magma ocean, the residual liquid and the new crystals might not have buoyancies that differ sufficiently to separate them, or the liquid might have sunk rather than risen. Chemical fractionation, but not physical separation, would thus occur so that bulk rock composition might not reflect the melting.

Brian Tonks of the University of Arizona and Melosh argued at the meeting that an abundance of motion rather than immobilization could have prevented physical separation. A magma chamber as deep as Earth's mantle would be vigorously stirred from top to bottom, they argued, because the vigor of the convection carrying heat to the surface depends sensitively on the size of the chamber. An ordinary chamber some kilometers deep is stirred convectively, but even millimeter-size crystals could settle out or float to the surface. Flows within a planet-scale chamber, on the other hand, would keep crystals even a meter across entrained in the flow. On a molten moon, such boulders would settle out, creating the observed europium anomaly. But in a molten Earth, Melosh says, the large drop from high pressures at the bottom of a magma ocean, where crystals would grow, to the upper magma ocean, where they would tend to dissolve, would limit crystal size and prevent their separation.

Among the dynamicists, these or other ways around the geochemistry seem like a good bet. "My attitude is that Earth was completely molten," says Stevenson, "and the answer lies somewhere in the dynamics." A number of geochemists are not beyond convincing. The moon's formation through a giant impact "is a very attractive hypothesis," says John Jones of the Johnson Space Center. There may after all be a way to avoid creating traces of a molten Earth or to erase them later, he says, but, for now, he "tends to go with the simplest hypothesis, that parts of Earth never melted, but I can't say it's true."

Geochemist Jeffrey Taylor of the University of New Mexico sees the giant impact hypothesis as the leading contender, but he cautions that definitively testing it with geochemical data will be difficult. There are the uncertainties in the whole-body compositions of Earth and the moon as well as in the relative contributions to the moon from the proto-Earth and the impactor. And there is the composition of the impactor, a parameter that advocates are free to vary as needed.

All in all, the giant impact hypothesis is liable to maintain its bandwagon status thanks to its strong dynamical support, the absence of incontrovertible conflicts with observation, and the failure of all alternative explanations. ■ **RICHARD A. KERR**

Ice Age Art Idea Toppled

By dint of experimental simulation and microscopic observation, University of Turin anthropologist Francesco d'Errico appears to have laid to rest a once popular explanation of certain aspects of ice age art. The interpretation of prehistoric art necessarily is an intellectually hazardous exercise, particularly when the images under scrutiny are remote from what we know today. It is difficult enough to understand the role in prehistoric society of lifelike images of animals painted and engraved on cave walls and rock shelters: different social contexts can imbue the same images with different meanings. But when the art is in the abstract—sequences of arcs, lines, dots, and so on—the mind is stretched even further in search of explanations.

One of the most inventive explanations of these abstract images to have emerged in recent times was advanced by Alexander Marshack, an independent scholar in New York. Noting that many engravings on cave walls and portable art objects appeared to be the result of repeated application over an extended period of time, he made the following suggestion: "These indicate some of the probable origins of later formal systems, such as writing, arithmetic, and true calendrics, which emerge soon after the Upper Paleolithic." Rather than being artistic cascades of dots and dashes, or even Paleolithic doodles, these patterns represented, for instance, a lunar calendar or a kill tally through the hunting season, said Marshack. He extended the idea of repeated use of images to the representational forms in painting and carving, a notion that had a lot of appeal in the interpretation of art as an integral part of prehistoric life.

Recently, however, support for Marshack's hypothesis began to erode. For instance, Randall White of New York University concludes that aspects of engraved patterns that had been assumed to be the product of repeated application of different tools over a period of time could in fact be produced by a single tool in a single engraving event. "When you use a flint burin to engrave a piece of bone the cutting edge evolves quite quickly," he explained to *Science*. As the edge dulls or chips with use the cross section of the incision changes, often abruptly. "In this way lines produced by one tool can look as if they were produced by many."

White also points out that although it is easy to engrave fresh bone, very quickly the surface becomes hard. "At this stage engraving becomes very difficult, and the marks look very different from those done in the surface of fresh bone." From these observations, derived from experiments on fresh bone, White concludes that the patterns of dots, lines, and arcs found on prehistoric bone objects were probably the product of single engraving events, not the gradual buildup of marks over a long period of time. "There is plenty of room for doubt about Marshack's hypothesis," says White.

D'Errico's approach was similar to White's, but he analyzed incisions made on pebbles by people at the very end of the ice age, the so-called Azilian tradition. By first making incisions on several hundred limestone pebbles and examining them under various sorts of microscopy, d'Errico was able to identify tell-tale indications of lines made by one tool, by different tools, and over different periods of time.

Armed with this database d'Errico then scrutinized 122 Azilian pebbles, dating from 12,000 to 10,000 years ago, and from 30 different sites in France. "Whereas various other artifacts have been regarded as lunar calendars or notation systems," notes d'Errico, "these pebbles can certainly be considered the fullest, most uniform, and best-dated collection of objects for which such an interpretation has been proposed." D'Errico's task was to determine whether the cascade of marks on each of the pebbles was etched in one sitting or by repeated application over a long period.

"We found that they had always been made by rapid, repeated tool movements," says d'Errico. "One is thus tempted to conclude that prehistoric man was more interested in the overall result." If the patterns were created at one sitting and not over a period, then the suggestion of calendrics must be rejected. "One may reasonably ask whether the idea of Upper Paleolithic calendars does not spring from our projection of what we imagine prehistoric man was like, as opposed to examination of the evidence with minds free of wishful thinking." ■ **ROGER LEWIN**

ADDITIONAL READING

R. White, "The manipulation and use of burins in incision and notation," *Can. J. Anthropol.* **2**, 129 (1982).
F. d'Errico, "Paleolithic lunar calendars: a case of wishful thinking?" *Curr. Anthropol.* **30**, 117 (1989).