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Integrated Approach to Identify Variables for the Prediction of a Slag Heap composition using time-domain IP/ERT and SIP in the lab

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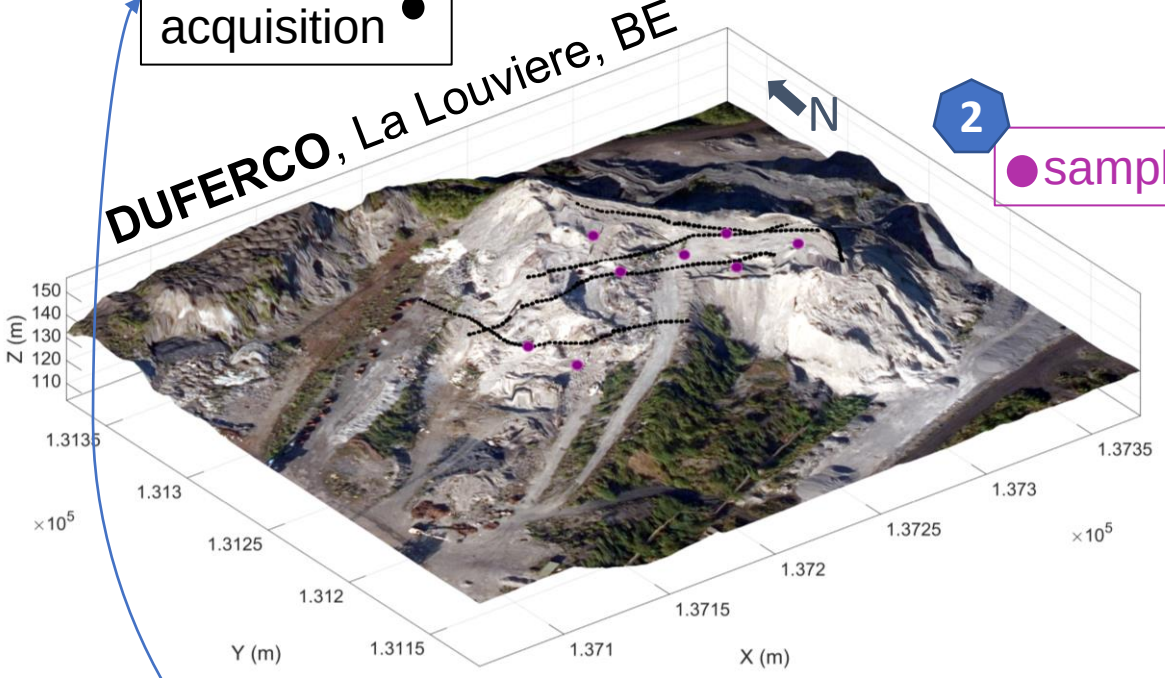
Objective

Identify slags of different chemical composition in a heap in view of resource recovery assessment

Methodology

1 3D ERT/IP acquisition ●



2 ●sampling

3

In the lab
- SIP

Particle size distribution
- XRF
- XRD
- ICP

CTP member of EMRA

4 What types of slags can be distinguished? correlations between chemical composition and (geo)physical parameters

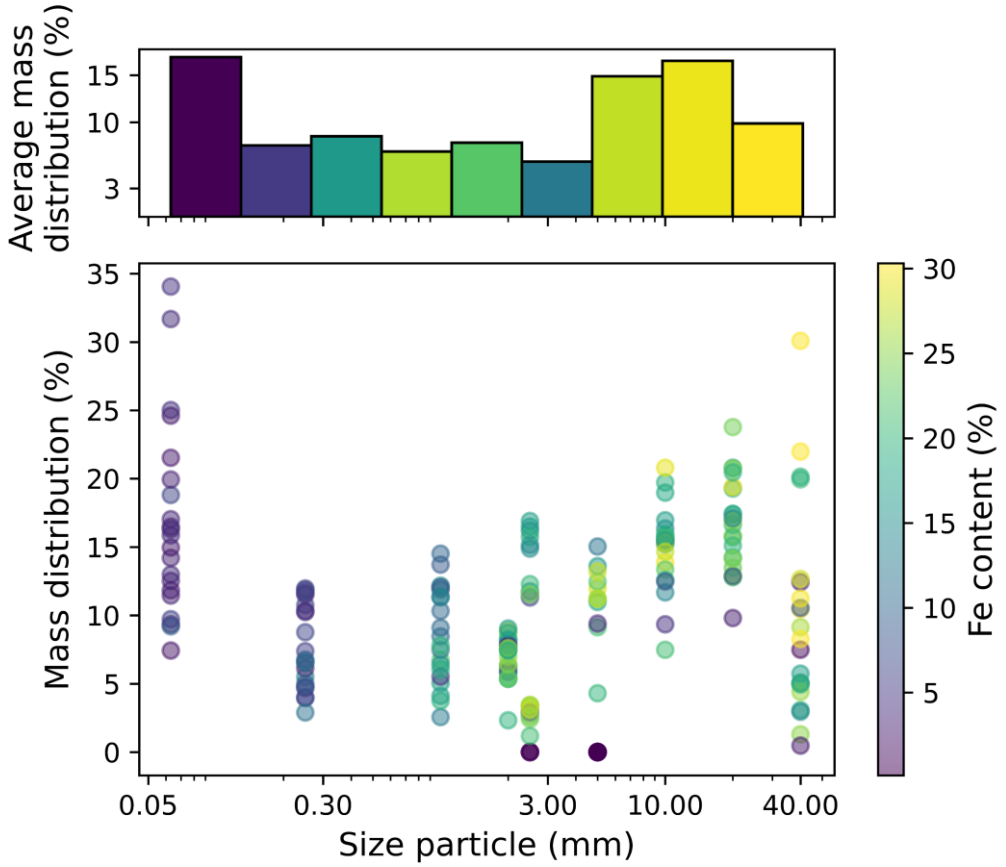
5 Identify clusters/classes = training data

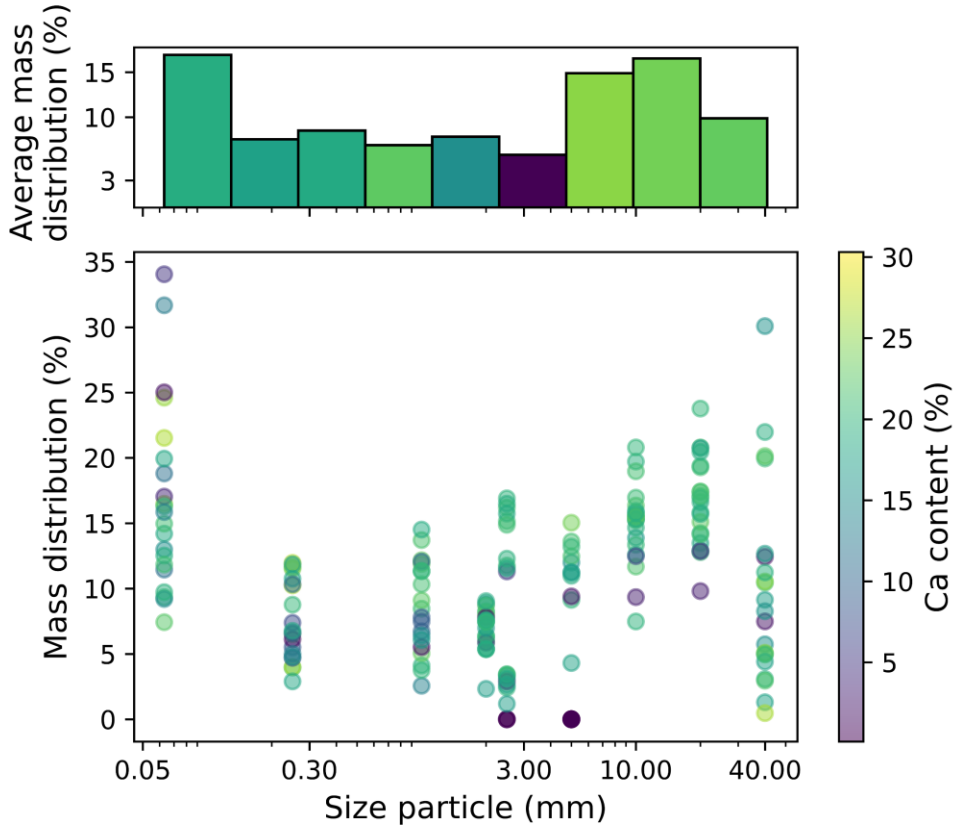
6 Predict different types of slags in the field acquisition domain

Results

3 XRF - elemental composition of samples

1) Per particle size





Results

3 XRF - elemental composition of samples

2) Average content

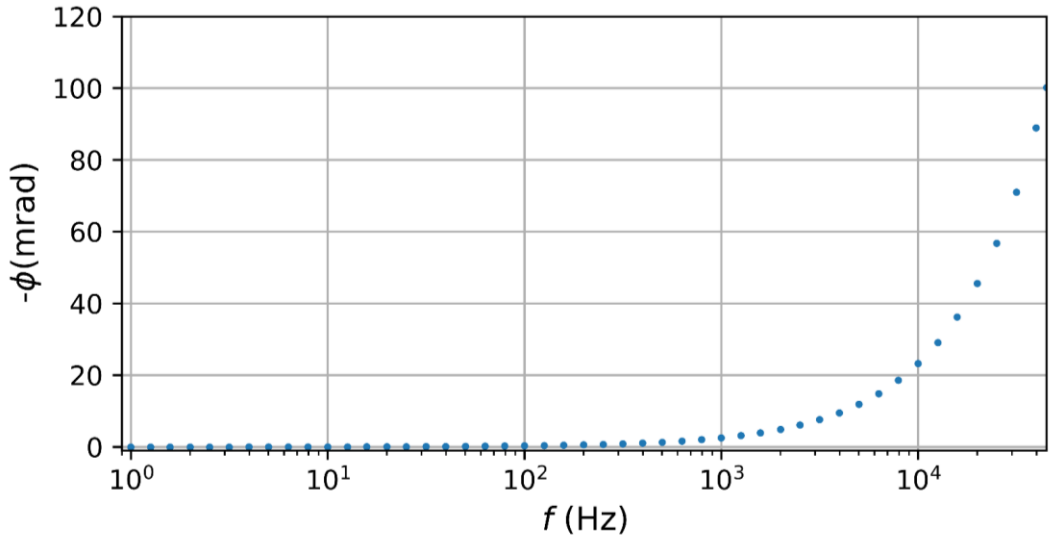
We used PCA on the average content of these six elements (previously standardized):

		Squared Loadings					
Principal Component (PC)	**Explained variance ratio**	Si	Al	Mn	Fe	Ca	Mg
1	0.73	**0.89**	0.79	0.76	0.75	0.63	0.54
2	0.11	0.033	0.09	0.004	0.001	**0.29**	0.23
3	0.098	0.046	0.021	0.074	0.18	0.061	**0.20**

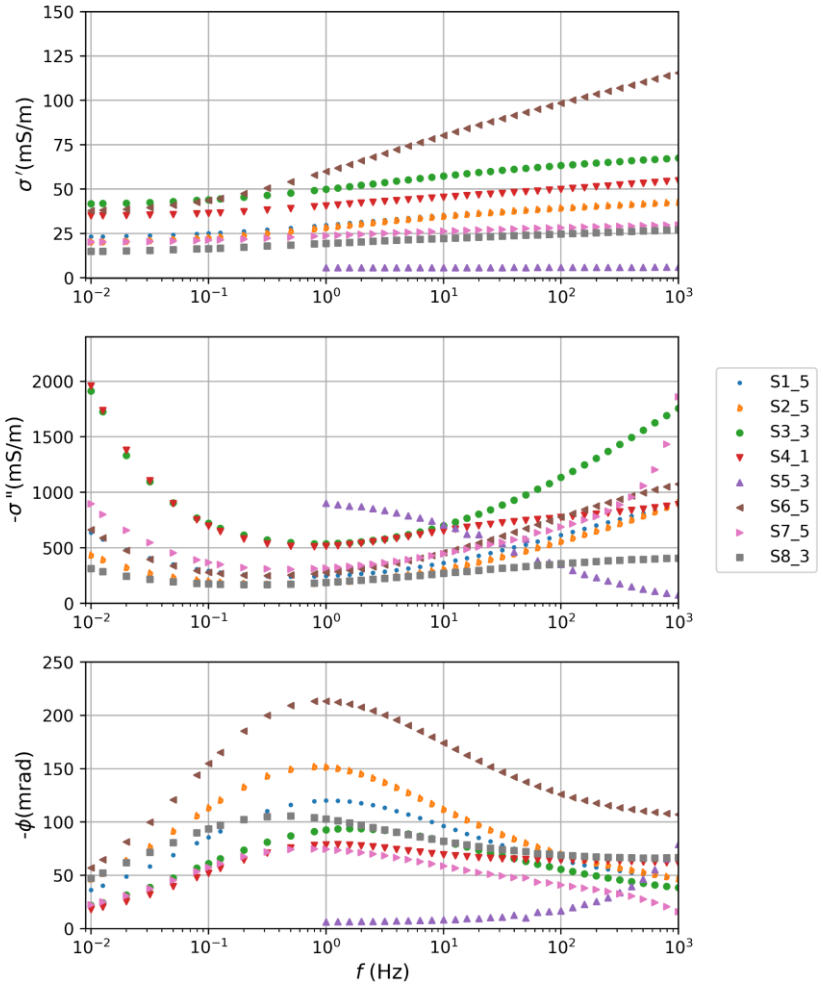
Results

We measured SIP on the samples collected at depths of 1, 3 and 5 m using a column of 1.5 dm^3 and the system Forschungszentrum Jülich ZEA-2-SIP04-V05 (Zimmermann *et al.*, 2010).

SIP only-water

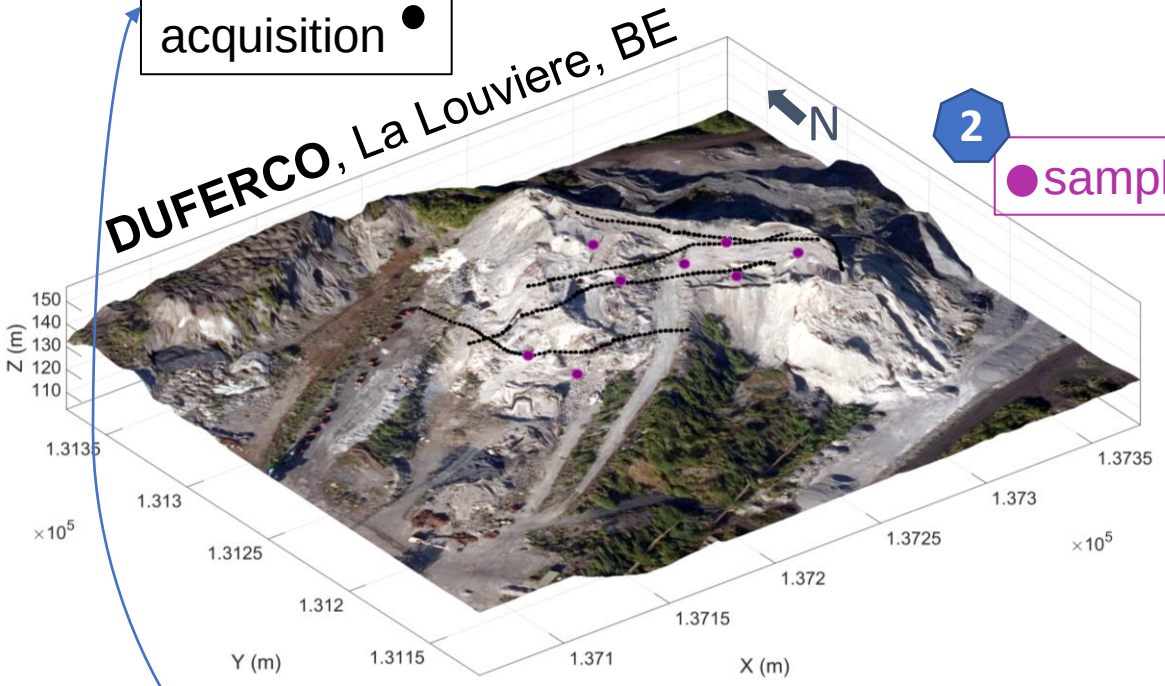


3 Overview SIP spectra



Methodology

1 3D ERT/IP acquisition ●



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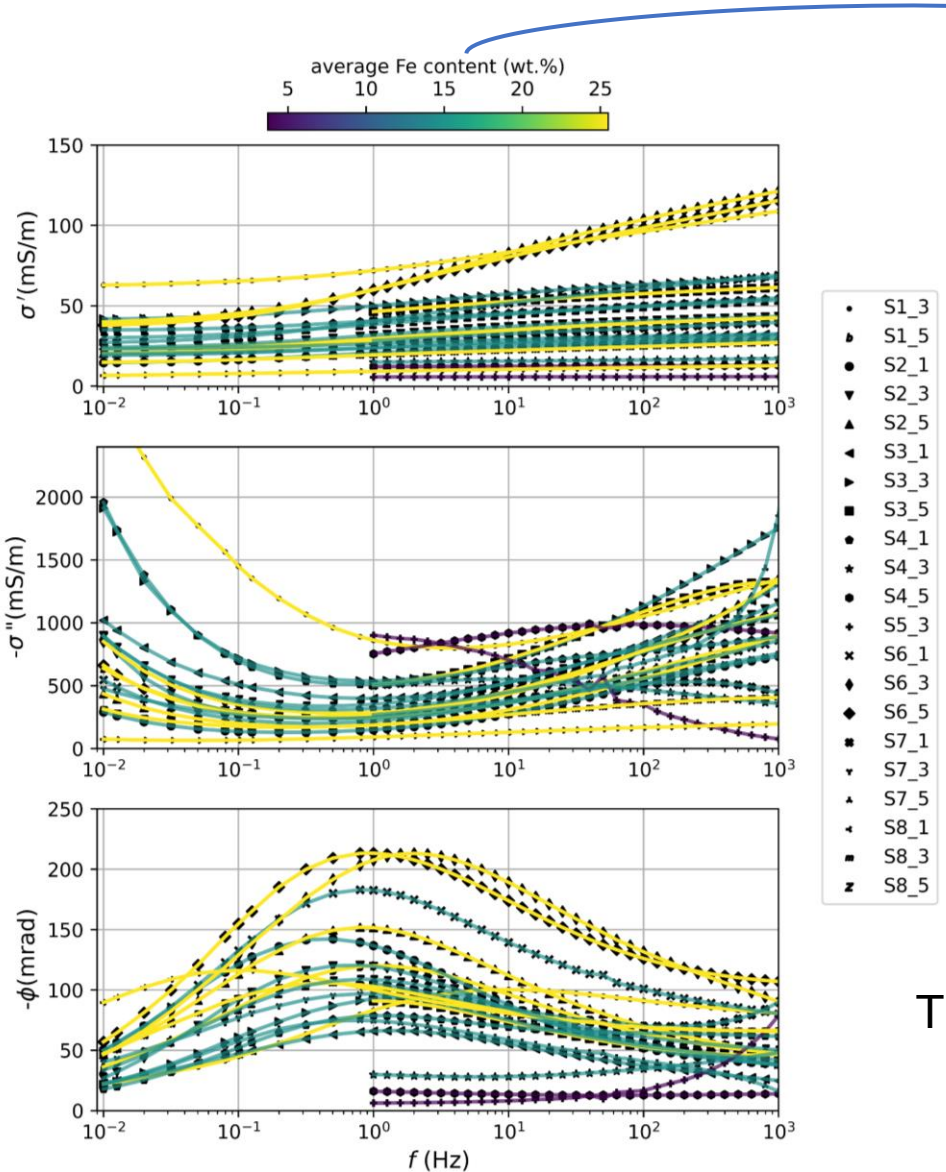
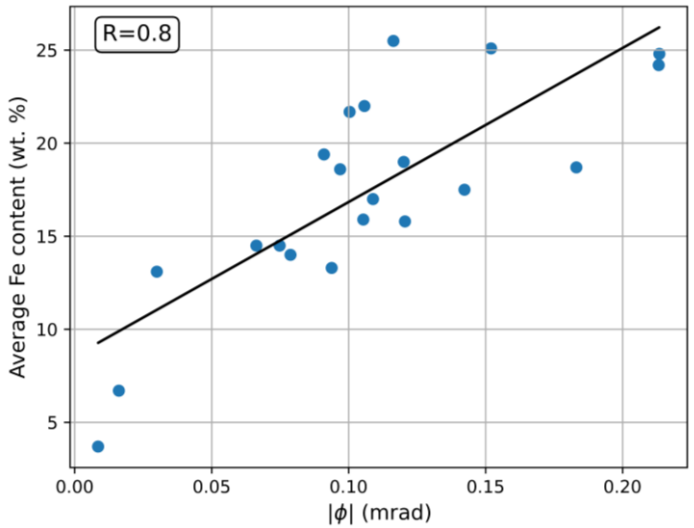
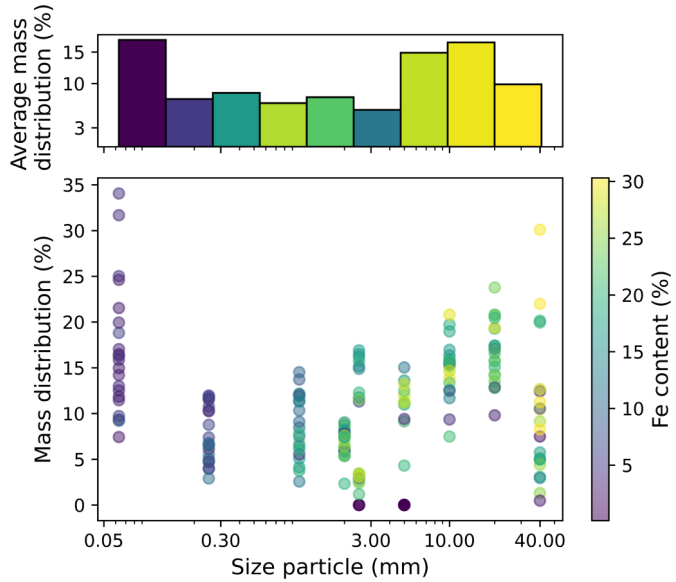
Results

4 Correlation between SIP (Φ) and chemical composition







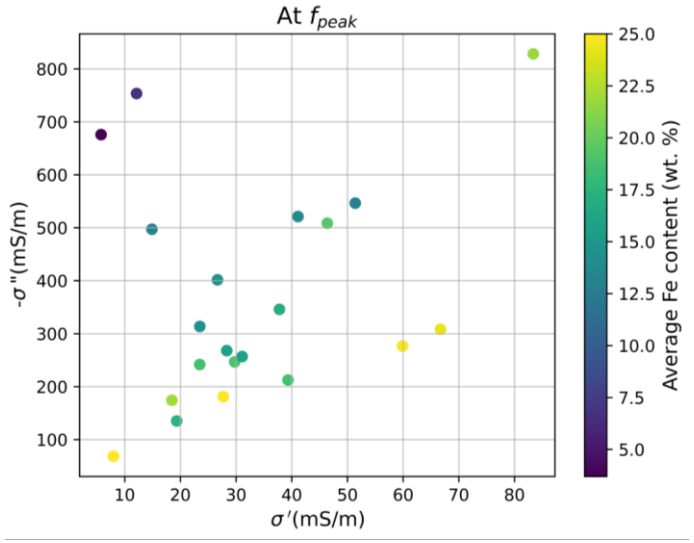
At relaxation frequency (f_{peak})

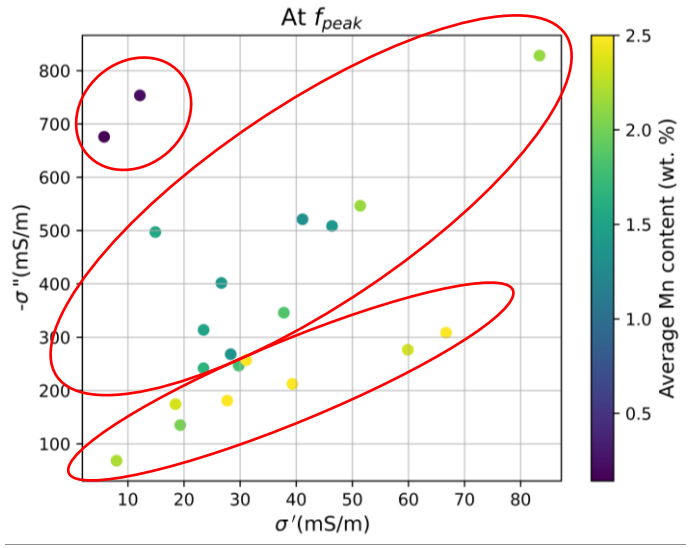
- Linear correlation between Φ and average **Fe** content = 0.8
- Linear correlation between average **Mn** content and Φ = 0.81

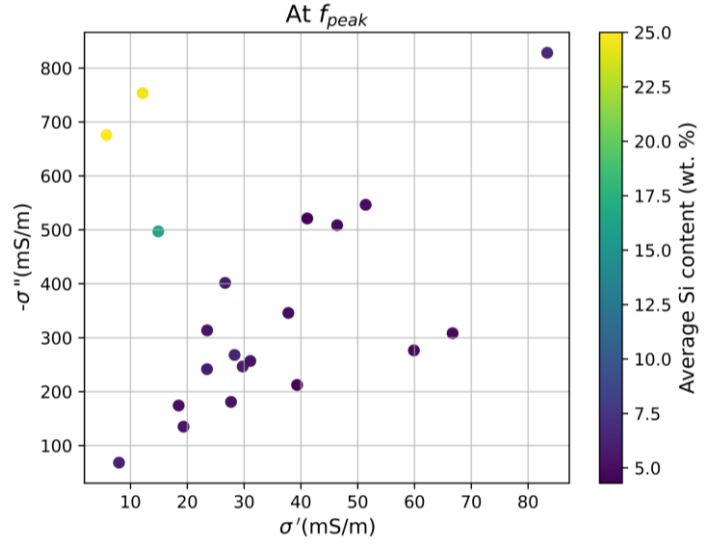
This behavior has been reported, e.g., Florsch *et al*., 2011; Qi et al., 2018

Results

5 Cross- plots of SIP spectra (σ' & σ") at f_{peak} and average content of Fe, Mn and Si







- Mn have zones or small, intermediate and large content in the cross-plots
- Two clear groups are observed for the Si content

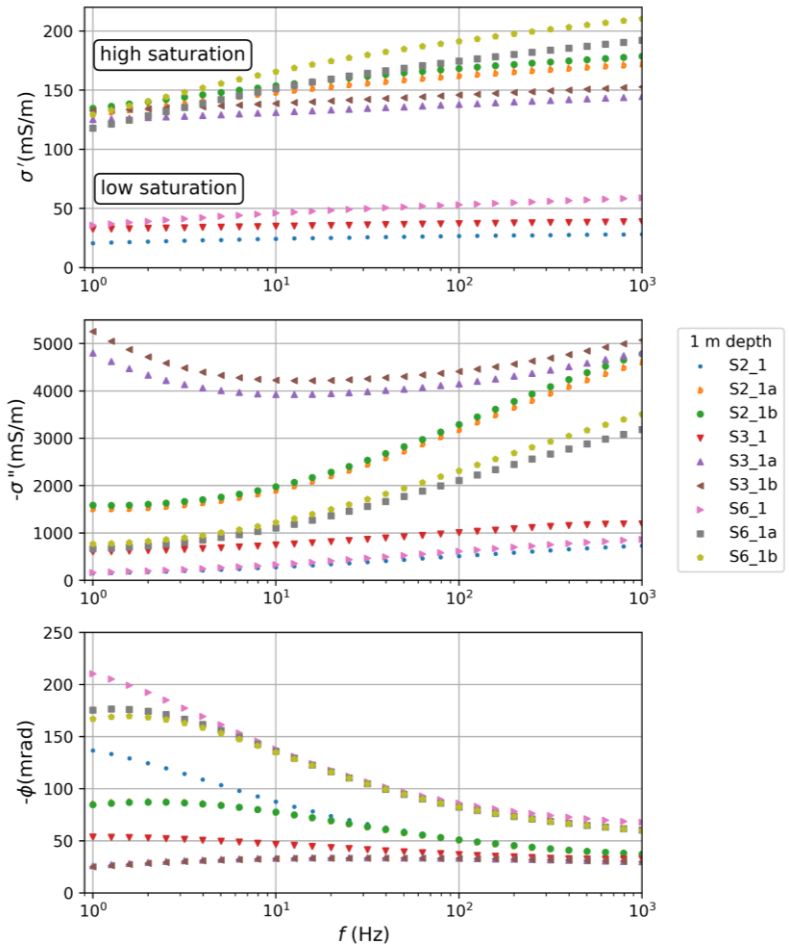
Results

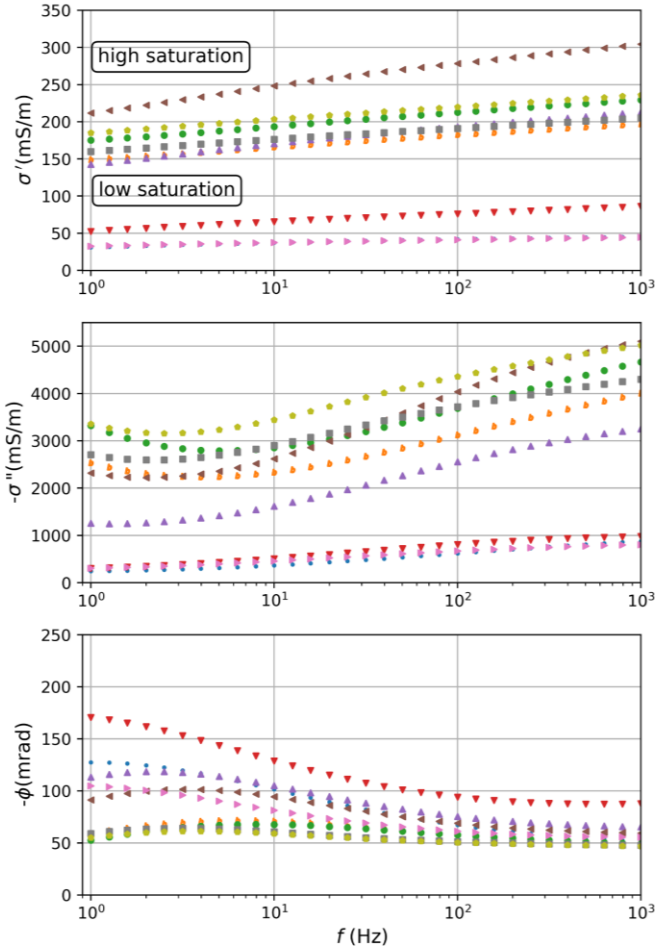
Impact of saturation on SIP spectra

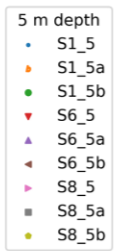
5 Samples were saturated injecting tap water from the bottom of the column. SIP spectra were measured:

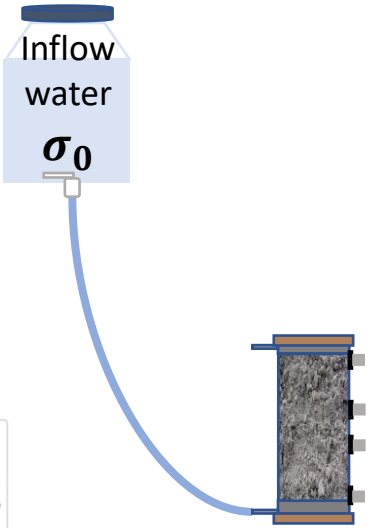
a. Immediately after full saturation

b. After a time period t ranging from 60 - 1100 minutes







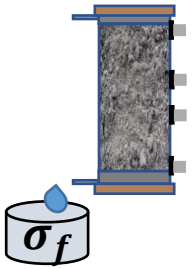


From SIP spectra:

- σ' and |σ''| increase with saturation
- Phase magnitude decreases with saturation and the frequency of the phase maximum is shifted towards larger values

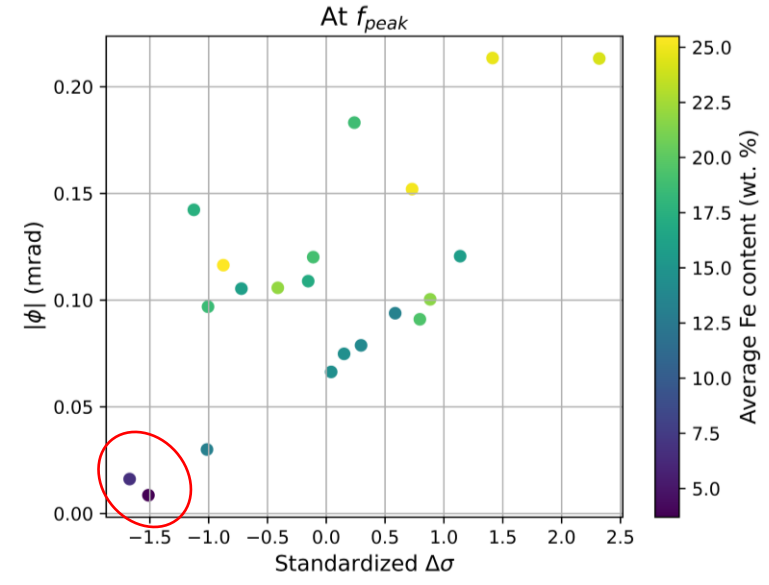
Results

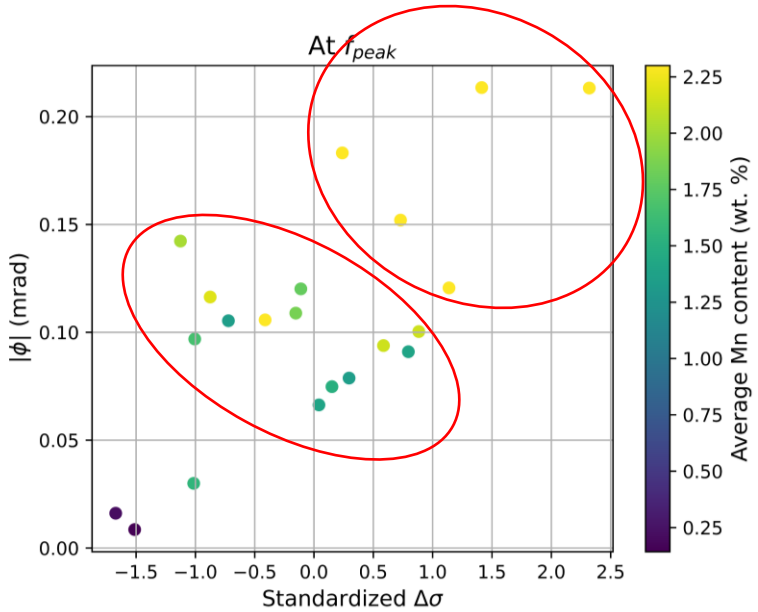
Impact of saturation on SIP spectra

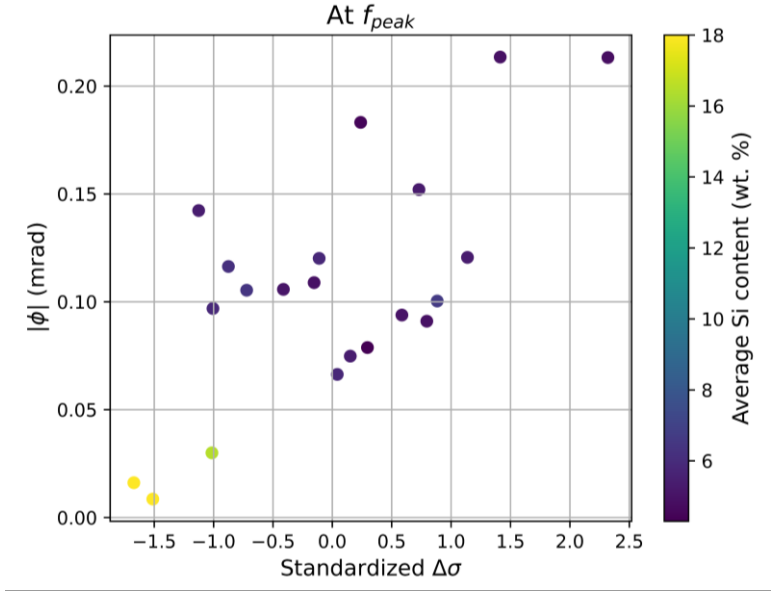


5 The water was drained out of the column after a time t and σ was measured = σ_f

1. We computed $\Delta\sigma = \sigma_f - \sigma_0$
2. As t = [60,1100] s then we standardized $\Delta\sigma$







We can roughly distinguish a cluster of 1) intermediate and 2) large values of Mn (similar to the one observed in the cross-plots **σ' & σ"**)

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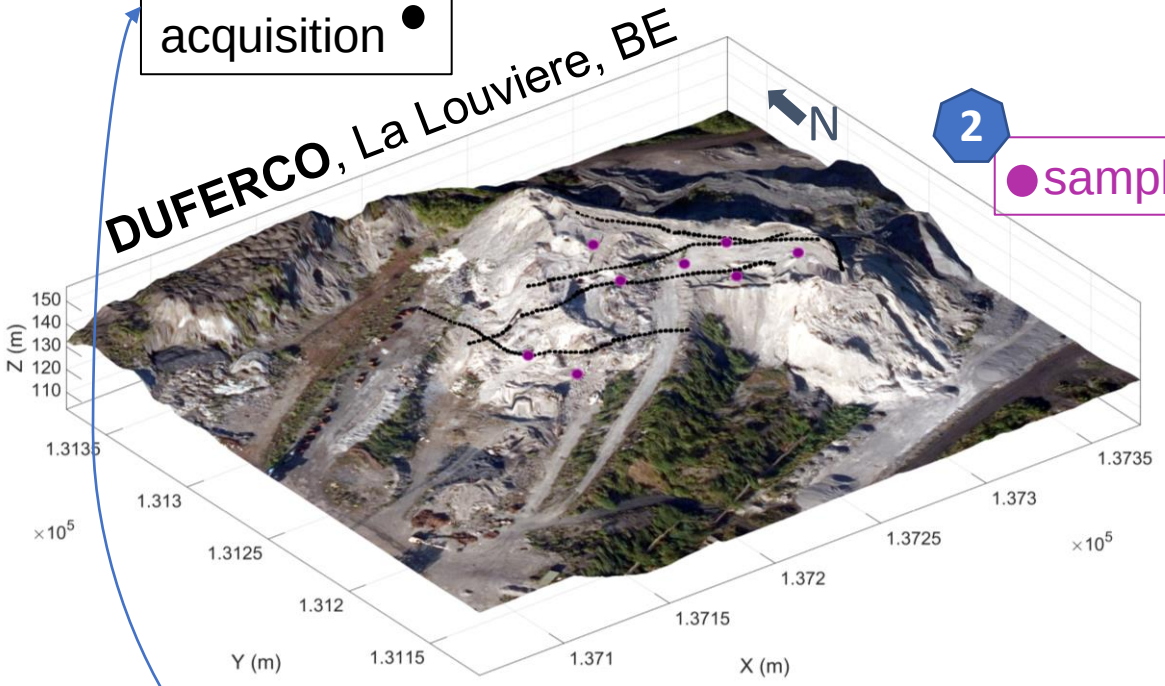

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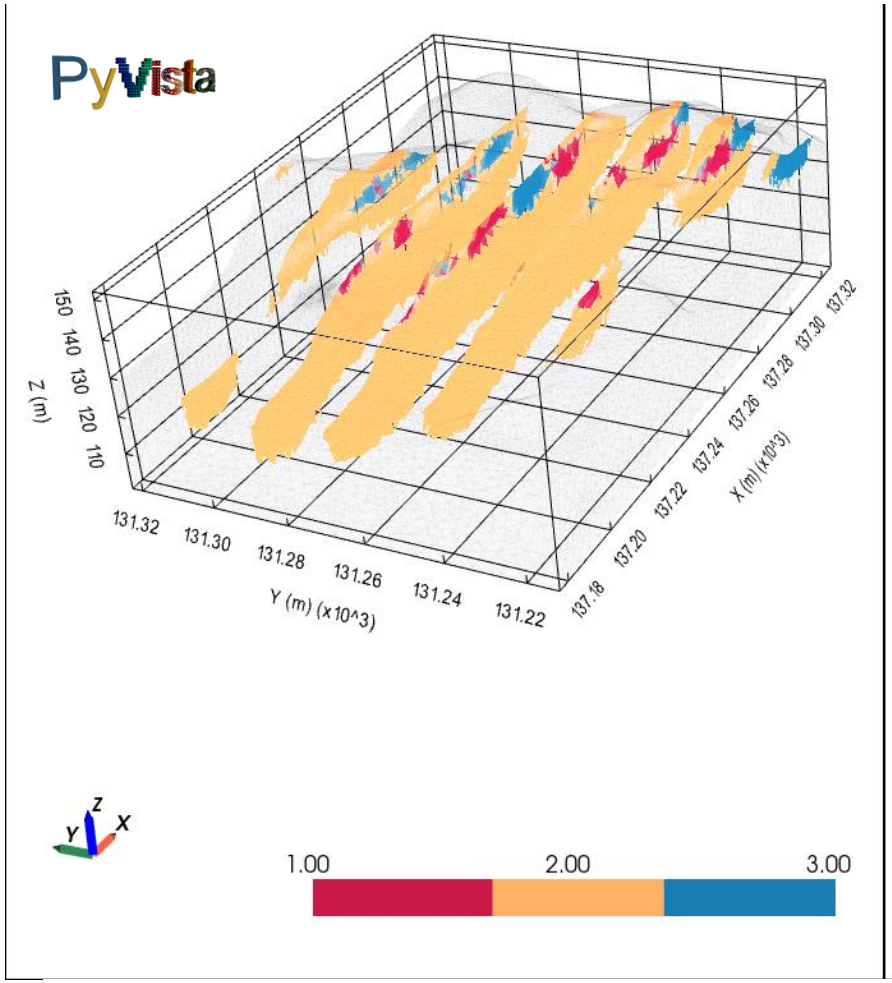
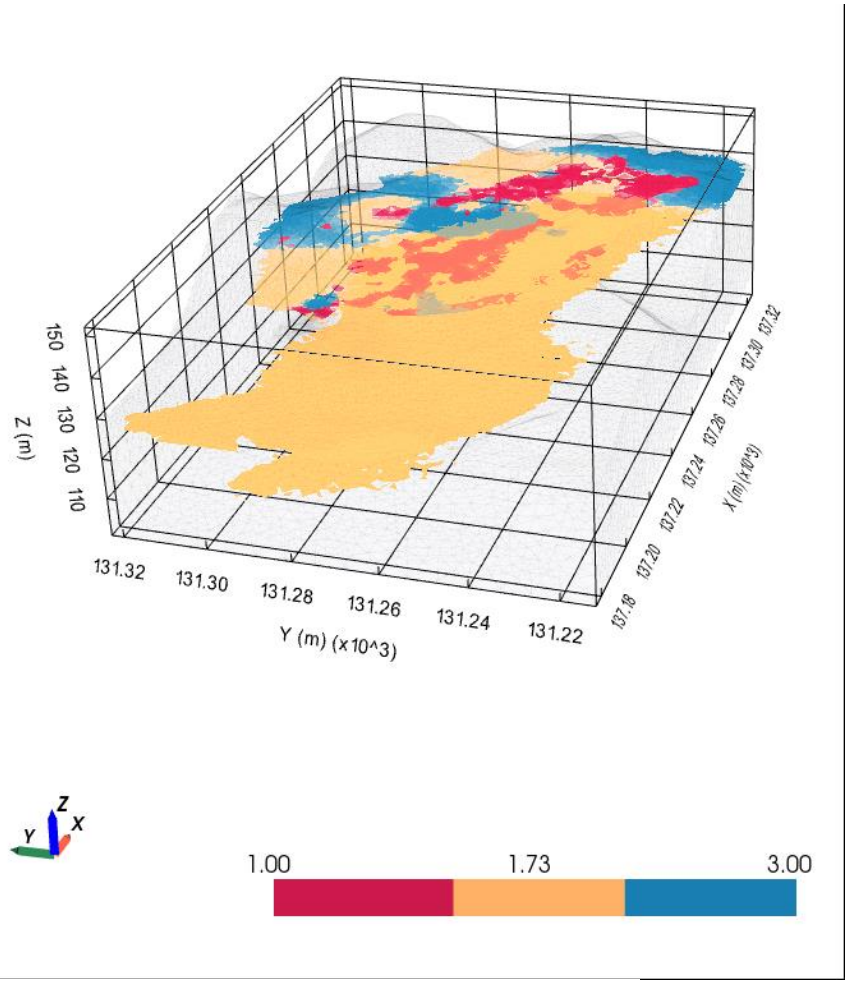
Results

6 Classification using probabilistic approach for 3 groups: slags of
1) large Fe/Mg 2) intermediate Fe/Mg 3) small Fe/Mg and large Si





1) Identify groups of samples of different Mn content
2) Build a dataset: ρ & *C* from inverted 3D model co-located with the samples and depth *z* of those samples (supervised learning)
3) Computation of conditional probabilities of the groups, given each element of the dataset
4) Computation of joint conditional probabilities for each group

see Jorunal 2000; Hermans and Irving 2017, Isunza Manrique et al., 2019

Conclusions

- The strongest (linear) correlation were found between ϕ at relaxation frequency and Fe content as well as Mn content
- Data were fitted using a double Cole-Cole model but correlations between inverted parameters and chemical analysis did not improve
- To infer on oxidative-weathering processes of these samples, measurements such as pH & Eh are needed

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