they yield. It is therefore postulated that marine sedimentary rocks have been underthrust below the igneous and metamorphic rocks that crop out and that the sedimentary rocks are currently undergoing metamorphism and are yielding the anomalous fluids. The metamorphic fluids may serve to aid tectonism as their pressures are limited only by the strength of overlying rocks.

Rising magmas may in some places supply the elevated temperatures necessary for metamorphism. In the Clear Lake area of California, CO_2-, B-, and NH_3-rich fluids are associated with recent volcanic rocks (*5*). However, similar fluids are found in many other areas where no young volcanic rocks are found, so that magma in the Clear Lake area and elsewhere may be regarded as a heat source rather than the source of the fluids that came from reacting sedimentary rocks. The mercury deposits of the coast ranges of the western United States may be products of low-grade metamorphism. Mercury may be an early metal removed from the source rocks during a thermal (metamorphic) event. Thus, mercury deposits may be found unassociated with other economic metal deposits.

In summary, it is proposed that the anomalous fluids so common in the Pacific coastal belt of the United States result from metamorphism of marine sedimentary rocks. Both inorganic materials and biologic remains are affected by the metamorphism, which yields various amounts of NH_4^+, H_2S, CO_2, B, and hydrocarbons to the fluids that escape in some places along faults. The metamorphic fluids in some places yield mercury deposits. The metamorphically derived fluids may also serve as a hydraulic medium for tectonic activity in the belt where the fluids are found.

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Megafauna and Man from Ayacucho, Highland Peru

Abstract. *Crude unifacial tools, choppers, and a burin have been uncovered in association with megafauna in a buried stratum that was radiocarbon dated at 12,200 B.C. in a cave in highland Peru. The tool types, megafauna, and date are significant with regard to the problem of the antiquity of man and his culture in the New World.*

During 1969 preliminary archeological investigations in the Ayacucho Valley of highland Peru, crude tools were found in direct association with the bones of extinct animals not previously found with human remains. A portion of humerus of a Megatheriidae from a stratum with tools has been dated by a relatively new radiocarbon determination technique as 12,200± 180 B. C. (UCLA 1464) (*1*). This is the earliest date on human remains in South America, and the find has implications for both New World prehistory and paleontology.

The purpose of this Peruvian research is to obtain information about the development of agriculture and the concomitant rise of prehistoric civilization in the second major nuclear area of the New World that can be compared with the long sequence previously found in Tehuacan, Mexico (*2*). So far about 450 sites have been found and there has been some testing of stratified sites (mainly dry caves or rock shelters) (*3*). The testings have revealed some early domesticated plants and a long pre-ceramic cultural sequence (Puente complex, 8000 to 6400 B.C.; Jaywa complex, 6400 to 5000 B.C.; Piki complex, 5000 to 3800 B.C.; Chihua complex, 3800 to 2700 B.C.; and Cachi complex, 2700 to 1700 B.C.).

One test in the south end of one of the caves, Pikimachay Cave (Ac 100), however, revealed a very much earlier artifact complex in its earliest stratum. In this test the stratigraphy was as shown in Table 1.

In the three lowest strata, Zones H, H1, and H2, 51 crude artifacts occurred in direct association with bones of extinct animals, two of which have not been previously found in association with man. In Zone H, 34 artifacts occurred with extinct animal bones; and Figs. 1 and 2 show a pebble chopper and a side scraper with a sloth rib. In Zone H1 there were 17 artifacts, and in Zone H2, one piece of polished bone was uncovered. The artifacts from the upper two zones are relatively similar and have been classified as the Ayacucho complex. They belong to six general categories.

The first and largest category (25 specimens) is unifaces which have been struck from ellipsoidal pebble cores by a blow against some part of the narrower axis and have large curved striking platforms. They consist of one thin flake retouched on one edge, 11 thick flakes retouched along one or more portions of the flake, five large flakes retouched on two opposite edges of the flake, four very large slabs (almost half a pebble) retouched along one concave edge with two additional ones retouched in such a manner as to have a concave cutting edge, one flake with a blunted or battered back edge with a concave retouched edge opposite it, and one smaller flake with a convex retouched cutting edge.

The second group (19 specimens) is made from the pebbles themselves and have large portions of the pebble's cortex still adhering. Most numerous were seven thick bifacial core choppers with battering along most of their edges, but there were five pebbles with bifacial retouching or battering along a single narrow portion or end of the ovoid pebble. Also, four pebbles had been retouched in such a way as to have two or three spurs along their cutting edges (denticulates?), two had concave retouched edges (gouges), and one had a narrow and deep concave retouched edge (spokeshave).

Another category is represented by four drill-like unifacial tools which had been manufactured from flakes struck from the longitudinal axis of pebbles, with the pebble's cortex still adhering

Table 1. Stratigraphy in south end of Pikimachay Cave.

Zone	Composition	Thickness (cm)	Content
A	Modern dung	5–10	
B	Light gray ash	5–20	Initial Period artifacts
C	Dark gray ash	20	
D	Light gray ash	5–10	
E	White ash	5–10	
F	Rock and gray ash	5–10	
G	Large rock fall	100–200	
H	Dark clayish stratum	5–10	Ayacucho artifact complex
H1	Yellowish loess stratum	5–20	
H2	Dark yellow soil	<5	

Fig. 1. The south test in Pikimachay Cave showing a cross section of the trench with its stratigraphy, a photograph taken from above. Urve Linnamae is pointing at a sloth rib in the dark cemented stratum, Zone H, which is associated with artifacts.

to one surface. Two of these had been chipped to single drill-like points, but the other two had spurs on them with a narrow concave chipped area between them (denticulates?).

The other three tools are relatively unique and comprise the three other categories. One is a conical piece of chipped flint with a series of spurs protruding from its base (a denticulate), and another is a long cuboid piece of flint with three burin blows struck from one end. The final tool is a small wedgelike piece of flint with the base of the wedge being its striking platform from which long flakes have been struck burin-style from the two narrow edges of the wedge as well as from one surface, giving it a "fluted" appearance.

Specifically, the complex as a whole cannot be duplicated in other congeries of tools of early man in South America, or for that matter in North America. The fluted wedge, the conical denticulate, and the burin, all minority tool types in Ayacucho, are similar to tool types seen from the surface of the five Exacto sites in coastal Ecuador (*4*). Burins vaguely similar to the one from Ayacucho also have been found in the Oquendo complex of coastal Peru and the Chuqui complex of the Atacama Desert of Chile, and burins even less similar occur at the El Inga and San Jose sites in highland Ecuador (*5*). The Ayacucho complex lacks projectile points, so it would seem to confirm Krieger's hypothesis that the earliest horizon in South America belongs to a pre-projectile point stage (*6*). The presence of many unifaces and choppers in the Ayacucho complex, also, would seem to confirm the hypothesis that some of the earliest Asiatic migrants into the New World brought with them "an industrial tradition of choppers, bifaces, amorphous flakes, and probably the Levallois Mousterian technique" (*7*). Thus, the Ayacucho complex has important wide implications concerning the Early Paleo-Indian Period.

Only two of the many bones uncovered have been inspected by a paleontologist (*8*). A portion of a humerus was identified as that of a Megatheriidae by R. Hoffsteter. He, however, cautioned us that the number of specimens of this genus was extremely limited and that the taxonomy was subject to considerable change. The other identified bone was a small fragment of a large mandible, most assuredly in the Camelidae and probably paleollama, but again Hoffstetter warned of taxonomic problems. Be that as it may, these are the evidence of the occurrence of these animals in the Andes and the first secure evidence of association of these extinct animals with man. We also uncovered a huge tibia of some sort of ungulate or subungulate.

We chose to date the Megatheriidae humerus because of its larger size and the likelihood that it would contain more carbon. The rib with artifacts (Figs. 1 and 2) and the humerus were, however, less than 1 m apart and clearly in the same deeply buried stratum, Zone H.

The dating of the remains of man with the extinct fauna also involved special problems. Portions of the Megatheriidae humerus from Zone H in direct association with the tools (Figs. 1 and 2) were cleaned with a wire brush and distilled water to remove any gross extraneous material. A small sample from the interior of the specimen was analyzed for its fluorine (0.86 percent) and nitrogen (0.71 percent) content. Then the collagen fraction of the bone was isolated according to a procedure (*1*) which destroys the mineral matrix in dilute hydrochloric acid and leaves the bulk of the protein intact. This method was chosen over another which produces individual amino acids and ignores contaminants such as tar found, for example, in bones stemming from Rancho La Brea, California (*9*). The reason for this choice was the probable absence of major contamination in the Pikimachay bone since it was found in the protective environment of a cave. Nevertheless, collagen isolated by the first procedure

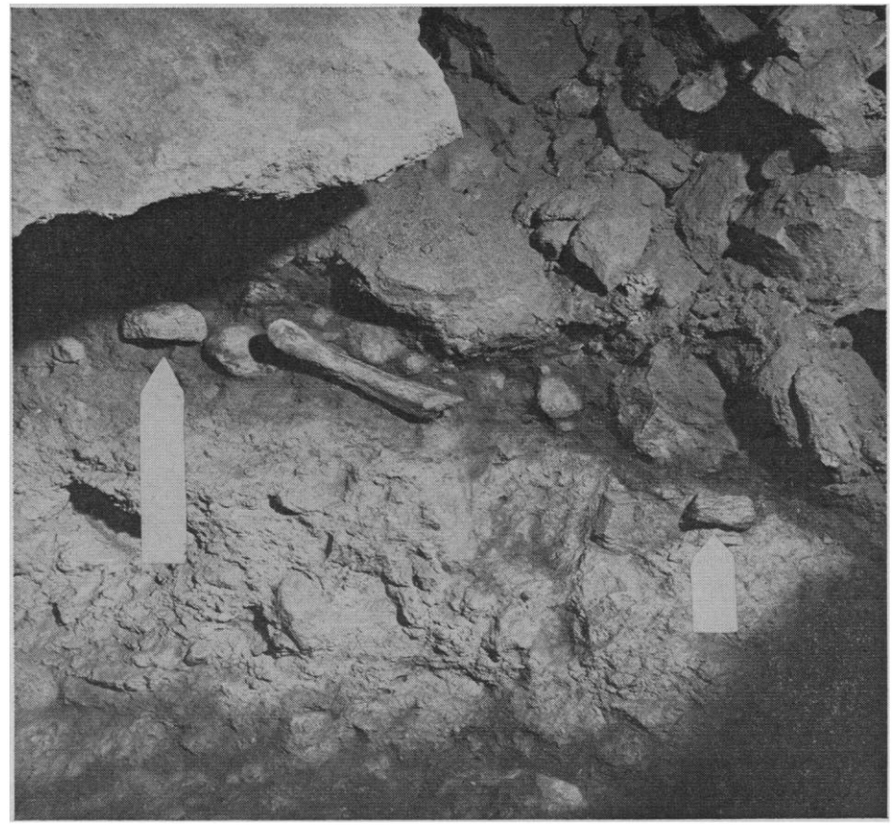

Fig. 2. Large arrow points to a chopper to the left of the rib in Zone H. Small arrow points to a side scraper at the right in the same stratum.

(*1*) was extracted repeatedly with dilute sodium hydroxide to remove substances (related to humic acid) of different specific activity in radiocarbon than the native collagen. Due to the size of the Megatheriidae bone, sufficient collagen was prepared which, after burning, filled the proportional counter to 80 percent with pure carbon dioxide (*10*). Subsequently this gas was counted for three separate periods of 2800, 1300, and 1200 minutes each, corresponding to ages of 14,180, 14,150, and 14,080 years. The final weighted composite date was calculated to be 14,150 ± 180 years (UCLA 1464) (*11*).

The date for the moment is the oldest radiocarbon date determined for South America, for which a case can be made involving direct association of man and megafauna. Further, the date is on a humerus from Zone H, the latest of the three zones with the remains of man, so older dates should be forthcoming. If man was well south in the Andes of South America by at least 13,000 B.C., when did he first enter South America?

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Shear Dependence of Effective Cell Volume as a Determinant of Blood Viscosity

Abstract. *The viscosity of suspensions of human erythrocytes (normal cells in plasma, normal cells in Ringer's solution containing albumin, and hardened cells in Ringer's solution containing albumin) was measured over a wide range of shear rates, and the macrorheological data were correlated with the microrheological behavior of erythrocytes and rigid particles. The formation of rouleaux increases the effective volume of erythrocytes as a result of (i) the increase in axial ratio and (ii) the limitation of deformation of individual erythrocytes. The effective cell volume is the fundamental determinant of blood viscosity.*

The anomalous behavior of blood viscosity, that is, its dependence on shear rate (*1*), has received the increasing attention of investigators in biomedicine, biophysics, and bioengineering. The shear thinning of blood viscosity can be attributed mainly to the shear-dependent deformation and aggregation of red blood cells (RBC) (*2*). Investigations on the microrheological behavior of suspensions have supplied fundamental information on the shear-dependent behavior of particles in suspensions (*3, 4*). By correlating such information with macrorheological data, I show that RBC aggregation and RBC deformation may exert their rheological effects through a common mechanism—namely, shear-dependent changes in the effective cell volume.

Viscosity was determined in a coaxial cylinder viscometer (*2*) over a shear rate range of 500 to 0.01 sec^{-1} at 37°C. Blood was obtained from healthy human subjects. The suspensions included normal RBC in heparinized plasma, normal RBC in 11 percent albumin-Ringer solution, and hardened RBC in 11 percent albumin-Ringer solution, all adjusted to a cell percentage of 45 percent (hematocrit values corrected for fluid trapping in cell column). The 11 percent albumin-Ringer solution (hereafter referred to as albumin solution) had the same viscosity (1.2 centipoises) as plasma but did not cause RBC aggregation. Hardened RBC were prepared by fixing RBC washed in Ringer in 0.5 percent glutaraldehyde solution (*5*).

At low shear rates (for example, 0.1 sec^{-1}), the viscosity is highest for normal RBC in plasma, lower with hardened RBC in albumin, and lowest for normal RBC in albumin (Fig. 1). With an increase in shear rate, the viscosity decreases for suspensions of normal RBC in both plasma and albumin but not for the hardened RBC in albumin. At shear rates above 10 sec^{-1}, the viscosity values of normal RBC in plasma and in albumin are essentially the same, and both are lower than the values for hardened RBC.

The presence of particles in a suspension causes an increase in viscosity as a result of disturbances in streamlines in the fluid medium (*6*). The degree of disturbance is determined by the effective volume concentration of suspended particles, which includes not only the actual volume of the particles but also a volume of external fluid immobilized hydrodynamically. The volume of external fluid immobilized depends on the axial ratio of the particles and the spatial and temporal alignment of the axes with flow—that is, particle orientation and rotation (*3*). The effective particle volume (V_E) of rigid disks and rods in dilute suspensions is much larger than the true particle volume (V_P) (*3, 7*). The ratio V_E/V_P was plotted on logarithmic coordinates against the axial ratio (R) (Fig. 2). For both the rods ($R > 1$) and the disks ($R < 1$), V_E/V_P decreases as R changes toward unity. When R becomes unity, V_E/V_P should be at a minimum and probably is near 1.5, the approximate value for rigid spheres (*8*).

Hardened RBC are rigid discoids with R equal to approximately 0.25 (2 by 8 μ); hence the V_E/V_P value is approximately 2.5 (Fig. 2). Since the

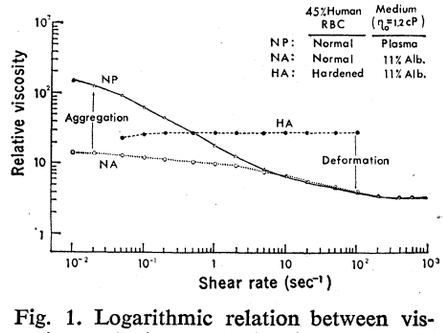

Fig. 1. Logarithmic relation between viscosity and shear rate in three types of suspensions, each containing 45 percent human RBC by volume. Each point represents the mean of four to six experiments. The standard deviations are less than 5 percent of the means.