varieties of agate, jasper, and silicified palms.

The Calico Mountains have also been famous for their vein-type ore deposits, in which hydrothermal quartz crystals are known to occur. The occurrence, therefore, of a few such crystals within the alluvial deposits could be attributed to a hydrothermal source. Furthermore, it is entirely possible that quartz-bearing vugs are integral parts of the intrusive igneous rocks making up the Calico Mountains. These possibilities must be more thoroughly checked before the presence of exotic materials is attributed to man.

As for the nearly spherical stones, their strangeness is dependent upon the natural range of sphericity displayed by gravel of similar igneous rocks in the deposits. I am unaware of any measurements of sphericity that may have been made, but even cursory examination of the pit walls will reveal a significant number of well-rounded cobbles, some of which are almost spheroids.

Anomalous concentrations of flakes in the master pits are interpreted as the waste material (debitage) at a flaking station. Reworking of fan surfaces by water could, however, concentrate flakes, so natural causes for such concentrations cannot be precluded. Nor can natural causes be eliminated in explaining the variations of magnetic intensity in the supposed hearthstone (*23*). At the 1970 conference (*1*), the possible effects of lightning were treated too lightly. Lightning and natural fires do affect the magnetic properties of rocks on the surface and are a possible explanation of the variations of magnetic intensity. In order to thoroughly investigate the significance of the magnetic data, all of the possible hearthstones, as well as random samples of similar rocks of the same horizon, should be tested. Rocks on the modern surface could be checked, as could stones from a newly made hearth, which would serve as a control.

Thermoluminescent dosimetry measurements would provide another independent means of determining whether the hearthstones had been heated.

The outstanding pattern of the hearth-like arrangement of stones is more pronounced now than it was in photographs sent to me soon after its discovery because the surrounding gravel matrix has been removed. Again, the anomaly of the ring of stones is a matter of degree. Other circular arrangements of stones can be discerned from time to time as the gravels are exposed, but not all of these are hearths. Circular arrangements of sorted stones, known as patterned ground, are typical of periglacial regions but are also known to occur in desert areas (*24*). The stone circles at the Calico site could represent this phenomenon on a buried surface. Furthermore, for the circular arrangements of stones around a hearth to remain intact is inconsistent with the broad vertical distribution of the artifacts, which suggests redeposition by mudflows.

Conclusions

After examining, for the sixth time, the Calico site and the specimens recovered from the lower Yermo formation, I find no evidence to alter my previous views—that is, that the evidence for artifacts remains uncompelling and that a natural origin cannot be precluded. In fact, normal natural processes are adequate to explain the origin of all of the phenomena observed at the Calico site. This does not mean that I am *convinced* that all of the specimens are geofacts, even though I am inclined to suspect it; but more testing of this hypothesis should be done by uncommitted investigators who are well qualified in modern quantitative geological techniques.

Whereas the magnetic data from the possible hearth are suggestive, there still remain alternative explanations that are equally as plausible as the variations; being the results of a man-made fire.

There appears to be no doubt that the lower Yermo formation is of pre-Wisconsin age, but there is little chance of applying absolute age-dating techniques directly to the deposit, except for the possibility of measuring the paleomagnetic field direction if suitable sediment could be found. A reversed polarity would establish the age as more than 600,000 years, an age that would be consistent with current geological estimates.

Appendix

The following are descriptions of the strata at the Calico site.

Relict paleosol: (i) A horizon (0.06 meter thick)—light gray, vesicular clayey, sandy silt with strong medium to coarse prismatic structure; siliceous pebbles and cobbles resting on the surface have dark brown desert varnish (manganese oxide) on their top surfaces and orange-red stain (ferric oxide) on their bottom surfaces, where embedded in the vesicular horizon; limestone pebbles and cobbles are without staining but show strong solution faceting; some translucent chert fragments show a thin (1 millimeter), opaque white patina beneath the orange-red staining; green mold or lichen occurs on the periphery of undersides of some rocks; (ii) B horizon (0.24 meter thick)—light reddish-brown, clayey sand loam with dispersed small pebbles, numerous root molds, and moderate to strong, medium to fine blocky structure breaking to angular; sharp transitional boundaries; (iii) Cca horizon (0.24 meter thick)—pinkish-white, very calcareous, clayey coarse sand and gravel with root molds and weak, fine platy structure; (iv) C horizon—lower Yermo formation where measured in main pit and upper Yermo formation.

Upper Yermo formation: sand (6.10 or more meters thick)—reddish-brown, weakly laminated, poorly sorted, hard but friable, coarse sand with small (5 to 10 millimeters) carbonate nodules and dispersed fine pebbles and lenses of rotten pebbles; some layers are cemented by calcium carbonate.

Lower Yermo formation: gravel (7.62 or more meters thick)—very pale brown, hard, compact, very calcareous, poorly sorted, clayey, sandy, angular to subrounded, cobble gravel composed of very rotten, friable, igneous cobbles and approximately 10 percent chert cobbles, some of which are weather fractured; in some places the cobbles are coated and cemented by laminated calcium carbonate (caliche); sharp unconformable (?) contact with upper Yermo (Fig. 3).

Barstow Formation: mudstone (15.24 or more meters thick)—light brownish-gray to brown bentonitic claystone and calcareous siltstone with interbedded volcanic ash lenses; upper 3.05 meters are very calcareous with sponge-like networks of calcium carbonate; sharp erosional upper contact; base not observed.

References and Notes

1. L. S. B. Leakey, R. D. Simpson, T. Clements, R. Berger, J. Witthoft, and participants, *Pleistocene Man at Calico* (San Bernardino County Museum Association, San Bernardino, Calif., 1972).
2. L. S. B. Leakey, R. D. Simpson, T. Clements, in *The 1970 Britannica Yearbook of Science and the Future* (Praeger, New York, 1969), pp. 65–77; R. D. Simpson, *National Geographic Society Research Reports, 1964 Projects* (National Geographic Society, Washington, D.C., 1969), p. 219; *National Geographic Society Research Reports, 1965 Projects* (National Geographic Society, Washington, D.C., 1971), p. 231.
3. L. S. B. Leakey, R. D. Simpson, T. Clements, *Science* **160**, 1022 (1968).
4. C. V. Haynes, Jr., in *The 1970 Britannica Yearbook of Science and the Future* (Praeger, New York, 1969), pp. 76–77.
5. ———, *Science* **166**, 709 (1969).
6. R. D. Simpson, *Masterkey* **32**, 4 (1958); *ibid.* **34**, 25 (1960).
7. E. H. Sellards, *Southwest J. Anthropol.* **16**, 160 (1960).
8. W. S. Glennan, "The Manix Lake lithic industry: early lithic tradition or workshop refuse?" (paper presented at the 37th annual meeting, Society for American Archaeology, Bal Harbour, Fla., 1972).
9. T. McCulloch, "Preliminary geologic map of Yermo and Nebo quadrangles, California" (U.S. Geological Survey, open files, unpublished map, 1966). "Formation" is not capi-

talized in the text because the name has not been formally designated.
10. E. W. Haury and V. Haynes, First Calico Hills report to the National Geographic Society (1963); V. Haynes, Second Calico Hills report to the National Geographic Society (1965).
11. Before present B.P. means, by international agreement, before A.D. 1950.
12. J. P. Buwalda, *Univ. Calif. Publ. Geol.* **7**, 443 (1914); E. Blackwelder and E. W. Ellsworth, *Amer. J. Sci.* **31**, 453 (1936); E. W. Ellsworth, thesis, Stanford University, Stanford, Calif.
13. G. J. Fergusson and W. F. Libby, *Radiocarbon* **4**, 113 (1962); C. L. Hubbs, G. S. Bien, H. E. Suess, *ibid.*, p. 227; *ibid.* **7**, 97 (1965); A. M. Bassett, *Abstr. Programs Geol. Soc. Amer.* **3**, 79 (1971).
14. M. Stuiver, *Radiocarbon* **11**, 545 (1969); A. M. Bassett, personal communication.
15. C. V. Haynes, Jr., *Nevada State Mus. Anthropol. Paps.* No. 13, 15 (1967).
16. In 1965, several members of the National Geographic Society inspection team found specimens of chert, discarded from the excavations, that they considered to be potential artifacts. One recommendation, therefore, was to save and classify according to size all discarded fragments of chert, and these are now stored in rows at the site.
17. K. P. Oakley, "Some comments on the Calico flakings" (unpublished report submitted to the San Bernardino County Museum).
18. V. Haynes, Third Calico Hills report to the National Geographic Society (1966).
19. K. P. Oakley, *Man the Tool-Maker* (Univ. of Chicago Press, Chicago, 1957), fig. 3, p. 13.
20. A. Jelinek, B. Bradley, B. Huckel, *Amer. Antiq.* **36**, 198 (1971).
21. V. Haynes, Fourth Calico Hills report to the National Geographic Society (1966).
22. ———, Fifth Calico Hills report to the National Geographic Society (1967).
23. *Sci. News* **98**, 364 (1970); (*1*, pp. 65–69).
24. C. C. Albritton, personal communication.
25. As a participant in the 1970 Calico Conference, I submitted an earlier version of this article to the San Bernardino County Museum for inclusion in the conference report. Because of its length it was rejected, and, at L. S. B. Leakey's request, publication was withheld until after the official report was in print. I wish to express my appreciation to the National Geographic Society, which sponsored my visits to the Calico site in 1963, 1965, 1966, and 1967; to the Institute for the Study of Earth and Man of Southern Methodist University for making it possible for me to attend the 1970 Calico Conference; and to the San Bernardino County Museum and the Calico staff and crew for their courtesies and hospitality during my visits to both the Museum and the site. Reading of the manuscript and constructive commentary by C. C. Albritton, E. W. Haury, and J. L. Shiner is also appreciated.

Control Circuits for Determination and Transdetermination

Bistable control circuits like those in bacteriophage lambda may function in *Drosophila* development.

Stuart A. Kauffman

In this article I propose a systematic theory for major aspects of imaginal disk determination and transdetermination in *Drosophila melanogaster*. Over the past decade experiments on these processes have revealed striking phenomena. *Drosophila* is a holometabolous insect with four major developmental stages. Embryonic development persists for about 22 hours after fertilization, then the larva hatches, grows for about 4 days, forms a pupa, and in 4 days undergoes metamorphosis to an adult. During metamorphosis many larval tissues break down and most portions of the adult's surface are formed from small structures in the larva called imaginal disks. Imaginal disk determination is the paradigm of normally irreversible commitment. Each disk is a small nest of cells set aside early in embryogenesis which is determined to develop during metamorphosis into a particular adult structure: wing, leg, or antenna, for example. At the time of determination, each disk consists of about 10 to 40 cells (*1*). During the ensuing three larval instars, the disks proliferate and by the third instar each consists of several thousand cells. Disk cells remain undifferentiated and never form a functional part of the larva. Despite their proliferation, each disk maintains its determined state and differentiates appropriately during metamorphosis.

Several years ago Hadorn (*2*) tested the capacity of disk tissue to maintain its determined state for very long periods of time by excising genital disks from third instar larvae and growing them in the abdomen of adult flies where they proliferate but do not differentiate. Tissue lines were carried by serial transfers in adults, and the maintenance of determination tested by implanting tissue fragments into larvae which then underwent metamorphosis. Hadorn found that even after several years, tissue initially derived from genital disks still metamorphosed to adult genital tissue. This important result demands that whatever the molecular carriers of determination may be, the determined state is a persistently regenerated, self-maintained state.

Hadorn also discovered that tissue lines initially derived from genital disks sometimes transdetermined and gave rise, when tested by metamorphosis, to adult tissue normally derived from another disk. Hadorn and his co-workers (*3–10*) found that each type of transdetermination, from genital to antennal structures, or from leg to wing structures, for example, occurs with a characteristic probability per transfer generation from adult to adult, and that the new state of determination is clonally heritable in the transdetermined tissue line. Evidence that transdetermination is not due to somatic mutation is provided by the discovery that transdetermination occurs in groups of contiguous cells not clonally related (*8*), and is too frequent to be due to mutation.

There are a number of striking features of the transdetermination flow pathway (Fig. 1). The most important is that there are specific sequences of transdeterminations. Genital disks transdetermine into antennal or leg structures; antennal or leg disks in turn transdetermine into wing structures; wing disks then transdetermine into mesothorax structures. Genital disks do not transdetermine directly into wing or mesothorax structures. The flow pathway gives evidence of a distance measure (that is, a measure of the degree of difference) between the states of determination in various disks. Haltere disks transdetermine directly to wing, but not to leg or genitalia; leg disk transdetermines directly to wing, but not to haltere. In some sense haltere is closer to wing than to leg

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Hope you can come ahead of Dr. Lackey and work over more flakes —

But do come whenever you can — we need you!

(c. 26-4-4.2)