CO_2 storage potential in Basalts

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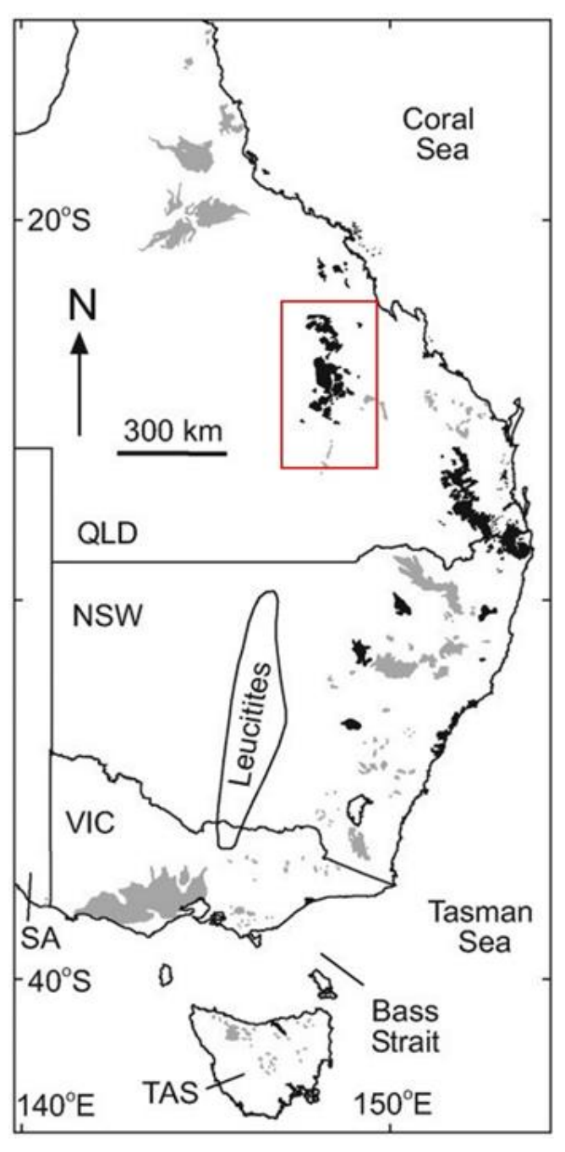
Introduction

- The transition to net zero will require CO_2 capture and geological storage
- Injection of CO_2 emitted from power plants, blue hydrogen or ammonia, cement, steel production, or direct air capture, are stored in depleted formations or aquifers (or used in enhanced oil or gas recovery)
- Generally, CO_2 structurally trapped under a cap-rock of low porosity/permeability at depths of greater than 1 km
- Supercritical CO_2 dissolves in formation water, acidifies, reacts with minerals modifying porosity, permeability and water quality (e.g. pH, metal concentrations)
- Subsequent mineral trapping to form carbonate minerals is the most secure form of storage
- For mineral trapping of CO_2 "dirty rocks" such as basalts with reactive minerals are preferable to clean sandstones to provide Ca, Mg, Fe for minerals trapping as carbonate minerals



- Eastern Australia has extensive basalt deposits – for example the central volcanics, lava fields, coal mine overburden…
- Basalts contain minerals such as olivine that are very favourable for CO_2 reaction and mineral trapping
- This has been demonstrated in the Carbfix field site in Iceland where CO_2 is turned into carbonate minerals within 2 years.
- In shallow formations CO_2 could be injected dissolved in water for a safer storage option to avoid leakage.

Figure 1: Map of the distribution of Cenozoic volcanic rocks in eastern Australia, central volcanos are shown in black and lava fields in grey. The Queensland central volcanics distributed to the north and south of Emerald are highlighted in the red box. Modified after Cohen et al., 2008

Basalt as a CO_2 storage option?

- Basalts in QLD are an excellent opportunity for permanent storage and mineralisation of CO_2
- This could be achieved by supercritical CO_2 or dissolved CO_2 injection or in combination with injection into depleted coals
- Ex situ mineralisation of basalt overburden or waste rock may be another option
- UQ is looking for industry interest to investigate the feasibility of CO_2 storage in basalts

Basalt core examples

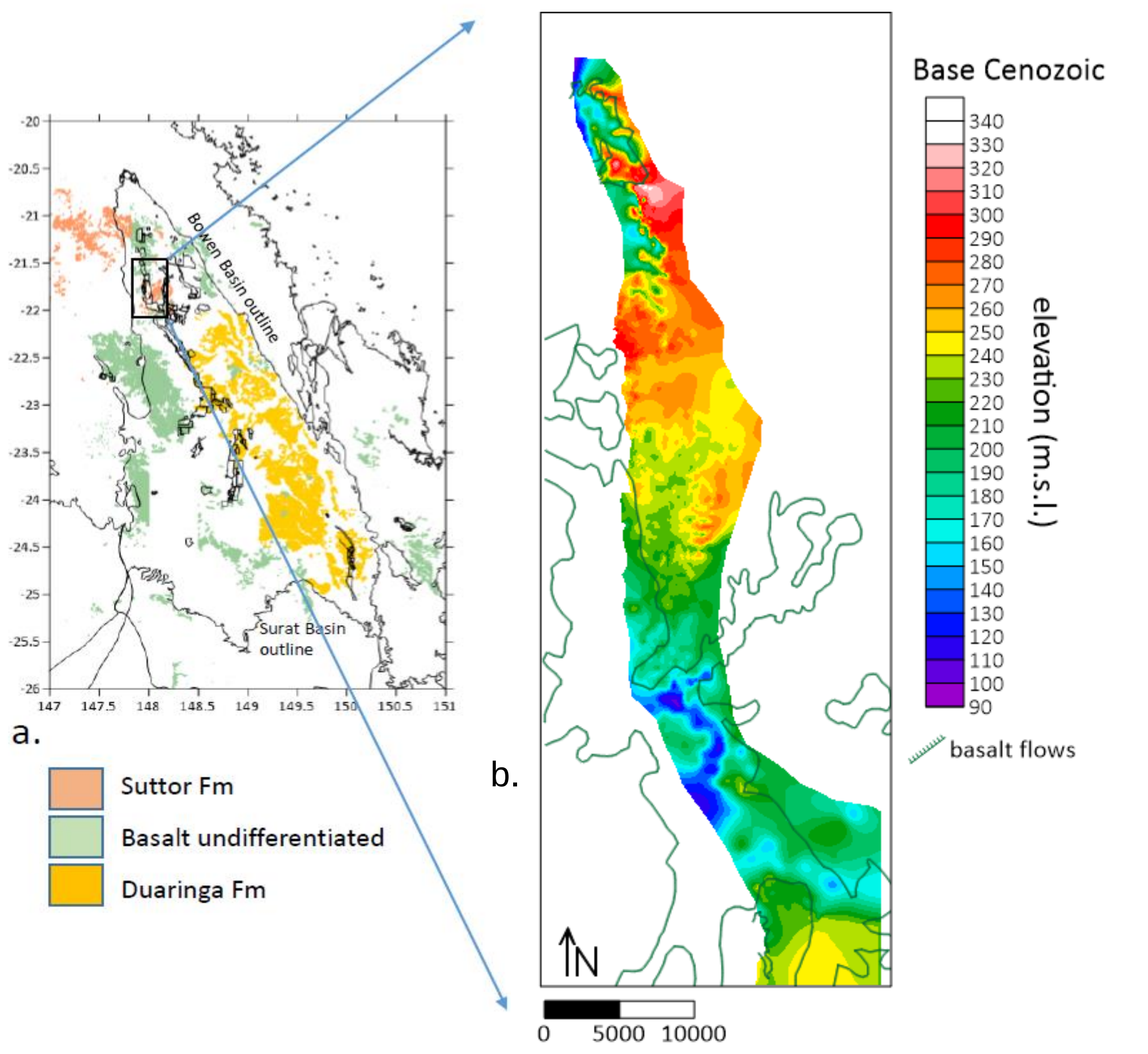
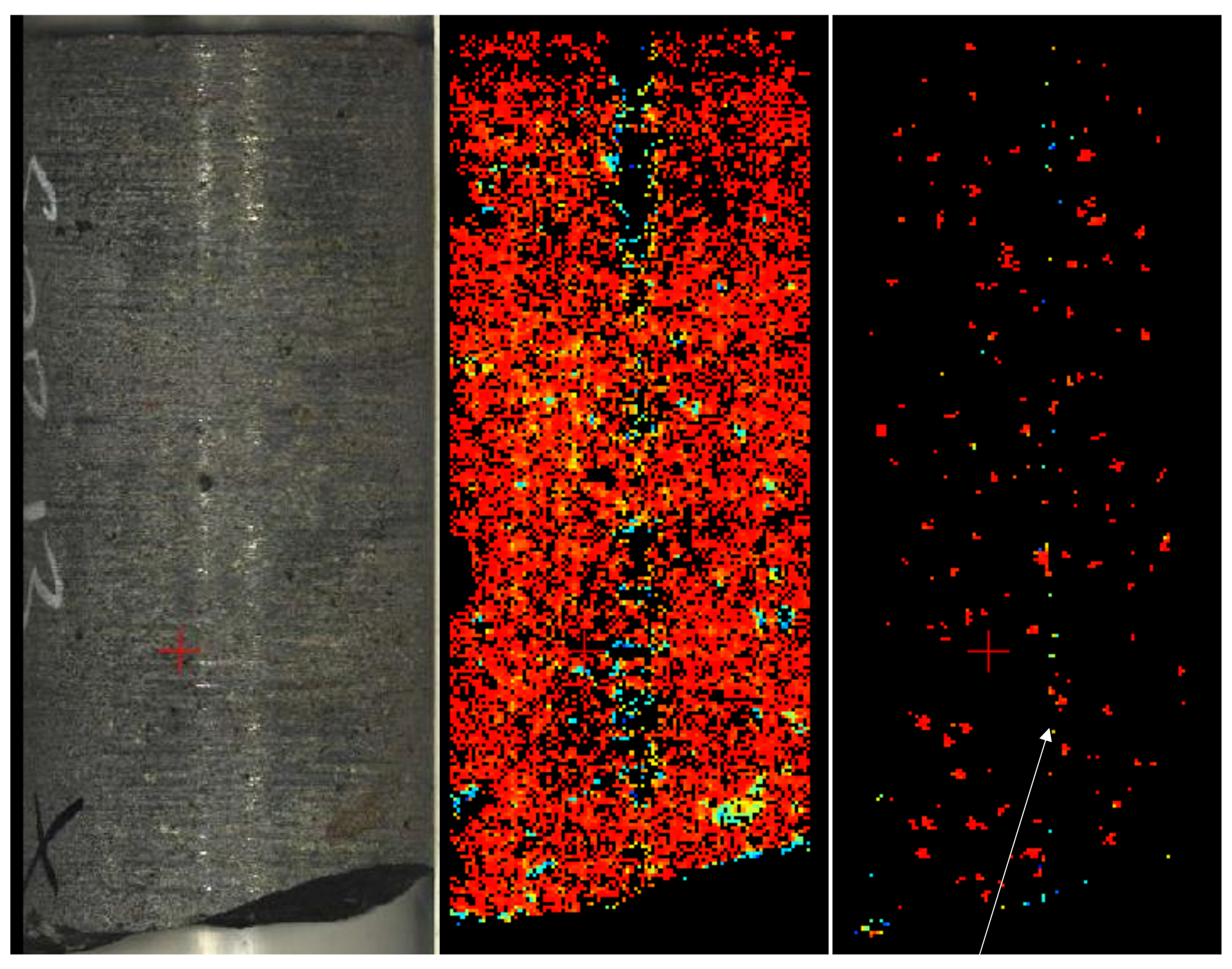


Figure 2: Location maps of surface basalts
a) in central Queensland relative to the Bowen Basin and illustrating the distribution of the Cenozoic basalts, Suttor and Duaringa formations mapped in the GSQ 1:100,000 scale map. Coal MDL's circa 2010 overlain for reference. b) close up map of the elevation of "Base of Tertiary" and mapped basalt flows in Esterle and Sliwa, 2000 that can be used for potential sampling.

Figure 3: Drill cores and Corescan analysis

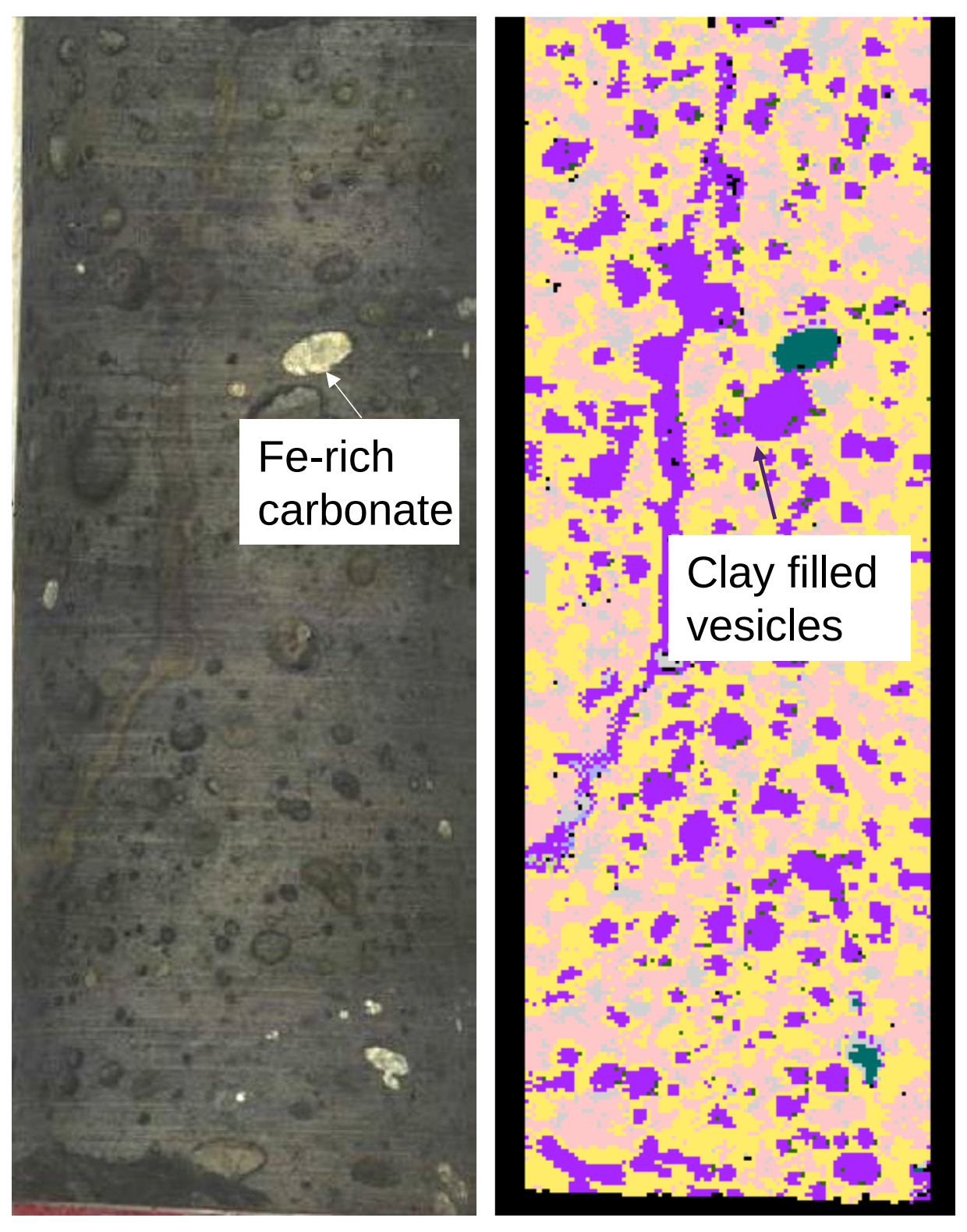
Core photo clinopyroxene Olivine phenocrysts



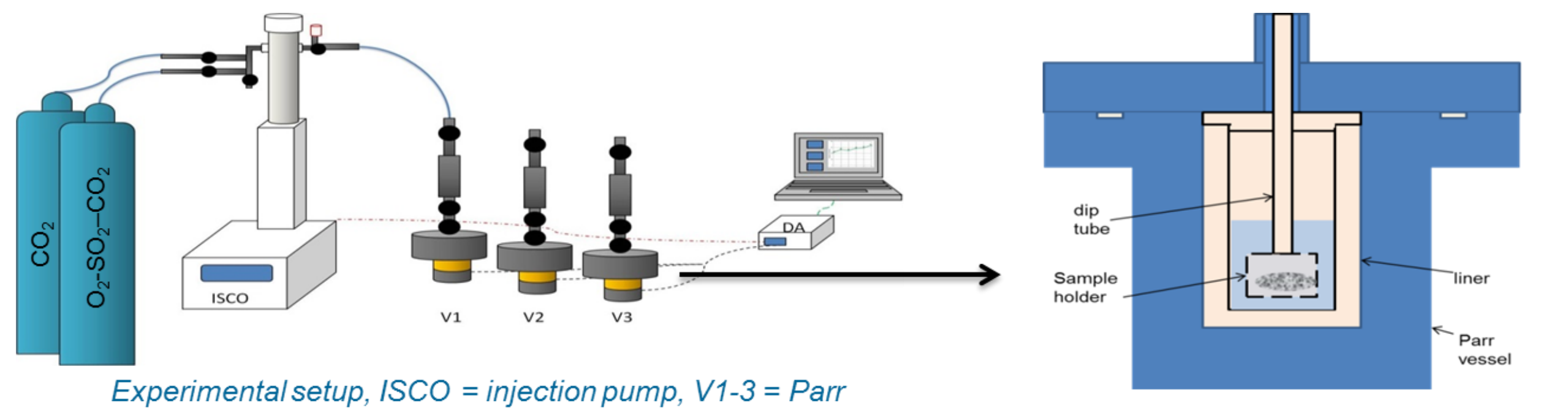
Potential for CO_2 mineral trapping

Core photo vesicular basalt

Hylogger Mineral map



Methods and results



Experimental setup, ISCO = injection pump, V1-3 = Parr vessels, DA = Data aquisition.

Ref: Pearce, J.K. et al., 2015. SO_2 Impurity Impacts on Experimental and Simulated CO_2-Water-Reservoir Rock Reactions at Carbon Storage Conditions. Chemical Geology, 399,65-86.

- Core characterisation: reservoir and seals including:
- Mineral content
- Metal/element content
- Porosity and pore throats
- Petrography
- CO_2-water-rock experimental reactions at reservoir conditions
- Characterisation of changes to minerals and poro-perm
- Characterisation of water quality and chemistry over time
- Geochemical modelling predictions, mineral trapping

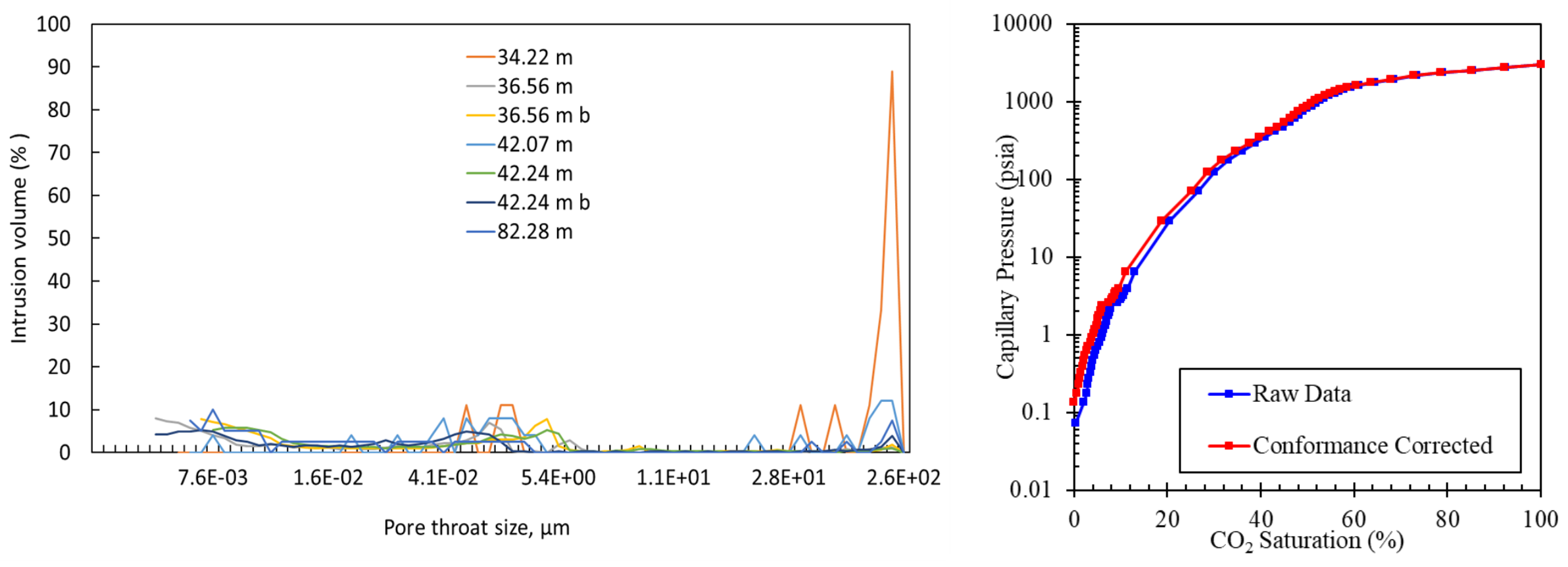
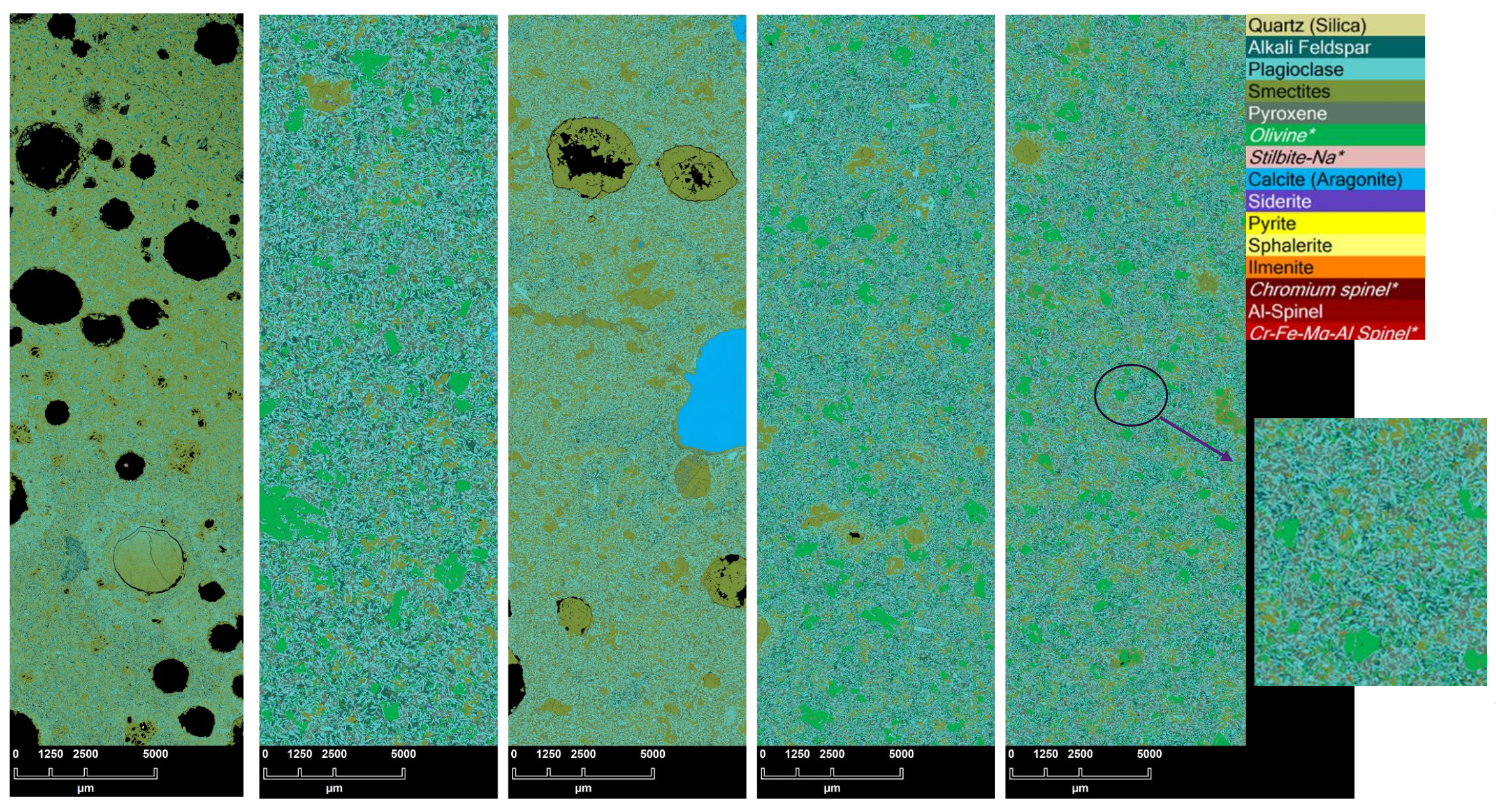


Figure 4: MICP (mercury injection capillary pressure) data examples including basalt pore throat distributions, and a CO_2-water capillary pressure curve.



QEMSCAN mineral components

	34.22	36.56	42.07	82.28
Mineral	(Wt%)	(Wt%)	(Wt%)	(Wt%)
Plagioclase	40.88	38.55	42.82	41.24
Smectites	10.58	40.88	14.46	15.6
Alkali Feldspar	15.88	1.82	14.66	12.83
Pyroxene*	16.48	12.37	13.34	15.03
Olivine*	14.16	0.16	12.91	12.47
Ilmenite	1.7	0.61	1.61	2.66
Quartz (Silica)	0.1	0	0.06	0.03
Cr-Fe-Mg-Al Spinel*	0.01	0.02	0.01	0.01
Stilbite-Na*	0.01	0	0.01	0.01
Chromium spinel*	0	0.01	0.01	0
Calcite (Aragonite)	0.04	4.38	0	0.05
Siderite	0.06	0.24	0.01	0.01
Porosity	0.07	0.97	0.09	0.07
Unclassified	0	0	0	0
Pyrite	0	0	0	0
Sphalerite	0	0	0	0
Al-Spinel	0	0	0	0
	99.97	100.01	99.99	100.01

Figure 5: QEMSCAN images: Left: Example of large vesicles (black). Clays (smectite/chlorite/kaolin) from alteration fill some vesicles. Mineral content in the 4 basalt samples selected for CO_2-water-rock reactions is shown.

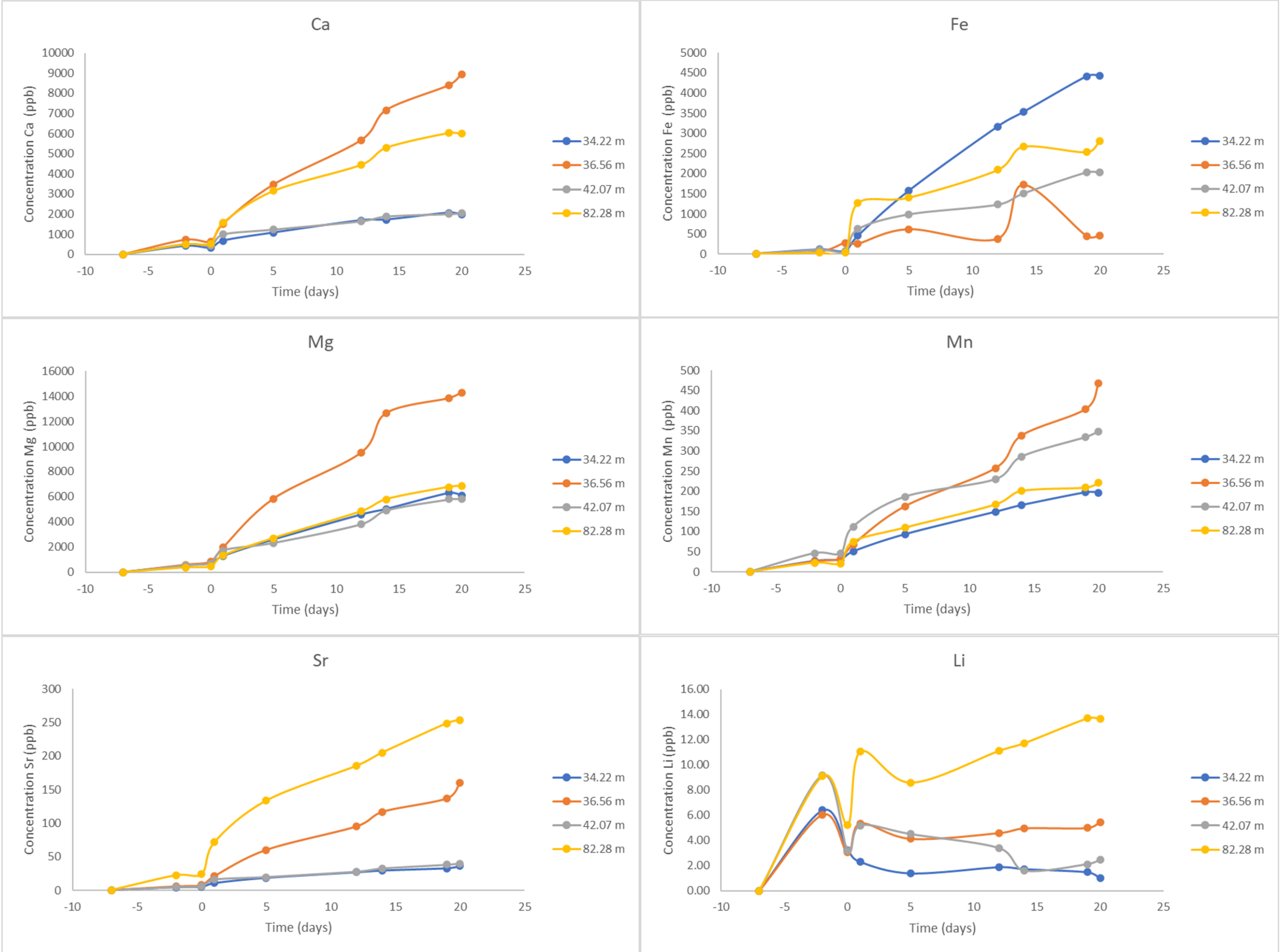


Figure 6: Change in dissolved ions during CO_2-water basalt experimental reactions with different mineralogy cores. Ca, Fe, Mg etc. released to formation water. CO_2 was added at time 0, after which solution pH decreased to ~ 5.

Conclusions

- ➢ Contain reactive minerals including olivine and plagioclase
- ➢ On CO_2 – low salinity water reaction at 40°C, 55 bar mineral dissolution release Ca, Mg, Fe, Mn, Sr, etc. to solution available for mineral trapping
- ➢ Basalts in Eastern Australia have potential as CO_2 storage and mineralisation targets
- ➢ Geochemical changes to reservoir and seal core and formation water from CO_2 reactions are an important element of CO_2 storage fasibility assesments and impact assessments.
- ➢ UQ has demonstrated capability in CO_2 storage applied research
- ➢ Further feasibility studies are needed
- ➢ These basalts also contain critical elements (Li, REE, CU etc.). Up to 50% of REE were acid extracted with weak and strong acid sequential extractions and alternatively could also provide a source of metals.
- ➢ Suggested future work: longer time scale reactions of these basalts and a range of other cores to demonstrate mineral trapping of CO_2

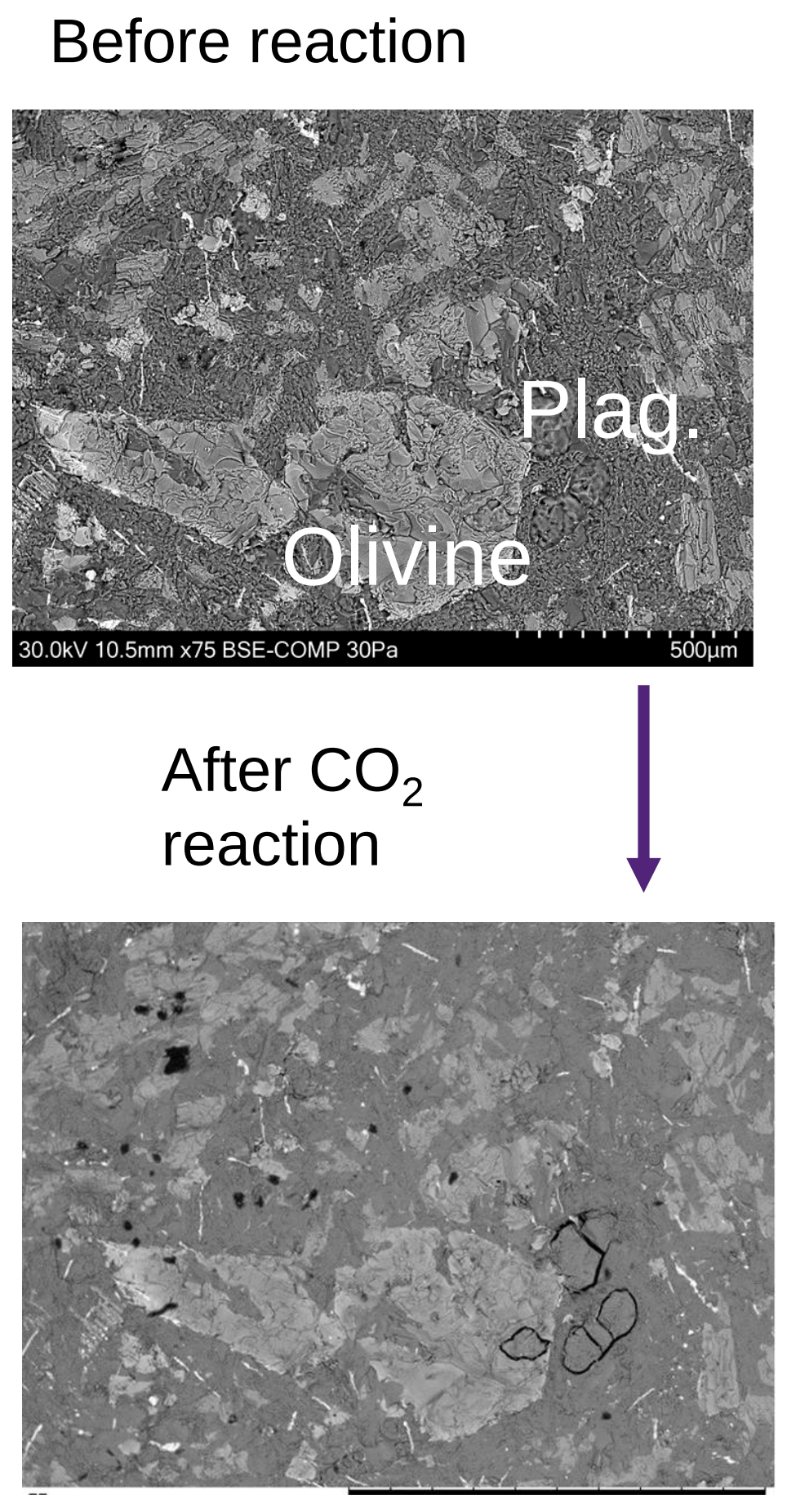


Figure 7: SEM image of a core surface before and after reaction. Showing that olivine was corroded.

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