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The Calico Site: Artifacts or Geofacts?

Chipped flints are either the oldest evidence of man in the New World or products of geological processes.

Vance Haynes

In October 1970, an international conference, sponsored by the University of Pennsylvania Museum and the L. S. B. Leakey Foundation, was held at Bloomington, California, to examine the results of archeological excavations of the San Bernardino County Museum at the Calico site and to examine deposits believed to be of pre-Wisconsin age for evidence of man's presence (*1*). The report of this conference and other published reports by the excavators have been simply generalized summations (*2, 3*), and even fewer reports of alternative interpretations have appeared in print (*4, 5*). My objective here is to review the latest evidence and offer an alternative hypothesis of the origin of the supposed artifacts. The hypothesis that the chalcedony specimens may be geofacts (artifact-like phenomena of geological origin) has not been adequately tested.

Background

The discovery of artifacts of a quarry workshop on the surfaces of the Calico foothills was made in 1948 by amateur archeologist Ritner Sayles. In subsequent years, Ruth D. Simpson described the site and the artifacts and defined the Manix Lake lithic complex (*6*). Much of this material, consisting mostly of waste flakes, abandoned cores, and a few blade cores and hammer stones, can still be found in concentrations scattered over the Calico foothills, where they have been protected by the San Bernardino County Museum.

Some observers believe the material of the Manix Lake lithic complex to be representative of a New World equivalent of the Lower Paleolithic industries of the Old World (*6, 7*). Other observers agree that the range of intensity of patination displayed on the artifacts suggests a considerable but undetermined range of antiquity, but they believe that the artifacts are typical of quarry workshops and are not necessarily analogous to tools of the Lower Paleolithic (*8*). L. S. B. Leakey, attracted to the site by the Paleolithic aspects of the artifacts, suggested in 1963 that excavations be conducted into the fan gravels to see if these artifacts could be found in situ, thereby proving their great antiquity. The result of the subsequent excavations has been that, instead of the clearly recognizable artifacts of the Manix Lake industry, much cruder and more controversial specimens, considered to represent a much more primitive industry, have been found (*1–3*).

Geologic Setting

The site is located approximately 4.5 miles (1 mile = 1.6 kilometers) northeast of Yermo, California, in deposits informally called the Yermo formation (*9*). These deposits (appendix) consist of clayey, coarse cobble gravel (the lower Yermo formation) and very coarse, arkosic sand (the upper Yermo formation). The upper and lower Yermo (Fig. 1) formations are in part interstratified, but, judging from the differences in weathering, it is probable that the lower gravel is much older than the coarse sand and its gravel facies.

These deposits make up what is believed to have been either an ancient pediment or an alluvial fan that at one time extended westward to the Calico Mountains as part of a large alluvial apron, graded to an ancient drainage system that no longer exists. The Calico foothills, as these deposits will be referred to, now stand as faulted, dissected remnants of the alluvial apron and contain at least two geomorphic surfaces that appear to represent ancient terraces cut into the Yermo formation during a very early stage of dissection (*10*).

The Calico foothills are isolated from the Calico Mountains proper by a younger alluvial apron (Fig. 2) made up of several fan surfaces and channel deposits. The higher (older) surfaces of the alluvial fans of unit C show stronger development of desert pavement, desert varnish, and weathering than do the lower (younger) surfaces, the youngest of which are still active. Intermediate surfaces appear to be graded to the shoreline features of the Coyote basin, dated 13,800 ± 600 B.P. (*11*) (LJ-958), and of ancient Lake Manix (*12*), dated 19,300 ± 400 B.P. (UCLA-121) and 20,050 B.P. by radiocarbon analysis of shoreline tufa and *Anadonta* shells, respectively (*13*). An earlier phase of Manix Lake is more than 47,000 (Y-1993) years old (*14*) and postdates early dissections of the Calico foothills.

Site Stratigraphy

The sediments being excavated are described in the appendix. At the site, they unconformably overlie bentonitic mudstones and calcareous ash beds of the Miocene Barstow Formation, which

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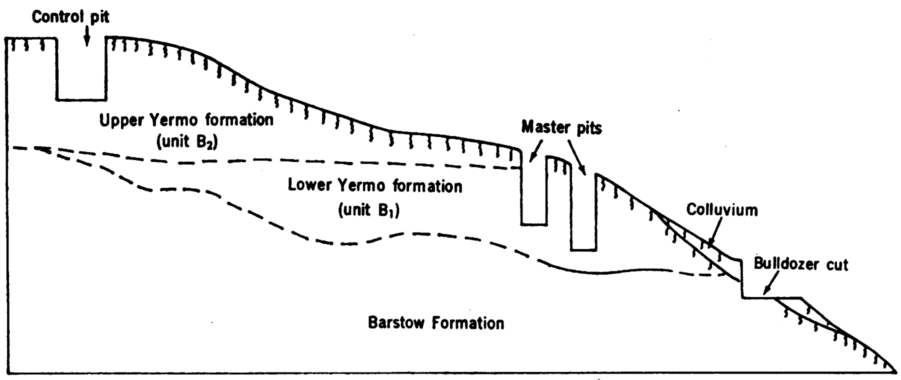

Fig. 1. Schematic geologic section of the Calico site area (no scale) showing master pits, control pit, and location of the original Leakey find in colluvium exposed in bulldozer cut.

has been well exposed by a prospector bulldozing for bentonite. The thickness of the Yermo formation varies greatly because it covers an irregular surface cut into the Barstow Formation by erosion before it was buried (Fig. 1).

The wide range of grain sizes and the high clay and silt content of the lower Yermo formation, in addition to the lack of sedimentary structure caused by moving water, suggest that the deposit was formed by mudflows out of the Calico Mountains. The cobbles and boulders in the deposit are composed of subangular to well-rounded, rotten igneous rock and subangular chert (Fig. 3). The rocks are from outcrops in the Calico Mountains and foothills 2 to 4 miles to the west. A few lenses of interstratified clayey sand indicate some reworking of the mudflow deposits by running water. The deposits are considerably weathered and are impregnated with secondary calcium carbonate (calichefied), as a result of pedogenic processes or possibly a reaction with groundwater.

The upper Yermo formation, which consists of coarse sand and grit with interstratified lenses of pebble to cobble gravel, is separated from the lower mudflow deposits by a relatively sharp contact that may represent a significant hiatus. The upper Yermo formation shows weak sedimentary structure and is not as calichefied as the lower gravel except near the surface, where pedogenic calcium carbonate occurs.

Ancient surfaces on the Yermo formation are characterized by a desert pavement with strong desert varnish, weather fracturing, and patination of chert. The pavement overlies a relict paleosol (appendix) that is much more strongly developed than the oldest soil in the younger alluvial fans, the youngest of which shows only incipient stages of pedogenesis.

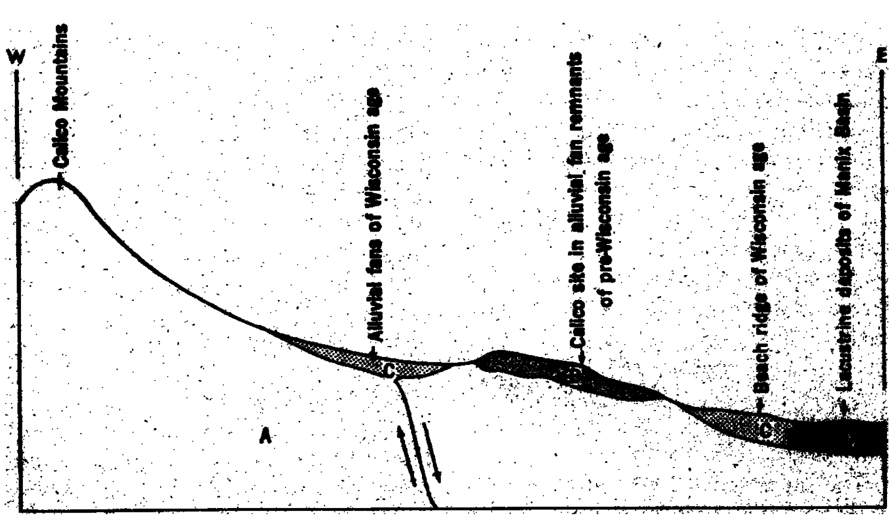

Fig. 2. Generalized geologic cross section of the Calico foothills area. (A) bedrock of pre-Pleistocene age; (B) Yermo formation of Pleistocene age; (C) unnamed alluvial fan deposits of late Pleistocene and Holocene age; and (D) Manix Lake beds of late Pleistocene age (no scale).

Age of the Lower Yermo Formation

The precise geologic age of the deposits at the Calico site cannot be determined at the present time because of a lack of suitable materials for either isotopic or paleomagnetic dating, but estimations can be made from the available geomorphic, pedogenic, and stratigraphic evidence. The lower Yermo formation is more weathered than any Wisconsin deposit I have ever observed, and this weathering occurred before the upper Yermo sand and gravel were deposited. An interval of unknown duration apparently occurred between deposition of the upper and lower Yermo formations, but it must have been longer than the Wisconsin stage to account for the considerable weathering of the lower formation before it was buried, which required additional time. One hundred thousand years would be a conservative estimate for the time required to weather the lower Yermo formation, erode it, and deposit the upper Yermo formation. These events were followed by a prolonged period of erosion that dissected the ancient alluvial fan and isolated the Calico foothills from the Calico Mountains. Subsequently, the relict paleosol under the desert pavement and on the eroded slopes developed to a stronger degree than did the mid-Wisconsin paleosol in the Las Vegas Valley, where the geochronology is better understood (*15*). The Calico relict paleosol is likely to be no younger than Sangamon in age (that is, at least 70,000 years old). Allowing 30,000 years for subsequent dissection and the cutting of terraces in the Yermo formation, a conservative estimate would be that the deposition of the lower Yermo occurred at least 200,000 years ago, not counting the time required for accumulation after the artifacts were deposited.

Concomitant with and following the isolation of the Calico foothills, extensive alluvial fans developed out of the Calico Mountains, surrounded the Calico foothills, and extended to the Manix Basin, where the lacustrine deposits of ancient Lake Manix were forming at least as early as 47,000 years ago (*14*). The beach deposits, some of which are dated 13,000 to 20,000 B.P. (*13*), were formed during times of quasi-stable lake levels, which may correlate with the Wisconsin stages (*10*). The Holocene is represented by desiccation of the lake basins, erosion and terracing of the Wisconsin fans, and the formation of lower fans.

It is obvious that the lower Yermo formation is post-Miocene and pre-Sangamon. Allowing for the geologic events outlined here, I have estimated that it is at least 500,000 years old (*4*, p. 72). Most other geologists have reached similar conclusions (*1*).

The question of whether the artifacts are natural or man-made should be independent of the age of the deposits, as long as the deposits are within the time span of human evolution. It is difficult, however, to ignore the fact that, if the Calico artifacts are of mid-Pleistocene age, which would make them several hundred thousand years old, they would have to have been made by pre-Neanderthaloid peoples. Yet after more than a century of investigation, there has been no evidence of significant human evolution in the New World.

Characteristics of the Specimens

As of 1968, approximately 200 pieces of chert or chalcedony had been judged by Leakey and his associates to have been man-made (Fig. 4); several hundred more were considered to be artifacts because of their association with the others (*3*). These specimens were selected from many thousands of other pieces considered to be natural.

The best specimens consist of flakes of chert showing the conchoidal bulbar scars caused by percussion of a tough rock against chert, for which conchoidal fracture is characteristic. A few pieces exhibit what Leakey believes to be faceted striking platforms, and there are many examples of concavo-convex flakes showing positive and negative bulbar scars parallel to each other. Some flakes with steeply worked edges are considered to be scrapers, and a few pieces with a few flakes removed from both sides are offered as examples of bifacially worked tools.

No specimen from Calico is as obvious an artifact as, for example, a typical Chellean hand ax, a Levallois flake, or a Mousterian point. There appears to be a gradual transition between what are considered to be artifacts, probable artifacts, possible artifacts, and nonartifacts. The number of specimens assigned to these categories will vary with the individual making the selection; in fact, it can be argued that some specimens found in the piles of rejected pieces are as artifact-like as some of the specimens cataloged as artifacts (*16*).

Distribution of the Specimens

The specimens considered to be artifacts come mostly from the coarse cobble to boulder gravel of the lower Yermo formation "master pits," where chert makes up a significant percentage of the gravel (Fig. 3). Very little layering is apparent in the walls of the pits and the consensus is that the deposit is mostly that of mudflows, with a few interstratified lenses of reworked sand. The vertical distribution of the artifacts is random throughout 8 to 10 feet of gravel (*2, 3*). If the deposit was indeed a mudflow, and there is little doubt of this, the scattered distribution of the presumed artifacts is to be expected. If these are indeed artifacts, then they have been redeposited.

Other test pits in the vicinity of the site, including the two "control pits," revealed few or no presumed artifacts, depending upon whose judgment is accepted; but the control pits exposed deposits in the upper Yermo formation of different lithology and grain size than those exposed by the master pits in the lower Yermo formation, and there was a smaller percentage of mudflow deposits in the control pits than in the master pits. K. P. Oakley further observed that chert is much less abundant in the exposures in the control pit (*17*).

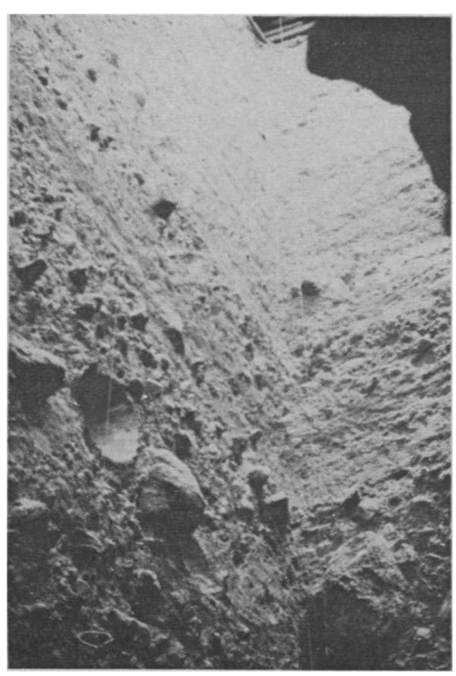

Fig. 3. Yermo formation as exposed in excavations at the Calico site, California. Igneous rocks are rotten enough to be cut through by trowels, whereas chert rocks remain intact. Depression is where large boulder has fallen away from the carbonate-clay matrix.

Alternative Explanation

In the Calico site, natural chert constitutes a significant part of the grain lithology. Therefore, the possibility that the artifacts could be of natural origin (geofacts) must be given equal weight as a working hypothesis of origin. The natural processes to which the chert fragments have been subjected in their 2- to 4-mile journey from the outcrops to their resting place in the fan are outlined as follows (*18*):

1) Fracturing of outcrops by tectonic stress and by weather fracturing (root pressure, freeze-thaw cycles, solar heating, and so on) produces angular, polyhedral fragments with sharp edges.

2) Movement of chert fragments down steep slopes by free-falling, tumbling, and sliding, either individually or en mass (a landslide), produces percussion fractures (bulbs, splits, hinge fractures, *erailleures*, and conical-concentric fractures, or "moons") and battered edges. A landslide can be expected to produce abraded edges and flaking by intergranular pressure.

3) Being tumbled for several miles down low to intermediate slopes by water and mudflows carrying tough igneous rocks as well as chert causes abrasion, battering, and flaking. Cobbles lodged in the stream bed or banks will have exposed edges and surfaces subjected to further battering, abrasion, and flaking by moving particles.

4) Burial in the aggrading alluvial fan removes chert fragments from further percussive action until they are reexposed by erosion, but it does not preclude fracturing and flaking by intergranular pressure.

5) Erosion and redeposition, being common phenomena in alluvial processes, can account for several generations of flaking observed on some pieces of chert, as well as the separation of flakes from their cores.

Weather fracturing is commonly recognizable as such, but, under conditions as outlined here, is it conceivable that chert fragments could be so modified as to appear to be the work of a primitive flint knapper? Because flint knappers commonly employ tough varieties of igneous rocks as hammers for percussion flaking, and because such rocks were a major constituent of the lower Yermo formation, the answer is *yes*. Furthermore, the pressure of a tough, rounded rock against an edge of chert can produce a pressure-flaked edge that can be indistinguishable from

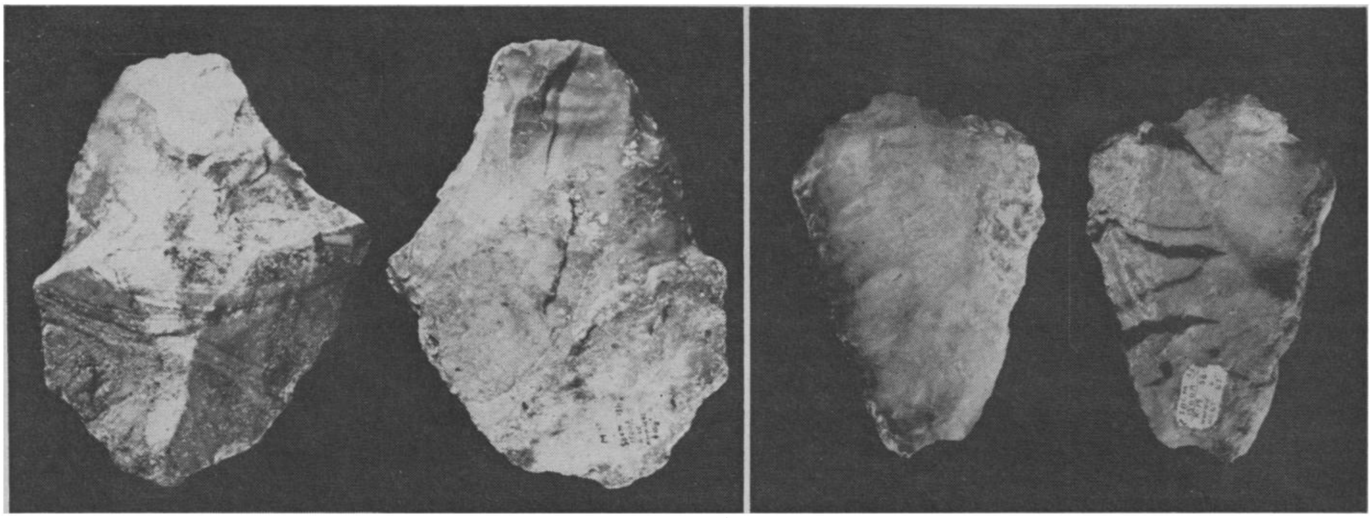

Fig. 4. Two specimens (front and back views) from the lower Yermo formation at the Calico site. [San Bernardino County Museum collections; photographs by C. Howe]

a man-made pressure-flaked edge (*19*).

Much of a knapper's skill in detaching a blade-like flake from a core is dependent upon the angle between the surface to be struck and the face to be removed. An acute angle is preferred, with the optimum angle dependent upon the material and type of flake to be removed. Obviously such angles can be produced, starting at the outcrop, by some of the mechanisms outlined here. Once a chert fragment with the proper angle between two surfaces is produced, the chances of the edge being flaked in transport are greatly increased.

Of the many thousands of pieces of chert that have been uncovered in excavations of the master pits at the Calico site, hundreds have been selected as being possible artifacts, and, from these, 200 or so have been selected as being the best examples. Authorities who have inspected this last group are divided in their opinions as to the origin of these flints because none is an obvious artifact. In reflecting upon the mechanisms of fracturing and transportation, I find that the few possible artifacts are insignificant in comparison to the total amount of chert that was moved at least 2 miles among coarse gravels at a time when the igneous cobbles were fresh and tough. It would be surprising *not* to find a few pieces that resemble artifacts.

For example, it would appear that two to four blows would be required to produce a blade-like, concavo-convex flake with positive and negative bulbs of percussion. One of the specimens most nearly resembling an artifact (SBCM, 1500A, 107, P-20) is such an example, but Jelinek and others (*20*) have shown that, given the right shape, such a flake can be produced by a single blow with a hammerstone.

Another possible artifact (SBCM, 1500A, S-19, 132) is made of yellow jasper, which is uncommon at the site, but the beaked end and the concave flaked edges can be produced by pressing a rounded pebble or rock edge against the edges of the original flake (*19*). This one operation produces a large number of individual flake scars that can be mistaken for retouching by a knapper. On the specimen in question, this has happened three times. Is this significant? Probably not, in view of the total number of chert fragments involved, but a statistical study would yield a more objective evaluation.

The possible natural production of geofacts in a chert-cobble and igneous-cobble facies of the fan should be tested, because they may be peculiar to mudflows of a given range in lithological composition and grain size. Modern quantitative geological techniques could be used in an effort to answer such questions as (i) What is the size distribution within the artifact-bearing zone? (ii) What are the proportions of chert to nonchert particles of various sizes within the size range of the artifacts? (iii) What are the proportions of artifact to nonartifact chert in each size category? and (iv) How do these proportions vary with respect to each other? Once these factors were understood, other portions of the lower Yermo formation with similar lithology could be sampled in a sufficient number of places to see if the artifacts are a natural part of this lithology or if they are confined to restricted and therefore anomalous loci.

Suggestions of this type (*21*) led to the excavation in 1967 of the two control pits, which I believed at the time would be an inadequate test because more and smaller test pits would have been statistically more representative (*22*). In addition, the natural origin hypothesis has not been adequately tested because of obvious dissimilarities between the lithology of the control pits and the master pits and because size analyses have not included the nonchert component of the gravels.

The single most difficult factor to overcome in such tests is the human element of subjectivity in selecting and categorizing the artifacts. One approach to this would be to have a group of lithic technologists individually select what they considered to be unquestionably artifacts had they been found in known archeological context. Those pieces selected by a majority of the authorities would then constitute the artifact sample from each test pit to be used in the quantitative analyses.

Other Evidence

In addition to the artifacts, other claims of evidence for human occupation during the time that the lower Yermo formation was formed include "exotic" lithic materials, anomalous concentrations of flakes, some nearly spherical stones, and a possible fire hearth. The exotic materials are jasper, moss agate, and quartz crystals; but, because jasper and moss agate are both varieties of chalcedony, it is quite possible that they constitute local variations. The Calico foothills, minor though they may be, are famous among amateur mineral collectors for their 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.

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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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