

# Reports

## Contaminated Meteorite

**Abstract.** One stone of the Orgueil meteorite shower contains an assortment of biogenic materials: coal fragments, seed capsules of the reed *Juncus conglomeratus*, other plant fragments, and an optically active, water-soluble protein material resembling collagen-derived glues. This sample seems to have been accidentally or deliberately contaminated shortly after the fall of the meteorite in 1864.

On 13 August 1962, one of us (A.D.F.) obtained a sample of the Orgueil carbonaceous chondrite from the Musée d'Histoire Naturelle at Montauban, France. This sample was a single stone of the Orgueil shower of 14 May 1864. According to the records of the museum, this stone (No. 9419) fell near Peillerot, and was turned over to the museum by Maître Fénicié, Mayor of Campsas, on some date between 27 May and 12 June 1864 (Fig. 1). This stone, weighing 34 grams, together with an 80-gram stone (No. 9420), was stored in a sealed glass display jar from 1864 until the spring of 1962, when the jar was opened by one of us (A.C.), and the 80-gram stone was sent to B. Nagy of Fordham University. The jar was closed but not resealed, and remained in the Orgueil exhibit of the museum during the summer of 1962.

Like most other Orgueil stones, the 34-g stone had crumbled during storage. In late July 1962, several grams were sent to Jean Deunff, micropaleontologist at Rennes, France. A few weeks later the remaining fragments, comprising 25.5 g, were brought to Chicago. The largest single fragment weighed 10.8 g and was covered to about one-fifth of its area with what appeared to be fusion crust (Fig. 2).

When we examined the sample in Chicago, we found it to contain several light-brown particles, up to several millimeters in size, unlike any we had ever seen in other samples of the Orgueil meteorite. Some of these appeared to be bits of gravel, and oth-

ers, plant fragments. One of two such structures, resembling seed capsules, is shown in Fig. 3, *a* and *b*. Both were firmly embedded in the black meteoritic matrix. A third capsule, of a different species, was found among the loose fragments (Fig. 4).

Although it was not embedded in meteoritic material, several black particles were firmly attached to it. It seems that it, too, had originally been embedded in the meteorite, but had become exposed when the meteorite crumbled apart. Similar plant fragments were independently discovered by Jean Deunff in his portion of the stone No. 9419.

Also found in the sample were several coal fragments. The majority of them were loosely dispersed, but one was deeply embedded in the large meteorite fragment shown in Fig. 2. That this material was indeed coal was confirmed independently by E. Olsen and H. P. Schwarcz, both of whom observed bedding planes, pyrite crystals, and other features characteristic of coal.

Since the plants were unmistakably biogenic, one might suspect that the plant- and coal-bearing fragments were not meteorite, but bits of soil inadvertently picked up with the meteorite. This idea seemed plausible, since the meteorite does have a dark color, similar to humus-rich soil (1). However, it was quickly ruled out by optical and x-ray diffraction examination of the plant-bearing fragments. The only minerals present in quantity were those making up the bulk of Orgueil—that is, magnetite, a layer-

lattice silicate ["Orgueil LM" (2)], epsomite, gypsum, troilite, and sulfur. A few grains of quartz and plagioclase (normally absent in Orgueil) were also found, suggesting a slight amount of contamination by terrestrial soil.

These findings were somewhat puzzling. Three alternative explanations suggested themselves for the origin of the plant fragments and coal embedded in the meteorite. (i) They were extraterrestrial. (ii) They were introduced into the stone accidentally; as, by plants growing through the stone. (iii) They were introduced into the stone by human intervention, either in an attempt to repair a broken specimen, or as a deliberate hoax.

The first possibility was initially viewed with some favor, since the plant fragments proved difficult to identify. However, such fragments are not easy to identify out of their natural setting, unless the person consulted happens to be especially familiar with the genus in question. We were not able to obtain a positive identification until February 1963, when the sample was returned to Montauban, and was recognized by one of us (A.C.) as belonging to a local reed, *Juncus conglomeratus* Linn. (Fig. 5) (3). The second capsule (Fig. 4) seemed to resemble *Alchemilla*, although the identification was not as definite in this case.

While we cannot completely rule out a chance resemblance between a terrestrial and an extraterrestrial plant, we believe that the similarity of the meteoritic capsules to southern French plants points strongly to terrestrial contamination, accidental or deliberate.

The second possibility, contamination by plant growth, seemed highly unlikely. Plants could have grown only in a moist environment, and the Orgueil meteorite is known to disintegrate in a matter of minutes upon exposure to water. Also, it is surprising that only seed capsules were present in the meteorite. A glance at Fig. 5 shows that the *Juncus* could not have grown through the meteorite without attracting some attention. Did the finder trim off the remaining parts of the plant, thereby concealing the extraneous origin of the capsules? This in itself would constitute a hoax. Moreover, the coal fragments could scarcely have "grown" into the meteorite.

This left the third possibility, that the sample had been altered by humans, as the only alternative. Orgueil is very friable, and disintegrates read-

ily in water. If the meteorite were moistened with water until it attained a pasty consistency, it might well be possible to mold foreign objects into it which would remain firmly embedded after drying. Possibly the epsomite in the meteorite, comprising about 15 percent of the total weight, might act as a binder. Tests showed that the material from No. 9419 could easily be molded into fairly hard and cohesive pellets which were somewhat less friable than similar pellets made from "normal" Orgueil. This greater firmness is not due to a difference in the epsomite content, which is virtually the same in the No. 9419 stone (14.7 percent) and normal Orgueil (15 to 17 percent). Curiously, these stones seemed to differ in their content of water-soluble, ultraviolet-absorbing organic matter. The spectra were featureless and very similar, but the specific absorbance of the No. 9419 extract was about 7 times greater than that of normal Orgueil.

Qualitative tests indicated that the excess absorbance was largely due to amino acids (4). An amino acid analysis by thin layer chromatography revealed some interesting differences between normal Orgueil and the No. 9419 material (5). Not only was the total level higher by a factor of about 8 (210 parts per million as opposed to 25 ppm), but certain amino acids such as arginine, aspartic acid, and proline were enhanced to a disproportionately high degree (Fig. 6). These differences can hardly be attributed to sample variability, since our analysis of normal Orgueil (shaded bars in Fig. 6) agrees remarkably well with the analysis of another Orgueil stone by Kaplan, Degens, and Reuter (6). Moreover, hydroxyproline, which was undetectable in normal Orgueil, was present in substantial amounts in sample No. 9419. This amino acid is an important and highly characteristic constituent of collagen, and hence of various animal glues and gelatin.

To investigate the possibility that sample No. 9419 had been contaminated with an animal glue, we examined a water solution of the amino acid fraction for optical activity at a wavelength of 5460 Å. A distinct rotation,  $\alpha = -0.0055 \pm 0.001$  degree, was found in the water extract. This result agrees rather well with the theoretical value (7) of  $-0.0064$  degree, calculated on the assumption that all amino acids detected in No. 9419 are the *l*-isomers normally found in

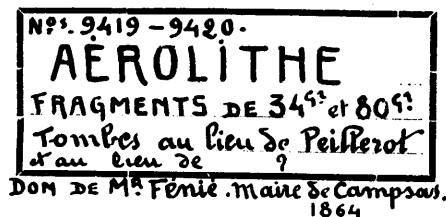


Fig. 1. Original label of Orgueil meteorite specimens Nos. 9419 and 9420 from Montauban Natural History Museum.

terrestrial living matter. Owing to the strong pH-dependence of optical rotation of amino acids, only an undetectably small rotation,  $+0.00018$  degree, would be expected in 1N HCl (7). Indeed, no optical activity was found when the sample was remeasured in 1N HCl.

In the normal Orgueil sample, no optical activity was detected. The expected rotation for a terrestrial assemblage was  $+0.0046$  degree in HCl solution and  $-0.0016$  degree in water. No activity was detected in either medium even when a Rudolph recording spectropolarimeter with a sensitivity of  $\pm 0.0005$  degree was used. It seems that most or all of the amino acids in normal Orgueil are racemic.

Apparently, sample No. 9419 has

been contaminated with a water-soluble protein of animal origin. Collagen typically contains about 5 to 15 percent hydroxyproline, so that the observed quantity of this amino acid, 15 ppm, would seem to correspond to no more than 100 to 300 ppm of protein. But the actual amount may well have been larger, about 0.1 percent or more, since the hydrolysis was carried out under relatively mild conditions where part of the protein would remain undecomposed.

What seemed to speak most strongly against the contamination hypothesis was the presence of fusion crust on the coal-bearing specimen in Fig. 2. However, this crust differed in some important respects from the fusion crust of other Orgueil stones.

The heat generated during flight through the atmosphere which melted the surface material of normal Orgueil stones to produce the fusion crust caused several profound changes that are almost impossible to obtain by other means. First, the mineral composition was altered: the layer-lattice silicate (Orgueil LM) was dehydrated and converted to olivine; the magnetite was progressively oxidized towards  $\gamma\text{-Fe}_2\text{O}_3$ ; accessory minerals (troilite,

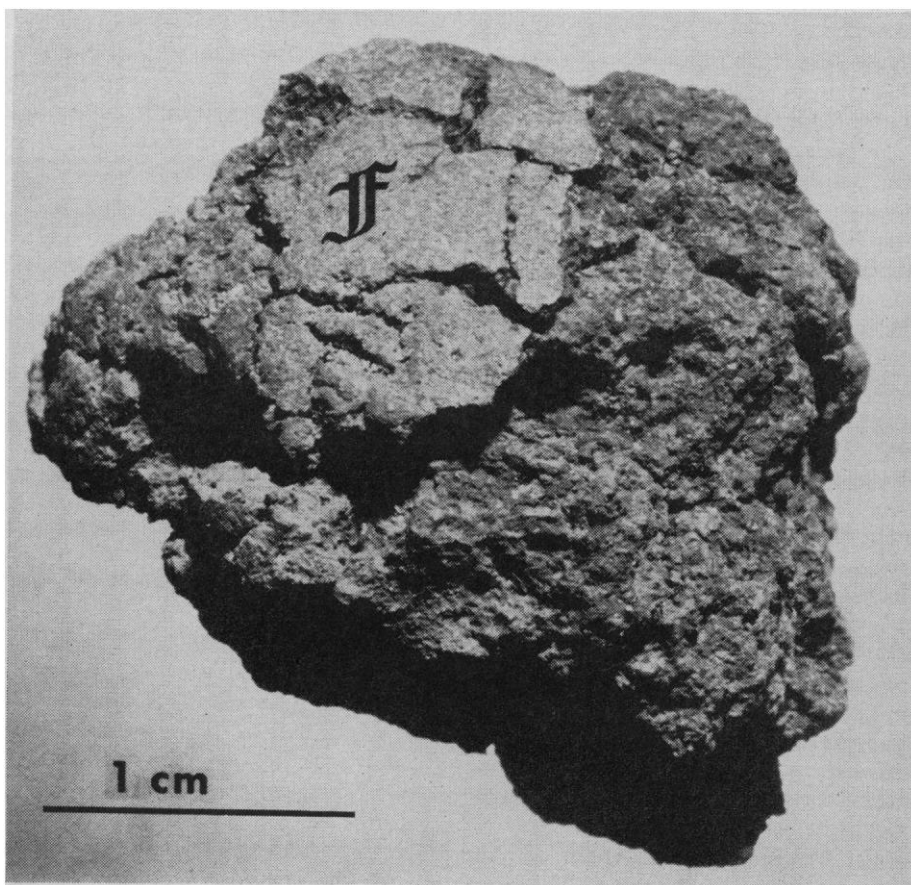


Fig. 2. Largest fragment of stone No. 9419 (F, "fusion crust").

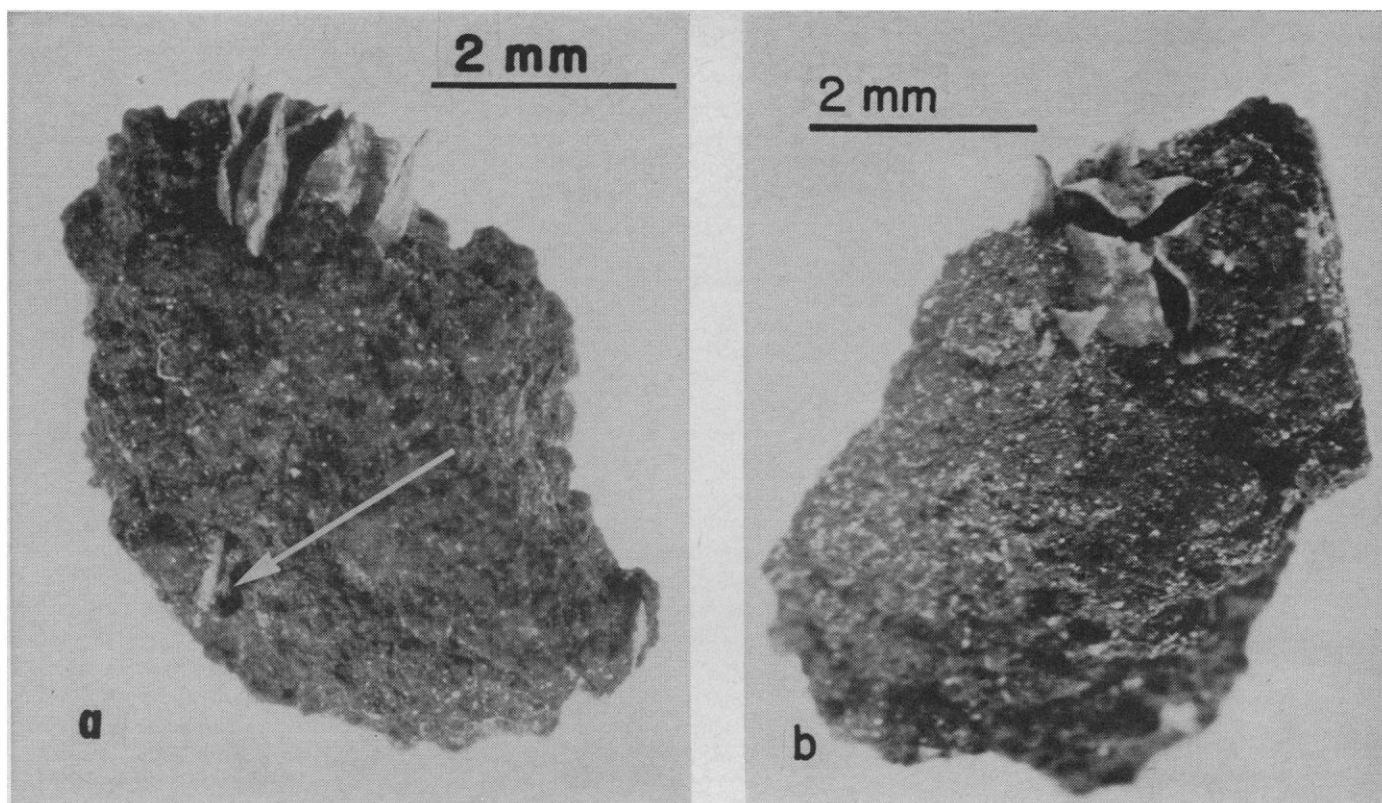


Fig. 3. (a) Seed capsule embedded in meteorite fragment. Arrow points to protruding stem. (b) The same fragment, end view.

dolomite, breunnerite, the calcium and magnesium sulfates) were destroyed; elemental sulfur was distilled away. Second, the morphology of the stones was changed: the crust is in some loci wrinkled in appearance due to slag-like threads or ridges; in others pocked with pores due to outgassing during the chemical processes mentioned above; in still others cindery, with a bubbly texture resembling lava. These generalizations are based on a study by one of us (E.R.D.F.) of over 100 carbonaceous chondrite individuals in the Washington, Chicago, Paris, and Montauban museums.

In contrast, the sample in question displays a "crust" with none of these characteristics. By x-ray diffraction it was shown to contain Orgueil LM, not olivine; salts were still present; plates of troilite were seen on the outer surface of the intact "crust"; sulfur was found embedded in it (as euheral orthorhombic crystals, melting point 114°C) rather than deposited on it; and the wrinkles, pores, and bubbles were absent. What is even more significant, a piece of genuine fusion crust was found in this specimen, embedded at right angles to the putative crust, so loosely attached that it soon fell off.

The meteoritic material itself also

differed somewhat from normal Orgueil, both macroscopically and microscopically. Although the total epsomite content of stone No. 9419 was quite normal, the textural distribution of this salt was definitely unusual. The white efflorescence and veining, which is characteristic of Orgueil, was completely lacking. In thin section, very

little epsomite was visible, and the texture looked somewhat disturbed. A quartz grain was present in the section (8). Together with the quartz and plagioclase grains mentioned previously, this constituted evidence for the presence of matter normally foreign to Orgueil.

The coal fragments, too, are almost

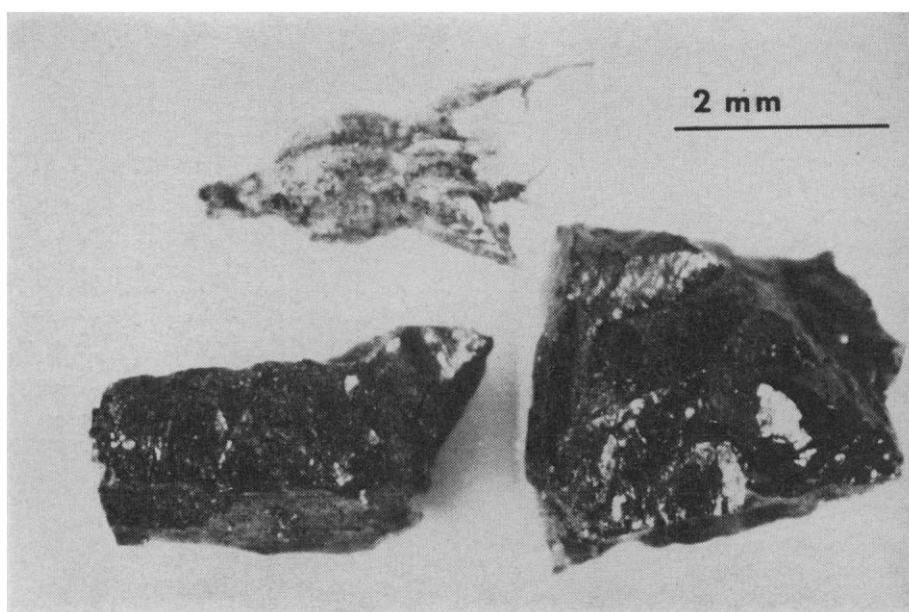


Fig. 4. A seed capsule of another genus, and two coal fragments found among disintegrated meteorite material.

certainly terrestrial. Since coal was not used as a household fuel in southern France during the 1860's, but was to be found mainly in blacksmiths' forges, it is not a very likely accidental contaminant.

There can be little question that stone No. 9419 has been contaminated. Most probably, the contamination occurred in 1864, shortly before or after the meteorite was put in the museum. However, we have not been able to establish with certainty whether the contamination was inadvertent or deliberate. Inadvertent contamination requires that someone picked up a partly disintegrated stone along with some plant and coal fragments and some glue, but very little soil. He must then have moistened the specimen, enough to render it plastic, but not enough to cause loss of epsomite, and molded it back into shape. He must have taken some pains with the job to produce such a remarkably good imitation of fusion crust.

Deliberate contamination calls for much the same sequence of events, except that the contaminants are assumed to have been introduced intentionally. Was there a motive for such

a deliberate hoax? Perhaps. In April 1864, only a few weeks before the fall of Orgueil, Pasteur delivered before the French Academy his famous lecture on the spontaneous generation of life (9). On 31 May 1864, 17 days after the fall of Orgueil, Cloëz (10) published an analysis of the meteorite wherein he noted the presence of materials resembling humic acid. He suggested that this implied the existence of life on the meteorite parent body. This report may conceivably have inspired a person of the proper disposition (either a local resident or a visitor interested in the meteorite fall) into playing a little practical joke on the scientists. Somehow the plot failed, and the contaminated stone went unrecognized for 98 years. Attractive though this hypothesis may be, we have found no support for it in the local newspapers of the time. Although the disintegration of the meteorite upon exposure to water was soon noted (11), no reference to extraterrestrial life was found in *Le Courrier de Tarn-et-Garonne* or *Comptes Rendus de la Société Sciences, Agriculture et Belles-Lettres de Tarn-et-Garonne* (12).

Both points of view have their merits, and we shall therefore let each reader follow his own preference in deciding whether the contamination was accidental or deliberate.

What bearing do these findings have on the purported evidence of extraterrestrial life in the Orgueil meteorite (13)? We must emphasize that sample No. 9419 is the only stone of the Orgueil shower for which we have evidence of alteration by human intervention. We have no reason to believe that the Orgueil meteorite samples in which Nagy *et al.* (13) claimed to have found evidence of extraterrestrial life (biogenic hydrocarbons and "organized elements") were similarly altered and contaminated. We have argued in previous publications (14) that the organized elements fell into two sharply distinct classes. Particles of the first class are scarce and, although they do have a strikingly biogenic appearance, they strongly resemble common airborne contaminants (for example, ragweed and juniper pollen, fly ash, and starch grains). These contaminants appear to have been accidentally acquired in the laboratory of Nagy *et al.* Ragweed, in particular, is a North Ameri-

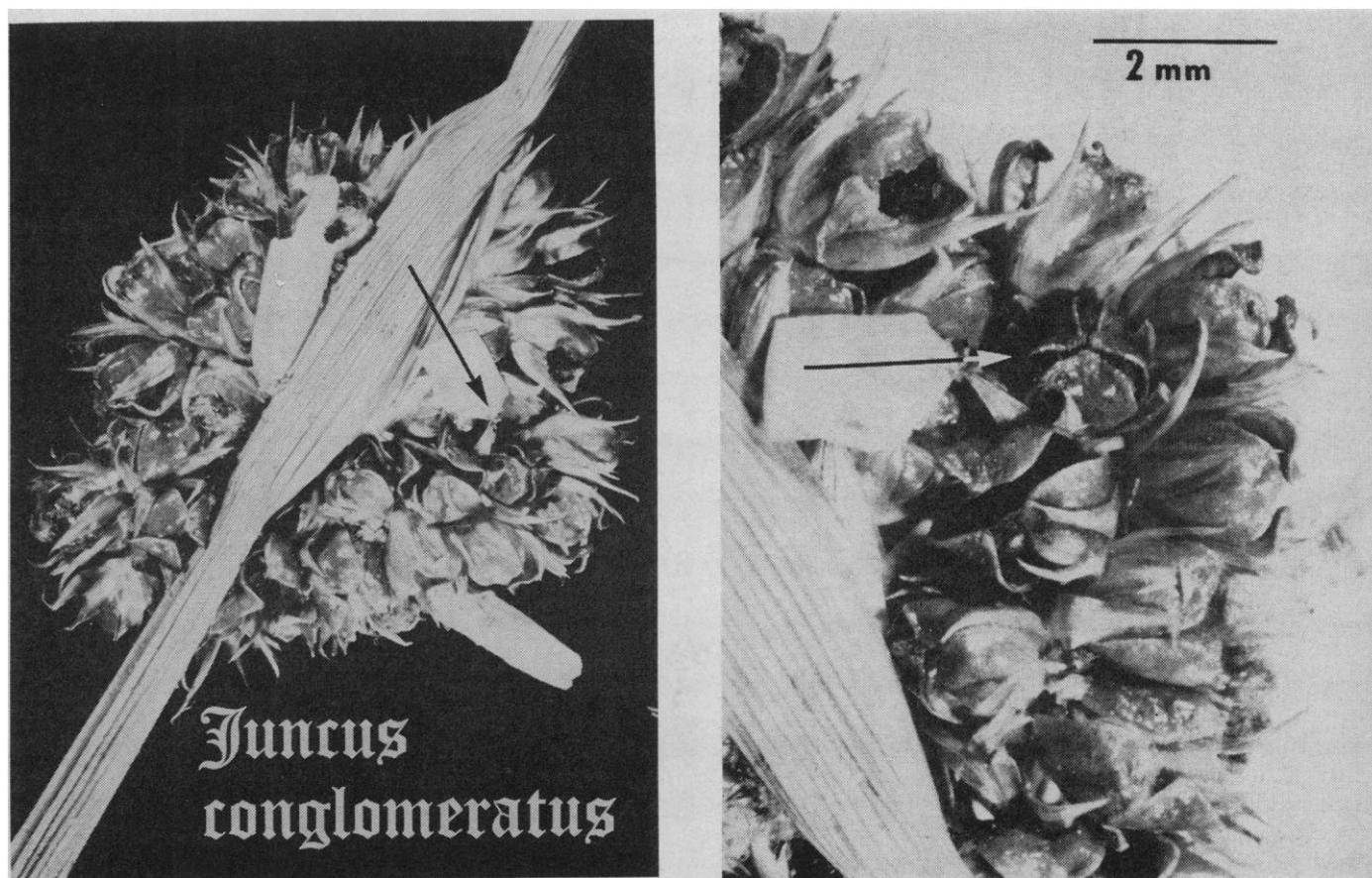


Fig. 5. Two views of the reed, *Juncus conglomeratus*, with seed capsules marked by arrows, which may be compared with the capsule shown in Fig. 3, (a) and (b).

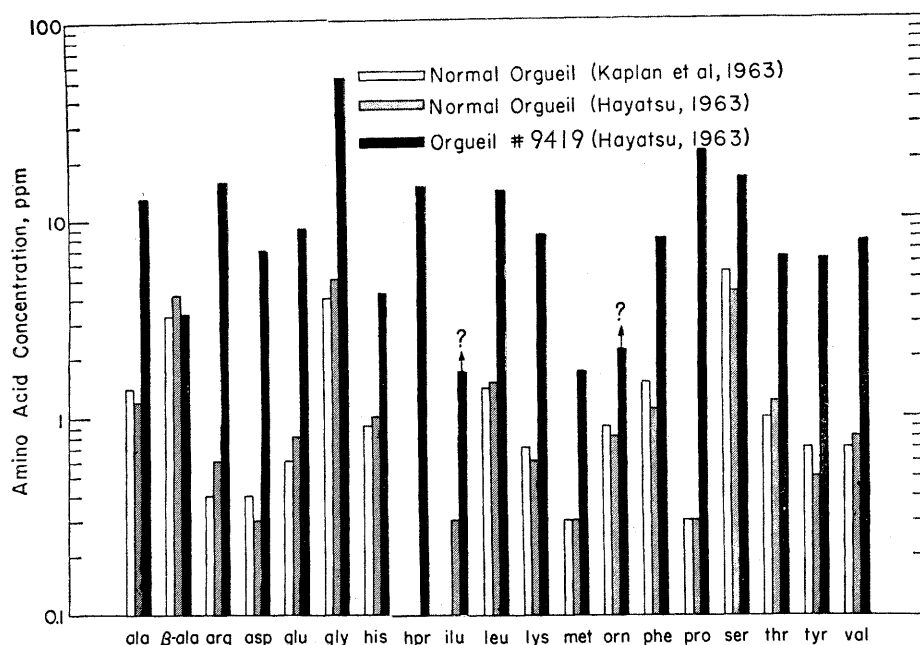


Fig. 6. Amino acid content of water extract from normal Orgueil and stone No. 9419. The individual acids are identified by the italicized portions of their names, as follows: *alanine*, *β-alanine*, *arginine*, *aspartic acid*, *glutamic acid*, *glycine*, *histidine*, *hydroxyproline*, *iso-leucine*, *leucine*, *lysine*, *methionine*, *ornithine*, *phenylalanine*, *proline*, *serine*, *threonine*, *tyrosine*, *valine*. Not detected were: tryptophan, norleucine, norvaline, sarcosine, and cystine. Four amino acids, arginine, aspartic acid, proline, and particularly hydroxyproline, are enhanced well beyond the generally increased level in the No. 9419 stone. This suggests contamination with a water-soluble protein.

can plant, and can hardly have entered the meteorite during storage in a European museum. Microscopic examination of stone No. 9419 failed to show a significant concentration of such highly structured particles. Instead we saw only the other abundant class of organized elements: greenish-yellow, vaguely rounded particles that we had previously observed in other, uncontaminated specimens of Orgueil. We had always maintained that these particles, while undoubtedly indigenous, were nothing but mineral grains. This point of view has now been confirmed by electron microprobe analysis (15), which shows these particles to consist either of limonite or of a hydrated silicate indistinguishable from the mineral matrix of the meteorite. Nagy *et al.* attach much importance to the fact that the limonite contains several percent of nickel and chlorine, but it so happens that these two elements are also present in limonitic rust of weathered iron meteorites (16). This similarity in composition may point to a similarity in origin. The organized elements may once have been metal grains which became oxidized to limonite during the preterrestrial "aqueous stage" (2) that produced the dolomite and epsomite.

The hydrocarbons, occurring at a

level of several thousand parts per million, are definitely indigenous, as pointed out earlier (17). But it was also noted that one cannot be equally certain of constituents in the 1 to 10-ppm range. This point gains additional emphasis from the observations reported in this paper.

To allay any suspicions that the contamination was the work of one or several of the present authors we wish to cite two facts. First, the plant fragments were independently discovered by Jean Deunff in another portion of the stone No. 9419. Second, all recent claims for extraterrestrial life in meteorites were based on hydrocarbons and microstructures. A hoax excluding these two, but including coal, plant fragments, and proteins makes little sense in the present controversy, though it might have made a good deal of sense in a similar controversy a century ago.

We have kept in close communication with Nagy and are satisfied that his material has not been similarly altered. Nevertheless, these observations point to the possibility that another contaminated Orgueil stone may exist somewhere. All the Orgueil stones now kept in museums passed through the Montauban Museum at one time, since the latter acted as a clearing

house for the distribution of the meteorite. It is not altogether improbable that a few other stones were similarly altered at that time and are now quietly reposing in some museum. We hope that the criteria described in this paper will make it possible to recognize such material.

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#### Notes and References

1. Actually, the soil in the region of Orgueil and Campsas is whitish or whitish-yellow. It is very poor in humic material and consists largely of minute quartz grains, 20 to 100  $\mu$  in diameter.
2. E. R. DuFresne and E. Anders, *Geochim. Cosmochim. Acta* **26**, 1085 (1962).
3. The identification as *Juncus* was proposed independently by R. Ross of the British Museum.
4. We are indebted to R. Gordon for performing these preliminary tests.
5. To obtain the amino acid fractions, the samples were extracted with water in a Soxhlet extractor for 24 hours. Both fractions were tested for proteins and peptides by infrared spectroscopy and the biuret color reaction. Only the extract from No. 9419 gave a positive test. It was therefore hydrolyzed with 20 percent HCl for 8 hours at 120°C. Both fractions were separated from inorganic salts on a Dowex-50 cation exchange column.
6. I. R. Kaplan, E. T. Degens, J. H. Reuter, *Geochim. Cosmochim. Acta* **27**, 805 (1963). Some fraction of the amino acids in normal Orgueil is undoubtedly due to contamination but this is immaterial for the present discussion.
7. J. P. Mathieu, J. Roche, P. Darville, *Amino Acids*, vol. 3 of *Optical Rotatory Power*, vol. 10 of *Tables of Constants and Numerical Data* (Pergamon Press, New York, 1959).
8. Identified by K. Fredriksson, B. Mason, and B. Nagy.
9. Walter Sullivan of the New York Times kindly brought this fact to our attention.
10. S. Clötz, *Compt. Rend.* **58**, 986 (1964).
11. M. Peyridieu, *Le Courrier de Tarn-et-Garonne* 17 May 1864.
12. We are grateful to Mr. C. C. Herrmann for assistance in this search.
13. B. Nagy, W. G. Meinschein, D. J. Hennessy, *Ann. N.Y. Acad. Sci.* **93**, 25 (1961); G. Claus and B. Nagy, *Nature* **192**, 594 (1961).
14. E. Anders and F. W. Fitch, *Science* **138**, 1392 (1962); F. W. Fitch and E. Anders, *ibid.* **140**, 1097 (1963); *Ann. N.Y. Acad. Sci.* **108**, 495 (1963).
15. B. Nagy, K. Fredriksson, H. C. Urey, G. Claus, C. A. Anderson, J. Percy, *Nature* **198**, 121 (1963).
16. J. D. Buddhue, *The Oxidation and Weathering of Meteorites* (Univ. of New Mexico Press, Albuquerque, 1957); E. Cohen, *Meteoritenkunde* (Schweizerbart, Stuttgart, 1903-1905), vol. 2, pp. 263-268, vol. 3, pp. 77-78.
17. E. Anders, *Ann. N.Y. Acad. Sci.* **93**, 651 (1962).
18. This work was supported in part by NASA grant NsG-366 research.

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