# Insight into Ceres' Chemical and Physical Evolution from Surface Mineralogy

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The *Dawn* Visible and Infrared mapping spectrometer has yielded critical information on the global mineralogy of the dwarf planet Ceres. While second order details remain to be resolved, a big picture of Ceres' evolution emerges that puts constraints on Ceres' early history and offers a background for supporting the interpretation of future observations.

We survey a broad space of input conditions using the *Geochemist's Workbench* and PHREEQ software, then run the FREZCHEM software to model chemistry derived from freezing the liquid phase in equilibrium with the observed mineralogical assemblage. The surface chemistry points to advanced alteration under high fugacity of hydrogen and is consistent with predictions for and observations of large ice-rich bodies. The simulations indicate that methane was abundant and helped regulate the redox environment. The combined hydrothermal and freezing simulations yield hydrohalite, a hydrated chloride commonly found in Earth's polar regions, as well as methane clathrate hydrates . The presence on Ceres' surface, at the global scale, of material formed at depth suggests a large-scale emplacement mechanism that cannot be simply explained by endogenic processes.

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