AGU 100 FALL MEETING

IMPACT OF MINERAL SURFACE AREA ON SIMULATED CO_2-BRINE-MINERAL REACTIONS AND REACTION RATES

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Surface area

Reactive transport modeling:

$$R_m = A_m k_m [f \Delta G_r]$$

R_m – reaction rate;

A_m – reactive surface area;

k_m – rate constant

$f \Delta G_r$ - thermodynamic driving force

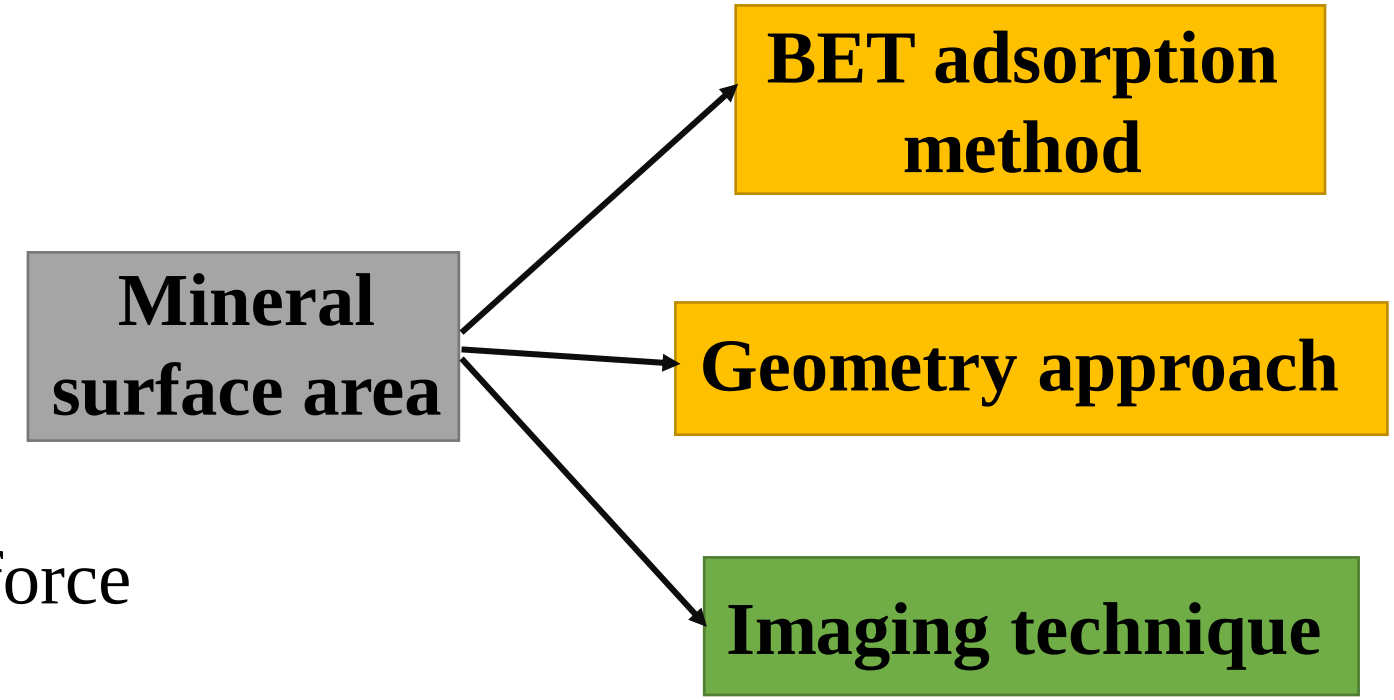


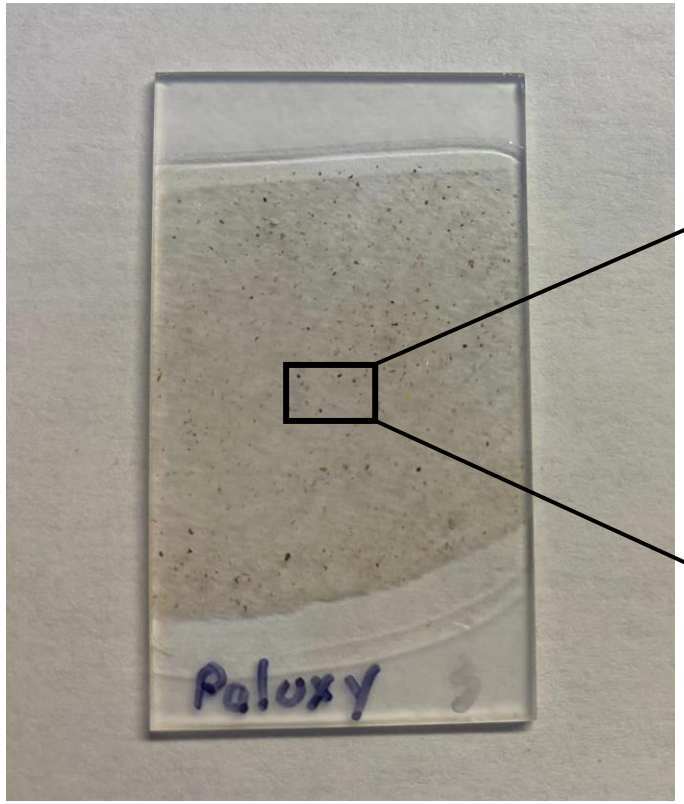
Image acquisition

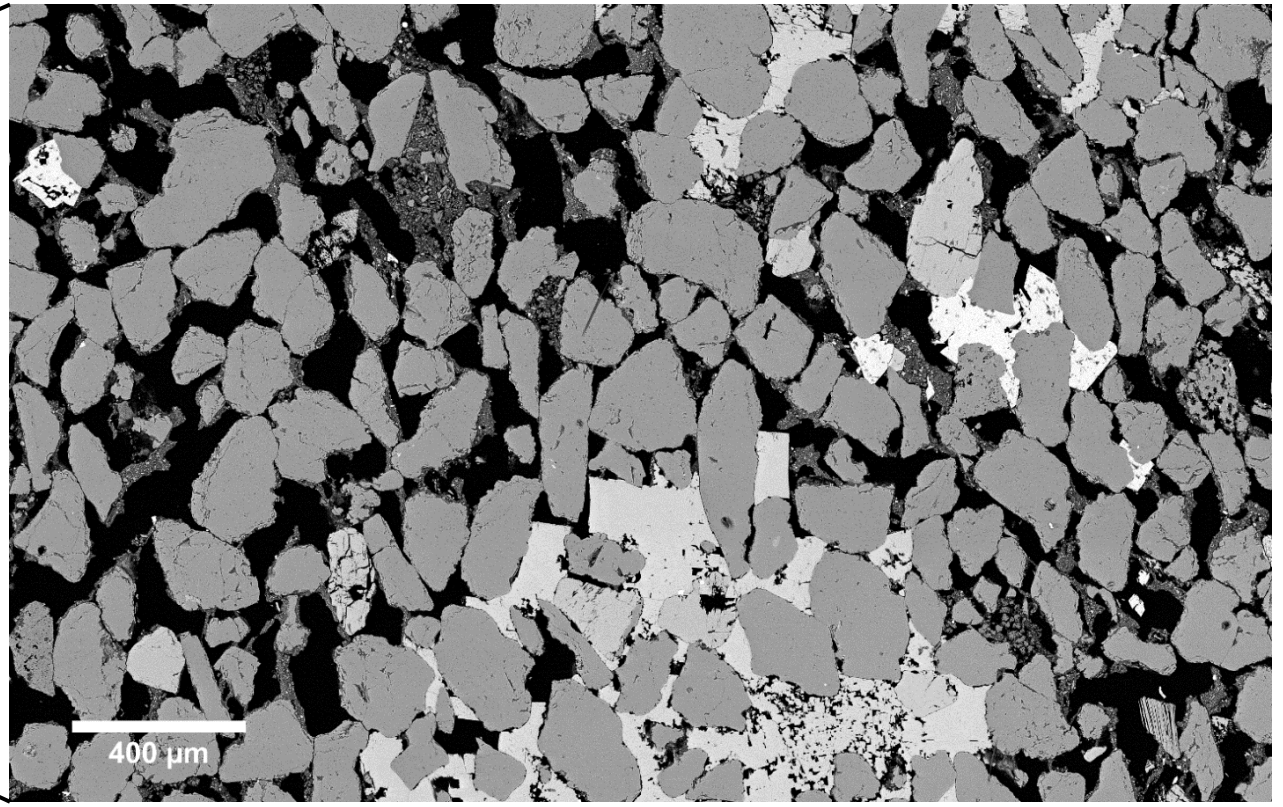
Thin section

Scanning electron microscope

Backscatter detector

SEM BSE image





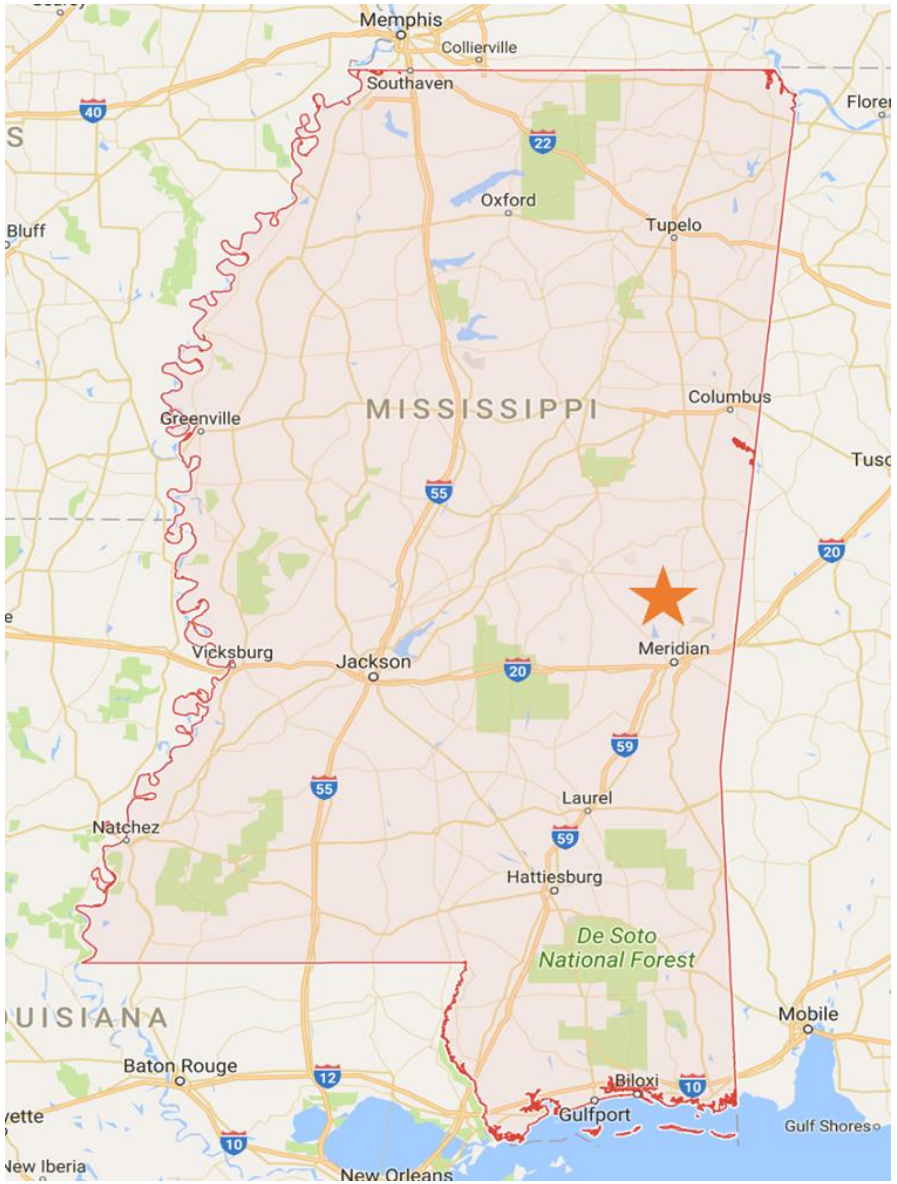
2.9 mm x 1.8 mm

5.34 mm^2

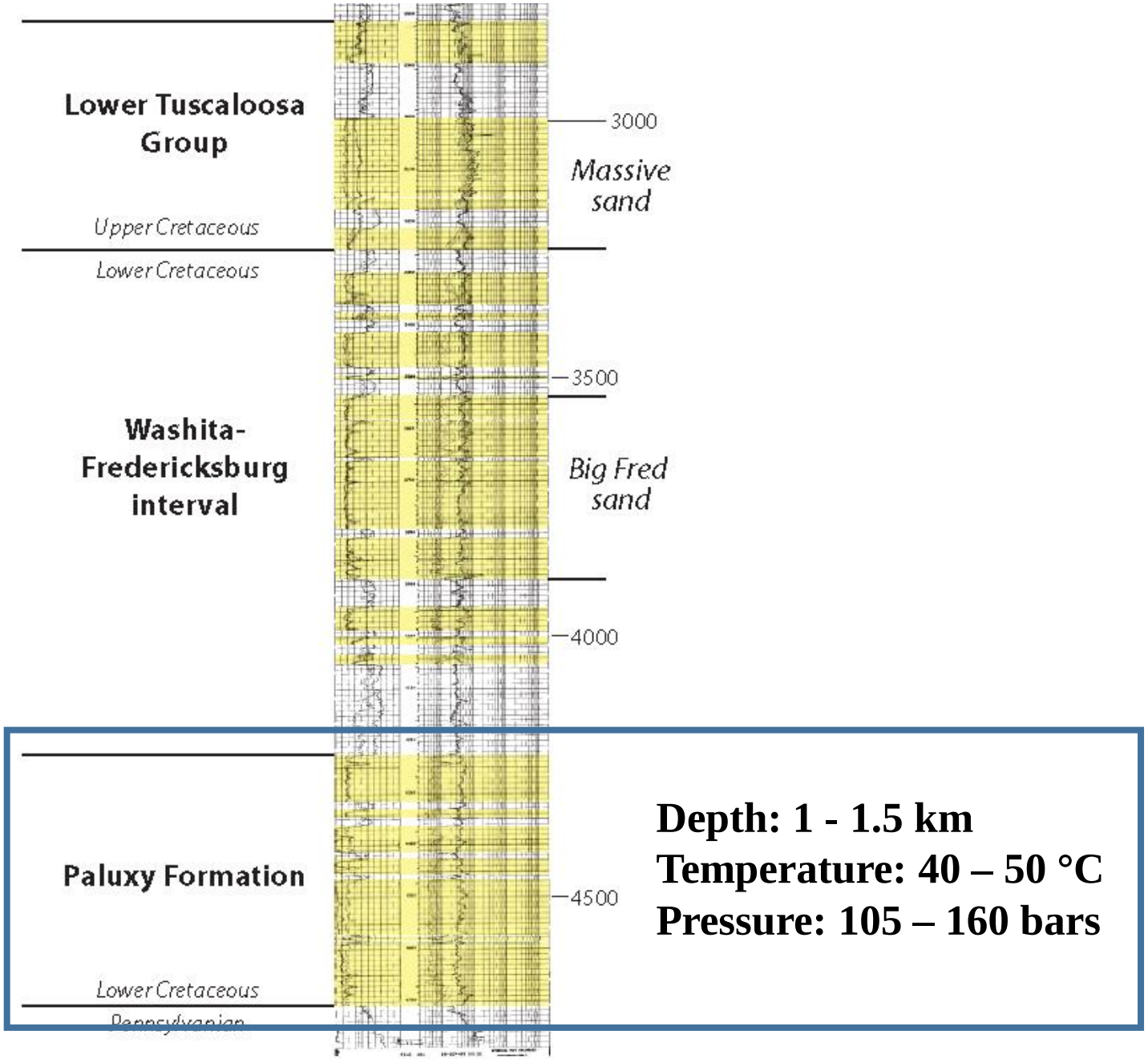
Resolution: 0.34 µm

Porosity: 0.25

Kemper pilot site



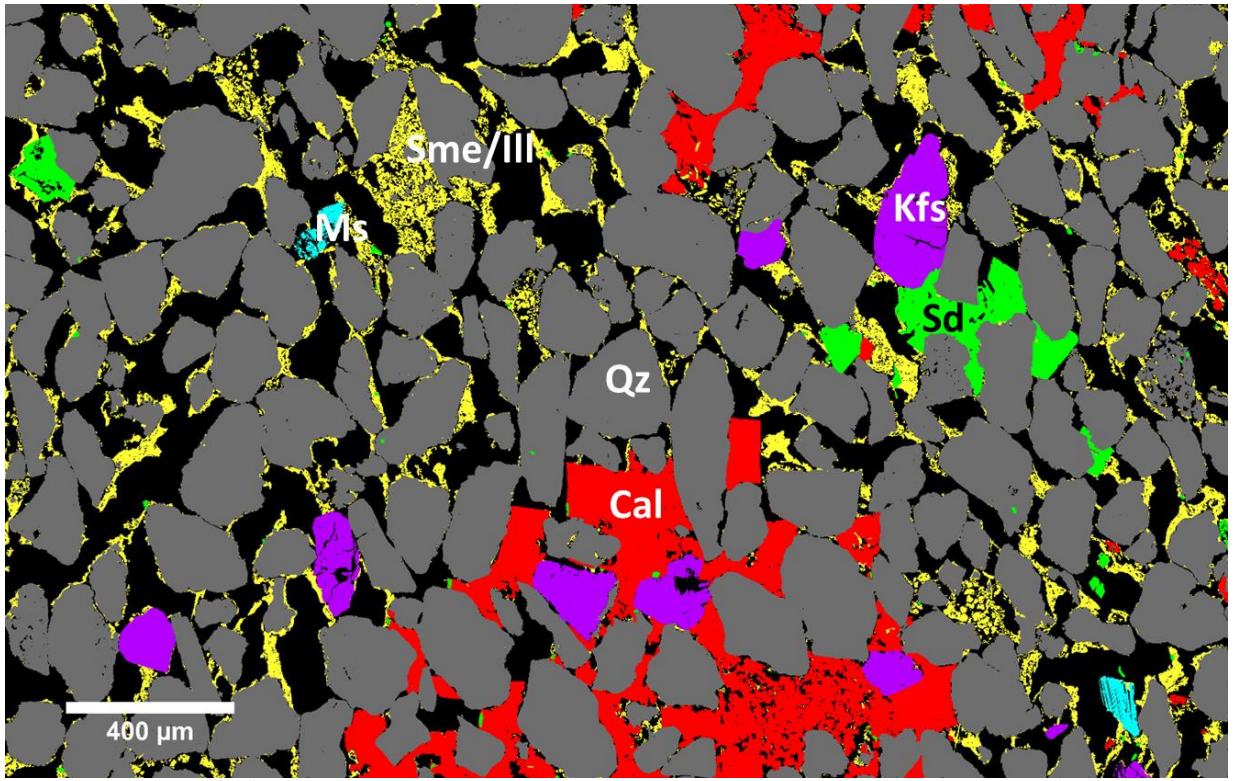
Source: Google map



Pashin, J.C., Hills, D.J., Kopska-Merkel, D.C. and McIntyre, M.R., 2008. Geological Survey of Alabama.

Mineral property quantification

Mineral phase segmented image



Quartz | K-feldspar | Muscovite
Calcite | Siderite | Smectite/illite

Qin and Beckingham, 2019

Mineral properties

Abundances

Accessibilities

Accessible surface area

What is the impact of image resolution on these measured properties?

Resolution effect

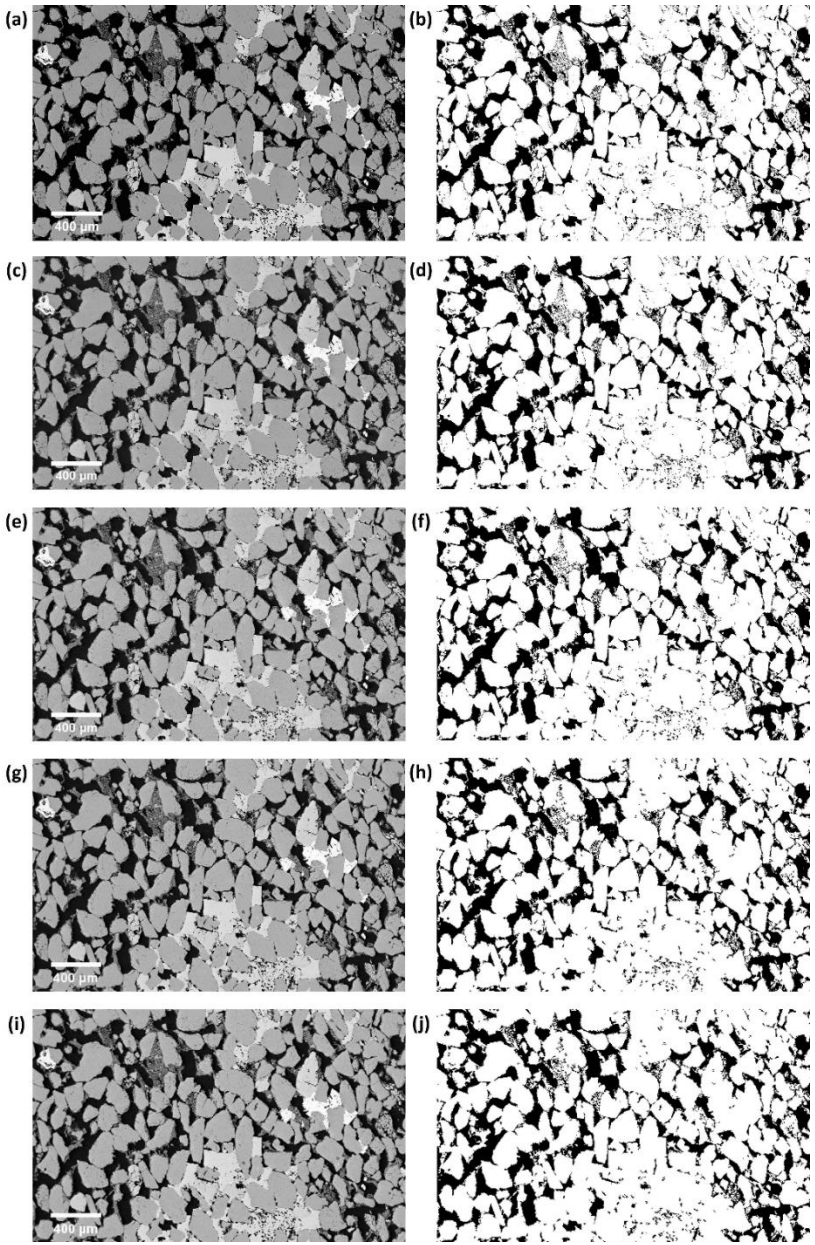
0.34 µm

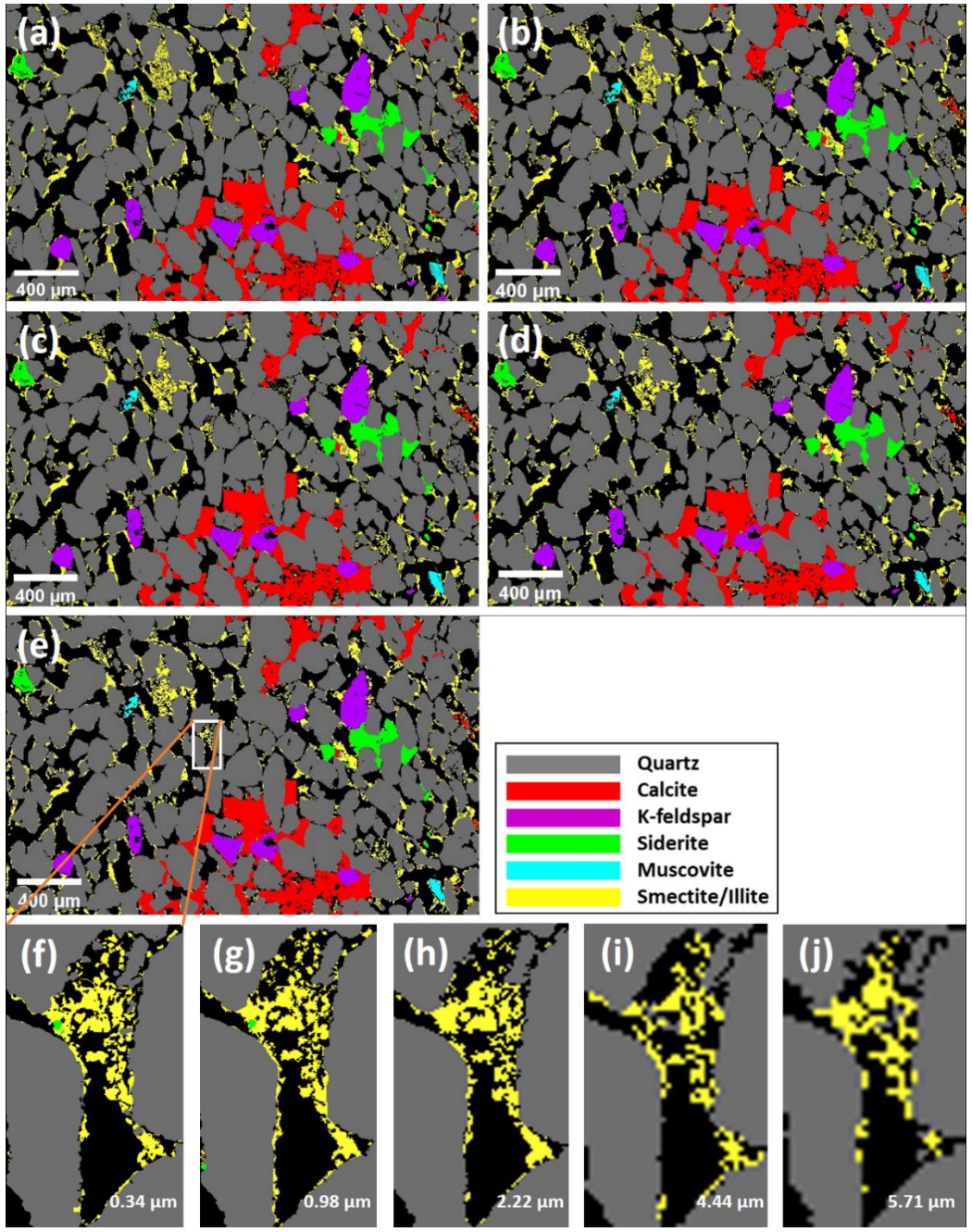
0.98 µm

2.22 µm

4.44 µm

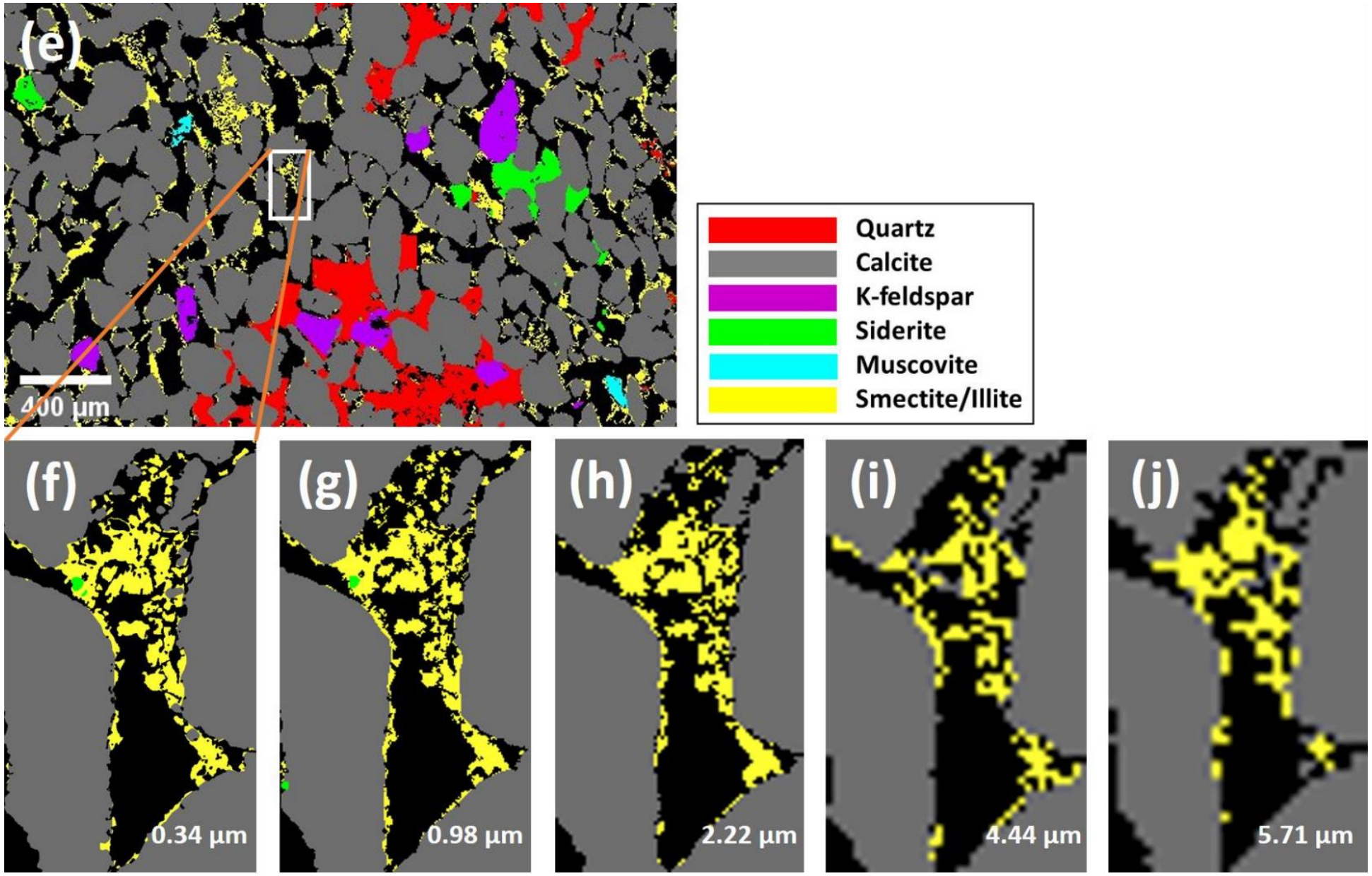
5.71 µm





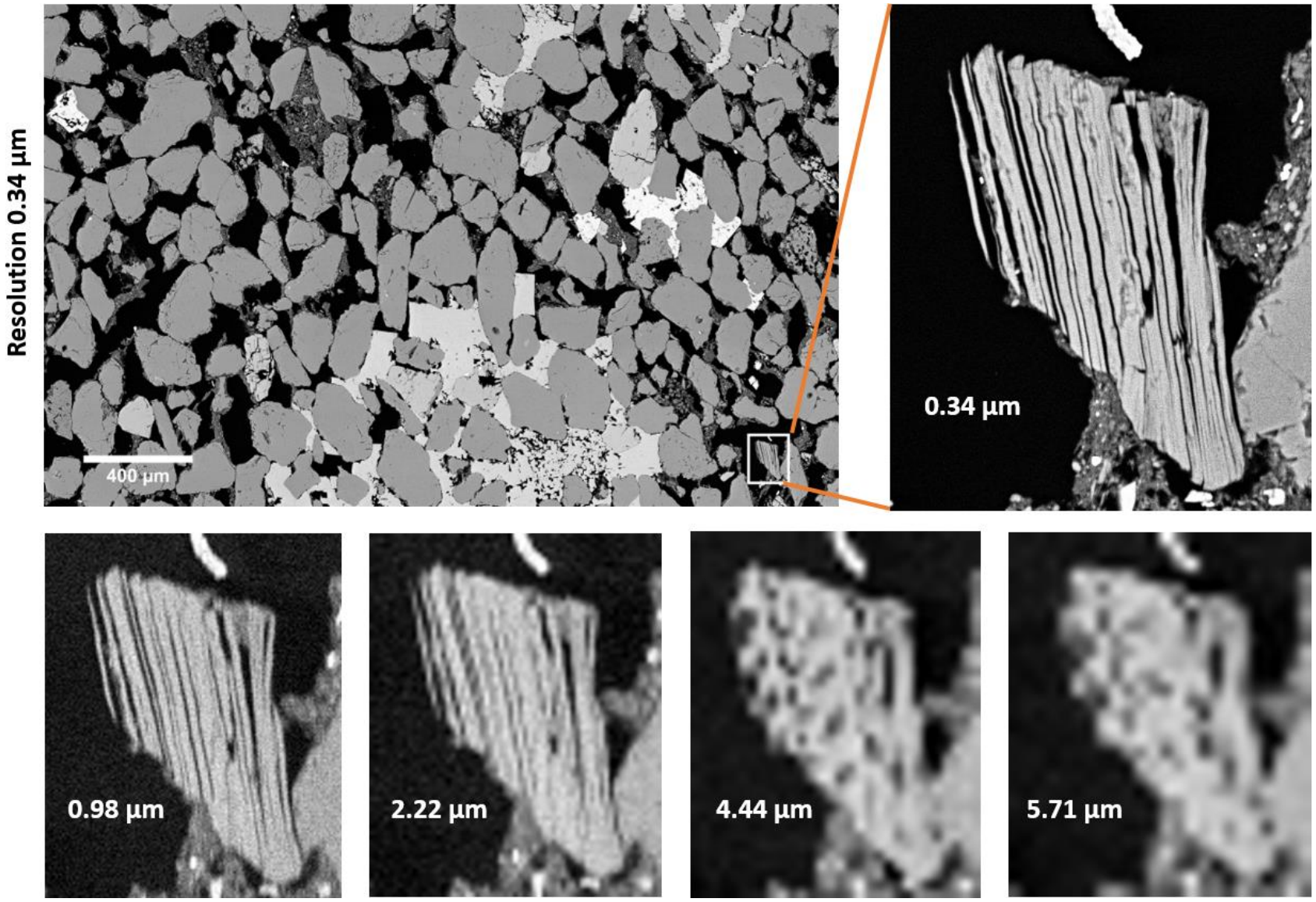
Qin and Beckingham, 2019

Resolution effect



Smectite

Resolution effect



Muscovite

Qin and Beckingham, 2019

Mineral abundances

Resolution (µm)	Quartz (%)	K-feldspar (%)	Calcite (%)	Smectite/Illite (%)	Muscovite (%)	Siderite (%)
0.34	76.45	3.50	9.63	8.23	0.31	1.88
0.98	77.14	3.37	9.04	8.32	0.31	1.82
2.22	78.31	3.36	8.97	7.31	0.33	1.73
4.44	77.99	3.37	9.30	7.02	0.30	2.02
5.71	78.73	3.26	8.72	7.27	0.32	1.70

Abundances agree relatively well with changing resolution

Mineral accessibilities

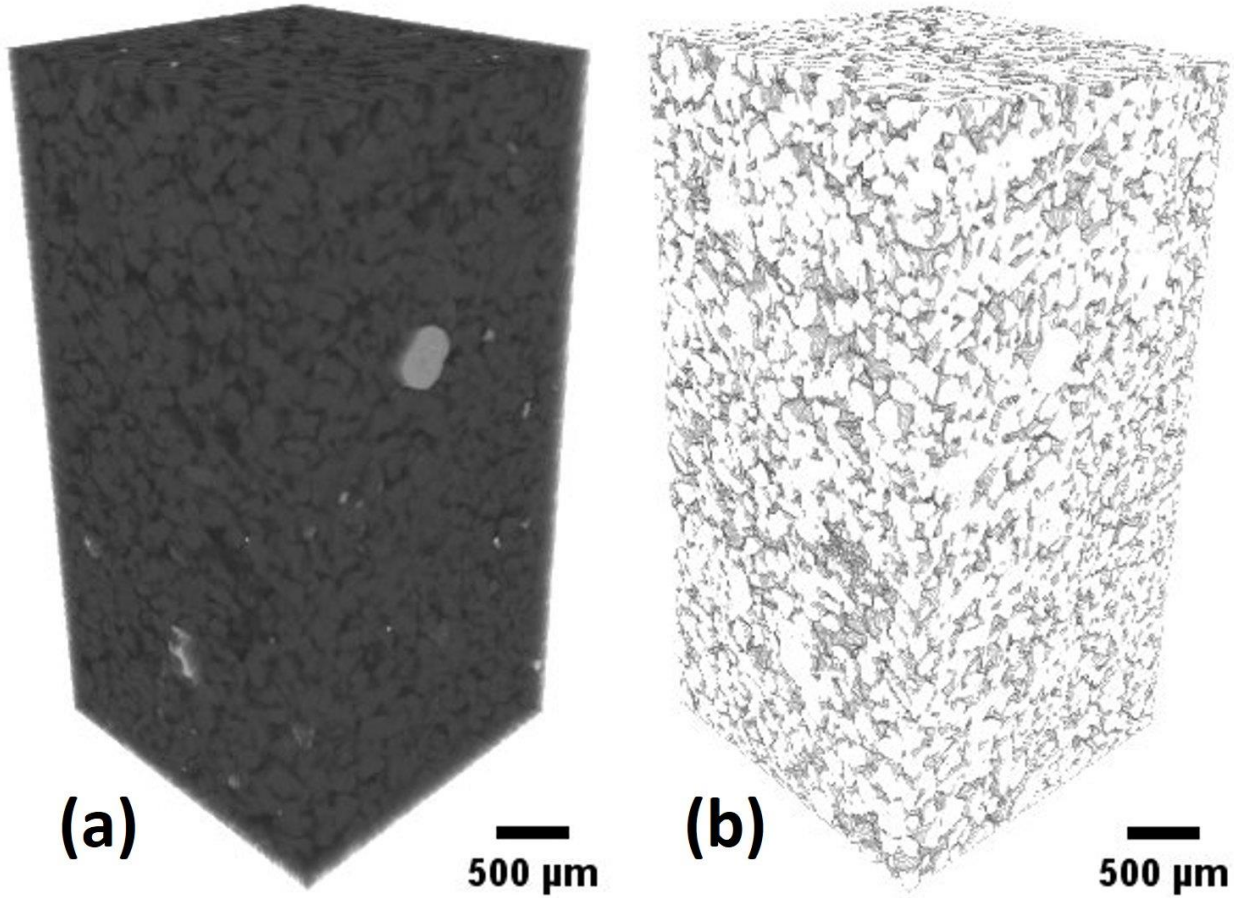
Resolution (μm)	Quartz (%)	K-feldspar (%)	Calcite (%)	Smectite/Illite (%)	Muscovite (%)	Siderite (%)
0.34	31.96	1.43	1.76	63.05	1.00	0.80
0.98	30.62	0.74	1.24	66.30	0.62	0.47
2.22	45.22	0.95	1.23	51.30	0.79	0.52
4.44	54.99	1.54	1.69	39.27	0.88	1.62
5.71	57.41	0.81	1.24	38.82	0.95	0.78

Quartz ↑ **Smectite** ↓

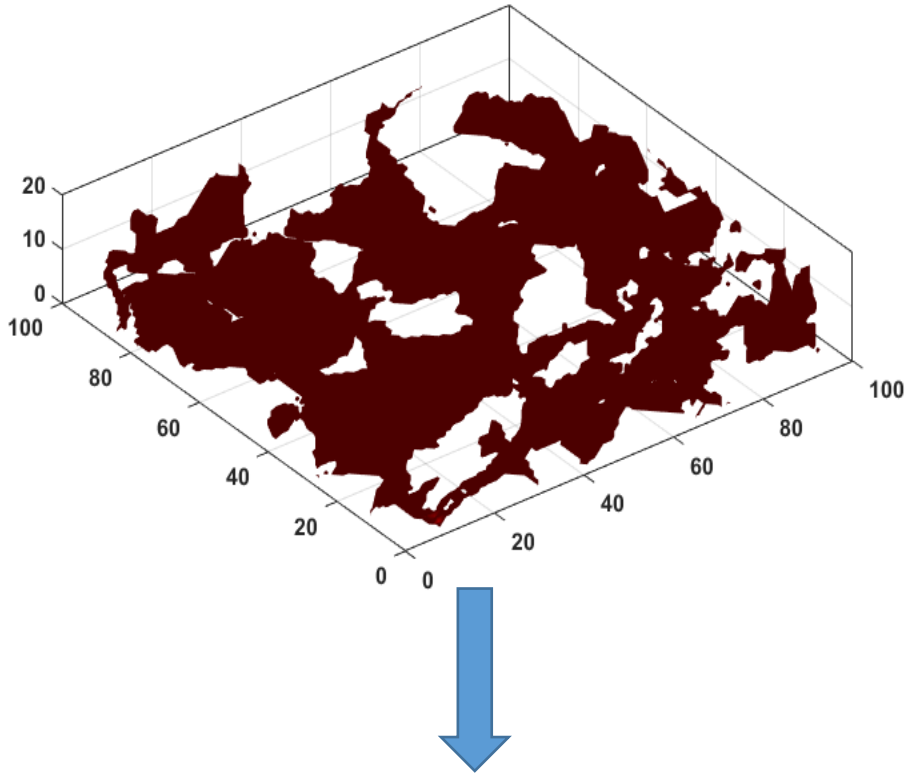
Total connected surface area

After Landrot et al., 2012

3D X-ray CT image



Connected pore space



Connected surface area

Mineral accessible surface area

Image Resolution (μm)	Quartz (m^2/g)	K-feldspar (m^2/g)	Calcite (m^2/g)	Siderite (m^2/g)
0.34	1.48E-02	6.60E-04	8.13E-04	3.72E-04
0.98	1.42E-02	3.43E-04	5.75E-04	2.18E-04
2.22	2.10E-02	4.39E-04	5.67E-04	2.38E-04
4.44	2.54E-02	7.14E-04	7.84E-04	7.47E-04
5.71	2.65E-02	3.74E-04	5.73E-04	3.60E-04

Variations < 1 order of magnitude

Does such variations in surface area effect reactive transport simulations?

Reactive transport model (CrunchFlow)

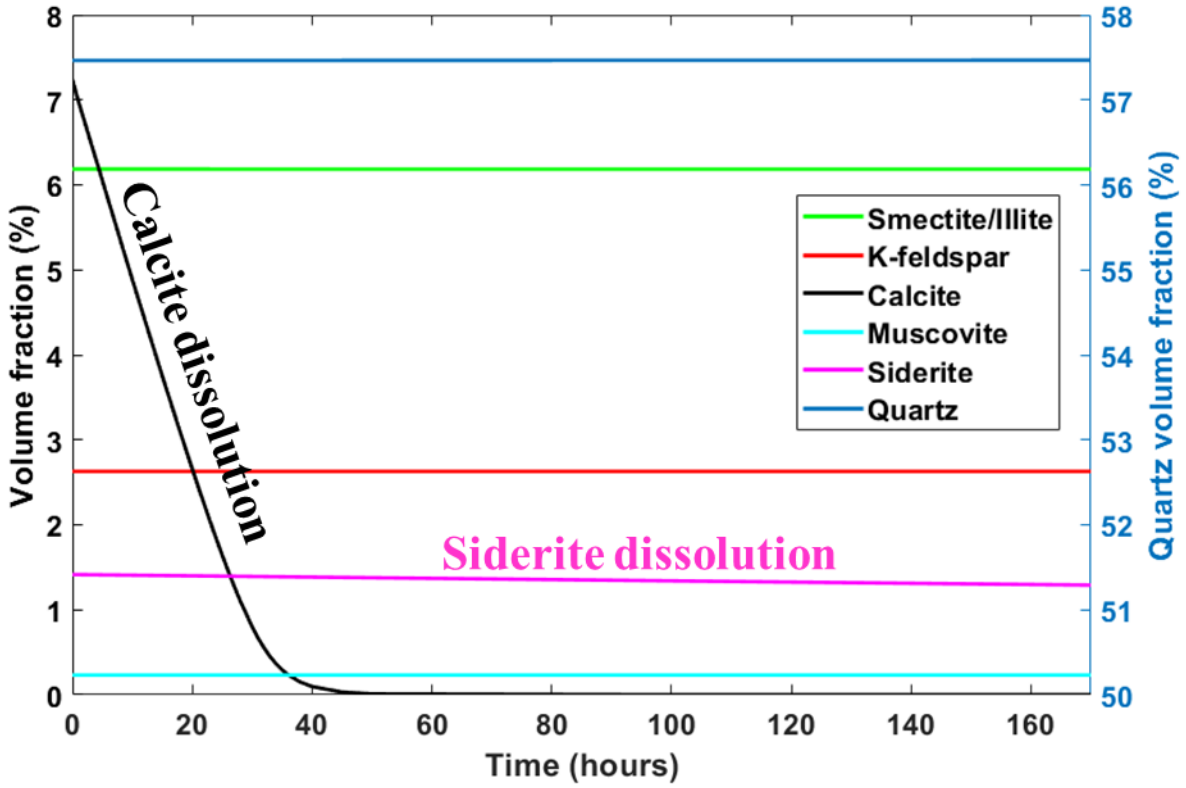
Output
- Mineral volume fraction
- Porosity

Time duration
- Short term 170 hours (7 days)
- Long term 7300 days

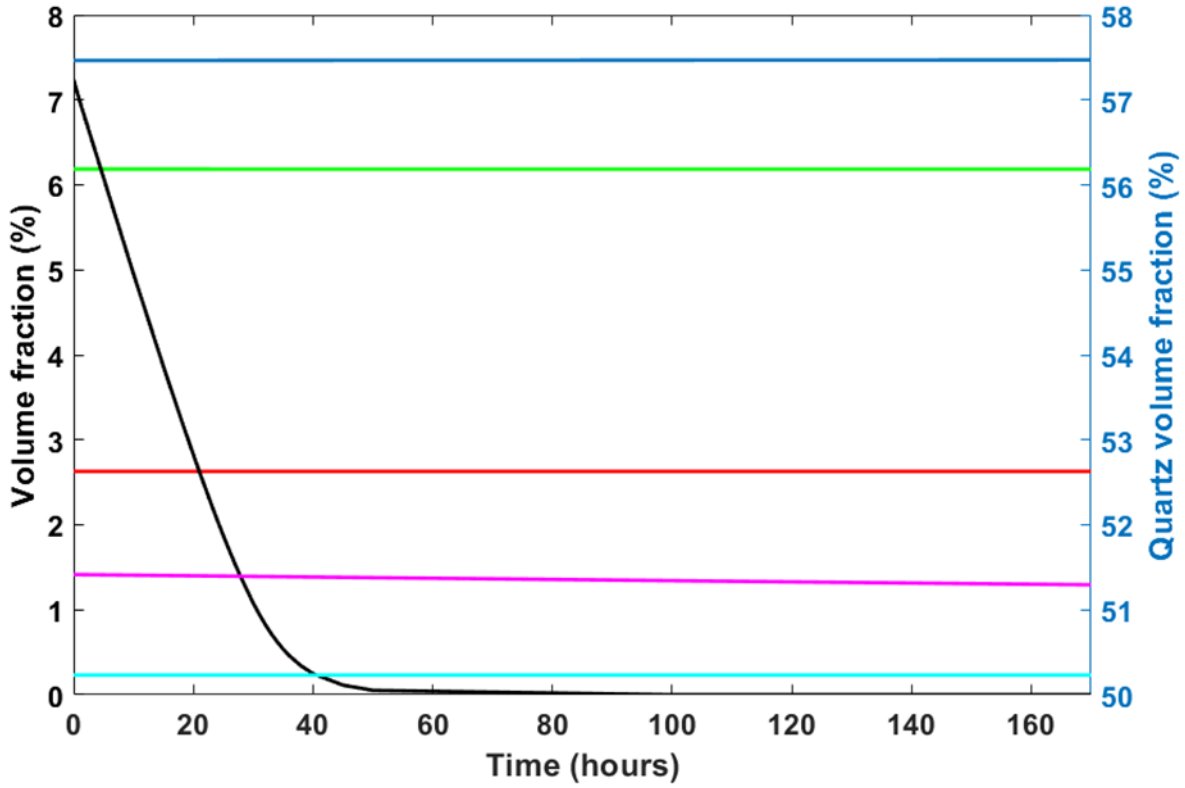
Surface areas	High resolution image Low resolution image	1 – 2 om High GSA Low GSA	3 – 5 om High lit. BET Low lit. BET

Mineral volume fraction (short term 170 hours)

High resolution image



Low resolution image

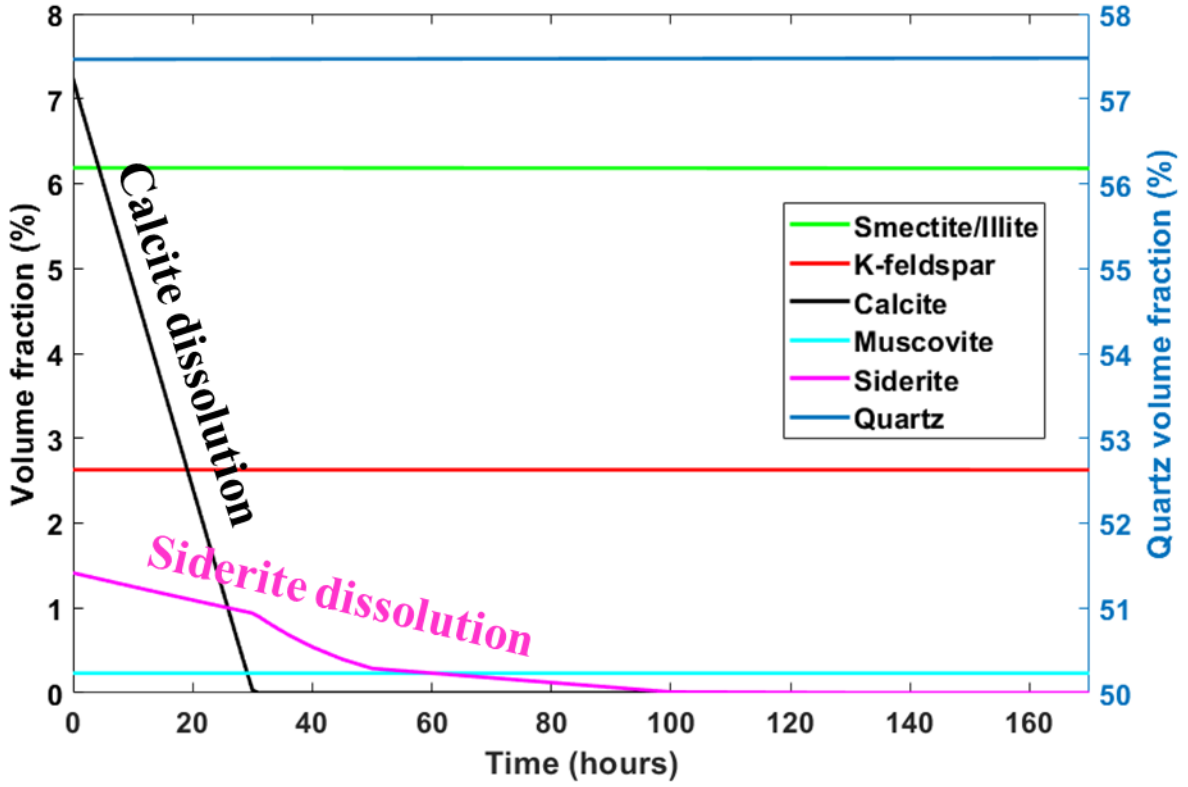


Calcite & siderite dissolve

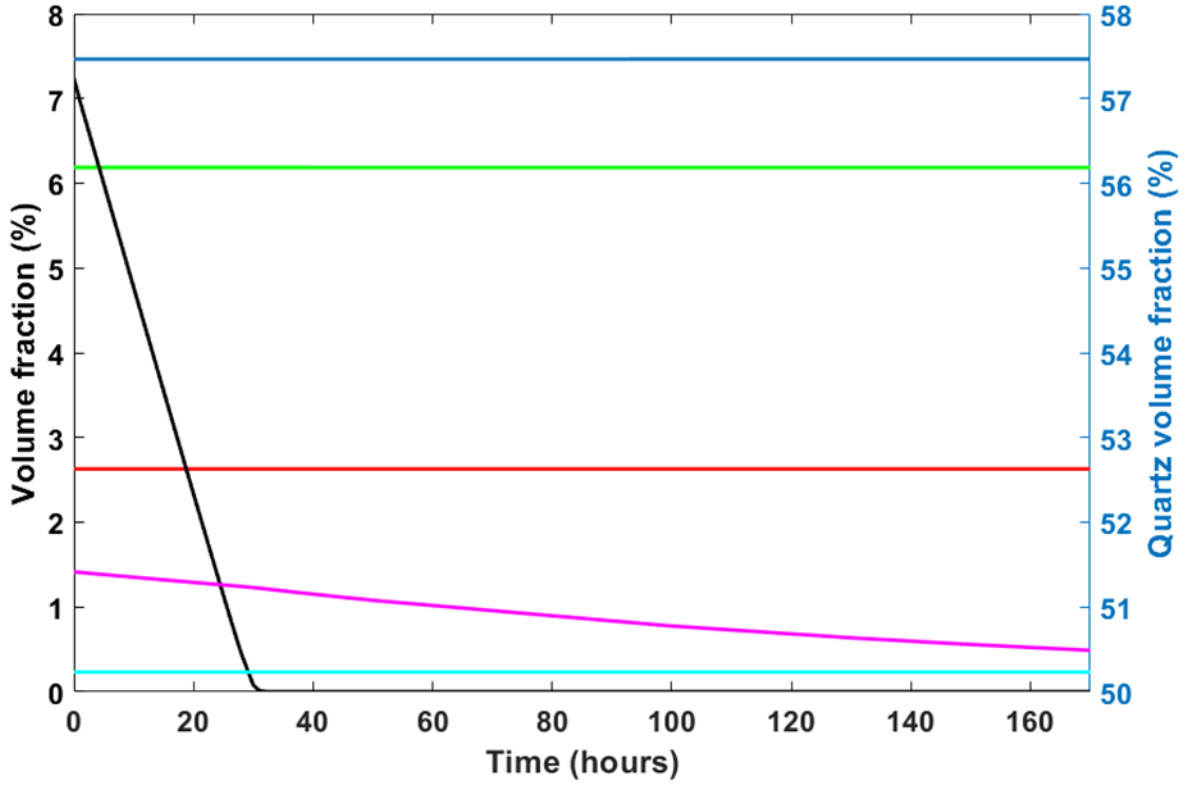
Small variations between simulations

Mineral volume fraction (short term 170 hours)

GSA high



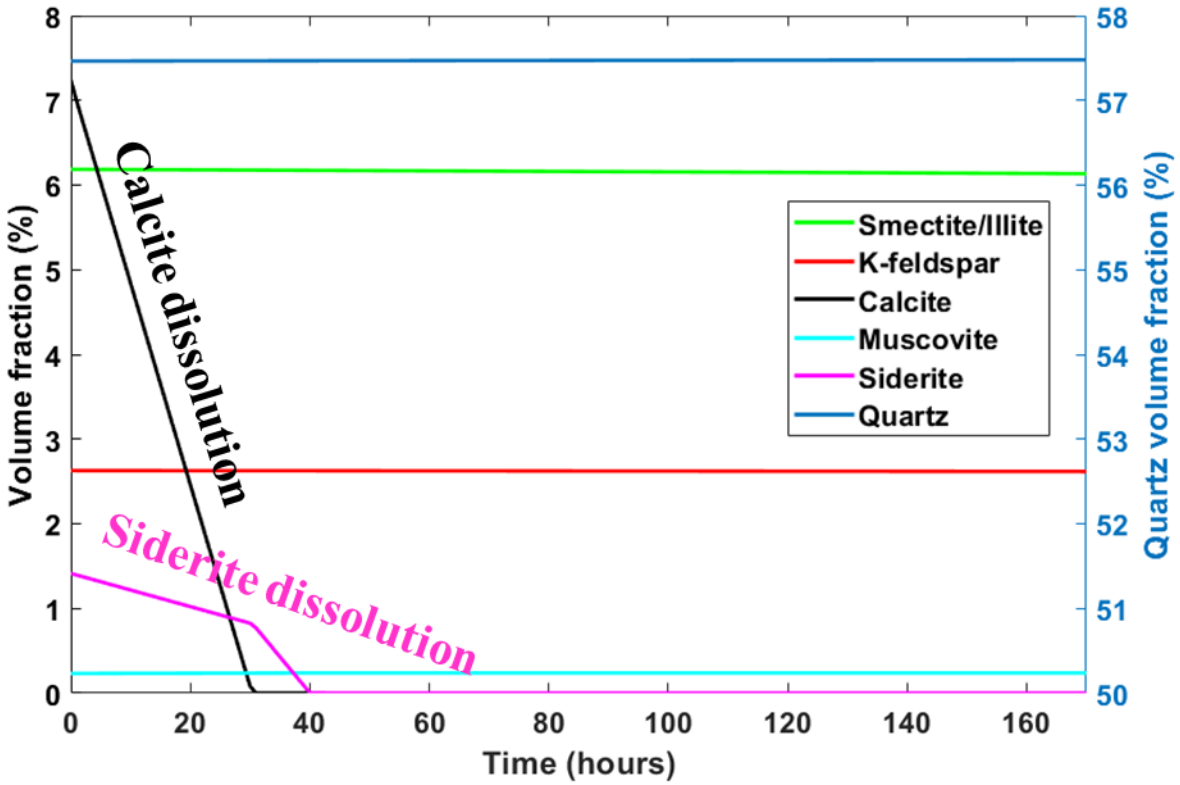
GSA low



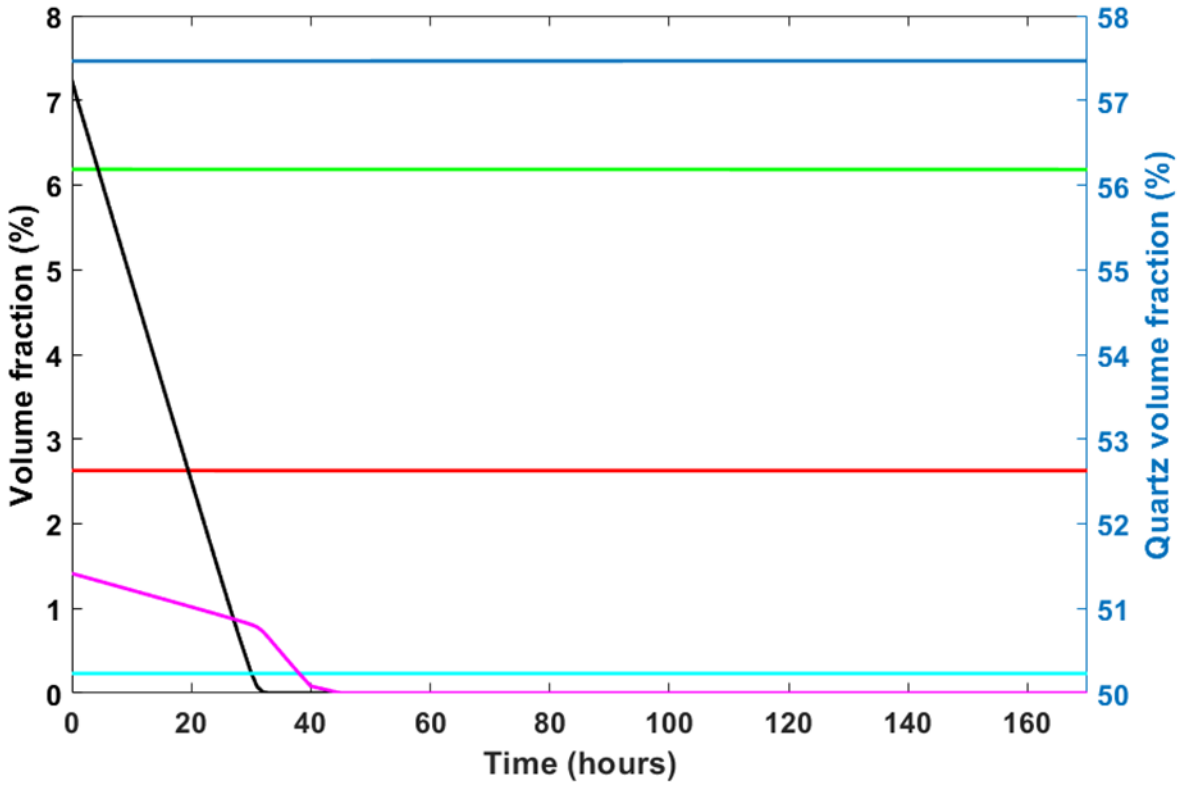
Calcite & siderite dissolve, faster siderite dissolution

Mineral volume fraction (short term 170 hours)

Literature BET high



Literature BET low



Even faster siderite dissolution

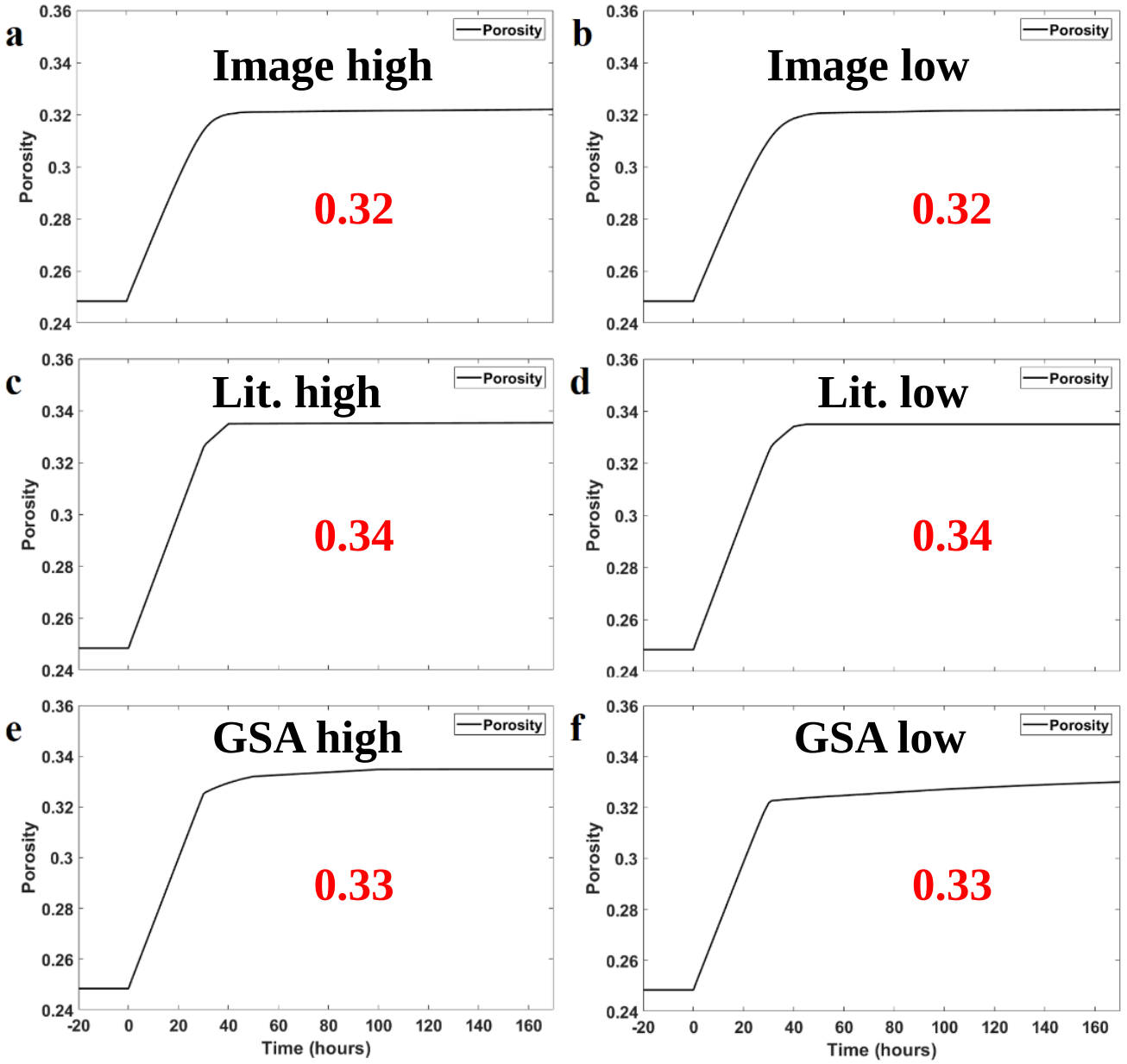
Calcite – small, Siderite - large

Mineral porosity (short term 170 hours)

Initial porosity: 0.25

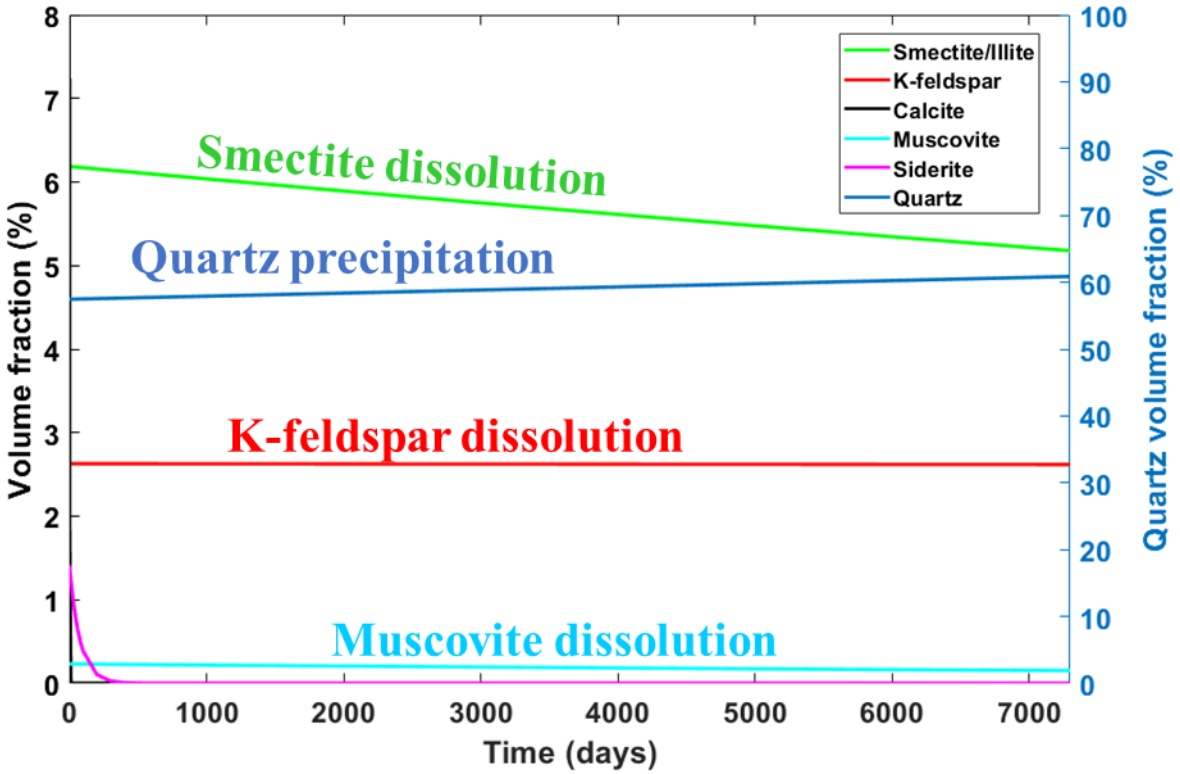
Increased to 0.32 – 0.34

The impact of surface area on short term porosity evolution is small

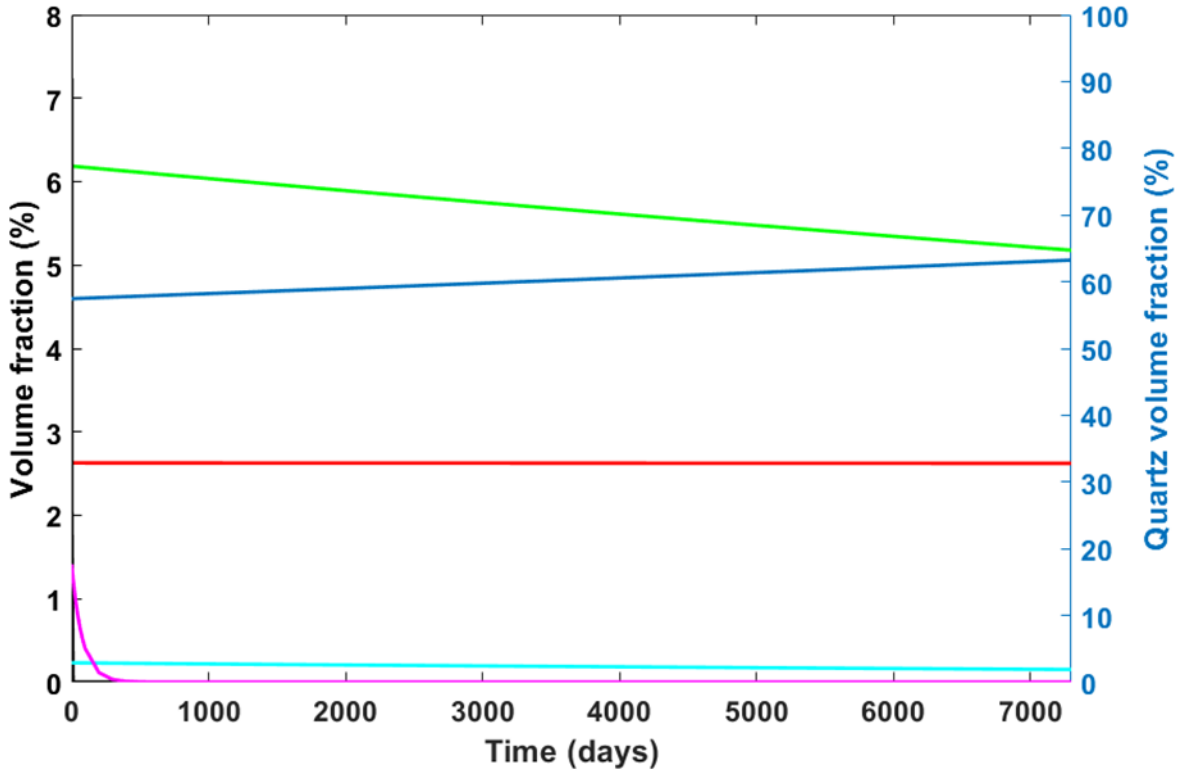


Mineral volume fraction (long term 7300 days)

High resolution image



Low resolution image



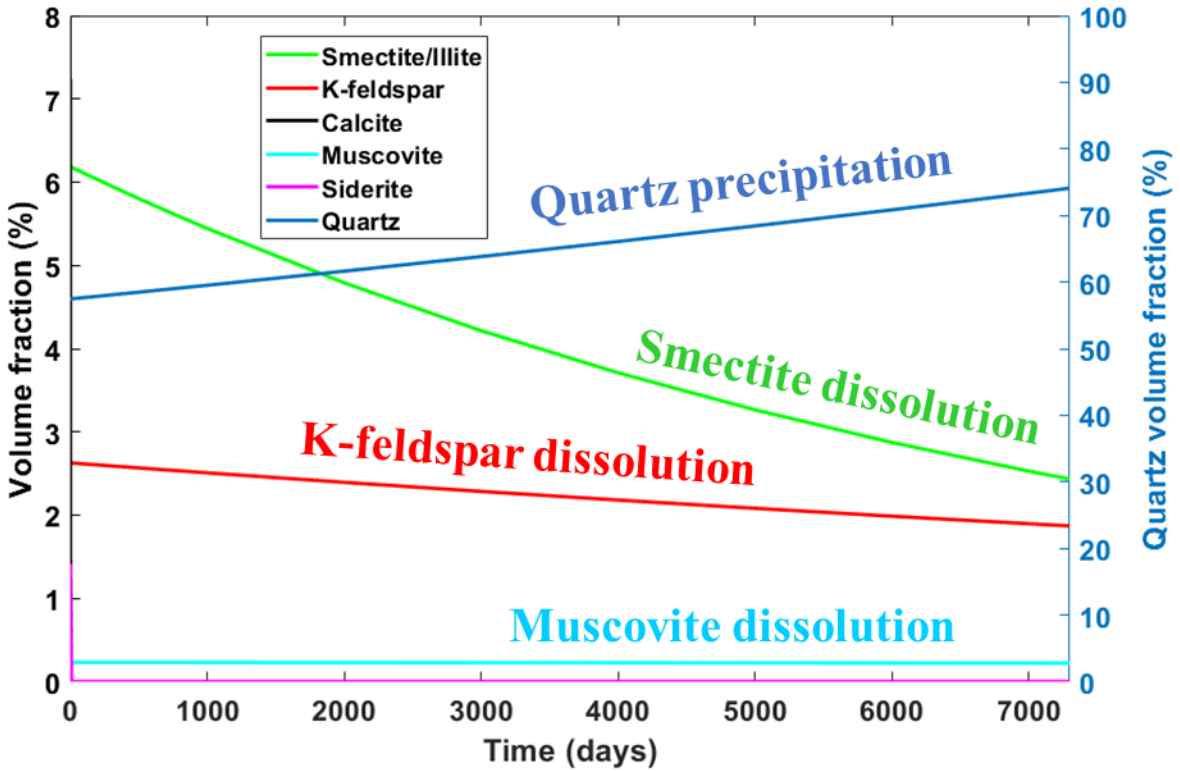
Calcite & siderite depleted, other minerals dissolve

SiO_2 precipitates

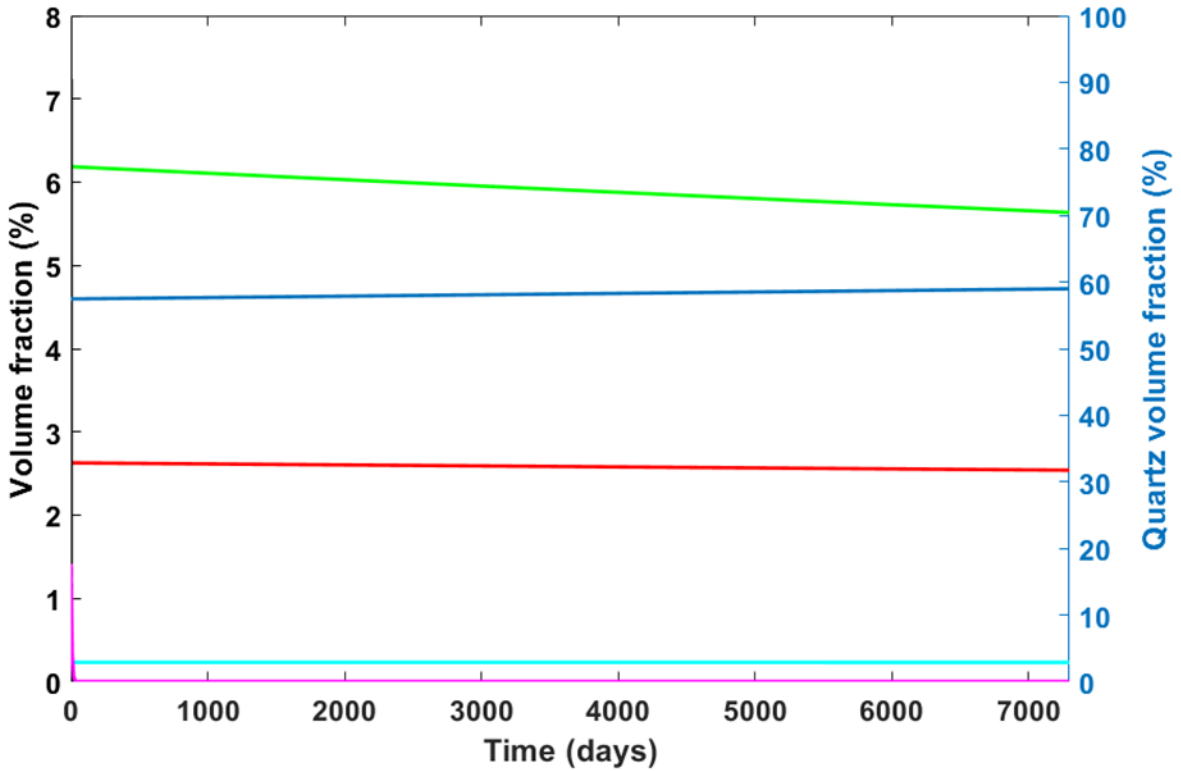
Minor variations between simulations

Mineral volume fraction (long term 7300 days)

GSA high



GSA low



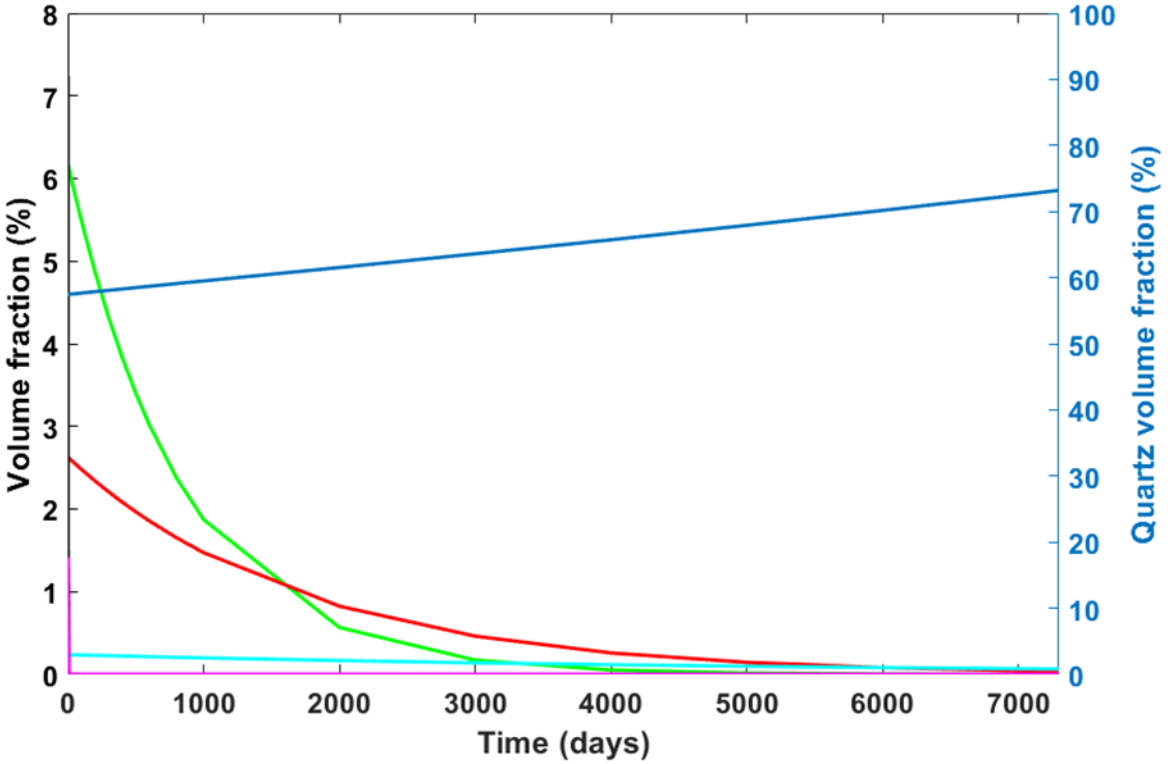
Faster smectite dissolution

More SiO_2 precipitation

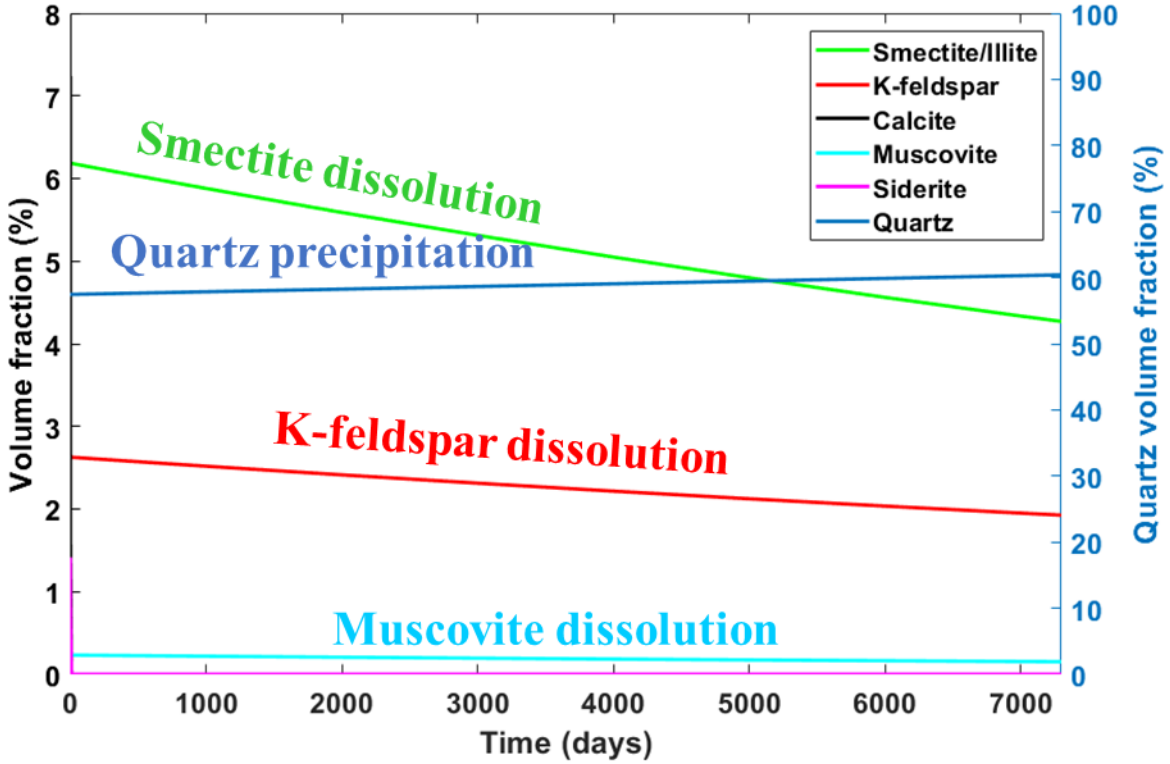
Large variations between simulations

Mineral volume fraction (long term 7300 days)

Literature BET high



Literature BET low



Even faster smectite dissolution

Even More SiO_2 precipitation

Larger variations between simulations

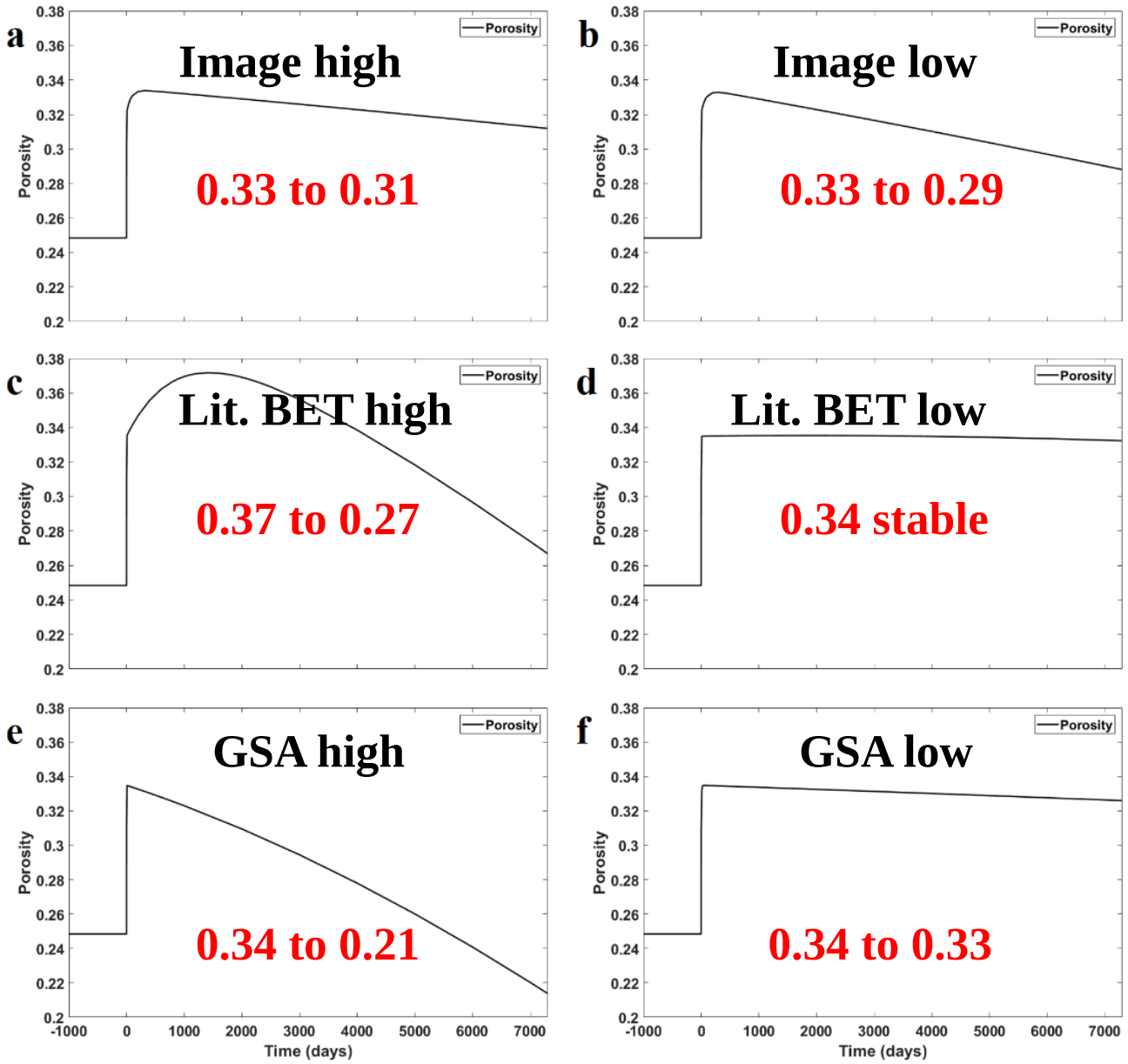
Mineral porosity (long term 7300 days)

Initial porosity: 0.25

First increased to 0.33 – 0.37

Then decreased to various extent

The impact of surface area on long term porosity evolution is significant



Conclusions

Reactivity	Category	Mineral	Surface area variations in om	Short term	Long term
More reactive	Carbonate	Calcite	1-3	Minor	Minimum
		Siderite	1-5	Large	Minimum
More stable	Non-clay	K-feldspar	1-3	Minimum	Large
		Muscovite	1-3	Minimum	Large
		Quartz	1	Minimum	Large
	Clay	Smectite	2	Minimum	Large

Simulation for short period (10s of hours) → **Reactive minerals (e.g. carbonate)**

Simulation for longer period (100s of days) → **Less reactive minerals (e.g. clay)**

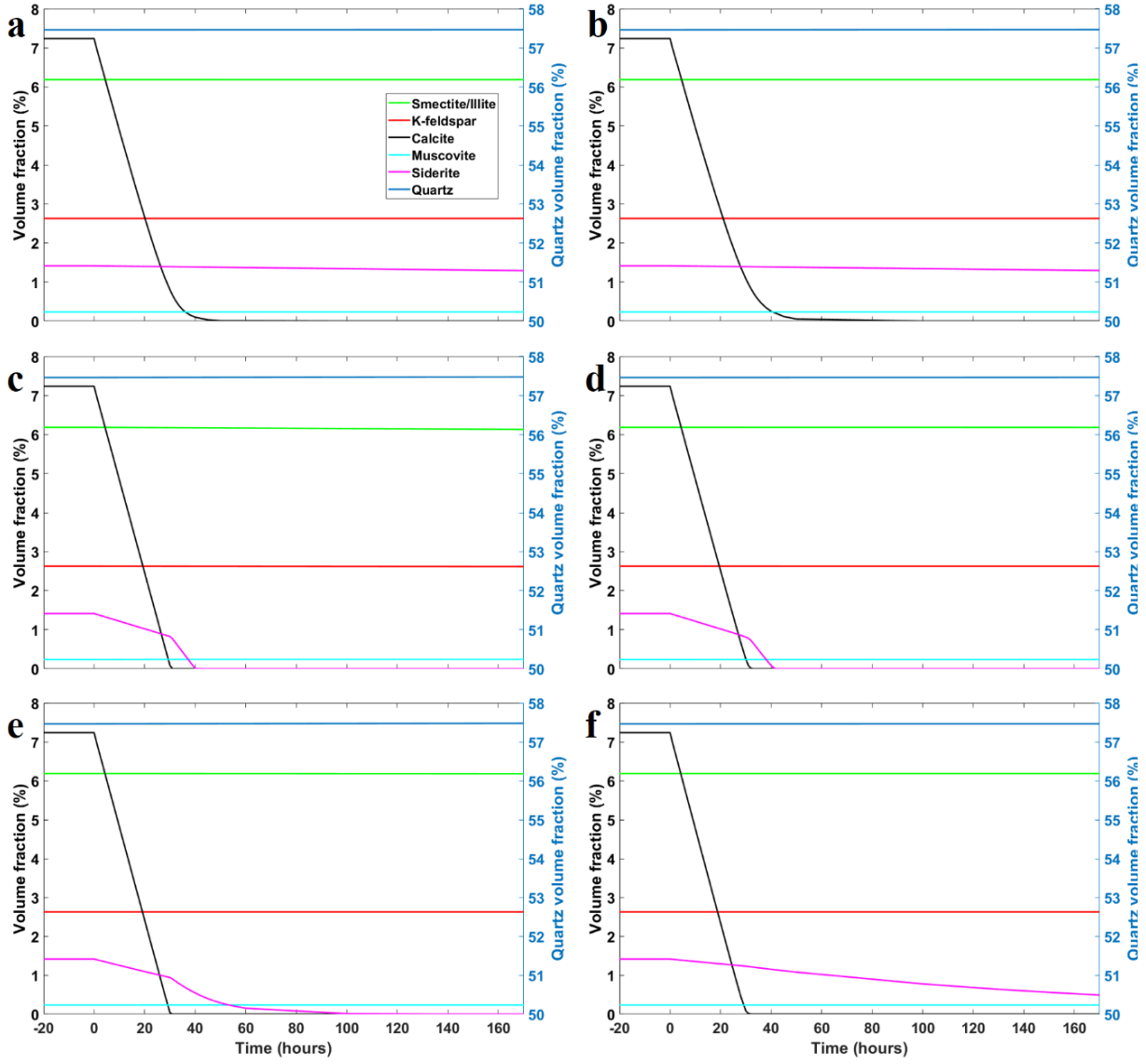
Acknowledgements

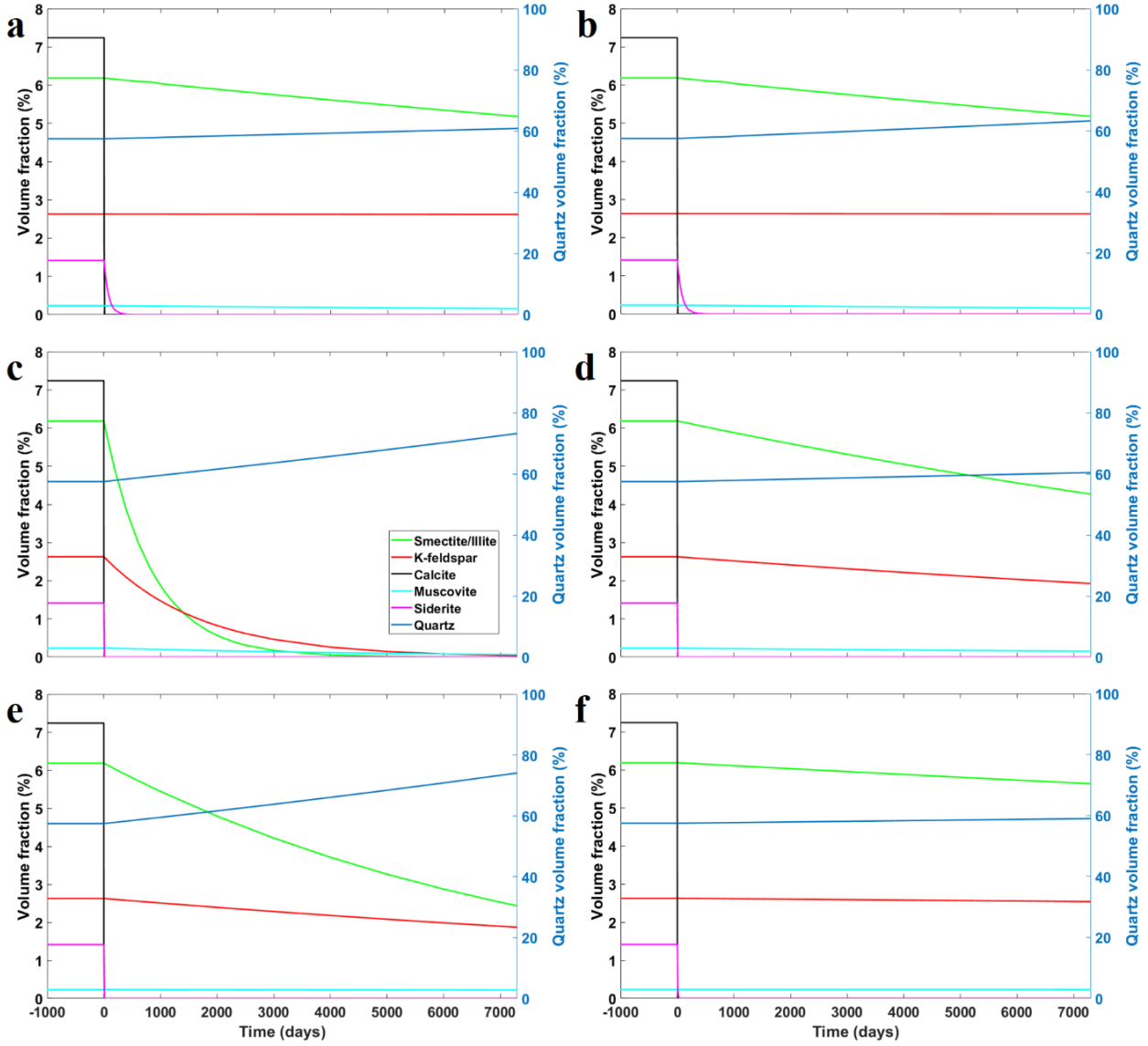
The “Establishing an Early CO_2 Storage Complex in Kemper, MS” project is funded by the U.S. Department of Energy’s National Energy Technology Laboratory and cost-sharing partners.

Questions?

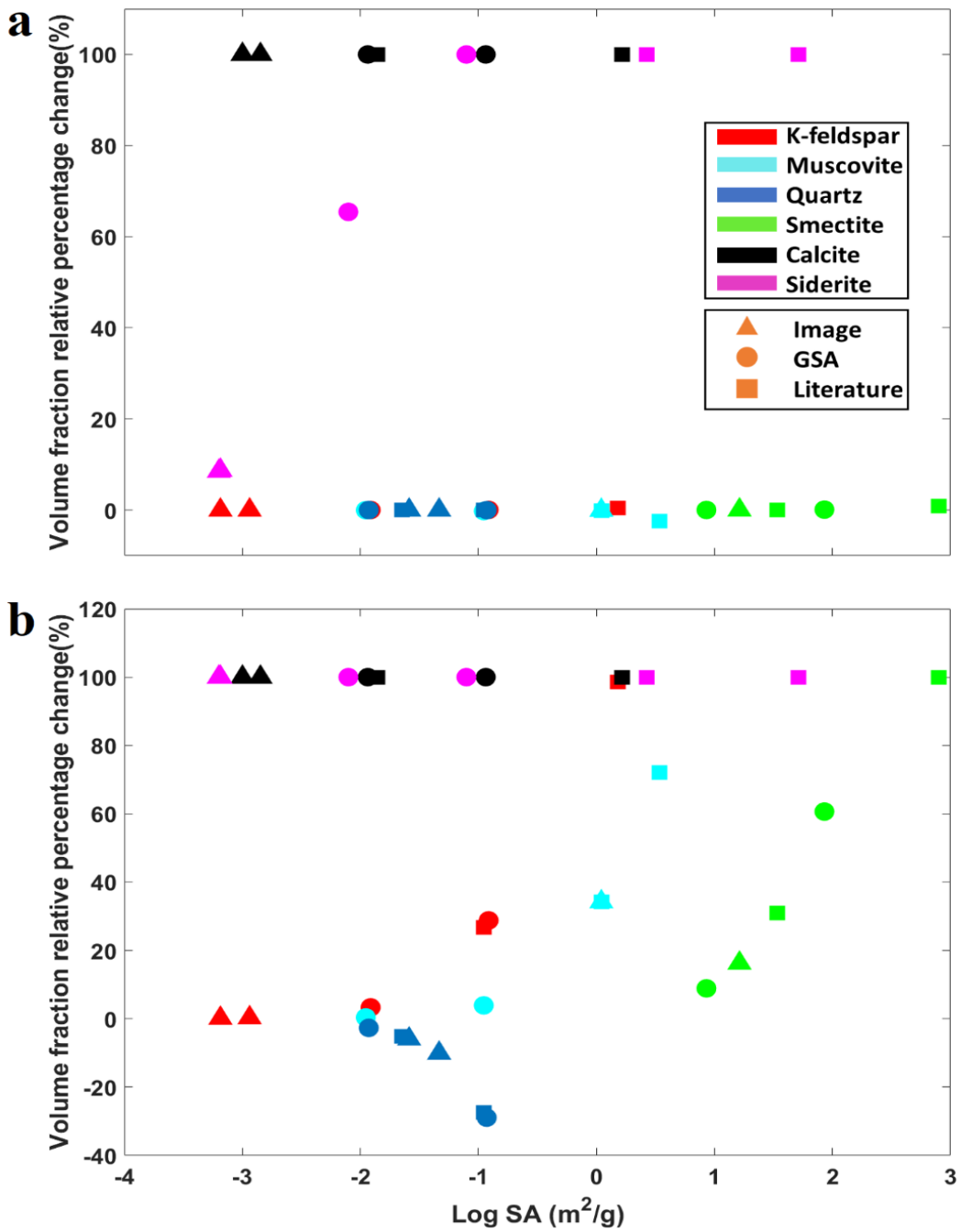
Short term VF

Long term VF





VF change vs. LogSA



Connected porosity