Effects of nanoparticles on clay stabilisation and coal permeability

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Project Aims

This projects aims to identify potential nanoparticles (NPs) to prevent clay swelling of the smectite clays and investigate their deployment in the coal seam gas reservoirs.
The main activities include 1) screening NPs for clay stabilization, 2) optimizing NPs concentration and evaluating effectiveness and 3) investigate the effects on coal permeability.

Performance of nanoparticles (NP) in distilled water and 4% KCl

Figure 1 shows the images of a visual swelling test.
The swelling index $=\frac{h_f - h_i}{h_f}$, h_i and h_f are the initial and final height, respectively.

Figure 1. Illustration of visual swelling test method

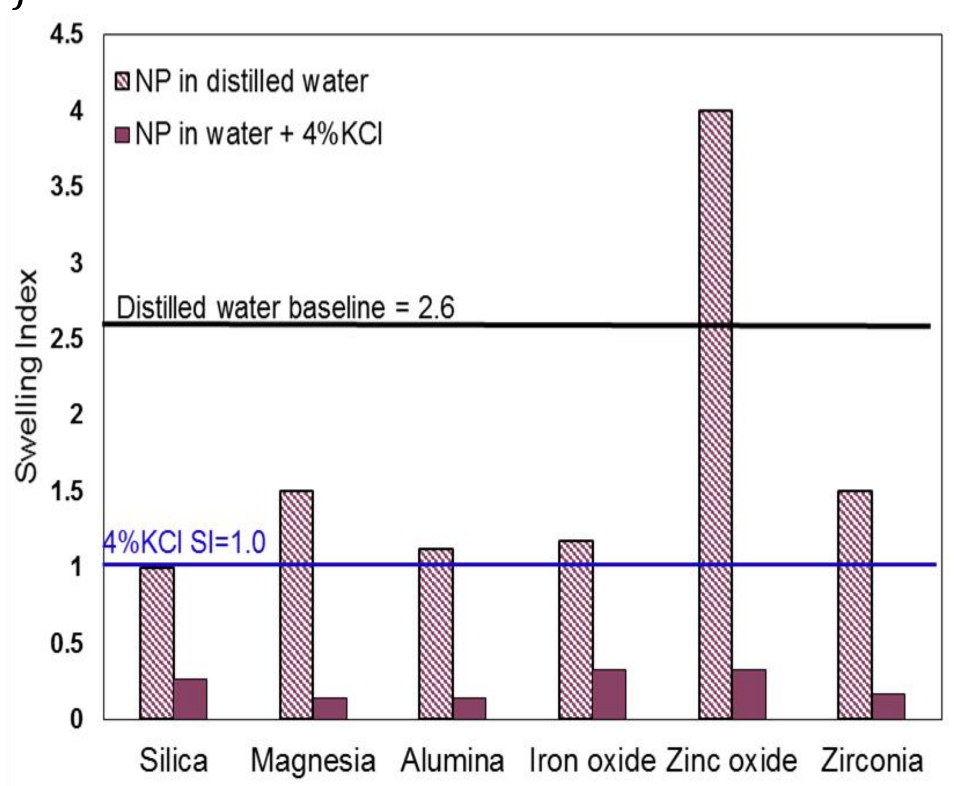

Figure 2. Swelling index of bentonite treated in distilled water and 4% KCl with 1 wt% nanoparticles. The reference lines show swelling index of clay in distilled water and 4% KCl

Figure 2 suggests that except for zinc oxide all of the nanoparticles show potential to prevent clay swelling in distilled water. In the presence of 4% KCl, clay swelling was inhibited with all selected NPs.

Effectiveness of NP after washing

To examine long-term performance of the MgO nanoparticle treatment as a clay stabiliser compared to traditional KCl brine treatments, the solution was decanted and refreshed every 24 hrs for up to 40 times.

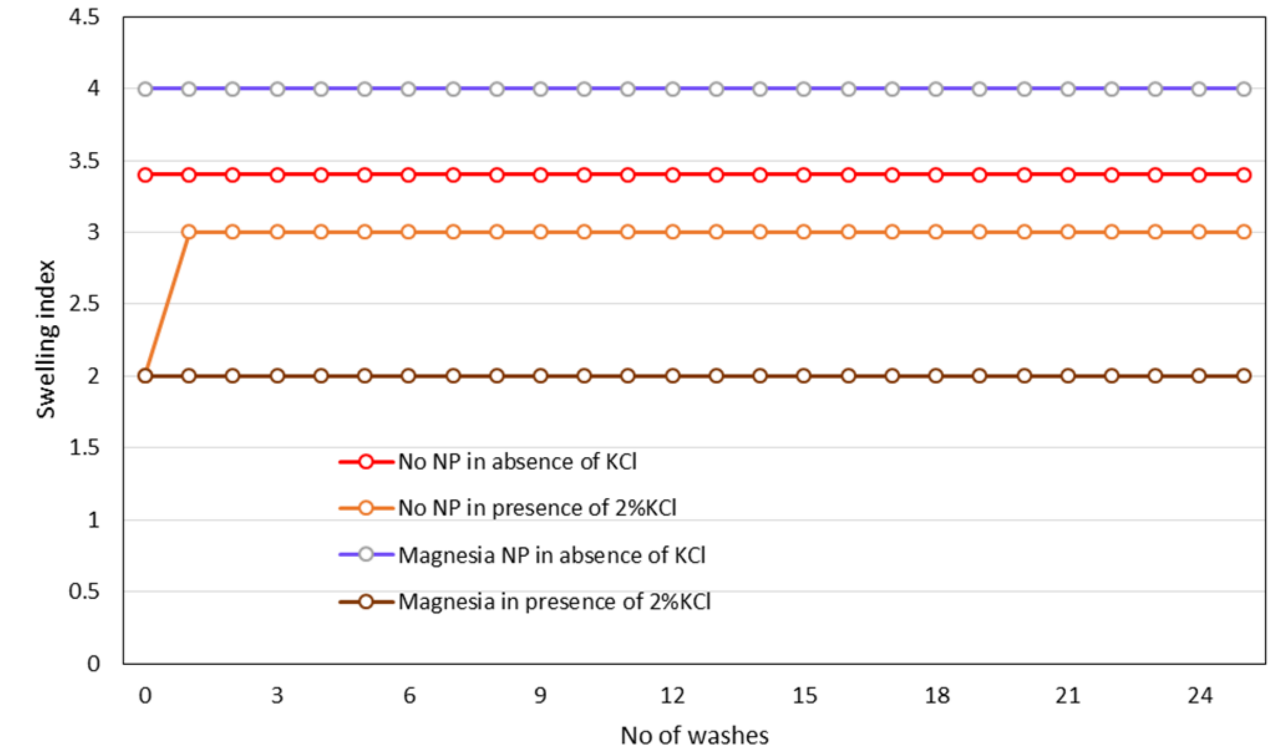

Figure 3. Effectiveness of MgO nanoparticle treatments to prevent bentonite swelling after washing KCl from the sample

Figure 3 shows the longevity of MgO treatment on clay swelling. Among these treatment conditions, the MgO in the presence of 2% KCl can be the most effective treatment, displaying lowest swelling index and stable swelling inhabitancy even after 40 washes.

Effect of NP injection on coal permeability

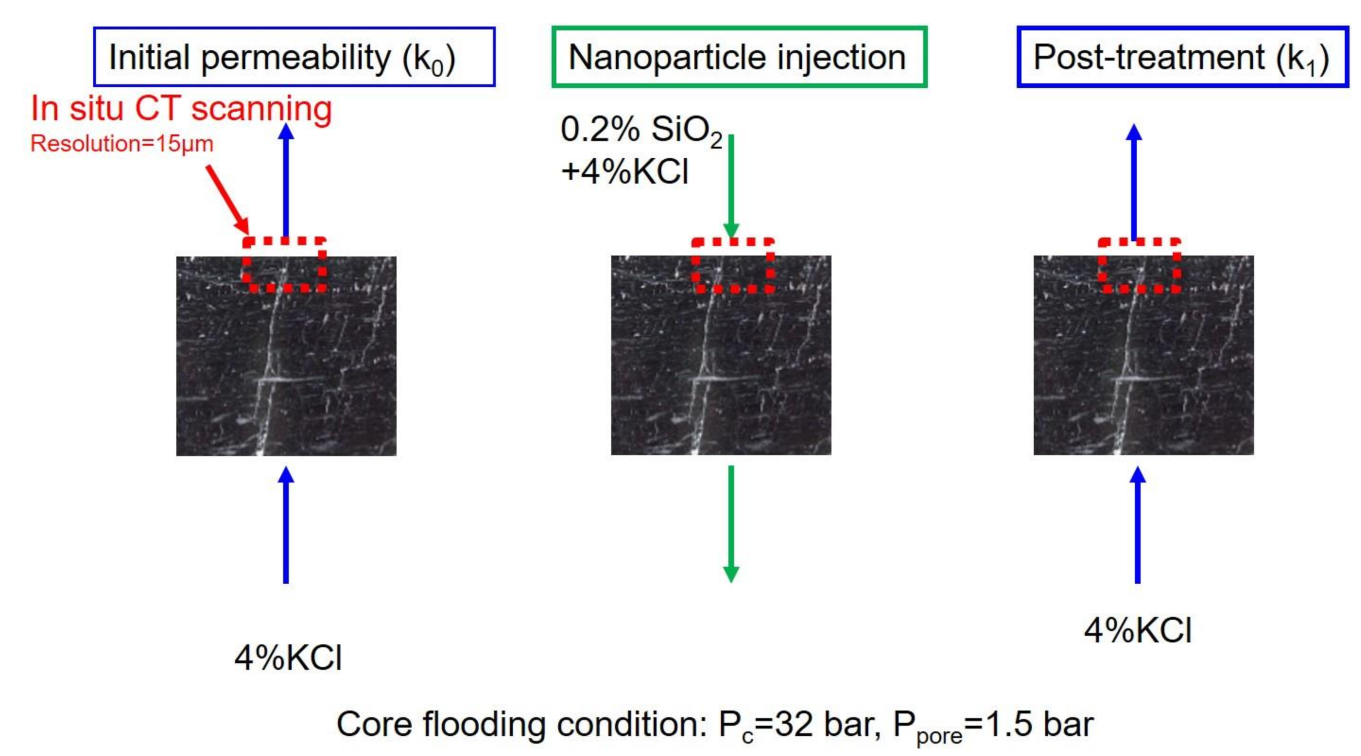

Figure 4. Experimental method of nanoparticle injection and permeability evaluation

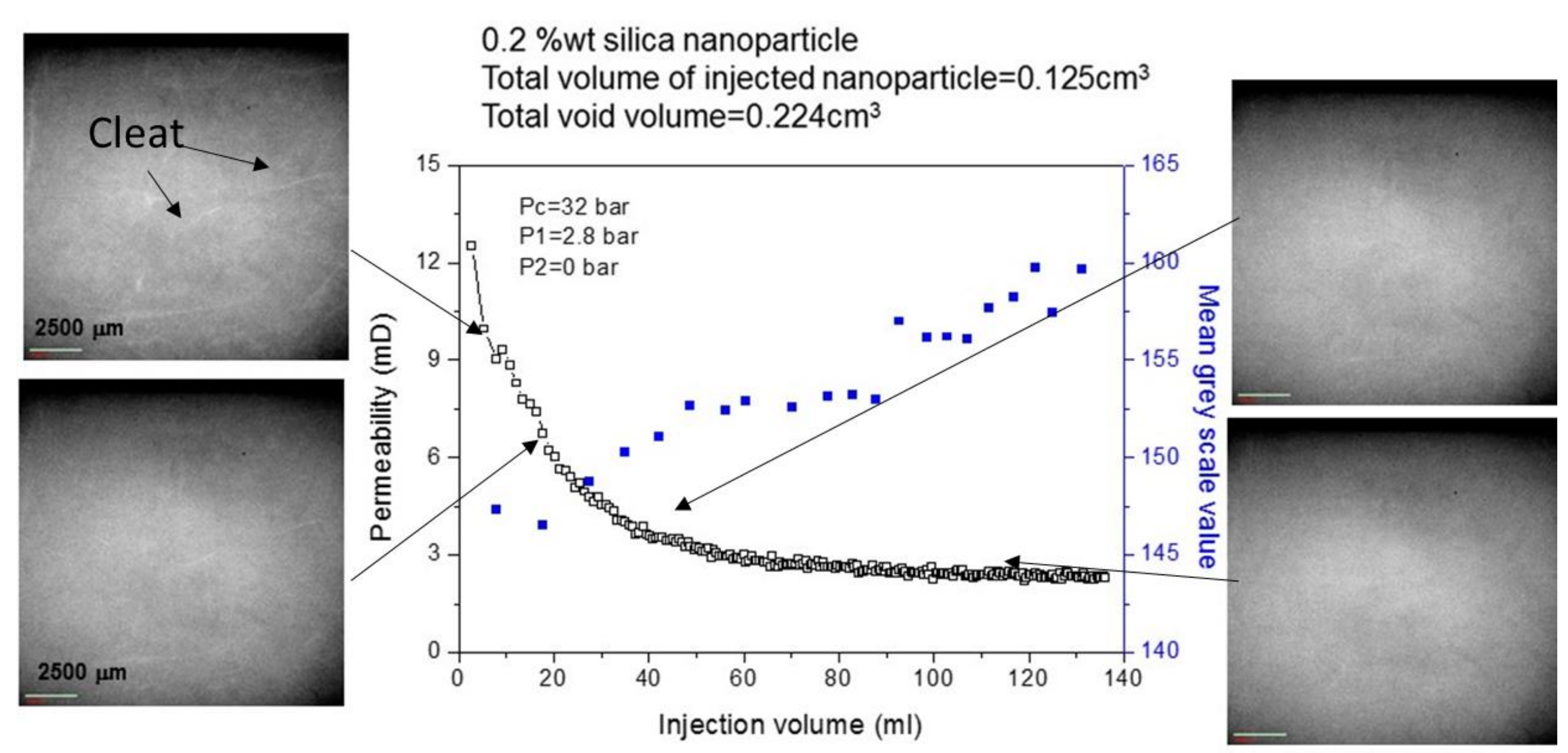

Figure 5. Effect of nanoparticle injection on coal permeability

Initial experiments were also carried out to study the effect of nanoparticle injection on coal permeability at a high nanoparticle injection volume. As indicated by 3D CT segmentation, the cleat/fracture fraction reduced from 0.88% to 0.02%.

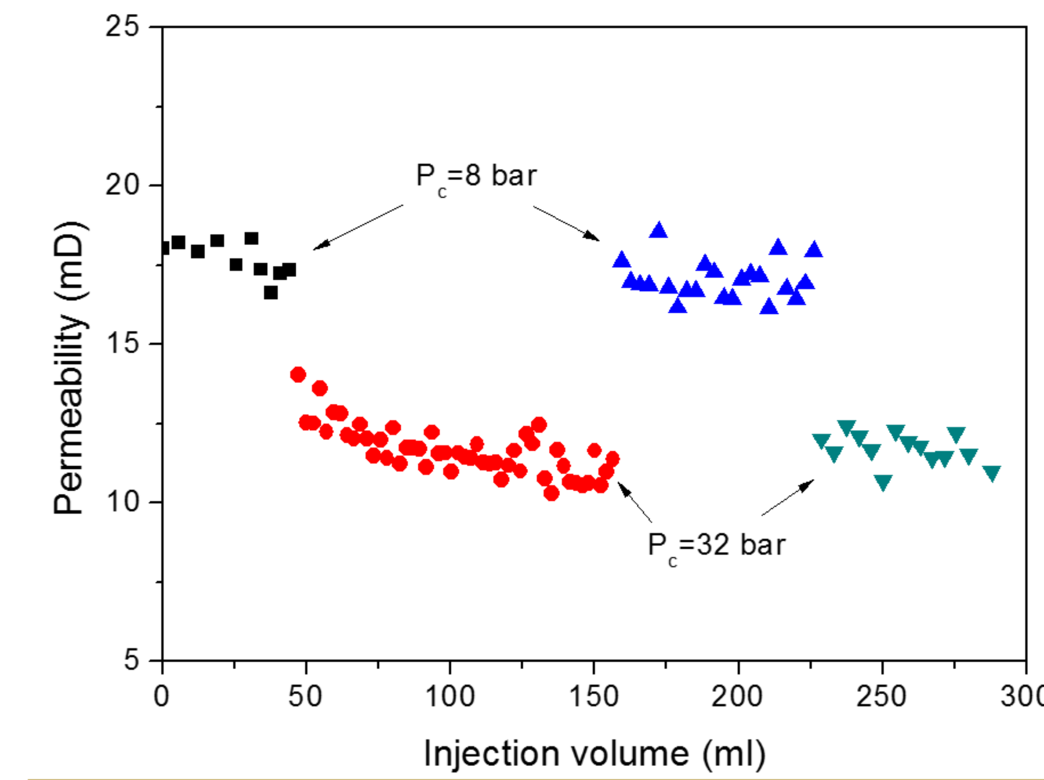

Figure 6. Recovery of permeability after de-stress and flush

3D CT images in Figure 6 represent blockage of cleats and reduce cleat/fracture volume. However, the permeability can be recovered back to initial permeability after de-stress and flush as shown in Figure 6. In future work, to mitigate the impact on coal permeability, the NPs size, injection amount and dispersion will be optimised. The NPs deployment methods will also be considered.

Conclusions

- SiO_2 and MgO nanoparticles show potential to prevent clay swelling in formation water in the absence and presence of KCl.
- The effects of nanoparticle on coal permeability have been examined by in-situ CT core flooding, observing permeability and cleat/fracture change with nanoparticle injection.
- Future work will focus on optimising nanoparticle injection conditions to minimise the permeability drop in the coal. The NPs transportation mode will also be investigated under different stress conditions.

Acknowledgements

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