Nanoparticles with potential to stabilise smectite clays in coal seam gas reservoirs

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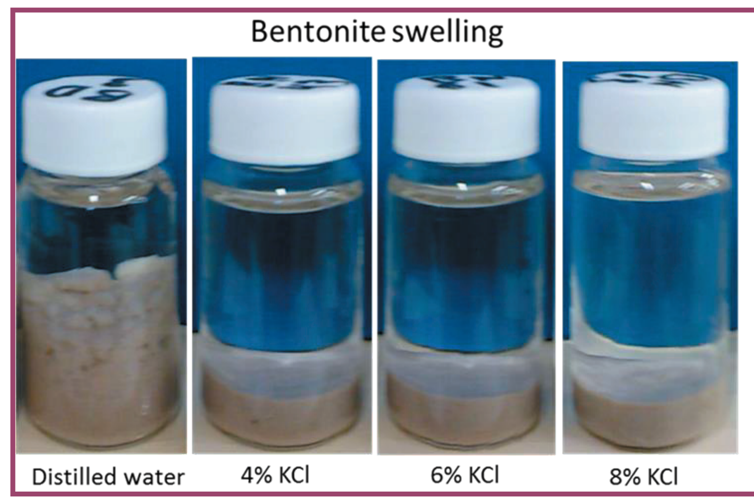
Project background and objective

Clay swelling in CSG wells leads to production of fines which decreases pump performance and increases operational cost of the well. Production of fines also reduces gas permeability in CSG reservoirs.

This projects aims to identify potential nanoparticles to prevent clay swelling of the smectite clays and investigate their deployment in the coal seam gas reservoirs.

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

Six nanoparticles were screened for clay swelling inhibition via a visual swelling test as shown in Figure 1. The swelling index of the clay was calculated as shown in the equation.



$$Swelling\ index = \frac{h_f - h_i}{h_i}$$

$$Where, h_f = final\ height$$

$$h_i = initial\ height$$

Figure 1: Illustration of visual swelling test method and swelling index calculation equation

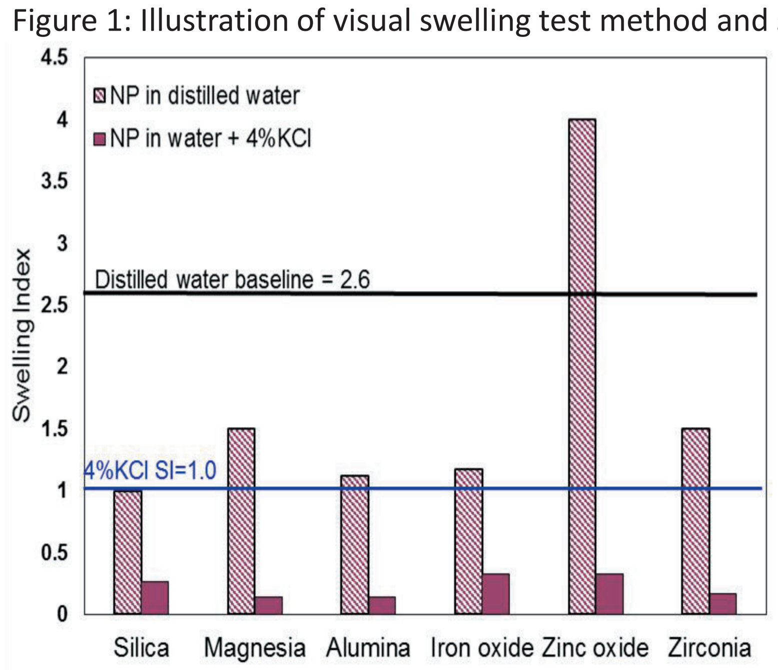


Figure 2: Swelling index of bentonite treated in distilled water and 4% KCl with 1 wt% nanoparticles. The reference lines show swelling index of clay in distilled water and 4% KCl

The performance of 1% by wt. nanoparticles in distilled water and 4% KCl is shown in Figure 2. Results suggest 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.

It is not clear if the clay swelling inhibition found was due to the effect of KCl or the NPs when in the 4% KCl solution.

Effect NP concentration on swelling index

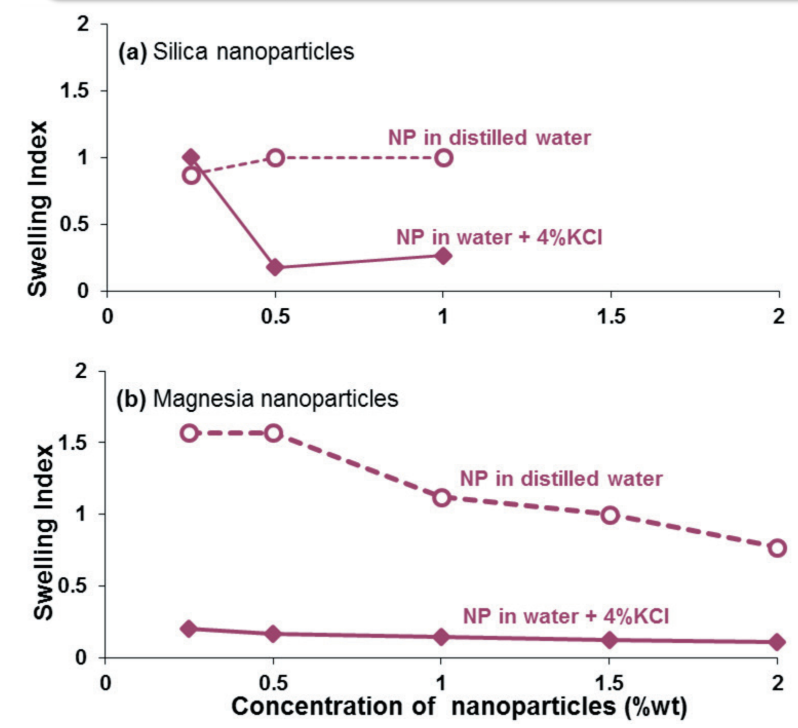


Figure 3: Effect of silica and magnesia nanoparticle concentration on swelling index of clay

The effect of SiO_2 and MgO concentration on clay swelling inhibition for bentonite clay was also studied in distilled water and in 4% KCl. The swelling index of the bentonite decreased with increases in the NP concentration until 1 wt%, beyond that negligible change in swelling index was observed for both NPs as shown as Figure 3.

Performance of NPs in model formation water

To mimic reservoir conditions, using published data, model formation water was prepared at pH 5 and 9 with salt concentration of 2500 mg/L and 9000 mg/L. SiO_2 shows potential to prevent clay swelling in formation water in the absence of KCl (Figure 4).

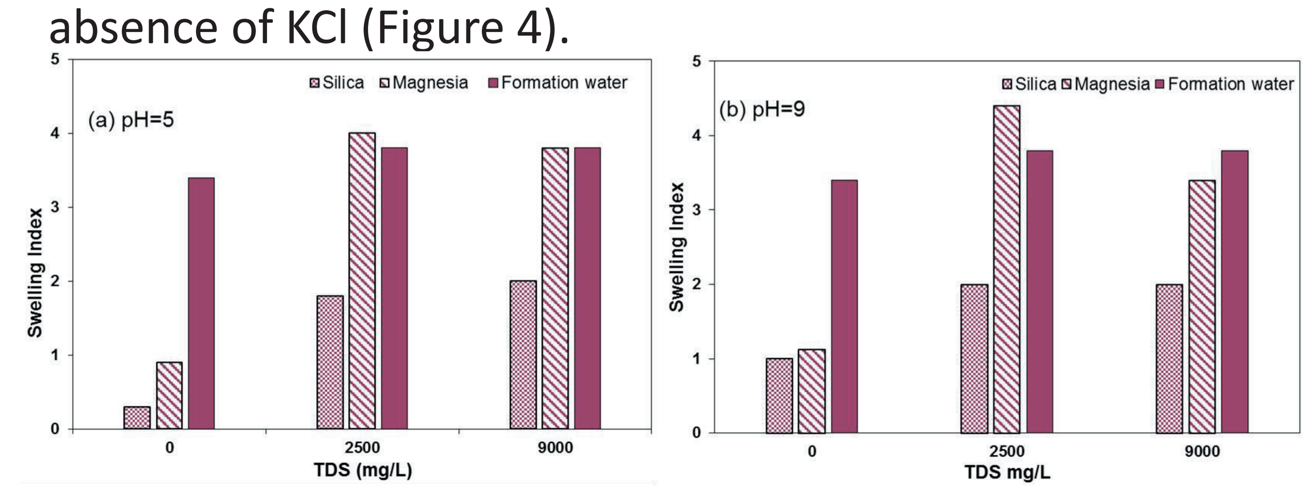


Figure 4: Swelling index of bentonite treated in model formation water with 1 wt % SiO_2 and MgO nanoparticles.

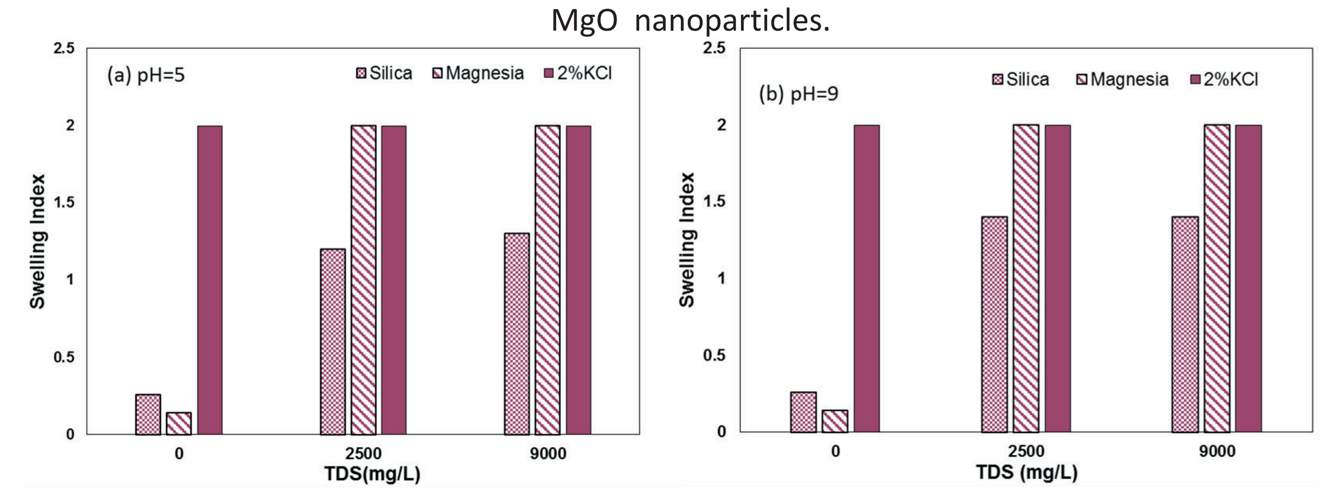


Figure 5: Swelling index of bentonite treated in model formation water in the presence of 2 % KCl with 1 wt% SiO_2 and MgO nanoparticles.

Effect of NP injection on coal permeability

The initial experiments were also carried out to study the effect of nanoparticle injection on coal permeability. The coal sample was from the low permeability region.

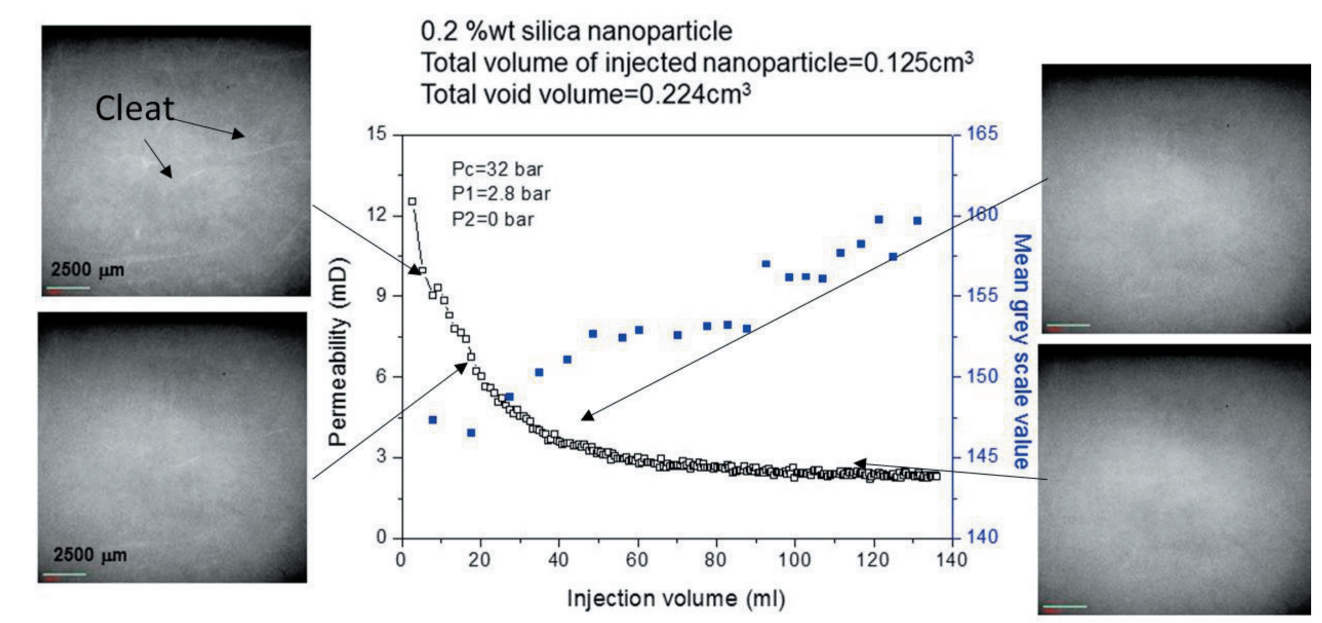


Figure 6: Effect of nanoparticle injection on coal permeability

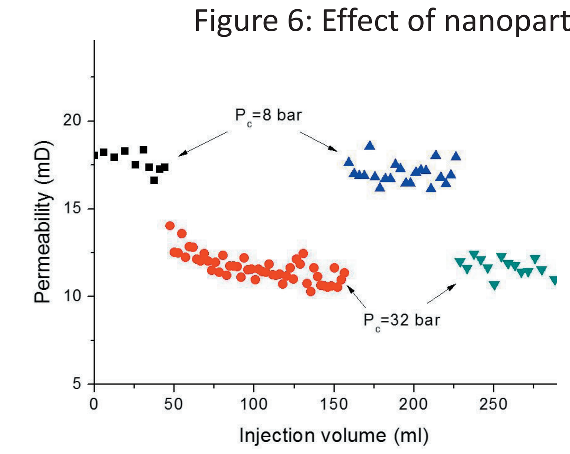


Figure 7: Recovery of permeability after de-stress and flush

As shown in Figure 6, coal permeability decreased after injection of SiO_2 dispersed in 4% KCl but it was recovered back to initial permeability after de-stress and flush as shown in Figure 7. CT scan images represent blockage of cleats.

Conclusion

- SiO_2 nanoparticles show potential to prevent clay swelling in formation water in the absence and presence of KCl
- Clay swelling is not inhibited when treated with MgO NP in the formation water but in the presence of KCl, swelling index decreased.
- Attraction forces of the nanoparticles could be responsible for clay swelling inhibition.
- Permeability decreased when NP was injected but recovered back after de-stress and flush.

Acknowledgements

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