is a sterile level of yellow ochre that is laminated and water-laid. This represents a period when human occupation was undesirable or at least not present.

The Sandia cultural level lies below the yellow ochre level and again represents a dry period. Two charcoal lenses or fire hearths were found in the Sandia level, and it was from these that the original C^{14} datings were made. The cultural material of the Sandia level is, of course, distinct and earlier by its very subposition beneath the Folsom stratum and the superimposed yellow ochre. Below the Sandia level is a sterile layer of clay representative of another wet period immediately following the formation of the cave itself in the Pennsylvania limestone.

Bryan was able to relate the wet and dry sequences in the Sandia Cave with exterior glacial happenings in the vicinity. On this evidence he was able to postulate that the Sandia People may have entered North America in the pre-Mankato interstadial or, as it is called in the Colorado-New Mexico area, the pre-Corral Creek or W_2-W_3 interstadial (*4*). From this evidence Bryan argued that Sandia hunters may have occupied Sandia Cave as early as 25,000 years before the present day. Bryan made this estimate before any C^{14} dates were available. Unfortunately, his untimely death prevented his ever knowing that his estimate had been remarkably accurate.

The geologic correlation of the wet and dry levels of the Sandia Cave seems to corroborate the evidence of archeological stratigraphy. The C^{14} dates recently measured by Crane logically fit in with a pattern already established by other data. We may only assume that human beings such as those who left the Sandia culture as evidence of their presence were already established in the American Southwest at least 25,000 years before our time.

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22 March 1955

Antiquity of the Sandia Culture: Carbon-14 Measurements

In 1952 Frank Hibben of the University of New Mexico submitted to us two fragments of mammoth tusk that came from the Sandia level of Sandia Cave in New Mexico in association with evidence of human habitation. In 1954 he submitted a third fragment. The Sandia level at which the tusk fragments were found was below the Folsom level of the cave. The Folsom level had been dated by C^{14} on a previous and inadequate sample of ivory fragments at about 11,000 years. The figure of about 11,000 years has so far seemed to represent, in American anthropology, a rather sharp cutoff beyond which little is known. Sandia material, therefore, occupies a position of unusual importance, and it will be of great interest to investigate thoroughly every bit of available material and to make available the results in detail. Our C^{14} measurements on the tusk material are presented here (*1*).

The radiocarbon dating method used at the University of Michigan employs a Geiger counter into which a gaseous, CO_2 sample is introduced. The method has the advantage, for the present investigation, that the amount of carbon sample required is very much smaller than that required in the method that employs a solid carbon sample. Only about 700 mg of carbon in the form of CO_2 are required to fill the counter, and a sample of raw material containing 2 g of carbon is usually sufficient (In our previous work, using carbon black samples, we required about 100 g of raw material.) The small weight of carbon that suffices for the present method made it possible to prepare, from the available Sandia tusk material, sufficiently large samples of CO_2 that were derived entirely from the *organic* (*2*) constituents of the tusk. This was a safeguard against the most likely source of extraneous carbon, namely, water-deposited carbonates.

The method of preparation of a CO_2 sample from the tusk material was, briefly, as follows. The tusk was broken up into small bits and heated in a closed iron vessel to a dull-red heat, in order to carbonize (char) the organic constituents. It was then treated with dilute hydrochloric acid to dissolve the carbonates and other acid-soluble compounds. After this treatment, finely divided carbon black remained, which was then washed and dried. The weight of the carbon residue was about 7 percent of the weight of the tusk material. The carbon was then burned to CO_2, and the CO_2 was purified in the usual way, which consists of absorption in ammonia, precipitation as $CaCO_3$, washing and re-evolution by HCl.

The tusk material received in 1952 was carried through the chemical process in two batches, each yielding enough CO_2 for two counter runs. The first two runs were compared with runs that had been made, both before and afterward, on tank CO_2, which had been standardized against CO_2 made from lampblack (petroleum origin) according to our standard procedure of preparation.

After carefully assessing the degree of consistency in the results that we had been obtaining, over a period of several months, on many different counter fillings of CO_2 of identical origin (both the tank CO_2 and the modern wood CO_2 were used) and other factors, we were confident in saying that the Sandia tusk was *at least* 20,000 years old. Actually, the counting rate obtained from the Sandia sample was the same as the average of the counting rates obtained from petroleum carbon, so the 20,000-year figure was merely a limit that expressed, conservatively, the limits of error.

The CO_2 from the second batch of the 1952 material was used in a new series of runs. In these runs the comparison was made directly against CO_2 samples prepared from dead carbon, and special care was taken to prepare and handle all the samples, both the dead carbon and the Sandia material, in exactly the same way. In this way the intermediate step of comparison with tank CO_2 was elimi-

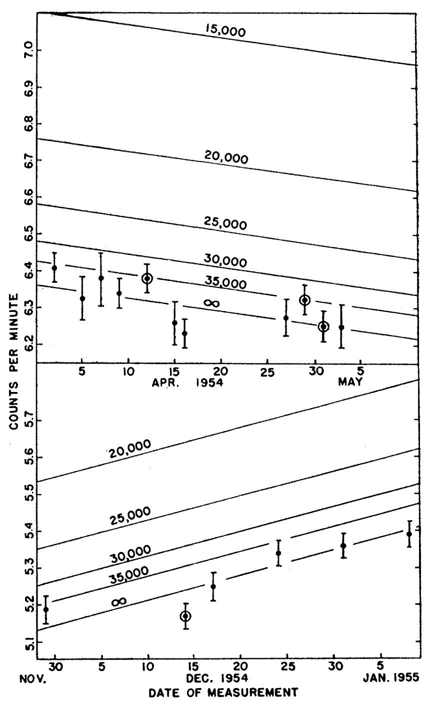

Fig. 1. C^{14} measurements on tusk material from the Sandia level compared with a number of measurements on samples of dead carbon. The Sandia measurements are identified by circles. The sloping lines correspond to the ages indicated. The vertical line through each point represents the standard deviation, based on the number of counts alone.

nated. For dead carbon, all but one of the samples was made by burning lampblack. One was made from tank CO_2, precipitated as $CaCO_3$ and carried through the usual purification process.

The results of the runs on the second batch of CO_2 are shown in the upper part of Fig. 1. Each run is indicated in its proper place on the day-of-the-month scale, and the standard deviation is shown. The gap between 17 and 26 April represents a period when the apparatus was shut down, because I was out of town. Smaller groups represent times when other samples, unrelated to the Sandia material, were run. They are not plotted, since they have no connection with the problem at hand. The line marked ∞ is an estimate of the "infinite age" counting rate, on the basis of the calibration runs shown. Its slope is caused by the gradual drift in the background counting rate over the period of more than a month. Such a drift is usual. Lines are shown that represent the counting rates for other ages, as labeled. Zero age would be 5 counts/min above "infinite" age. The Sandia samples are indicated by circles. The one on 12 April is a 48-hr run. The ones on 29 April and 1 May are two successive 48-hr runs on the same counter filling.

In the lower part of Fig. 1 is shown the result for the tusk material received in 1954. On the basis of all the runs made on the tusk material, we can say that there appears to be no significant difference in counting rate between the Sandia samples and the control samples of dead CO_2, when the statistical limits and the degree of consistency between runs are considered. With regard to the lower limit that can be placed on the age, the diagram speaks for itself. Twenty-five thousand years would certainly be a very conservative lower limit. A lower limit of 30,000 years would be consistent with the usual practice in assessing limits of error.

The great age of the Sandia tusk naturally raises the question whether it is contemporary with the evidences of habitation among which it was found, or whether, instead, we have discovered that among the men who inhabited the cave there were archeologists who collected and brought home tusks belonging to earlier times. Although the probability that such an explanation is correct is small, it nevertheless emphasizes the need for C^{14} measurements on other material from the same level.

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Notes

1. This work was supported by the Michigan Memorial Phoenix Project.

2. The remains from the protein materials, such as blood, as distinguished from the simple, acid-soluble compounds, such as the carbonates and the phosphates.

11 March 1955

Consensual Pupillary Response in Birds

Although the consensual reflex has been reported by Noll (*1*) to occur in birds, the behavior of the two pupils upon the stimulation of one eye with light is so markedly different that the question arises whether the apparent consensual contraction is a true reflex. In the typical consensual reflex of mammals, a beam of light directed into one eye causes the pupils of both eyes to contract simultaneously, and the contractions are equal in amount and duration. In the bird, on the contrary, the pupil of the stimulated eye contracts more promptly and with a greater contraction than does the pupil of the nonstimulated eye. Furthermore, the contraction of the pupil of the nonstimulated eye is capricious. It appears irregularly and varies in intensity and duration, and it is independent of the reaction of the pupil of the stimulated eye. Consequently, it is evident that if this slight, often momentary, reaction of the contralateral eye is a consensual pupillary reflex, it is markedly different from that of man and of other mammals.

The possibility that this small variable contraction of the pupil of the nonstimulated eye of the bird is not a reflex mechanism at all, but is instead a response to direct stimulation of the light, was suggested by some observations on pigeons. If one flashes an ordinary two-cell pencil flashlight into one eye of the pigeon so that the beam of light strikes the eye along the optic axis, the light will pass through the head of the bird and through the opposite eye. The pupil of the opposite eye will be illuminated to an intensity that is clear and unmistakable. A dissection of the head of the pigeon reveals that there is less than 1 millimeter of transparent bone and tissue between the two optic orbits. A beam of light can readily pass through this thin structure that intervenes between the two eyes. (Detailed microscopic drawings of these structures are given in Chard and Gundlach, *2*.)

As a result of this illumination from the rear, the retina is subject to direct stimulation. When this occurs, the pupil of the nonstimulated eye contracts. Since the light is greatly reduced in intensity because of the passage through the head, the contraction is necessarily smaller than that of the pupil of the eye upon which the light directly impinges. If the beam of light enters the first eye at too great an angle to pass through the head and strike the eye on the other side, then there is no consensual contraction. The observed variability in duration of the consensual reaction is then the result of a shift in the direction of the beam of light. In other words, what has appeared to be a consensual pupillary reflex in the bird is, in fact, nothing but the reaction of the pupil to the direct stimulation of light passing through the head.

Additional support for this conclusion has been obtained from observations on the owl. The visual axes of the owl are nearly parallel, and the projection of a beam of light directly upon one eye does not permit the light to pass through the head in the direction of the opposite eye. No consensual pupillary contraction whatsoever can be seen in the owl.

On the basis of these findings some evidence is now available that indicates that there is a functional, as well as an anatomic, difference between the visual systems of the bird and the mammal. As expected, the evidence shows a greater independence of function between the two eyes of the bird than there is between the two eyes of the mammal.

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References and Notes

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6 June 1955

Our Upper Colorado River Project

Paul B. Sears expresses the opinion that, in regard to the much discussed Upper Colorado Irrigation Development (and evidently the Echo Park Dam) "the remedy is simple . . . such aspects of major problems (should) be referred to competent boards of scientists" [*Science* **121**, 5A (29 Apr. 1955)].

Perhaps too many people—scientists included—have the feeling that the Echo Park Dam is the major point of contention in this controversy. Certainly everyone should know that California has a high-powered, well-financed committee whose main job is to prevent any irrigation development on the Colorado River above Lake Mead. This committee has been successful in persuading the nature lovers of the nation to oppose the Upper Colorado River projects, paying no attention to the promise of federal authorities to the people of that region that a storage project would be permitted when the Dinosaur Monument was extended in area. Thousands who have not seen Dinosaur National Park have responded