**Summary:** Authors review thermal evolution models for asteroids that have undergone metamorphism (ordinary chondrites), aqueous alteration (carbonaceous chondrites), and melting and differentiation (HED achondrites) using $^{26}$Al decay as their primary heat source. These models reasonably match observations and account for effects of regolith, water ice and fluid flow, redistributing of heat sources.

**Important methods, figures, and findings:**

In this summary the primary heat source is $^{26}$Al decay which has an initial homogenous composition in the solar system. Other heat sources include electromagnetic induction and impacts, although these parameters are not well constrained. This results in a heliocentric distribution of asteroid spectral types that largely persists even after alteration by dynamic stirring and ejection. In this way, thermal evolution models give insight into the thermal structure of the asteroid belt with peak temperatures falling closer to the Sun.

**Models for Ordinary Chondrites (effect of regolith):**
The heat movement through Oc parent body asteroids is dominated by conduction (only minor fluids present). Metamorphism observed in Oc occurred at temperatures up to $\sim$1175 K. Regolith has much lower thermal conductivity than consolidated rock, and their insulating effect causes high metamorphic grade boundaries to move closer to the surface and protracted thermal histories.

**Models for Carbonaceous Chondrites (effect of water ice and fluid flow):** The heat movement through Cc parent body asteroids includes hydration reactions releasing heat as well as hydrothermal convection and “exhalation” of water to dissipate heat. Aqueous alteration happens at low temperatures. There is no self-consistent model that reconciles reaction heat, isotopic exchange, and fluid flow.

**Models for Differentiated Asteroids (effect of redistributing heat sources):** Models are distinct from those for chondrite parent bodies due to melting and differentiation. Melting and melt segregation are poorly constrained with models requiring extensive or limited melting. Thermal evolution models generally include the three stages (1) radiogenic heating until core formation (2) mantle heating until crust formation (3) heating and cooling of differentiated asteroid. Some models that include redistribution of $^{26}$Al during differentiation result in reverse thermal gradients, inhibiting heat loss.

**Outstanding Question:**
1. How would further constraining other parameters such as induction heating and incremental accretion affect the models and how we understand the thermal evolution of asteroids?

**References for Further Reading:**


Summary: Cooling rates calculated from Ni profiles across taenite lamellae were used to test a genetic link between main group (MG) pallasites and IIIAB irons. Authors found that pallasites cooled below 975K at diverse rates and are thus not all from the core-mantle boundary (CMB), but rather a range of depths in a well-mixed olivine/Fe/Ni body that could have formed via a grazing impact on a differentiated asteroid/protoplanet. Group IIIAB irons cooled much faster and cannot be from the same body as MG pallasites, as previously thought.

Important findings: Some have hypothesized that MG pallasites could have crystallized from the liquid in the IIIAB body, which if proven would support pallasites forming at the CMB. But a conclusive genetic link has not been proven using the distribution of oxygen isotopes, siderophile elements, shock features, or exposure ages. Instead this work focuses on identifying a link using cooling rates. They use the metallographic method to estimate the cooling rates of the metal in the pallasites (Fig. 1). These rates were corroborated by measurements of tetrataenite bandwidth and size of high-Ni particles in the cloudy zone of both pallasites and IIIAB taenite. They found that MG pallasites cooled at 2.5-18 K/Myr and IIIAB irons cooled at 50-350 K/Myr (Fig. 2). The much faster cooling rate of IIIAB irons means that MG pallasites cannot have formed at the CMB of the IIIAB iron parent body. They argue that MG pallasites could have been formed by a glancing impact (Fig. 3) that stripped the parent body (asteroid or protoplanet) of its olivine mantle and molten metal from the outer IIIAB-like core. They argue that although the MG pallasites have a range of cooling rates, they need not be from different parent bodies but are likely from a range of depths within the parent body. Based on thermal models using the slowest cooling rate they acquired from the above methods, the parent would have had a radius of 400km.
A petrological and chemical reexamination of Main Group pallasite formation  
(Bosenberg et al., 2012)  
As Presented by Sierra Kaufman

**Main Point:** This paper presents a model for Main Group pallasite formation which depends on fractional melting of a chondritic parent body into four layers (crust, dunite layer, pallasite layer, s-rich core). It presents the weaknesses previous models have including a general layout for what must be explained for a model to become an acceptable explanation.

**Summary:** Here the authors present a model for main group pallasite formation (Fig. 11). It begins with a chondritic parent body and fractionally melts it to form sulfide-rich metal liquid and basaltic liquid. Differentiation begins as the basaltic melt rises to form the crust and the metal melt sinks to form a core. The olivine, pyroxene, and metal left in the middle will become the pallasite and mantle layers. The melting continues and the sulfur is ejected from the middle layer (this explains the lack of troilite in the pallasites). The silicate melt is expelled from the pallasite layer and during the final stages of cooling the minor phases form.

The three textures of pallasite olivine (euhedral, rounded, and fractured) can be explained through initial crystallization, resorption from surrounding melt before the formation of the phosphorous olivine, and shockwaves from later impacts respectively.

**Outstanding Questions/Critiques:** The paper does not offer an explanation for the “missing dunite” phenomenon. There is a later paper\(^1\) which offers an explanation through catastrophic destruction and preferential loss of olivine-rich mantles. This is a non-model dependent explanation. Is there an inherent issue with any model which does not explain the lack of olivine meteorites or is this something which should be an acceptable shortcoming?

This paper is presenting a model applicable to the Main Group pallasites and makes a point to mention it does not cover the Eagle Station group (which has had little work performed on it\(^2\)). Should we accept a model for pallasite formation that does not cover all the possible parent bodies if these is supposed to be a repeatable process so there can be several parent bodies easily formed? Lastly, is a chondritic starting material assumption acceptable? Is it any better than the papers which assume the relation to iron meteorites IIIAB\(^3\)?

**Further Reading:**

