Reports

Occultation of the Bright Star Regulus by Venus

Abstract. This occultation was observed and timed visually early in the afternoon of 7 July, in Madrid, Spain. The duration of the occultation was 11 minutes, 4.4 seconds, and mid-occultation occurred at 14 hours, 25 minutes, 9 seconds U.T. Over 600 individual photographs, which define the relative positions of Venus and Regulus, were obtained.

In this age it is no longer often that astronomers are given the opportunity to observe an astronomical event of significance and beauty for the very first time in recorded history.

The recent occultation of the bright star Regulus by Venus, on 7 July 1959, was such a rare event; there is, indeed, no record of its ever having been observed in the past.

I accordingly resolved to observe this occultation visually and to give my entire attention to watching the phenomenon as closely as possible, not only because this was an "astronomical first" but because no instrumental observation could be expected to cover the entire phenomenon as well as the eye. This was because Regulus was to disappear at the dark, nighttime limb of Venus and to reappear from behind the very bright, daylight limb; the eye is a remarkable instrument for handling such contrasts in brightness, whereas the photoelectric cell, for instance, is relatively helpless.

The occultation of Regulus could not be properly observed in the United States, and so, through the kindness of Donald Menzel, director of the Harvard College Observatory, who arranged for and directed several "occultation expeditions," and of the National Aeronautics and Space Administration, which gave financial support to the Smithsonian Institution for this venture, I was able to use a 5-inch visual refractor at the Madrid Observatory.

As I watched through the telescope, I kept up a running commentary which was recorded, along with two sets of independent time signals, on two tape recorders. (I had resolved to eliminate nearly all possibility of mechanical or electrical failure. As an additional backup, I also timed the event with a stop watch.)

In Madrid, the occultation occurred in the early afternoon, with Venus high in a bright blue, cloudless sky. For several days in advance, in practice sessions, I had set the telescope on Venus and Regulus separately, but by noon on 7 July, the two objects were already close together in the field, Venus looking like a miniature moon shortly before the first-quarter phase and Regulus like a twinkling bright star against a bright blue background.

It is not customary today in scientific accounts to dwell upon the beauty of a phenomenon. I would leave break with this custom to remark that the moments just before occultation presented a spectacle of singular beauty. If one considers the familiar crescent moon-and-star symbol as represented on a flag or other device, but now replaces it by a miniature, bright yellow, crescent moon with an actively twinkling greenish-yellow star almost within the crescent, and both set as living jewels in a clear turquoise matrix, one will, I hope, pardon my digression. The beauty of the spectacle was further enhanced for me by the knowledge that I was witnessing an extremely rare event, and one which would not again be observed for centuries to come.

Then, suddenly, the actual occultation was at hand.

The visual impression of the immersion was that it occurred very rapidly, and I was rather surprised on the playback of my tapes to find that the period from the time I first definitely noticed the fading of Regulus to the *g* of *gone* in "it's going, going, it's . . . gone" was 3.2 seconds. In fact, I stated that it seemed to be starting to go 8 seconds before final eclipse, which came at 14 hours, 19 minutes, 37.1 seconds U.T., more than a minute before the published expected time, but this early indication may have been an effect of seeing.

Regulus definitely became enlarged just before it disappeared. The phenomenon looked like a very speeded-up sunset, Regulus disappearing like a drop of greenish liquid coming in contact with an absorbent surface. The greenish hue was very probably a contrast effect between the B-type Regulus and the G-type Venus, even though Regulus was occulted by the dark limb of Venus. The 3-second major phase of disappearance was uniform, or "straight line" as far as my eye could tell.

As reappearance became due, I made it a point to repeat positively that I didn't see it. I first noted the reappearance of Regulus as a tiny yellowish pimple of light, quite attached to the lighted limb of Venus, at 14:30:41.5 U.T. I was rather surprised that Regulus did not appear green by contrast with Venus. The emersion seemed definitely more leisurely than the immersion. Upon playback of the tapes I noted that I said it was still "emerging, emerging, . . ." 12 to 14 seconds after I first saw it. It did not appear to "blossom out" from the lighted limb as it had "blossomed down" at the dark limb. This must probably be ascribed to the great difference in contrast between Regulus and the dark and lighted limbs of Venus, although it must be remembered that the daylight and night upper atmospheres of slowly rotating Venus may not affect transiting starlight in the same manner.

Duration of the occultation in Madrid was 11 minutes 4.4 seconds by both time signal systems recorded by my tapes, but 11 minutes, 4.6 seconds by stop watch. Mid-occulation for Madrid was at 14:25:09.3 U.T. if no correction is made for the fact that the eye will note a star's disappearance before it is photoelectrically invisible and will not note its reappearance until enough light is present to call attention to it. These effects tend to cancel out, although reappearance will probably be noted systematically later than the disappearance point is noted earlier than it actually happened. Reaction time, however, will act in the same sense in both cases, both events being timed later than they really are. Thus 14:25:9 might be adopted for mid-occulation at Madrid.

The effect of irradiation was pronounced. The illuminated hemisphere of Venus looked much larger than the dark hemisphere proved to be; it seemed as

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Type manuscripts double-spaced and submit one ribbon copy and one carbon copy.

Limit the report proper to the equivalent of 1200 words. This space includes that occupied by illustrative material as well as by the references and notes.

Limit illustrative material to *one* 2-column figure (that is, a figure whose width equals two columns of text) or to *one* 2-column table or to *two* 1-column illustrations, which may consist of two figures or two tables or one of each.

For further details see "Suggestions to Contributors" [*Science* 125, 16 (1957)].

though Regulus was shining through the dark limb of Venus, if one judged the size of the dark side from the apparent size of the brightness of the luminous hemisphere. This, of course, is a very well-known phenomenon.

Roger Hosfeld, a member of my party, using one of the Madrid Observatory telescopes through the kindness of the director, R. Carrasco, was able to obtain a long series of photographs from which the changing relative positions of Venus and Regulus (with corresponding times) can be obtained. The timing of this occultation serves as an important reference point in the theory of the orbital motion of Venus.

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Paleolithic Paint

Abstract. Discovery of hematite and kaolinite in excavations of late paleolithic occupation sites at Les Eyzies (Dordogne), France, raises anew the question of the nature of the paint used by paleolithic people. Hematite as a pigment source is widely documented, but the presence of kaolinite imported into prehistoric sites poses problems. The suggestion is made that white clay might have been used as an "extender pigment" to mix with colors such as that derived from hematite.

Archeologic excavations under the direction of H. L. Movius Jr., exposed late paleolithic occupation levels in the Abri Pataud at Les Eyzies (Dordogne), France, during the summer of 1958 (*1*). Several thousand stone and bone implements, much animal bone, and some human skeletal material was found. In addition, some carving on stone came from the Périgordian Final level and some rock which may have been painted was found in this level as well as in the overlying Proto-Magdalenian level. We are here concerned with the discovery of earth materials which may have formed part of a paleolithic paint palette.

Examples of what the archeologist terms "red ochre" were found in each of the two main cultural horizons. These are small, earthy chunks 2 to 3 cm in maximum dimension. Field examination showed them to be hematite (Fe_2O_3), and x-ray analysis of one showed the hematite to be essentially pure. The chunks had been "used," for each was artificially shaped by abrasion which produced relatively flat, intersecting facets. Similar objects were reported earlier from the nearby Grotte de Font-de-Gaume and other sites (*2*). The abrasion is recorded in fine, nearly parallel scratches on the flattened faces. These marks are absent along the narrow ridges separating the abraded faces.

No earthy hematite occurs in the limestone cliffs near the abri, or in the stream deposits of the neighboring Vézère River. Such hematite does occur however, in association with clays of Tertiary age described below.

That the hematite was used as a pigment source is an unproved but not unwarranted suggestion and has been advanced by others for similar finds (*2, 3*). We are, however, on more tenuous, albeit more tantalizing grounds, when we consider the significance of fist-sized lumps of unctious clay found in deposits of Périgordian Final age of the Abri Pataud. This material is not characteristic of the limestone rubble fill of the shelter, nor is there any known occurrence of pockets of such material in the Cretaceous limestone in which the abri has formed. X-ray analysis shows the material to be the clay mineral kaolinite, a material that could only have been brought into the site by man from some outside source.

Several occurrences of clay are known in the general vicinity of the site, and at least two of these are commercially exploited today. These clays represent the weathering, during the Tertiary, of Cretaceous limestone. They occur in large masses, perhaps in sinkholes, in the uplands flanking the Vézère River valley where the site is situated. Brindley and Comer (*4*) report both kaolinite and halloysite clays from the Les Eyzies deposits, and x-ray examination of samples I collected reveals the same assemblage.

Why was the clay imported into the abri? It was clearly not for use in pottery making, a technical art which then lay several thousand years in the future. Could it have been used by a local artist? For instance, modeling in clay is known from the paleolithic stations of Tuc d'Audoubert and Montespan (Ariège), France. No clay modeling, however, has yet been reported from the Abri Pataud.

Is it possible that the clay was in some way connected with painting? If so, then it might have been used as a white pigment. White is rare in the surviving paleolithic art of western Europe, although it has been suggested that kaolinite was used as a white pigment in some of the later European paintings (*5*) and in the prehistoric paintings of Africa (*6; 7*, p. 250).

Another possibility exists, namely, that the kaolinite was used to mix with colored pigments. Thus the kaolinite could have been used for what is known in the paint industry as an "extending pigment." An extending pigment should have a low opacity, and the index of refraction of kaolinite (1.560 to 1.570) allows it to meet this requirement. In fact, kaolinite has been used as an extending pigment in modern paint manufacture.

As far as I know, the nature of the vehicle for paleolithic paint is still unknown. It is most generally held that pigments were mixed with animal fats (*3, 8*). No analyses are available to test this or any other hypothesis. There is some ethnographic evidence, however, that Bushmen used animal fat (*7*, p. 251; *9*) as well as the latex-like sap of some plants (*9*) as a vehicle for pigment, and urine, milk, blood, and honey also have been suggested (*9*). Strangely enough, common water has not been suggested as a vehicle.

We do not know whether the occupants of the Abri Pataud used clay in painting. Nevertheless, the presence of clay in the cultural horizons of the abri reminds us that as yet we know very little concerning the technical side of prehistoric painting. We are quite obviously in need of organic and inorganic chemical analyses as well as mineralogic analyses of paleolithic paint.

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References and Notes

1. H. L. Movius, Jr., describes the site and reports preliminary excavations in *Archaeology* 7, 82 (1954). Progress reports covering the 1958 excavations are contained in H. V. Vallois and H. L. Movius, Jr., *L'Anthropologie* (in press) and H. L. Movius, Jr., *Congrès International de Préhistoire,* Hamburg (in press). During the summer of 1957 and 1958 I conducted geologic investigations in cooperation with the archeologic program and with the assistance of B. B. Morgan, V. E. Gwinn, and J. C. Stewart. National Science Foundation grants to Movius and me have provided financial support. This report has benefited from helpful comments by G. L. Jepsen, Department of Geology, Princeton University.
2. L. Capitan, H. Breuil, D. Peyrony, *La Caverne de Font-de-Gaume aux Eyzies (Dordogne)* (Monaco, 1910), pp. 48–52.
3. H. Breuil, *Four Hundred Years of Cave Art,* translated by M. E. Boyle (Centre d'Études et de Documentation Préhistoriques, Montignac, Dordogne, France, 1952), p. 45.
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5. M. C. Burkitt, *Prehistory* (Cambridge Univ. Press, Cambridge, 1921), p. 205.
6. ———, *South Africa's Past in Stone and Paint* (Cambridge Univ. Press, Cambridge, 1928), p. 113.
7. S. Cole, *The Prehistory of East Africa* (Penguin Books, Harmondsworth, England, 1954), p. 250.
8. H. F. Osborn, *Men of the Old Stone Age* (Scribner's, New York, 1915), p. 415; H. Obermaier, *Fossil Men in Spain,* translated by C. D. Matthew (Yale Univ. Press, New Haven, Conn., 1924), p. 224; G. G. McCurdy, *Human Origins* (Appleton, New York, 1924), p. 234.
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