Superposition of IP signals measured on pyrite–sand mixtures

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Introduction

- IP is a valuable tool in ore exploration to get insights into the material properties of ores, slags, and other processing residuals.
- Most studies have been focused on **single fractions** of metallic particles with varying grain size (Fig. 1) or varying volume percentage (VP).
- The chargeability has been accepted as a proxy for the metal content and the relaxation time for the particle size.
- We investigate whether mixtures with **two fractions** of different grain size and the same VP (Fig. 2) can be presented by an additive superposition of the spectra measured with single grain size fractions.
- The measured spectra are fitted to Pelton-models and processed by a Debye decomposition to get the relaxation time distribution (RTD).
- We compare the resulting values of chargeability and the spectra of imaginary conductivity, phase shift, and RTD.

Material

- 11 unconsolidated **pyrite - sand mixtures**, measured with SIP-ZEL (Tab. 1)
- 6 samples consisting **of a single pyrite grain radius** mixed with sand (E - samples) with a pyrite content of **2.75 VP**
- 5 samples containing **two different grain radii** within the sand (Z – samples) with a pyrite content of **5.5 VP**
- Pyrite grain radius between 31 - 1000 µm, quartz sand grain radius ~100 µm

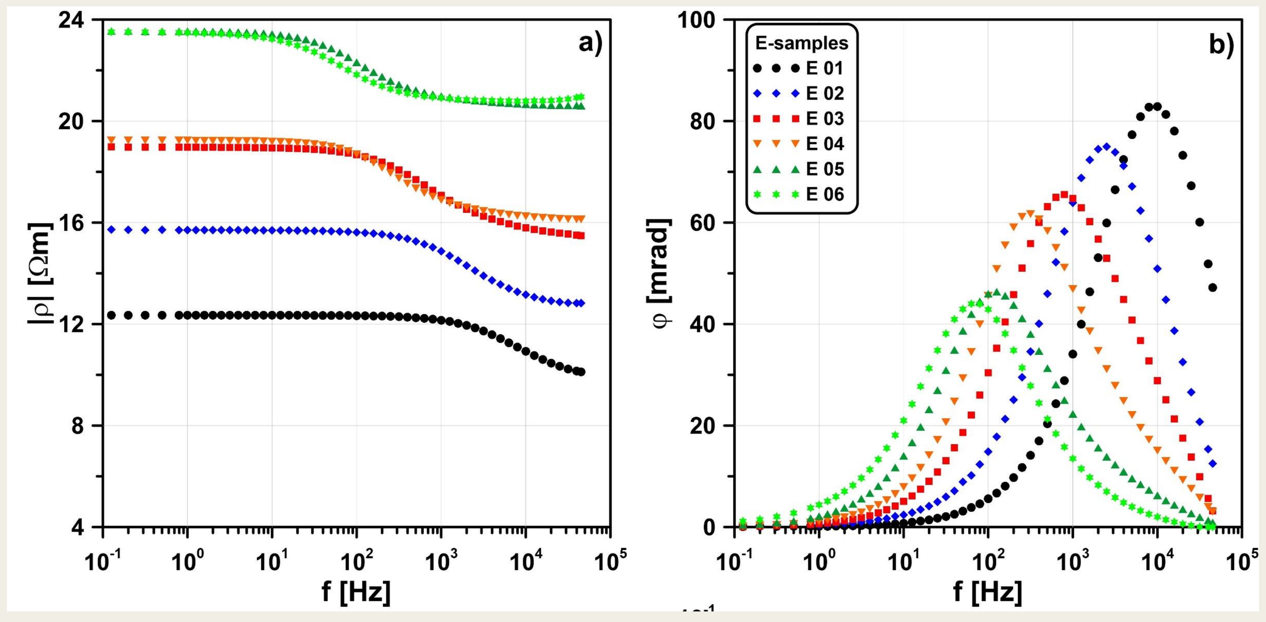

Fig. 1: Spectra of the E-samples with a single pyrite grain radius: a) resistivity amplitude, b) phase shift.

Sample	First pyrite grain radius [µm]	Second pyrite grain radius [µm]	Mean pyrite grain radius r_{gm} [µm]	Pyrite content p_v [VP]
E 01	31 - 56	-	42	2.75
E 02	56 - 100	-	75	2.75
E 03	100 - 177	-	133	2.75
E 04	177 - 315	-	236	2.75
E 05	315 - 500	-	397	2.75
E 06	500 - 1000	-	707	2.75
Z 01	31 - 56	500 - 1000	172	5.50
Z 02	56 - 100	500 - 1000	230	5.50
Z 03	100 - 177	500 - 1000	307	5.50
Z 04	177 - 315	500 - 1000	409	5.50
Z 05	315 - 500	500 - 1000	530	5.50

Tab. 1: Overview about the measured samples with a single pyrite grain radius (E-samples) and two different pyrite grain radii (Z- samples).

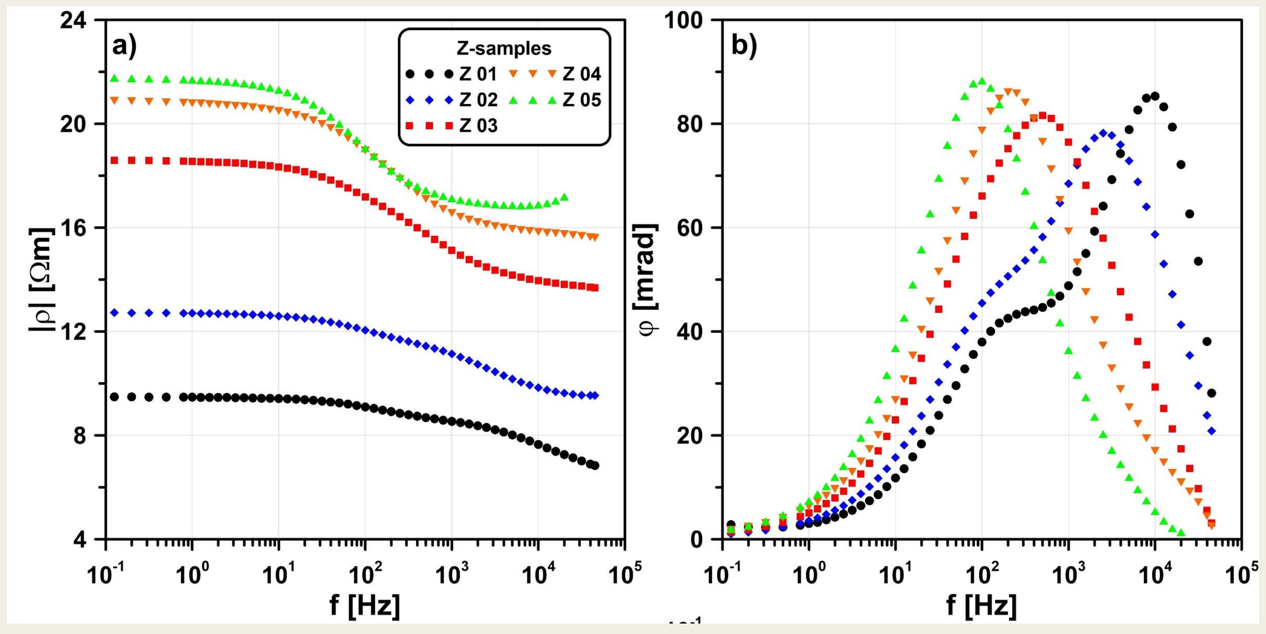

Fig. 2: Spectra of Z-samples with two pyrite grain radii: a) resistivity and b) phase shift.

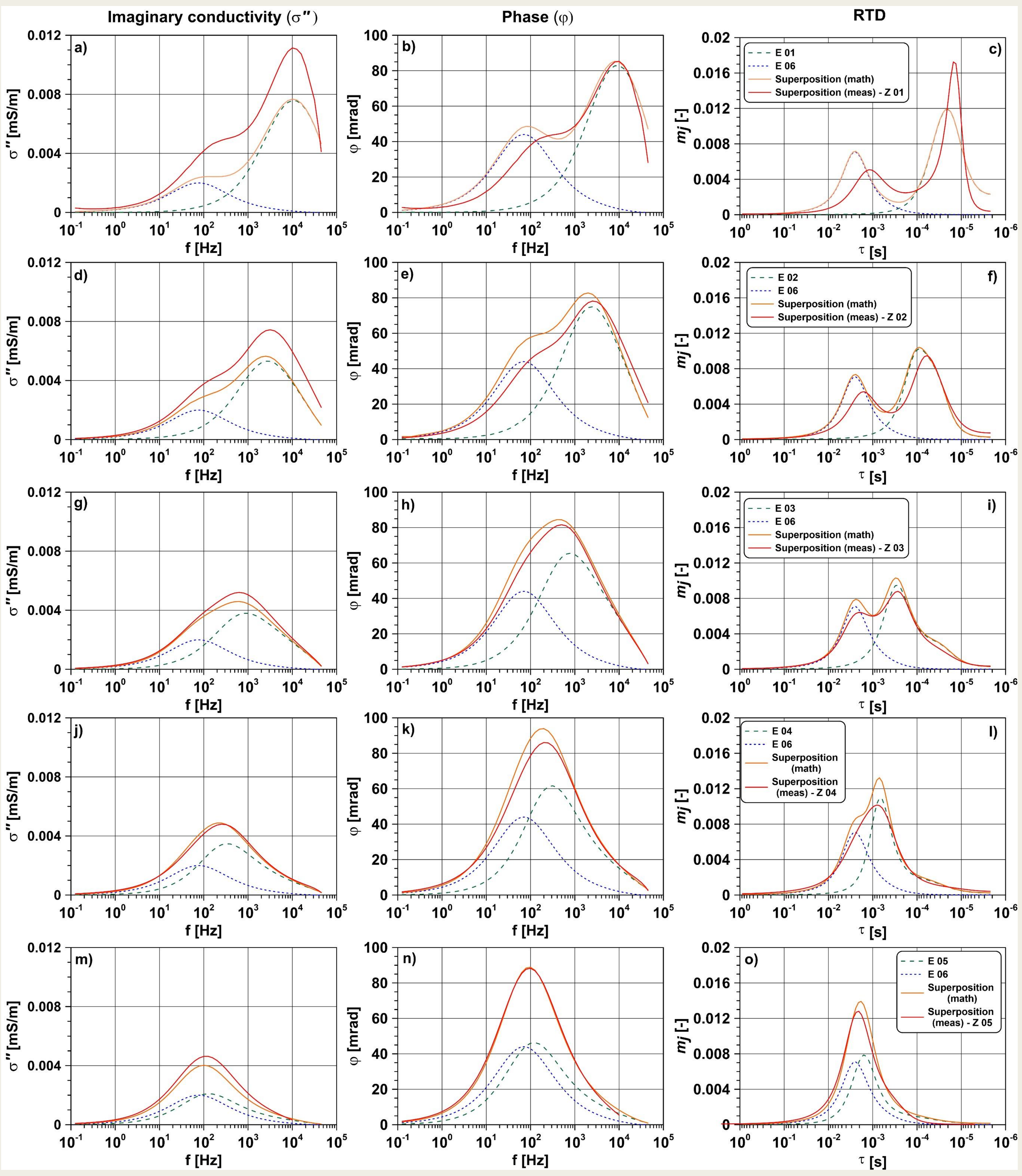

Fig. 3: Superposition of spectra of samples with different pyrite grain radii for the imaginary conductivity, phase shift, and the RTD from Debye decomposition. Consider that the τ-axis is scaled in inverse direction (from larger to lower values).

Results

- E-samples (Fig. 1): An increase in resistivity (ρ), a decrease in chargeability (m), and a decrease in the peak frequency (f_{peak}) is observed with increasing pyrite grain radius.
- Although equal in VP, the fraction with the lowest grain size indicates the strongest IP effect.
- Z-samples (Fig. 2): An increase in ρ, a decrease in m and a decrease in f_{peak} is observed with increasing radius of the **fraction of smaller pyrite grains**. The spectra become wider for an increasing radii difference between the two pyrite grain fractions.
- **Phase spectra** indicates a good agreement between the measured (red line) and mathematically predicted (orange line) additive superposition (Fig. 3, middle column).
- The mathematical superposition underestimates the measured superposition of **spectra of imaginary conductivity** (Fig. 3, left column).
- The agreement becomes better for fractions with similar grain size (see sample Z 05, lowermost row in Fig. 3).
- Although equal in VP, **chargeabilities** m_a, m_P, *and* m_t decrease with increasing grain size (Figs. 4, 5). Mathematical superposition overestimate the values determined from the measured spectra.

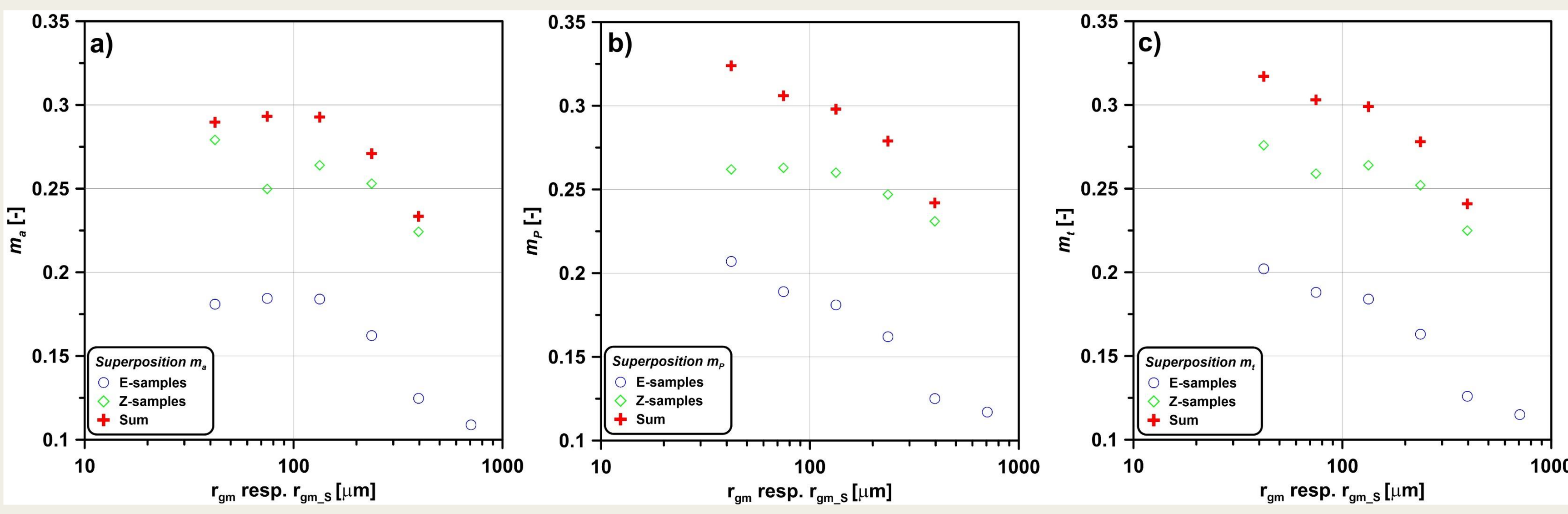

Fig 4: Superposition of different chargeabilities (m_a, m_P and m_t) versus grain size r_{gm} (E-samples) or for the smallest grain size fraction r_{gm_s} (Z-samples). Sum (red crosses) corresponds to the mathematical superposition via addition. (a) Approximate chargeability m_a, (b) chargeability of the Pelton model m_P and (c) total chargeability resulting from the Debye decomposition m_t.

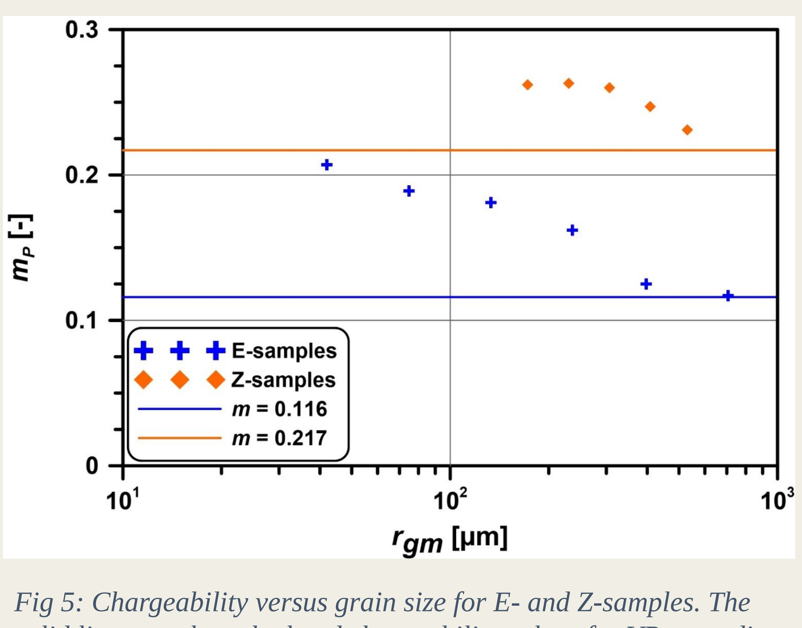

Fig 5: Chargeability versus grain size for E- and Z-samples. The solid lines are the calculated chargeability values for VP according to Gurin et al. 2015 (2.75 VP - blue, resp. 5.5 VP - orange).

Conclusions

- Mathematical superposition of spectra of σ″, phase shift, and RTD provides a useful approximation.
- Although equal in VP, chargeability and RTD-amplitude decrease with increasing grain size.
- RTD amplitude does not reflect the VP of a certain grain radius.
- **Chargeability** is not a suitable proxy for the **volumetric metal content** (for particles r_{gm} < 500 µm).

Reference: Gurin, G., Titov, K., Ilyin, Y. & Tarasov, A., 2015. Induced polarization of disseminated electronically conductive minerals: a semi-empirical model, Geophys. J. Int., 200(3), 1555–1565.

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