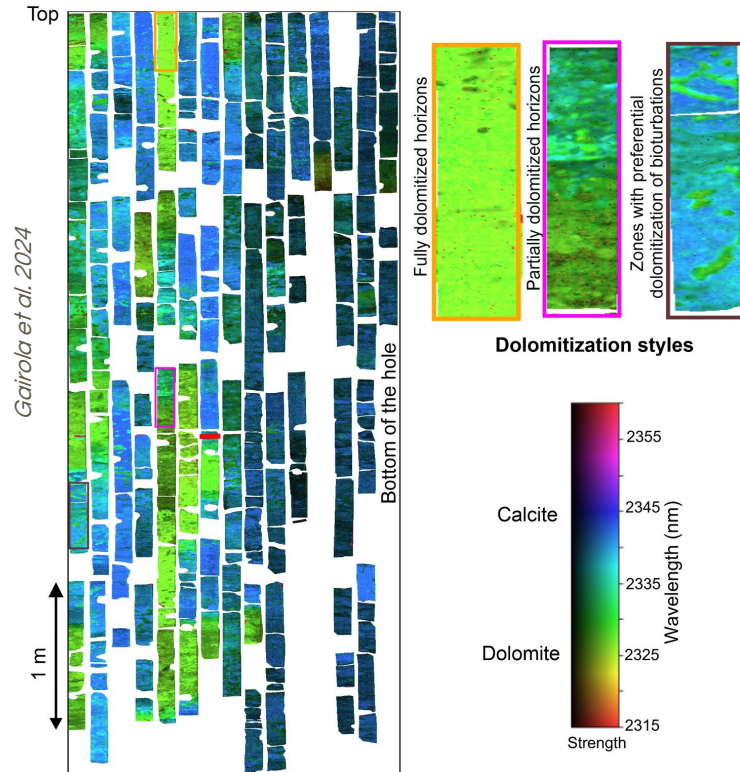


Integrating Single-Point Spectral and Scattered X-Ray Fluorescence Data to Generate Compositional Maps of Rock Surfaces: A Machine Learning Approach

Raphael B. Hunger, Carlos R. de Souza Filho, Rebecca D. P. M. Scafutto, Bernardo T. Freitas, Diego F. Ducart

University of Campinas, Brazil

Introductory Remarks



Determining the mineralogical and elemental surface distribution of rock materials has become fundamental to hydrocarbon reservoir characterization and mineral exploration

- Non-destructive, pixel-by-pixel rock surface scanning techniques significantly stand out
 - Ex.: Hyperspectral imaging and micro-X-ray fluorescence (μ XR),

Main advantages:

- Fastness of data acquisition and high spatial / spectral resolution

Main disadvantages:

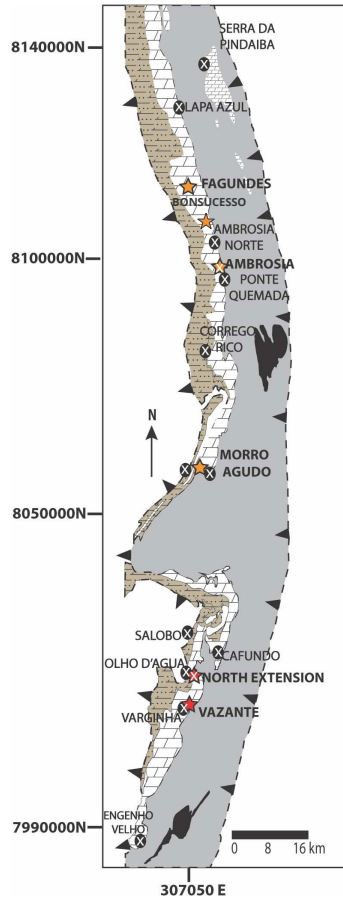
- Relatively expensive analytical equipment
- Transport between locations is considerably complex

Introductory Remarks



The application of portable devices to establish the mineralogical and compositional variation of rock materials represents an excellent and cost-effective alternative

Vazante-Paracatu District



- 1. São Francisco Craton
- 2. Brasília fold belt

- ★ Zn - Pb sulfide deposit
- ★ Zn silicate deposit
- Drill collar - Litho geochemistry
- ⊗ Drill collar - Pb isotope sample

LATE MESOPROTEROZOIC STRATA

Upper Vazante Sequence

- Lapa Formation
- Morro do Calcário Formation and Serra do Poço Verde Formation
- Serra do Garrote Formation
- Lagamar Formation

Fernandes et al. 2019

FORMATION	THICKNESS	DESCRIPTION
Lapa ★	~650 m	Calcareous phyllites and black phyllites and lenses of dolomite
Morro do Calcário ⚒	200-400 m	Stromatolitic dolomite bioherm, dolomite breccia, and dolarenite
Serra do Poço Verde ⚒	50-200 m	Dolomites and dolomudstones
	150-300 m	Dolomites, dolomudstones, marls interbedded with phyllites and litharenites
	200-300 m	Dolomites, dolomudstones, and dolarenites
Serra do Garrote	>500 m	Phyllites, carbonaceous phyllites and rare litharenites
Lagamar	~250 m	Dolomites, limestones and dolomite breccias, and conglomerate

Upper Vazante Group

- Microbial mats
- Columnar stromatolites
- Conophyton stromatolites
- ★ Sulfide Zn-Pb occurrence
- ⚒ Sulfide Zn-Pb mine
- ⚒ Silicate Zn-Pb mine

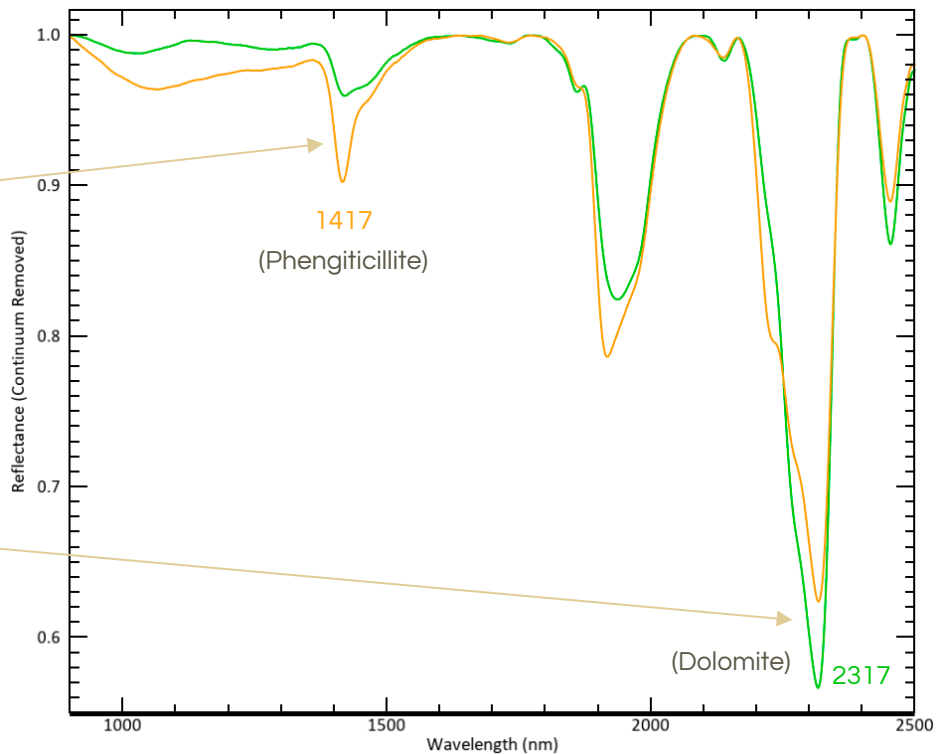
Mixed siliciclastic-carbonate marine succession (Tonian age; Alvarenga et al. 2019)

Spectral Evolution Data

BSCD_0206/140.90m



Dolostone



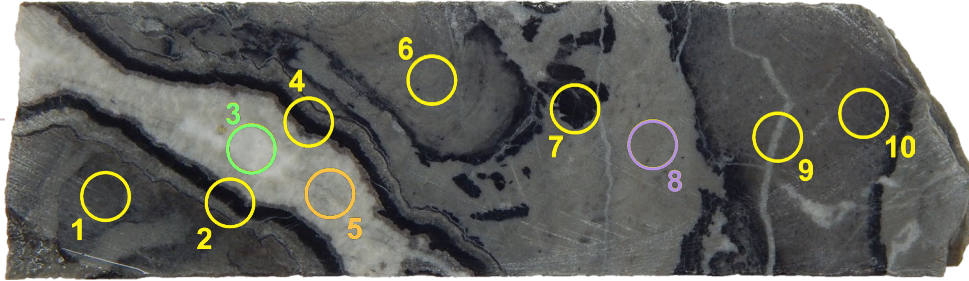
Original Sample Image



8 cm

4 cm

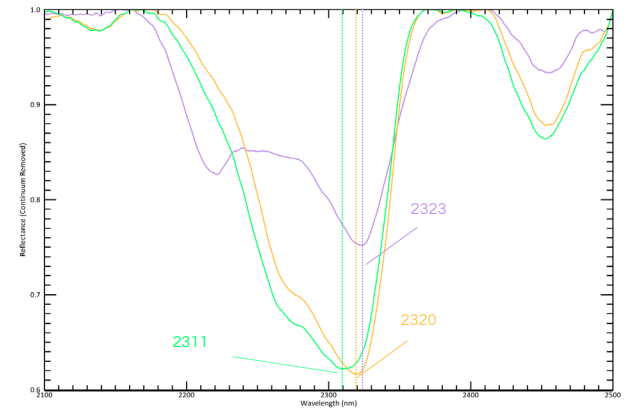
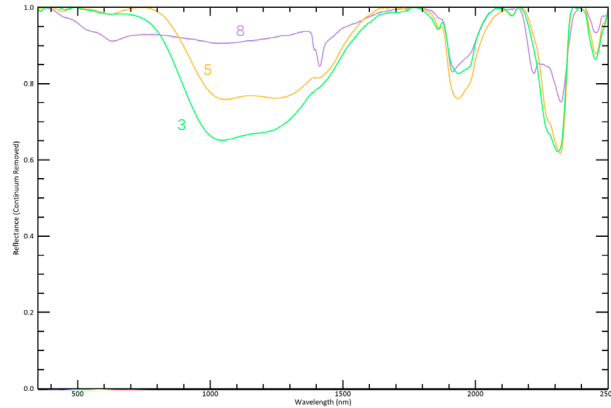
Integrating Hyperspectral & pFRX Data



AFD01A/398.45m

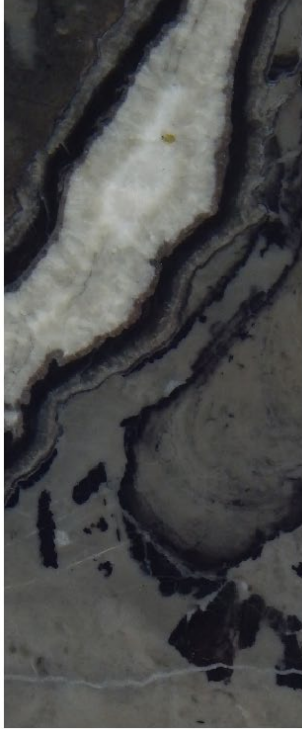
Position	MgO	Al2O3	SiO2	K2O	Ca	Mn	Fe
1	30.5758	5.24	30.1495	0.9185	19.7189	0.0772	0.8839
2	10.4249	< LOD	89.6369	0.0709	11.4316	0.0297	0.3003
3	54.7114	0.964	0.292	0.0488	19.5163	0.1133	1.2334
4	15.1158	< LOD	76.2649	0.0941	14.0677	0.0351	0.2922
5	41.3327	1.2267	0.3253	0.0695	25.0857	0.1519	1.1292
6	33.7322	3.3968	20.9574	0.6765	21.3801	0.0356	0.7338
7	15.0135	7.5178	42.3816	1.1924	21.2555	0.0094	1.234
8	32.9425	6.7297	28.3445	0.956	19.7364	0.0235	0.4455
9	37.1622	0.8799	14.2847	0.1438	24.0585	0.0697	0.7262
10	33.4178	0.7312	17.4752	0.1684	23.9147	0.0301	0.258

Open-space filling
hydrothermal
alteration
affecting the
dolostone

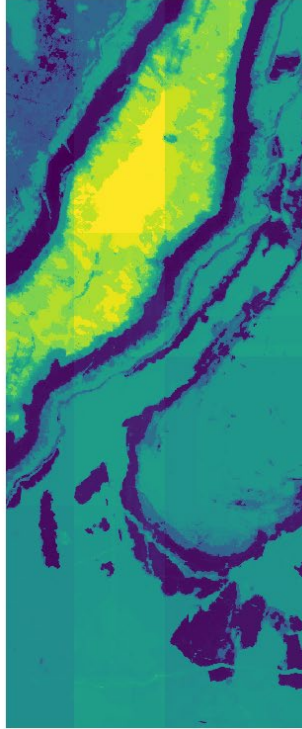


Compositional Maps (pFRX)

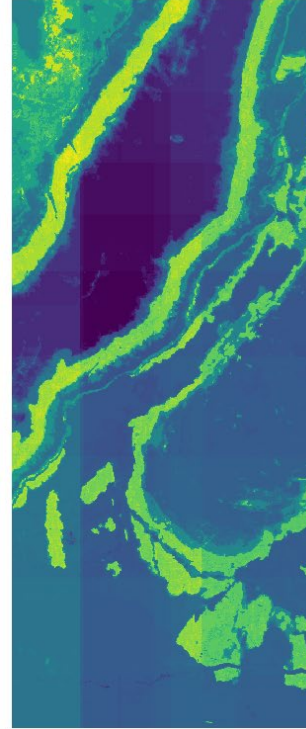
Original Sample Image



Random Forest (MgO)



Random Forest (SiO₂)



KNIME Workflow

Data Input

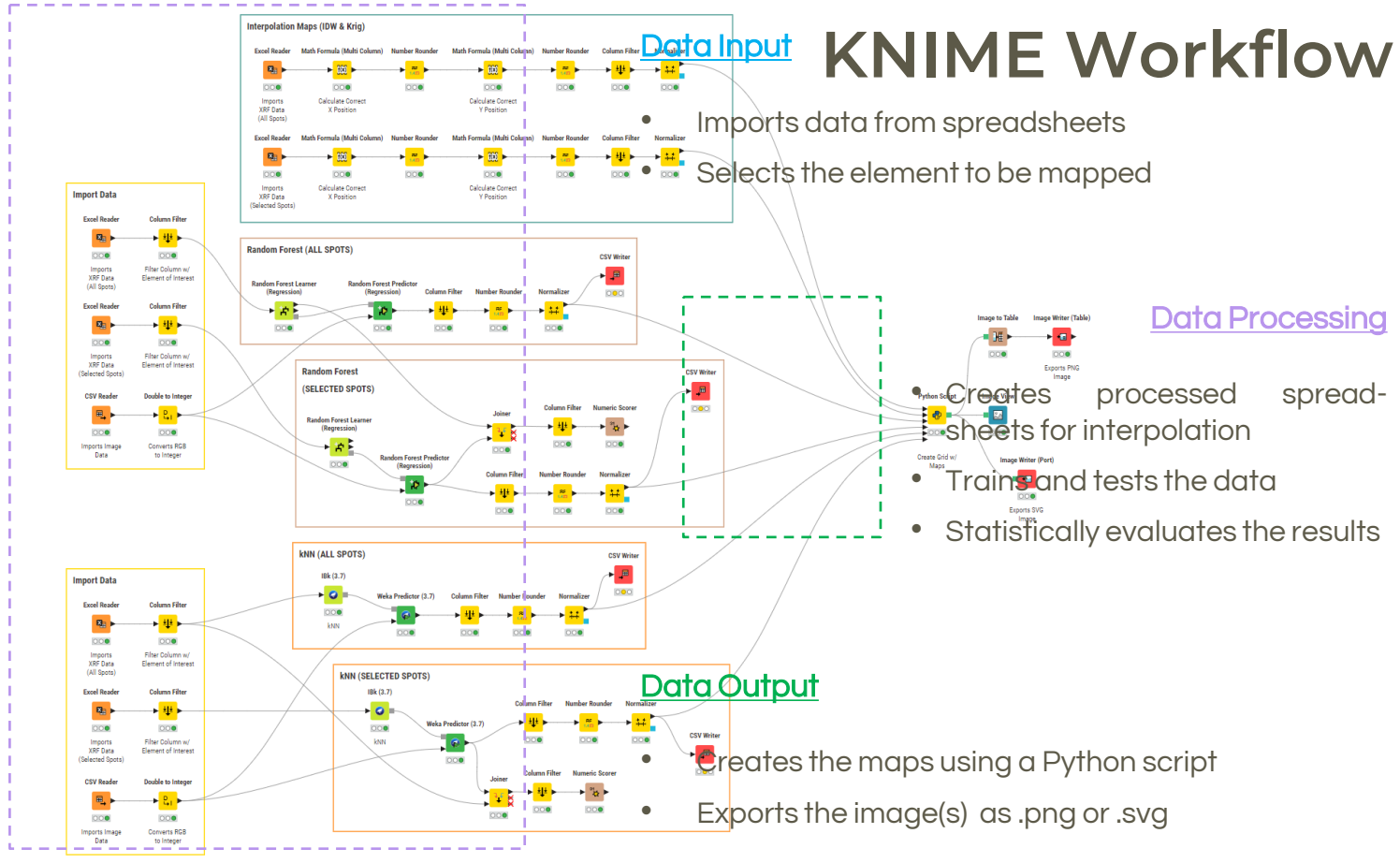
- Imports data from spreadsheets
- Selects the element to be mapped

Data Processing

- Creates processed spreadsheets for interpolation
- Trains and tests the data
- Statistically evaluates the results

Data Output

- Creates the maps using a Python script
- Exports the image(s) as .png or .svg



Concluding Remarks

- The preliminary outcomes of this work demonstrate that:
 - Even a small number of analytical pXRF data spots can produce satisfactory machine learning, compositional maps that show good correlation with the spectral information
 - Distinct mineral generations (e.g., dolomite) with variable compositions can be discriminated using this cost- and time-effective approach
 - The integrated spectral-mineralogical and compositional characterization of rocks performed in this study could provide valuable insights into:
 - The impacts of hydrothermal activity on the porosity, permeability and heterogeneity of petroleum reservoirs
 - The paragenetic evolution of hydrothermal mineral deposits