British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Entec

Radiocarbon dating of the groundwater from the La Rocque and St Catherine test boreholes, Jersey

Summary

Radiocarbon dating of water samples from the two test boreholes was used to test the conclusion in the joint BGS–Entec technical report[1], that

"the isotopic signatures obtained from the 'shallow' and 'deep' groundwater at the two test sites were indistinguishable and were also consistent with the range of isotope signatures for Jersey groundwaters",

was not compromised by the presence of waters that fell before the last Ice Age (Pleistocene), i.e. under different climatic conditions. The ages obtained for the groundwaters from the two test boreholes indicate that the waters were recharged far more recently than the last Ice Age (Pleistocene), i.e. under the present climatic conditions (Holocene).

The previous published conclusions of the investigation therefore remain entirely valid.

Introduction

Measurement of the dissolved concentrations of modern atmospheric trace gases (CFC-11, CFC-12 and SF_6), make it is possible to determine the presence of groundwater recharged during the past half-century. This was undertaken for groundwater samples obtained from both the La Rocque and St Catherine test boreholes using samples obtained at the start and the end of the three day constant-rate pump test[1].

Results indicated that approximately one-third of the pumped groundwater at La Rocque was of modern (past 50 years) origin and that the proportion of modern to older groundwater remained fairly constant during the three-day constant-rate pump test. This, together with water level responses in the nearby shallow observation borehole, indicates that the shallow and deep aquifers at La Rocque were hydraulically connected[1].

At St Catherine, the proportion of modern water increased during the three day test pumping (from ~15% to ~25%). This variation probably resulted from an increasing proportion of younger, more saline and most likely seawater contaminated shallow groundwater being drawn downward through interconnected fractures in the rock into the borehole as it was pumped.

[1] fully reported in the main technical report 'Jersey Deep Groundwater Investigation'

The groundwaters were further analysed to determine the age of the older (pre-1950) groundwater component in both boreholes, using radiocarbon (^{14}C) dating. This was undertaken principally to determine whether the groundwater fell as rain during colder climatic conditions of the Pleistocene Ice Age (more than 10,000 years) or if recharge occurred more recently, under current climatic conditions.

Background

Radiocarbon dating has a number of uncertainties, particularly when applied to groundwaters that were recharged less than 1000 years ago. The uncertainties principally derive from:

i. Estimating the amount of dilution of the water's radiocarbon activity by 'dead' carbon from the aquifer rock.
ii. Estimating the amount of augmentation of the water's radiocarbon activity due to the post-thermonuclear testing modern water component.

Both these uncertainties were factored into the age estimates by:

i. Measuring the $\delta^{13}C$ values of the carbonate contained in the bedrock using rock chips sampled at depth during the drilling of the test boreholes and comparing this with the $\delta^{13}C$ values of the bicarbonate in the water.
ii. Assuming realistic values for the 'initial activity' for the modern groundwater component

Results

At La Rocque, the radiocarbon modelling results indicate an age for the older component of the groundwater of less than 1000 years. Radiocarbon dating is not definitive for waters within the 0–1000 year age range, and the best estimate for the older groundwater component at La Rocque is that it recharged from rainfall that occurred a few hundred years ago.

For the St Catherine groundwater sample, an age estimate of over 1000 years can be made, even before taking the modern ^{14}C contributions into account. Taking this factor into account produces model ages for the older component of groundwater at St Catherine in the range 4000–5000 years before present.

Conclusion

The ages obtained for the groundwaters from the two test boreholes indicate that the waters were recharged more recently than the last Ice Age (Pleistocene), i.e. under the present climatic conditions (Holocene). This means:

- The conclusion in the joint BGS–ENTEC report, that 'the isotopic signatures obtained from the 'shallow' and 'deep' groundwater at the two test sites were indistinguishable and were also consistent with the range of isotope signatures for Jersey groundwaters', remains entirely valid.

- The shorter residence time of the older component of groundwater at La Rocque as compared to that at St Catherine is consistent with the bedrock having an overall higher permeability at La Rocque than at St Catherine. Thus, rainfall falling in the recharge area of the test boreholes would take longer to circulate to depth at St Catherine, and in consequence would be older than at La Rocque.

- It is anticipated that under similar geological and hydrogeological conditions, ages similar to those obtained from the two test boreholes are likely to be found elsewhere on Jersey.