GLIMMERINGS FROM THE PAST: LIGHT EMITTED BY METEORITES UNDER AN ELECTRON BEAM PROVIDES CLUES TO THE HISTORY OF THE EARLY SOLAR SYSTEM. John DeHart and Derek Sears, Cosmochemistry Group, Department of Chemistry and Biochemistry, University of Arkansas, Fayetteville, AR 72701 and Gary Lofgren, Johnson Space Center, Houston, TX 77058.

Meteorites are ancient records of conditions and processes occurring at the very beginning of the solar system, when the Sun, Earth and the planets were forming from a swirling cloud of dust and gas, four and a half thousand million years ago. One of the strangest components in the meteorites are the chondrules; they also make up the largest fraction of the meteorites. For over 150 years scientists have been intriqued by chondrules. The Englishman, Henry Sorby, who was one of the first persons to look at meteorites under the microscope, described the chondrules as 'droplets of fiery rain' produced when solar flares shot our from the Sun. Other scientists have suggested that they are solidified droplets produced when lightning streaks shot through the gas and dust during the formation of the solar system. Most modern scientists prefer mechanisms of this second sort, in which dust is suddenly flash-heated, but there is no agreement that it was lightning that caused the heating. One of the difficulties is that chondrules can show show considerable differences in composition and in recent years scientists have suggested that there may have been considerable movement of material in the early solar system.

In attempting to resolve some of the questions surrounding the chondrules, a group from the University of Arkansas and the Johnson Space Center at Houston, have been examining the light emitted by meteorites when a stream of highly energetic electrons is forced down onto their surface. The light emitted is termed the cathodoluminescence (electron beams were once known as cathode rays), and photographs show which components luminesce and the colors of the luminescence. Modern techniques also exist for determining the composition of the individual components in the rock, and this helps to further understand the cathodoluminescence.

What the Arkansas/JSC group have found is that the cathodoluminescence of meteorites comes mainly from the chondrules. In the Indian meteorite Semarkona, some chondrules brightly luminesce blue, yellow or, occasionally, red, while others do not luminesce at all. The group performed a detailed study in order to explain these observations. They concluded that it all depended on the details of the way the chondrules were melted and subsequently cooled; luminescence being restricted to those that were heated most or cooled most rapidly. The group saw no need to invoke widescale movements of material in the early solar system to explain the diversity in chondrule properties.

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Having established this point, the group then considered what happened to the meteorites next. The dust and chondrules, together with some grains of other materials (mainly metal particles), came together as a single rock, which grew into an object several miles in diameter. Objects this size contain sufficient amounts of radioactive elements that the heat produced caused the objects to become warm and temperatures up to 1000 C may have eventually been reached. It is possible to identify many meteorites that have suffered this heating, in fact unheated meteorites are very rare, and the Arkansas/JSC group found that cathodoluminescence helped them to recognise some of the effects of this heating.

Parent body heating caused several changes in the minerals in the meteorites. It 'smoothed out' variations in different grains of the same mineral, and it caused the glass in the chondrules to form crystals, usually of a mineral called 'feldspar'. Both these heat-induced changes therefore had very marked effects on the cathodoluminescent properties of the minerals in the meteorites. Smoothing out mineral compositions caused most of the original grains in the meteorite (the olivines and pyroxenes) to lose their ability to show cathodoluminscence. This is because it is only when olivine and pyroxene are free of iron can they cathodoluminesce, and the redistribution of iron ensures that all minerals have uniformly high levels. On the other hand, the heating process produced feldspar which is highly cathodoluminescent. The net effect is that the total level of cathodoluminescence goes up drastically with heating, but the variety of mineral types involved drops, and the range of cathodoluminesce colors is reduced to one, the unearthly blue luminescence of feldspar.

There were other strange and relatively rare minerals in meteorites when they first formed from the gas and dust of the early solar system, but which were highly unstable and disappeared under the influence of even the mildest levels of heating. Cathodoluminescence provides a unique means of locating these unusual minerals, and following the effects of parent body heating. It seems, therefore, that watching the light coming from minerals as the electron beam cascades onto the meteorites is more than a passing curiosity; it is adding to our knowledge of the events surrounding the birth of our planet and the rest of the solar system.