# Tracing groundwater flow paths in fractured rock using naturally-ocurring organic biomarkers.

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Determining the source of infiltrating surface water into a groundwater system is often difficult, especially when the candidates are chemically similar. Here we explore how organic biomarkers that naturally occur at the surface can be used to establish the source of infiltration. This novel approach to groundwater tracing avoids the need to add chemical tracers to the water system; such tracers are often not fully recoverable and may be damaging to the environment. Different surface environments have specific biomarker signatures, reflecting the flora and fauna in each particular environment. As surface water infiltrates it transports surface organic biomarkers into the groundwater system. Analyses of biomarker signatures from different surface environments can therefore be compared to that of the groundwater under investigation.

Here we present the results of a case study using naturally occuring biomarkers to trace the source and infiltration pathways of the groundwater, in combination with compound-specific isotope analysis of $\delta^{13}C$. Our study focuses on groundwater sampled from boreholes advanced from within the tunnels in the Grimsel Test Site (GTS), Switzerland. The GTS cuts granitoid host rocks up to 500m below a topographic ridge adjacent to a glacial-fed lake. This is a well-characterised groundwater system in which our method can be validated using previous investigations into the source of the groundwater. Soil, lake and groundwater samples were collected and tested for naturally occuring biomarkers using GC-MS, and for compound-specific isotopes ($\delta^{13}C$) using GC-IRMS. These were then compared to biomarkers found within the groundwater. Seven out of eight samples contained only biomarkers derived from surface soils and had none characteristic of the adjacent lake. This confirms that the fractures are fed from surface water and not from the lake as independently validated by O and H isotope data. Our study shows that naturally occuring biomarkers are useful tools for determining groundwater origins, particularly when used in combination with traditional analytical techniques.