18 October 1963, Volume 142, Number 3590 SCIENCE

Upper Paleolithic Cultures in Western Europe

The first cultures of modern man in western Europe were not so closely unified as had been thought.

Denise de Sonneville-Bordes

Western Europe had its first "great civilization" during Upper Paleolithic times (sometimes called the Age of Reindeer). For about 25,000 years—from 35,000 or 40,000 to about 10,000 B.C.—this area was inhabited by powerful tribes of *Homo sapiens* physically like us. Like the Mousterians, their predecessors and perhaps ancestors, they dwelt in caves, rock shelters, and open-air camp sites, and they lived by hunting and fishing, in a glacial environment. Like their predecessors they made tools and weapons by chipping hard stones, mainly flint, but because they used new techniques, they made more specialized and more complex implements than the Mousterians. They also made tools of bone, ivory, and antlers (mainly of reindeer and red deer). Above all, with these Upper Paleolithic peoples mankind took a decisive step forward in mental development, as the art objects (found for the first time in an archeological context) and paintings on the walls of the caves, as well as the greatly increased number of human burials, bear witness.

This earliest culture of *Homo sapiens* in western Europe was not so closely knit as one would have expected among primitive peoples. The various cultures that the component peoples developed, successively or simultaneously, have only rather general characteristics in common. The greatest complexity is in southwestern France, between the Loire River and the Pyrenees. This region, the richest in sites and cultural remains, is rightly considered the classical region of definition of these cultures. Most of the names of Upper Paleolithic cultures (the Perigordian, the Aurignacian, the Magdalenian, and the Azilian) are derived from type sites in this region, the only exception being the Solutrean. From the stratigraphical sequences and the typological comparisons, H. Breuil and D. Peyrony, the famous French prehistorians, established a general classification (Table 1). During Upper Paleolithic times, local factors played a considerable role in the choice of sites for human occupation. Thus, there are hiatuses and regional differences outside the classical region.

The author is master of research at the Centre National de la Recherche Scientifique, Laboratoire de Préhistoire de la Faculté des Sciences de Bordeaux, Bordeaux, France.

Climate and Fauna

Climate, fauna, vegetation, and human life were still, at this time, under the direct influence of the great glaciations which were the main features of Pleistocene European prehistory. Coming down from the Scandinavian mountains, a thick and enormous ice sheet —an *inlandsis*—covered the lowlands of northern Europe and stretched out over the shallow North Sea. Near the borders of this huge glacier were areas where peoples, in what is now England and Wales and the Belgian Ardennes, lived (Fig. 1). The sites of southern Germany and Switzerland were under the influence of the great alpine glacier, which spread out to the north over the Swabian Jura and Bavarian plateau and to the west of the French Jura down to the Rhone River. The French Massif Central, less high, shows only localized glacial features, and human penetration of this area was possible along the main valleys. The Pyrenees, where glaciers formed only on the peaks, were never impassable, and cultures there spread through the lower valleys, on the Atlantic side between what are now the Basque countries and the Spanish Cantabrian Mountains, on the Mediterranean side between present-day Roussillon and Catalonia.

The Upper Paleolithic cultures appeared during the Würm glaciation, the last of the four great glaciations in Europe. As in the glaciations that preceded it, there were minor advances and regressions during the Würm glaciation. The advances, or stadials, are called Würm I, II, III, and IV; the intervening regressions, or interstadials, are called Würm I/II, II/III, and III/IV. Following the Mousterian culture, which spanned Würm I and Würm II and ended during the Würm II/III interstadial, the Upper Paleolithic began at the end of Würm II/III. It continued through Würm III and Würm IV and disappeared at the very beginning of postglacial times.

Thus, western Europe had, in general, a severe climate during these times, with variations depending on latitude and on position relative to the ice sheets. That the climate was severe can be seen from the fauna and the deposits in rock shelters. Under the roofs of the caves and shelters, angular congelifracts became detached from the wall by the action of the intense cold. When the climate was less severe

Table 1. Upper Paleolithic cultures in western Europe.

Southwestern France	Northern Spain	Italy	Belgium	Great Britain	West Germany	Switzerland
Azilian	Azilian		Epimagdalenian	Epimagdalenian	Epimagdalenian	Epimagdalenian
Final	Final		Final	Creswellian		Final
Upper (V–VI)	Upper (V–VI)		Upper		Upper	Upper (V–VI)
Middle (III–IV)	Middle (III–IV)		Magdalenian		Middle(?)	Middle
Lower (I–II)	Magdalenian				Magdalenian	Magdalenian
Magdalenian						
Upper	Upper					
Middle	Middle					
Lower	Solutrean					
Solutrean						
Final (V)						
Protomagdalenian		Grimaldian				
Final IV						
Evolved III	Evolved	Evolved Perigordian	Evolved Perigordian			
Middle II	II		II			
I	I		I			
Aurignacian	Aurignacian	Aurignacian	Aurignacian	Aurignacian(?)	Aurignacian	Aurignacian(?)
Lower	Lower					
Perigordian	Perigordian					
Mousterian	Mousterian	Mousterian	Mousterian	Mousterian	Mousterian	Mousterian

and precipitation was greater, layers of sand and clay were often deposited by the water. These rarer periods of warm climate and greater humidity are marked by the formation of stalagmitic floors. From the succession of these different types of sediments in the numerous sites of southwestern France, D. Peyrony, and later F. Bordes, were able to formulate a general outline of the climate in this region during Upper Paleolithic times.

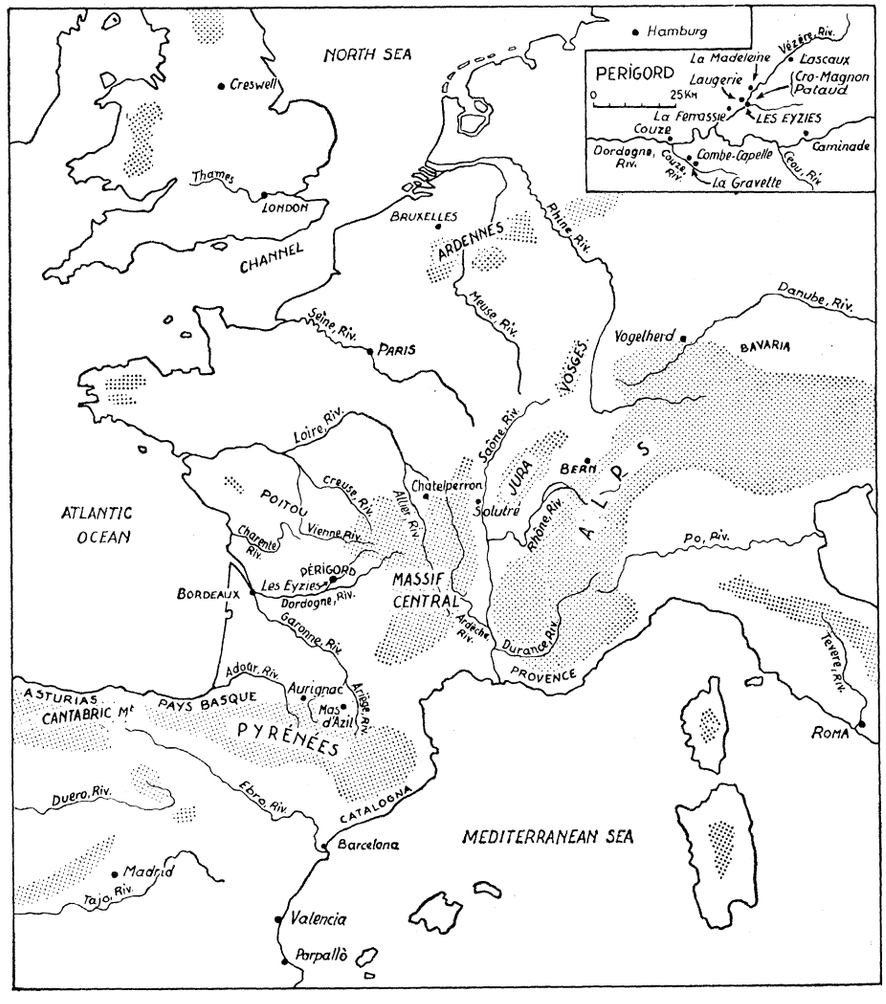


Fig. 1. Map of western Europe in Upper Paleolithic times.

The fauna of the Upper Paleolithic is well known from the remains of game found in the archeological layers and from the numerous examples of Upper Paleolithic art. Like the Mousterian fauna, this is a cold fauna. It includes arctic animals (reindeer, musk ox, wolverine, arctic fox, arctic hare, . . .) and animals which have completely disappeared from our planet (mammoth, woolly rhinoceros, cave bear, . . .), besides mountain game (mountain goat, chamois, . . .) and great herds of horses, oxen, bison, and red deer. According to F. Prat, the Saiga antelope (now a dweller of the cold steppes of Central Asia), till then almost unknown in Atlantic Europe, made occasional appearances, in numerous herds, in the hills of southwestern France, but only during the Magdalenian. The cold fauna, with reindeer, penetrated at last into the meridional peninsulas of Spain and Italy.

Technical Innovations

It has been generally believed that blade *débitage* was a characteristically Upper Paleolithic innovation and that, in the Upper Paleolithic, blades were the basic stone form from which implements were manufactured. In truth, this invention dates back to the Acheulean, and blade *débitage* was widely used in some Mousterian cultures. Besides blades (Fig. 2, Nos. 4–7; Fig. 3, No. 1; Fig. 4, Nos. 1, 5; Fig. 5, No. 7; Fig. 6, Nos. 7, 13, 16) and bladelets (Fig. 2, No. 2; Fig. 3, No. 5; Fig. 4,

No. 2; Fig. 6, Nos. 8–12), the men of Upper Paleolithic times also made flakes (Fig. 2, Nos. 8, 10; Fig. 3, Nos. 2–4, 6, 7; Fig. 6, No. 14). At some stages of their cultures—for instance, in the Aurignacian—flake implements are more numerous than blades. So the Upper Paleolithic is not exclusively a "blade culture," even though a good proportion of the tools, and, in some stages (such as the Upper Magdalenian) an overwhelming majority of them, are blade or bladelet tools.

These populations showed true originality in inventing new types of tools. However, the Mousterian tool types—for instance, side scrapers (Fig. 2, No. 9) or denticulate tools (No. 10), which were especially numerous in the Early Perigordian—were made till the end of the Paleolithic. The typical tools of the Upper Paleolithic, which had occurred occasionally in the Mousterian, were now the most important tools, with varied subtypes: end scrapers (Fig. 2, No. 8; Fig. 3, No. 1; Fig. 6, No. 2), burins (Fig. 3, Nos. 3, 4; Fig. 4, No. 1), and borers (Fig. 4, No. 3). Multiple tools were numerous: double scrapers (Fig. 5, No. 2), multiple burins (Fig. 2, No. 5; Fig. 4, No. 5; Fig. 6, No. 1), multiple borers (Fig. 6, Nos. 4–6). Composite implements were invented, and two or more different tools were made on the same piece of flint—for instance, end scraper and burin (Fig. 4, No. 4; Fig. 6, No. 13). This common tool assemblage gives a kind of uniformity to the Upper Paleolithic cultures, even if there is a considerable range of variation in the proportions of the different types from culture to culture. In addition to the tools common to these cultures there were tools found only in one culture and characterized either by the technique of retouch or by the general morphology, or by both: in the Perigordian, backed points with abrupt retouch (Fig. 2, Nos. 6, 7); in the Aurignacian, thick scrapers (Fig. 3, Nos. 2, 6, 7); in the Solutrean, foliate tools with a very flat parallel retouch (Fig. 6, Nos. 1, 5–7).

In making tools of antler, ivory, and bone, the Upper Paleolithic men were true innovators. They used two different techniques of *débitage*. In the first or "wedge" technique, a beveled reindeer antler was used as a wedge to split another antler lengthwise. The second, and later, technique was the "groove and splinter" method: with a burin, two parallel grooves were made in the bone or antler, down to the marrow. The splinter of bone or antler thus detached was scraped, then polished on sandstone to form the tool. The splinters were made into various tools, some of them quite elaborate: bone points with split bases (Fig. 3, No. 8; Fig. 7, No. 2) or beveled bases (Fig. 3, No. 9); needles (Fig. 5, No. 4); half-cylindrical wands (Fig. 7, No. 7); harpoons (Nos. 3–6); spear-throwers (No. 1); and thong-stroppers or shaft straighteners (No. 8). The tools were hollowed out, smoothed, and shaped to make them easier to grasp, bind on, and handle. Decorative patterns and even, during the Magdalenian, engraving and carving sometimes made these implements real works of art (Fig. 7, Nos. 1, 8).

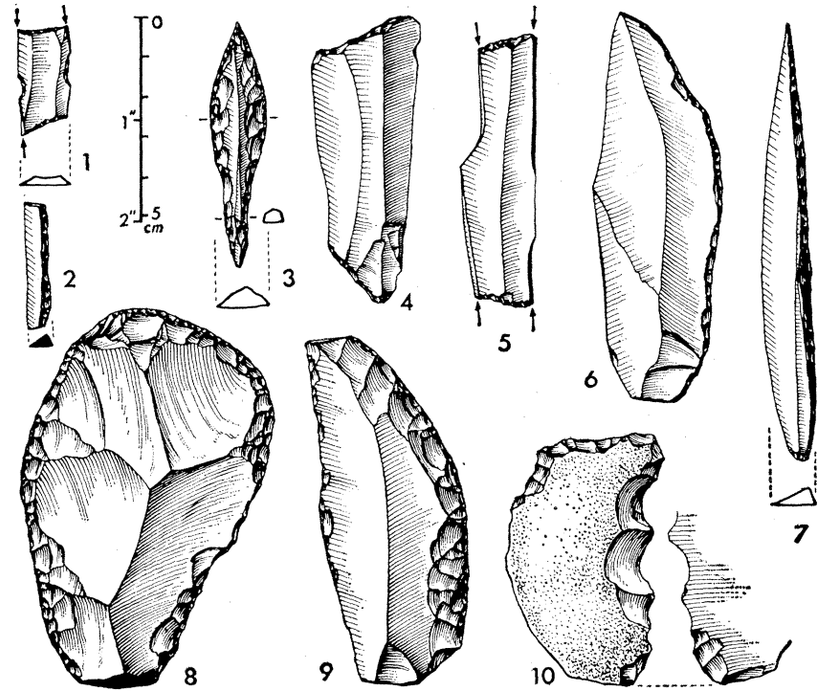


Fig. 2. Perigordian tools. 1, Noailles burin; 2, backed bladelet; 3, Font-Robert point; 4, "*elément tronqué*"; 5, quadruple burin; 6, Châtelperron point; 7, Gravette point; 8, end scraper; 9, side scraper; 10, denticulate tool.

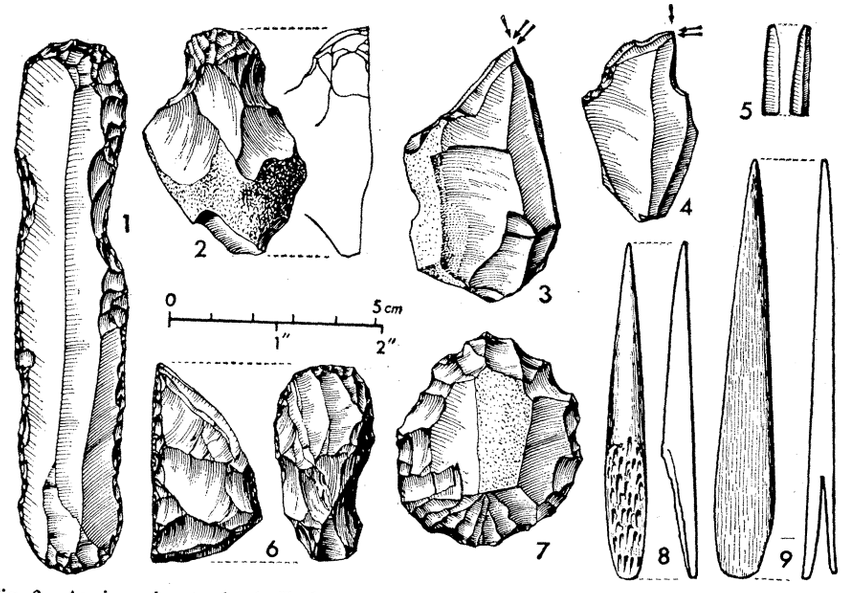


Fig. 3. Aurignacian tools. 1, End scraper on an Aurignacian blade; 2, nosed scraper; 3, dihedral burin; 4, busked burin; 5, bladelet with semi-abrupt retouch; 6, carenate scraper; 7, denticulate scraper; 8, bone point with beveled base; 9, bone point with split base.

Stratigraphical Sequences

In southwestern France, the rich and numerous Upper Paleolithic sites can be divided into two main zones (Fig. 1). The first comprises the limestone countries north of the Garonne River. Open to the Atlantic Ocean to the west, this zone forms a belt around the high and cold lands of the Massif Central and includes Poitou, Charentes, and Périgord. The second zone includes the Pyrenees region and its piedmont, from the Adour valley to the Ariège. To these southwestern areas may be added the valleys of the Saone and the Rhone, north-south passageways where cultural territories meet: the Solutrean does not cross the Rhone, nor does the Magdalenian cross the Durance. The Upper Paleolithic in this region has been used as a reference base for the rest of Europe.

In the excavations made there, mainly by D. Peyrony and E. Peyrony near Les Eyzies (Dordogne) at La Ferrassie (Fig. 8, top) and Laugerie-Haute (Fig. 8, right) and later by F. Bordes at Laugerie-Haute and by H. L. Movius at the Pataud shelter, the general stratigraphic sequence is as follows. After the enormous Mousterian deposits, which represent the Würm I and the Würm II stadials, the Upper Paleolithic begins, in the reddish and clayey layers of the Würm II/III interstadial, with a culture, the Early Perigordian (La Ferrassie, layer E), whose lithic components are often crushed as a result of frost action (Fig. 2, No. 10). Deposits of thermoclastic *éboulis* with cold fauna, representative of the beginning of Würm III, contain the various levels of the Aurignacian, I–IV (La Ferrassie, layers F, H, H′, and H″). In a layer containing more sandy, small *éboulis*, formed when the climate had moderated slightly, are found remains of the evolved Perigordian (La Ferrassie, layers J, K, and L). Apparently this moderation did not last, for remains of the final Perigordian are found in a layer containing large thermoclastic *éboulis* (Laugerie-Haute, layers B and B′). Above it comes an exceptional culture, the Protomagdalenian (Laugerie-Haute, layer F), also found recently over the same Perigordian by Movius at Pataud. The Aurignacian V has been found, to date, only at Laugerie-Haute. The cold climate persisted into the Lower Solutrean, as shown by the fact that these levels, too, contain thermoclastic material (Laugerie-Haute, layer H′), but the Middle Solutrean (layer H″) and the Upper Solutrean (layer H″′) evolved during the period of climatic moderation of the Würm III/IV interstadial. In this same interstadial we find the remains of Lower Magdalenian culture; phases I, II, and III are found in sandy and clayey layers, where the proportion of the angular *éboulis* produced by frost action on the walls of the shelter increases from the bottom to the top (Laugerie-Haute, layers I′, I″, and I″′).

In the earliest Würm IV deposits there is extensive evidence of the collapse of the roofs of shelters, caused by the erosion of frost action on the interior of the shelters. This is followed by deposition of layers made of loose, angular *éboulis*. In these layers are found materials of the Upper Magdalenian, classified in three phases—IV, V, and VI—at La Madeleine shelter. Heavier precipitation and more temperate conditions progressively brought the great glacial period to an end. The sandy and clayey layers (often rich in snail shells) of the Magdalenian and Azilian, last of the Paleolithic cultures, are frequently covered by stalagmitic floors. The cold reindeer fauna is now replaced by a residual fauna, with red deer, wild boar, and lynx. Mesolithic times begin.

Some dates obtained by the radiocarbon technique by De Vries of the University of Groningen, the Netherlands, make it possible to determine the stratigraphical chronology with some precision. These dates are 26,930 B.C. ± 250 years (GRO-1491) for the Aurignacian of the Caminade shelter (excavations by F. Bordes, D. de Sonneville-Bordes, and Mortureux); 19,785 B.C. ± 250 years (GRO-1876) for the Protomagdalenian of Laugerie-Haute (excavations by F. Bordes) and about 18,250 B.C. for the same culture at Pataud (excavations by Movius)—a rather surprising discrepancy, for these two layers seem to be strictly contemporaneous; and 18,700 B.C. ± 300 years for the Lower Solutrean of Laugerie-Haute (excavations by F. Bordes).

Typological Classification

From the study of tool assemblages we can trace the evolution of the cultures whose succession is established by the stratigraphical sequences.

The cycle of the Aurignaco-Perigordian cultures, which occupy the beginning of the Upper Paleolithic, appears from the work of D. Peyrony to be more complex than H. Breuil had believed. Breuil had envisioned a linear

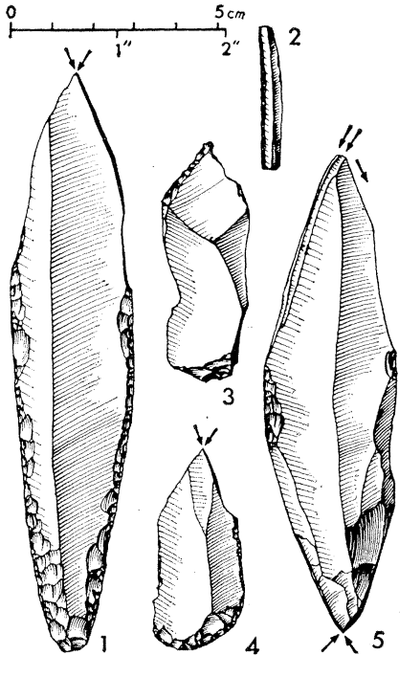


Fig. 4. Protomagdalenian tools. 1, Dihedral burin; 2, backed bladelet; 3, borer; 4, burin-scraper; and 5, double dihedral burin.

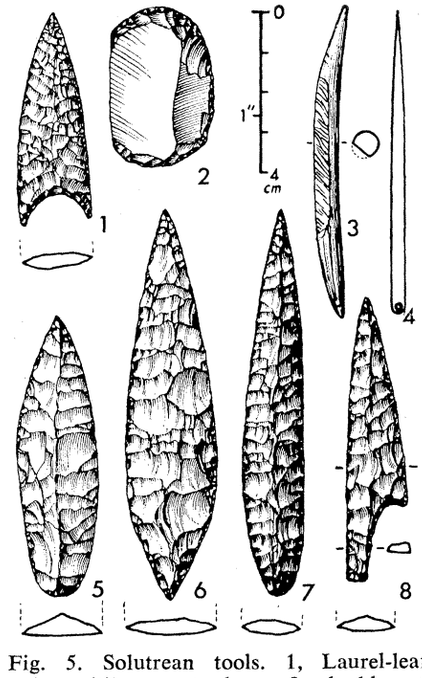


Fig. 5. Solutrean tools. 1, Laurel-leaf point with concave base; 2, double-end scraper; 3, curved bone point; 4, needle; 5, unifacial point; 6, laurel-leaf point; 7, willow-leaf point; 8, shouldered point.

development of a single civilization, the Aurignacian, which he subdivided into Lower Aurignacian, with Châtelperron points; Middle Aurignacian, with split-base bone points; and Upper Aurignacian, with Gravette points. From his excavations at La Ferrassie and Laugerie-Haute, Peyrony distinguished in this complex two different cultures: the Perigordian, which combines the inferior and the superior stages of Breuil's Aurignacian, and the Aurignacian (*sensu stricto*), which is Breuil's Middle Aurignacian. Recent excavations at Laugerie-Haute and Pataud have somewhat complicated Peyrony's schema.

The Perigordian has, in every one of its stages, points with backing by abrupt retouch—Châtelperron points with a curved back (Fig. 2, No. 6) in the lower stage and Gravette points with a straight back (No. 7) in the evolved stages. In the lower stage, the ordinary tools, often somewhat awkwardly made, are associated with Mousterian-like tools—side scrapers (No. 9) and denticulates (No. 10). In the later stages the proportion of these Mousterian-like tools diminishes, and the ordinary tools—mainly end scrapers (No. 8) and burins, often multiple ones (No. 5)—are better made. Not found at earlier levels, backed bladelets (No. 2) make their appearance. Special tools, such as truncated blades (No. 4), tanged Font-Robert points (No. 3), and tiny multiple Noailles burins (No. 1), first appear in the evolved Perigordian. No art objects and very few bone tools occur in the Lower Perigordian. In the evolved Perigordian, where only a few types of bone tools occur, and these not numerous, little female statuettes called "Venuses" are found.

The Aurignacian is characterized by implements made with a special kind of wide, heavy retouch (Fig. 3, No. 1); by thick carinate scrapers (No. 6) and nosed scrapers (No. 2); by busked burins (No. 4); by bladelets with a semi-abrupt retouch (No. 5); and by a rich, elaborate set of bone tools. The evolution of this culture can be clearly followed at La Ferrassie: decrease in the proportion of implements with the special Aurignacian retouch, increase in the proportion of burins, and increase in the ratio of nosed scrapers to carinate scrapers. The split-base bone points (No. 9), typical of the very earliest stage, are replaced first by flat, lozenge-shaped points, then by lozenge-shaped points with an oval section, then by biconical bone points with a circular section. The very late Aurignacian V of Laugerie-Haute has dihedral burins (No. 3), thick denticulate scrapers (No. 7), and bone points with a single bevel on which the bone canals can be seen (No. 8)—a feature which occurs only at this level of this site during the Paleolithic. The first animal paintings, in red or black, appear in the early Aurignacian, together with coarse, deeply grooved engravings.

Everywhere, in France, the Aurig-

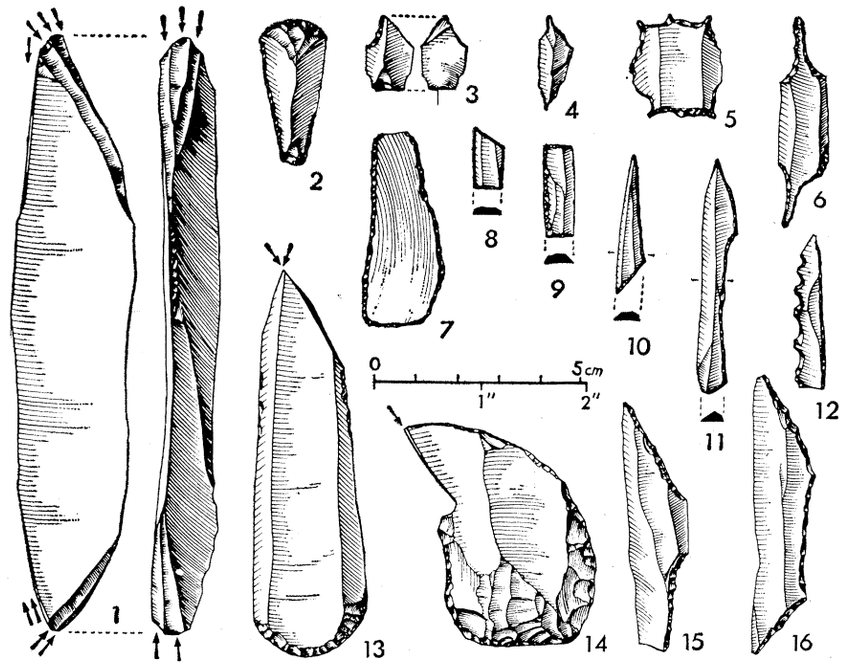


Fig. 6. Magdalenian tools. 1, Double dihedral burin; 2, end scraper; 3, "microburin"; 4–6, borers; 7, "raclette"; 8, trapezoid; 9, rectangle; 10, triangle; 11, shouldered point; 12, backed denticulate bladelet; 13, burin-scraper; 14, parrot-beak burin; 15, shouldered point with oblique truncation; 16, trapezoid.

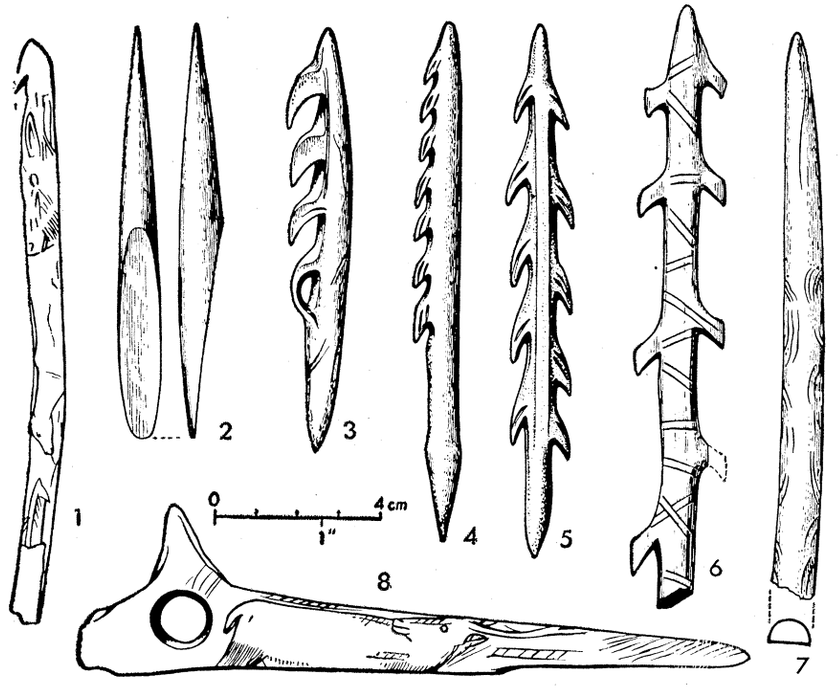


Fig. 7. Magdalenian tools. 1, Spear-thrower; 2, bone point with beveled base; 3–6, harpoons; 7, half-cylindrical wand; 8, arrow-shaft straightener.

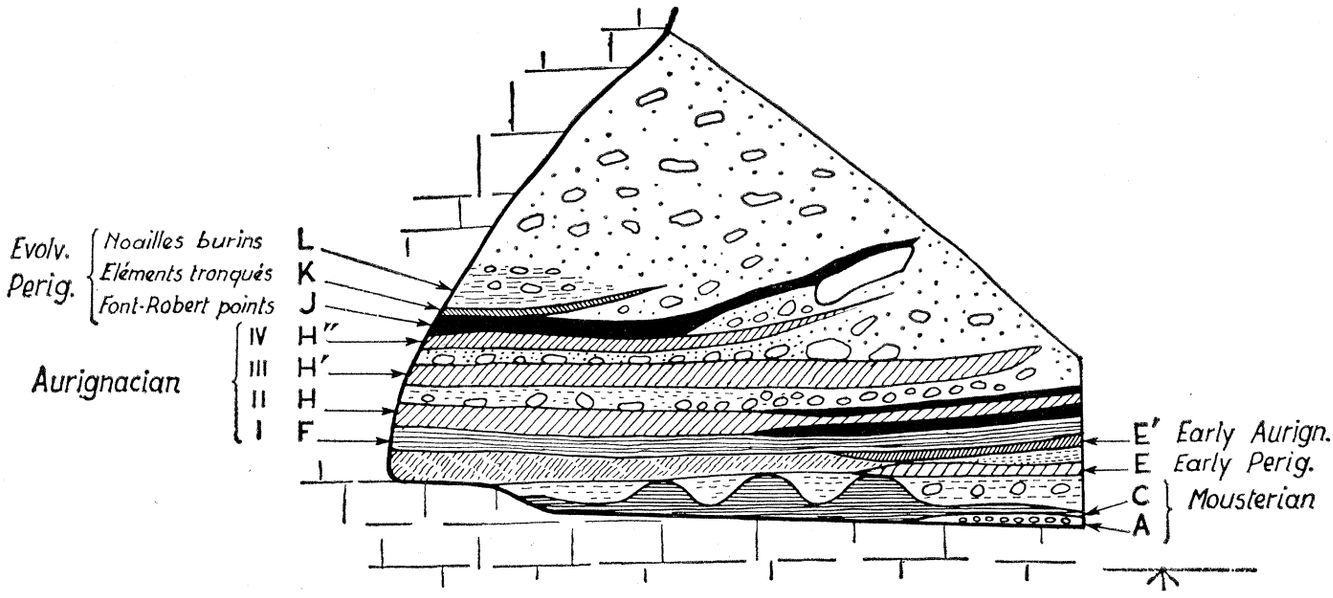
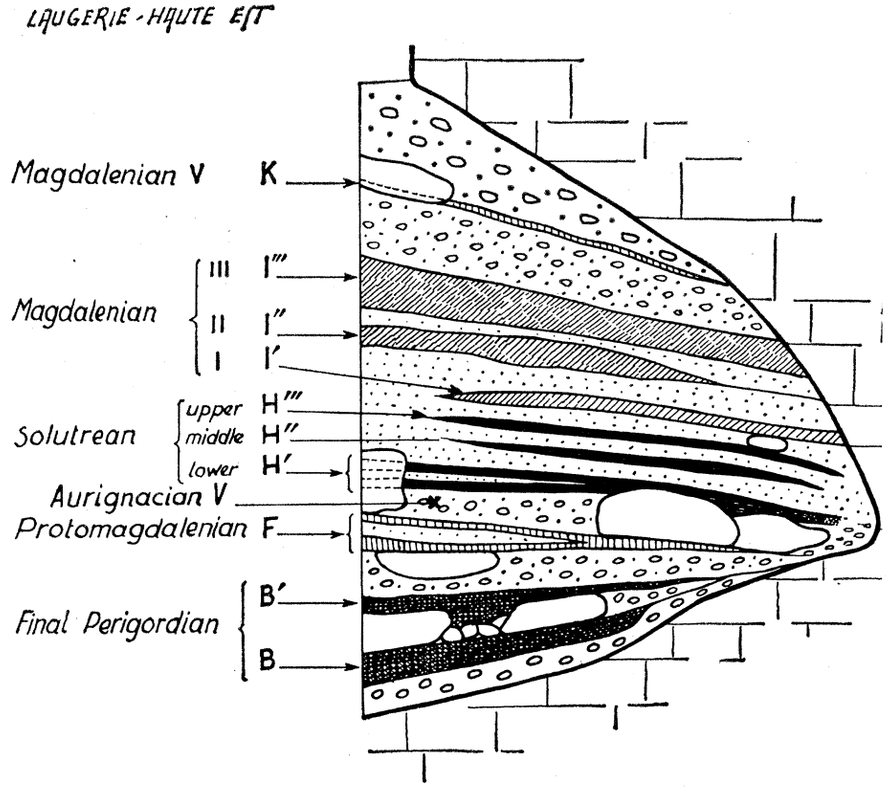


Fig. 8. (Top) Schematic section at La Ferrassie (Dordogne), showing the stratigraphic sequence of Aurignacian and Perigordian cultures. (Right) Schematic section at Laugerie-Haute East (Dordogne), showing the stratigraphic sequence of Perigordian, Protomagdalenian, Solutrean, and Magdalenian cultures. [After D. Peyrony and E. Peyrony.]



nacian and the Perigordian complexes are totally independent of each other, without reciprocal influences. The typical tools of the one are not found in the other, and the common tools occur in different proportions. The technical and typological continuity between the Lower and the Upper Perigordian seems to indicate that the Perigordian and the Aurignacian evolved contemporaneously.

The Protomagdalenian is known only from Laugerie-Haute and Pataud. The tools are especially beautiful—well-retouched blades; numerous burins, often double (Fig. 4, Nos. 1 and 5); end scrapers and burin-scrapers (No. 4); borers (No. 3); numerous backed bladelets (No. 2); and sundry bone tools. The relation of the Protomagdalenian to the other cultures is yet to be established.

All known subdivisions of the Solutrean occur only in southwestern France, and even there they are infrequent. All have tools with the flat Solutrean retouch, with parallel edges, and a very uniform distribution of the common tools—simple or double-end scrapers (Fig. 5, No. 2) and a few burins, borers, and composite tools. The special tools, always plentiful, change from one substage to the other. Among them are unifacial points (No. 5), laurel-leaf points (No. 6), shouldered points (No. 8), and willow-leaf points (No. 7), all with the characteristic Solutrean retouch. Bladelet tools are rare; Mousterian-like tools are fairly numerous. Despite the invention of the eyed needle (No. 4), the bone tools are mediocre and lack variety. This culture disappears after showing a remarkable mastery of flint work. The Solutreans also made beautiful bas reliefs of animals.

The Magdalenian has an elaborate assemblage of bone tools, which are found in abundance and which Breuil used for purposes of classification. The lithic assemblages gathered by Peyrony increase the precision of classification. The Lower Magdalenian is characterized by several types of bone points (Fig. 7, No. 2), among them grooved points. Among the characteristic stone tools are small flakes with a very abrupt retouch [the "raclettes" (Fig. 6, No. 7)] and small triangles (No.

10), the first of numerous geometric forms to appear in the Paleolithic. After the Magdalenian III, in which the first half-cylindrical wands appear (Fig. 7, No. 7), the relative proportions of the various types of stone tools remain the same. There is remarkable unity among the Magdalenian lithic assemblages. They include burins, often double (Fig. 6, No. 1) and always plentiful; end scrapers (No. 2), less numerous; sundry composite tools, mainly scraper-burins (No. 13), borers, and microborers (Nos. 4–6) of various types; and numerous backed bladelets, sometimes denticulate (No. 12). In the Upper Magdalenian, harpoons with one side barbed (Fig. 7, No. 4) and then with two sides barbed (No. 5) are added to this lithic assemblage. In the late Magdalenian some new types are added to the usual flint-tool kit: parrot-beak burins (Fig. 6, No. 14), shouldered points (No. 11), and foliate points. Some sites also contain numerous geometrical microliths: triangles, semilunates, rectangles (No. 9), trapezoids (No. 8), and the so-called microburins (No. 3), the waste products of the fabrication of the other forms. All these geometrical microliths occur frequently in the Mesolithic cultures that follow. Of all the early cultures the Magdalenian is by far the richest in art forms, be they engraved or sculptured weapons, like the spear-throwers (Fig. 7, No. 1), or implements like the shaft straighteners (No. 8), or paintings and engravings on cave walls.

The Azilian, which marks the end of the Upper Paleolithic, has a less varied lithic assemblage of rather awkward, smaller tools. They include mainly flint points with a curved back [Azilian points (Fig. 9, No. 3)] and very short end scrapers (No. 2). Since tools of these types are already present in most late Magdalenian assemblages, it is very likely that there was a connection between the two cultures. Wands, punches, and flat harpoons with or without a basal perforation shaped like a button hole (No. 1) were made of the antlers of red deer. Some pebbles engraved with geometric patterns or painted with red and black dots or bars are the only manifestation of artistic expression.

North of Provence, in the Rhone and the Saone valleys, Aurignacian is known and Upper Perigordian is well represented. Ardèche is rich in Lower Solutrean sites. At Solutré, near Mâcon, over the Upper Perigordian layers, in which thousands of horse bones occur, are Middle and Upper Solutrean levels, but no shouldered points occur in them. Throughout the Rhone valley, no parrot-beak burins occur in the Upper Magdalenian.

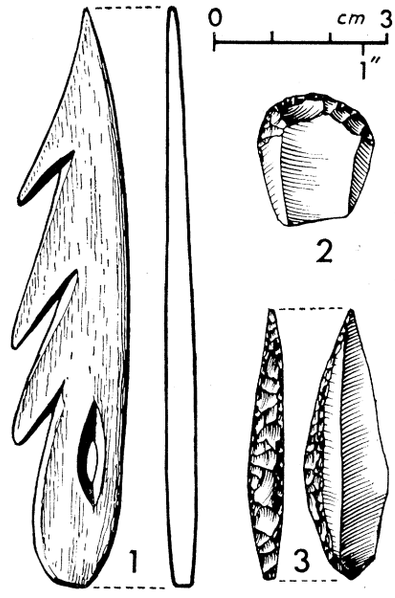


Fig. 9. Azilian tools. 1, Flat harpoon; 2, end scraper; 3, Azilian point.

Extension, Geographical Gaps, and Facies

Outside this region of southwestern France, the Upper Paleolithic is neither so complex nor so continuous (Table 1). Spain, more than any other country, belongs to the same cultural community, in spite of the barrier of the Pyrenees. The Atlantic coast was more widely used than the Mediterranean coast as a route of communication. The sites in Cantabrian Spain between the sea and the high Cantabrian Pyrenees are very numerous until one reaches the present-day province of Asturia, whereas Catalonia has very few Paleolithic sites. Only traces of the Early Perigordian are found in Catalonia. On the other hand, the Aurignacian, with split-base points, is widely found, mainly in Cantabrian Spain. Here the Upper Perigordian is less rich and less complex than it is in France. The Solutrean, which first occurs here in its middle stage, with laurel-leaf points, has some original tools, typically Spanish: laurel leaves with a concave base (Fig. 5, No. 1) and curved bone points with a median flat area striated by fine oblique lines (No. 3). In the Asturias, associated with tools of classical type, are found tools of quartzite, often coarsely made. These include side scrapers, planes, thick-flake end scrapers, denticulate and notched tools, and large retouched blades. Despite changes in other aspects of the assemblage, these tools continue, with the same distribution of types, in the Magdalenian. The Magdalenian first occurs in Cantabrian Spain in its median phase (Magdalenian III), but it is mainly and magnificently represented by stages V and VI, with special laterally perforated harpoons, typically Spanish (Fig. 7, No. 3). As in France, it is overlain by Azilian layers, which are numerous in the Basque country. In eastern Spain the cultures attributed to the Upper Paleolithic, such as Solutrean and Magdalenian at the Parpallo site, near Valencia, are very special and seem to be partially related to the Mediterranean cultures.

Provence, which lies east of the Rhone and fronts on the Mediterranean, and Italy down to Mount Circeo, near Rome, belong to the same cultural complex as France at the beginning of the Upper Paleolithic, yielding Aurignacian with split-base points and Upper Perigordian with Gravette points. But toward the end of Würm III, these Mediterranean areas, where neither the Solutrean nor the Magdalenian penetrated, separated from the continent, culturally speaking. A special culture, the Grimaldian, a kind of Perigordian, occurred early and continued to the end of glacial times. This is characterized by geometrical microliths, round scrapers, and microburins, and is poor in bone tools.

In Belgium, in the caves of the Ardennes, the Aurignacian with split-base points overlies important Mousterian levels, without any intercalation of Lower Perigordian. Here the Aurignacian is similar to the Aurignacian of France, though perhaps poorer in typical blades and in busked burins. The Upper Perigordian seems poorer and rarer. There is a long gap, and then evidence of a Paleolithic occupation of the Upper or late Magdalenian phase, at the end of Würm IV. This differs from the late Magdalenian in France: there are no parrot-beak burins, there is an abundance of borers, and barbed harpoons are rare. There are some Azilian points. It differs from, and is certainly older than, the Epimagdalenian of open-air sites, where Azilian

Fig. 10. Engraving from the Magdalenian VI period: the "Venus of Couze" (Dordogne), from an excavation by F. Bordes.

points and tanged points are abundant. This Epimagdalenian of a slightly later date is very common on the plains of northern Europe. There are few works of art in this Belgian Magdalenian.

The caves of Great Britain have produced rather poor assemblages, the oldest of them being attributed to the Aurignacian, the more recent and more numerous, to a very late Magdalenian-like culture, the Creswellian. The bone-tool assemblage includes needles, arrow-shaft straighteners, and barbed harpoons, sometimes of Magdalenian type, sometimes of a later type—flat, with angular barbs. Curved-back points in the shape of large trapezoids (Fig. 6, No. 16), truncated or bitruncated, link these cultures to the Epimagdalenian of the Northern Plains, but the fauna is still of glacial type, with reindeer.

In western Germany, the Rhine valley and the Bavarian plateau were occupied by Paleolithic man at two different times. Here the Aurignacian with split-base points has a rich and original assemblage of stone tools. This includes numerous pieces with Aurignacian retouch, numerous burins (but no busked ones), and a few carinate scrapers or nosed scrapers. Animal statuettes, the oldest known, have been found in the Vogelherd cave in Württemberg. The second occupation occurred very late, in the last Magdalenian. There are many open-air sites and caves in the Swabian Jura. The assemblage, which includes needles and harpoons, differs widely from the French assemblage with respect to stone tools. Borers (Fig. 6, No. 6) are plentiful and varied; there are no parrot-beak burins; shouldered points, with an oblique truncation (Fig. 7, No. 15) show a relationship with the cultures of the open-air sites to the north, near the edges of the glaciers around present-day Hamburg (the Hamburgian culture).

Paradoxically, the greatest demographic expansion occurred during the periods of more severe climate—the Aurignacian and Upper Magdalenian. During the periods of milder climate—for example, the Lower and even the Upper Perigordian, the Solutrean, and the Lower Magdalenian—the cultures were less widespread and the populations were more scattered. Except in Spain, the Lower Perigordian, the Solutrean, and the Lower Magdalenian are totally unknown outside the classical region and the Rhone valley. During the Upper Magdalenian, the density of population was relatively high in France, as evidenced by the great number of sites occupied for the first time, and by the richness of the sites in animal remains, tools, and works of art. Open-air sites, sometimes with pavements of pebbles, are often found, along the rivers, near the fords where herds of game crossed the stream, or in places where salmon fishing was good (the vertebrae of salmon are very common in the archeological layers).

During this period there was extensive penetration of mountainous areas, where previously only a few tribes of Aurignacian or Upper Perigordian peoples had made their way. In the Massif Central, small sites are scattered along the high parts of the Loire and Allier valleys. In the Pyrenees, man occupied the valleys he had penetrated during the Aurignaco-Perigordian but had relinquished during the Solutrean. The alpine regions, liberated by the receding glaciers, were progressively occupied. Peoples coming from Jura, Dauphiny, and Savoy settled the south of what is now Switzerland, while others from the Rhine and Danube valleys settled in the north of that country. This late Magdalenian, without parrot-beak burins and with some shouldered points with oblique truncation, seems closely related to the late Magdalenian in Germany. Some of the bone tools, such as the barbed harpoons (Fig. 7, No. 6), are very original.

The end of glacial times was fatal to this striking human expansion. The disappearance of the cold fauna and the replacement of the steppe, rich in game, by forests was followed by a demographic regression and break-up of the Upper Paleolithic cultures, resulting in the traditions which are grouped together under the general names of Mesolithic and Epipaleolithic. The relative cultural unity of western Europe was broken, and man's first great period of creative activity came to an end.

Ways of Life

Man of the Upper Paleolithic lived by hunting and fishing, as man of the Mousterian did. The coexistence of numerous tribes in neighboring sites suggests a delimitation of hunting territories and a fairly high level of social organization. The fact that huge or dangerous animals were frequently killed suggests that there was a high degree of coordination of activity in the society. The habitation sites are at the entrance of caves and in rock shelters, so very few implements are to be found inside the deep, painted caves such as that of Lascaux. Fire was in general use and had been at least since the Mousterian. Open-air encampments, numerous mainly during the Aurignacian, the Upper Perigordian, and the Magdalenian, were perhaps hunting camps or seasonal habitations.

The custom of burying the dead, known since the Mousterian, was now general, and as a result the men of Upper Paleolithic times are physically well known. The body, buried in a flexed position, was almost always sprinkled with red ocher and adorned with necklaces and arm-rings of shells and pierced teeth. It is sometimes a woman holding a very young (perhaps stillborn) child in her arms. A single burial is known from the Lower Perigordian, from Combe-Capelle, Dordogne—a man of small stature, with

prominent brows. Numerous complete skeletons of men belonging to the Cro-Magnon race have been found in Aurignacian layers. Human remains from the Upper Perigordian are generally fragmentary, as are those from the Solutrean, and this gives great importance to the skeleton found in the Protomagdalenian at Pataud, by Movius, as a representative of man at the end of Würm III. From Magdalenian III on, burials were more common, either because there was an increase in population or because there was increased concern over the fate of the deceased. Magdalenian man of the Chancelade race is different from his predecessors but is still dolichocephalic.

Art, the most impressive innovation of the Upper Paleolithic, was not constantly and everywhere at the same height. In England and Belgium, examples are few or mediocre. Art objects are well dated by the assemblages which are to be found with them in the archeological layers. The oldest examples are the animal statuettes of the Aurignacian of Vogelherd, Germany. The statuettes of fat women, called "Venus," are Aurignaco-Perigordian. Their geographical distribution is very wide, from the Atlantic Ocean to the Ukraine, but there are none in Spain. In Magdalenian times, representations of more slender women are engraved on stone or bone. The last one to be found was discovered in 1962 by F. Bordes in the Magdalenian VI of Couze, Périgord (Fig. 10). Beautiful realistic or stylized art objects abound in the sites of France, Spain, and Switzerland, mainly in the Upper Magdalenian levels, but elsewhere they are scarce or totally lacking. Cave art is more limited in distribution. The bas reliefs of animals and, less often, of human figures, which begin in the Upper Solutrean and continue into the Magdalenian, are found only between the Loire and the Pyrenees. Wall engravings and paintings, invented by the Aurignacians, are found throughout the Upper Paleolithic, especially during the Magdalenian. They are numerous in France and Cantabrian Spain, but are represented in Italy only by some schematic figures in the southern part of the peninsula. They are unknown in Great Britain, Belgium, Germany, and Switzerland. The cave art of eastern Spain, attributed to the Upper Paleolithic by Breuil, is probably more recent.

Conclusion

Despite the appearance of continuity, western Europe in the Upper Paleolithic did not have a constant cultural unity. Except in the extraordinarily active and creative center of southwestern France and, up to a point, Cantabrian Spain, this brilliant civilization knew only two great periods of expansion—the Aurignacian, at the beginning of Würm III, and the Magdalenian, during Würm IV. These two great cultures differed considerably east and west of the Rhine, which seems to have been a cultural border. It was between the Loire and the Pyrenees that the art of Paleolithic man knew its longest and most complete development.

Bibliography

D. de Sonneville-Bordes, "Le Paléolithique supérieur en Périgord," thesis, Faculté des Sciences de Paris, Delmas, Bordeaux (1960).
———, *L'Age de la Pierre* (Presses Universitaires de France, Paris, 1961).

The Radiation Belts, Natural and Artificial

Many characteristics of the radiation belts have been clarified by data obtained by Explorer XV.

C. E. McIlwain

Since the discovery, early in 1958, of the geomagnetically trapped radiation, over 200 detectors of charged particles have been launched into space for the purpose of measuring the fluxes of trapped particles (*1*). In spite of this intensive effort, a clear picture of the fluxes of trapped particles cannot be obtained from the information now available in published form. Some of the factors causing this situation are as follows.

1) The presence of particles of many categories at each position in space makes it difficult to measure any one component. (Plausible but incorrect assumptions as to the composition of the radiation have often led to misinterpretation of data.)

2) The particle fluxes are so intense that the detectors are often jammed.

3) The spatial distribution of any one component is typically quite complex.

4) The spatial distribution depends strongly on the type and energy of the particle.

5) The particle fluxes change with time.

6) Particles have been artificially injected by at least eight high-altitude nuclear detonations. (It is often difficult to decide what fraction of a measured flux was artifically injected.)

On 27 October 1962 the National Aeronautics and Space Administration launched a satellite, Explorer XV, which was specifically designed to obtain data that would fill some of the more serious gaps in the information available at that time. An orbit for Explorer XV was chosen such that the satellite would traverse the region of space containing the highest particle fluxes, and would traverse it in such a manner that nearly complete maps of

The author is associate professor of physics and director of the Space Sciences Laboratory, University of California at San Diego, La Jolla.