

Physical Property Measurements at the Geological Survey of Canada Paleomagnetism and Petrophysics Laboratory

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Natural Resources Canada
Ressources naturelles Canada



Petrophysical Methods

Sample Preparation



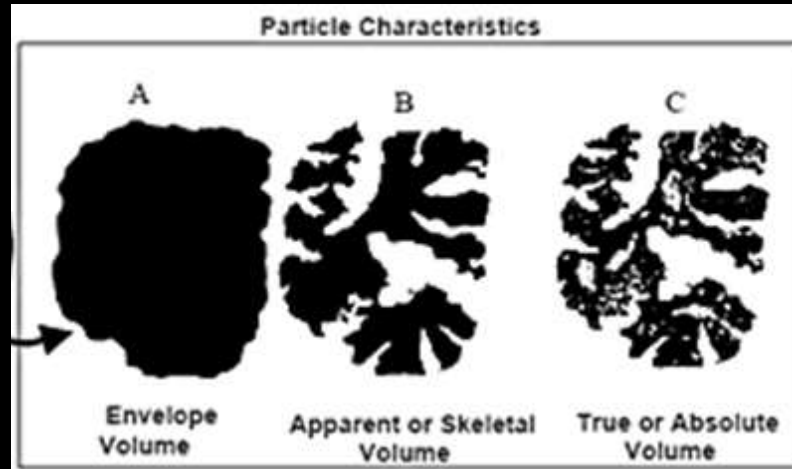
Cylinders

2.5 cm diameter

2.2 cm high

- Perfect for paleomagnetism magnetometer
- Too small for pegmatite / coarse-grained rocks
- SCALING

Density and Porosity Measurements



Weight in Air – Weight in Water
Jolly Balance



Distilled water under vacuum

Density and Porosity Measurements

Table 1: Density and Porosity terms and symbols.

Term	Symbol	Formula
Dry Weight	W_D	
Saturated Weight	W_S	
Immersed Weight	W_I	
Water Density	ρ_W	
Grain Volume	V_G	$(W_D - W_I) / \rho_W$
Pore Volume	V_P	$(W_S - W_D) / \rho_W$
Bulk Sample Volume	V_B	$(W_S - W_I) / \rho_W$
Grain Density	ρ_G	$W_D / (W_D - W_I) * \rho_W$
Dry Bulk Density	ρ_B	$W_D / (W_S - W_I) * \rho_W$
Saturated Bulk Density	ρ_S	$W_S / (W_S - W_I) * \rho_W$
Water Porosity	P_W	$(W_S - W_D) / (W_S - W_I)$

Magnetic Susceptibility and Remanence



Sapphire SI2B susceptibility meter



GF Instruments SM20 Magnetic Susceptibility Meter

Magnetic Susceptibility and Remanence



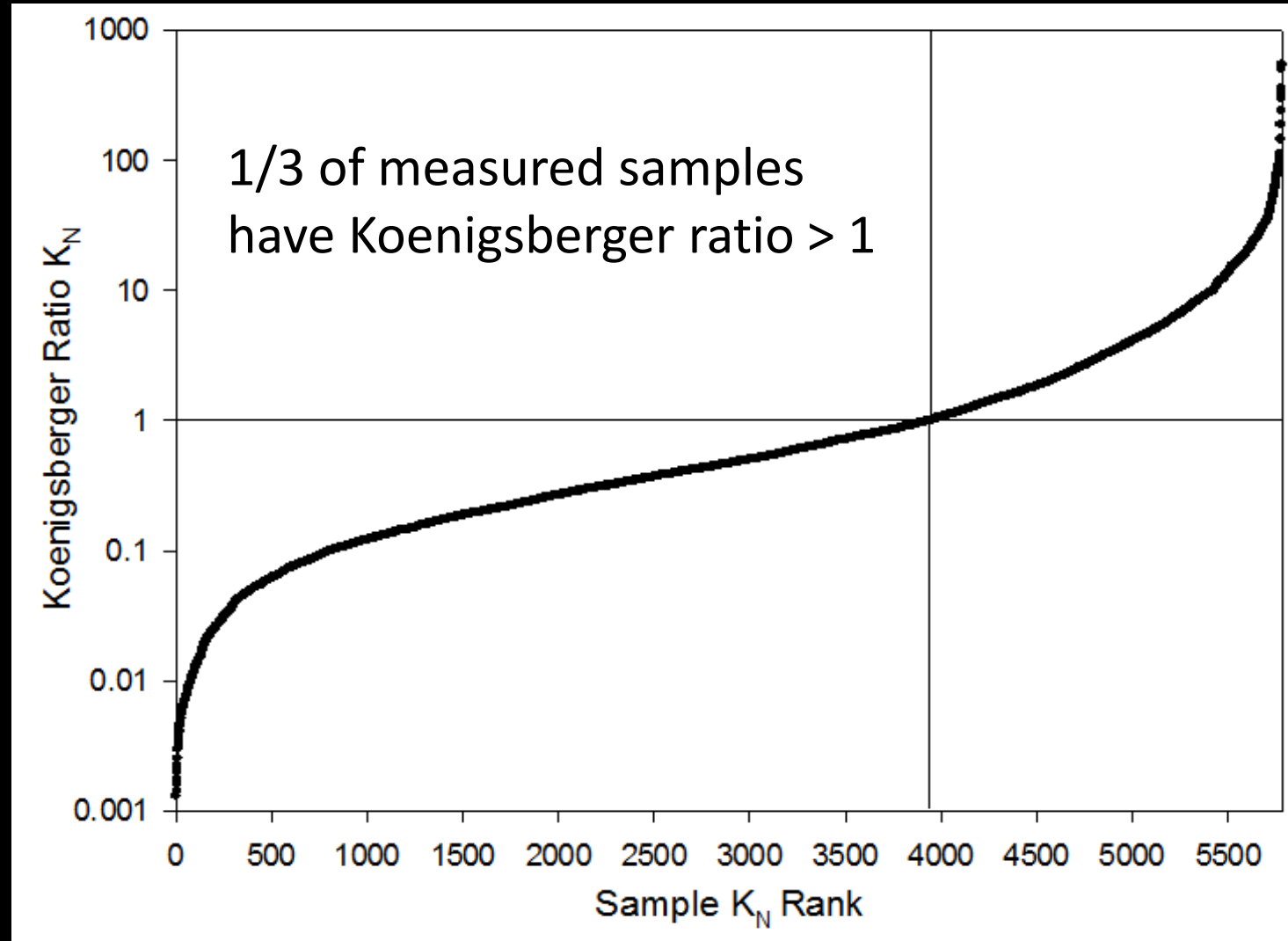
AGICO JR-5A spinner magnetometer

Magnetic Susceptibility and Remanence

Table 2: Magnetism terms and symbols.

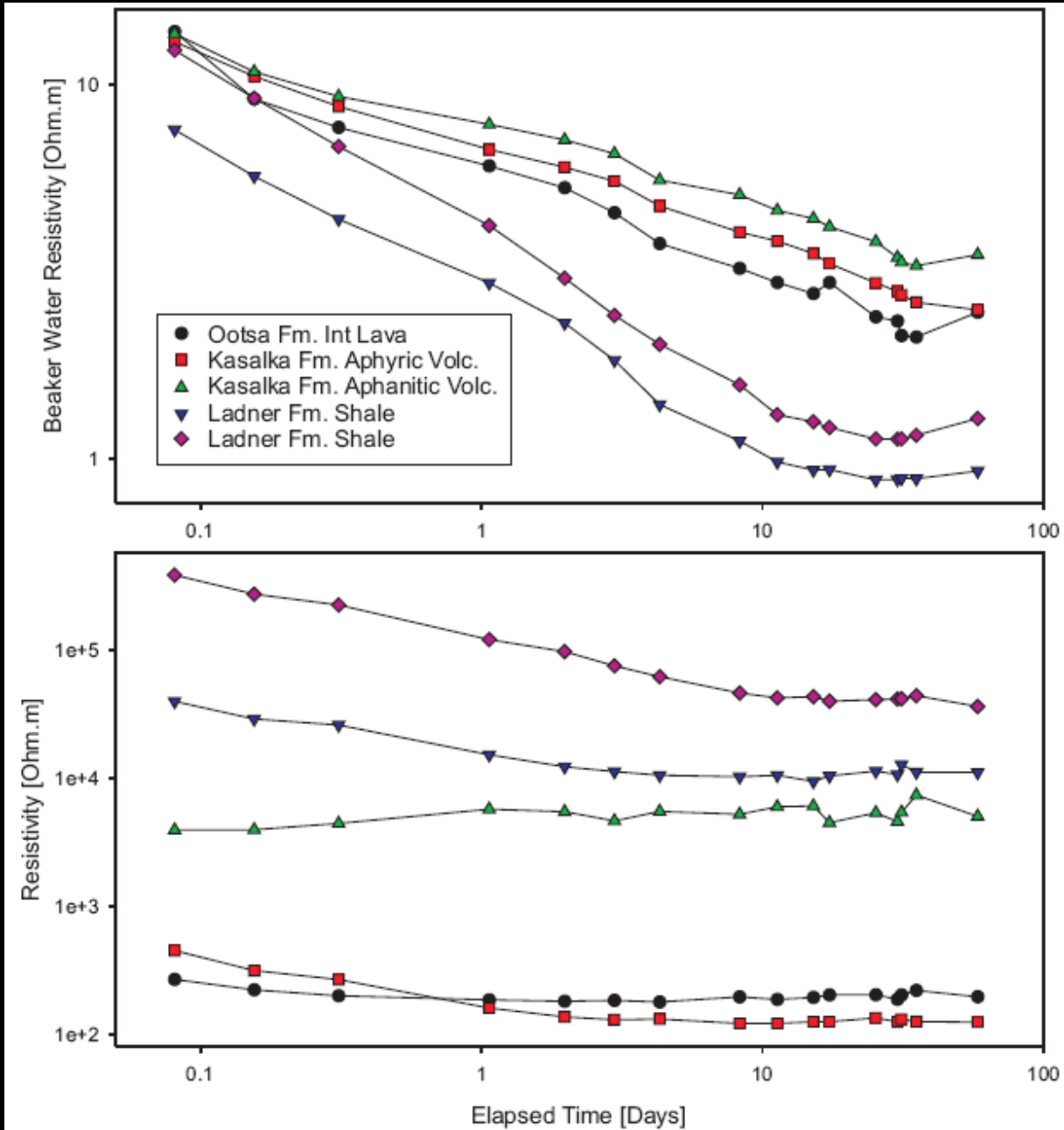
Term	Symbol
Magnetic Susceptibility	χ_0
Natural Remanent Magnetization	NRM
Koenigsberger Ratio	K_N
Permeability of Free Space $4\pi \times 10^{-7} \text{ (A/m)/T}$	μ_0
Geomagnetic Field (A/m)	H_0
Geomagnetic Induction (T)	B_0
Induced Magnetism (A/m)	M_I
Remanent Magnetism (A/m)	M_R
Saturation Magnetism (A/m)	M_S
Remanence of Saturation (A/m)	M_{RS}
Coercive Force (T)	H_C
Remanent Coercive Force (T)	H_{CR}

Magnetic Susceptibility and Remanence

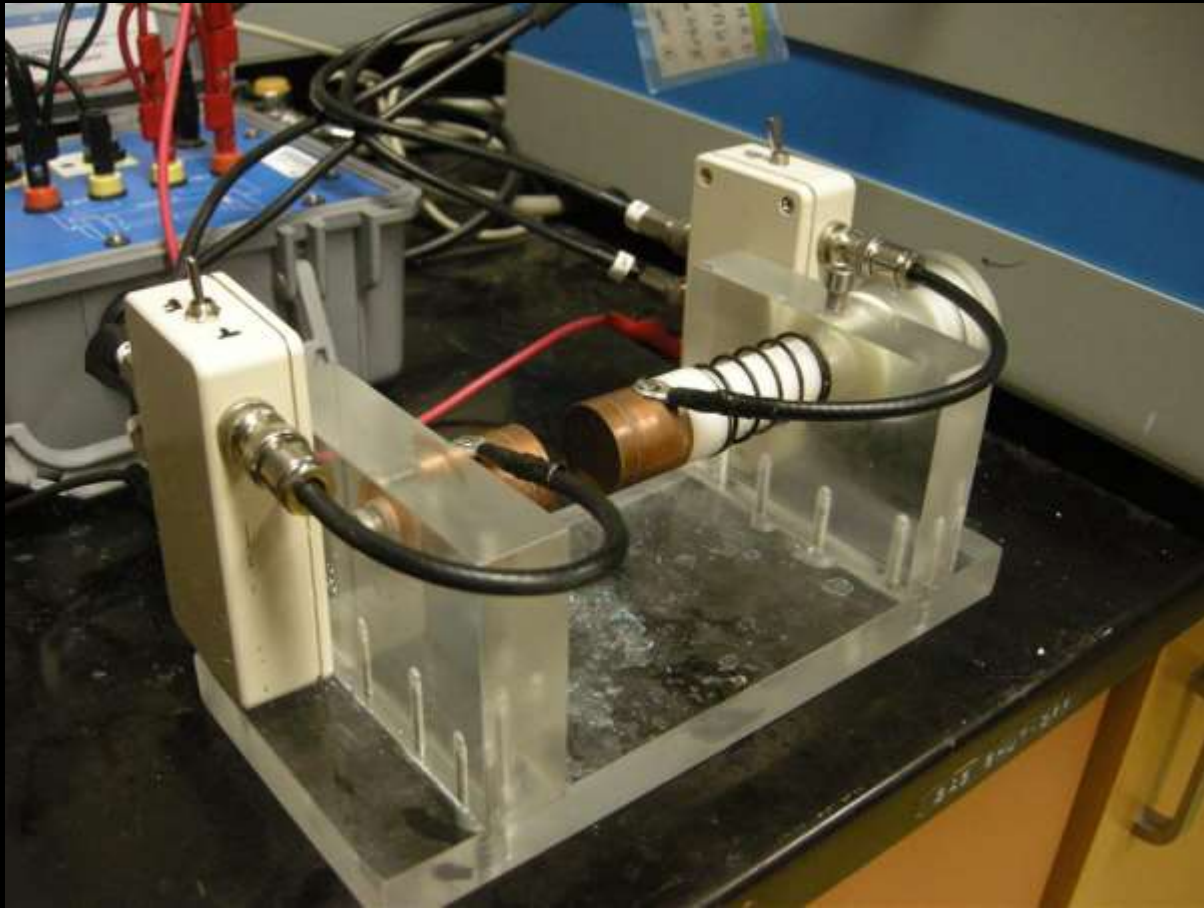


$$\text{Koenigsberger ratio} = \frac{\text{Remanent Magnetization}}{\text{Induced Magnetization}} = \frac{\text{NRM}}{\chi_0 H_0}$$

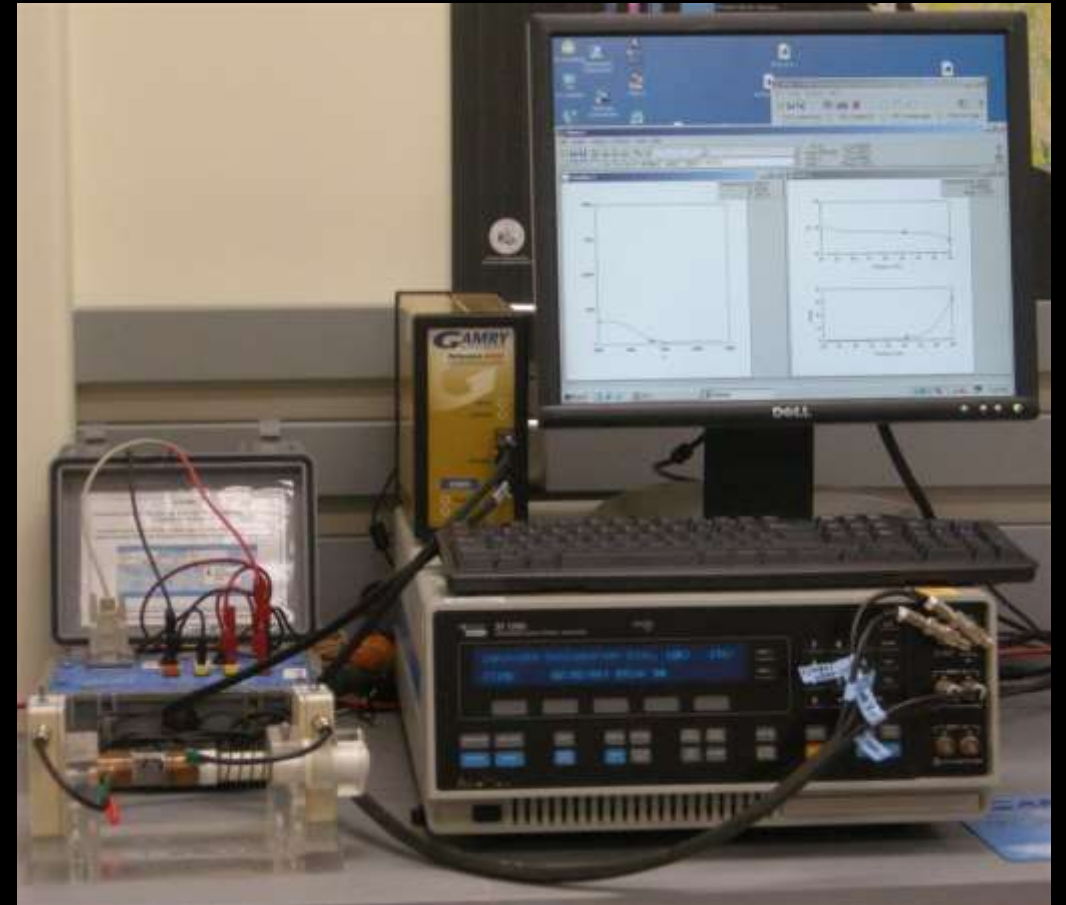
Electrical Impedance Spectroscopy



Electrical Impedance Spectroscopy



Sample holder with Copper – Copper Sulfate contacts



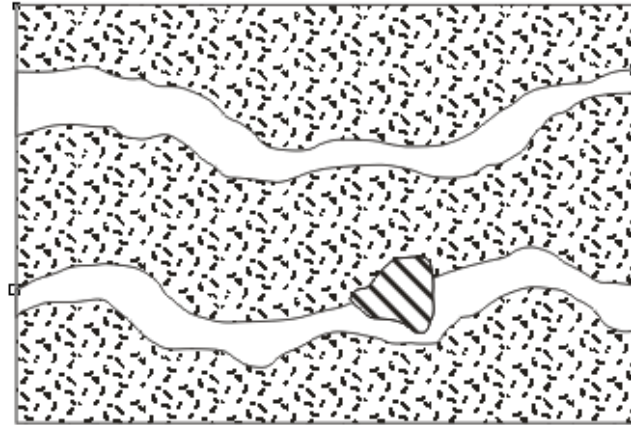
Solartron 1260 Frequency Response Analyzer (frequency domain), GDD SCIP (time domain), and Gamry Reference 600+ (both)

Electrical Impedance Spectroscopy

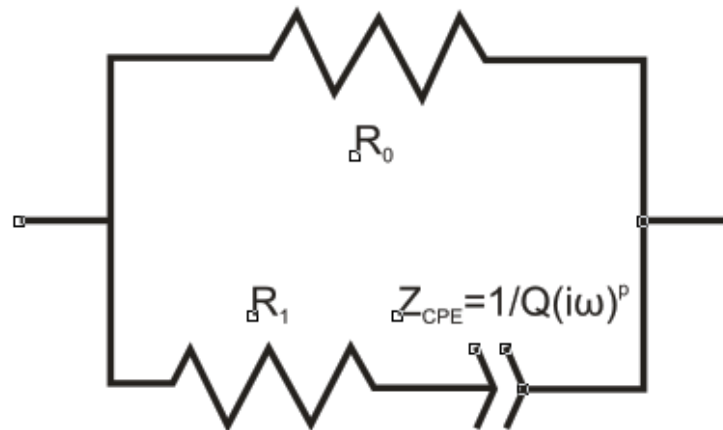
Table 3: Electric terms and symbols.

Term	Symbol
Resistance (Ω)	R
Electrical Resistivity (Ωm)	ρ
Capacitance (F)	C
Electrical Impedance (Ω)	Z
Electrical Impedance Spectrum	EIS
Linear Frequency ($\text{Hz} = \text{s}^{-1}$)	f
Angular Frequency [s^{-1}]	ω
Impedance of a Constant Phase Element (Ω)	Z_{CPE}
Initial Chargeability (mV/V)	M_0
Newmont Standard Chargeability (ms)	M_X

Electrical Impedance Spectroscopy



Mineralized Rock



Equivalent Circuit

Pelton, 1977

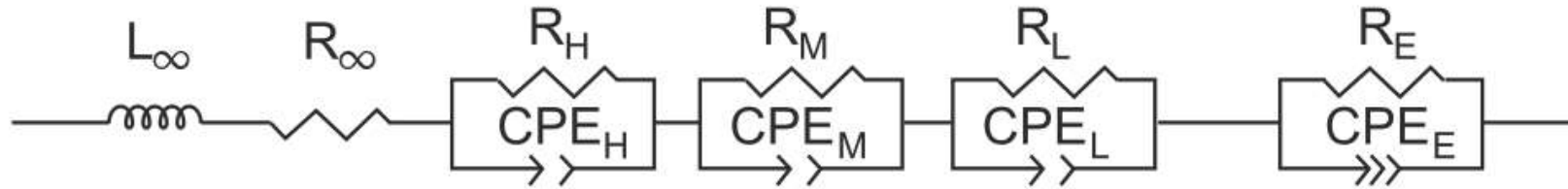
Resistivity
(Energy Loss)

and

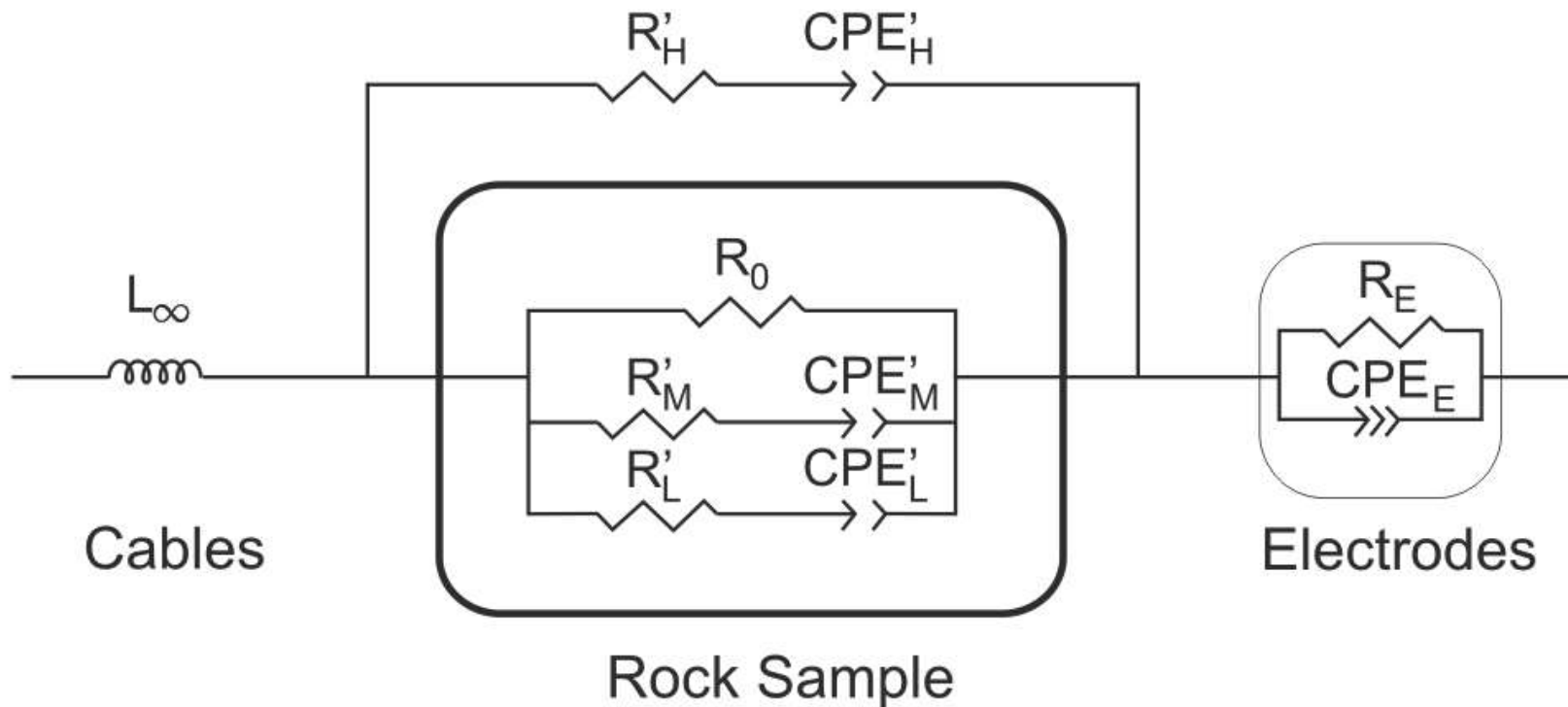
Chargeability
(Energy Storage)

Electrical Impedance Spectroscopy

Series Circuit, for intuitive manipulation

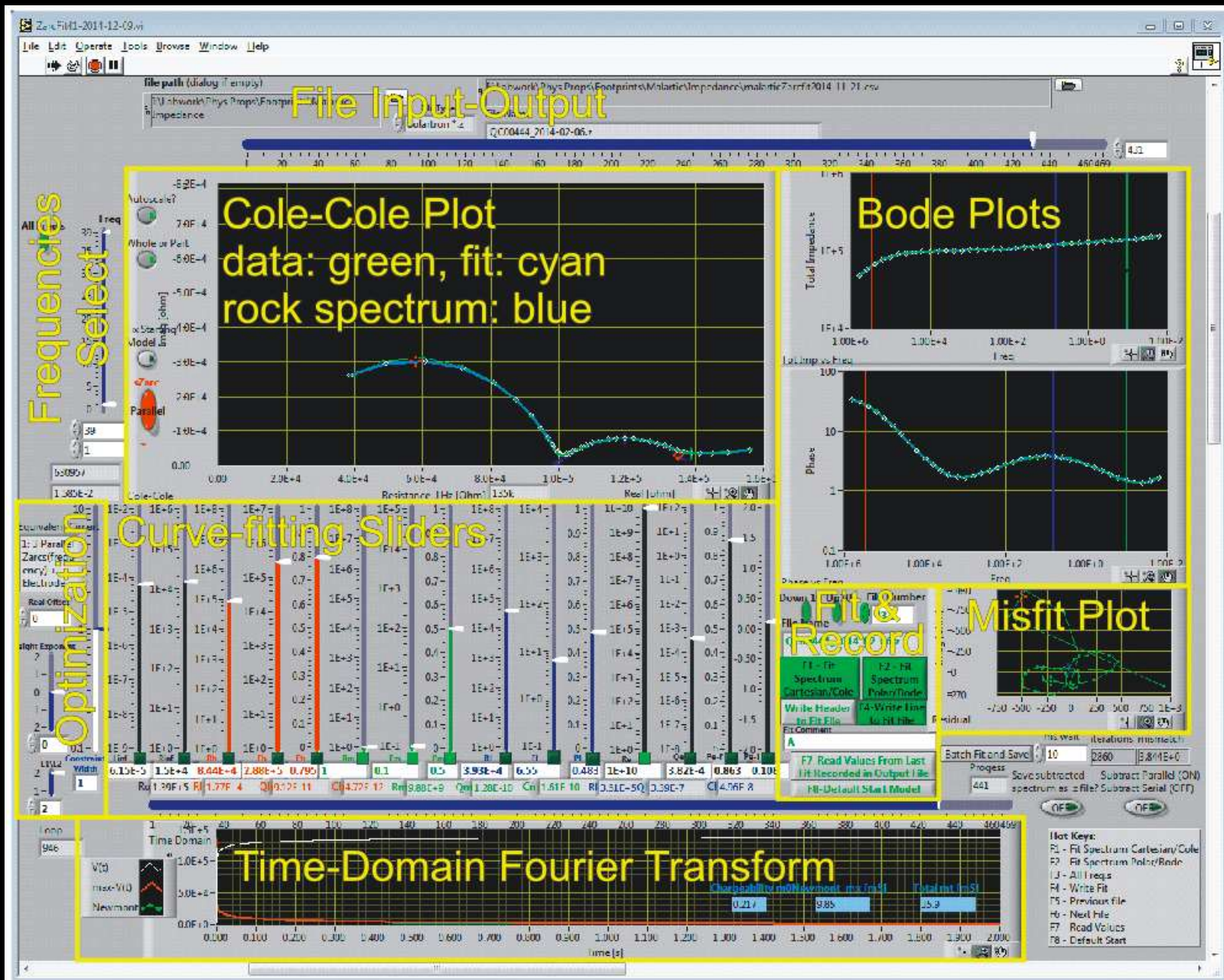


Parallel Circuit, more realistic representation

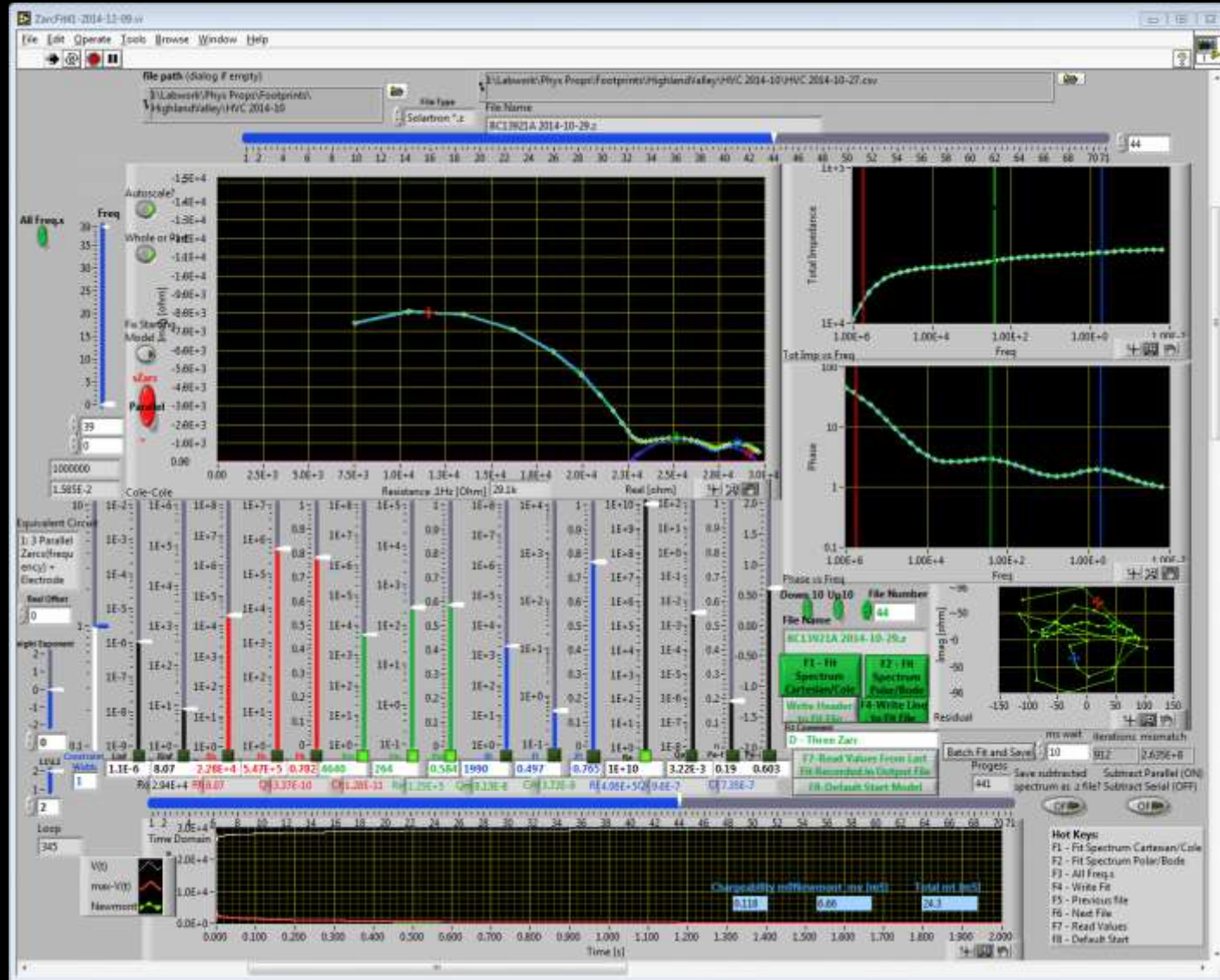


Electrical Impedance Spectroscopy

Zarcfit



Electrical Impedance Spectroscopy



Sericite altered granite with bornite mineralization