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Systematics of Saline Hydrothermal Systems: Evidence from the Sub-aerial Saline Systems on Iceland

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Submarine hydrothermal systems from the East-Pacific Rise and the Mid-Atlantic Ridge show distinctly different B, Cl, Br and B isotope ratios. New data from the saline and semi-saline hydrothermal systems from Iceland can be used to show how these different saline systems may be related using a simple model of phase separation and water rock interaction.

Iceland hosts the completely-saline Reykjanes hydrothermal system and the semi-saline (~66% seawater) Svartsengi hydrothermal systems. These hydrothermal systems can not be related to the high temperature meteoric water hydrothermal systems examined by Aggarwal et al., (2000), as the seawater signatures dominate. However, since the geological sequence in Iceland is dominated by tholeiitic basalt, the Icelandic saline sub-aerial systems may be compared to their non-sedimented submarine counterparts.

Boron isotope ratios were measured by PITIMS in Bristol and this data along with that of Cl, B and Br data are shown in Table 1 for the Icelandic saline systems. Data for seawater and several submarine systems is also shown in this table for comparison.

The Cl/Br ratio for all saline systems is close to that of seawater (Cl/Br ~ 659), however some variability is evident. The cause of these variations has been suggested to be either the precipitation of a Cl bearing mineral or phase separation, where the residual fluid becomes enriched in Cl (Oosting and Von Damm 1996). Addition of Br or Cl from the rocks to the fluid is negligible as is the addition of magmatic Br and Cl from volcanic gases (Cl/Br ~150). Svartsengi and Reykjanes systems have undergone a significant change in Cl/Br ratio (460 and 960 respectively) possibly as a consequence of phase separation.

Comparison of Cl/Br and B isotope ratios for the saline systems indicate that the mid-Atlantic ridge hosted systems show higher Cl/Br than their counterparts from the East Pacific Rise, and lower ratios than the sub-aerial systems from Iceland. If phase separation is the most significant cause of Cl/Br variations, this would indicate that some degree of phase separation occurs in the mid-Atlantic Ridge systems. Pressure and temperature data indicate that the Icelandic fluids have undergone subcritical phase separation unlike the submarine systems which due to the greater pressure would undergo supercritical phase separation. The effect of phase separation on B isotope ratios is negligible in these saline fluids. This conclusion is in agreement with that of Spivack et al., (1990), who noted no isotopic fractionation during supercritical phase separation.

Due to the range and limited dataset for the sub-aerial systems, it is not possible to ascertain if the Reykjanes fluid is isotopically lighter than that of the Svartsengi fluid. The Svartsengi system is a well mixed system and shows little heterogeneity in other trace elements. The precise nature of the PITIMS measurements and reproducibility of the methyl-borate extraction technique can not account for the systematic difference (0.6‰).

Boron concentrations and B isotope ratios indicate a simple mixing between a seawater end-member and a model end-member that is similar to that of Icelandic basalts. Despite probable modification of the seawater due to absorption processes in the cold downwelling part of the hydrothermal system, it appears that this modification is insignificant and a pure seawater end-member may be used. Using the dataset in this study, there is not a complete range in B concentration and B isotope ratios between these two end members. Instead, there is a limiting process which gives rise to a minimum $\delta^{11}B$ of 24‰. This limiting process has yet to be evaluated.

In conclusion, phase separation appears to control the Br and Cl concentrations of the saline hydrothermal fluids. Boron concentrations and isotopic data indicate the process of conservative mixing between a seawater end-member and an end-member similar to that of the non-saline Icelandic hydrothermal fluids. An additional process possibly water/rock ratios is also evident in limiting the B isotopic composition of saline fluids.

	B mM/kg	Br mM/kg	Cl mM/kg	Cl/Br	$\delta^{11}B$ ‰
Svartsengi well 7	798	504	365	724	28.9
Svartsengi well 8	746	477	358	750	27.3
Svartsengi well	9	461	340	737	
Svartsengi well 11	723	463	328	708	26.7
Reykjanes well		8	807	561	25.7
Reykjanes well 9	821	644	563	874	26.1
Seawater	426	813	541	665	39.5
MAR Kane	520	866	572	660	26.8
Broken Spur 3	468	770	470	610	24.3
11 N EPR 6	480	545	346	635	34.7
11 N EPR 1	470	1157	735	635	36.8

Table 1. Compositions of Icelandic saline hydrothermal fluids and several submarine hydrothermal fluids.

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