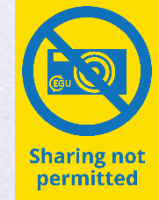


Size-resolved mineralogy and grain size-shape analysis of airborne and deposited mineral dust in northern China

Katja Bohm^{1,2}, Hui Tang^{2,3,4}, Bin Wang⁵, Sergio Andò¹, Anu Kaakinen², Thomas Stevens^{2,6}, Johanna Salminen², Ove Haugvaldstad^{3,7}, Eduardo Garzanti¹, and Jianrong Bi⁸



¹Department of Earth and Environmental Sciences, University of Milano-Bicocca, Milan, Italy; ²Department of Geosciences and Geography, University of Helsinki, Helsinki, Finland; ³Department of Geosciences, University of Oslo, Oslo, Norway; ⁴Climate System Research, Finnish Meteorological Institute, Helsinki, Finland; ⁵Department of Geography, Shaanxi Normal University, Xi'an, China; ⁶Department of Earth Sciences, Uppsala University, Uppsala, Sweden; ⁷Norwegian Meteorological Institute, Oslo, Norway; ⁸College of Atmospheric Sciences, Lanzhou University, Lanzhou, China

METHODS AND FIRST RESULTS:

1. BACKGROUND AND AIMS

3. GRAIN SIZE AND SHAPE

4. MINERALOGY

7. FUTURE WORK

2. SAMPLING

5. MAGNETIC PROPERTIES

6. SOURCE CONTRIBUTION MODELLING

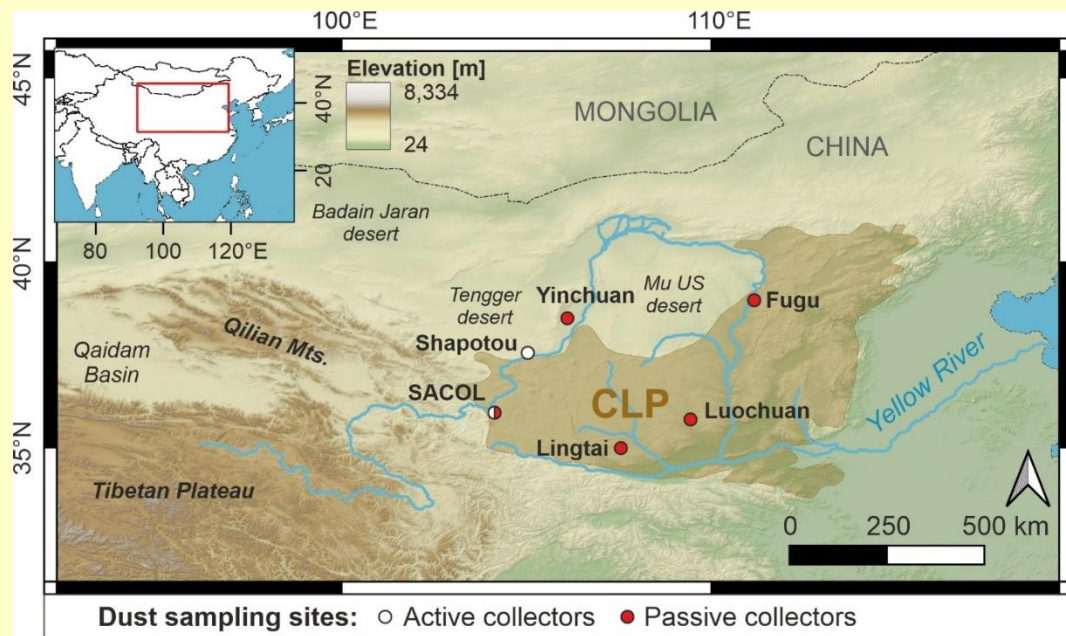


Next:
Background & Aims
(1/3)

Photo: The thick Quaternary loess (dust) deposits of the western CLP taken from the SACOL research station (Lanzhou University)

Background & Aims

- The Chinese Loess Plateau (CLP) region in northern China experiences dust and sandstorms every year.
- Dust is transported from the large dry regions in China and Mongolia via westerly and northwesterly winds.



NATURE AND ENVIRONMENT | ASIA

Sandstorm engulfs Chinese town

04/27/2021

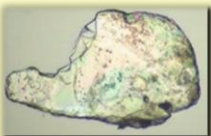
Meteorologists have warned people to stay indoors to avoid the sand lifted from the Gobi desert in the north.



Towns in Linze county, northern China, were hit hardest

Image: AFP

<https://www.dw.com/en/china-sandstorm-engulfs-town-in-gansu-province/a-57347674>



Background & Aims

- Not only today, dust has been depositing in the CLP region for millions of years to form loess and Red Clay deposits
- ~25 Myr nearly continuous records of aeolian dust
- Important archives of past climates and dust-climate interactions
- **CLP is a unique location to combine studies of past and present mineral dust**



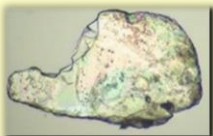
Aeolian Red Clay in Lantian, southern CLP



Quaternary Loess (2.6–0 Ma)

Neogene (~7–2.6 Ma)
Red Clay

*Dust deposits (loess and Red Clay) in Baode, northern CLP
(Photo: Anu Kaakinen)*



Background & Aims

- My previous work (PhD) studied the provenance of the pre-Quaternary aeolian dust deposits of the CLP region
- Current postdoc-project* studies the modern dust properties and provenance in the CLP region and
 - **Combines past (geology) and present-day (atmospheric sciences) dust research**
 - **Provides high-resolution observational data on dust properties in East Asia**

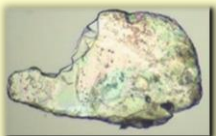
Modern dust **PROVENANCE** (analysis and observations)

- Spatiotemporal variation
- Grain-size and -shape-dependent variation
- Links to specific climate or weather phenomena



PRESENT → **PAST**

- Validate provenance methods used in sourcing past CLP dust deposits
- Driving mechanisms behind the present-day provenance changes
- Use these information to improve the interpretations of past
 - East Asian dust cycle
 - dust-climate interactions in varying global climate states



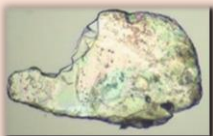
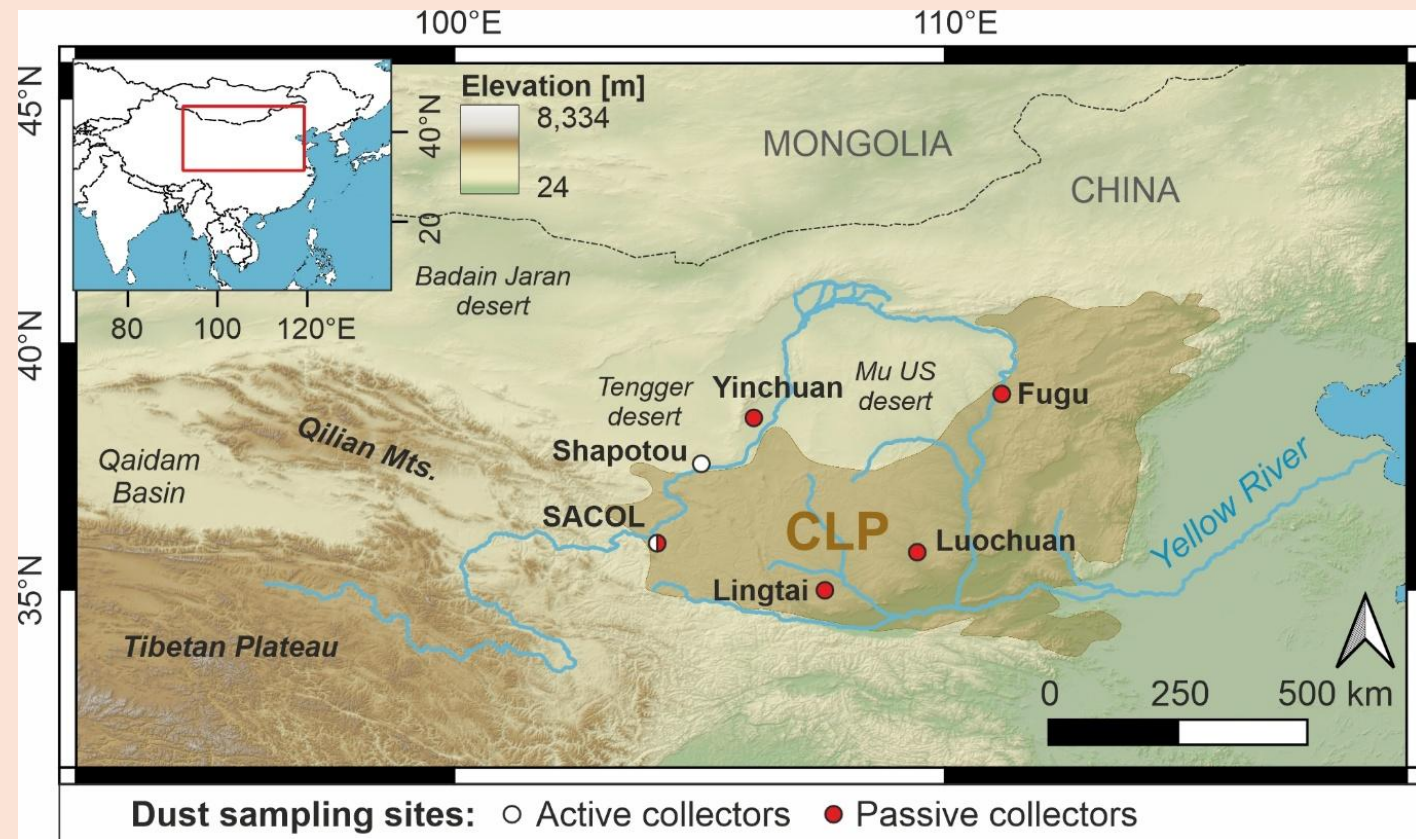
Dust sampling

Active collection during dust events (visible dust) from ~2 m above ground

- Airborne particles
- **Two sites: Shapotou** and Lanzhou University Semi-Arid Climate and Environment Observatory (**SACOL**)

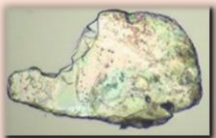
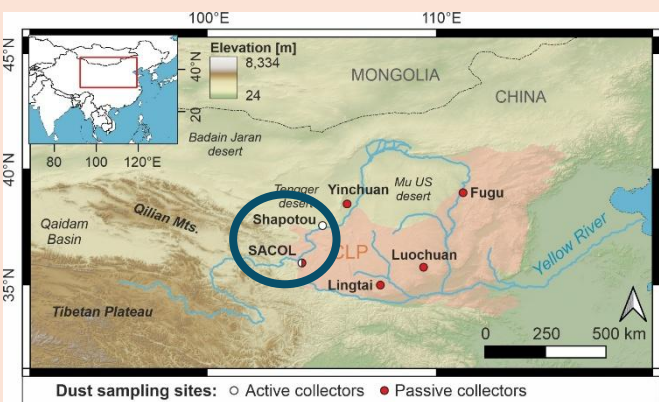
Passive sampling for longer periods (weeks to months)

- Deposited particles
- **5 sites: SACOL, Yinchuan, Lingtai, Luochuan & Fugu**



Dust sampling: Active traps

- Active collection during dust events (visible dust) from ~2 m above ground
- Cyclone dust collector FK-2200 (Zhucheng Weimin Machinery Co., Ltd., Shandong Province, China)



Dust sampling: Active traps

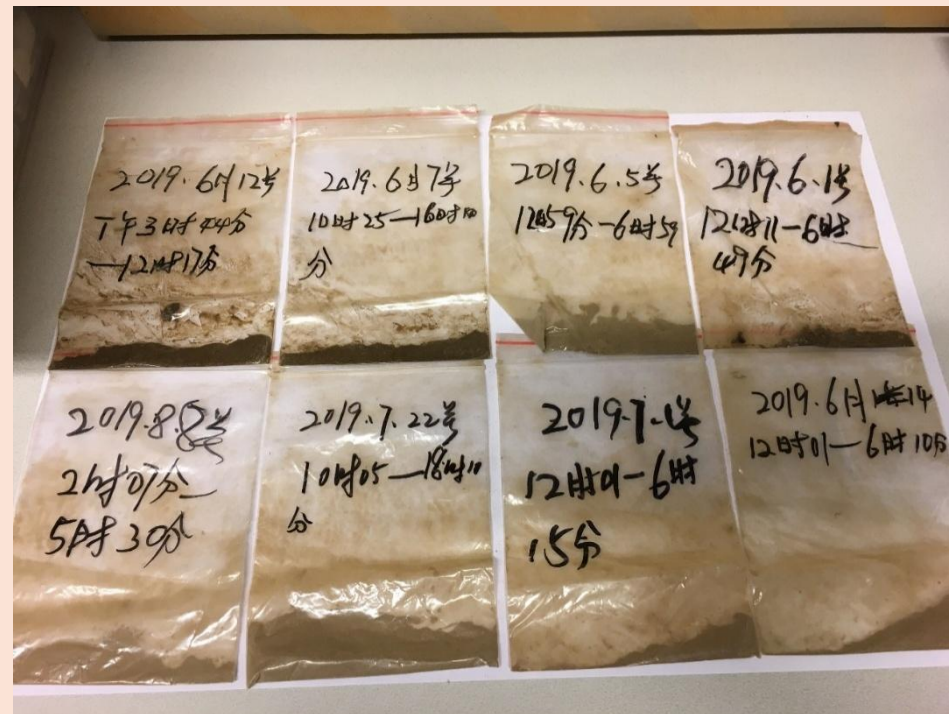
- Active collection during dust events (visible dust) from ~2 m above ground
- Cyclone dust collector FK-2200 (Zhucheng Weimin Machinery Co., Ltd., Shandong Province, China)

Shapotou:

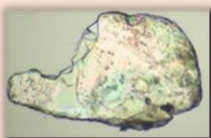
- 2019: 22 samples collected between 8 April and 2 September
- 2020: 23 samples collected between 14 June and 1 November
- 2021: 59 samples collected between 12 January and 17 July

SACOL:

- 2019: 1 sample
- 2020: 1 sample: dust events from 13 February to 13 May
- 2021: 2 samples: 14.–30.3. and 26.4.–6.6.
- 2023: 2 samples



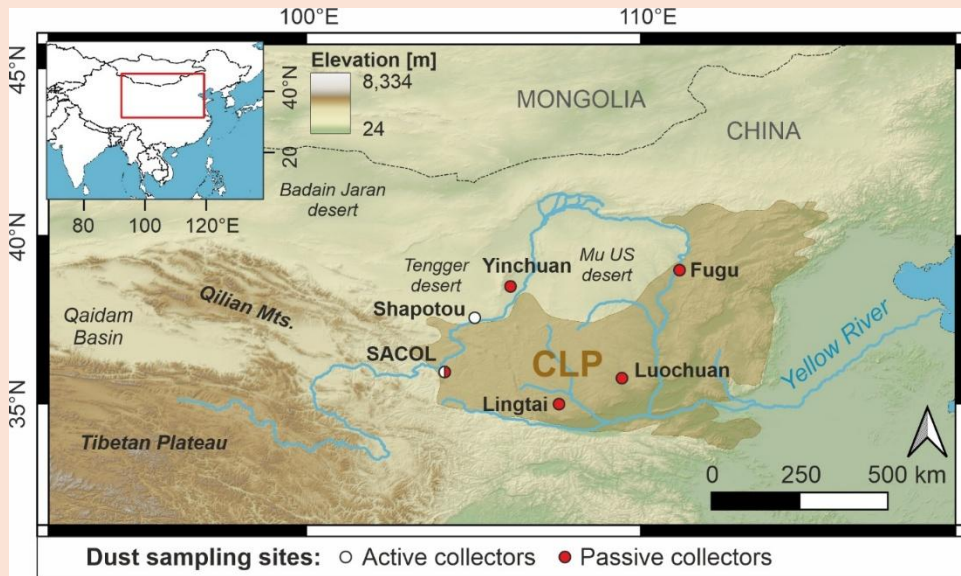
Samples from Shapotou



Dust sampling: Passive traps

- Passive collection of dust deposition for weeks to months
- 5 sites: SACOL, Yinchuan, Lingtai, Luochuan & Fugu
- Modified dust deposition trap after Webb et al. (2015)*
 - Stainless steel pot with marbles for cover

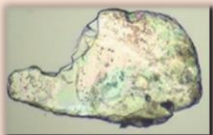
* Webb NP, Herrick JE, Van Zee JW, Hugenholtz CH, Zobeck TM, Okin GS, 2015. Standard Methods for Wind Erosion Research and Model Development: Protocol for the National Wind Erosion Research Network. USDA-ARS Jornada Experimental Range, Las Cruces, USA.



Passive trap 3D model
(without marbles)

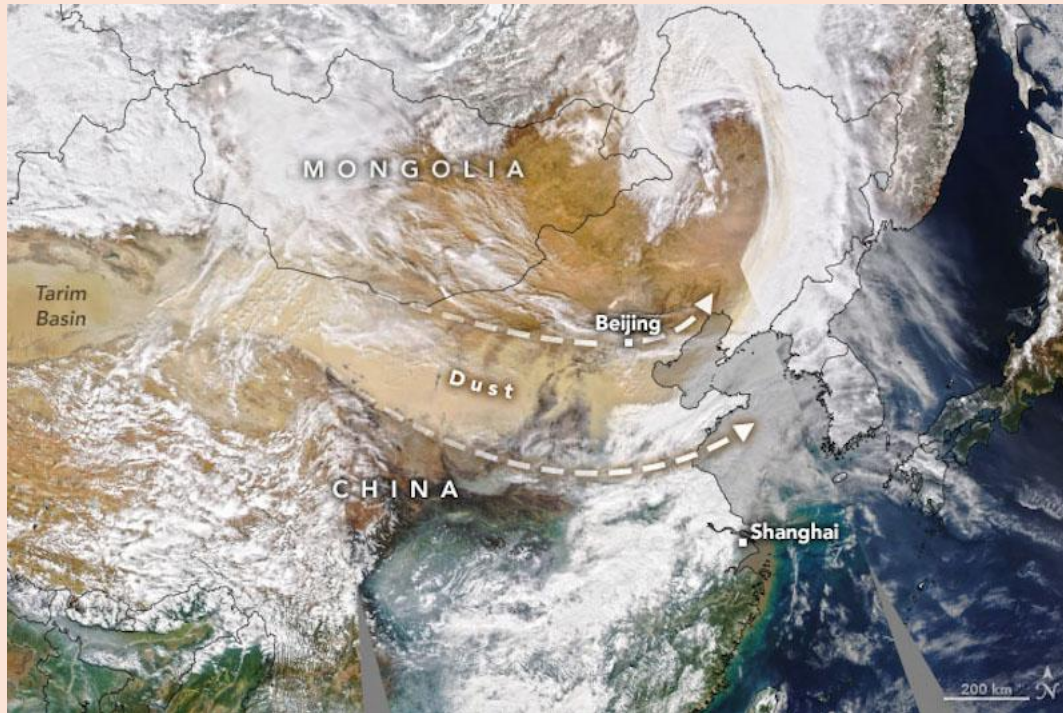


Passive traps on the roof in Yinchuan

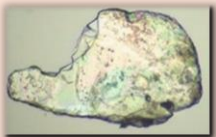


Dust sampling

- 2021 super dust storm (15–18 March) occurred during sampling period
- The largest dust storm in intensity and territorial coverage in a decade (China Meteorological Administration)

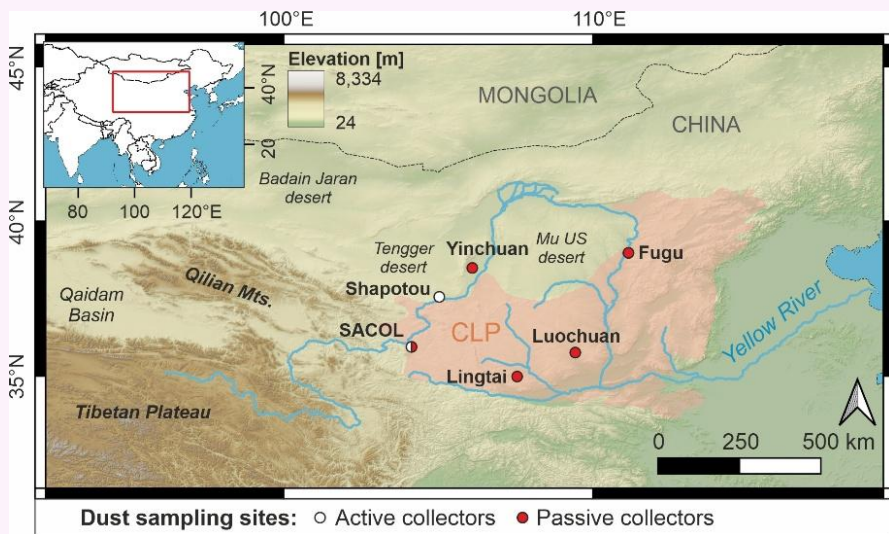


Images: NASA and Stephen Shaver/UPI

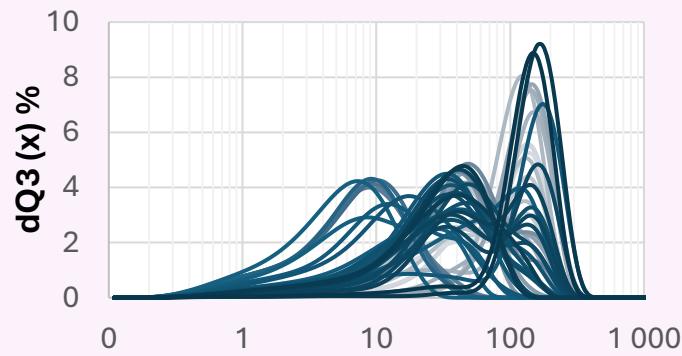


Grain size distribution

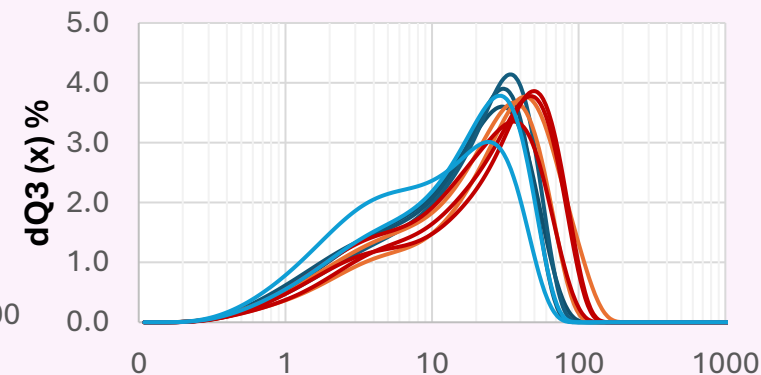
- Fritch Analysette 22 at the University of Helsinki
- All sites have similar grain size distributions (~bimodal peaks: <math><10\ \mu\text{m}</math> & $30\text{-}50\ \mu\text{m}$)
- Except: Shapotou has multiple samples with main peaks at $>100\ \mu\text{m}$ and at $\sim 10\ \mu\text{m}$ (next slides)



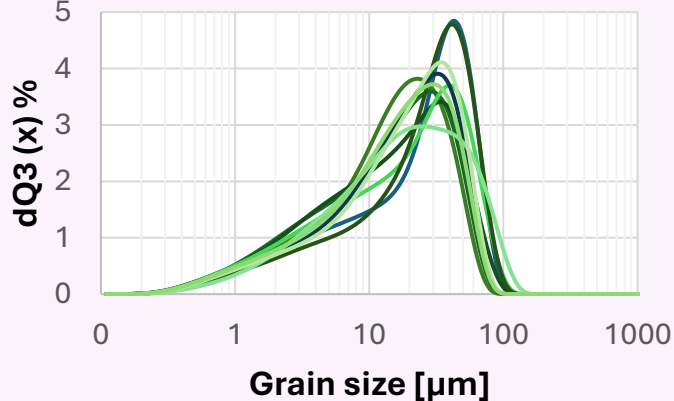
Shapotou (active trap)



Passive traps only



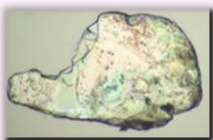
SACOL (active and passive traps)



Grain size [μm]

— Luochuan — Yinchuan
 — Fugu — Lingtai

Menu



Previous:
Sampling (5/5)

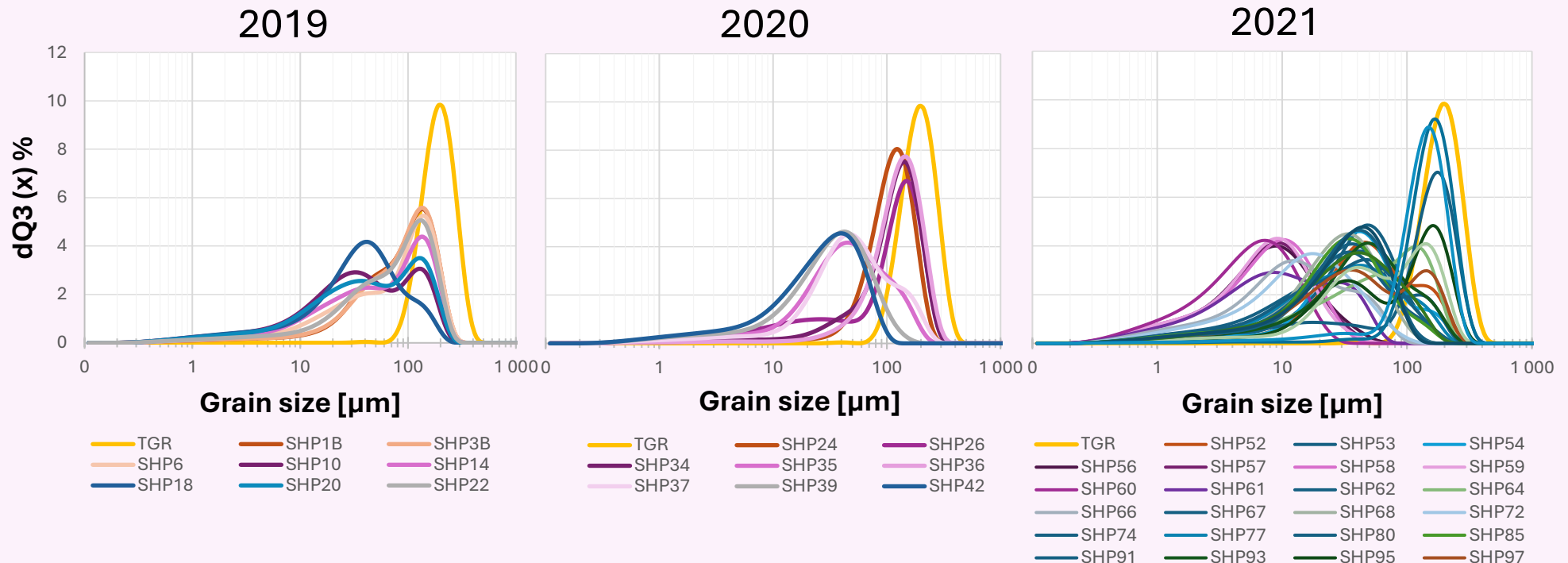


Next:
Grain size and
shape (2/4)

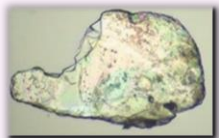
Grain size distribution

- The Shapotou GSD is likely a mix of the Tengger desert dune sand (TGR: yellow) and finer dust from another location
- In year 2021: multiple samples with a finer grain size mode (~10 μm) than in the previous years (next slide)

Shapotou



Menu



Previous:
Grain size and
shape (1/4)

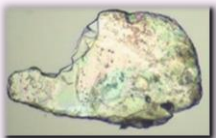
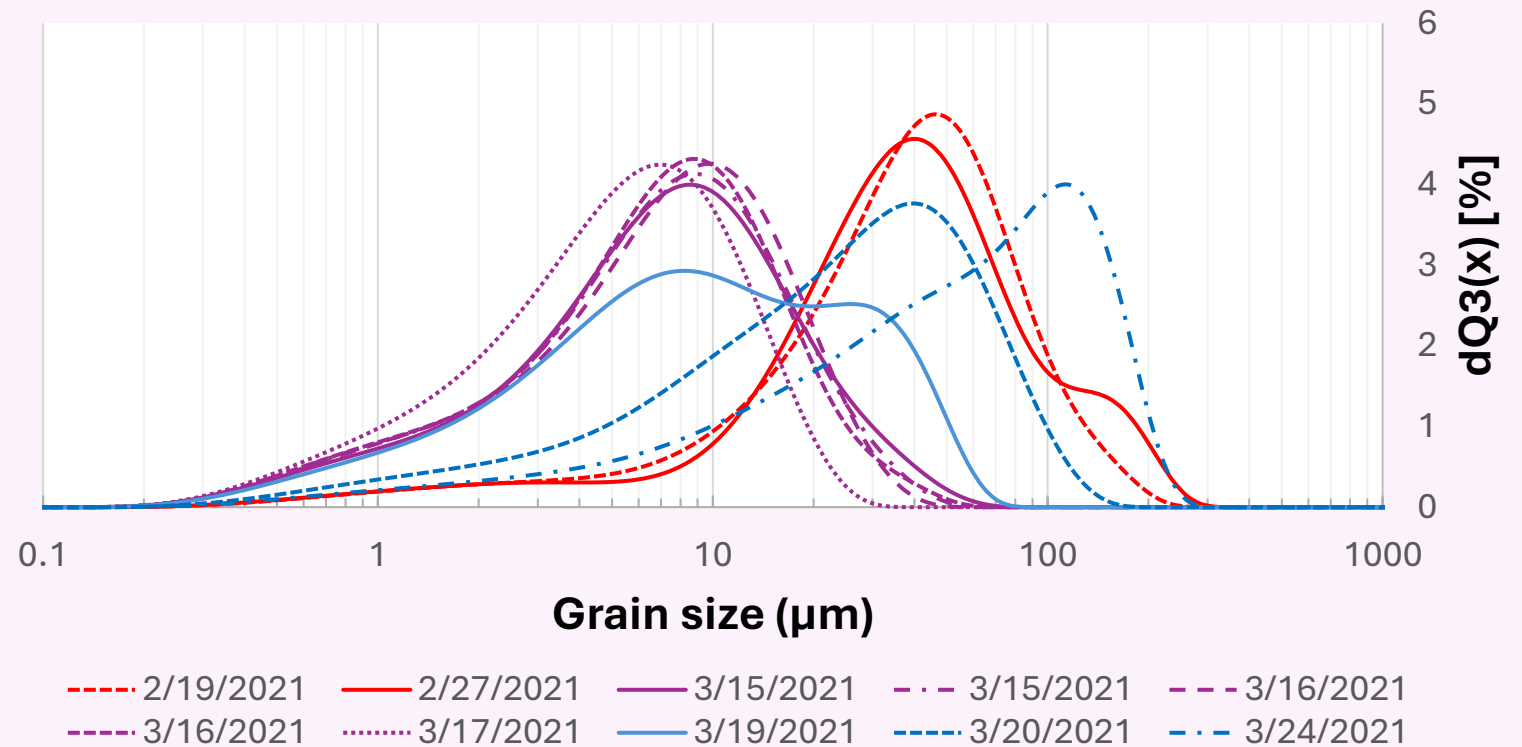


Next:
Grain size and
shape (3/4)

Grain size distribution

- The mid-March 2021 super dust storm (purple) has a finer grain size than before (red) or after (blue) it

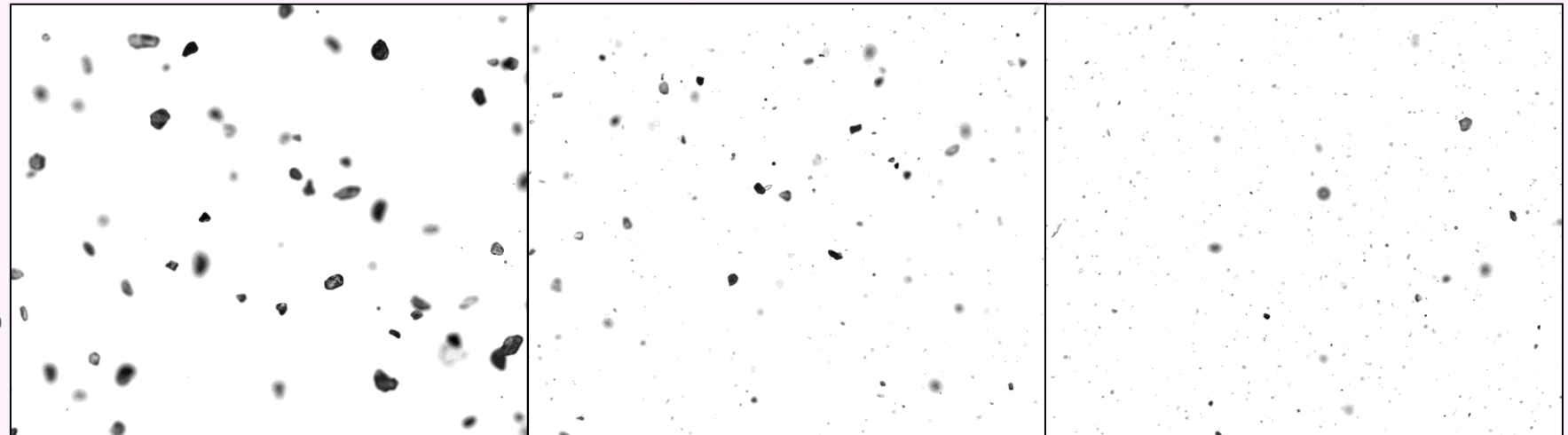
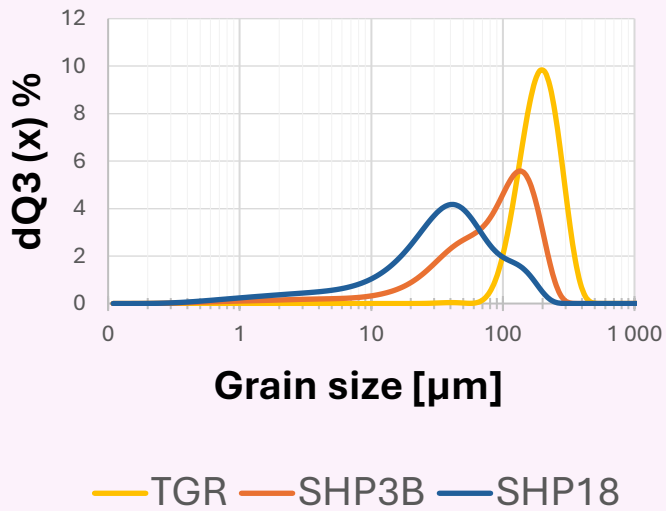
Shapotou



Grain shape parameters

- Fritch Analysette 28 at the University of Helsinki: Dynamic Image Analysis (DIA)
- Measured at the same time as the grain size distribution
- Thousands of particles are identified from the images
- The samples with the finest grain sizes are not suitable for the image analysis
- The shape parameters (e.g. circularity, convexity, elongation) may thus only represent the coarser grains
- Full analysis of the results still ongoing

Shapotou year 2019

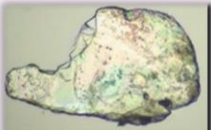


TGR: Tengger dune sand

SHP3B

SHP18

Menu



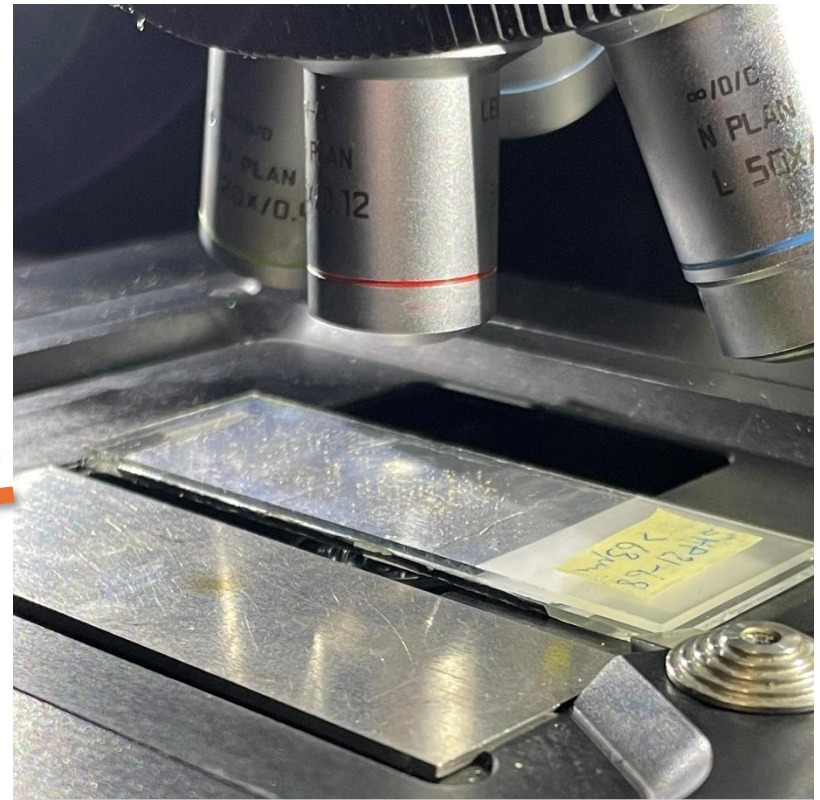
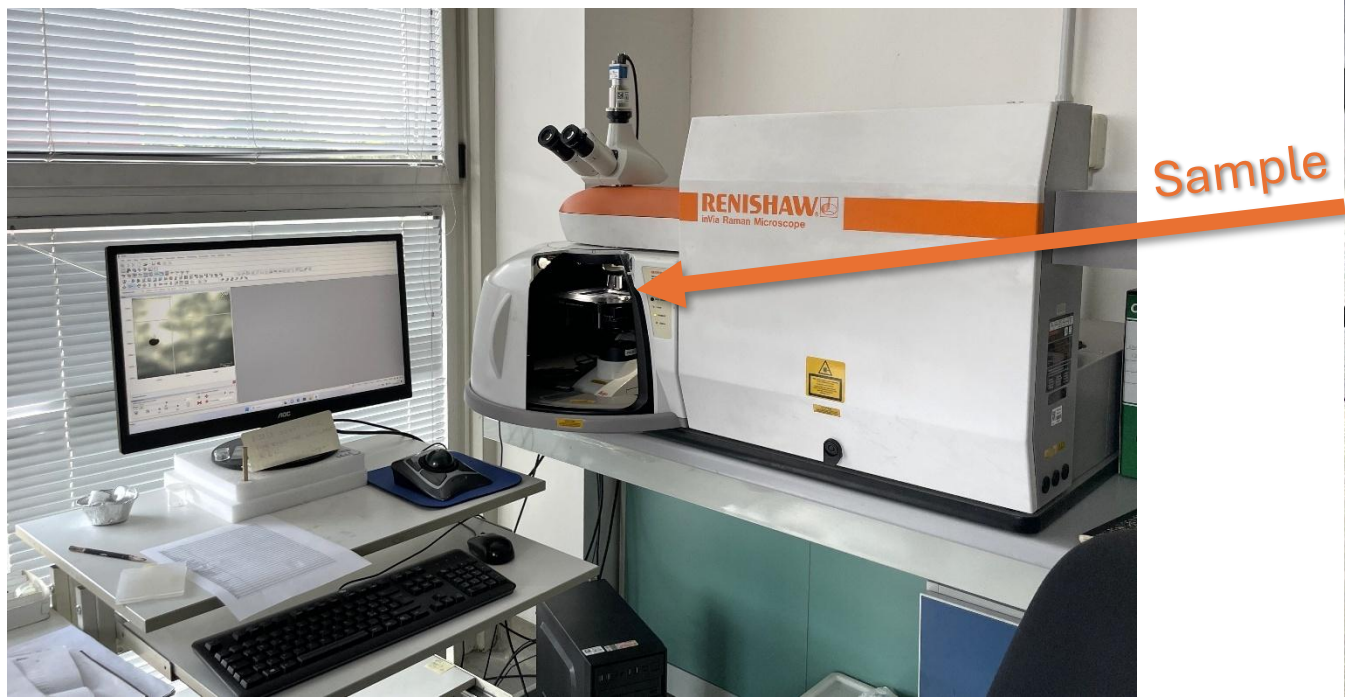
Previous:
Grain size and
shape (3/4)



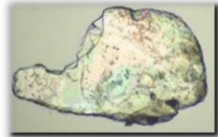
Next:
Mineralogy (1/10)

Mineralogy: Raman Spectroscopy

- Renishaw inVia™ Raman Microscope at the University of Milano-Bicocca
- Raman spectroscopy (RS) provides chemical and structural information on minerals and other materials
- RS measures the change in energy (Raman shift) caused by scattered light interacting with molecular vibrations in the material

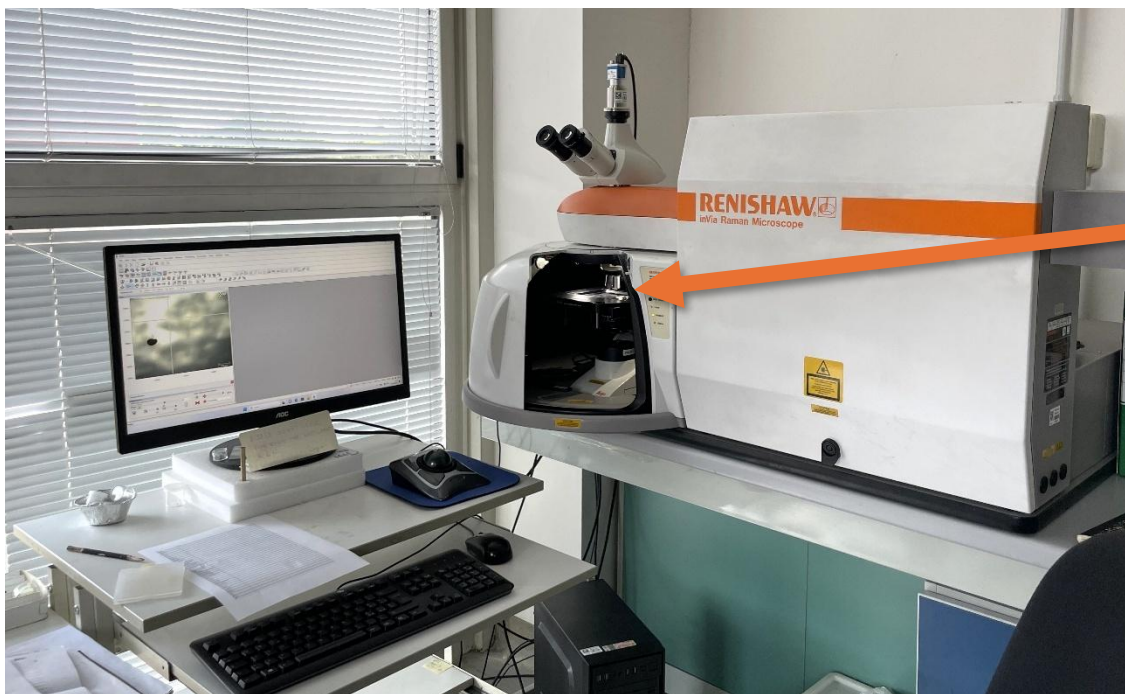


Smear slide: the grains have been distributed on a glass slide with water and dried on a hot plate, no cover slide

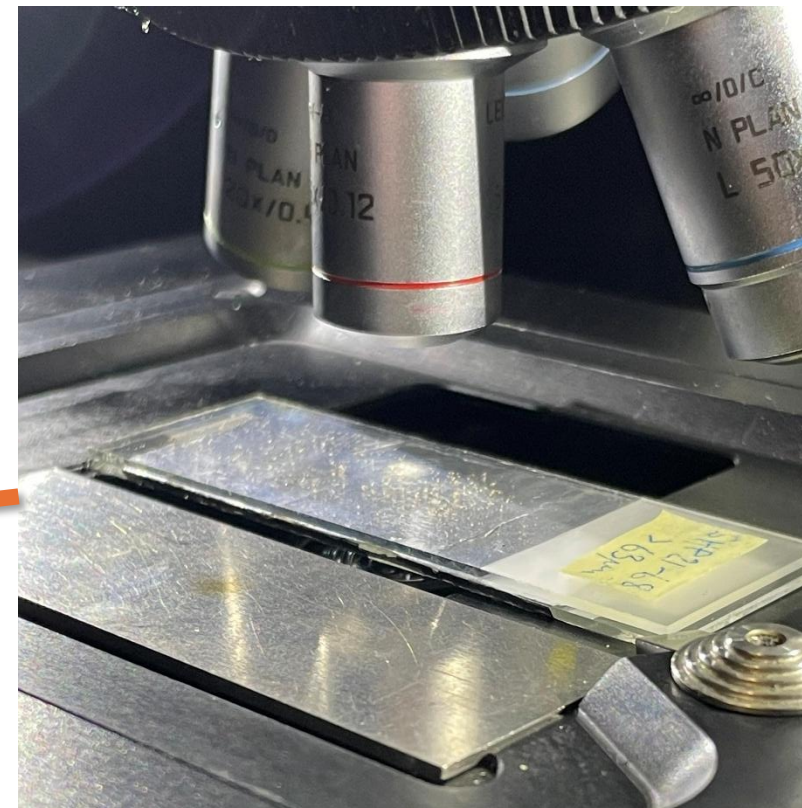


Mineralogy: Raman Spectroscopy

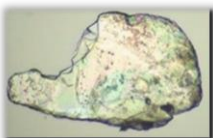
- Analysis of a single grain is fast (seconds to minutes)
- Can be applied to $>2 \mu\text{m}$ grains (laser spot size $2 \mu\text{m}$) ($<2 \mu\text{m}$ mineralogy will be measured by XRD)
- Minimal sample preparation, non-destructive, grains can be retrieved after analysis
- A mix of multiple minerals (rock fragments or impurities on the grain surface) can be identified from the same analysis spectrum



Sample

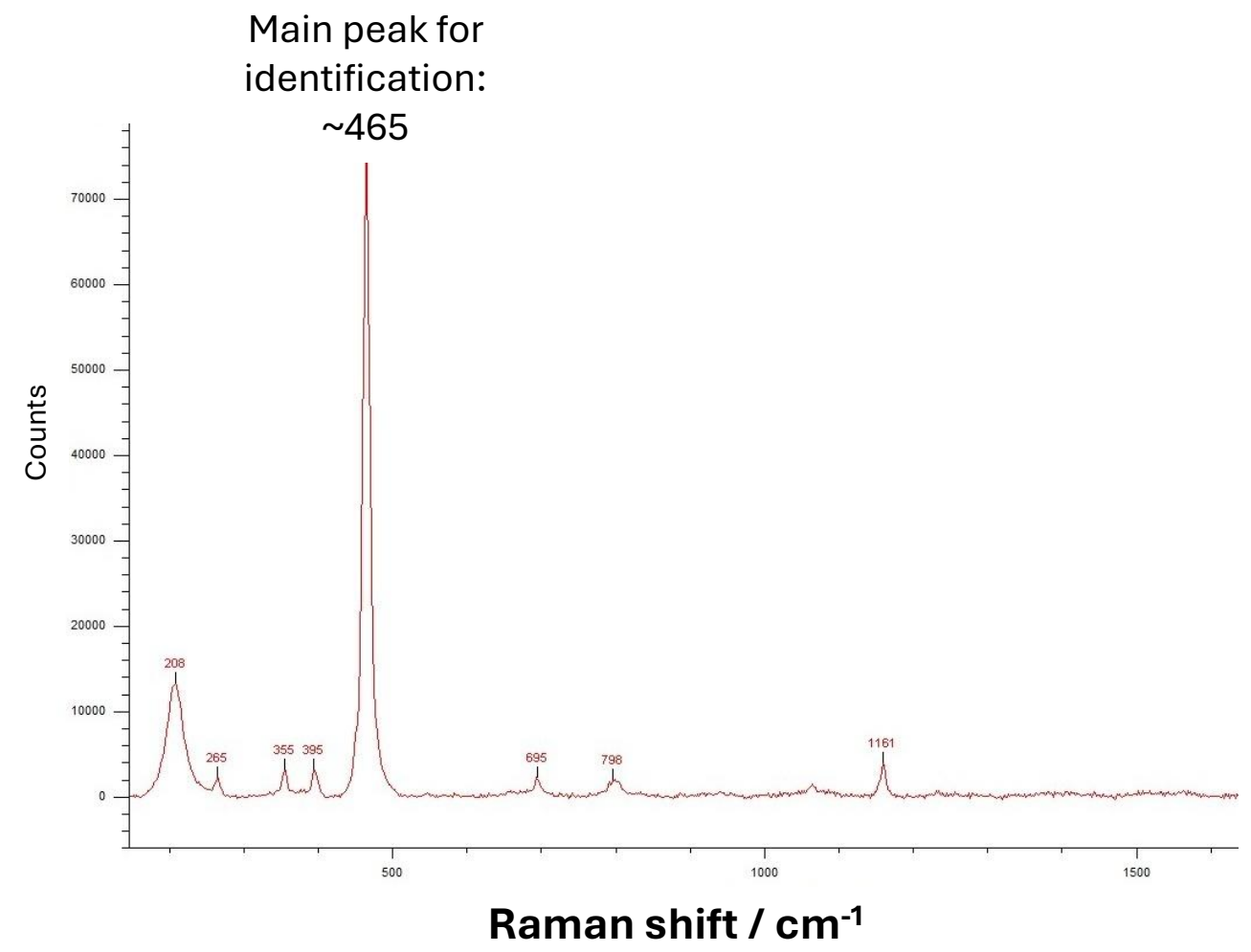
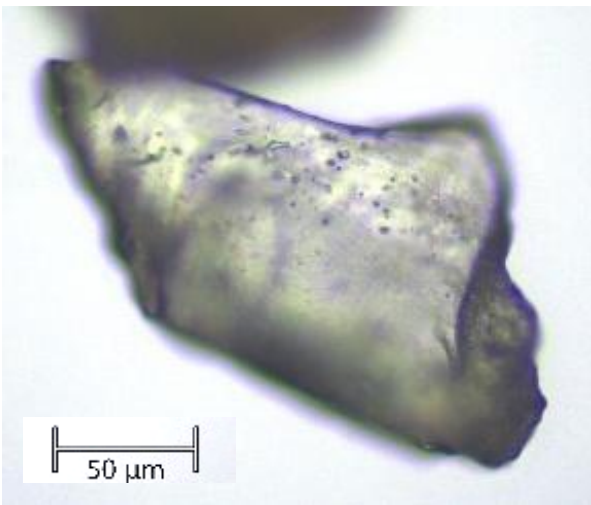


Smear slide: the grains have been distributed on a glass slide with water and dried on a hot plate, no cover slide

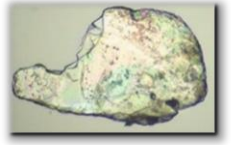


Mineralogy: Raman Spectroscopy

- An example of a quartz grain and its Raman spectrum:



Menu



Previous:
Mineralogy
(2/10)

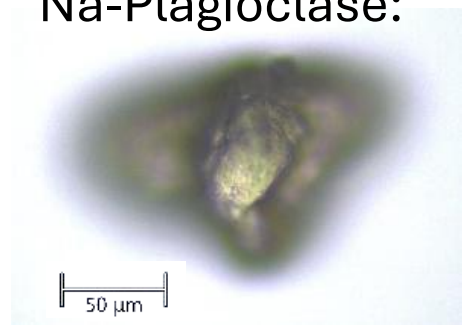


Next:
Mineralogy (4/10)

Mineralogy: Raman Spectroscopy

- Feldspars: Plagioclase vs. K-feldspar
- Slightly different main peak positions for identification
- Sample: SHP21-68, >63 μm fraction

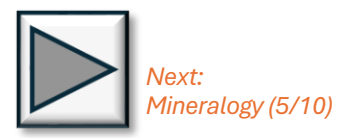
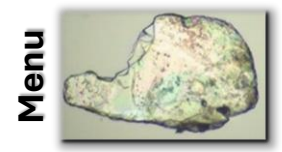
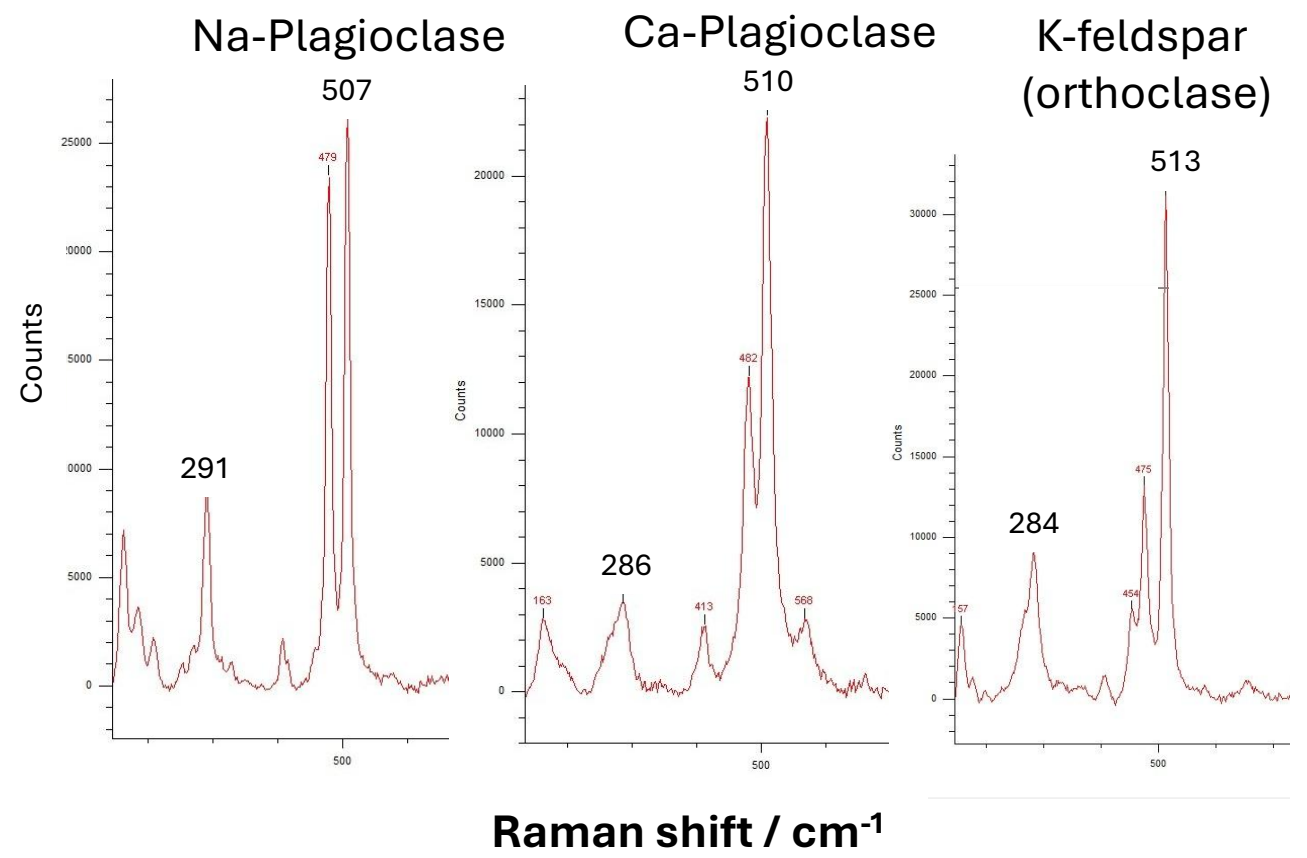
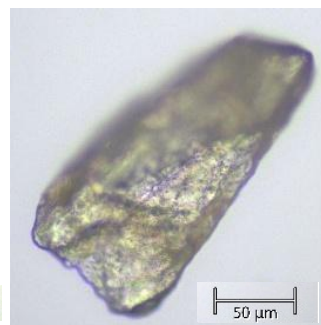
Na-Plagioclase:



Ca-Plagioclase:



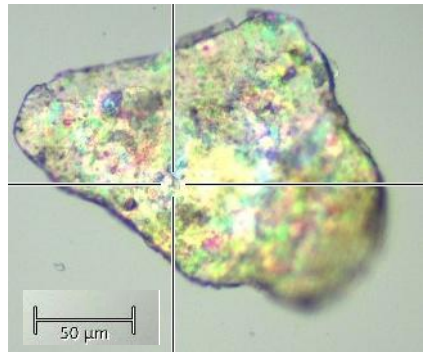
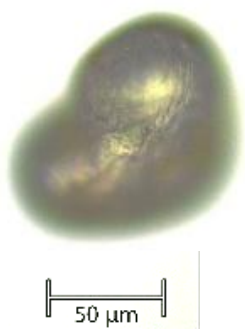
K-feldspars:



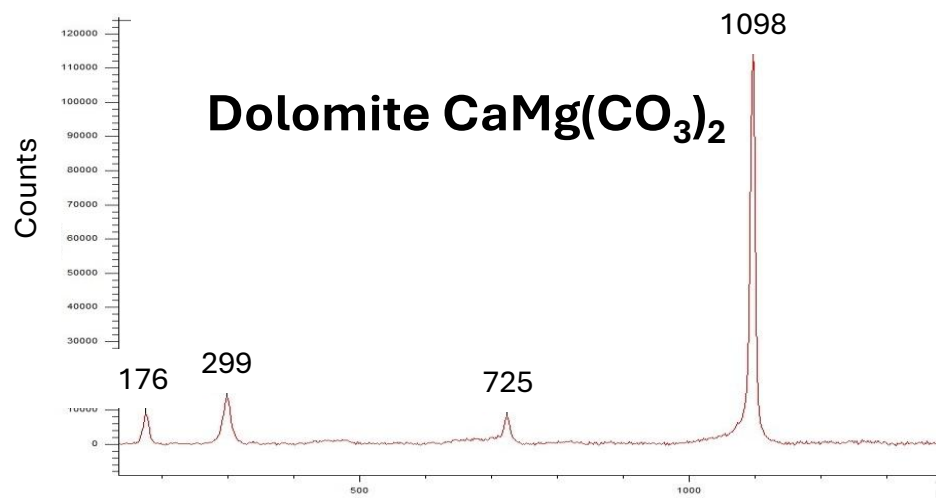
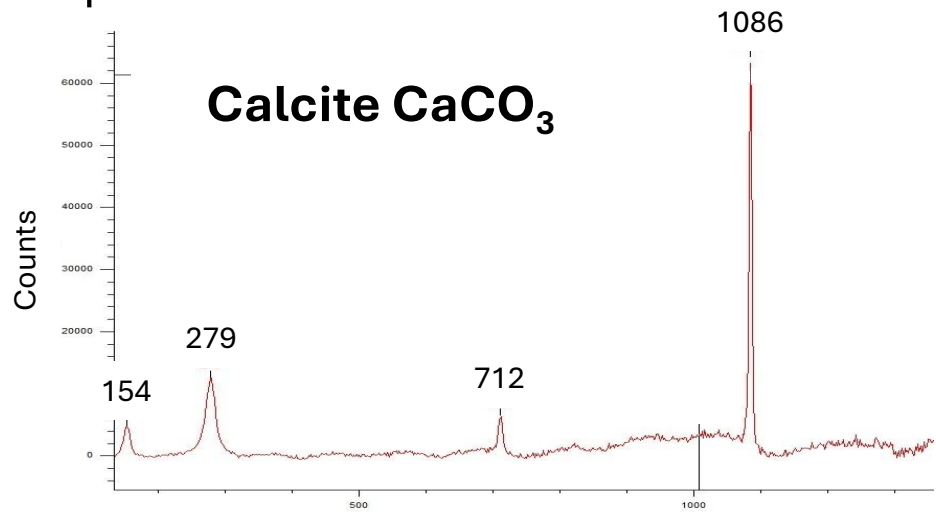
Mineralogy: Raman Spectroscopy

- Carbonates: Calcite (main peak ~1086) vs. dolomite (main peak ~1098)
- Sample: SHP21-68, >63 μm fraction

Calcites:

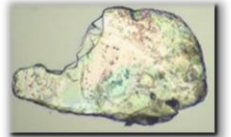


Dolomite:



Raman shift / cm^{-1}

Menu



Previous:
Mineralogy
(4/10)

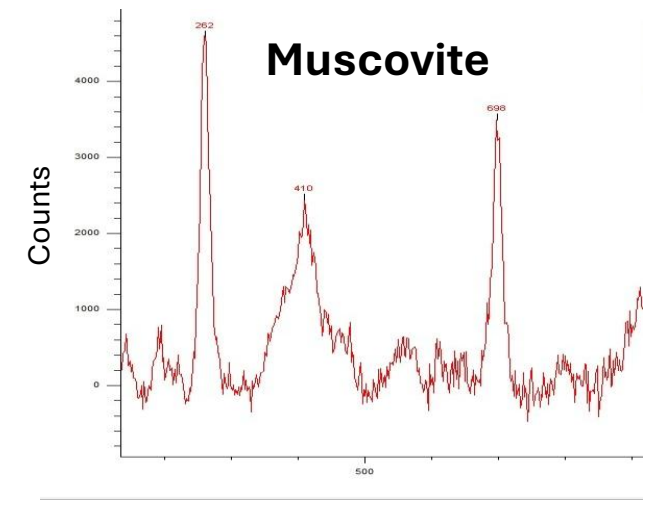
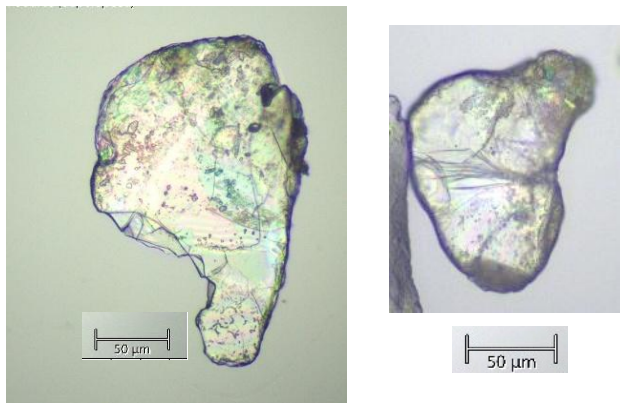


Next:
Mineralogy (6/10)

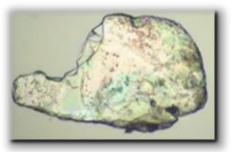
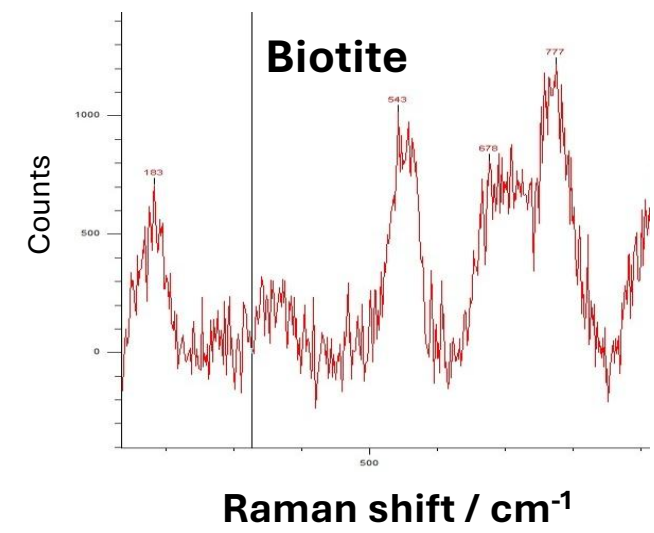
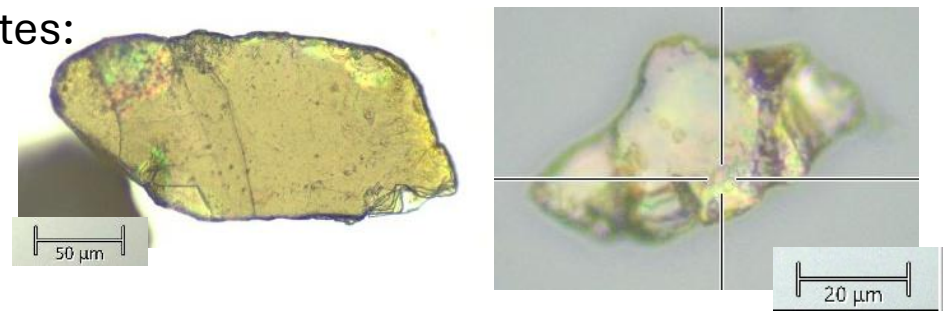
Mineralogy: Raman Spectroscopy

- Micas: Muscovite & biotite (clearly different spectra)
- Sample: SHP21-68, >63 μm & 20-63 μm fractions

Muscovites:



Biotites:

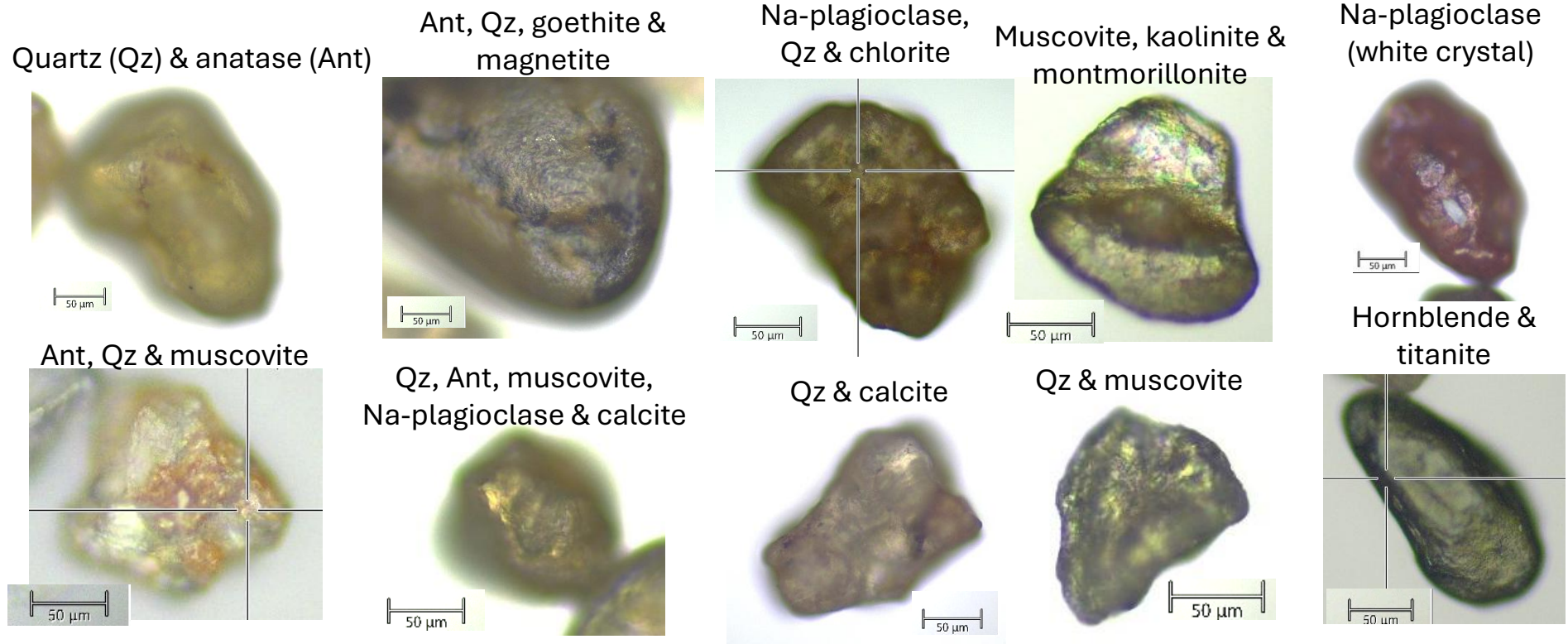


Mineralogy: Raman Spectroscopy

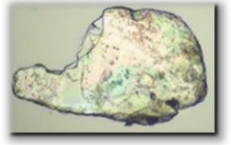
- Point counting on a line or line counting
- ~300 mineral counts
- ~Volume percentage of minerals
- additional data on, e.g., roundness of grains, chemical composition of single grains

Examples of rock fragments (RF) found so far

Sample: SHP21-68
>63 μm fraction



Menu



Previous: Mineralogy (6/10)



Next: Mineralogy (8/10)

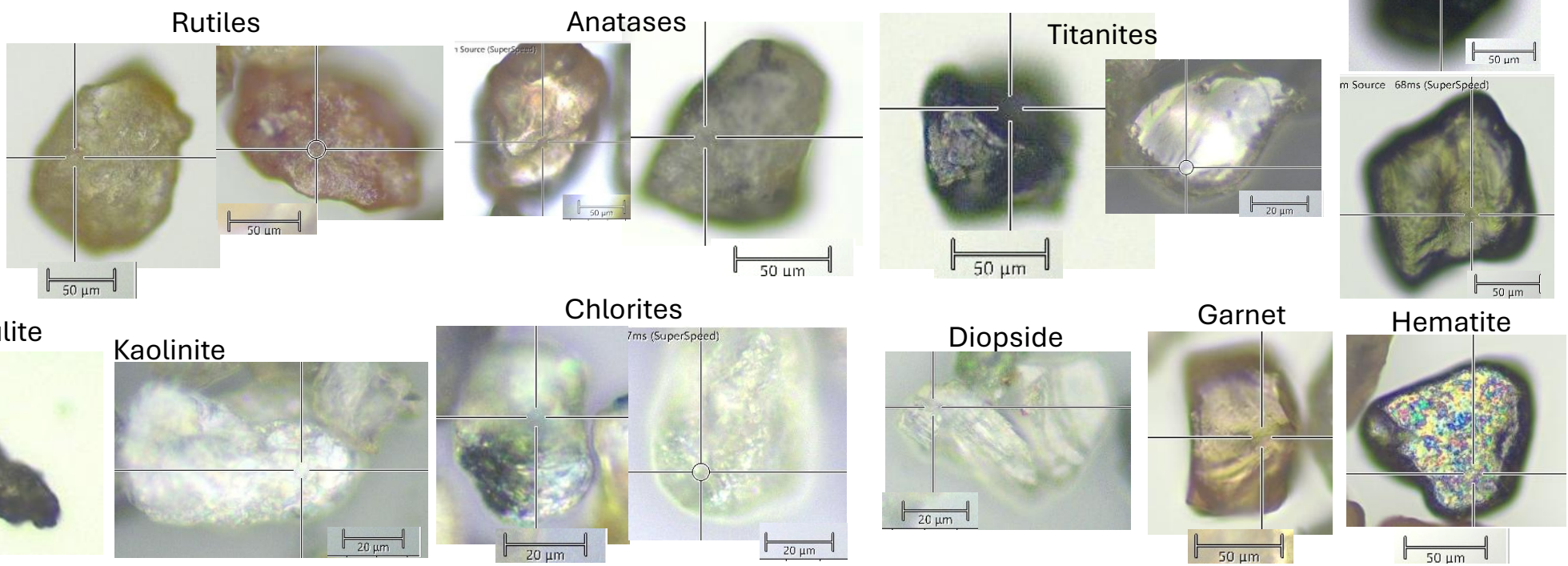
Mineralogy: Raman Spectroscopy

- Point counting on a line or line counting
- ~300 mineral counts
- ~Volume percentage of minerals
- additional data on, e.g., roundness of grains, chemical composition of single grains

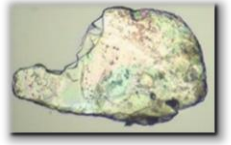
Miscellaneous minerals found so far

Samples: SHP19-3, SHP21-68 & SHP21-69

>63 μm & 20-63 μm fractions



Menu



Previous:
Mineralogy
(7/10)



Next:
Mineralogy (9/10)

Mineralogy: The first results (one sample)

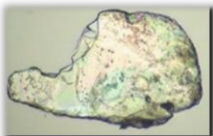
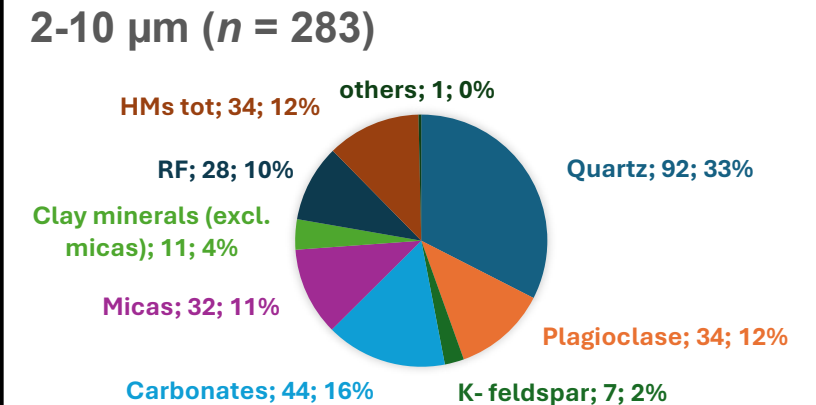
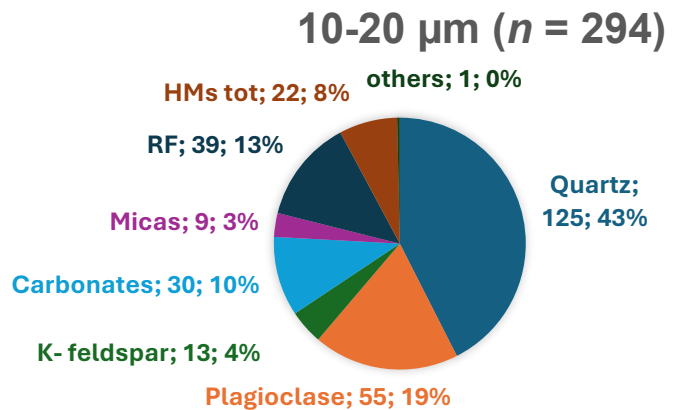
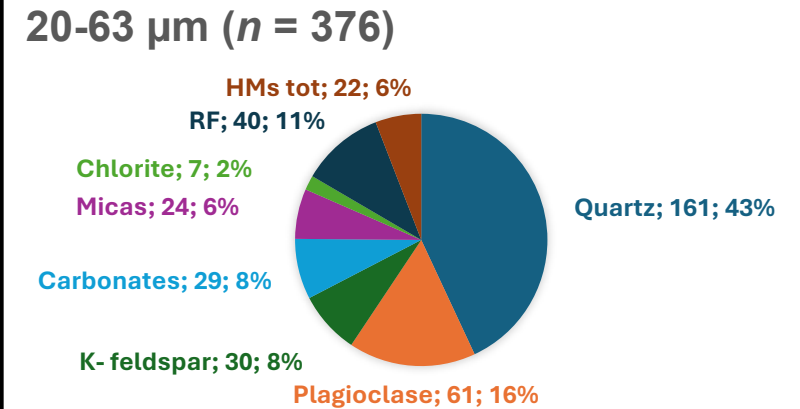
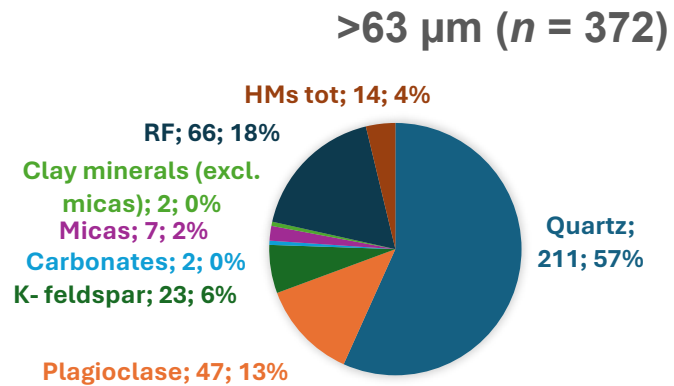
- Four grain size fractions: >63 μm, 20-63 μm, 10-20 μm, 2-10 μm
- Sample: SHP21-69
- Active collector in Shapotou
- Date of collection: 2021-04-15

Coarser grains:

- More quartz, K-feldspar (KF), Rock fragments (RF)
- Less carbonates, heavy minerals (HMs), clay minerals, micas

Finer grains:

- More carbonates, HMs, clay minerals, micas
- Less quartz, KF, RF
- More mineral diversity



Mineralogy: The first results (one sample)

- Four grain size fractions: >63 μm, 20-63 μm, 10-20 μm, 2-10 μm
- Sample: SHP21-69
- Active collector in Shapotou
- Date of collection: 2021-04-15

CARBONATE COMPOSITION:

Sand fraction:

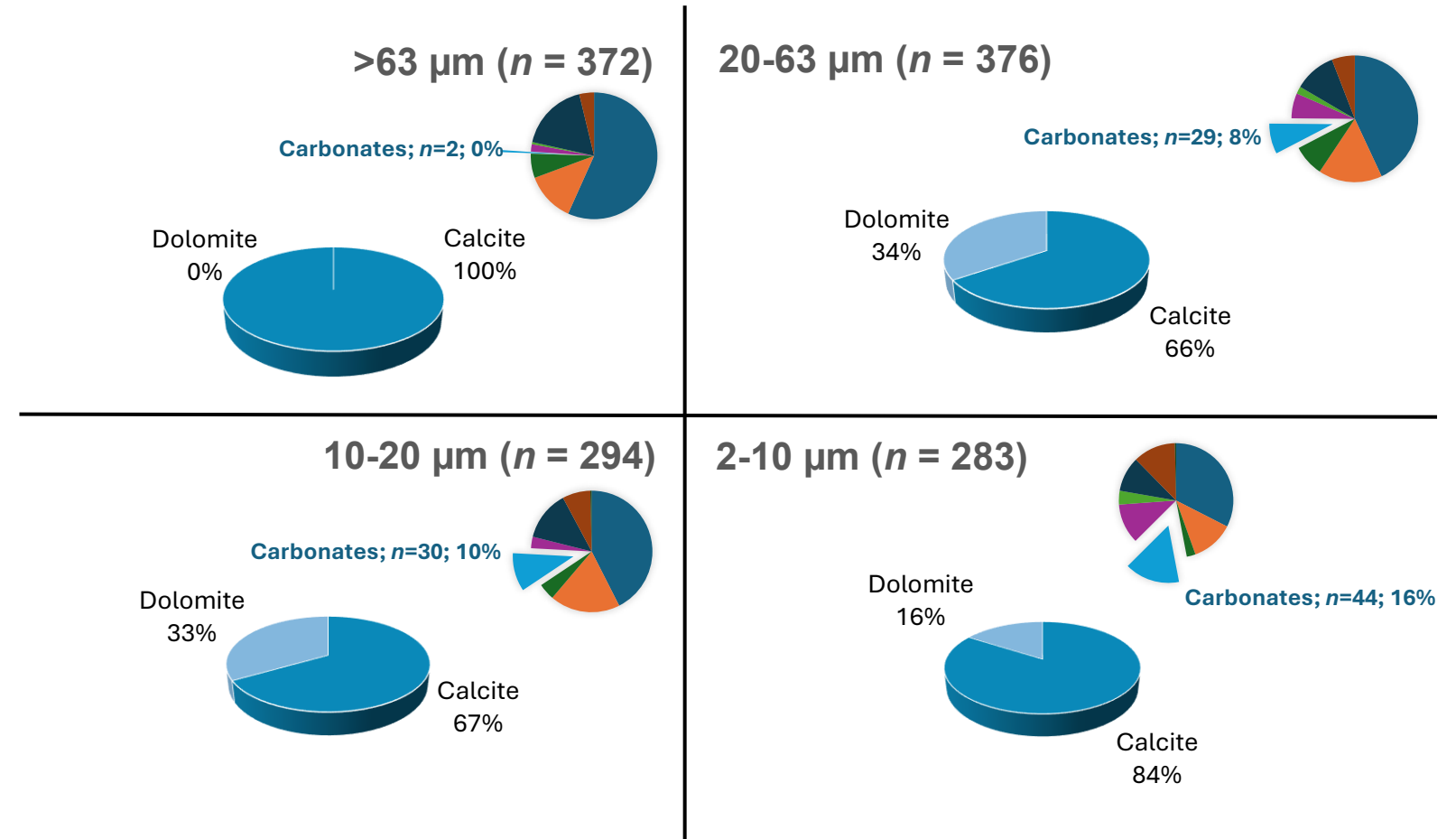
- very low carbonate content

Coarser silt fractions:

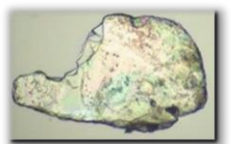
- Mostly calcite
- Third of carbonates are dolomite (Mg-carbonate)

Finest silt fraction:

- More carbonates
- Mostly calcite
- Less dolomite than in the coarser silt fractions



Menu



Previous:
Mineralogy
(9/10)



Next:
Magnetic methods (1/3)

Magnetic susceptibility (MS)

- Measurements at Uppsala University and University of Helsinki
- MS describes how much a mineral gets magnetized in an external magnetic field
- Information on mineral composition, grain size and crystal structure
- This presentation: MS measured in different frequencies of the applied/external magnetic field → information on the size of the magnetic (Fe-oxides) grains (next slides)

Samples in measurement containers

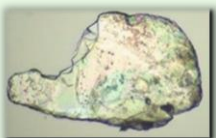


Frequency-dependent MS: χ_{fd} [%]

$$\chi_{fd} = \frac{100(\chi_{lf} - \chi_{hf})}{\chi_{lf}}$$

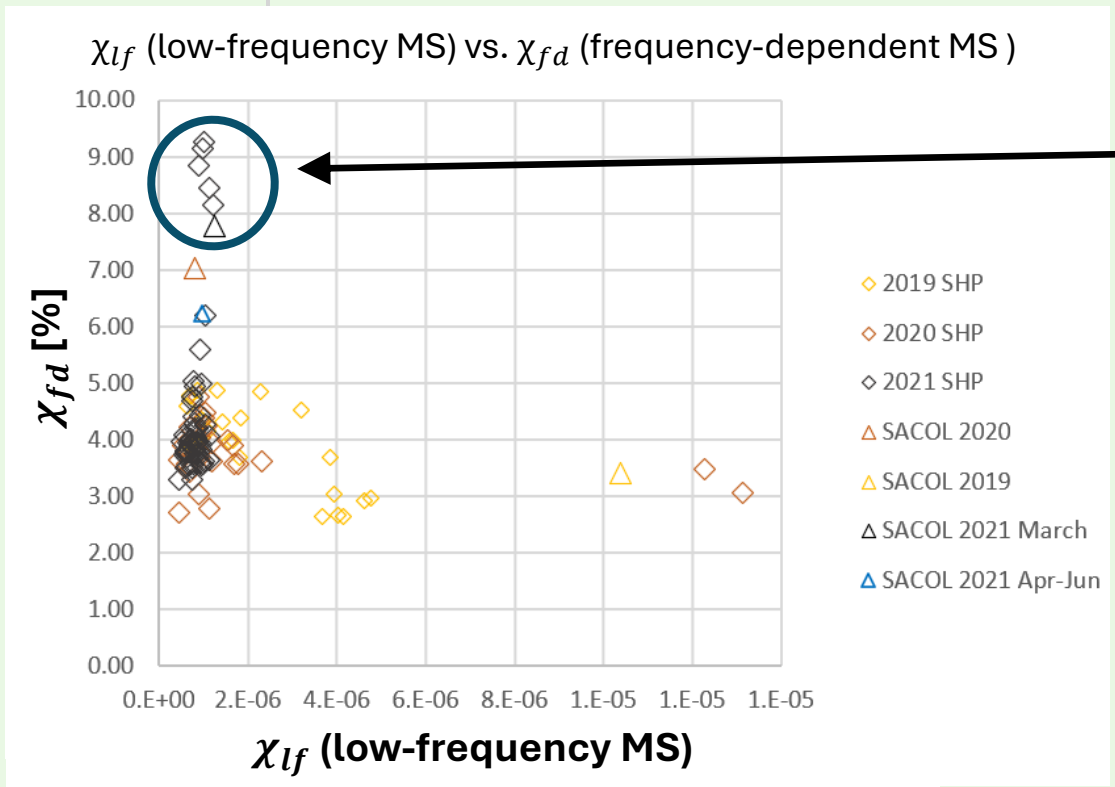
χ_{lf} = low-frequency MS

χ_{hf} = high-frequency MS



Magnetic susceptibility (MS)

- Mid-March 2021 super dust storm, both at Shapotou (SHP; diamond) and SACOL (triangle), has a higher frequency-dependency of MS than other samples
- More superparamagnetic particles (i.e., small nanoscale ferromagnetic grains)
- Finer grain size of the Fe-oxides

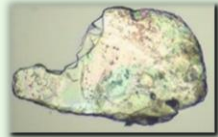


Mid-March 2021 super dust storm



Photo: Stephen Shaver/UPI

Menu



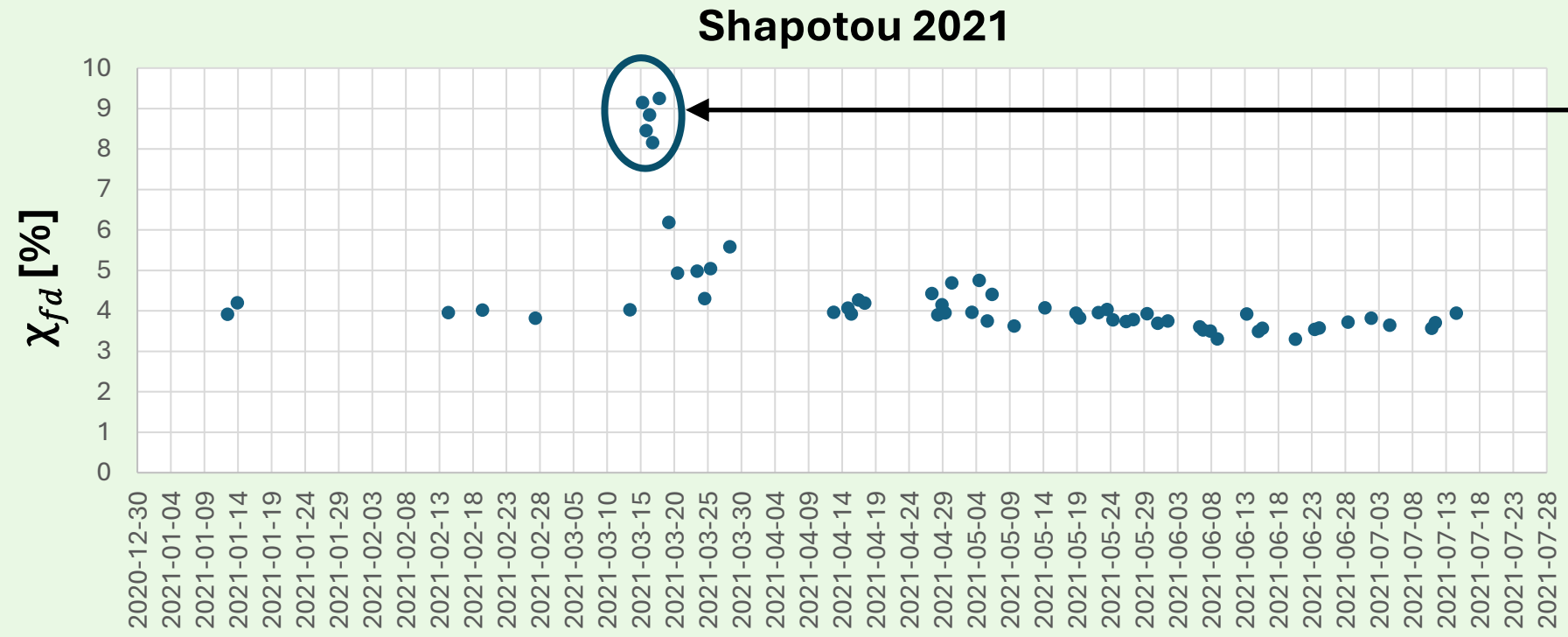
Previous: Magnetic methods (1/3)



Next: Magnetic methods (3/3)

Magnetic susceptibility (MS)

- Temporal variation of frequency-dependent MS at Shapotou in 2021
 - Mid-March 2021 super dust storm has clearly a higher frequency-dependency of MS than other samples
- More superparamagnetic particles (i.e., small nanoscale ferromagnetic grains)
- Finer grain size of the Fe-oxides

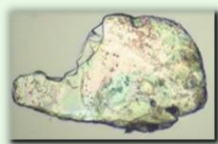


Mid-March 2021 super dust storm



Photo: Stephen Shaver/UPI

Menu



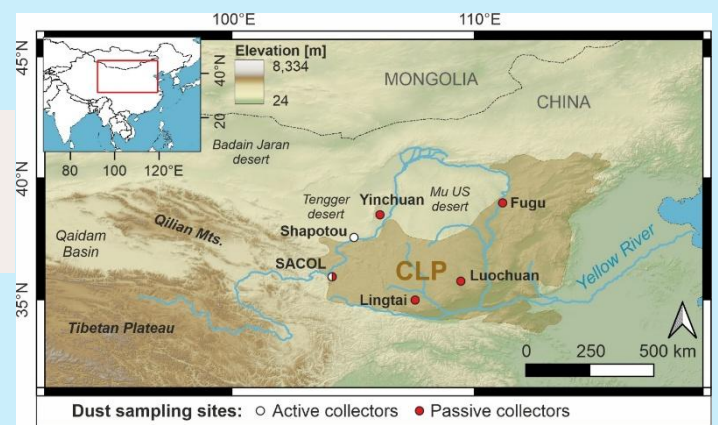
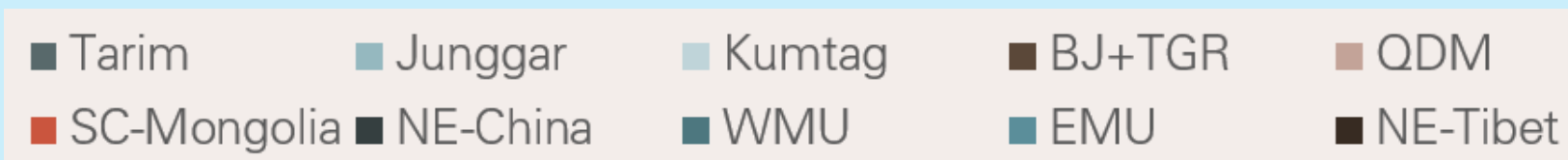
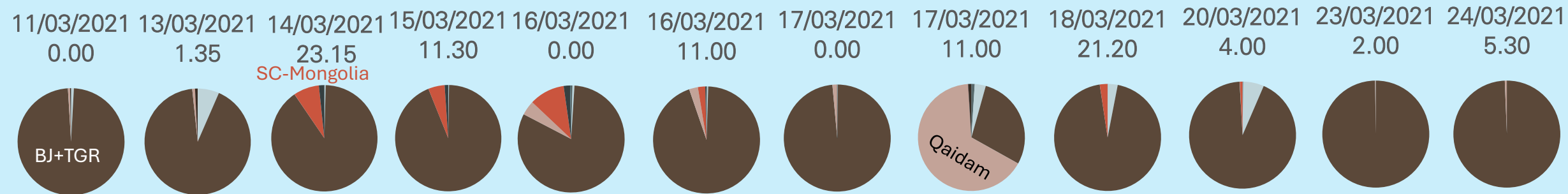
Previous:
Magnetic
methods (2/3)



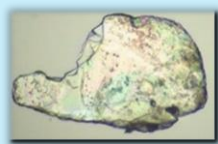
Next:
Source contribution
modelling (1/2)

Dust source contribution modelling: Shapotou 15-20 μm

- Model: FLEXPART-FLEXDUST
- **Mid-March 2021 super dust storm**
- Mongolian sources increased at the first stages of the storm (14/03/2021), westerly sources (Qaidam) increased at the later stages of the storm (17/03/2021)
- Most times the main sources are Badain Jaran and Tengger deserts (BJ+TGR)



Menu



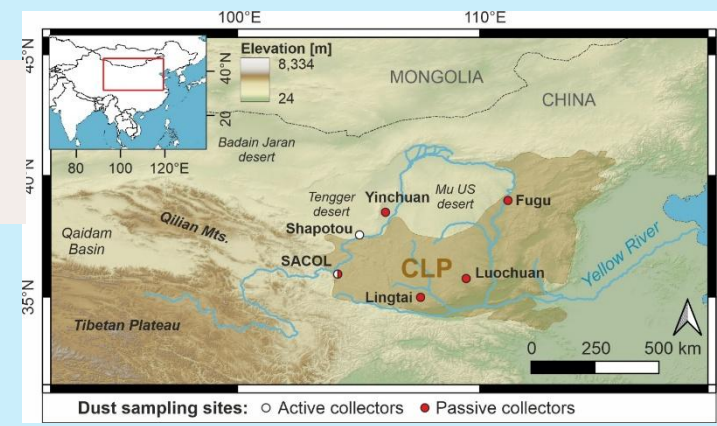
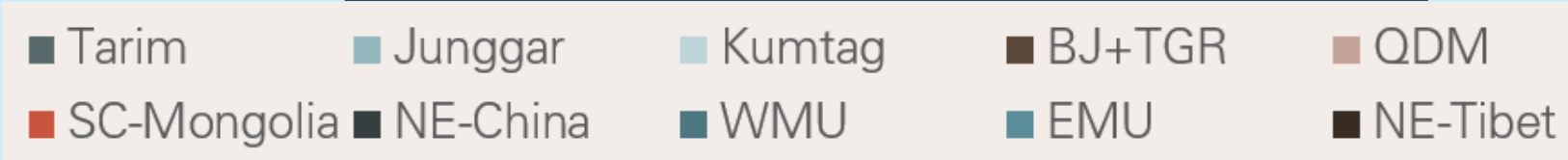
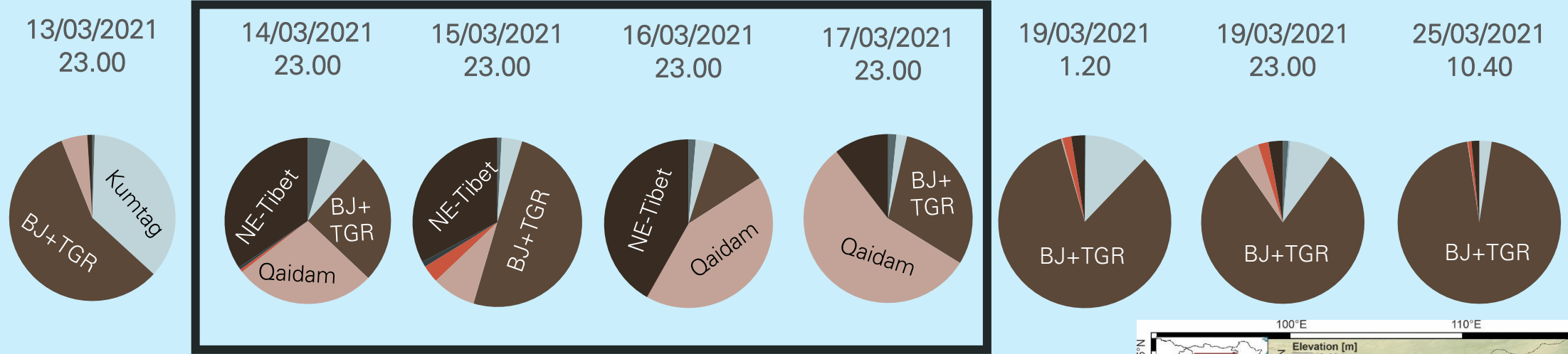
Previous: Magnetic methods (3/3)



Next: Source contribution modelling (2/2)

Dust source contribution modelling: SACOL 15-20 μm

- Model: FLEXPART-FLEXDUST
- **Mid-March 2021 super dust storm**
- Qaidam (QDM) and NE Tibetan Plateau sources increased during the storm
- Before and after the storm, the main sources are Badain Jaran and Tengger deserts (BJ+TGR)





Future work

- This work is part of an ongoing postdoc project at UNIMIB 2025-2027: *Atmospheric mineral dust properties and provenance in East Asia: New perspectives on past and present dust-climate interactions*
- Funded by Finnish Cultural Foundation



Finnish Cultural Foundation



Current status of the project:

	MAGNETIC PROPERTIES	GRAIN SIZE AND SHAPE	MINERALOGY	SOURCE CONTRIBUTION MODELLING	PROVENANCE ANALYSES	COMPARISON OF PAST AND PRESENT CLP DUST
Data collection status	Done	Done	Ongoing	Ongoing	To be done	To be done
Data analysis status	Ongoing	Ongoing	To be done	To be done	To be done	To be done

How do the dust properties and provenance vary in space and time?

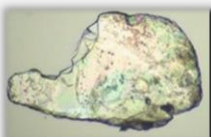
What are the meteorological or climatic conditions behind possible variations?

How reliable are sedimentological provenance methods in sourcing aeolian dust?

(How) can we use the information on modern dust to better interpret the geological dust records of the CLP?

Questions to be answered:

Menu



Previous: Source contribution modelling (2/2)

