# On the origin of groundwater from Olkiluoto Island on the coast of the Gulf of Bothnia

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During the site selection programme for nuclear waste disposal, Teollisuuden Voima Oy has collected groundwater samples from boreholes drilled down to 1000-m depth. Earlier studies already showed (e.g. Pitkänen et al. 1994) three different end-member groundwater types mixing in the bedrock due to the land uplift. They were 1)modern fresh rainwater in the upper part of the bedrock recharged since the island rose above the sea level about 3000-2500 B.P., 2)brackish Na-Cl water layer originating from the modern and former Baltic Sea at 100-500-m depth, and 3)deep-occuring saline Ca-Na-Cl-type water interpreted as a remnant of ancient hydrothermal processes on the basis of the Br/Cl ratio and stable isotopes of water.

Latest comprehensive sampling from multipacked boreholes reveals new details from the brackish water layer in particular. Na-Cl water enriched with $SO_4$ (Fig. 1) has been indentified at a depth of 100-300 m. The salinity clearly exceeds the present value of the Gulf of Bothnia (Cl ~ 3600 mg/l), whereas the Br/Cl ratio indicates a sea water origin (Fig. 2). The $^{18}O$-$^{2}H$ values plot on a mixing line between the samples of the present Baltic (highest at the site) and the group of fresh and other brackish waters at the site, indicating warmer recharging conditions than nowadays. Below this sulfate-rich layer firstly Cl (salinity) and $^{18}O$ are depleting with $SO_4$ (Fig. 1), but the Br/Cl ratio keeps stable (Fig.2), reflecting the mixing with colder diluted water in the system. At greater depths, the $^{18}O$ and Br/Cl ratio begins to increase with Cl towards the values of the most saline groundwaters (Cl > 20 000 mg/l).

According to the chemical characteristics of $SO_4$-rich water, it is most likely that it has infiltrated from the Litorina Sea, which was the only more saline stage (7500-2500 B.P.) and also a warmer period than the modern Baltic stage during Holocene in the Gulf of Bothnia (e.g. Eronen 1988). Kankainen (1986) estimated that the highest Cl content in the Litorina Sea in Finland was about 6500 mg/l. The stage was about 2 °C warmer than nowadays, and $^{18}O$ of the Litorina Sea water could have been between -5.2 and -4.7 ‰. The $^{14}C$ data of $SO_4$-rich layer (20 - 35 pM) coupled with the tritium results of overlying groundwaters (3-10 TU with 50-60 pM) support the age of the Litorina Sea. The lighter isotope content than in modern sea water can be explained by the mixing with a colder, dilute pre-Litorina water, probably meltwater from the Weichselian ice sheet. According to the preliminary mixing calculations using Cl as a conservative tracer, the $SO_4$-rich layer would contain 55-70 % water originated from the Litorina Sea and the rest would be glacial meltwater with $^{18}O$ varying between -18 and -23 ‰. The chemistry suggests (Fig. 1 & 2) that the displacement of meltwater by heavy Litorina water decreases below the $SO_4$-rich layer. In the lower part of the brackish water layer the changes in chemistry imply the increasing mixing of saline end-member water. The deep location below the cold end-member and high $^{18}O$ content indicate a preglacial origin for saline water. As a final conclusion, hydrochemistry of Olkiluoto seems to contain a well developed profile of climatic changes from modern time through former Baltic stages in the area to preglacial times.

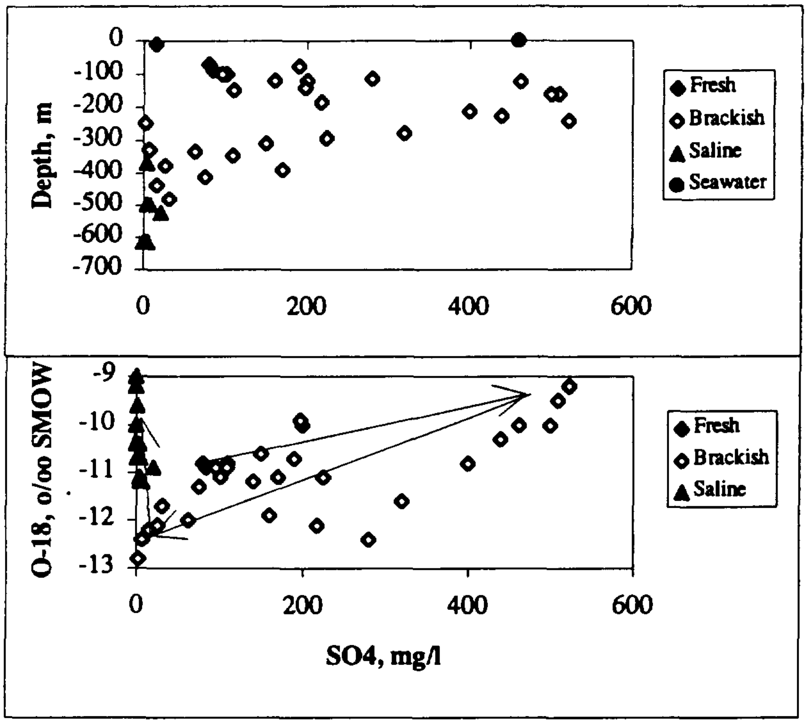


Figure 1. Sulphate variation against depth and O-18. Arrows show general trends with depth from shallow depths through the $SO_4$-rich layer towards the lower part of the brakish layer and finally to saline water.

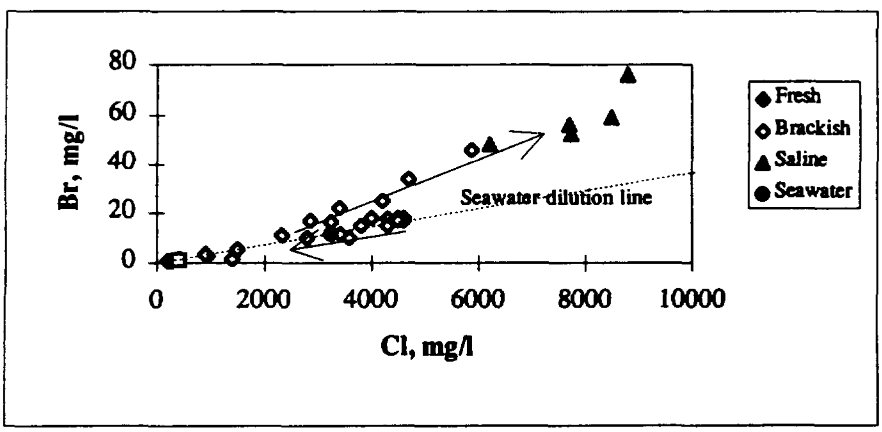


Figure 2. Br versus Cl. Arrows show general trends with depth from the $SO_4$-rich layer towards saline layer.

## References

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