

Pellas and Storzer find that in shocked whitlockites the density of etchable dislocations is so high that they cannot study fossil tracks. They then discount our evidence for  $^{244}\text{Pu}$  fission tracks in a whitlockite from lunar breccia 14321 on the grounds that most of our etch pits may have been due to dislocations.

In many lunar rocks we commonly observe whitlockites so badly shocked that they do not etch properly. In contrast to Pellas and Storzer, we have chosen not to focus attention on the difficulties of determining fission track ages in shocked crystals but to search for unshocked crystals. In breccias as complex as 14321, and in many rocks from Apollo 16 and Apollo 17 boulders, there is a large variability of shock effects, and with patience one can usually locate a few large, unshocked crystals in a large volume of sample. In our study of breccia 14321 we were very fortunate to find a large (300 by 500  $\mu\text{m}$ ) whitlockite which, although partially fractured into several otherwise unaltered smaller pieces, was not strongly shocked. It was on this crystal that we made the measurements of  $^{244}\text{Pu}$  fission tracks (1). Nowhere in that report did we refer to the crystal as shocked, in spite of the contrary statement in the second sentence of the comment by Pellas and Storzer.

We now discuss the evidence that etch pits in unshocked whitlockites, and their replicas, really correspond to fossil tracks and not to dislocations, as suggested by Pellas and Storzer. [Our concern about the distinction between etched fission tracks and etched dislocations and other defects goes back a decade (2).] In rock samples 14321 and 72255 we have observed variations in the track density within whitlockites and apatites which mirror variations in the induced fission track density in adjacent Lexan maps. The density of the etch pits in these grains thus varies with the uranium content, as it should if the etch pits correspond not to dislocations but to fission tracks. Our studies of the distributions of etch pit diameters and of track lengths in whitlockites from four lunar rocks reveal a distinctly bimodal character. We can attribute the large pits (long tracks) primarily to fission with a small contribution from iron-group cosmic rays, whereas the small pits (short tracks) are almost certainly due to spallation recoils. The density of the small pits is proportional to the cosmic-ray exposure age of the parent rock and semi-

quantitatively agrees with the production rate of about one track per square centimeter per year determined by Crozaz *et al.* (3). It is not plausible that etched dislocations would have a bimodal length distribution or that the density of "underetched fission tracks" (that is, dislocations; see Pellas and Storzer) should correlate with the cosmic-ray exposure age of the whitlockite. In an igneous clast that had accumulated a high density of iron-group cosmic-ray tracks in the lunar soil before it was incorporated into breccia 14301, we measured about the same track density in a whitlockite grain and in an adjacent feldspar grain. The cosmic-ray tracks in the whitlockite became visible after a 70-second etch in 0.1 percent  $\text{HNO}_3$ , claims of Pellas and Storzer to the contrary notwithstanding.

The strongest evidence that our interpretation of the etch pits as  $^{244}\text{Pu}$  fission tracks was correct is the independent confirmation by isotopic rare gas analysis. Marti *et al.* (4) analyzed xenon isotopes in their sample of rock 14321 and attributed excesses of heavy xenon isotopes to the fission of  $^{244}\text{Pu}$ . Their inferred initial Pu/U ratio of 0.02 is in good agreement with the value 0.017 from our track analysis. Recently Braddy *et al.* (5) have derived a fission track age of  $\sim 3.94 \times 10^9$  years for rock 72255, based on our analysis of  $^{244}\text{Pu}$  and  $^{238}\text{U}$  fission tracks. Reynolds and his co-workers (6) have since determined a  $^{39}\text{Ar}$ - $^{40}\text{Ar}$  age of  $4.00 \pm 0.03 \times 10^9$  years for the same rock. In these two whitlockites from different rocks, the ratio of the fission track density to the uranium concentration is virtually the same, even though the uranium concentrations differ by a factor of about 4.

We conclude that meaningful fission track ages can be determined in unshocked whitlockites without interference from dislocations.

I. D. HUTCHEON, P. B. PRICE  
*Department of Physics, University of California, Berkeley 94720*

#### References and Notes

1. I. D. Hutcheon and P. B. Price, *Science* **176**, 909 (1972).
2. R. L. Fleischer, P. B. Price, E. M. Symes, *Am. Mineral.* **49**, 794 (1964).
3. G. Crozaz, R. Drozd, H. Graf, C. M. Hohenberg, M. Monnin, D. Ragan, C. Ralston, M. Seitz, J. Shirck, R. M. Walker, J. Zimmerman, *Geochim. Cosmochim. Acta* **2** (Suppl. 3), 1623 (1972).
4. K. Marti, B. D. Lightner, G. W. Lugmair, *Moon* **8**, 241 (1973).
5. D. Braddy, I. D. Hutcheon, D. Macdougall, J. Stevenson, unpublished results.
6. D. A. Leich, D. Phinney, J. H. Reynolds, unpublished results.

22 November 1974

## AAAS NEWS

(Continued from page 826)

"Aging and the Quality of Life," "Information Technology and Individual Privacy," and "Can Arms Control Succeed?" In all, NPR broadcast 12 hours of programming from the meeting.

Indubitably, the subject that pleased NPR the most, being a perfect marriage of content and media, was Professor Thomas Stockham's presentation on his work in recovering and simulating the voice of Enrico Caruso.

## AAAS Board Urges Continuation of ERTS

On 23 January, the AAAS Board of Directors issued a statement urging the continuation of the Earth Resources Technology Satellite (ERTS) Program at least through the launch and operation of a third satellite. The statement pointed out that "A promising but exotic technology such as ERTS requires a number of years of experimentation and refinement to define the range of opportunities, stimulate utilization mechanisms, perfect the technology, . . . [and] provide a base for future operational systems funded appropriately by private and public sources."

The ERTS satellites are essentially orbiting platforms which are equipped to observe and map the resources and topography of Earth. The first satellite, ERTS 1—recently renamed LANDSAT 1—was launched in July 1972 and has returned more than 100,000 images to Earth. LANDSAT 2 was launched January 22 of this year. A third LANDSAT is in the planning stages. At the time of the Board's statement the funding of the third LANDSAT and further ERTS efforts was in question.

The statement, sent to Chairman Moss of the Senate Space Sciences and Aeronautics Committee and Chairman Teague of the House Committee on Science and Technology by AAAS President Margaret Mead, points out that this program "could lay the foundation for an informational tool and utilization system of unparalleled value to the entire world," but that "further innovations and technical advances are required" especially the improved use of the ERTS "information in earth resource decisions, management, and policy." For further information or a copy of the Board statement, contact Dr. Richard Scribner, AAAS.