

# Secular variation in the $^{87}\text{Sr}/^{86}\text{Sr}$ composition of groundwater, Stampriet artesian aquifer, Namibia

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Understanding natural controls on water chemistry in aquifer systems is important for assessing anthropogenic impact on groundwater, both for the prediction of such impact and for remediation. The Stampriet aquifer has well-correlated geochemical trends characterized by alkalinity and pH, major and trace element geochemistry, oxygen isotopes and some radionuclide tracers. The strong evidence of a climate signal in this aquifer based on atmospheric noble gas concentrations and oxygen isotopes (Stute and Talma, 1997), along with  $^{14}\text{C}$  age determinations and the extensive chemistry available on these samples, makes it an ideal natural laboratory for studying the effects of climate change on aquifer chemistry. Because of the wide natural variability in  $^{87}\text{Sr}/^{86}\text{Sr}$ , related to age and Rb/Sr of the rock sources, as well as the high solubility of Sr in water, the Sr isotope system is a sensitive tracer of solute processes and pathways. We have analysed the Sr isotope composition of 20 water samples collected from wells along the flow path, as well as 4 rock samples (aquifer and confining beds), to help constrain the sources of Sr to the aquifer.

Deep confined aquifers can contain water that has been isolated from the atmosphere for long periods of time, and thus can be important archives of palaeoenvironmental information. Water samples from the Stampriet Auob aquifer in Namibia range in age from modern to approximately 45 ka ( $^{14}\text{C}$ , uncorrected). A well-defined transition in noble gas-based temperatures from this aquifer that indicate a  $5^\circ\text{C}$  lower ground temperature during glacial times has been previously demonstrated (Stute and Talma, 1997). Oxygen isotopes from these same water samples further imply significant changes in the moisture regime of this region, consistent with previous regional studies of palaeoclimate (Lancaster, 1989; Vogel, 1989).

## Sampling and results

The Stampriet aquifer is located in the southeastern part of Namibia. It has a relatively small recharge area where the annual mean precipitation is about 300 mm. It is an important aquifer as many of the wells are artesian and thus are important to agriculture in this semi-arid region. The  $^{87}\text{Sr}/^{86}\text{Sr}$  of 20 water samples collected from wells along the flow path ranges from 0.71583 to 0.72627. Additionally, there is a strong correlation between the  $^{87}\text{Sr}/^{86}\text{Sr}$  and the Sr concentration of the water samples, with glacial age samples showing lower values of both (Fig. 1). The  $^{87}\text{Sr}/^{86}\text{Sr}$  of four rocks from the region are generally more radiogenic than the water samples, from 0.724280 to 0.738999, with only one rock sample overlapping the water data (Fig. 2).

## Discussion

Possible sources of Sr to the aquifer include rainwater, dry precipitation, reactions with the aquifer rock, and/or mixing with another water source ('leaking' into the confined aquifer). Mixing with another water source is unlikely, as there is evidence from noble gas data and the consistent  $^{14}\text{C}$  data that the water has not been contaminated or exposed to the atmosphere after entering the confined aquifer. Two factors strongly argue against progressive water rock interaction as a mechanism for developing the Sr systematics of the waters: 1) *decreasing* Sr concentrations as the waters age, and 2) the greater difference between the Sr isotope composition of the older samples relative to the host aquifer. There is evidence of water/rock or, more likely, water/soil interaction. Ca and Na concentrations show a very strong inverse linear trend, with Na increasing with water age and Ca decreasing

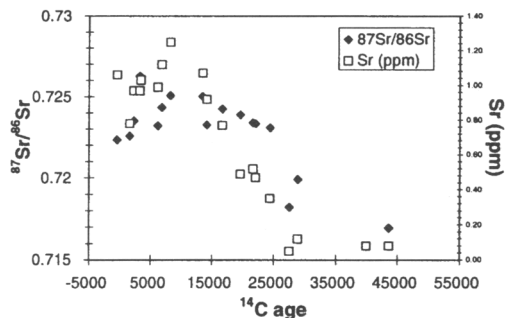


FIG. 1.

consistent with ion exchange processes. The concentration trend for Sr is more complicated, suggesting a different source or process than for Ca.

An interpretation consistent with the data relates to residence time of Sr in the soil, or how long the Sr is 'stored' before being mobilized into the aquifer. In this scenario, wet conditions during glacial times would lead to a shorter residence time in the soil and a greater flushing effect, and thus lower concentrations of Sr with more of the rainwater signal preserved. This is consistent with other palaeoclimate evidence that this region experienced humid conditions in the glacial, such as speleothem formation (Vogel, 1989). In contrast, dry conditions lengthen the residence time in the soil zone resulting in a relative increase in Sr concentrations in the groundwater.

A second influence on the Sr isotope composition, especially in the lower concentration glacial samples, is wind direction and thus changing dust sources and/or sea salt aerosols transported to the region. Dry precipitation could be a major source of Sr in the groundwaters considering the Stampriet is a predominantly quartz sandstone aquifer. Present day precipitation originates from the Indian Ocean, resulting in a large continental isotope effect on the  $\delta^{18}\text{O}$  of rainfall in this area, while a change to a

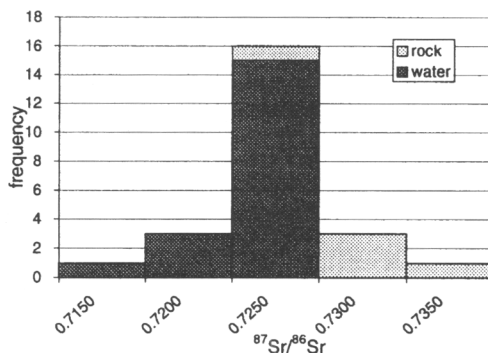


FIG. 1.

western wind source would result in less of a continental effect.

### Conclusion

The Sr isotopic composition and concentration of groundwater is usually thought to be the result of water-rock interaction along the flow-path. There is strong evidence in the Stampriet aquifer of Namibia that this cannot be the case. Instead, Sr systematics of these groundwaters are controlled predominantly by dust and aerosol transport to the recharge area, and/or Sr residence times in the soil zone of the recharge area. In any case, climate (rainfall, wind direction) must have a large influence on the Sr isotope composition and concentration and thus is an important but often overlooked process in hydrogeochemical studies.

### References

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