invalidate the results; descriptive statistics do not require controls. Fortunately, however, Posavac provides us with a comparison between MMPI scores from both patients with pain and other medical patients. Note that his factor 1 is a manifest subjective distress factor, with very high loadings on depression (D), anxiety (Pt), confused thinking (Sc), and introversion (Si). This factor is *not* to be found in our patients with chronic pain and suggests a striking difference between the two groups. As further support for differences between the patient groups, we refer Posavac to a paper (*5*) (of which Swenson is a coauthor) which shows clear MMPI differences between pain patients and other medical patients. Merskey and Spear (*6*) review numerous similar findings.

Wolff objects to our interpretation of factor 1. We quite agree with him that this factor is independent of the pain factor, and pointed this out. We also emphasized that the average scores on the scales comprising this factor were within normal limits; were they not, they would have suggested an interpretation of a psychoticism factor. However, the average scores were not "similar to those of the standardization healthy norm group." They are a standard deviation (on the average) above the mean, reflecting a distinct (albeit subclinical) difference from the healthy norm group. This supports our labeling and interpreting the cluster of scales on factor 1 as an "interpersonal alienation and manipulativeness" factor. In addition, we described this finding as supporting clinical descriptions of pain behavior, rather than vice versa (*7*).

Finally, Bookstein's comment that "factor 1 does not load on any variables of the pain cluster, so its estimation is useless for the clinical treatment of pain" represents a common confusion that we were very careful to avoid. We state that factor 1 has clear implications for the rehabilitation of patients with pain, not for treating pain (*8*).

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References and Notes

1. N. H. Nie, D. H. Bent, C. H. Hull, *Statistical Package for the Social Sciences* (McGraw-Hill, New York, 1970), p. 220.
2. B. B. Wolff, *J. Abnorm. Psychol.* **78**, 291 (1971).
3. R. A. Sternbach, S. R. Wolf, R. W. Murphy, W. H. Akeson, *Psychosomatics* **14**, 226 (1973).
4. M. R. Bond, *Br. J. Psychiatr.* **119**, 671 (1971).
5. L. F. Pilling, T. L. Brannick, W. M. Swenson, *Can. Med. Assoc. J.* **97**, 387 (1967).
6. H. Merskey and F. G. Spear, *Pain: Psychological and Psychiatric Aspects* (Ballière, Tindall & Casell, London, 1967), pp. 71–87.
7. G. Timmermans and R. A. Sternbach, *Science* **184**, 806 (1974).
8. This confusion has impaired both the treatment of pain and the rehabilitation of pain patients. See R. A. Sternbach, *Pain Patients: Traits and Treatment* (Academic Press, New York, 1974).

20 November 1974

Plutonium-244 Fission Tracks: An Alternative Explanation for Excess Tracks in Lunar Whitlockites

Recently Hutcheon and Price (*1*) reported on the presence of ^{244}Pu fission tracks in lunar breccia 14321. The mineral phase investigated for its fossil track record was a large *shocked* whitlockite crystal; the fission track excess attributed to the spontaneous fission of ^{244}Pu was of the order of 30 percent. This finding seems to be supported by the observation that in situ-produced fission xenon of ^{244}Pu was present in the same rock (*2*). However, as the ^{244}Pu fission track excess is rather small, it could be due to several factors which have not been considered by Hutcheon and Price. (i) Using the spontaneous fission decay constant 8.46×10^{-17} year^{-1} (*3*) rather than 6.85×10^{-17} year^{-1} (*4*) for the calculation of the ^{238}U fission track contribution within 3.95×10^{9} years would lower the apparent track excess by about 20 percent. (ii) Lunar whitlockites are known to be highly enriched in rare-earth elements (*5*). Therefore, because of the high thermal neutron absorption cross section of gadolinium, the uranium content of the whitlockite measured with a given thermal neutron flux in the reactor could have been underestimated by Hutcheon and Price, which in fact would also lower an apparent track excess. For instance, the presence of 1 percent gadolinium in a 500-μm crystal would lower the uranium content apparently by about 20 percent. (iii) A misinterpretation of dislocations as fission tracks would also explain an apparent track excess. As we have evidence for the existence of dislocations in whitlockites of breccia 14321, we will concentrate our discussion only on this subject.

One polished section of this rock, previously studied for the cosmic-ray track record (*6*), was surveyed for whitlockites. By a process of alternate polishing (in steps of 10 μm) and etching (for 30 seconds at 22°C in 0.25 percent HNO_3 solution) ten whitlockites ranging in size between 6 and 30 μm were found. The densities of etch pits determined by optical and scanning electron microscopy (SEM) on replicas were found to range between 0.18×10^7 and 34×10^7/cm^2. When the etch-pit densities are low, the alignments of many pits can be observed. Two crystals having etch-pit densities of 0.18×10^7 and 16×10^7/cm^2, respectively, were large enough (~ 25 by 15 μm and 30 by 18 μm) to be studied in more detail. After the first etching they were irradiated with ^{252}Cf fission fragments in order to superimpose on them track densities of 2×10^7 and 50×10^7/cm^2, respectively. Then the crystals were etched for 30 seconds (same conditions), and we observed that their etch-pit densities remained the same as before (Figs. 1 and 2). In other words, the ^{252}Cf fission tracks were not revealed. In the crystal with the low etch-pit density the fission tracks were visible in the SEM after an etching time of 50 seconds; however, the heavily corroded crystal surface made their observation difficult. In the crystal with the high etch-pit density the surface was completely destroyed after etching for 50 seconds and, therefore, fission tracks were not visible.

In another attempt to verify the nature of the etch pits in the whitlockite grains of breccia 14321 we erased a possible fossil fission track record by maintaining the whitlockite sample at a temperature of 500°C for 1 hour. At this temperature fission tracks are completely erased in chondritic whitlockites. In the annealed chip we found ten more whitlockites (between 5 and 15 μm) by applying the same procedure as before. In these crystals the etch-pit densities ranged between 0.4×10^7 and 15×10^7/cm^2, that is, in about the same interval as that found in the unannealed sample. The crystal with the lowest etch-pit density (in fact, there were only five etch pits) was then irradiated with $2 \times 10^7/cm^2$ fission fragments of ^{252}Cf. By etching in steps of 30 seconds each, the ^{252}Cf fission tracks became visible after 60 seconds with the expected track density and with a length of about 0.5 μm. In this case the fission track pattern was clearly distinguishable from the earlier pattern of five etch pits which by this time had increased in size.

From the above results we arrive at the following conclusions: (i) The etch-pit records of the 20 whitlockites studied in our sample 14321 are most probably dislocations. (ii) In order to convert the fission tracks in our whitlockites into a form visible in an SEM, etching times of about 50 seconds (0.25 percent HNO_3 at 22°C) are required. However, depending on the density of dislocations, most whitlockites disintegrate prior to the revelation of fission tracks because the dislocations as well as other shock features etch much faster.

Since our whitlockites contain dislocations to various extents, it can be argued that the shocked whitlockite studied by Hutcheon and Price (*1*) possibly contained dislocations also. Indeed, these authors etched their crystal for 30 seconds with the same etchant we used. Then they counted on a replica only the long "tracks" and rejected the very short ones as being due to spallation recoils. It can, therefore, be argued that what they considered to be fission tracks might well have been dislocations, whereas their "spallation recoil tracks" might have been in part underetched fission tracks. Thus the "track excess" attributed to ^{244}Pu fission is by no means convincing.

The evidence for dislocations in lunar whitlockites does not appear to be restricted to breccia 14321. For example, Burnett *et al.* (*7*) suggested that, in a whitlockite of breccia 12013, many of the etch pits were probably dislocations owing to their alignment. In this respect also the so-called "hot spots" [that is, regions enriched in etch pits, whereas uranium is homogeneously distributed (*8*)] could be interpreted in terms of dislocations; the same features are also observable in shocked chondritic whitlockites. The same interpretation might also hold for the ^{244}Pu track record in whitlockites from Apollo 15 KREEP (potassium, rare-earth elements, and phosphorus) basalt fragments suggested by Haines *et al.* (*9*). This interpretation is supported by the fact that the whitlockites studied came from lunar soils that are known to be frequently shocked to various extents. In addition, Haines *et al.* (*9*) etched their crystals for 10 seconds only with 0.1 percent HNO_3, an etching condition that would hardly seem likely to develop fission tracks but which might reveal dislocations.

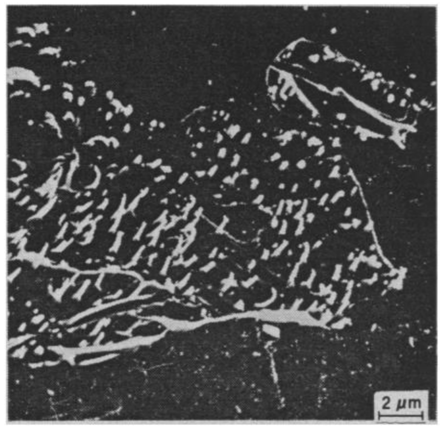

Fig. 1. Scanning electron microscope pictures of a plastic replica of a whitlockite crystal from breccia 14321. The sample was etched for 30 seconds in 0.25 percent HNO_3 at 22°C; this treatment revealed an etch-pit density of $1.6 \times 10^8/cm^2$.

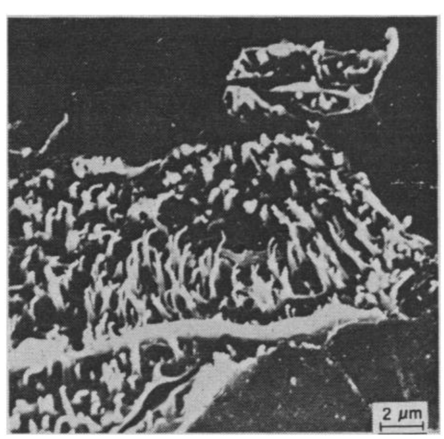

Fig. 2. Plastic replica of the same whitlockite as in Fig. 1, but after irradiation with $5 \times 10^8/cm^2$ ^{252}Cf fission fragments and additional etching for 30 seconds (same conditions). The etched figures increased in size but their number remained virtually the same; ^{252}Cf fission tracks were not revealed by this treatment.

The presence of in situ–produced fission xenon from ^{244}Pu in breccia 14321 (*2*) seems to suggest the presence of ^{244}Pu fission tracks in whitlockites from this rock. However, as shown above, they might not be observable in shocked whitlockites as the crystals disintegrate prior to track revelation. On the other hand, in chondritic whitlockites ^{244}Pu is up to two times more enriched than ^{238}U if compared to the bulk (*10*). Since plutonium exhibits the chemistry of the rare-earth elements rather than that of uranium, the enrichment factor should be even higher in lunar whitlockites. Therefore, provided fission tracks could be revealed in whitlockites of breccia 14321 (in unshocked crystals, for instance) and, provided fission track fading is negligible at lunar temperature within 3.95×10^9 years, then the expected fission track excess due to ^{244}Pu should be much higher than indicated from the ^{244}Pu fission xenon found in 14321 bulk samples (*2*) and, of course, much higher than the rather small "track excess" found by Hutcheon and Price (*1*). In short, as long as fission tracks in lunar whitlockites are not positively identified and dislocations [as well as spallation recoils (*8*)] are rigorously ruled out, claims for ^{244}Pu effects cannot be advanced.

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References and Notes

1. I. D. Hutcheon and P. B. Price, *Science* **176**, 909 (1972); I. D. Hutcheon, P. P. Phakey, P. B. Price, *Geochim. Cosmochim. Acta* **3** (Suppl. 3), 2845 (1972).
- K. Marti, B. D. Lightner, G. W. Lugmair, *Moon* **8**, 241 (1973).
3. A. Spadavecchia and B. Hahn, *Helv. Phys. Acta* **40**, 1063 (1967); D. Galliker, E. Hugentobler, B. Hahn, *ibid.* **43**, 593 (1970); W. Gentner, D. Storzer, R. Gijbels, R. Van der Linden, *Trans. Am. Nucl. Soc.* **15**, 125 (1972).
- R. L. Fleischer and P. B. Price, *Phys. Rev. B* **133**, 63 (1964).
- W. L. Griffin, R. Amali, K. S. Heier, *Earth Planet. Sci. Lett.* **15**, 53 (1972).
6. J. L. Berdot, G. C. Chetrit, G. C. Lorin, P. Pellas, G. Poupeau, *Geochim. Cosmochim. Acta* **3** (Suppl. 3), 2867 (1972).
- D. S. Burnett, M. Monnin, M. Seitz, R. M. Walker, D. Woolum, D. Yuhas, *Earth Planet. Sci. Lett.* **9**, 127 (1970).
8. 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).
9. E. L. Haines, I. D. Hutcheon, J. R. Weiss, in *Abstracts of the Fifth Lunar Science Conference* (Lunar Science Institute, Houston, 1974), p. 304.
10. G. J. Wasserburg, J. C. Huneke, D. S. Burnett, *J. Geophys. Res.* **74**, 4221 (1969); R. S. Lewis, *Geochim. Cosmochim. Acta*, in pre F. A. Podosek, *ibid.* **36**, 755 (1972); *Earth Planet. Sci. Lett.* **8**, 183 (1970).
11. We thank the unknown reviewer for constructive criticisms. Financial support for one of us (D.S.) was obtained from the Centre National de la Recherche Scientifique and the Deutsche Forschungsgemeinschaft.

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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}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 μm) 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}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 semiquantitatively 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 HNO_3, claims of Pellas and Storzer to the contrary not withstanding.

The strongest evidence that our interpretation of the etch pits as ^{244}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}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}Pu and ^{238}U fission tracks. Reynolds and his co-workers (*6*) have since determined a ^{39}Ar-^{40}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.

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References and Notes

1. I. D. Hutcheon and P. B. Price, *Science* **176**, 909 (1972).
2. R. L. Fleischer, P. B. Price, F. 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.