## Acheulian Occupation Sites at Torralba and Ambrona, Spain: Their Geology

Abstract. *The Acheulian occupation sites of Torralba and Ambrona, central Spain, lie within the Torralba Formation, a complex of alluvial and slope deposits dating from a long period of glacial climate before the Holstein (Mindel-Riss) interglacial.*

In 1888 fossil mammals were found 156 km northeast of Madrid, near Torralba del Moral (Fig. 1) (*1*). Sporadic excavations by the Marques de Cerralbo about 1907–11 exposed an early Acheulian site (*2*) that gained wide publicity without publication of reports in any detail. Pedro Palacios, in examining the geology, distinguished three strata: a basal lacustrine clay (50 to 90 cm) embedding the site, an intermediate layer of sterile marl (100 cm), and a surface zone of weathered red clay (*3*). A Mindel-Riss (Holstein) interglacial age had been proposed for these deposits (*4*).

The Torralba site and its twin at Ambrona, some 2 km upstream, were systematically excavated by F. C. Howell during the summers of 1961–63. I was responsible for the geology (*5*); E. Aguirre and others, for the paleontology; and J. Menéndez-Amor and F. Florschütz, for the palynology. It soon became evident that the occupation levels at Torralba and Ambrona, representing a number of kill or butchering sites, were among the oldest in Eurasia, dating from a long, rather cold interval preceding the Holstein interglacial. Carbonized wood and charred bone occur and are among the earliest evidences of human use of fire.

Torralba and Ambrona are 1100 to 1150 m above sea level near the headwaters of the Rio Jalón, a major tributary of the Ebro, not far from the Ebro-Duero and Ebro-Tajo watersheds (Fig. 1), where several high erosional surfaces (*6*) are dissected by steep-sided, flat-floored valleys. The climate is submediterranean (Köppen symbols *Csb*), with dry, warm summers (July mean, 19°C) and mild winters (January mean, 2°C, *7*). The uplands are formed by dolomitic limestones (basal Jurassic), whereas clays, marly limestones, and evaporites (Keuper or Upper Triassic) are intersected in the lower valleys.

The sites lie within a complex of alluvial and slope deposits along the margins of the Rio Masegar valley; these sediments, representing two fragments of a +40- to 45-m stream terrace of the Masegar, are here formally designated the Torralba Formation. At both sites solifluction beds or cryoclastic slope wash form the base, which is topped by alternating sands, marls, and gravels originating in stream, swamp, or slope. Repeated erosional disconformities and facies changes correlate between the two sites and are taken to represent several climatic oscillations between cold and temperate humid conditions. Alluviation was followed by calcification and by intensive rubefaction, the last suggesting deep chemical weathering.

The stratigraphy of these sites (Table 1, Figs. 2 and 3) is based on some 375 linear meters of geologic-microstratigraphic sections at scales of 1:20 and 1:40 and on subsequent sedimentological studies. Morphometric analyses of gravel refer to the modified Lüttig method outlined by Butzer (*8*); Munsell colors are given for dry sediments.

The Torralba Formation is underlain by red Keuper clays, frequently slumped or convoluted; at Ambrona there may also be a massive sequence of slumped and convoluted beds of different facies. These light bluish-gray (5 B 7/1) to olive-gray (5 Y 6/2-3) clays, clay silts, and detrital marls, at least 6.5 m thick, are wholly sterile yet distinct from the local Keuper; they may have formed under reducing conditions and been later redeposited by solifluction.

The basal bed of the Torralba Formation (Table 1, member I) is a cryoclastic detritus called the Red Colluvium; it is recorded only at Torralba. The matrix is a red (2.5 YR 5/6) to

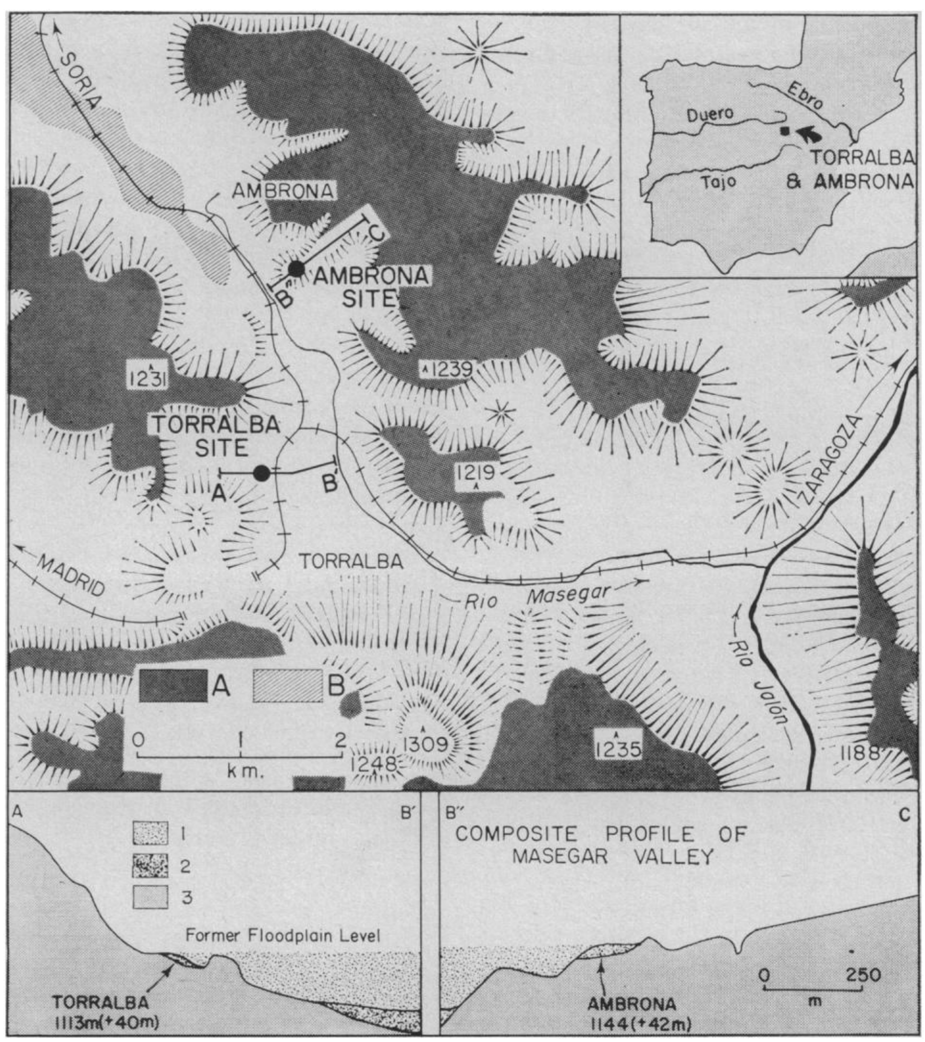


Fig. 1. The Acheulian sites of Torralba and Ambrona. *A*, Mio-Pliocene erosional surface in 1200 m; *B*, Late Pliocene erosional surface in 1125–1135 m; *1*, eroded Pleistocene fill; *2*, intact Pleistocene fill; *3*, railroad tracks before 1958. Vertical exaggeration of profile, × 4.5.

reddish-yellow (5 YR 7/6) sandy silt or silty sand derived from eroded red paleosols and from the red Keuper clays; the coarse material is angular, flattish in shape, and crudely stratified. More than half these rock fragments are freshly fractured on one or more faces; the fracturing implies a scree derived from frost-weathered bedrock on the upland slopes. The next unit is a light gray (5 Y 6-7/1-2) sandy silt (unit IIa) attaining 4 m in thickness; abundant limonitic staining suggests former waterlogging. At Ambrona convoluted lenses of coarse quartz sands with a few pebbles suggest solifluction. At the Torralba site unit IIa grades laterally into a gravelly sand upslope. At each site there may be a terminal subfacies of up to 30 cm of clayey silt. The contact between the typical sandy facies and this clayey silt may be contorted with festoons due to either cryoturbation or differential plastic sliding. Lying disconformably on Keuper clays or on Red Colluvium, unit IIa contains fairly abundant pollen. These generally homogeneous fine-grained deposits suggest a primarily fluvial origin, but slumping, congelifluction, and slopewash also were involved in their formation.

Table 1. Rock-stratigraphic units at Torralba and Ambrona.

| Member, bed | Facies | Maximum thickness (cm) | |
|---|---|---|---|
| | | Torralba | Ambrona |
| | *Sahuco Formation* | | |
| II, c | Fine dark alluvium | 80 | |
| II, b | Coarse brown alluvium | 70 | |
| II, a | Reddish colluvium | 125 | |
| I, e | Yellowish sands | 10 | |
| I, d | Reddish colluvium | 55 | |
| I, c | Reddish alluvium | 60 | |
| I, b | Reddish colluvium | 30 | |
| I, a | Cryoclastic detritus | 20 | |
| | *Ambrona soil* (terra fusca) | | |
| | (B) horizon | 160 | 150 |
| | (B) C horizon | 10 | 35 |
| | Ca horizon | 10 to 20 | 10 to 60 |
| | *Torralba Formation* | | |
| V, d | Coarse red alluvium | 165 | 95 |
| V, c | Fine red alluvium | | 85 |
| V, b | C-gravel | | 60 |
| V, a | Gritty marl | | 90 |
| IV, b | Gray marl | 150 | 200 |
| IV, a | Marl with channel beds | | 220 |
| III, b | B-gravel | | 15 |
| III, a | Upper gray colluvium | 80 | 80 |
| II, d | Brown marl | 90 | 150 |
| II, c | Lower gray colluvium | 100 | ? |
| II, b | A-gravel | 30 | 60 |
| II, a | Gray silts and sands | 70 | 400 |
| I | Red colluvium | 400+ | |

Human habitation is first evident in unit IIb, a widespread horizon of coarse, subangular to subrounded gravel. Moved by both rolling and sliding motions, the A-gravel (Table 1) still mantles parts of the upland; at the sites it dips steeply down into the valley, suggesting either that unit IIa had not filled the valley completely or that a period of downcutting had intervened. Most of these gravels are decidedly cryoclastic and, at Torralba, stone rings (25 to 40 cm in diameter) and stone garlands are common in this horizon; such soil-frost phenomena imply frequent freeze-thaw alternations (*9*). The minute, intercalated lenses of homogeneous silts also suggest frost-sorting and solifluction, even though colluvial washing was primarily responsible; this indicates greater cold as well as accelerated surface runoff. From the orientation and dispersal of bones from single animals, as well as from the absence of evidence of rolling or wear of artifacts, it is evident that, although some downslope sliding may have taken place, cultural associations, independent of orientation, have been preserved atop or among the A-gravels.

Unit IIc, the Lower Gray Colluvium, clearly represented only at Torralba, comprises white to light gray (2.5 Y 7-8/2), well-stratified, broadly horizontal, gritty sands showing solifluction festoons over a basal disconformity. At Torralba one or two 10-cm intercalated bands of heterogeneous, noncryoclastic detritus, lacking soil-frost structures, indicate water-laid screes (AB-gravels). Cultural horizons with articulated bone occur on top of both of these intergrading lenses. In general unit IIc suggests a coarse valley fill; common limonitic staining supports this explanation. The overlying brown marl, unit IId, varies from a clayey to a sandy or gritty brownish-gray (2.5 Y 5-6/2) marl; inclined at angles of up to 5 or 10 percent, it is identical in facies with swampy accumulations that are still laid down near active springs in the valley today. A moist, more temperate climate is implied.

Member III of the Torralba Formation is quite analogous to some of the earlier beds. The Upper Gray Colluvium (unit IIIa) was preceded by erosion and ushered in by solifluction, but lacks significant gravel horizons. There is strong evidence at Ambrona that the combined thickness of units IIc, IId, and IIIa in lateral valleys exceeded 15 m. Here, too, the top bed is a well-defined gravel pavement (unit IIIb) coinciding with a significant cultural horizon; the subrounded to rounded, medium-grade pebbles are mildly cryoclastic, but otherwise of fluvial type. Homogeneous light gray to olive-gray (5 Y 6-7/1-2) marls (member IV) rest disconformably on member III; limonitic staining along prismatic structure cracks or in horizontal bands, with flecks of loose oxide precipitates as well as calcareous nodules, all suggest seasonal waterlogging at time of deposition. Basal strata are inclined along the subsurface and may be gritty, while most of the beds are almost horizontal. Analogous sediments, with identical gastropods, are still forming in poorly drained, seasonally inundated sedge and grass flats of the Masegar-Duero watershed today. The Gray Marl is a fine fill relating to the alluvial flats of an aggrading floodplain. Toward the center of the valley the original thickness of the Gray Marl probably exceeded 10 to 15 m; its surface marks the culmination of a +40- to 45-m "high" terrace of the Masegar-Jalón. Higher on the slopes (Fig. 3) the Gray Marl may graduate into complex slope deposits, mainly gritty silts. In general, a rather moist, temperate climate is inferred. Occasional coarser beds, the bed-load deposits of a meandering stream branch, interrupt the lower gray marls (unit IVa) at Ambrona. Gravel morphology resembles that of unit IIIb, but there is a moderate cryoclastic component with 22 percent of the pebbles mechanically frac-

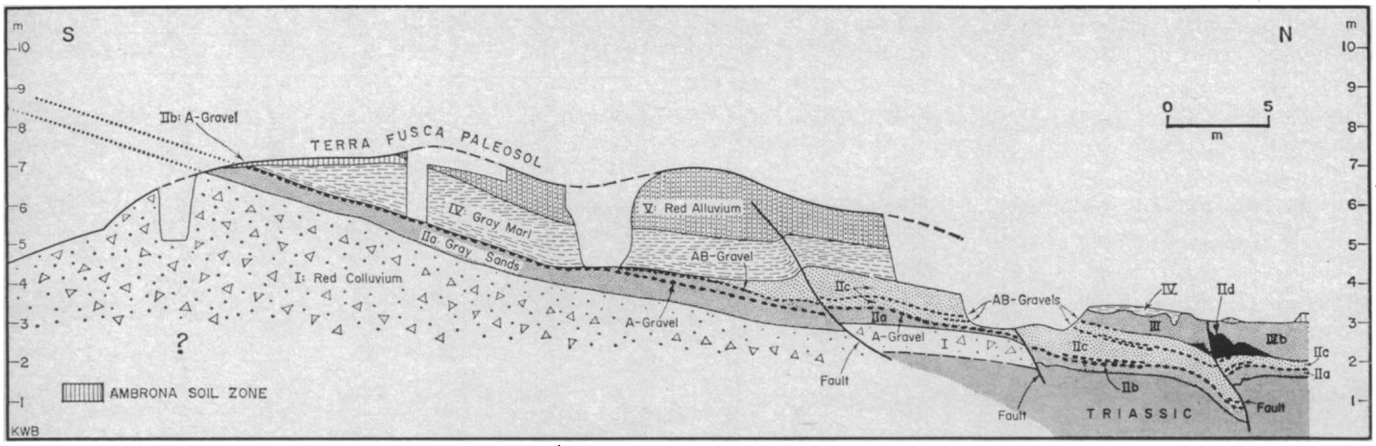


Fig. 2. Composite stratigraphic profile of the Torralba site. Verticle exaggeration, $\times$ 2.

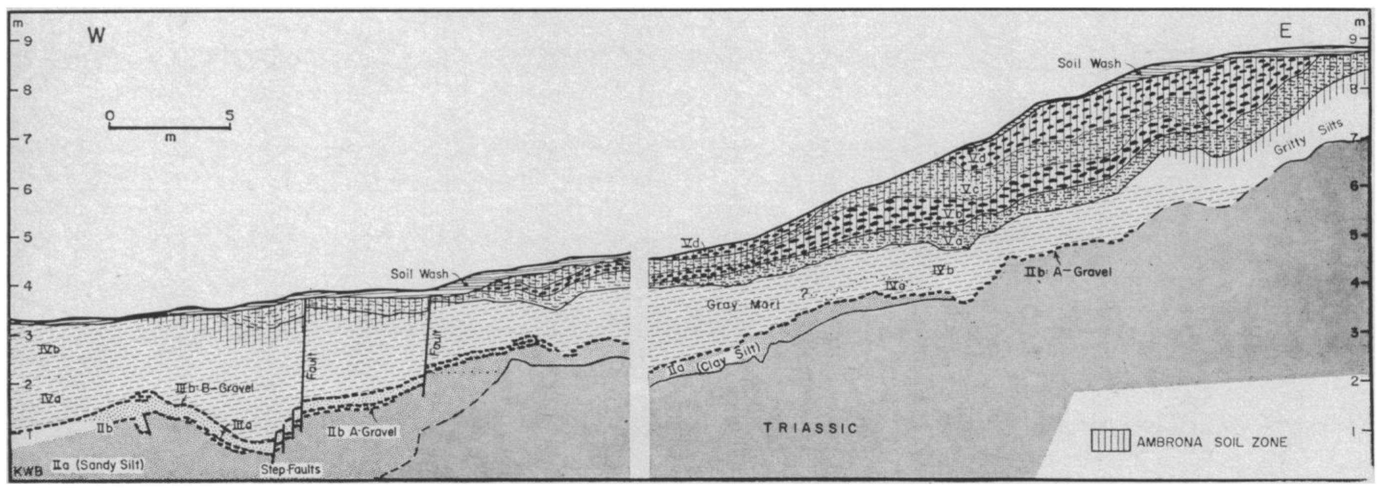


Fig. 3. Composite stratigraphic profile of the upper part of the Ambrona site. Unit IId is intercalated between IIb and IIIa in the lower part of the site. Vertical exaggeration, $\times$ 2.5.

tured before or after final deposition. This suggests a climate appreciably colder than today's during deposition of unit IVa. Evidence of human occupation is abundant in unit IVa but lacking in unit IVb.

Member V of the Torralba Formation, the Red Alluvium, is a more or less conformable sequence of alternating gritty silts and cryoclastic detrital gravels. The morphology suggests shallow alluvial fans deposited on the edge of the +40- to 45-m floodplain by minor drainage lines after general aggradation had ceased. The basal bed, ranging from a gritty marl to a gravelly sand, rests disconformably on unit IV. It is followed by subangular, detrital, medium-grade gravel with a 31-percent component of mechanically fractured pebbles (bed Vb). Pebbles are notably squat (rather than flattish) in shape, suggesting a dominance of rolling motions. The finer-grained bed Vc is a clay silt with some gritty bands, while the upper gritty conglomerate (bed Vd) duplicates bed Vb. Units Vb, Vc, and Vd are in fact conformable, but some 39 percent of the pebbles are mechanically fractured. The overall sedimentology of member V, which attains more than 4 m in thickness on the uplands near Ambrona, suggests a cold but comparatively dry climate during the formation of all but bed Vc. Cultural remains are fairly abundant in the lower beds at Ambrona. The red color of most of member V reflects subsequent soil development rather than the primary sediment.

The Torralba Formation originally filled a valley, previously excavated to about its present dimensions, to a depth exceeding 35 m. The deposits relate to periods of temperate or cold climate, judged by high percentages of cryoclastic pebbles, repeated evidence of solifluction (in part associated with stone rings), and the notable absence of soil horizons reflecting chemical weathering. Except for member V, available moisture was at least as abundant as, often much more so than, in the modern water balance. Yet much of the time a good deal of bare soil or rock was exposed, so that upland denudation and deposition of slope gravels were permitted. During the more temperate phases, geomorphic activity was less pronounced, and more gentle valley alluviation was typical. The former trend suggests processes such as are now underway near or above the alpine tree limit; the latter suggests forested uplands. A glacial age, with alternating cold maxima or stadials [I, II (b and c), III, V] and more temperate interludes or interstadials (IId, IVb), offers the only reasonable overall explanation; this interpretation is largely substantiated by the palynological evidence (*11*).

The soil zone, which sets the terminus to the Torralba Formation, is exclusively developed on members IV and

V and is widely recorded at both sites. It can best be studied where developed in the homogeneous parent material of the Gray Marl, although such sections are usually truncated by erosion. A typical profile, from pit F of the 1962 excavations at Ambrona, can be described as follows. Ap horizon (10 cm): reddish-brown (5 YR 5/4), very stoney, coarse, sandy silt, with coarse-blocky structure; largely of colluvial origin. (B) horizon (60 cm): reddish-brown (5 YR 5/4), homogeneous, clayey silt, with coarse blocky to prismatic structure and some (probably recent) humus; secondary dendrites of calcium carbonate and sulfate in cracks; $CaCO_3$ content, 10 to 15 percent. (B)C horizon (25 cm): reddish-brown (5 YR 5/3-4) zone as in (B) horizon, but with patches of nonoxidized materials; 3-mm calcareous concretions and 2- to 3-mm pyrolusite stains. Ca horizon (25 cm): white (10 YR 8/1) calcified marl with evaporite dendrites and pockets as well as limonitic staining. C horizon (160 cm): light gray (5 Y 6/1) marl, with coarse prismatic structure and with limonitic stains and calcareous nodules; $CaCO_3$ content, 30 to 50 percent.

The (B) and transitional (B)C horizons may attain a combined thickness of about 170 cm without macroscopic evidence of illuviation. A similar soil with such intensive chemical weathering has not formed in central Spain since this time; local soil development is now limited to modest rendzinas. The paleosol is a typical *terra fusca* (*10*). Formation probably can be attributed to a period of humid, subtropical climate that followed incision and drainage of the +40- to 45-m floodplain of the Masegar.

Younger sediments commonly occur downstream from Torralba; they were artifically exposed by a long trench cut northward from the site into the first-order drainage line known as the Torrente de Sahuco. What I formally designate the Sahuco Formation occupies a channel younger than the Torralba Formation; it rests on both derived, red, Keuper-clay silts and a gritty, sandy silt apparently relating to the older Pleistocene deposits.

The basal unit (Ia) is a coarse cryoclastic detritus lacking fine matrix; it was 46 percent mechanically fractured before or after final deposition. This scree occupies the center of the former channel and is followed by a reddish-brown (2.5 to 5 YR 5/4), silty, coarse cryoclastic detritus (41 percent mechanically fractured) of colluvial type that also is confined to the channel (unit Ib). The succeeding reddish-brown (5 YR 5/4) fill ranges from a silty, subangular gravel in the former channel to a sandy marl of colluvial-type upslope (unit Ic). Preserved only on the slopes are reddish-brown (2.5 YR 4/4) clayey silts of colluvial type (unit Id) and reddish-yellow (5 YR 6/6), homogeneous, silty sands of uncertain significance.

Channel cutting preceded deposition of the upper member. Unit IIa, a reddish-brown (5 YR 5/4) sandy silt, with subangular gravel, occupies this channel and suggests a slope wash. A coarse, noncryoclastic, subangular, alluvial gravel, with a brown (7.5 YR 5/4) silt matrix (unit IIb), follows. Finally a dark brown (10 YR 3/3), organic, clay silt, with dispersed coarse subangular gravel, closes the formation. This organic alluvium derives from highly humic rendzina soils that were once present on the uplands.

The upper Sahuco Formation was later subject to channel cutting and is now overlaid by 60 to 120 cm of stoney, reddish-brown (5 YR 4/4), colluvial soil, the product of historical soil erosion. Pollen occurs sporadically in most of the Sahuco beds; artifacts and bones are entirely absent. The lower member suggests a period of cold climate that was followed by moist, slightly more temperate conditions; the upper member implies a moist, temperate climate with only limited frost.

Both sites were subject to complex microfaulting or sag after sedimentation of the Torralba Formation and development of the Ambrona soil (Figs. 2 and 3). The faulting can be attributed to lubrication, deformation, and slumping of subsurface Keuper clays, presumably during the dissection of the Torralba Formation and at a time of relatively moist climate.

The middle Jalón displays three alluvial formations: (i) a "low" terrace (at relative elevations of +3.5 to 6 m), fine-grained, with noncryoclastic gravel and a rendzina climax soil; (ii) a "middle" terrace (+12- to 21-m), primarily unconsolidated gravel, mildly cryoclastic (15 to 21 percent mechanically fractured), but lacking soil-frost structures; the surface carries traces of a poorly developed reddish paleosol; and (iii) a "high" terrace (+22- to 32-m), with cryoclastic, convoluted, calcreted conglomerates (27 to 39 percent mechanically fractured), but lacking a preserved paleosol. Although no direct field correlation is possible, the Torralba Formation can be correlated with the "high" terrace of the Jalón; the Lower Sahuco Formation, with the "middle" terrace; and the Upper Sahuco, with the "low" terrace. Similar correlations of the Torralba Formation with the "high" terrace of the upper-Tajo drainage—in part with bifacial tools—or with massive calcreted breccias elsewhere on the uplands are highly suggestive. Since the "low" terrace is presumably of Würm glacial age, it can be argued that the "high" terrace and the Torralba Formation are local equivalents of the antepenultimate glacial complex, that is, Elster or Mindel; this suggestion is supported by the *terra fusca* paleosol. Pedogenetic processes of such intensity are sufficiently unique to permit broad regional correlation, and tentative identification is made with the Tyrrhenian I (Holstein interglacial)—age *rotlehm* paleosol of Catalonia (*12*).

The proposed correlation of the Torralba Formation with the Elster glacial (presumably Elster II), on conventional geologic-stratigraphic reasoning, is supported by the biologic evidence. The presence of Tertiary relicts, such as the Japanese umbrella fir *Sciadopitys* and pines of *haploxylon* type, favors a pre-Riss age. Similarly a faunal assemblage, characterized by a form of *Elephas antiquus* with primitive traits and by a fallow deer (*Dama* sp.) more archaic than *D. clactoniana*, also indicates an Elster context. The fact that the geologic evidence clearly indicates a glacial age permits convincing correlation of the Ambrona soil zone with the Holstein; of the Torralba Formation with the Elster. The temporal relation of member I to members II–V is uncertain: the interval may have been long, whereas members II through V suggest a fairly continuous and intelligible sequence. Judging by the many erosional surfaces and the records of repeated and sizable climatic fluctuations, I tentatively suggest a period of $x.10^4$ years for the accumulation of the Torralba Formation and the +40- to 45-m terrace.

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## Artifact from Deposits of Mid-Wisconsin Age in Illinois


Abstract. *Discovery of an artifact of human manufacture imbedded in Roxana loess, classed as Altonian substage of the Wisconsin stage of the Pleistocene, of an age of 35,000 to 40,000 years, contributes to the determination of the age of man in the New World.*


An artifact of almost undeniable human manufacture (Fig. 1) has been discovered in west-central Illinois (SW¼ NW¼ SE¼ sec. 19, T5N, R3E, Fulton County), well-imbedded in the nearly vertical face of a fresh road cut. If the artifact is the same age as the stratum where it was found, 35,000 to 40,000 years (*1*), it is extremely important in determination of the age of man in the New World.

Because this is an isolated artifact and because the road cut was made by heavy machinery, there is, of course, the unlikely possibility that the specimen was dragged from another area or fell from the surface above and was pushed into the face of the cut by the machinery. A thin scattering of archeological materials attributable to Archaic occupation (10,000 to 3,500 years ago) on the surface adds some credibility to this possibility. Due to the sheerness and fresh condition of the cut at the time of discovery, however, it would appear to be impossible that the artifact fell from the surface and lodged after completion of the cut. Another equally implausible possibility is that the specimen was intruded by natural means (for example, burrowing animals, uprooting of trees) from the bottom of the Peoria loess 1.1 meters above, which dates after 20,000 years ago.

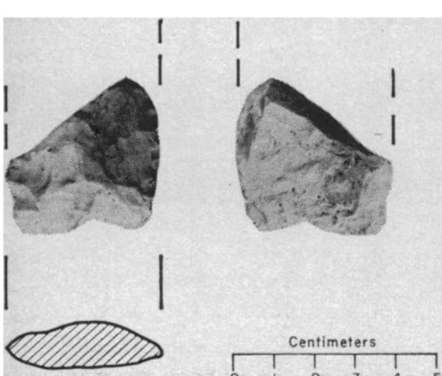


Fig. 1. Obverse, reverse, and cross-section of artifact.

The artifact, one end of which is broken by an old fracture, is plano-convex, well-trimmed, and percussion flaked; and the material is a rather poor-grade gray chert which occurs as pebbles in the local glacial tills.

The Pleistocene stratigraphy in the road cut was studied, the deposits were sampled, and the fractions of the samples of diameter less than 2 microns were analyzed by x-ray diffraction. The stratigraphy at the locality and significant data from the x-ray analyses are shown graphically in Fig. 2. The stratigraphic units are characteristic of the Illinois Valley region and have been described in detail through this part of Illinois (*2*). The Peoria loess consists of yellow-tan massive silt with a relatively deep surface soil at the top. It has been leached of carbonate minerals except in the lowermost 50 centimeters, which contain a minor amount of dolomite (determined by acid in the field and checked by x-ray diffraction). In the lowermost 30 centimeters is a crenulate zone of charcoal flecks; the peaty zone that is typical of the Farmdale is not present in this locality. The Roxana silt consists of loess in the upper two-thirds (zones II to IV) and sandy silt grading downward into sandy, pebbly silt at the base (zone I). The Roxana has been entirely leached of its carbonate minerals and contains a soil at the top and one or more soils in the basal part. Below the Roxana silt is a strongly developed Sangamon soil at the top of Illinoian till; this soil grades downward into typical, calcareous, Illinoian till in the lower part of the cut.

The age of the stratigraphic units has been determined by numerous radiocarbon dates, both on snail shells and on wood, in western and central Illinois. Several ages from the lower part of the Peoria loess have ranged from 17,000 to 20,000 years ago. A large number of dates from the Farmdale peats and silts fall in a range between 22,000 and 27,000 years ago. Although Farmdale peat does not occur in this section, its stratigraphic position is between the Peoria loess and Roxana silt. For the Roxana silt, two ages from the upper part of zone II and the lower part of zone III in southwestern Illinois, determined from snail shells, were 35,000 ± 1,000 and 37,000 ± 1,500 years (samples W-729 and W-869), and ages for peat in a comparable stratigraphic position in

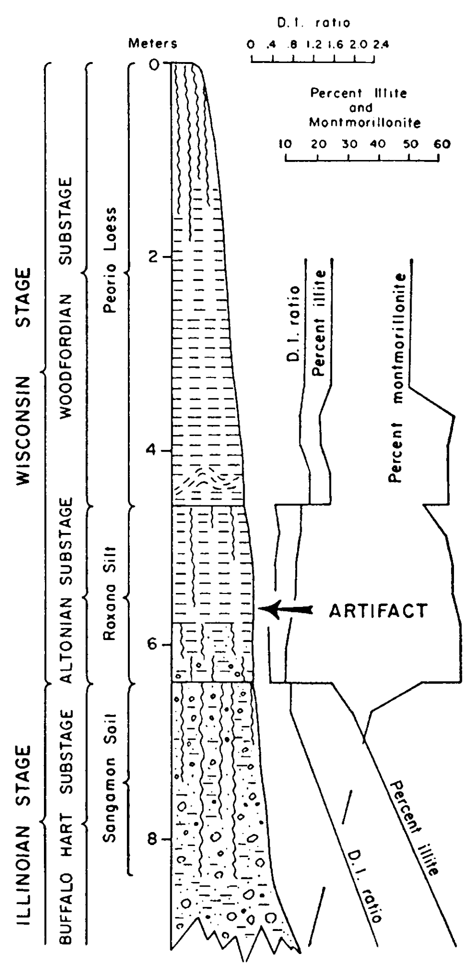


Fig. 2. Stratigraphic succession at the site of collection. The diffraction-intensity ratio (*D.I. ratio*) and percentages of illite and montmorillonite in the fraction of particles less than 2 microns in diameter are shown graphically.