Large field impressed anisotropy of magnetic susceptibility (AMS) in metamorphic volcanoclastic rocks from the western Central Pamir with ilmeno-hematite as the main magnetic carrier

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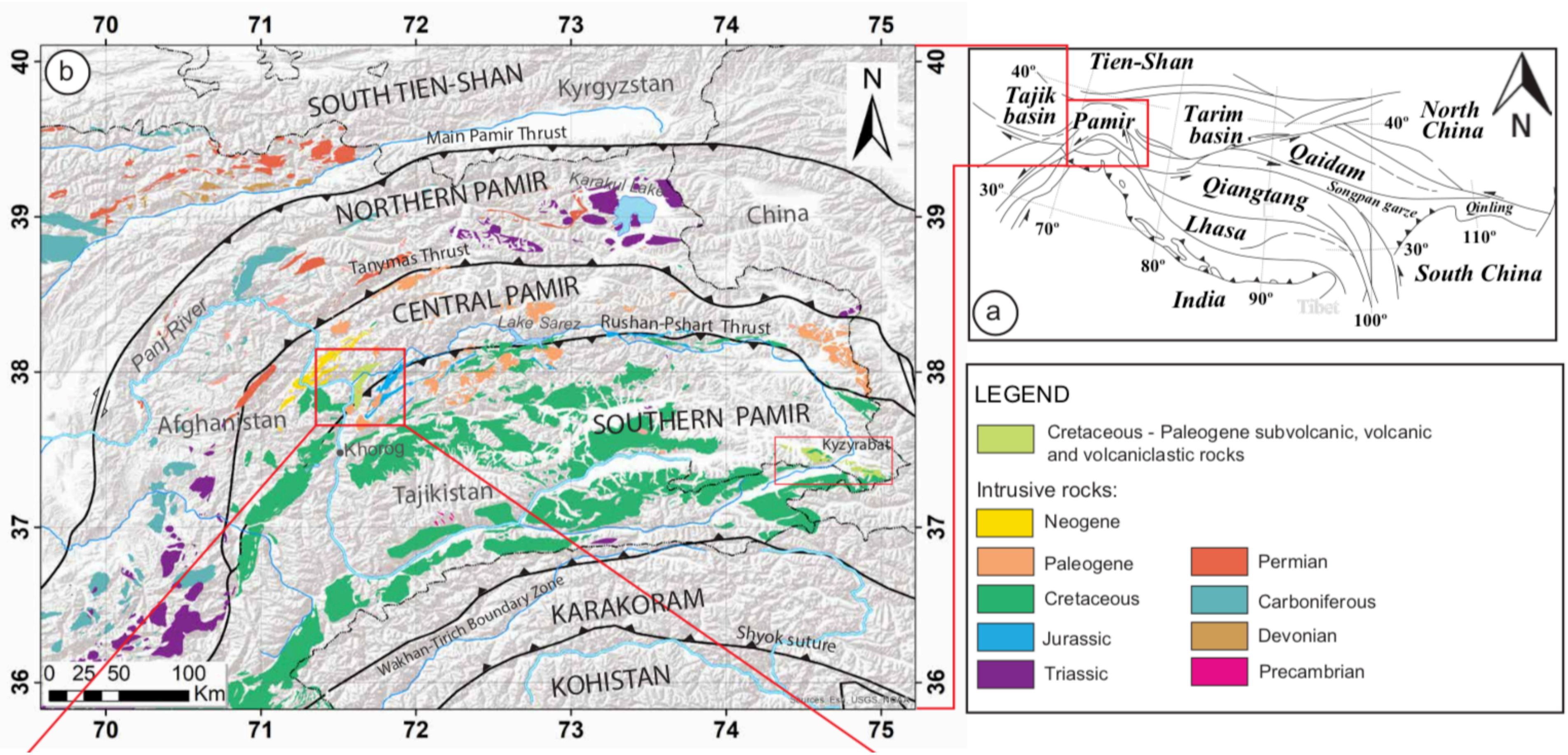
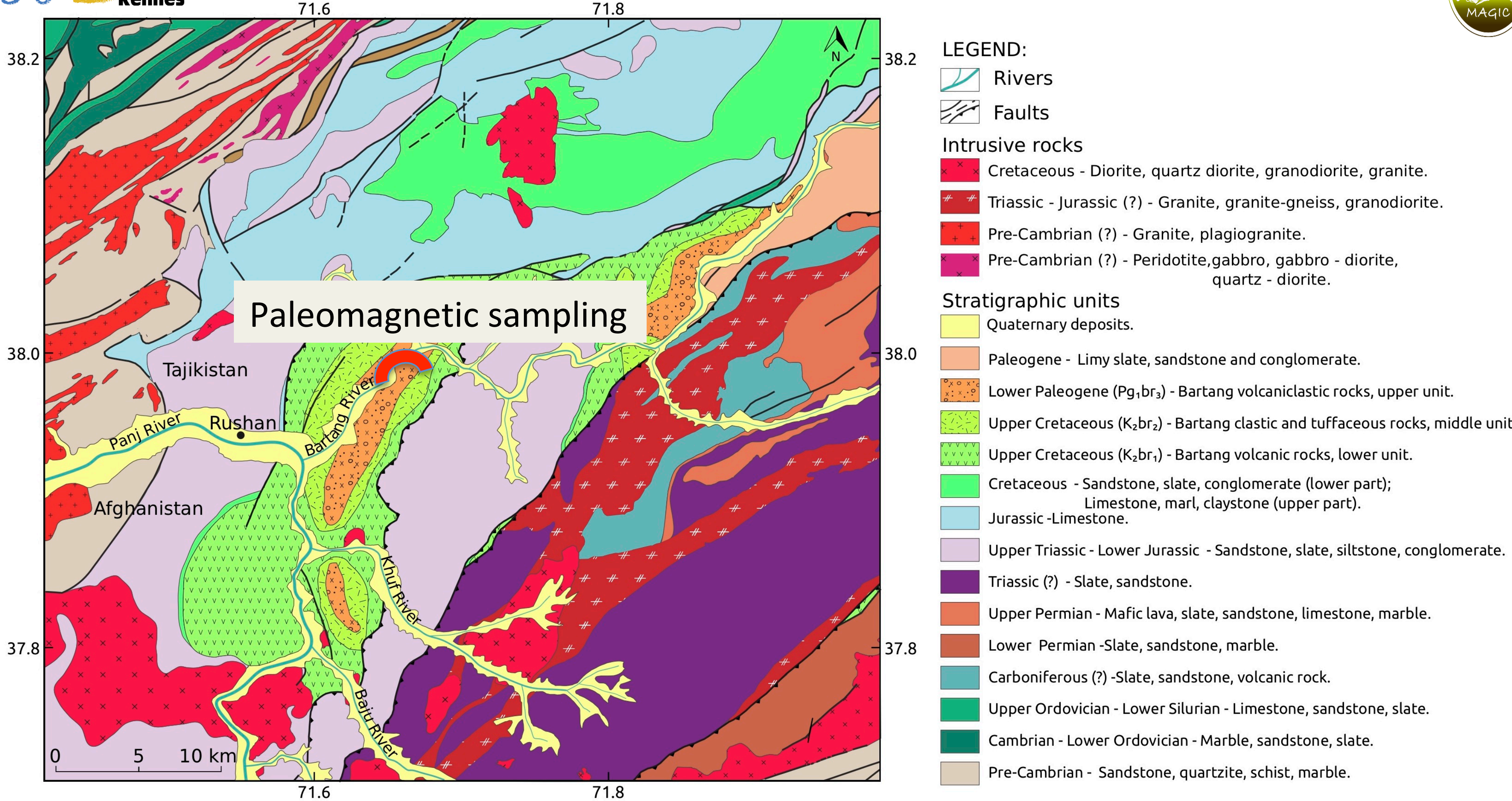
- A Field impressed magnetic fabric is the change in the anisotropy of magnetic susceptibility after a sample has been subjected to a strong DC or AF magnetic field.
- Field impressed AMS fabric, although it has been recognized for a very long time, has been the subject of very few publications in the paleomagnetic literature. This effect has been mainly described in samples with magnetite as a main magnetic carrier. This fabric is usually of low magnitude and observed mainly in nearly isotropic rock after application of static AF demagnetization or after acquisition of an isothermal remanent magnetization (IRM).
- Forty four paleomagnetic sites have been sampled in a >2 km thick sequence of Cretaceous volcano-clastic rocks from the western Central Pamir mountain (Tadjikistan).
- These rocks present a medium grade level of metamorphism characterized by fine grained recrystallisation of biotite and incipient schistosity.

First part of the presentation : Paleomagnetic study of the Bartang volcanoclastic rocks

Second part : description of the AMS fabric induced by IRM

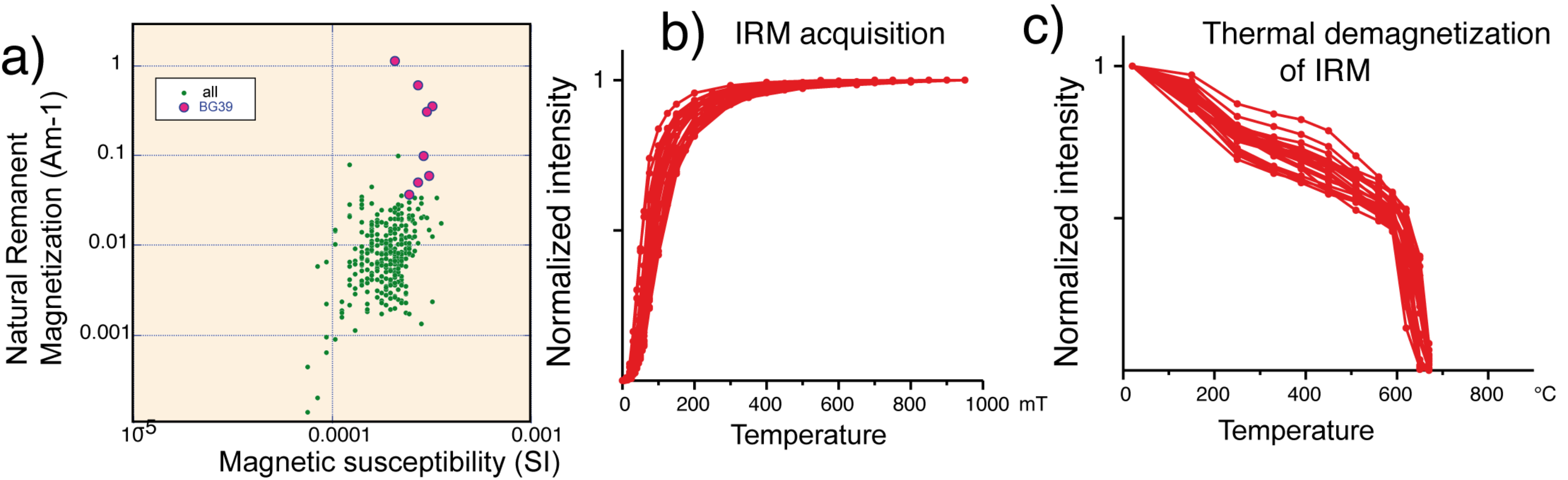


General geological map showing the location of the study area



Forty four paleomagnetic sites have been sampled in a >2 km thick sequence of Cretaceous volcano-clastic rocks in the Bartang valley from the western Central Pamir mountain (Tadjikistan).

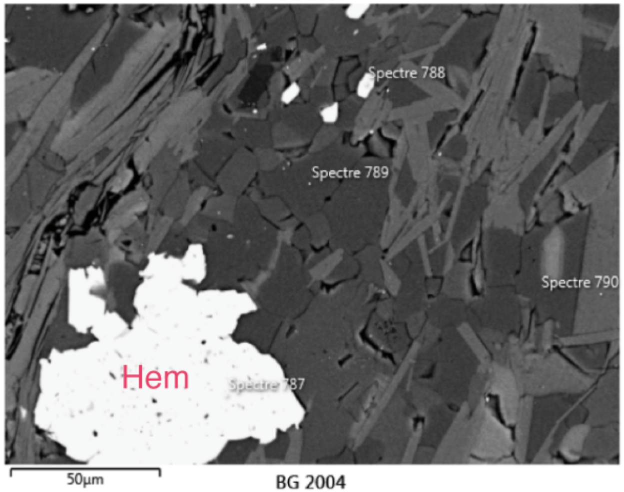
44 sites were sampled along a ~2km section of the volcanoclastic sequence.
8 samples were drilled at each site in the most fine-grained siltstones.



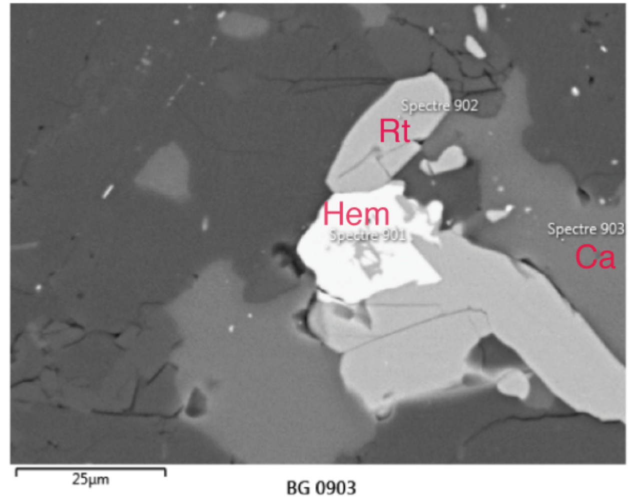
All samples except those from one site (BG39) have low intensity of Natural Remanent Magnetization (~0.01 Am-1) and low magnetic susceptibility (< 0.0004 SI). Acquisition of isothermal remanent magnetization indicates near saturation above 600mT. Thermal demagnetization of the IRM shows a main unblocking temperature between 610-650°C. Acquisition of thermoremanent magnetization (TRM) in the laboratory in a 50µT field give TRM values of ~0.5Am-1. Site BG39 is the only site with intensity of the natural remanent magnetization compatible with a TRM.

SEM observations

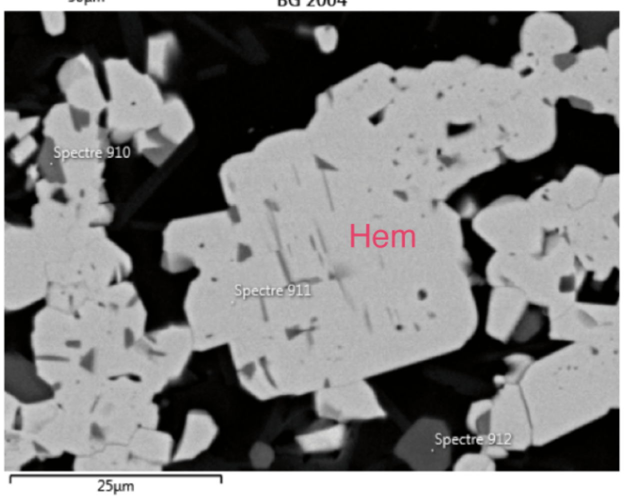
BG 1607



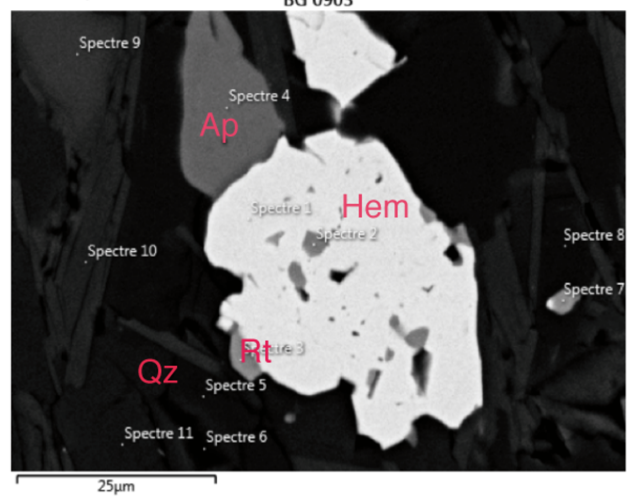
BG 2004



BG 2004



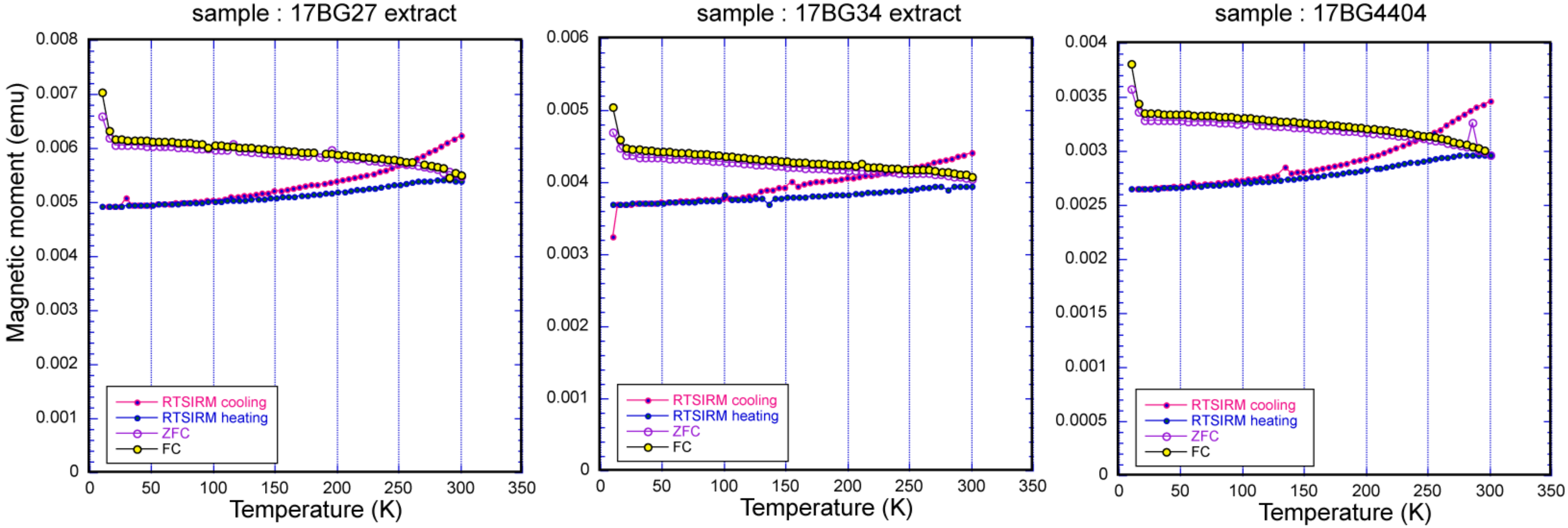
BG 0903



All samples contain quartz, calcite, biotites and oxides. Large grains (~25 µm) of Hematite are the dominant oxides. Rutile inclusions are numerous in the hematite grains.

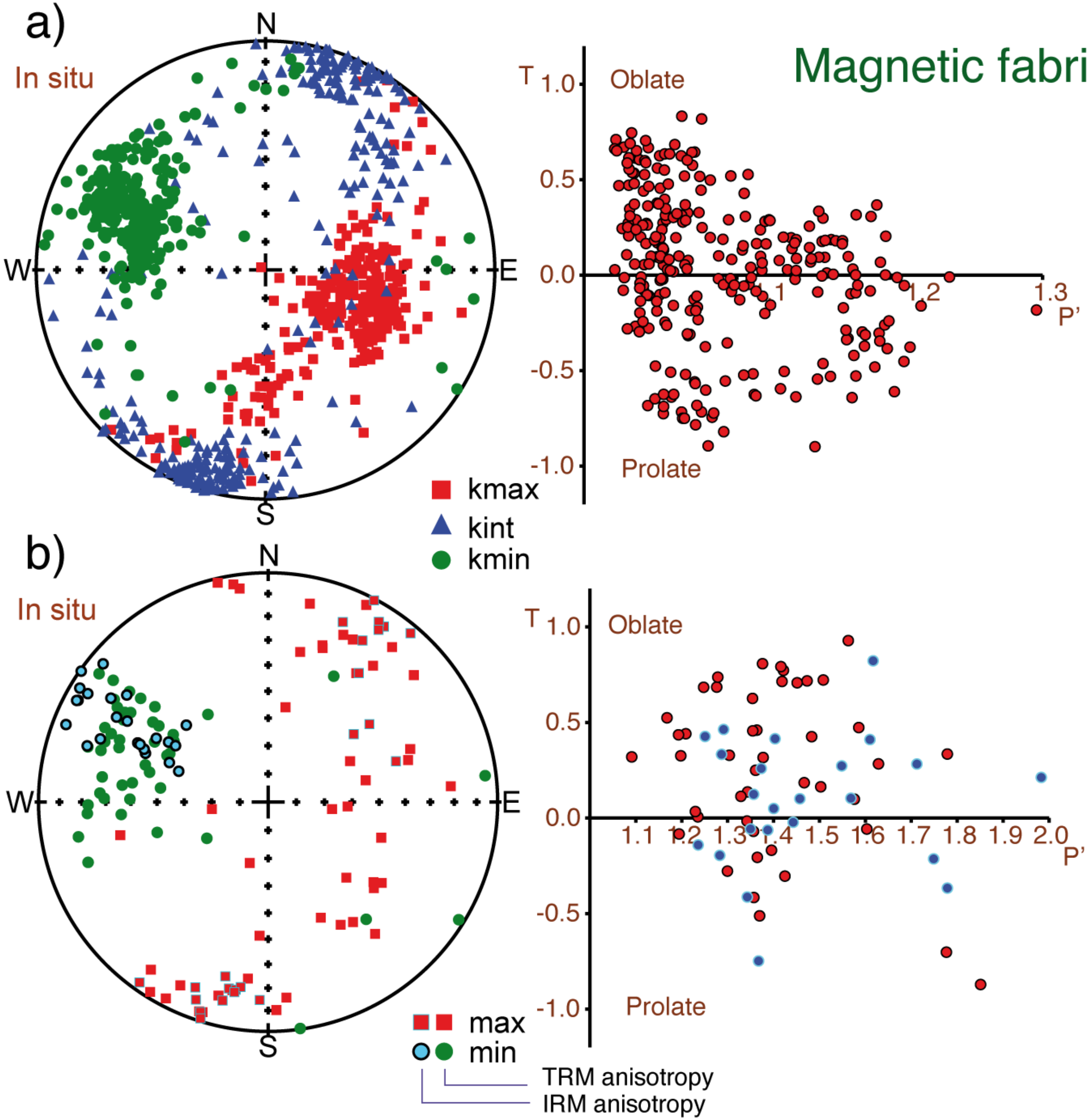
EDS data show that all the hematite grains contain ~5% Titanium. The irregular shape indicates recrystallisation.

The titanium content explains unblocking temperatures significantly lower than the hematite Curie point (~680°C).



MPMS measurements (at IPGP) of samples from the Bartang volcanoclastic rocks show no evidence for the Morin transition or the Vervey transtion.
Thus there is no trace of magnetite. The Morin transition is likely suppressed by 10 to 15% of ilmenite in a solid solution with hematite as suggested by the EDS/SEM data.

Magnetic fabric



The Bartang sequence records a well defined anisotropy of magnetic susceptibility (AMS) fabric (a). The magnetic foliation is dipping to the E-SE with a steep dipping magnetic lineation. This fabric is consistent with the regional NNE-SSW deformation at 15Ma. The shape of the magnetic ellipsoids varies from oblate to prolate. In AMS fabric, paramagnetic minerals like biotite may contribute as much as hematite.

In order to assess the magnetic anisotropy due to oxides, we have carried anisotropy of IRM in a field of 950mT and anisotropy of TRM acquired in low field by cooling below 670°C (b).

The degree of magnetic anisotropy is stronger and up to 2.0. While the magnetic foliation is also dipping to the E-SE as the AMS foliation, lineations of anisotropy of TRM and IRM are distributed along a girdle.

Samples were progressively thermally demagnetized. Exemples of demagnetization plots are shown in a, b and c (figure next slide). At several sites the characteristic magnetization is scattered.

d) A mean ChRM was determined at 13 sites and the directions are distributed along a girdle which is not different from the one observed on the magnetic lineations of the ellipsoids of anisotropy of remanent magnetization.

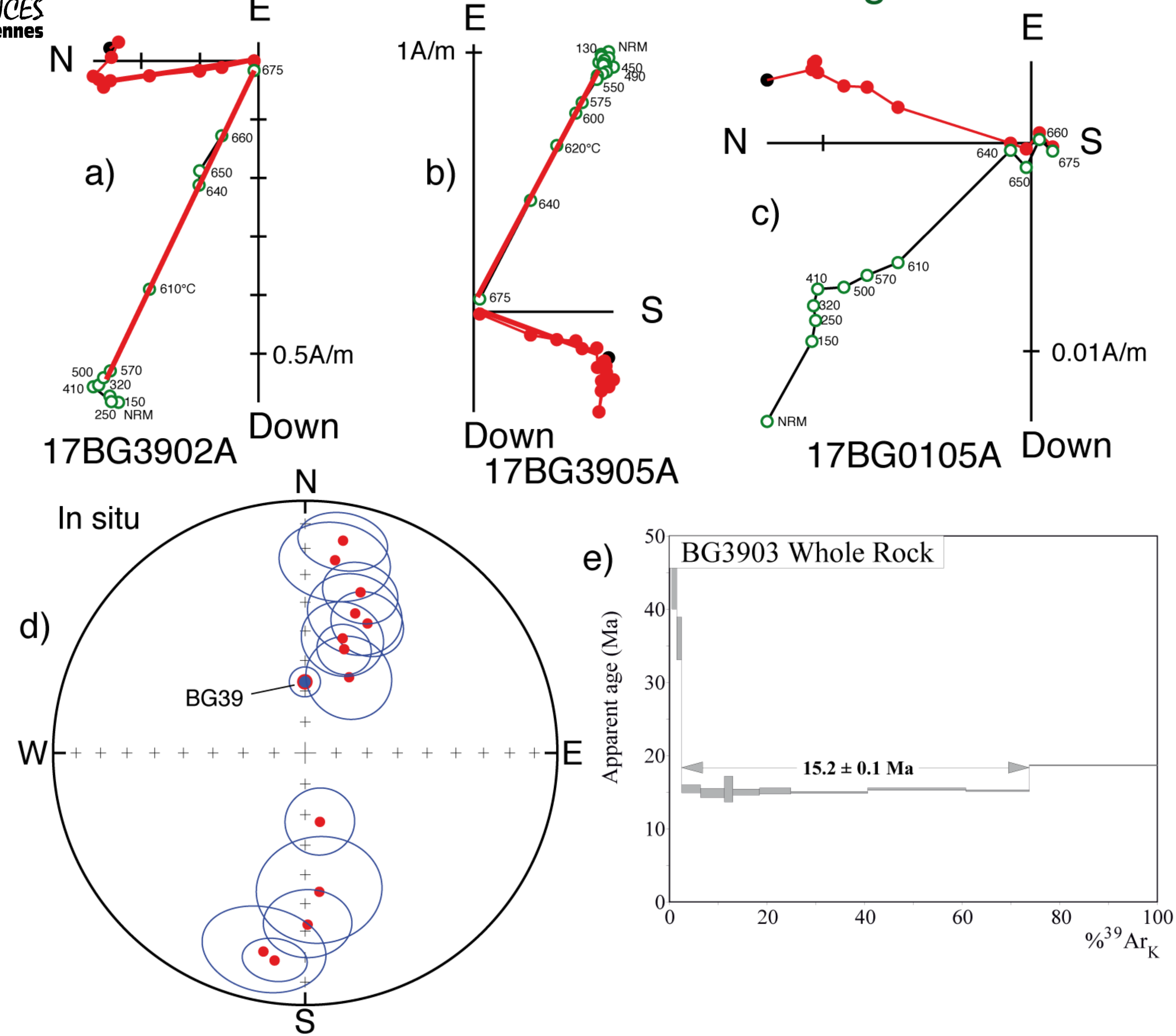
Site BG39 is the only site where strong magnetization and antipodal ChRMs of normal (a) and reverse polarity (b) is observed.

e) A whole rock 40Ar/39Ar experiment (Gilles Ruffet, Univ. Rennes) on one sample from site BG39 provides a plateau age of 15.2±0.1 Ma that confirm metamorphism during dome emplacement in the Central Pamir.

The Bartang volcanoclastic sequence was deformed during metamorphism as described by Stearns et al. (2014; doi : 10.1002/2014TC003774). The temperature was not high enough to permit a TRM like remanent magnetization to be recorded except at one site (BG39).

At all other sites the samples' NRMs are in a nearly demagnetized state where ChRMs are mainly controlled by the samples' magnetic fabric.

Characteristic Remanent magnetizations

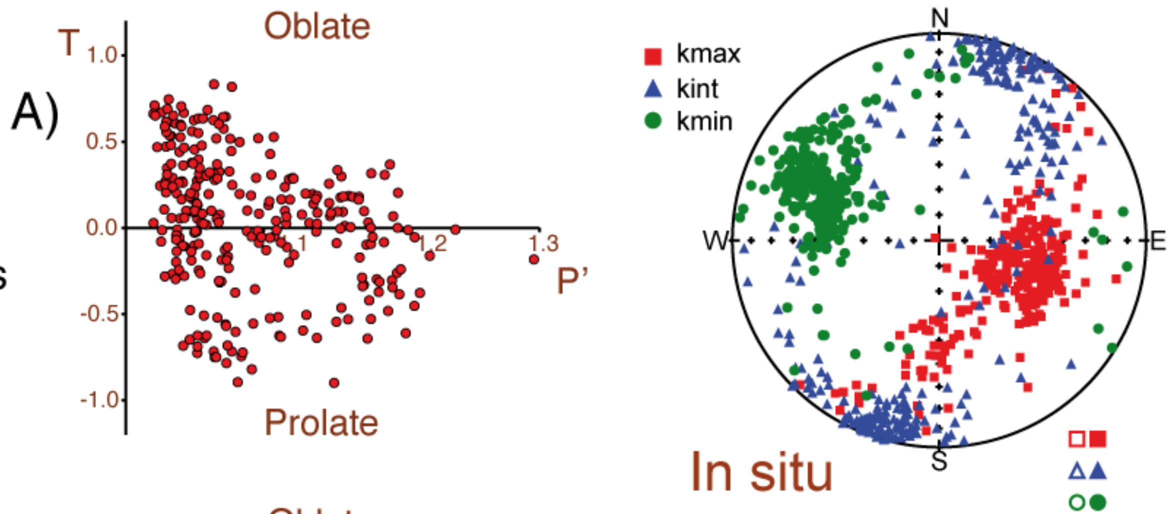


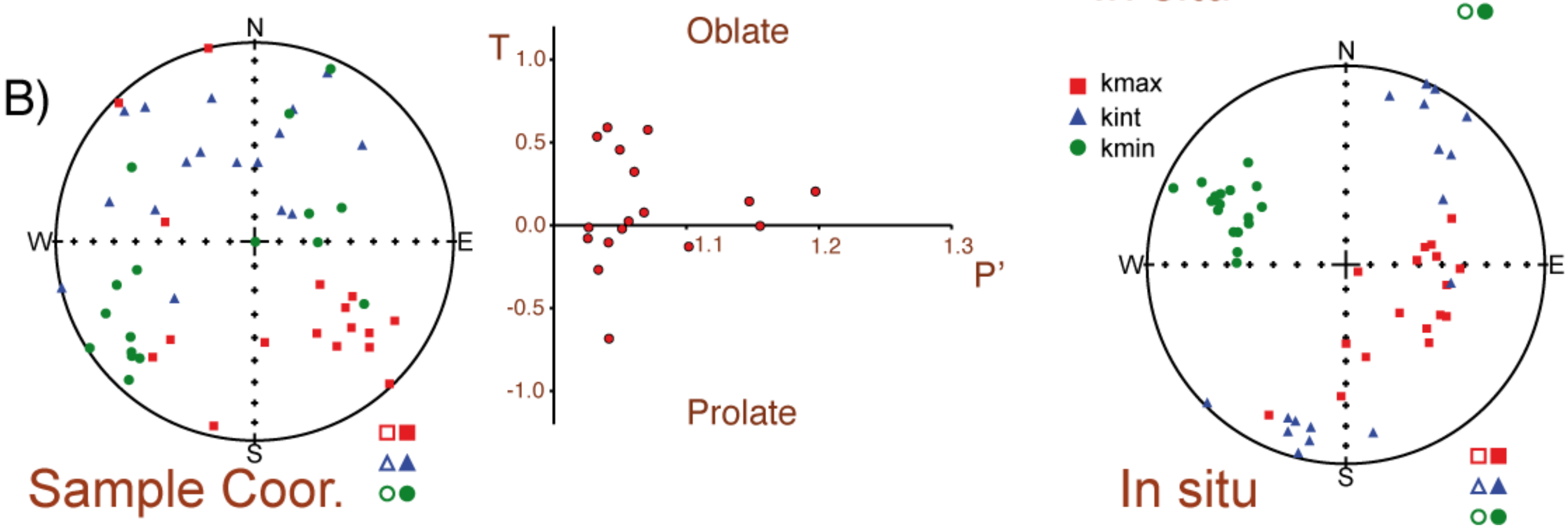
Field impressed AMS

- In the course of the paleomagnetic study, we discover that the AMS fabric was modified after imparting an IRM in the samples
- Here we show results obtained on several samples.
- In addition to samples that were not heated for thermal demagnetization, we also made experiments on samples heated in the lab up to 680°C.

A) AMS all samples, in *in situ* .
Magnetic susceptibility range 15-25 10^{-5} SI

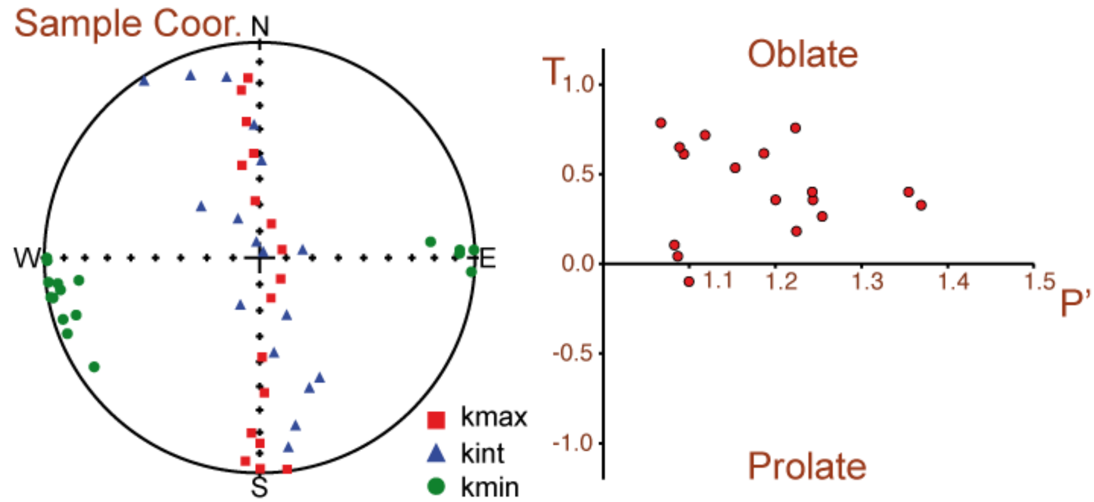
B) 17 selected samples prior to IRM acquisition



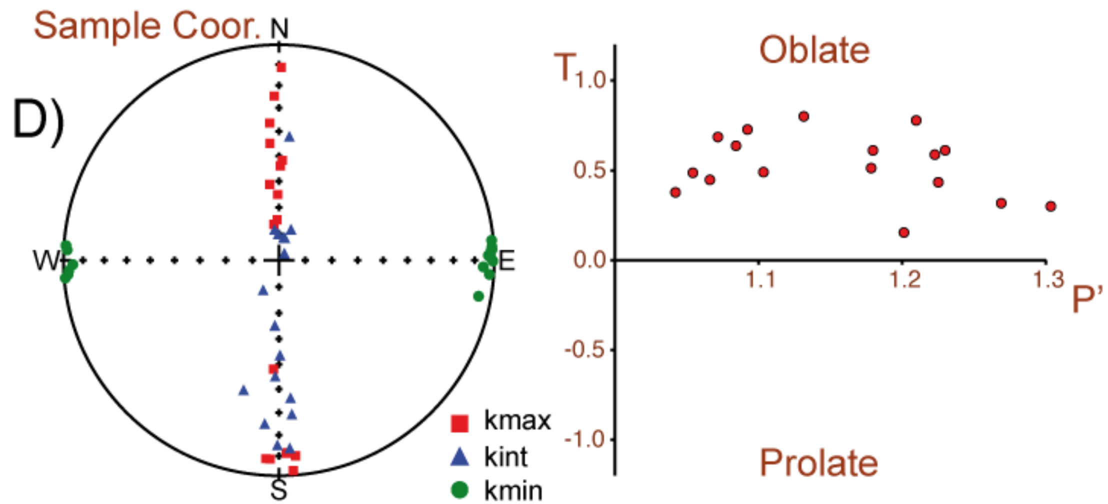


AMS in selected samples prior to IRM acquisition showing that the initial AMS fabric is more or less random in sample coordinate

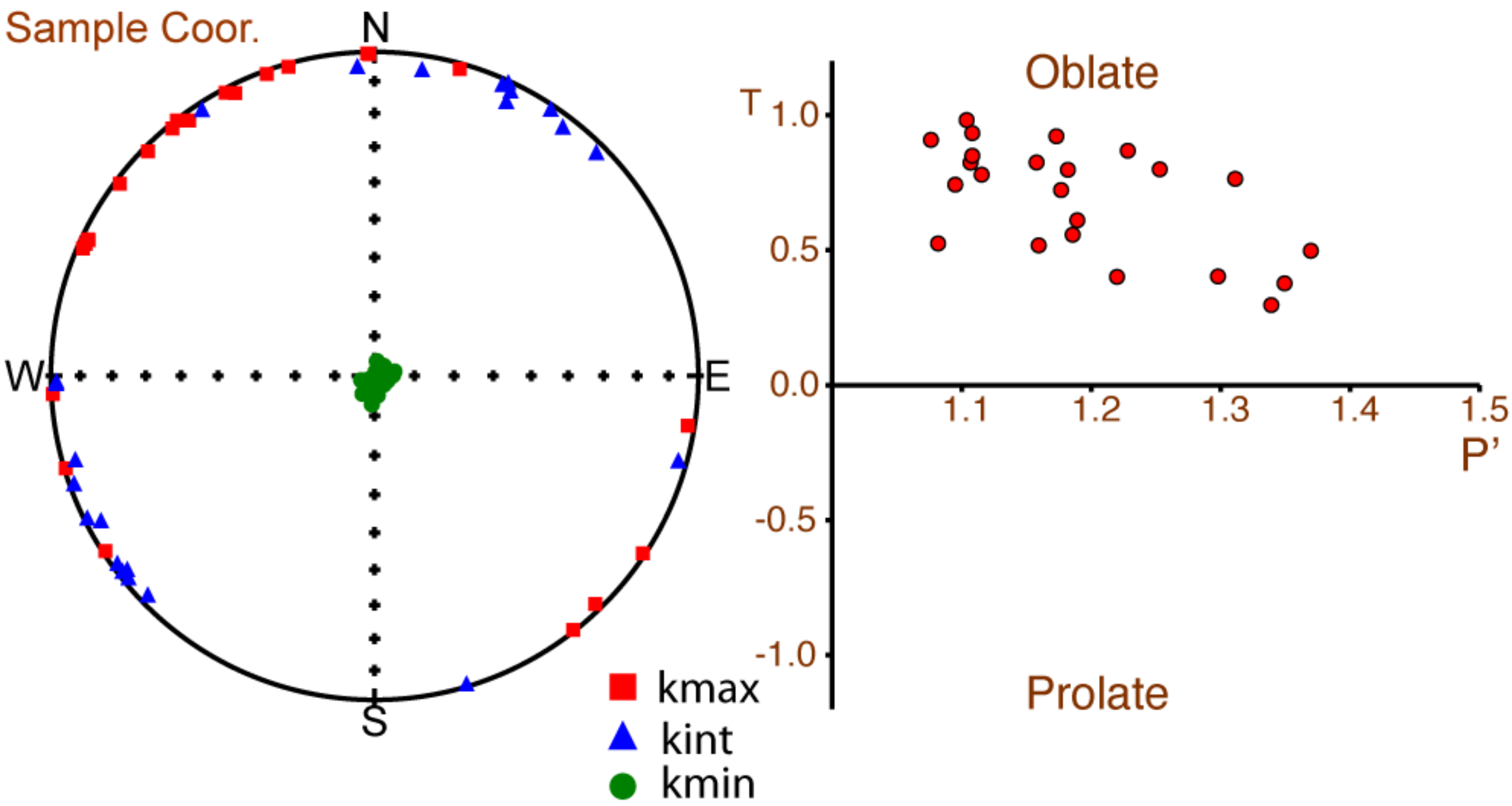
C= AMS after IRM acquisition at 950mT along the Y axis



D= C - initial AMS

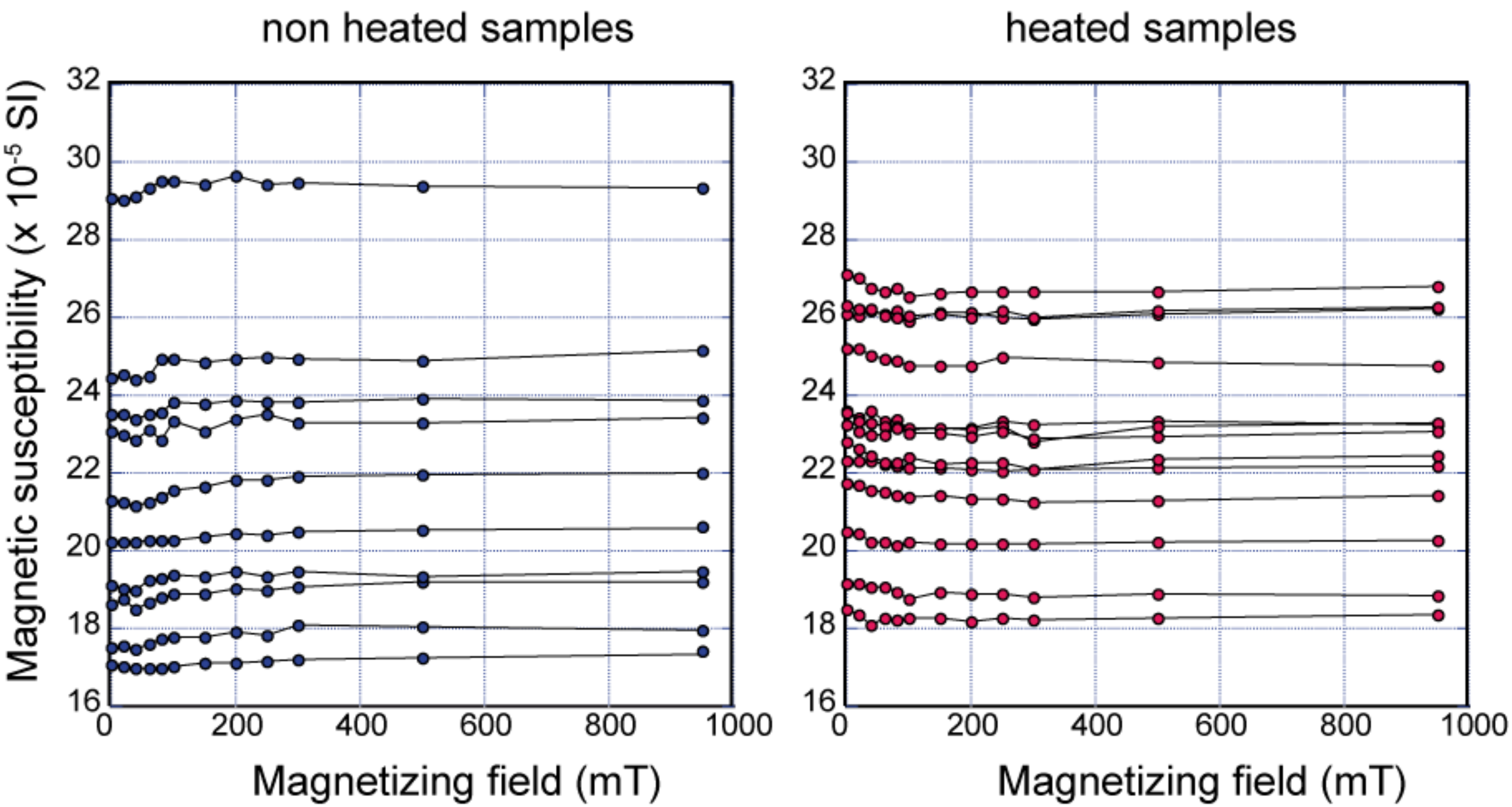


After IRM acquisition, the AMS minimum axis rotates toward the direction of IRM acquisition, here the Y axis (E-W direction on the stereoplots). The induced fabric is better observed after substraction of the initial AMS fabric. The magnetic susceptibility is stronger in the plane orthogonal to the Isothermal remanent magnetization



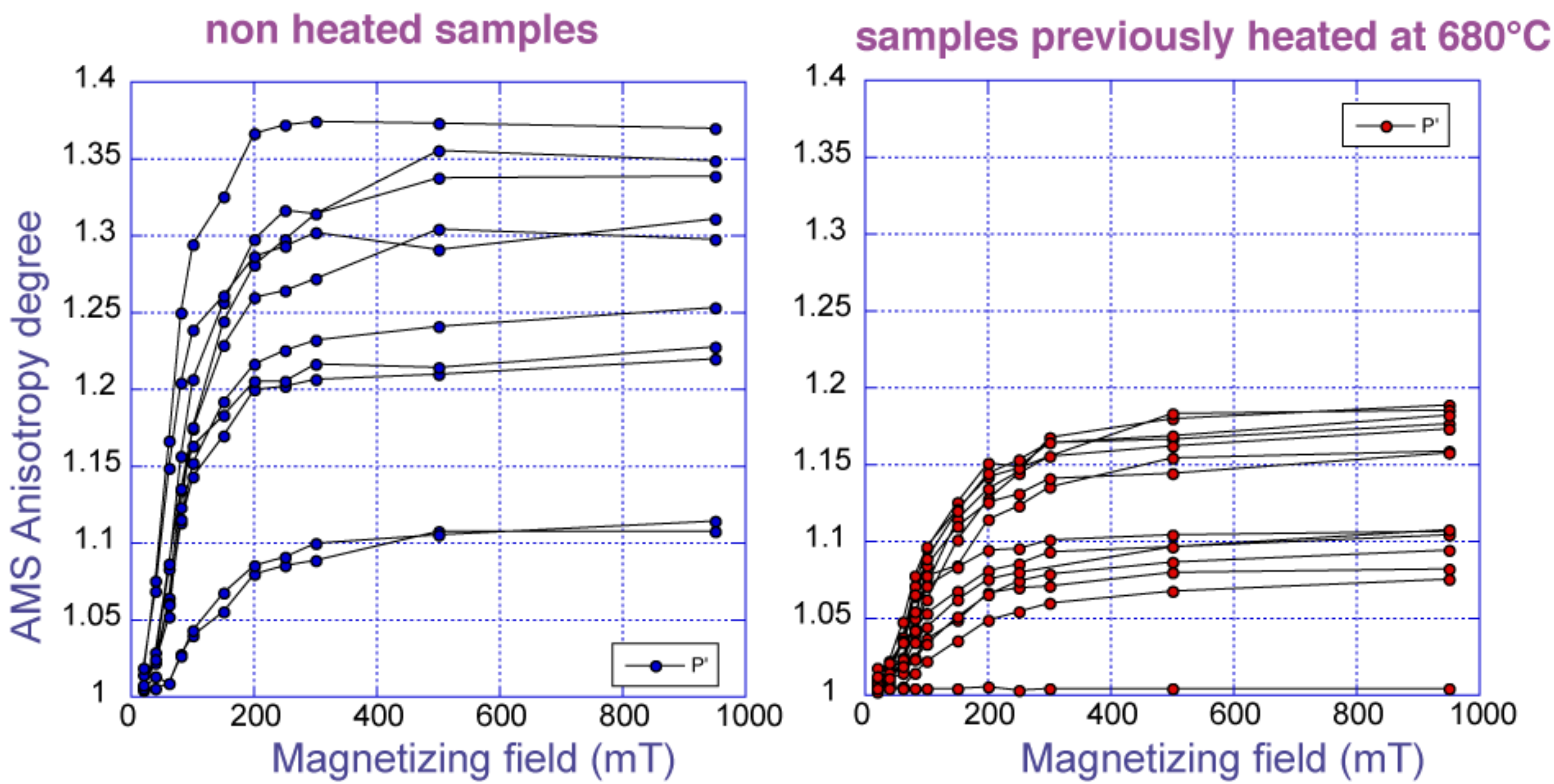
If the AMS is measured after imparting an IRM along the Z direction then a field-impressed AMS has a minimum susceptibility along the Z axis.

Magnetic susceptibility along X after IRM acquisition along Z



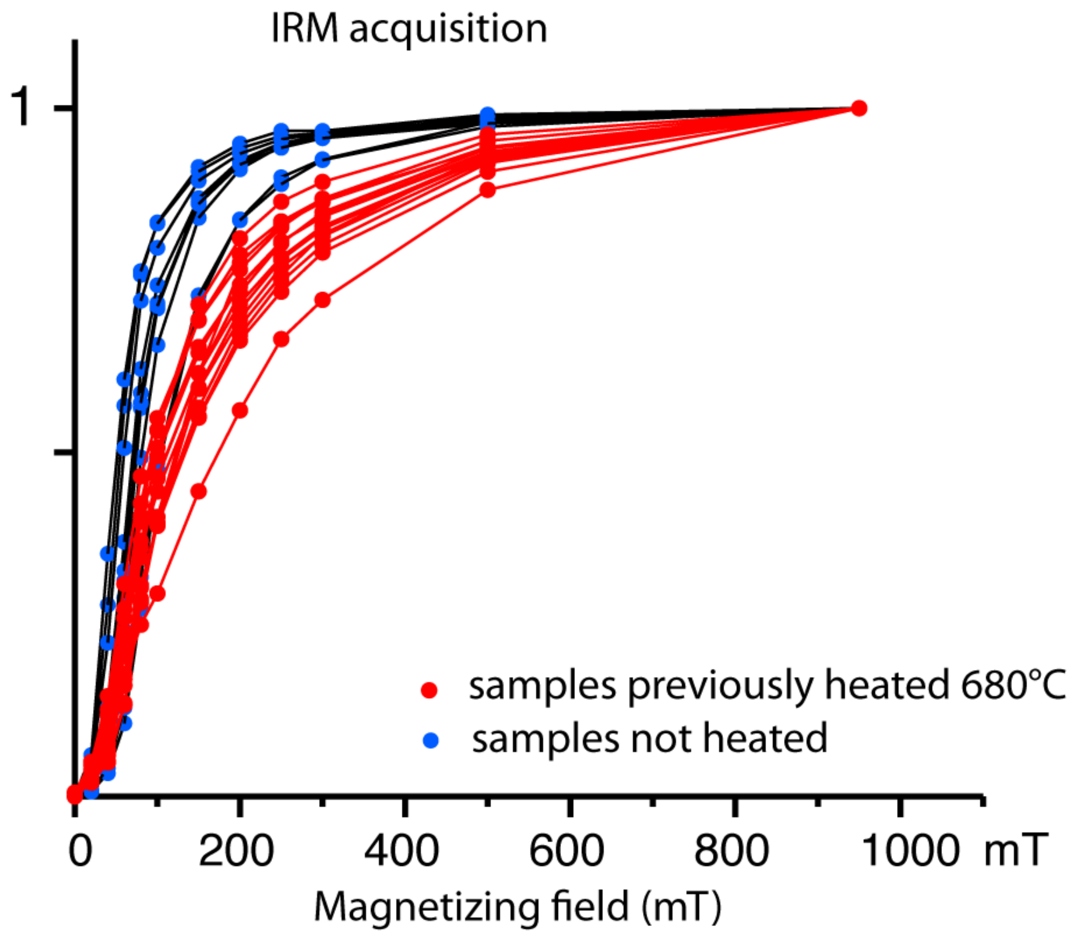
The magnetic susceptibility is almost constant in the direction orthogonal to the IRM

Comparison of the induced AMS anisotropy degree with increasing field value during IRM acquistion



The AMS fabric was measured after each step of IRM acquisition. We can see that the magnitude of the induced magnetic fabric increases with the imparted field and mirror the IRM acquisition curve.

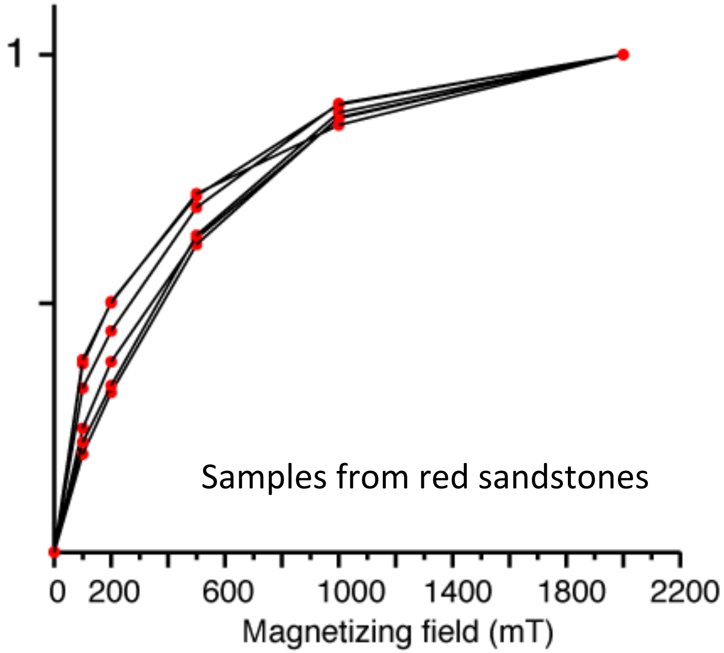
The sample with no significative effect corresponds to one heated sample for which a large increase in magnetic susceptibility upon heating was detected. Thus the mineralogy of this sample was modified.

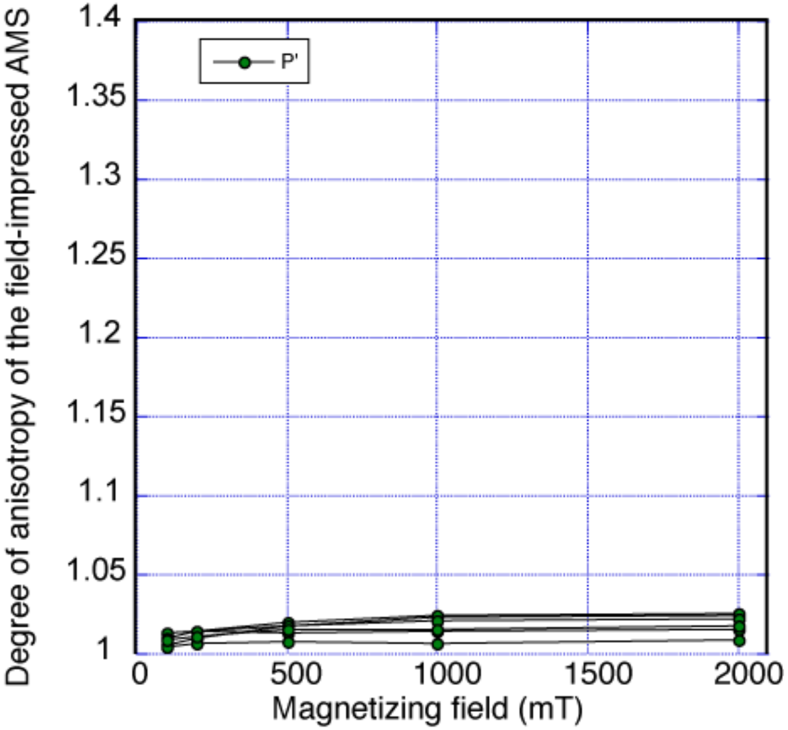


Samples that have been heated up to 680°C have slightly higher coercivities than non heated samples, likely due to oxidation of the titanohematite grains. This difference was also observed in the shape of the curve of the degree of the field-impressed magnetic fabric versus the magnetizing field value used for the IRM.
(see previous slide)

Can we detect the effect in hematite-rich red sandstone?

Is there a fraction of metamorphic hematite in the red beds from the nearby Late Miocene sedimentary basin?





Five samples in red sandstones with hematite as the main magnetic carrier were processed. IRM acquisition shows that saturation is not reached by 2 Teslas. The field-impressed AMS is much lower and no greater than 1.03. Further work is needed to test the possibility that these sandstones contain a small amount of metamorphic hematite.

Conclusions

- Metamorphism in the upper greenschist facies may lead to the formation of metamorphic hematite
- The hematite contains 10 to 15% of ilmenite in solid solution
- Samples with this magnetic carrier present a strong field-impressed AMS fabric after IRM acquisition
- The magnetic susceptibility decreases strongly in the direction of the IRM
- AMS data may not reflect the initial magnetic fabric when they are measured after IRM acquisition