

# THE EFFECT OF CHANGING THE SALINITY OF THE GROUNDWATER ON SIP OF SANDSTONES

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## Abstract

Previous work between the University of Birmingham and Technical University Clausthal examined the basic shape of the complex conductivity spectra of sandstones saturated with a synthetic groundwater solution and compared the two different laboratory measurement procedures. It is known that the Spectral Induced Polarisation (SIP) is also dependent upon the pore fluid so we examined the effect of two different salinity groundwaters on the SIP response. The changes caused by decreasing the salinity of the groundwater varied widely for different sandstones with both increasing and decreasing phase angles recorded along with some changes in the shape of the spectra. We are now continuing to make multiple salinity measurements with a variety of cations in order to better quantify these changes.

## Introduction

The Spectral Induced Polarisation (SIP) method provides a vast amount of information on sandstones. However, the information is only just beginning to be understood and is providing some very promising results for future investigations into aquifer sandstones. These results could give useful information on pore size and surface area (Scott & Barker, 2004). SIP could also give a lithological ‘fingerprint’ for a sandstone. Previously the measurement systems of the University of Birmingham and TU Clausthal were compared and found to produce similar results (Scott et al., 2003). It is known that the SIP results are dependent on the pore fluid and particularly on the different cation species and the concentration. For initial experiments with changing the pore fluid two different strength brines were chosen. These include a high salinity synthetic groundwater used previously by Scott et al. (2003) and the lower salinity Clausthal tap water, at about 0.1 times the ionic concentration (Table 1).

**Table 1.:** Cation concentrations for the low and high salinity brines

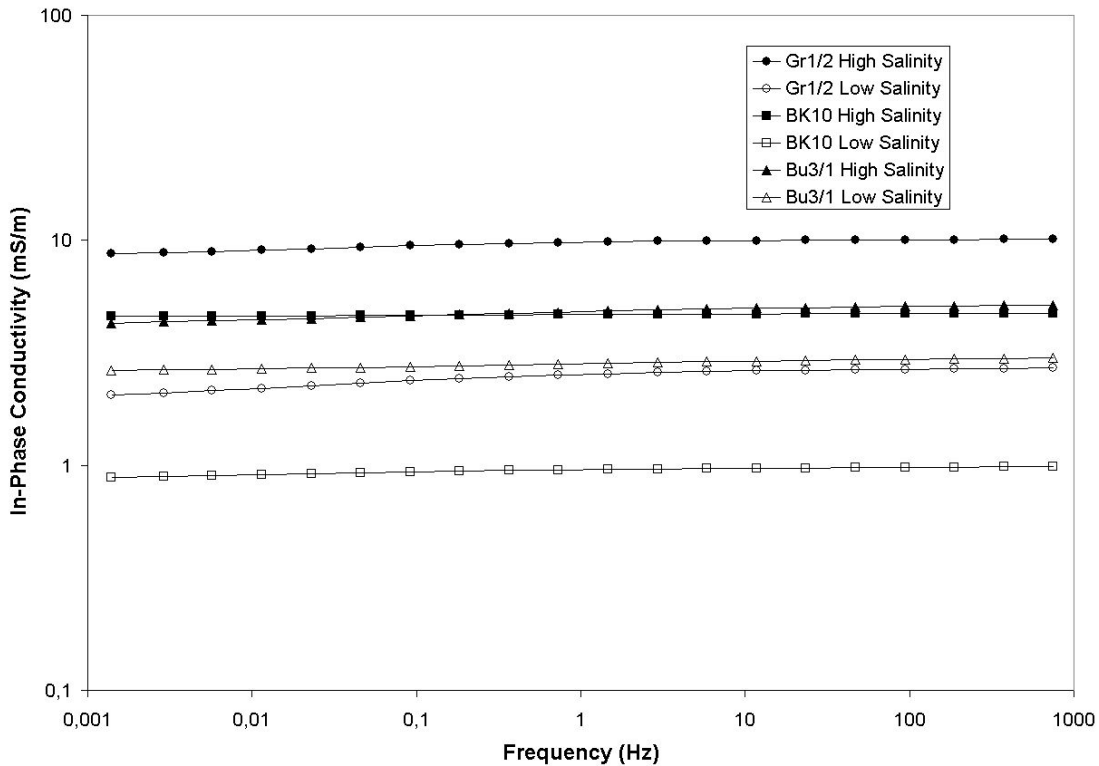
	Ca <sup>2+</sup> (mg/l)	Mg <sup>2+</sup> (mg/l)	Na <sup>+</sup> (mg/l)	Zn <sup>2+</sup> (mg/l)	Sr <sup>2+</sup> (mg/l)	Fe <sup>3+</sup> (mg/l)	$\sigma$ (mS/m) 20 °C
<b>LOW SALINITY (CLAUSTHAL TAP WATER)</b>	6.61	2.56	6.38	0.10	0.03	0.10	≈ 10
<b>HIGH SALINITY (BIRMINGHAM SYNTHETIC GROUNDWATER)</b>	60	30	34	0	0	0	≈ 67

## Results

The SIP results for three samples of sandstone, a cretaceous greensand (Gr1/2), a UK Triassic Sherwood Sandstone (BK10) and a German Bunter Sandstone (Bu3/1), saturated with the two different strength brines are displayed in Figures 1, 2 & 3.

The phase spectra (Figure 3) are often used to examine the frequency dependence of the polarisation. It can be seen that decreasing the salinity over this range can cause the phase angle to either decrease or increase, depending on the sandstone. A maximum phase angle would be expected to occur somewhere around this salinity range from previous IP investigations at a single frequency (Flath, 1989, Lesmes & Frye, 2001). The quadrature conductivity spectra (Figure 2) are the same shape as the phase spectra but are considered to be a better indication of the polarisation strength of the sandstone. The quadrature conductivity and hence the polarisation strength decreases with decreasing salinity for all of our samples over this salinity range. The in-phase conductivity (Figure 1) is closely linked to the conductivity of the pore fluid and the change in the ratio of in-phase conductivity to pore fluid conductivity can be used to give an apparent formation factor, however, this varies with salinity at these low salinities for shaly sandstones.

Sandstones with low polarisation and a relatively flat phase/quadrature spectrum such as BK10 (Figures 2 & 3) were sometimes seen to develop a peak in the spectrum when the salinity was reduced. For some samples the position of the peak in the phase/quadrature spectrum does not change with the reducing salinity (Figures 2 & 3) but in other samples there is a notable change in the position of the peak, for example Bu3/1 (Figures 2& 3).



**Figure 1.:** In-phase conductivity spectra at 20 °C.

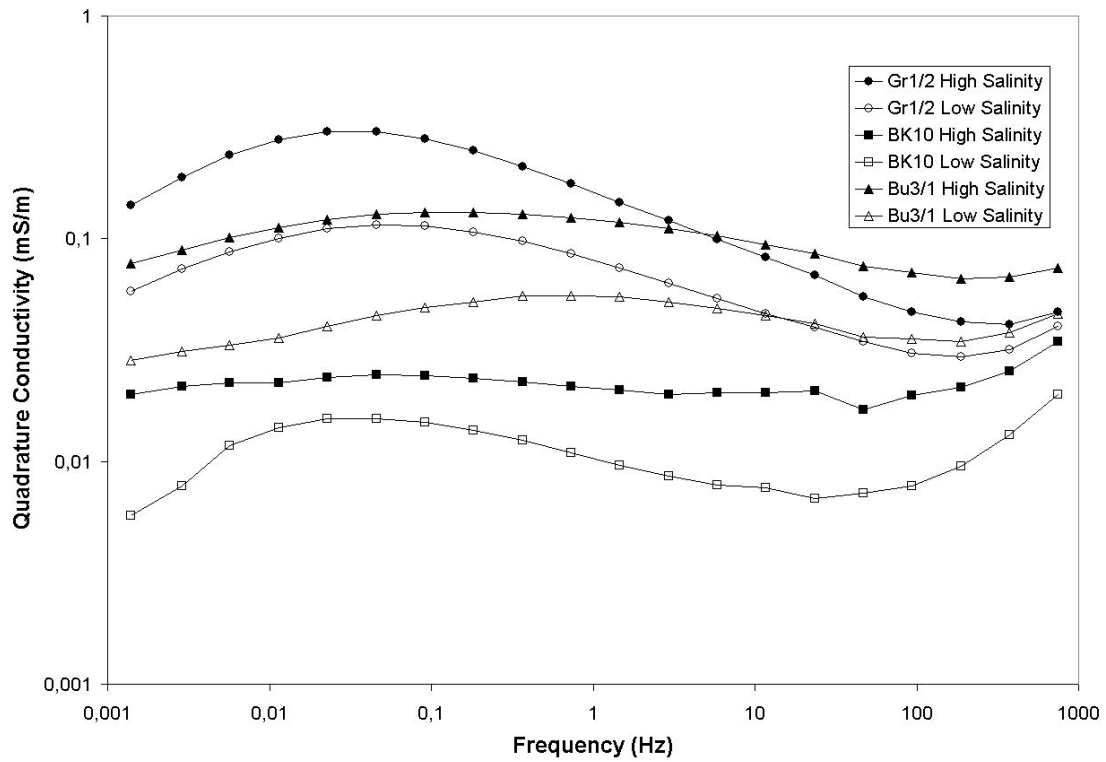


Figure 2.: Quadrature conductivity spectra at 20 °C.

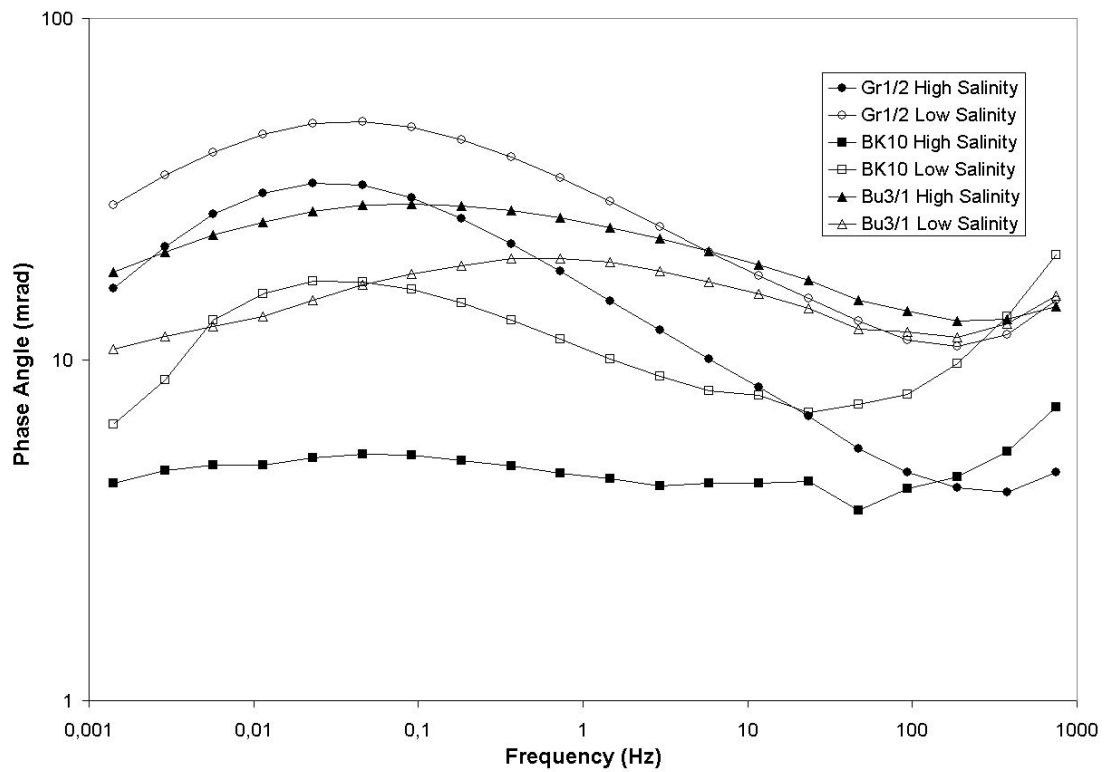


Figure 3.: Phase spectra at 20 °C.

## Discussion

The polarisation is a pore surface phenomena in the sandstone so the effect of different ions and concentrations on the pore surface is important. The pore surface - pore fluid interactions can be complicated and the reasons for the observed changes in the spectra are still unclear. For example whether the changing shape of the spectra can be due to changes in the pore surface coatings of the sandstone, such as the clays, or just that different ions are present at the surface as the pore fluid strength and ionic composition is changed. The shifting of the peak to higher frequencies with reducing salinity for sample Bu3/1 suggests a faster electrical relaxation is occurring and the reason for this could potentially be an increase in a more loosely bound ion like  $\text{Na}^+$  at the pore surface but this needs much more investigation and the next step will be to make comprehensive multiple salinity measurements with a variety of different ions on a number of samples. By just using a single type of cation and anion for each measurement the interpretation should become clearer. Interesting results such as the relative ionic mobilities at the pore surface could be determined.

## Conclusions

We have investigated the effect of changing the synthetic groundwater salinity by a factor of around 10. The spectra change in several different ways for the different sandstones. The quadrature conductivity generally increases with increasing salinity over this salinity range but the phase angle can decrease or increase depending on the sandstone. Further multiple salinity investigations for a variety of different ions are now being made in order for a full quantification and interpretation of the results obtained to date.

## References

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