Multiphysics: Fluid Mixing and Brine Pool Formation for Economic Geology Applications

Christian Schardt
University of Minnesota-Duluth, Dept. of Geological Sciences, 1114 Kirby Drive, Duluth, MN, 55812

Introduction: Significant submarine mineral deposits form when hot, metal-laden, saline fluids emerge onto the seafloor and mix with ambient seawater. Resulting fluid density changes can trigger fluid buoyancy reversal, the formation of a 'brine pool', and metal accumulation (Figure 1). The physical-chemical processes operating within such 'brine pools' are poorly understood but are crucial for the understanding of these systems. Recent fluid-rock modeling data (Schardt, 2014) and with field observations in the Red Sea form the basis for mixing simulations using COMSOL.

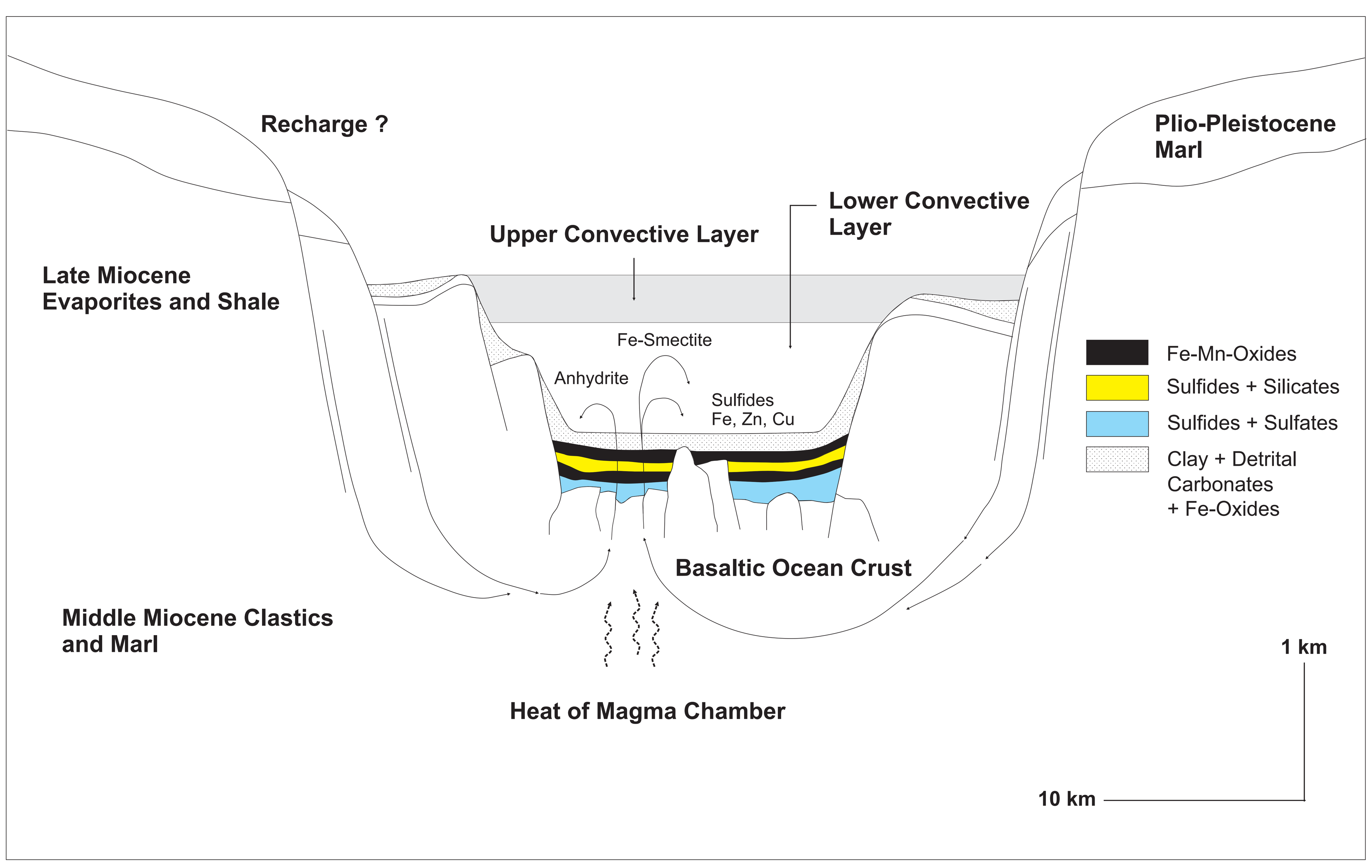

Figure 1 Schematic profile of the Red Sea Deep Atlantis II Deep showing brine pool layers and geology (modified from Bäcker,1973).

Computational model and methods: The model investigates the mixing of hot, highly saline hydrothermal fluids with cold seawater in a submarine depression to assess the conditions necessary to develop a brine pool. This approach includes turbulent non-isothermal fluid flow and free fluid mixing using the SST turbulence model. Salinity and density changes will be monitored using the transport of diluted species module.

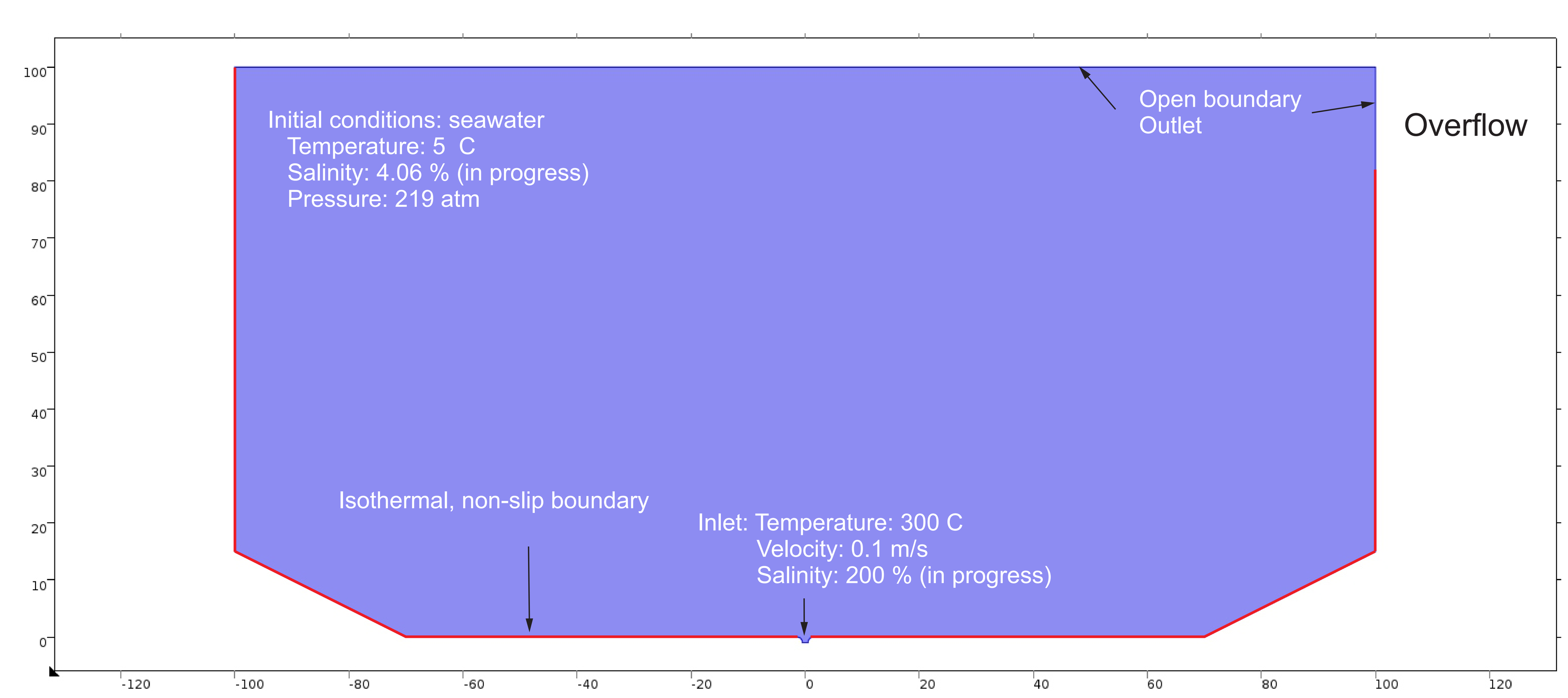

Figure 2 Model geometry, boundary, and initial conditions as well as fluid injection location.

Aims: - track salinity/density changes and fluid buoyancy reversal

- determine physical-chemical conditions of brine pool formation

- study internal pool conditions (convective layers, diffusion)

Results: A buoyant plume is rising < 1 h after start. Temperatures in the plume center remain above 150 C for the majority of the plume height (Figure 3). Fluid flow shows counter-rotating convection pattern (Figure 4). Plume shape changes significantly after ~ 60 h because of changes in the overall basin temperature, accompanied by major changes in fluid flow patterns and direction (Figure 5 a and b).

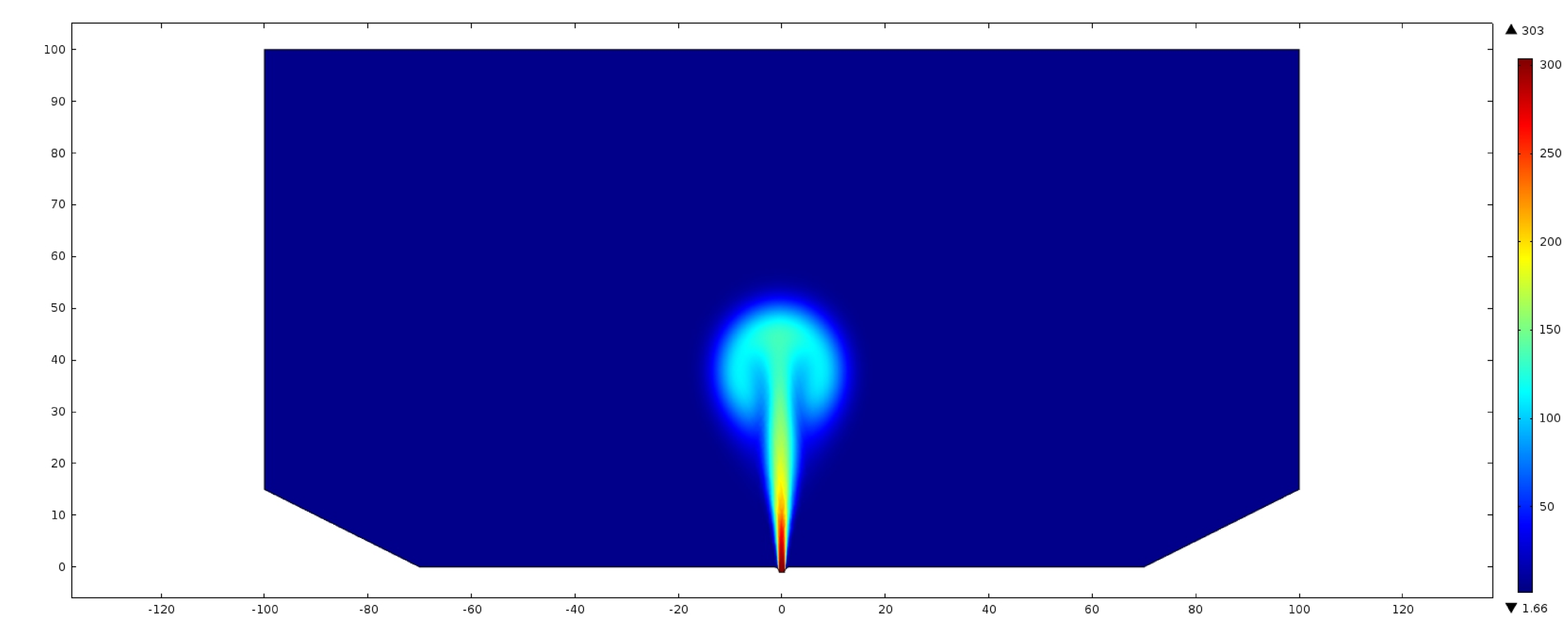

Figure 3 Discharge temperature distribution after 7 h (C)

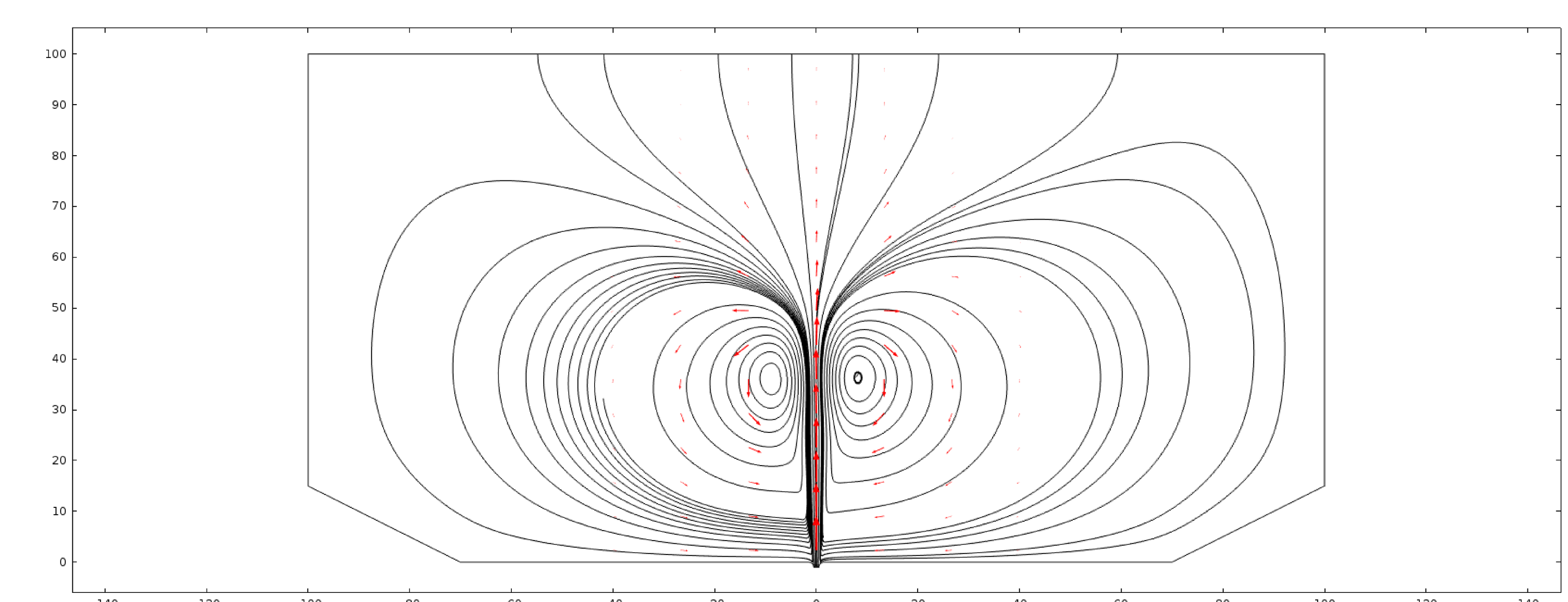

Figure 4 Discharge fluid streamlines after 7 h. Arrows indicate relative fluid flow magnitude (maximum 0.1 m/s).

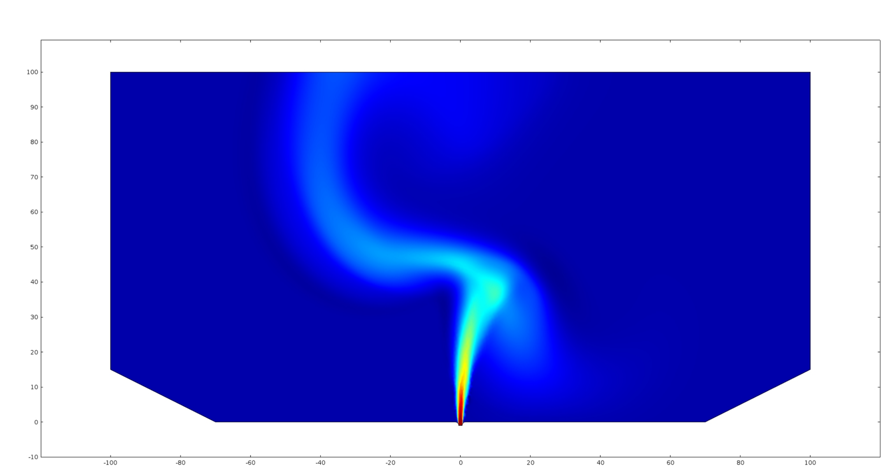

Figure 5 a Shift in plume shape after 62 h due to overall temperature increase in the basin.

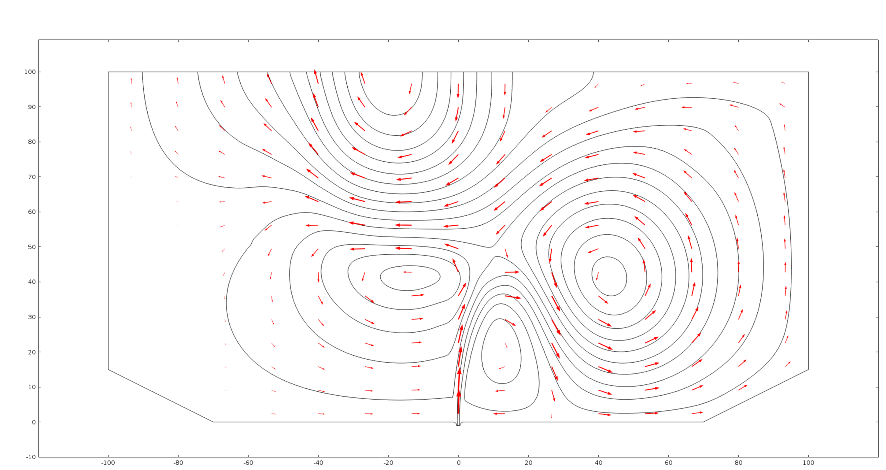

Figure 5 b Fluid flow patterns shift after 62 h caused by plume deformation.

Conclusions: Fluid discharge and plume development realistically reflect conditions within the submarine basin and agree with field observations. Significant changes in discharge plume behavior occur relatively quickly after onset (< 100 h). The presence of the overflow feature seems to affect fluid flow behavior to some degree. Implementation of realistic mixing density changes, buoyancy reversal, and brine collection on the bottom, controlled by critical water properties (e.g. density, viscosity) as a function of mixing temperature and salinity remains a challenge. Further work is required to accomplish these goals.

References:

1. Bäcker, Die rezente hydrothermal-sedimentäre Lagerstätte Atlantis II Tief im Roten Meer, Geolog. Rundschau, v. 52, p. 697-737, (1973)

2. Schardt, Hydrothermal fluid migration and brine pool formation in the Red Sea: The Atlantis II Deep, Mineralium Deposita (in review), (2014)