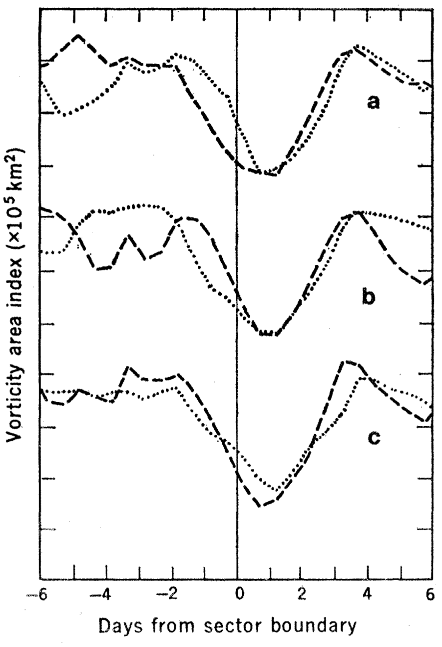

Fig. 2. Same format as Fig. 1; the list of boundaries used in Fig. 1 was divided into two parts according to (a) the magnetic polarity change at the boundary, (b) the first or last half of winter, and (c) the yearly intervals 1964 to 1966 and 1967 to 1970. (a) The dotted curve represents 24 boundaries in which the interplanetary magnetic field polarity changed from toward the sun to away, and the dashed curve 29 boundaries in which the polarity changed from away to toward. (b) The dotted curve represents 31 boundaries in the interval 1 November to 15 January, and the dashed curve 22 boundaries in the interval 16 January to 31 March. (c) The dotted curve represents 26 boundaries in the interval 1964 to 1966, and the dashed curve 27 boundaries in the interval 1967 to 1970. The curves have been arbitrarily displaced in the vertical direction, but the scale of the ordinate is the same as in Fig. 1, that is, each interval is 5×10^5 km^2.

described below do not appear in the summer.

Figure 1 shows the average response of the hemispheric vorticity area index to the sector structure sweeping past the earth. We emphasize that although the times at which well-defined sector boundaries passed the earth have been used as the phase signals, the response of the vorticity index is influenced by the sector structure for several days on each side of the boundary, and not only by the sector boundary. On the average, the vorticity index begins to decrease about 1½ days before the sector boundary passes the earth, reaching a minimum about 1 day after the boundary and then increasing during the next 2½ days.

The vorticity index is influenced by many physical effects. In this analysis we seek to discover the influence of one particular physical effect—the solar magnetic sector. Since the phase (zero day) of the analysis is fixed by the time at which a sector boundary passes the earth, physical effects on the vorticity index related to the sector structure will tend to be reinforced in this analysis, and other physical effects on the vorticity index not related to the sector structure will tend to occur at random phases and therefore to be averaged out. The physical mechanism causing the results described here is not revealed by the present analysis; however, we anticipate that extensions of this analysis may help us to discover possible physical mechanisms.

The significance and reproducibility of the results shown in Fig. 1 have been investigated by dividing the data sample into two parts and performing the same superposed epoch analysis separately on each part. Figure 2 shows the results for analyzing separately the boundaries in which the field polarity changed from toward the sun to away from the sun and the boundaries in which the field polarity changed from away to toward. Also shown are the results of separate analyses of the boundaries occurring between 1 November and 15 January and those occurring between 16 January and 31 March. Finally, the boundaries occurring during the years 1964 to 1966 and those occurring during the years 1967 to 1970 have been analyzed separately. We note that the analyses performed on these various subsets of the data gave essentially the same results, so that the results shown in Fig. 1 are independent of the magnetic polarity change at the sector boundary, the portion (first half or last half) of the winter interval analyzed, and the yearly interval (1964 to 1966 or 1967 to 1970) analyzed.

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References and Notes

1. J. M. Wilcox, *Space Sci. Rev.* **8**, 258 (1968).
2. W. O. Roberts and R. H. Olson, *J. Atmos. Sci.* **30**, 135 (1973).
3. J. M. Wilcox and D. S. Colburn, *J. Geophys. Res.* **77**, 751 (1972).
4. ———, in preparation.

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Cotton Remains from Archeological Sites in Central Coastal Peru

Abstract. *Cotton remains from four archeological sites in central coastal Peru, representing a time sequence from about 2500 to 1000 B.C., were compared with similar materials obtained from living wild and cultivated forms of* Gossypium barbadense *L. The comparison revealed that the archeological cotton samples were primitive forms of* Gossypium barbadense, *differing little from present-day wild forms of the same species. Although not the earliest cottons recorded for the New World, they appear to represent the earliest stages of cotton domestication yet recorded.*

We report here on a recent analysis of archeological cotton remains, in central coastal Peru, which may be of general interest to crop plant evolutionists and anthropologists. A more extensive treatment of the data will be published elsewhere (*1*).

Cotton was one of the first plants to be domesticated on the northern and central coasts of Peru (*2*). Today, all primitive cotton cultivars (the so-called "dooryard types") which are found in coastal Peru and Ecuador belong to one species, *Gossypium barbadense* L. Wild forms of the same species occur in dry coastal areas north and south of the Gulf of Guayaquil, on Isla de la Plata (an island offshore from Manta, Ecuador), and on several Galápagos islands (*G. barbadense* var. *darwinii* Hutchinson). The wild forms possess a number of morphological criteria

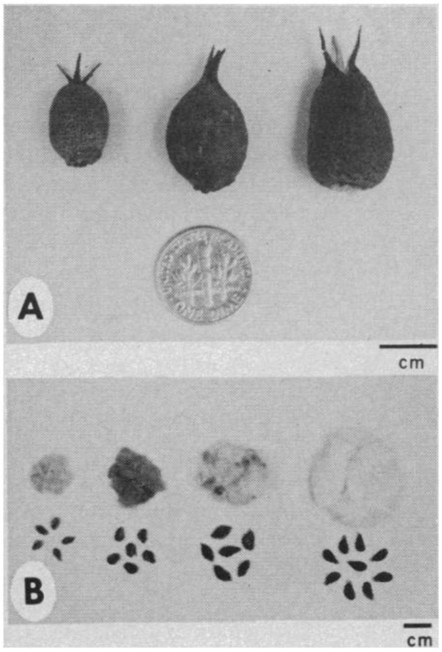


Fig. 1. (A) (Middle) Archeological boll from Punta Grande site (Conchas phase); (left and right) immature and mature bolls of a wild form of *barbadense* (Ecuador). (B) Individual locks removed from cotton bolls, showing fiber above and seeds below. From left to right: *darwinii* (Galápagos), Punta Grande site (Conchas phase), wild *barbadense* (Ecuador), dooryard *barbadense* (coastal Peru).

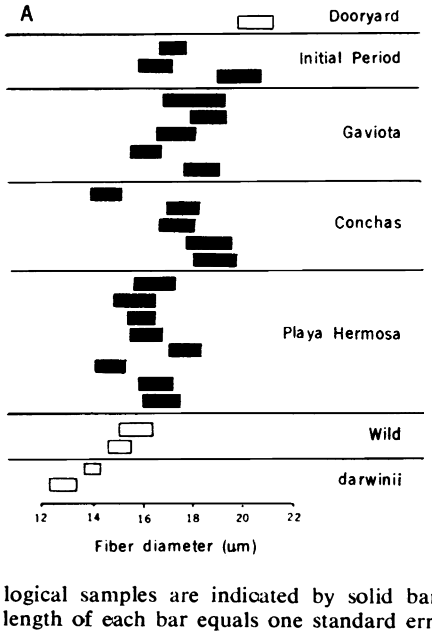
which distinguish them rather clearly from their cultivated relatives. Among these are the following: (i) small bolls with pointed beaks; (ii) small seeds with hard seed coats, bearing a "fuzzy" undercoat of short fibers in addition to the "lint" fibers; (iii) sparse fibers which do not aggregate the seeds into compact "locks" but allow them to scatter more or less individually from the open boll; (iv) fibers with narrow diameters but relatively thick walls; and (v) fiber colored a dingy brown or grayish-white (not clear white or uniform shades of brown, as in cultivated forms). Many of the foregoing distinguishing features can be recognized and measured in well-preserved archeological material (*3*). Thus the purpose of this study was an attempt to answer two questions:

1) Can the archeological cotton material be identified as a form of *G. barbadense*?

2) In comparative morphological terms, does the archeological cotton exhibit a transition between present-day wild and present-day cultivated forms of the same species?

All the materials analyzed were excavated by one of us (M.E.M.) from four sites, located in the Ancón-Chillon area of central coastal Peru (*4*). All of these sites (Pampa, Camino, Punta Grande, and Tank Site) are coastal midden sites, formerly associated with fishing camps. Comparative stratigraphy, supplemented by radiocarbon dating, establishes that the collective occupations of the sites covered a span of 1500 years. During this period, artifacts and biological remains preserved at the sites record a transition from a migratory hunting subsistence, through a fishing-littoral economy, to the initiation of a settled agriculture. The earliest levels belong to the Preceramic Period (about 2500 to 1750 B.C.). This is followed by the Initial Period, when pottery and most of the crop plants make their first appearance. On the basis of technological styles involved in the construction of twined fabrics, the Preceramic Period can be subdivided (*5*) into three phases: Playa Hermosa (about 2500 to 2275 B.C.), Conchas (about 2275 to 1850 B.C.), and Gaviota (about 1850 to 1750 B.C.). Most of the cotton materials were associated with the Conchas and Gaviota phases. They included (in descending order of abundance): scraps of twined fabrics and cordage; unprocessed fibers, either loosely wadded or compressed into tight plugs; carbonized seeds; uncarbonized seeds and kernels; and boll segments with seeds and fibers attached. Only a few seeds and scraps of cordage were obtained from the Playa Hermosa phase.

Observations and measurements made on the archeological materials were compared with similar data on standard forms of living material. The latter had been maintained in a tropical garden, Jamaica, West Indies, and included dooryard forms of *barbadense*, collected in coastal Peru and Ecuador, wild forms of the same species from the Santa Elena peninsula (Ecuador) and from Tumbes (Peru), and samples of the wild variety, var. *darwinii*, from the Galápagos Islands. Measurements were made of boll shape and size, seed size, and fiber diameter, and observations were made on the color of unprocessed fiber samples and on certain boll characters known to be of taxonomic significance (*3*). Because most of the archeological seeds were completely carbonized, it was necessary to carbonize the seeds of the standard types also, for comparative purposes. This was done by heating the seeds to 200°C in a vacuum, which reproduced satisfactorily the appearance of "naturally" carbonized archeological seeds. Fiber samples were teased out from scraps of cordage, mounted in 85 percent lactic acid, and stored for 3 days to allow the fibers to uncoil and expand. The images of the fibers (magnification, about × 800) were measured in arbi-



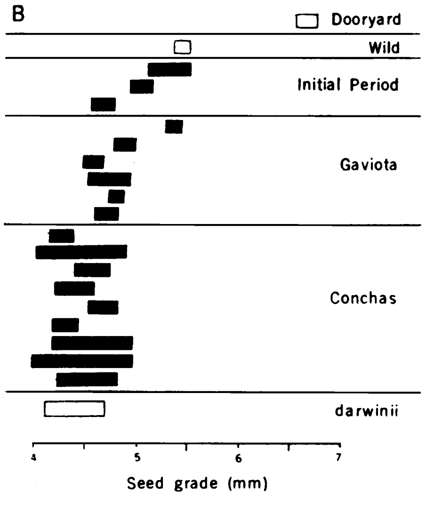


Fig. 2. Time trends in the dimensions of (A) fibers and (B) carbonized seeds obtained from archeological sites. Archeological samples are indicated by solid bars, present-day standards by open bars. The length of each bar equals one standard error on each side of the sample mean. All the Initial Period and Gaviota samples were obtained from Tank Site; Conchas samples were obtained from Tank Site and Punta Grande; Playa Hermosa samples were obtained from Camino and Pampa sites. "Seed grade" is a measure of seed size (*6*).

trary units, later converted to micrometers.

Three kinds of evidence support the conclusion that the archeological cottons were primitive forms of *Gossypium barbadense* L.

1) A useful taxonomic criterion for distinguishing *G. barbadense* from the only other species known to have been cultivated in the New World (*G. hirsutum* L.) is the presence or absence of fringe hairs surrounding the floral nectary (*3*). A floral nectary recovered from a single archeological boll was devoid of fringe hairs, as in *barbadense*.

2) Samples of unprocessed fibers obtained from Tank Site and Punta Grande could be grouped with some confidence into three distinct color classes—chocolate, reddish-brown, and "near-white." The chocolate-colored fibers had a very soft texture and disintegrated into dusty particles when handled. Soft textured fibers of this characteristic color are unknown in any present-day species of *Gossypium* other than *barbadense*, and even in this species the chocolate color is rarely found beyond the limits of coastal Peru and Ecuador.

3) Only four intact bolls were available for measurement. All were obtained from the Punta Grande site. Comparison with present-day standards showed that they did not differ significantly in shape or size from bolls of wild forms of *barbadense* (Fig. 1A).

Differences in the size of the boll reflect differences in boll contents, that is, in the number and size of seeds and in the amount of fiber borne on the seeds. These differences are illustrated in Fig. 1B where the seeds and fibers extracted from individual boll segments (individual locks) are compared. There is a progressive increase in the number of seeds, the size of the seeds, and the amount of fiber in the following sequence: var. *darwinii*, archeological sample, wild *barbadense*, cultivated *barbadense*.

Fiber samples were available from most strata, from the Playa Hermosa phase through the Initial Period. Carbonized seed samples were not found in the earliest (Playa Hermosa) phase but were available from most of the later levels. Thus data on fiber diameter and seed size could be recorded over a relatively long time sequence and compared with similar data from living standards. The results of these comparisons are summarized in the form of charts (Fig. 2). The charts show that fiber diameter and seed size tend to increase progressively from the earlier to the later levels. The magnitude of the increase is about 10 to 15 percent in both characters, which would probably be associated with a considerable increase in the yield of fiber (*6*). The range of mean fiber diameters in the archeological samples lies between the means of present-day wild and present-day dooryard standards. The range in seed size lies between those of wild Galápagos forms (var. *darwinii*) and wild mainland forms of *barbadense*. The archeological remains show that variations in fiber color (chocolate, reddish-brown, and possibly white) were established early in the chronological sequence, but that the primitive fuzzy-seeded condition was retained over the entire period represented by our samples (no smooth black seeds were found, although it is well known that simple genetic mutants determine fiber color and the presence or absence of fuzz on the seed coat).

Although these cotton remains are not the earliest to be recorded in the Americas, they seem to represent the earliest stages of domestication yet reported. Cotton obtained from the Tehuacán Valley of Mexico, and dated 3500 to 2500 B.C., was apparently "fully domesticated" (*7*).

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References

1. S. G. Stephens and M. E. Moseley, *Amer. Antiquity*, in press.
2. J. B. Bird, *Natur. Hist.* **57**, 296 (1948); E. P. Lanning, *Peru before the Incas* (Prentice-Hall, Englewood Cliffs, N.J., 19 F. Engel, *Trans. Amer. Phil. Soc.* (*new series*) **53**, 1 (1963).

S. G. Stephens, *Amer. Antiquity* **35**, 367 (1970).

4. M. E. Moseley, thesis, Harvard University (1968); T. C. Patterson and M. E. Moseley, *Nawpa Pacha* **6**, 115 (1968).

M. E. Moseley and L. K. Barrett, *Amer. Antiquity* **34**, 162 (1969).

6. S. G. Stephens, *Amer. Natur.* **99**, 355 (1965).
7. C. E. Smith, Jr., and S. G. Stephens, *Econ. Bot.* **25**, 160 (1971).

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Permian Ammonoid Cyclolobus from the Zewan Formation, Guryul Ravine, Kashmir

Abstract. *Ammonoid cephalopods serve significantly as a basis for correlation of strata near the boundary between the Paleozoic and Mesozoic Erathems. This is a report of the diagnostically Late Permian (uppermost Paleozoic) ammonoid* Cyclolobus walkeri (*Diener, 1903*) *from the Zewan Formation 20 meters below the Permian-Triassic contact at the classic section in Guryul Ravine, Srinagar region, Kashmir.*

Since the first half of the 19th century, it has been apparent that assemblages of fossil organisms can be grouped as "ancient," "medial," or "recent" in overall aspect. These groupings formed the basis for Phillips' definition (*1*) of the geological eras: Palaeozoic, Mesozoic, and Kainozoic. Even casual comparison reveals basic differences between marine invertebrate faunas of those three eras, with the era boundaries representing intervals of faunal crisis (*2*).

The Paleozoic-Mesozoic boundary, between the Permian and Triassic systems, is commonly represented by a regional unconformity (*3*). However, there are a few areas where fossiliferous marine Permian and Triassic strata are thought to follow in a sequence devoid of major hiatus. Recent interest in the era boundaries has stimulated detailed biostratigraphic analysis of these few critical boundary successions, particularly those in Soviet and Iranian Armenia and in Central Iran (*4*); the Salt Range of Pakistan (*5*), Kashmir (*6–8*), South China (*9*), and East Greenland (*10*).

Richly fossiliferous Late Permian and Early Triassic strata have been known in the Srinagar area of Kashmir since the pioneering studies of Hayden (*11*) and of Middlemiss (*12, 13*). Subsequent detailed field investigations (*6–8*) have focused on Guryul Ravine, 10 km southeast of Srinagar near the village of Khunamuh. There the Permian-Triassic boundary is drawn where the "sandy shales" of the Zewan Formation (formerly Zewan Series) are succeeded by a "black shale," not yet named formally. Both otoceratid and ophiceratid ammonoid cephalopods, each definitive of the Early Triassic, occur 3.5 m above the base of the black shales in direct association with the distinctively Early Triassic pectinacean genus *Claraia* and several taxa of the characteristically Paleozoic