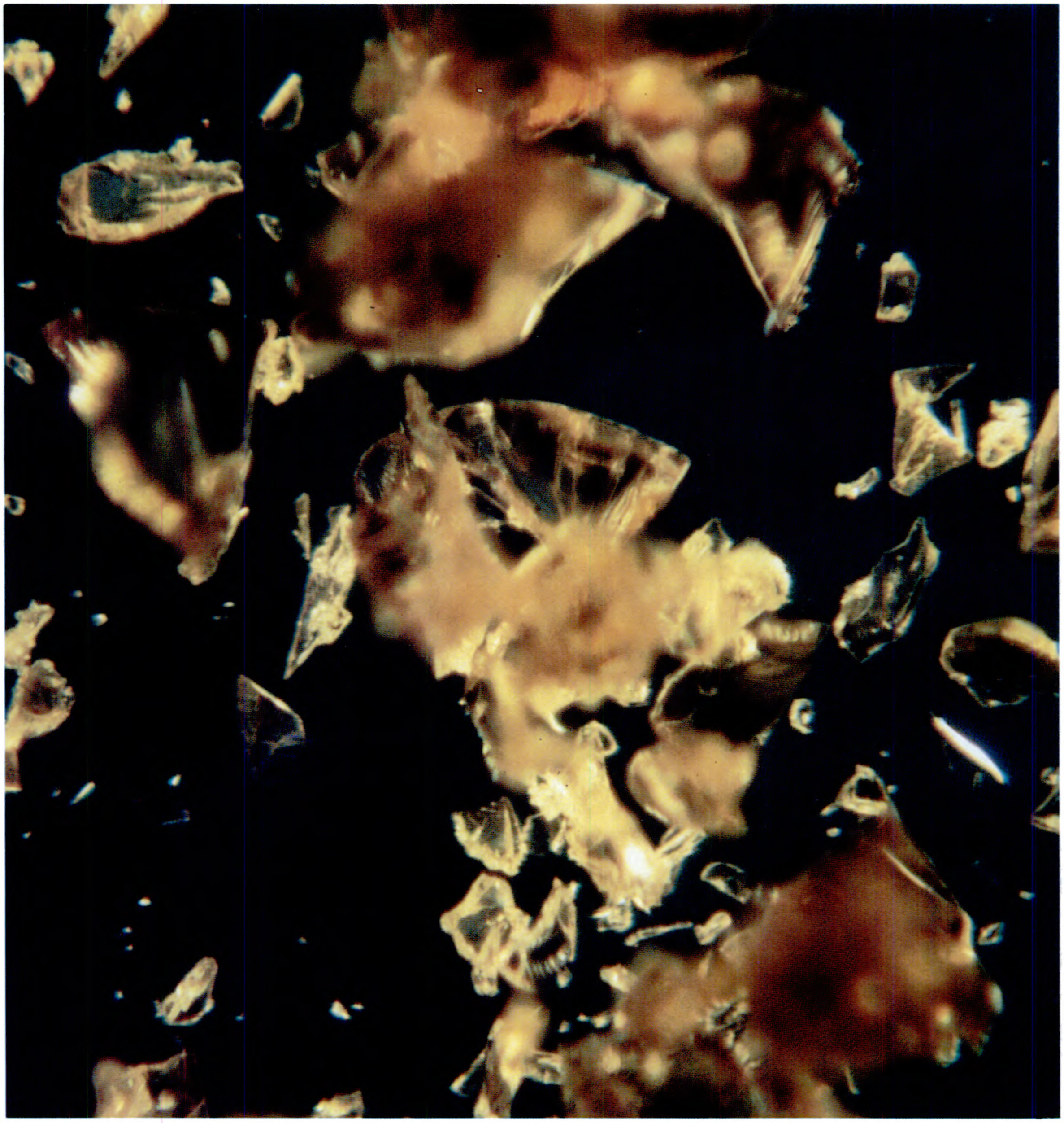
Meteorites and Cosmic Dust



Platinum-Group Element Alloys in Meteorites

Joel D. Blum, Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, CA 91125

The platinum-group elements (platinum, iridium, osmium, palladium, rhodium, and ruthenium) are exceedingly rare in the Earth, Moon, and most meteorites. However, in some tiny clusters of grains within primitive meteorites, they are enriched to levels higher than in most valuable platinum ore deposits on Earth. The platinum-group elements are observed as submicroscopic nuggets of one or more metal compositions, which in turn occur clustered together with more common nickel-iron metal and sulfide and oxide minerals as small spheroidal grains called "opaque assemblages" (fig. 53). The meteorites that contain opaque assemblages are aggregates of particles that are believed to have formed by direct condensation from the solar nebula—the cloud of gas out of which the Sun and planets of our Solar System ultimately formed. Opaque assemblages have overall proportions of platinum-group elements close to what one would predict (from fundamental chemical principles) to have condensed as the first solid material from a hot part of the solar nebula as it began to cool. What is puzzling, however, is the occurrence of a wide variety of discrete metal compositions within individual opaque assemblages; in particular, each metallic phase contains only a few of the platinum-group elements rather than all of them. One possibility that has been proposed is that the various metals and sulfide and oxide minerals in opaque assemblages each formed by condensation under highly variable conditions in different source regions of the solar nebula and were later aggregated to form the opaque assemblages. This scenario, however, faces the difficult question of why the wide variety of metals and other minerals that form opaque assemblages are almost always mixed in proportions that yield overall platinum-group elemental proportions equal to those predicted for condensation of one mixture of the elements.

To understand better the origin of opaque assemblages in meteorites, the author conducted experiments in which the chemical compositions and textures of the platinum-group element alloys and sulfide and oxide minerals in opaque assemblages were reproduced by subjecting mixtures of metals to a variety of temperatures and gas atmospheres in the laboratory. The experiments demonstrate that the diverse metallic phases and other minerals could not have condensed separately and later aggregated to form opaque assemblages. Instead, opaque assemblages probably originated as homogeneous alloys of nickel and iron with the platinum-group elements dissolved within them, early in the history of the Solar System (when the dominant element in the nebular gas was hydrogen). Later in the history of the Solar System, when the nebula began to cool and small planets formed, more sulfur and oxygen were present as gases. The homogeneous alloys were unstable in the presence of these gases and

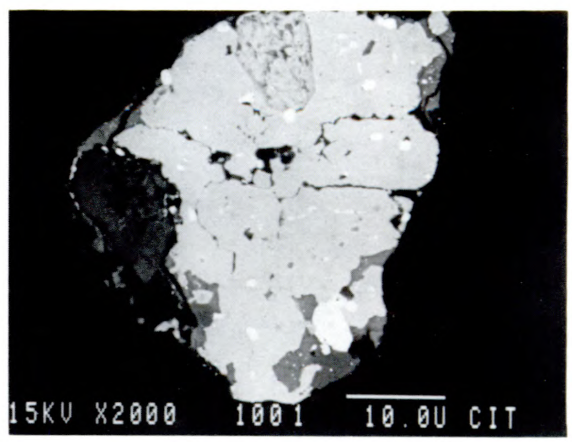


Fig. 53. Scanning electron microscope image of a meteoritic opaque assemblage rich in platinum-group elements; the scale bar is 10 micrometers (1/2500 of an inch) long. The white regions are alloys of nearly pure platinum-group elements, the light gray regions are nickel-iron alloys with lesser amounts of dissolved platinum-group elements, the gray mottled region at the top center is molybdenum sulfide, and the dark gray regions are nickel-iron sulfide and iron oxide.

reacted with them in a process similar to the rusting of steel. This caused the precipitation of the distinct platinum-group element-rich metallic phases and the sulfide and oxide minerals. Therefore, the alloys and sulfide and oxide minerals that form opaque assemblages reflect low-temperature conditions in the solar nebula and possibly the early planets, whereas the overall platinum-group element proportions in opaque assemblages reflect the early high-temperature condensation of matter from the solar nebula.

In summary, these laboratory experiments demonstrate that low-temperature reactions are capable of producing virtually all of the metals and sulfide and oxide minerals observed in opaque assemblages in meteorites. Nuggets rich in precious platinum-group elements that occur in meteorites are, therefore, not the oldest solid materials in the Solar System as was once thought; rather, they formed during the rusting of nickel-iron metal at low temperatures in the solar nebula or on early formed planets.