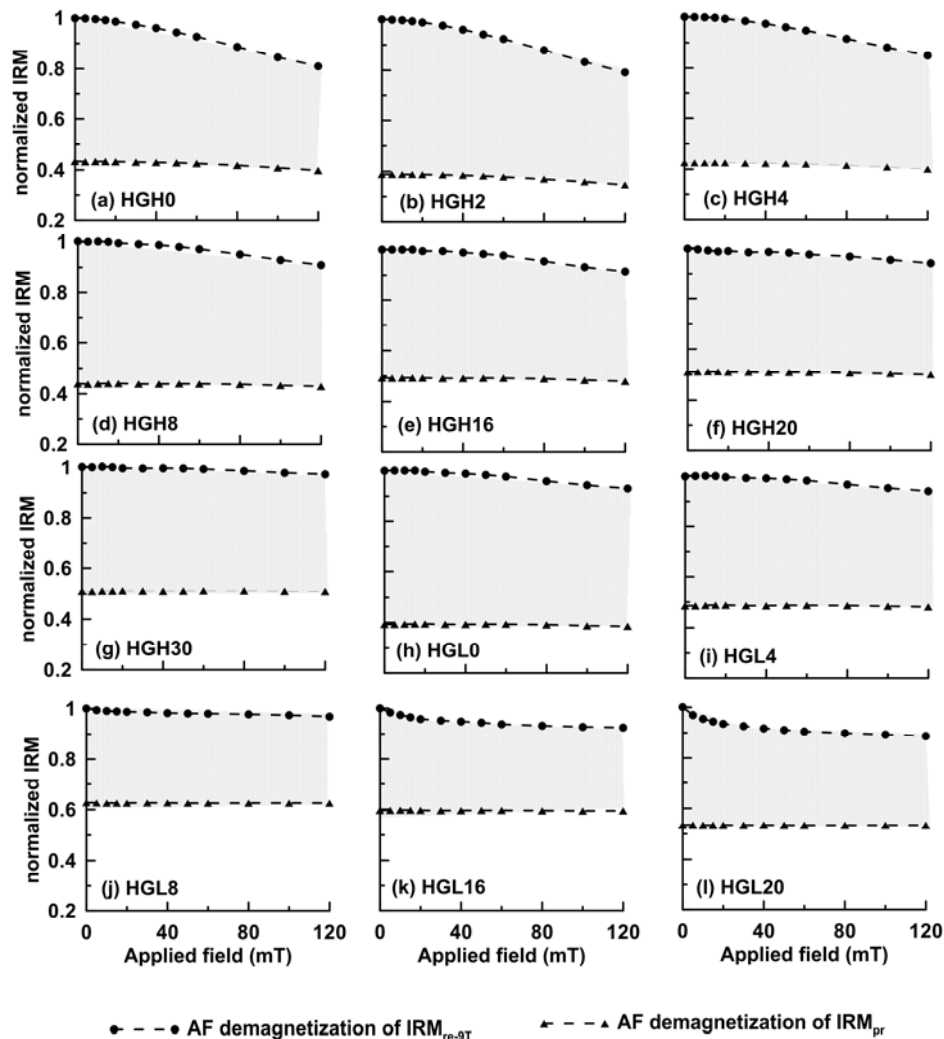


B_c and B_{cr} are slightly enhanced

Results and discussions

17/32

(2) Comparison between pressure and AF demagnetization



$IRM_{1.44GPa}$ are slightly demagnetized by AF;

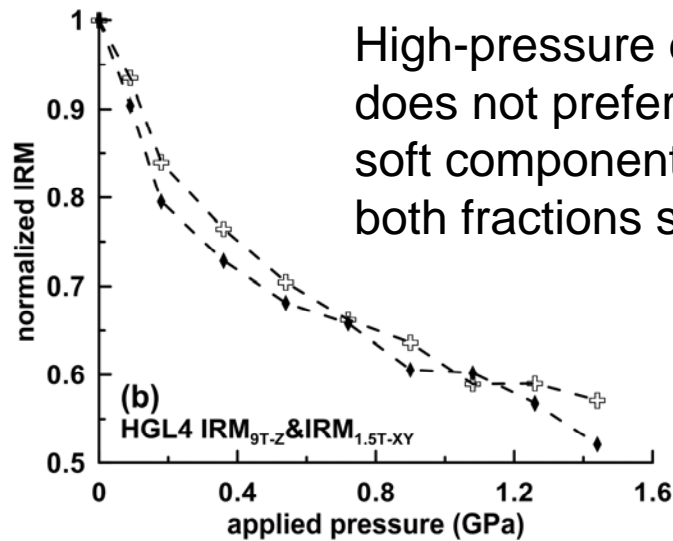
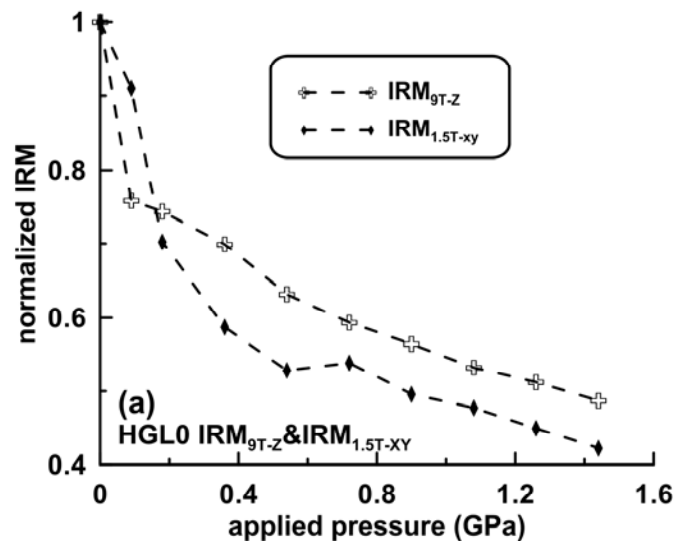
10~20% IRM_{re-9T} can be demagnetized by AF;

The shaded area can be taken as the differences of pressure and AF demagnetization.

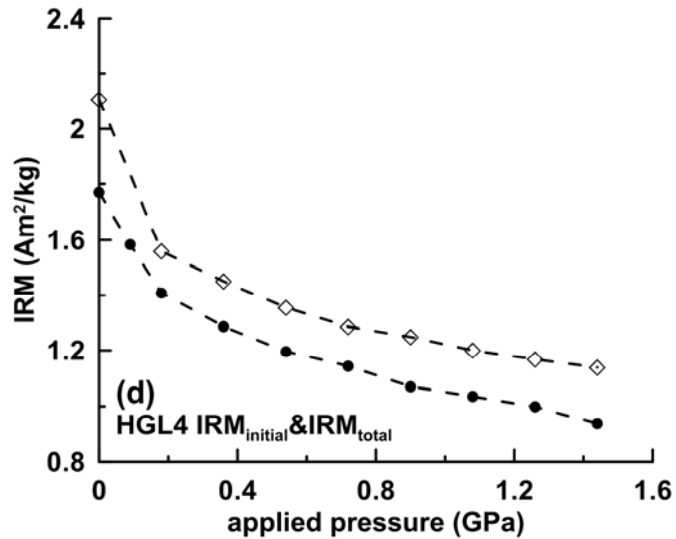
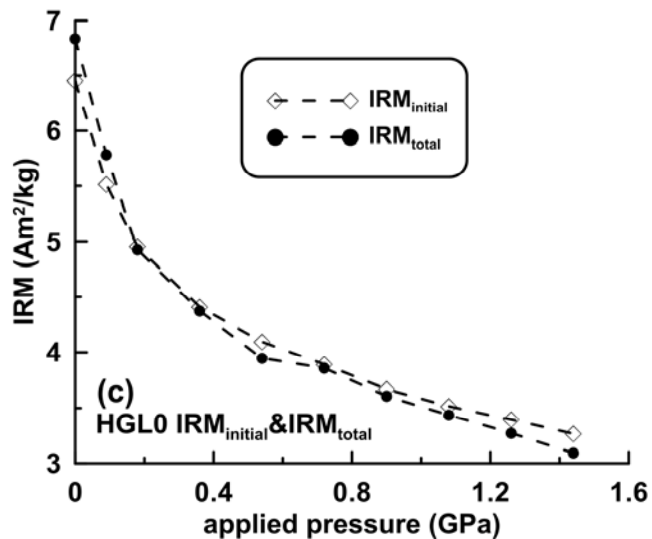
Is there some preferences on Soft component?

Results and discussions

18/32

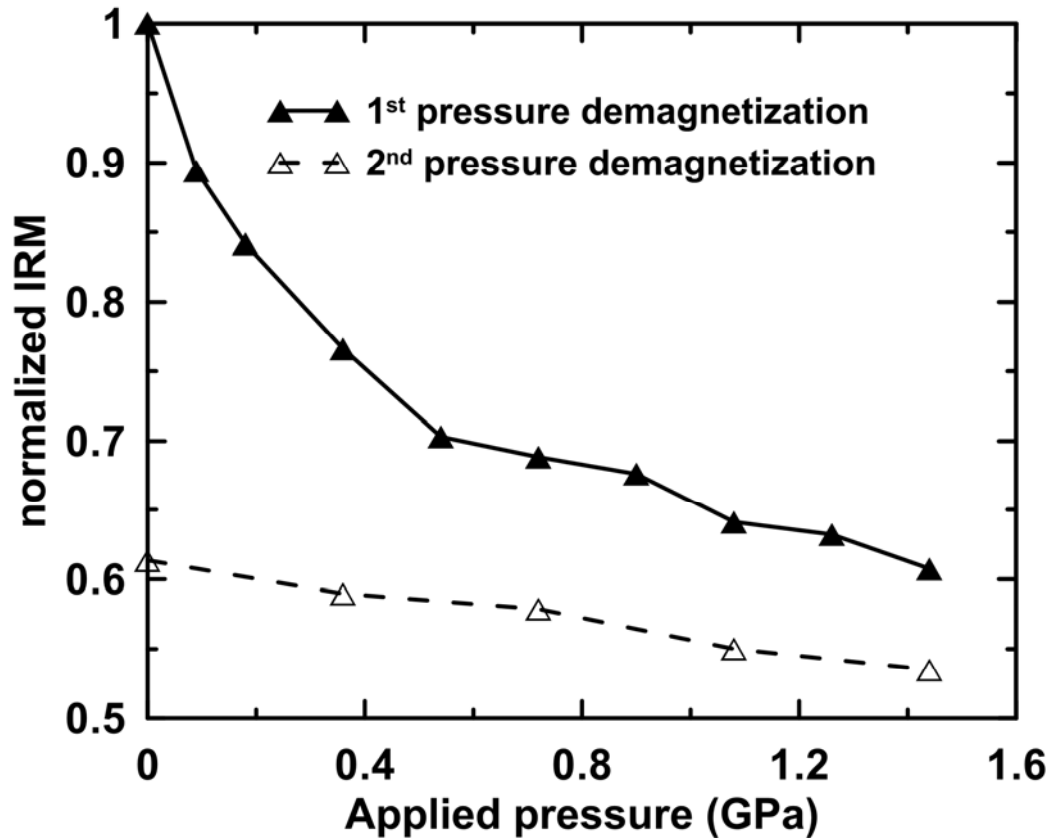


High-pressure demagnetization does not preferentially work on soft component but affect both fractions simultaneously.



Results and discussions

19/32



IRM can be reduced by repeated compression

Results and discussions

20/32

Summary:

- (1) A half of initial IRM can be destroyed by a pressure of 1.44 GPa;**
- (2) Demagnetization degree is correlated with Al content and remanent coercivity;**
- (3) High pressure demagnetization is more effective than AF demagnetization. in addition, it can work on both soft and hard components.**

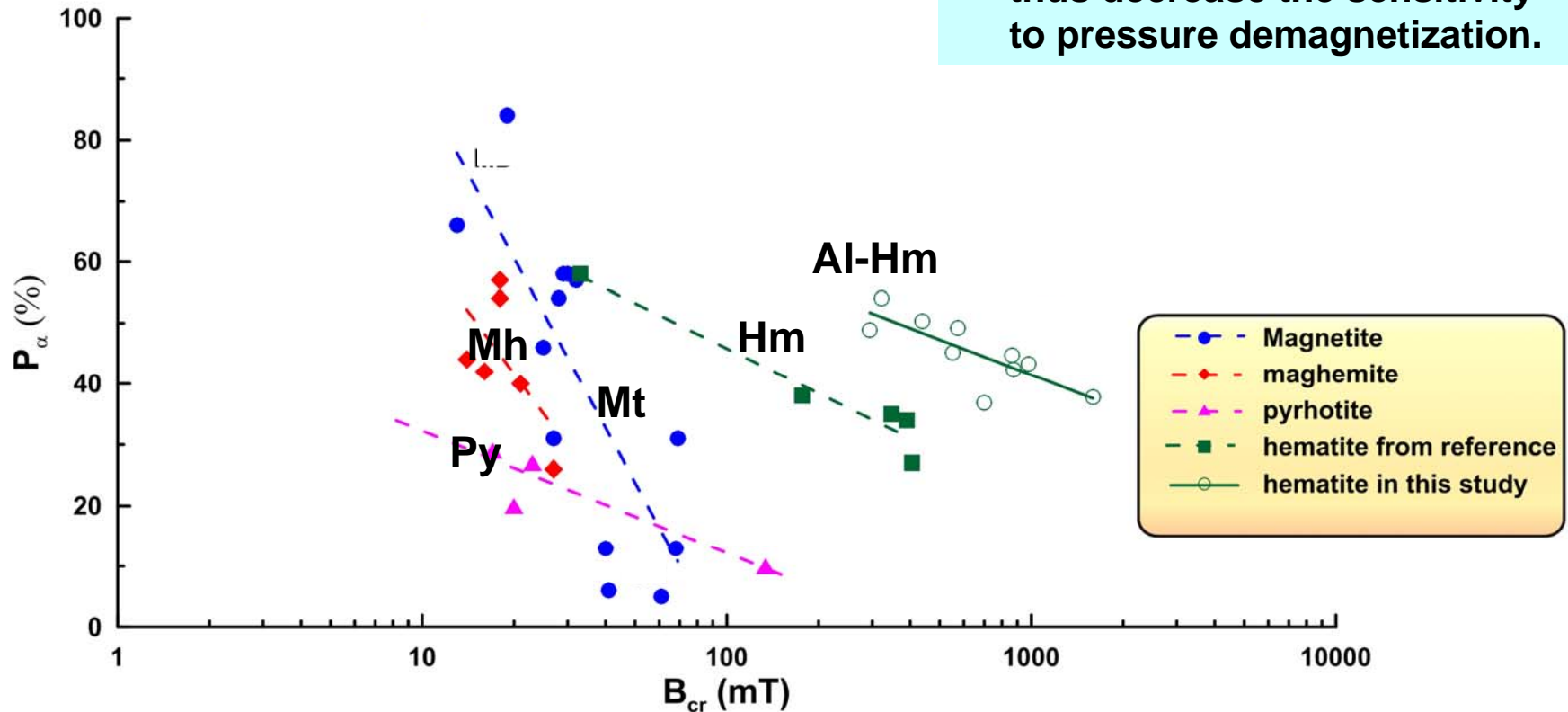
Results and discussions

21/32

How does pressure work on magnetic minerals?

$$P_{\alpha\infty} = -A \log(B_{cr}) + C$$

(1) High B_{cr} can inhibit the rotation of spins under compression, thus decrease the sensitivity to pressure demagnetization.

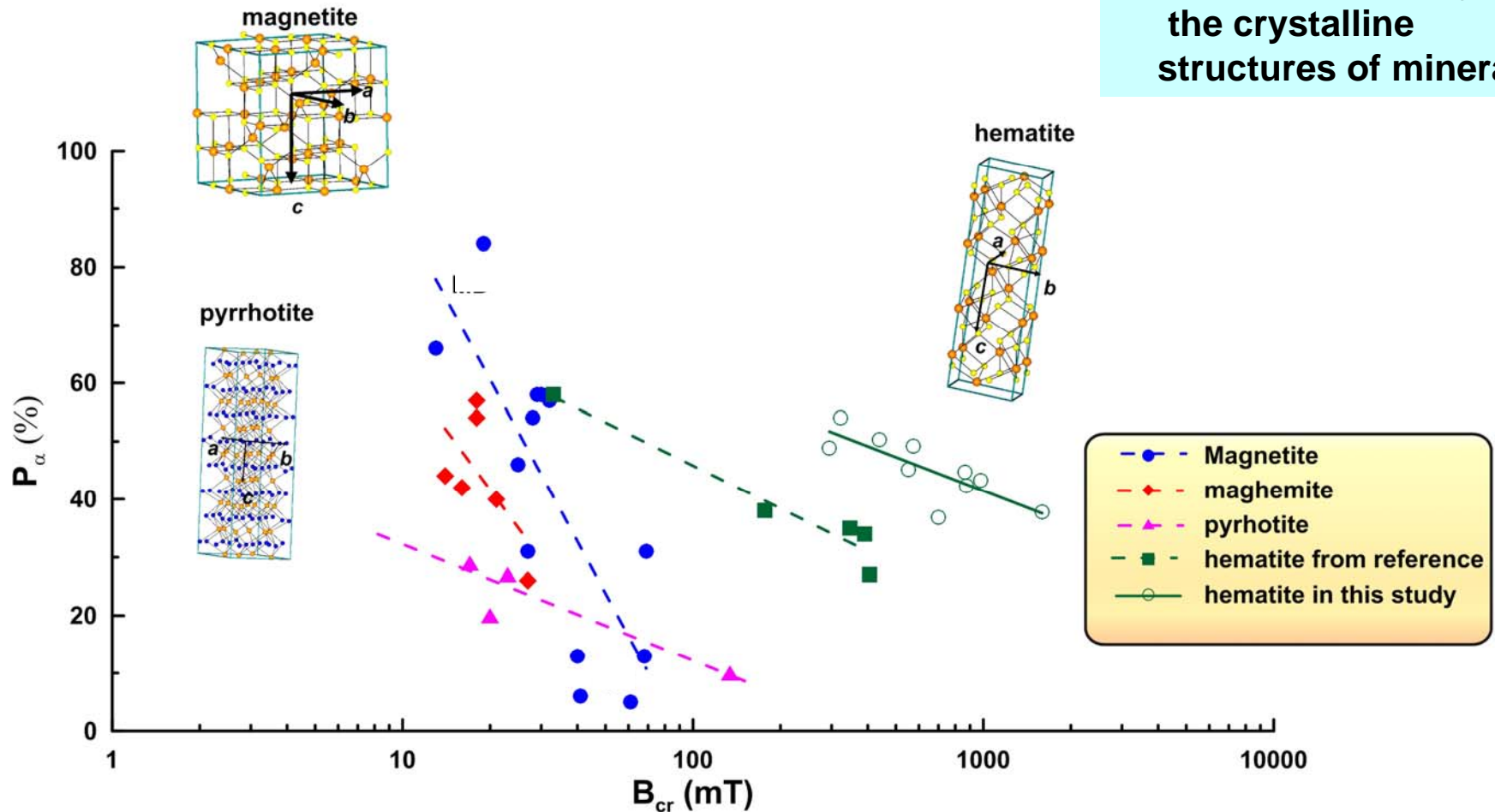


Results and discussions

22/32

How does pressure work on magnetic minerals?

(2) A is controlled by the crystalline structures of mineral.

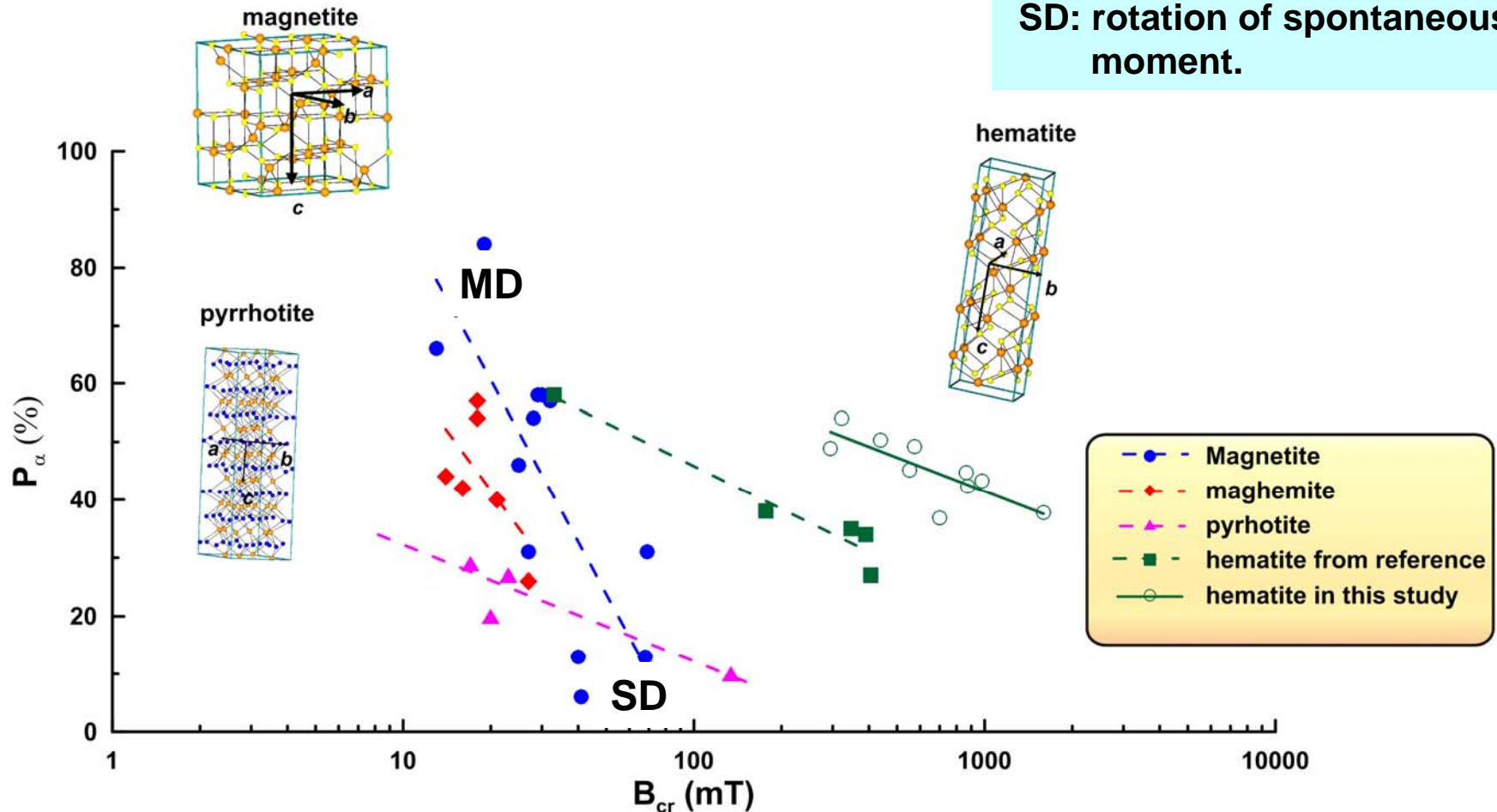


Results and discussions

23/32

How does pressure work on magnetic minerals?

(3) Domain state:
MD: movement of domain wall;
SD: rotation of spontaneous moment.

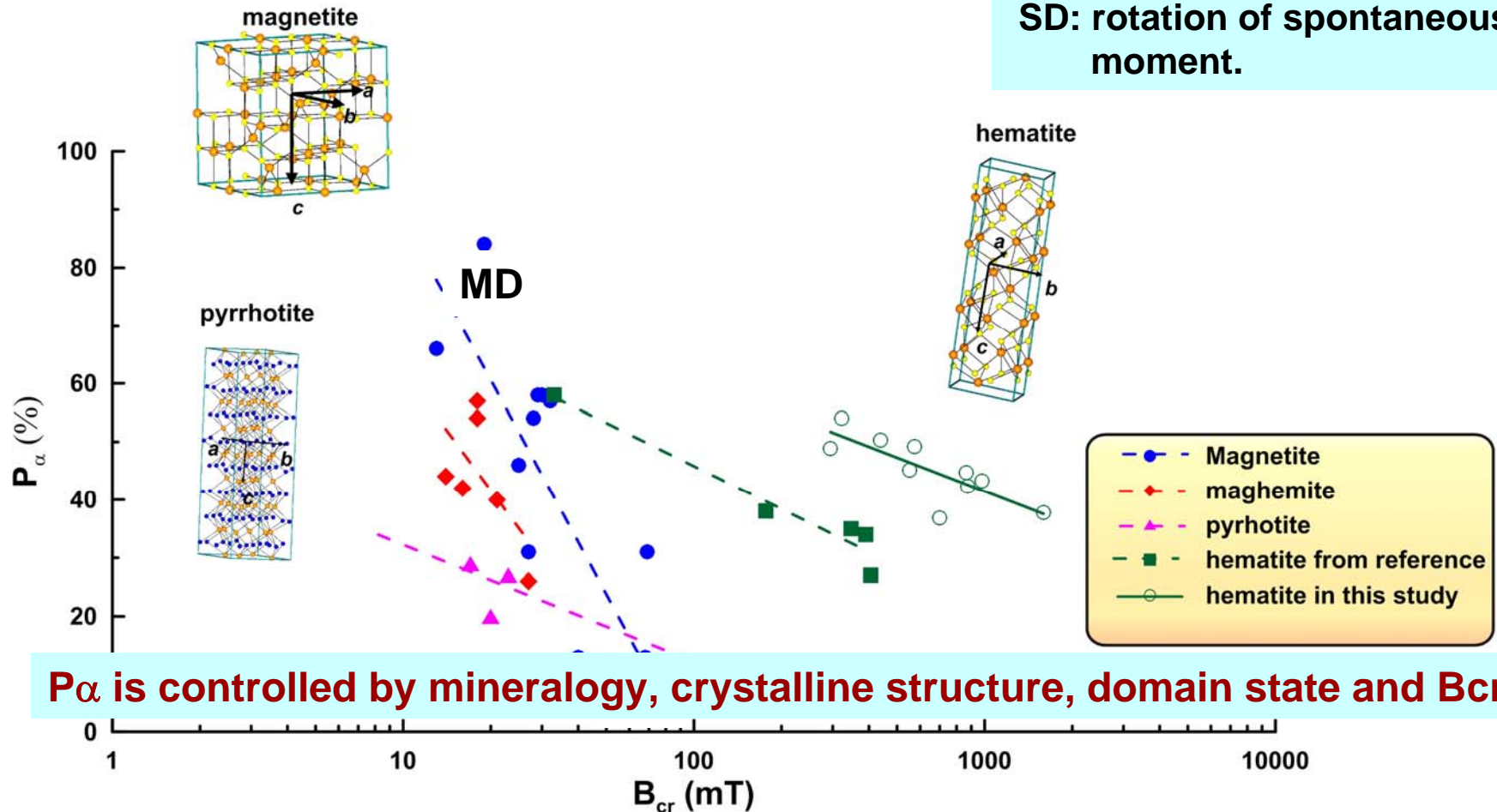


Results and discussions

24/32

How does pressure work on magnetic minerals?

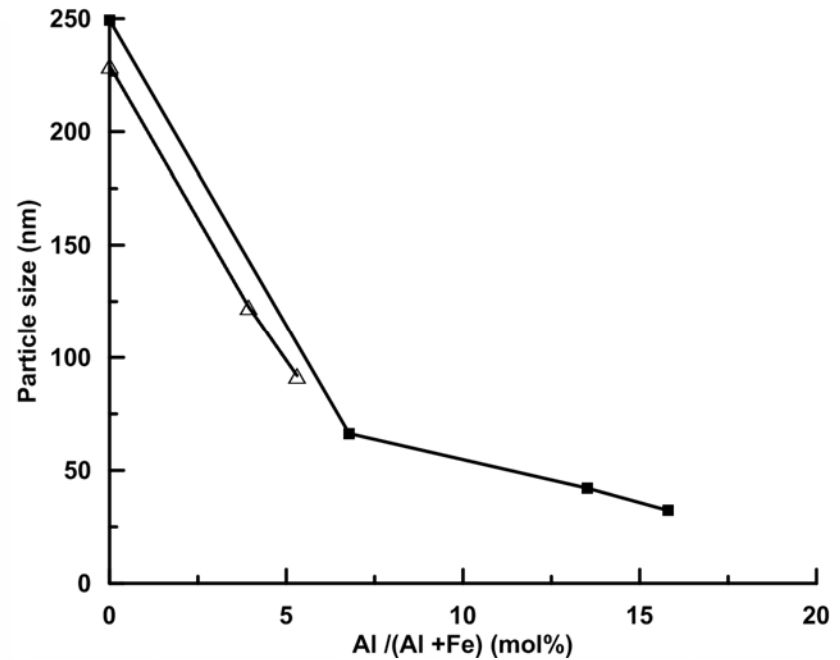
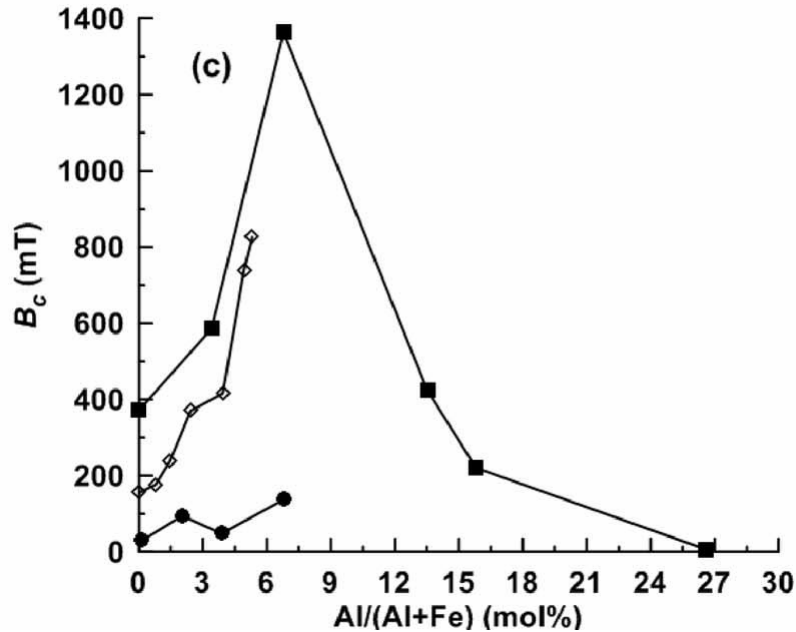
(3) Domain state:
MD: movement of domain wall;
SD: rotation of spontaneous moment.



Results and discussions

25/32

How did Al substitution influence the demagnetization degree?

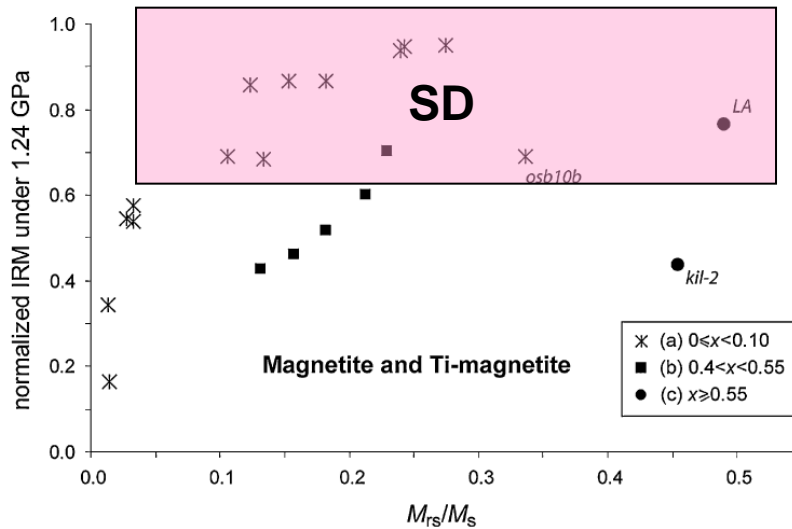


Jiang et al.(2012)

Results and discussions

26/32

How did Al substitution influence the demagnetization degree?



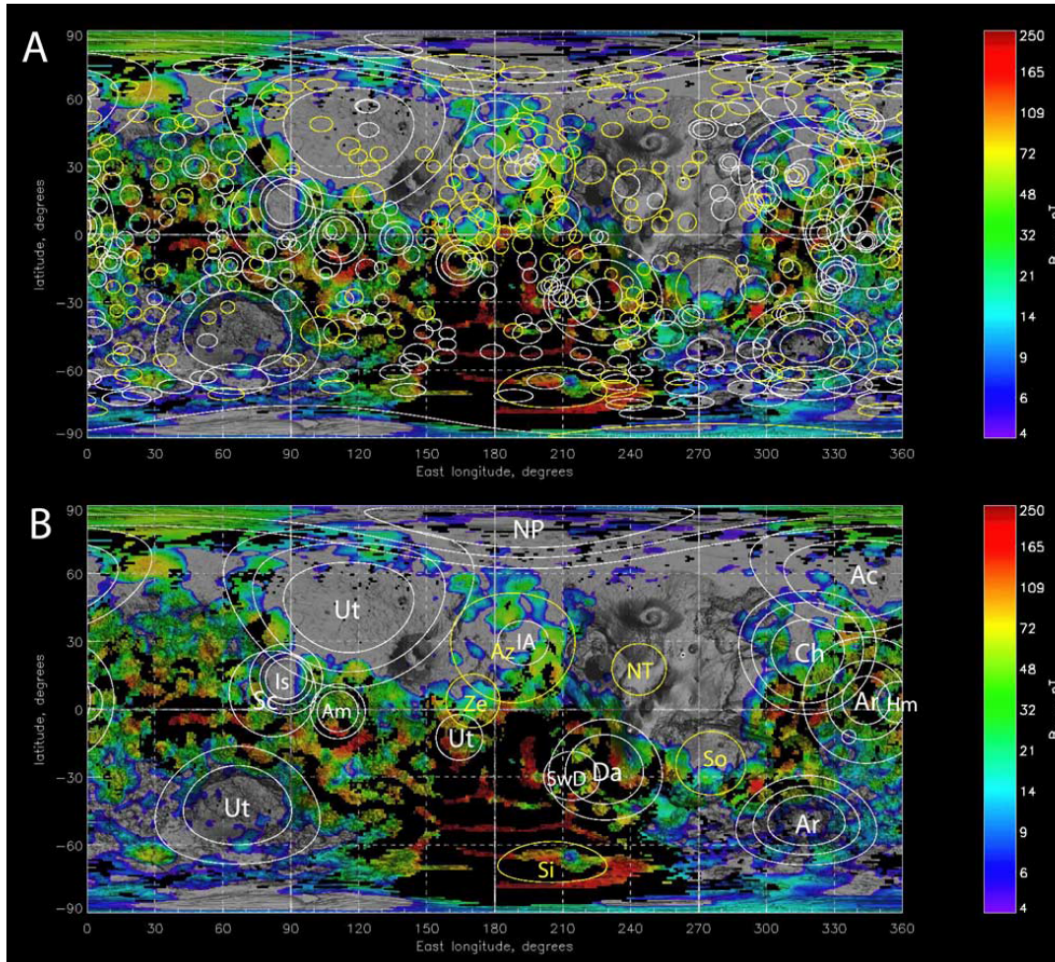
Bezaeva et al.(2010)

Al influences the demagnetization degree mainly through changing B_{cr} instead of particles size

Results and discussions

27/32

Implications for planetary studies

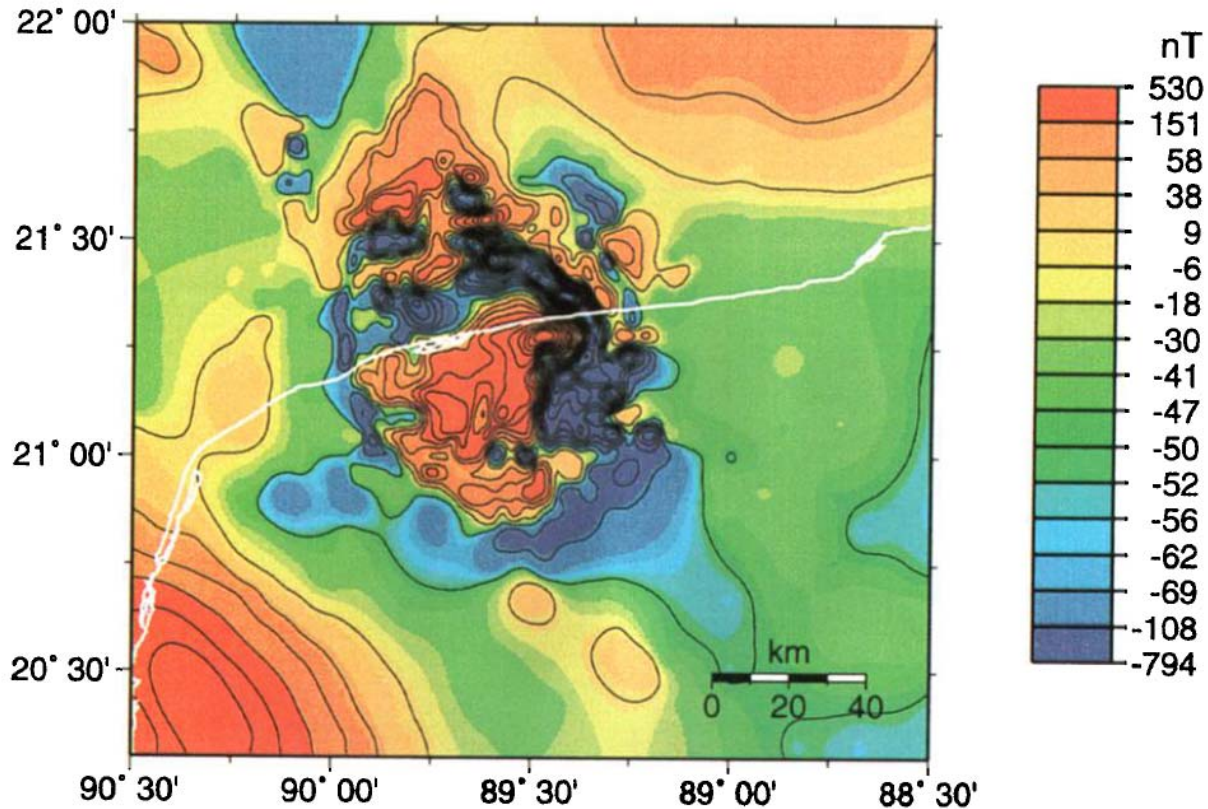


**Younger impact basins:
Low magnetic anomalies
Pressure demagnetization**

Lillis et al.(2008)

Results and discussions

28/32



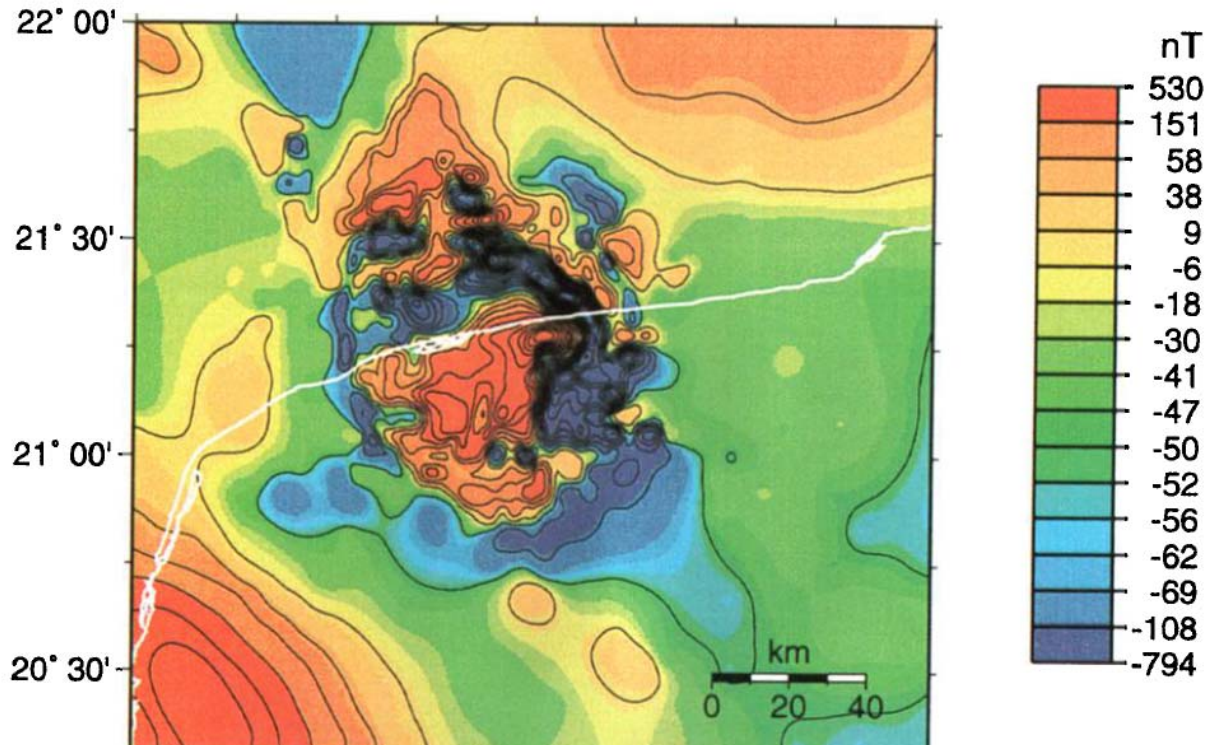
The magnetic anomalies of Chicxulub Crater in Mexico

High magnetic anomalies! Why?

Pilkington and Hildebrand (2000)

Results and discussions

29/32



Dynamo → **Magnetic Field**

Mars
Earth

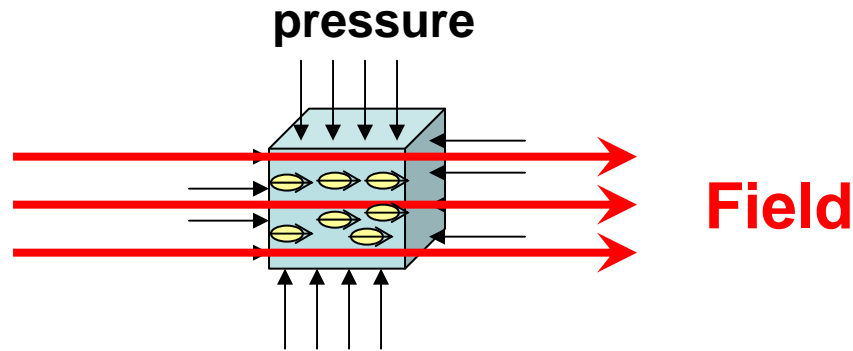
stop
work

No
Yes

rand (2000)

Results and discussions

30/32



**Samples obtain a pressure remanent magnetization (PRM),
contributes to the magnetic anomalies**

Future work..... pressure + magnetic field

Conclusions

- (1) Up to half of initial IRM can be destroyed by a pressure of 1.44 GPa applied to hematite samples.
- (2) The demagnetization degree is controlled by the magnetic hardness, crystalline structure and domain state of minerals.
- (3) Al substitution influences the resistance to pressure by generating defects in magnetic lattices, thus increasing B_{cr} .

Thank you!

Happy Spring Festival!