PRF# 56166-ND8

Temperature-Dependent Physical Properties of Evaporites and Related Rocks: New Constraints on the Thermal evolution of Sedimentary Basins

Alan G. Whittington, Geological Sciences, University of Missouri, Columbia, MO

In year 1 of the project, we focused on the thermal properties of carbonate minerals and rocks. We showed that dolomite has a higher thermal diffusivity and conductivity than calcite, and consequently that dolomitized basins will have higher conductivities and cooler temperatures than calcite-dominated basins, all other factors being equal (Merriman et al. 2018, *Geosphere* 14: 1961-1987). In year 2, we have focused on measuring the thermal properties of shales, and have used thermal modeling to investigate how variations in thermal conductivity as a function of mineralogy, texture, and temperature affect geothermal gradients and maturation windows in sedimentary basins.

1. Thermal properties of shales.

In collaboration with Prof. Anne Hofmeister (Washington University, St. Louis), we measured the thermal diffusivity (D) and isobaric heat capacity (C_P) of 8 different shales from 20°C to 300°C. Shales have considerably lower D and greater C_P values than other common sedimentary rocks. The room-temperature D of sandstone (Branlund and Hofmeister, 2008 *American Mineralogist* 93:1620–1629), limestone (Merriman et al., 2018 op. cit.), and shale (this study) is 3.1, 1.5, and 0.8 $mm^2 \cdot s^{-1}$ respectively, decreasing to 1.1, 0.5, and 0.4 $mm^2 \cdot s^{-1}$ at 300°C. The changes in D and C_P also result in a decrease in thermal conductivity (k) with increasing temperature, where $k = D \cdot C_P \cdot \rho$, and ρ is density.
We are currently exploring variations in the properties of shale as a function of mineralogy, cement type (silicic, carbonate, or ferruginous), and organic carbon content. Higher organic carbon contents result in lower D and k values, and a smaller temperature-dependence (Fig. 1). Preliminary results suggest that thermal properties of shales can be modeled to a reasonable degree of uncertainty ($2\sigma = 0.05$ $mm^2 s^{-1}$) using a linear dependence on modal quartz content, and exponential dependence on temperature, and a linear dependence on organic carbon content.

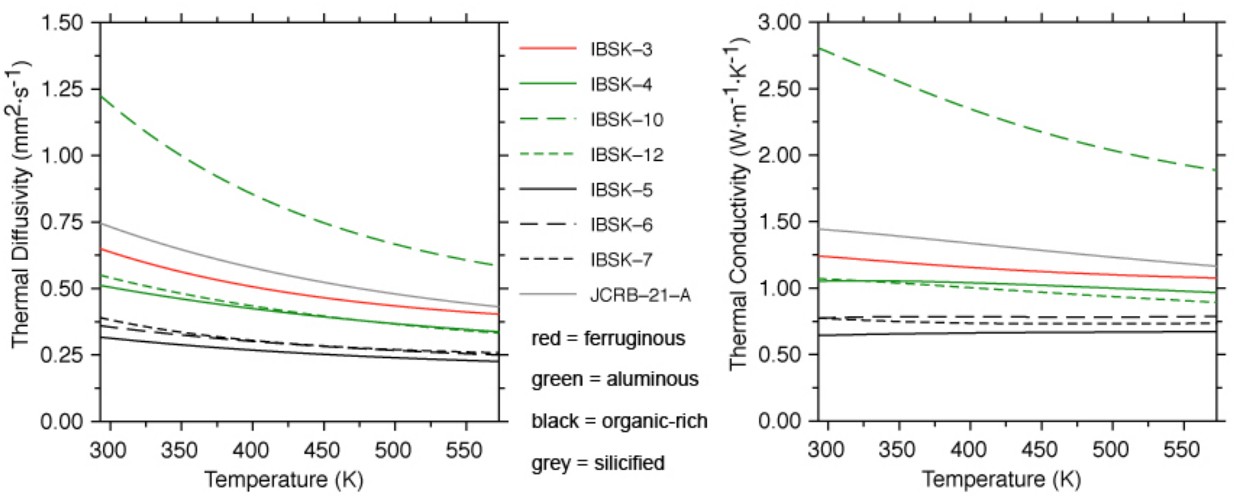

Figure 1. Thermal diffusivity and thermal conductivity of selected mudstones and shales.

2. Thermal modeling of the Illinois Basin.

Samples from the Illinois Basin record anomalously high vitrinite reflectance temperatures, in the range 120-160˚C, at the surface and in boreholes (Fig. 2). The highest temperatures are from the southern Illinois Basin, with lower temperatures to the north, and this has been hypothesized to be the result of a northward migrating plume of hot groundwater (Marino et al. 2015, *AAPG Bulletin* 99:1803-1825). The alternative explanation is an exceptionally large degree of exhumation in an apparently stable intracratonic setting.

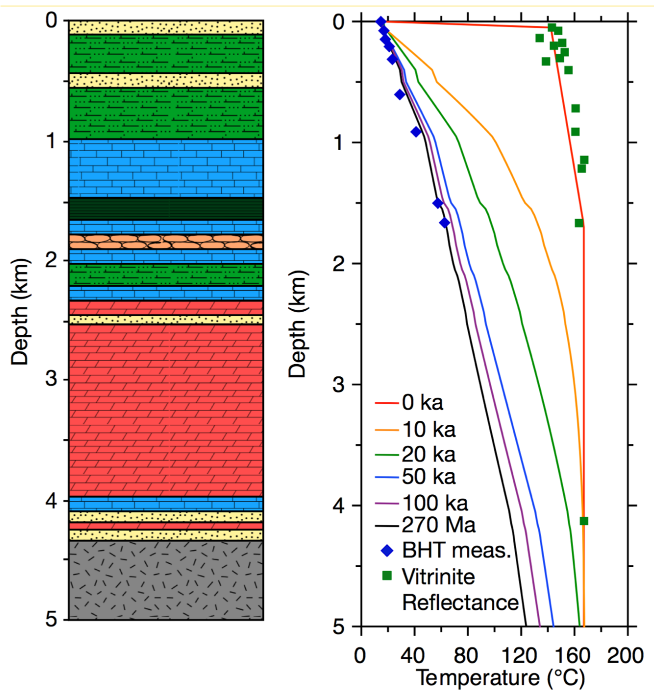

Figure 2. Thermal models of geotherms in the Illinois Basin, using lithologically appropriate temperature-dependent thermal properties (sketch stratigraphic column on L).

Modeled present-day geothermal gradients match well with borehole temperature measurements (BHT; diamonds).

The models also simulate the changing geotherm after heating triggered by a pulse of hot groundwater passing through the basin. Peak temperatures during the thermal pulse are constrained by vitrinite reflectance measurements. The conductive geothermal gradient returns to within ~10 degrees of steady- state (present-day) values in ~50 ka (blue line).

Ongoing modifications to this model will incorporate the effects of non-convecting pore fluid on thermal properties.

3. Thermal anomalies associated with salt diapirs

We have been using lithologically appropriate temperature-dependent thermal properties in 2-D conductive thermal models of sedimentary basins. We are testing the thermal effects of salt diapirs for a range of shapes, sizes and depths

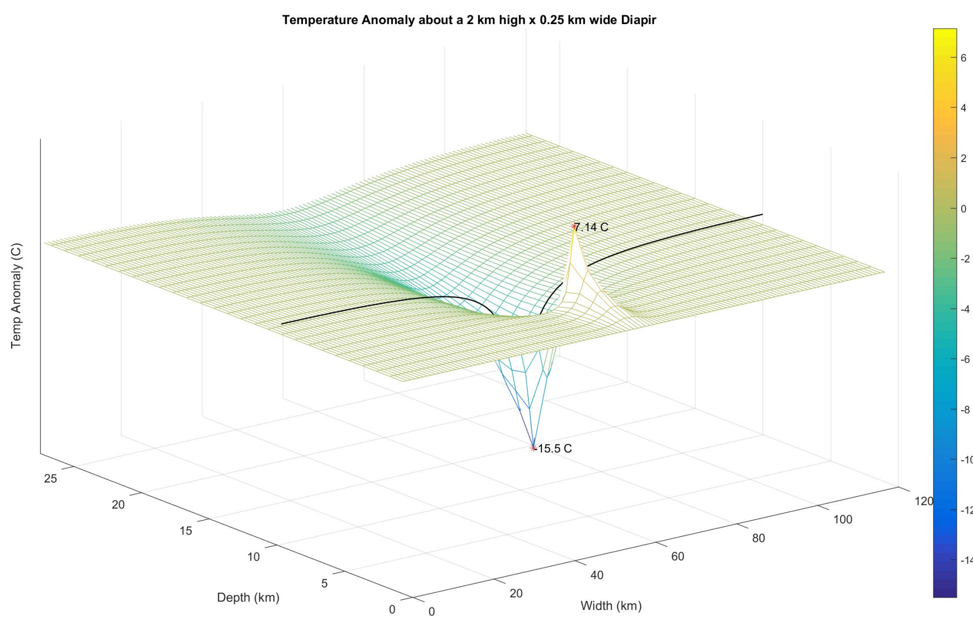

Figure 3. Thermal anomalies around a 2 km high, 250 m wide salt diaper.

Students supported by this project (* in the list below) have presented their research at national meetings. We anticipate two further publications, on mudstones and on salt diapirs, in the no-cost extension year.

Halverson, B.*, Kenderes, S.*, Merriman, J.*, Whittington, A., 2018. Cooking with salt: thermal anomalies associated with salt diapirs, and their effects on the maturation of surrounding hydrocarbons. GSA Annual Meeting, Indianapolis IN [poster]

Kenderes, S.*, Hofmeister, A., Merriman, J.*, Whittington, A., 2018. The effects of temperature-dependent thermal properties in modeling geothermal gradients of the Illinois basin. GSA Annual Meeting, Indianapolis IN [talk]

Kenderes, S.*, Hofmeister, A.M., Merriman, J.D.*, Whittington, A.G., 2017. Exploring the influence of texture and composition on the thermal transport properties of mudstones. AGU Fall meeting, New Orleans LA [talk]