scale by means of the relation $(B - b) = 0.324$ mag for Uranus and $(B - b) = 0.303$ mag for Neptune.
8. The oblateness of Uranus is important because the rotational axis of the planet lies nearly in the ecliptic plane. Hence, the apparent cross section varies as Uranus revolves around the sun. The pole of Uranus last faced Earth in 1946. Photometric oblateness corrections have the form (for an ellipsoid of revolution)
$$\Delta \text{mag} = 1.25 \log[1 - (1 - b^2)\cos^2(\theta - L)]$$
where b is the ratio of the polar-to-equatorial diameter (unity minus the oblateness) and $(\theta - L)$ is essentially the Uranocentric colatitude of Earth [see (6)]. Two modern determinations of the oblateness are 0.01 ± 0.01 [R. E. Danielson, M. G. Tomasko, B. Savage, *Astrophys. J.* **178**, 887 (1972)] and 0.03 ± 0.008 [A. Dollfus, *Icarus* **12**, 101 (1970)].
9. I thank M. J. Price and the participants at the Solar Constant Workshop for illuminating comments. Supported since 1972 by the National Science Foundation.

7 July 1975

The Flowers Found with Shanidar IV, a Neanderthal Burial in Iraq

Abstract. *Analysis of soil samples from the Shanidar IV burial, Shanidar cave, revealed the same pollens throughout the sequence, with variations in frequency. However, samples 313 and 314 contained, in addition, several pollen clusters of as many as 100 pollen grains, evidence that complete flowers were introduced into the burial cave.*

Soil samples from Shanidar cave have been available since 1960 (*1*). The first palynological analysis indicated that the samples were poor in pollens and thus very difficult to process. Certain levels appeared to be completely sterile. In addition, a palynological atlas was still to be drawn up, and no other analysis had been undertaken in the area. Because of these difficulties, I dropped the idea of a larger and more complete report, even though I had already published a few articles touching on the botanical problems at Shanidar (*2*). I thought that other, richer paleolithic stations in the Near East would be discovered. However, no cave has yielded a last glaciation (Würmian) sequence of pollen evidence comparable to that of Shanidar. Since my comparative collection of recent flora is now much enlarged, and the pollens of Zawi Chemi and of Shanidar represent the only series associated with paleolithic industries, I decided to proceed with a new assay.

The preparations already done were restudied, and all of the samples not yet worked on were examined. Those determinations too ambiguous, as on difficult and fossilized pollen specimens (date and chestnut), were discarded. Even though the older layers yielded extremely poor results, the collection of about 6,000 determinations for Shanidar cave and 10,116 for Zawi Chemi Shanidar (the nearby early village site) gives a general view of the flora and its history.

With a few exceptions, the same pollens are found throughout the Shanidar cave sequence from top to bottom. However, their frequencies vary, particularly those of the arboreal pollens, which are clearly more numerous in the older levels. Climatic oscillations prompted fluctuations in the flora, but as a whole the assemblage remains very uniform.

Then, in 1968, two newly prepared samples (numbers 313 and 314) appeared, from almost the first glance, to be different from the others. The number of composites in these samples greatly exceeded those of the other samples. A remarkable fact was that instead of the normally isolated pollen grains found in caves, many of them appeared to be clustered in groups which contained from two to more than 100 pollen grains. Certain of these clusters have retained the form of the anther of the flower. Finally, another unusual trait manifested itself: of the 28 different plants identified in the samples, only seven were found in clusters. Some of these clusters contained two or three different species of ag-

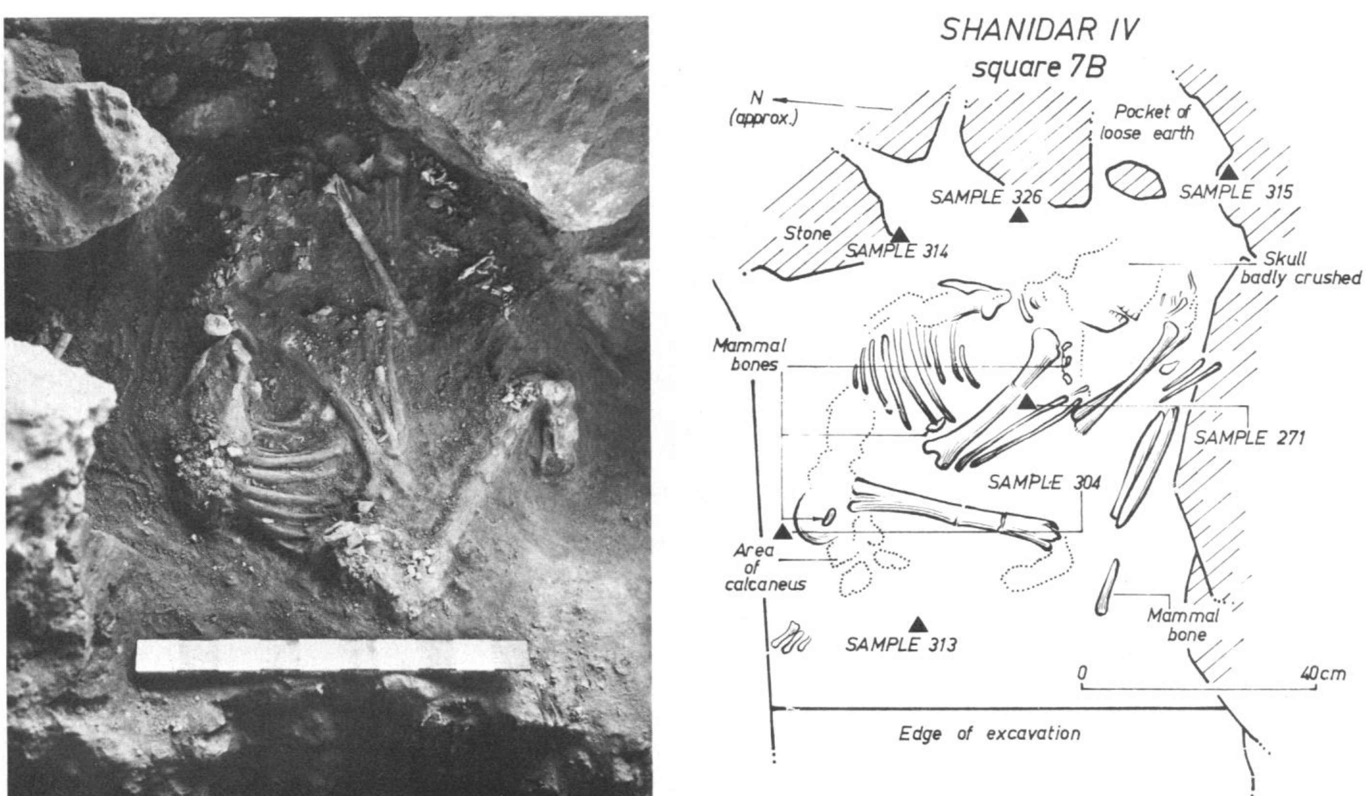

Fig. 1. Shanidar IV, as exposed in the niche of stones in Shanidar cave, northern Iraq; (left) photograph; (right) diagram. The long bones to the upper right of the skeleton belong to another Neanderthal, Shanidar VI. [Photograph courtesy of Ralph Solecki]

glutinated pollens. Thus we may conclude that complete flowers (at least seven species) had been introduced into the cave at the same time.

Although the remains of flowers or catkins are found from time to time in open-air sites (habitation or lacustrine deposits), their presence is unnatural in the interior of a cave. These two samples were collected at a distance of 15 m from the cave entrance; neither birds, nor rodents, nor the presence of mammalian coprolites can explain the presence of the assemblage of flowers—unique among our samples. My first efforts, therefore, were directed toward the precise location of the two samples concerned.

The stratigraphy of Shanidar cave is very complex because of marked slopes and the fallen boulders, often of great dimensions, which have disturbed certain zones. The work of the archeologist was impeded by these difficulties and the fact that the excavation had to proceed rapidly because it lay within the proposed Bekhme dam area, a threat at the time. Despite these difficulties, the metric coordinates were plotted with a great precision by Ralph Solecki (*1*). This precision has proven to be of utmost importance for my analysis.

The first check on the origin of the samples indicated that numbers 313 and 314 formed part of a series of six samples collected in the grave of the Neanderthal, Shanidar IV. Three of these samples (numbers 315, 326, and 271) had already been processed and analyzed. They appeared to be no different from the samples from the other levels of the cave. The remaining sample of the series, number 304, was also processed. Although not rich in pollens, this sample appeared to contain groups of agglutinated pollens, and in its dominant species, it is clearly related to sample 313. In fact, the two samples are separated by a horizontal distance of only 25 cm.

The positions of the samples are located on the plan of Shanidar IV (Fig. 1). Here, one should cite the following notations of Ralph Solecki (*3*) in his excavation notebook:

"*Sample 271*: Loose brown sandy loam; above the middle of the skeleton proper, 7.57 m.
Sample 315 and sample 326: south and east of Shanidar IV, on same level.
Sample 313: Soil sample from below and to west of Shanidar IV.
Sample 314: 20 cm. N.E. of Shanidar IV; dark brown loamy soil overlying what looks like a dark organic discolored layer.
Sample 304: Shanidar IV skeleton, soil sample, north of the pelvis area."

In his notes, Solecki observed the difference between the two soils: "the soils around the skeleton seemed to be lighter and looser above and around the skeleton than the soil below, which was loamy and tough." It is evident that the upper soil is posterior to the burial of the individual; this is also true for those sediments which infiltrated between the bones. Samples 271, 315, and 326 belong to this upper soil. The soil of the grave on which the skeleton lay is dark and humic. Trace elements analysis has not yet been carried out on this soil.

Table 1. Distribution (numbers) of clusters found in three samples.

Flower	Isolated pollens	Clusters	Mixtures of species	Minimum number of pollen grains
Senecio and *Achillea*	411	61	15	880
Centaurea	399	70	7	780
Ephedra altissima	25	7	12	74
Muscari	16	7		41

When viewed under the microscope, the soil of the grave is certainly different from the other soils. Not only is it richer in pollens, but it contains numerous vegetal elements. Very small pieces of wood were noticed during the preparations for pollen analysis (*4*). One fact which may be of ethnobotanical interest is that some wood specimens are carbonized, but the majority of the specimens, among which were those which could be identified, were not. This implies that the wood had been introduced into the grave for some purpose other than for fire. Pieces of vegetal tissue confirm the presence of numerous plants which decayed in the relatively humid layer at that level in the cave. This level was later buried under more than 7 m of deposit.

In one of the slides of sample 313 an unusual object was detected. It was identified as a scale of a butterfly wing (Fig. 2). It needs little imagination to suppose that a butterfly alighted on a flower that was subsequently introduced into the cave (*5*).

A stalagmitic crust is intercalated between the levels at a depth of 8.6 m, indicating a humid period, a phenomenon corroborated by the palynological results. The maximum variety of arboreal species occurs in the lowermost Mousterian levels. Shanidar IV is situated 1 m higher, but coincidence of humid climate with the introduction of a large amount of vegetal and organic matter have without doubt induced the formation of the very humic level. This layer was covered and sealed in by sediments and rockfall, preserving it for millennia.

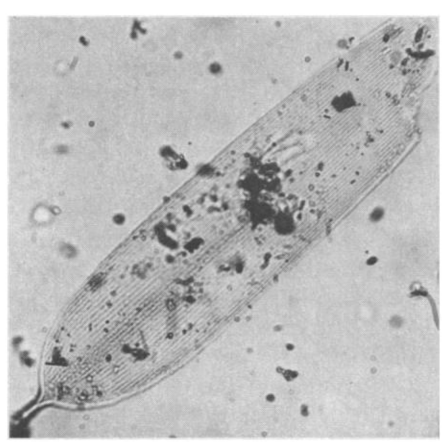

Fig. 2. Butterfly wing from sample 313 (× 400).

It is regrettable that no additional samples were taken at points in the soil which could have permitted the more exact delineation of the deposit associated with plant remains. Shanidar IV was placed in an enclosure of stones which apparently bounded the grave. We now examine the three flower-bearing samples.

Fortunately, samples 313 and 314 are situated on either side of the skeleton and it seems probable that the deposit was continuous under the skeleton. A number of the plants identified are of a long-stemmed variety; others on the contrary are small with short stems (*Muscari*-type, for example). Thus there must have been a certain number of the same plant species since the same flowers are found separated by a distance of 67 cm, that is, the distance between the two samples. Any displacement seems improbable in the deposit.

Number 304, collected from behind the skeleton, is much poorer in flowers. However, this same sample shows the greatest density of wood fragments.

More than 2000 pollen grains have been identified in the collection of samples 313, 314, and 304. The majority of these pollens come from those species which were present in clusters, that is, those which arrived at their position in the cave as actual flowers. The remainder of pollen grains, numbering 226 and representing 20 different species, consists of isolated grains that were deposited following the same process as in the other levels, that is, carried in by humans, animals, wind, and infiltration of soil from outside the cave. These pollen grains represent the normal deposit in this cave interior; their number and the types of plants present conform completely to the other normal samples analyzed.

The flora is dominated by herbaceous plants. In order of decreasing importance, one finds Compositae, chenopods (goosefoot), Gramineae (grasses), Caryophyllaceae, *Ephedra* (types *dystachya* and *fragilis*), Dipsacaceae, *Artemisia*, and several others.

The arboreal pollens are less numerous, constituting 25.6 percent of the total assemblage of 226 pollen grains. However, the introduction of pollens from small grasses into the cave was favored because of their tendency to be collected by humans and animals as they traversed grassland or clearings before entering the cave. The arboreal species are dominated by oak (19 grains), pine (17 grains), juniper (16 grains), and ash. Two pollen grains of fir should be particularly noted; possibly they were carried by the wind from a distance. However, in one of the samples, stratigraphically the closest at 7.5 m (in excavation square D-8), six pollen grains of fir were found. These two samples are the only ones containing fir pollens, although the study analyzing the wood fragments indicates that the presence of fir relatively close to the cave seems possible.

The geographic situation of Shanidar cave at an altitude of about 765 m places the cave within the zone of marked vertical gradients; the nearest summits reach 1900 m. Numerous valleys cutting the mountains suggest the presence of microclimates related to the different slope exposures. The early Würm period, during which the older Mousterian deposits were laid down in a relatively humid environment, allowed for a certain diversity of flora. Dry grassland with more or less steppic plants such as Compositae liguliflores, *Ephedra*, Chenopodiaceae, and *Artemisia* were coexistent with high-altitude forests composed principally of conifers; at the same time ash and alder were sheltered in the river valleys and the drier oak and pine extended over the sunnier slopes.

As the botanical identification of the flowers in the grave of Shanidar IV is particularly important, it was necessary to attain the greatest possible precision as to their specific identity. The large number of pollen grains, more than 1500 for the composites, was a welcome aid.

This exhaustive study was conducted at Gröningen in collaboration with W. van Zeist, whose knowledge of Middle Eastern flora permitted a maximum number of identifications to be made. We recognize seven different plants in the form of flowers. An eighth raises a problem which is discussed below. The most numerous flowers are: *Achillea*-type, *Senecio*-type, *Centaurea solstitialis*-type, Liliaceae (*Muscari*-type), and *Ephedra altissima*-type.

Two other species could not be identified. The first species was very numerous but the very small, three-furrowed pollens had absolutely no ornamentation. This excluded attribution even to a botanical family.

In the above list, the first four species cited contain herbaceous plants, the flowers of which have very brilliant colors: blue for the *Muscari*, yellow for the *Senecio*, and more varied for the other Compositae. This does not apply to the *Ephedra*, whose flowers are very small and less visible. On the contrary, its flexible and ramose branches lend themselves rather well to the making of some sort of bedding on which the dead could have been laid.

Another problem has not been resolved, namely, the presence of many Malvaceae (type *Althaea*) pollen grains. Very large, covered with spikes, and extremely easy to spot in the slides, they occur in small numbers in the majority of the levels of the cave. But here, their quantity is excessive when viewed in relation to current plant distribution. One hundred thirty-four Malvaceae and 108 assorted pollen grains (not including the flowers) were found in sample 313, and 125 Malvaceae and 93 assorted pollen grains were found in sample 314. Although they never occur in clusters, the percentage of these isolated pollens is inexplicable for the moment.

Table 1 shows the clusters found in the three samples and the isolated pollen grains of the same species. The numbers indicated for the clusters are only minimum numbers as it is often impossible to do countings in these very compact masses. Those of the Compositae (types *Senecio*, *Achillea*, and *Centaurea*) usually form groups of from 2 to 15 grains but some contain approximately 30 grains. Certain unidentified pollens can be much more numerous.

Thus, during one of the early phases of the Würmian period, a more humid climate than during the present time favored a more dense arboreal vegetation in the vicinity of Shanidar cave. Nowadays, in the Zagros Mountains, the flowers which we have cited bloom in the months of May through June. It is possible that because of the climatic changes, a slight difference in the period of bloom exists; but one may assume that the placement of the Neanderthal man, Shanidar IV, at Shanidar cave on a bed of ramose branches and of flowers occurred more than 50,000 years ago between the end of May and the beginning of July.

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References and Notes

1. R. S. Solecki, *Science* **139**, 179 (1963).
2. A. Leroi-Gourhan, "Le Neanderthalien IV de Shanidar," *Bull. Soc. Prehist. Fr.* **65**, 79 (1968); R. S. Solecki incorporated the data from this paper in *Shanidar; The First Flower People* (Knopf, New York, 1971).
3. R. S. Solecki, personal communication.
4. J. L. Vernet made the analysis and botanical identifications.
5. M. Girard made this observation.

25 January 1975; revised 27 May 1975

Galilean Satellites and Jovian Energetic Particles

Abstract. *The observed infrared temperatures of the four Galilean satellites, Io, Europa, Ganymede, and Callisto, are inconsistent with their equilibrium temperatures. Since these satellites appear to have little or no atmosphere, the discrepancies may be explained as due to the heating of their surfaces by energetic particles from Jupiter's radiation belts. The required energy fluxes are not entirely unreasonable and decrease with the distance of the satellite orbit from Jupiter.*

It is postulated here that the observed infrared temperatures of the four Galilean satellites, Io, Europa, Ganymede, and Callisto, may only be understood if there is an additional source of energy other than the sun supplying heat to the surfaces of these satellites; one such additional source may be high-energy particles in Jupiter's magnetosphere. Furthermore, there is some indication that the effect diminishes with distance from Jupiter. The large sodium clouds observed about Io are undoubtedly connected with such bombardment.

Observations of the infrared temperatures of Io, Europa, Ganymede, and Callisto have been summarized by Morrison and Cruikshank (*1*) for the wavelength regions from 8 to 14 μm and 17 to 28 μm. The principal values listed in Table 1 are the means of the lowest and highest values for the tolerances of the measurements as quoted by Morrison and Cruikshank (*1*). The deviations of these mean values from the lowest and highest values are indicated by the parenthetical values in Table 1. All the temperatures listed represent equivalent blackbody temperatures for the satellite radii shown in Table 1, as taken from (*1*).

Table 2 lists satellite orbital radii (in Jupiter radii) as well as the visible phase integral (q_v), geometric albedo (p_v), and Bond albedo (A_v) as taken from Morrison and Cruikshank (*1*) [see (*2*) for definitions of these terms].