tive to wavelength (d/λ) normalized to the spacing for zero contribution from the central component (d_0/λ). It can be seen that if the relative amplitude of the central component decreases the fringe nulls will appear at progressively lower values of d/λ, in qualitative agreement with both the VLBI data and the observed change in total flux density.

It will now be argued that this three-component model also gives reasonable quantitative results as well. From the measurements of Whitney *et al.* (*2*) the observed relative change in the null position is equivalent to a 9 ± 3 percent displacement in d between mid-October 1970 (d_1) and mid-February (d_2) (that is, $d_1/d_2 = 1.09$). With this condition and the assumption that the net change in the central component (ΔS_c) is −0.42 unit, a knowledge of the total flux of the two outer components (S_o) would permit us to locate the null positions d_1/d_0 and d_2/d_0 in Fig. 2. This flux density S_o is an unknown parameter of the model, but it must be less than the total source flux density of about 13 units, which includes contributions from other more extended components seen by the Haystack beam (4 arc minutes) but resolved out by the interferometer. From the above information and the slope of the curve in Fig. 2, it can be shown that S_o must satisfy the condition: $\Delta S_c/S_o \approx 0.14\,(d_2/d_0)$. Since the model requires that d_2/d_0 must be greater than 1 (because S_c is greater than 0) and that ΔS_c is -0.42 ± 0.12, the flux density S_o of the two outer components must be approximately 3.0 ± 0.9 units, a value that is in good agreement with the total correlated flux density measured by the interferometer in February 1971 (*2*).

Thus, a model for 3C279 in which a variable component is centrally located between two stationary nonvarying components equally sharing a flux density of about 3.0 ± 0.9 units is consistent with both the observed time variations of the total flux density and the interferometric results. Because the model is very sensitive to the uncertainty in the net change in flux density (ΔS_c), precise values of the flux density of the central component [$S_c(t)$] cannot be obtained. However, in order to account for the observed correlated flux density seen by the interferometer it is necessary to require that S_c contribute less than a few tenths of a unit in February 1971. A model in which the flux density of the central component declined from about 0.6 unit in October 1970 to near 0 at the end of 1970 (as suggested by the minimum in Fig. 1) and then flared up slightly to about 0.2 unit in February 1971, reaching a level of about 0.5 unit later in 1971, would be plausible within the uncertainties of the data. In such a model the corresponding values of d_1/d_0 and d_2/d_0 in Fig. 2 would be 1.13 and 1.04, respectively.

The parameters of the simple model suggested here can, of course, be further refined by considering components that are not point sources and by fitting the model to the numerical data defining the observed fringe amplitude curves. In addition there are other, less simple variable-source models that can be made consistent with the data. For example, a model could be considered in which two components are separating at apparent superrelativistic speeds but with their flux densities decreasing in unison. Such a possibility seems less likely, however. It might also be argued that the observed variations in flux density are taking place in a component whose linear size is greater than about 20 parsecs and hence is resolved out by the interferometer. It is evident from the minimum in late 1969 that the variable component under consideration in 3C279 is probably only about 1 year old, and it is certainly less than 5 years old, as evidenced by the 1965 minimum. Thus, its linear diameter must be no more than a parsec or two, and hence the variable component must have affected the observed VLBI fringe amplitude curves, even if not as suggested in this report.

The model for 3C279 presented here can be readily tested by a third set of VLBI observations made after 1971.2. If the central component did indeed increase by about 0.5 flux density unit in 1971, as suggested by Fig. 1, then this model would predict that the null in the fringe amplitude curve should appear back near its original position in October of 1970.

WILLIAM A. DENT
Department of Physics and Astronomy, University of Massachusetts, Amherst 01002

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3. In addition to the interpretations of this result given in (*2*), A. Cavaliere, P. Morrison, and L. Sartori (*ibid.*, p. 525) have suggested that such superrelativistic speeds are due to changing radio images resulting from relativistic illusions.
4. The details of the observational procedures, calibrations, and numerical tabulations are being prepared for publication (W. A. Dent and G. Kojoian).
5. See, for example, observations at 8 Ghz by W. A. Dent in a review paper by K. I. Kellermann and I. I. K. Pauliny-Toth [*Annu. Rev. Astron. Astrophys.* **6**, 417 (1968)] or the data of H. D. Aller and E. T. Olsen (*Astron. J.*, in press).
6. This model was briefly mentioned in (*2*) but was not considered seriously.
7. I am indebted to the staff of the Haystack Observatory for their continuing and patient support. I wish to thank G. Kojoian and J. Kapitzky for their contributions in obtaining and processing the data. I would also like to acknowledge helpful conversations with T. A. Clark, K. I. Kellermann, and S. H. Zisk. Supported by NSF grant GP-14690. Research programs are conducted at the Northeast Radio Observatory Corporation Haystack Observatory with support from NSF grant GP-25865 and from NASA grant NGR 22-174-003 and contract NAS9-7830. Contribution No. 125 of the Five College Observatories.

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Preceramic Sequences in the El Abra Rock-Shelters, Colombia

Abstract. *A series of crude stone artifacts, characterized by a trimming mainly of the working edge of a single face of a chert flake or a fragment of a nodule, was excavated in the El Abra rock-shelters, north of Bogotá, Colombia. The tools indicate a cultural complex distinct from others that have been described for the Paleo-Indian of South America.*

Recent excavations in the preceramic levels of the El Abra rock-shelters, Sabana de Bogotá, have revealed a series of chert stone tools distinguishable from others that have been described for South America. Although new types were added over a time range estimated to be from 10,500 B.C. to A.D. 1000, nearly all the tools were characterized by an alteration of only the working edge of a single face by percussion-flaking of the raw material. In function they appear to have been useful for butchering, hide-working, and wood-cutting (Fig. 1). Chert does not occur in the vicinity of the rock-shelters but can be found in outcrops of the sabana (an extinct lake bed) exposed in small tabular chunks and in the river terraces where it has the form of water-rounded pebbles or large flakes and chunks with dulled edges. In the manufacture of the artifacts, raw material, both in the natural form and in the form of rough man-made flakes and rough fragments, was utilized. Sandstone, which fell into the deposits from the sides and ceilings of the rock-shelters, was rarely altered into artifacts, but some spalls with dulled edges suggest their occasional use by man. The conclusion that the preceramic people hunted is based upon bone fragments in the deposits since no projectile points were found.

The El Abra rock-shelters were surveyed and tested in 1967 and more fully investigated in 1969 (*1*) by investigating teams from the Indiana University Museum, the Hugo de Vries-Laboratorium (*2*), and the Instituto Colombiano de Antropologia (*3*). These sites (sites 2, 3, and 4) lie at the west base of one of two parallel, horizontally stratified sandstone escarpments that form a corridor cross-cutting a ridge that projected outward into Lake Bogotá, which drained about 40,000 to 30,000 years ago.

The strata within the caves have in general a pattern of inverted, concentric crescents, but are complicated by rockfall, occupational debris, intrusive fireplaces, and graves. By utilizing radiocarbon dates, pollen profiles, and volcanic ash lines, we were able to make correlations between some of the deposits in the rock-shelters and the sabana as a whole. For purposes of discussion, the stone industries will be described by their association with widespread depositional units. Only those units (C, D, and E) that contain evidence of human occupation, however, will be discussed.

Depositional unit C is composed of varying sediments laid down during the late Pleistocene (estimated to be 18,000 to 10,000 years B.P.). Although the climate was still cold and dry, increasing rainfall during subunit C1-C2 raised the water table gradually so that toward the end of the phase swamps were formed in low areas of the sabana, for example, a pond in front of rock-shelter 2. During subunit C3, a warm, moist climate caused a forest (mostly alder or forest type of flora) to spread over the basin as the older páramo vegetation, now confined to higher altitudes in the Andes, retreated. It was during this warm interval that the first evidence is found of human occupation in the El Abra rock-shelters. Thus, in the lower half of the subunit C3 deposits of rock-shelter 2, 16 small chert flakes and pebbles were found; in the upper half of the subunit 21 were found.

Table 1. Critical radiocarbon dates from the El Abra rock-shelters.

Sample	Date (B.P.)	Date (B.C.)	Shelter number	Depositional unit
GrN-5556	12,400 ± 160	10,450	2	C3
B-2134	10,720 ± 400	8,750	2	C4
GrN-5746	9,325 ± 100	7,375	2	D
B-2133	8,810 ± 430	6,850	3	C4-D
B-2137	8,760 ± 350	6,810	3	D

Subunit C4 was deposited during a return to a relatively dry climate when the forest of large trees was replaced by dwarf woodlands mixed with abundant *Compositae* and intermingled with open areas of grasslands. Radiocarbon dates from rock-shelter 2 indicate that this event occurred between 11,000 and 10,000 years B.P. (Table 1). In this site 21 pieces of chert were excavated, and the same number in rock-shelter 3.

Depositional unit D comprises sediments deposited during the early and middle phases of the Holocene, prior to the introduction of agriculture and ceramics in the sabana. The initial phase began about 10,000 years B.P., but the termination is not precisely dated, although, as discussed below, it may have ended about A.D. 300. During the first millennium the climate rapidly ameliorated and much of the sabana was again covered with a forest of large trees, while many of the marshes and small lakes dried up or were reduced in size. Baked clay-lined firepits appear definitely in the El Abra rock-shelters for the first time, although hearths and charcoal accumulations occur in lower strata.

The warmer climate did not result in any marked use of the El Abra rock-shelters, even though the estimated rate of annual deposition of chert in unit D is about seven times that of unit C (0.19 piece in contrast to 0.029 piece). This is still an average of less than one piece of chert deposited per year (3072 pieces) over an estimated span of 7000 years.

Depositional unit E, the uppermost strata in the sabana, contains in the El Abra rock-shelters evidence of agriculture (corn pollen) and Chibcha types of ceramics. A single ^{14}C date (sample B-2136) of 340 ± 260 B.P. (A.D. 1610) from the midsection of unit E indicates the upper half to have been deposited in Post-Contact times, as do Colonial types

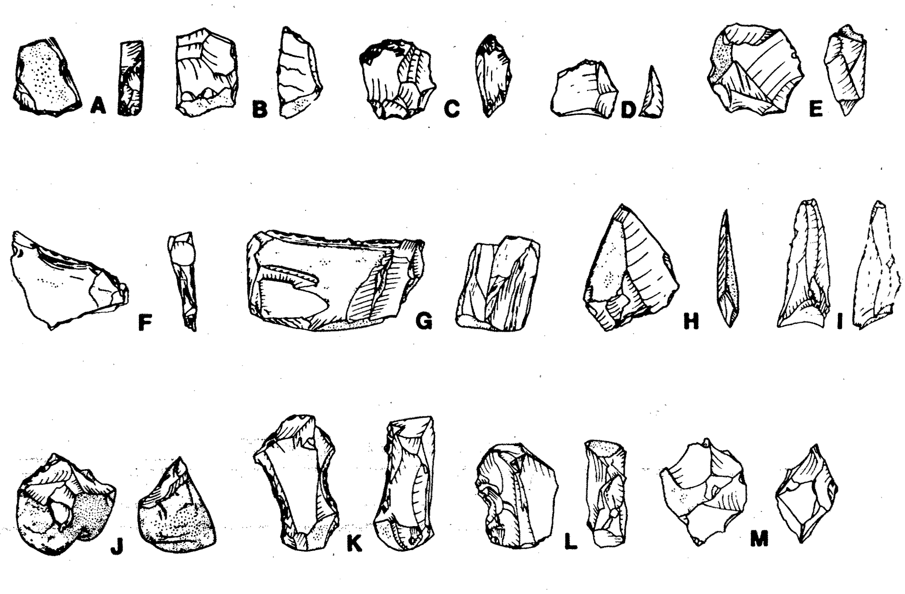

Fig. 1. Chert artifacts from El Abra rock-shelters: (A–C) end scrapers; (D) semilunar scraper; (E) ovoid scraper; (F–G) side scrapers; (H–I) triangular scrapers or perforators; (J) diamond-shaped scrapers; (K–L) spokeshaves; (M) bifaced core.

of glazed sherds. No dates were obtained from the El Abra rock-shelters indicative of the introduction of maize and ceramics. Possibly the introduction occurred about A.D. 300 if the charred maize grains associated with Chibcha types of pottery at the Los Solares, Sogamosa, site by E. Silva Celis are representative of the initial entrance into the sabana of these traits. His maize sample (sample GrN-4729) is dated 1640 ± 50 B.P. (A.D. 310).

The pollen profile of unit E reveals a decrease in the areas of forests accompanied by an increase in the vegetation of open areas. This fact may be the result of increasing deforestation of the sabana by man for agricultural purposes. The caves were still used by small groups of men at uneven intervals even though there was a slight increase in the estimated annual deposition of chert (2.6 pieces in contrast to 0.36 piece in the underlying subunit D2).

Because so few other preceramic sites in Colombia have been excavated, it is not possible to make detailed comparisons. Those tools that we have examined and additional ones briefly noted by Reichel-Dolmatoff (*4*) differ from the ones from El Abra in that they exhibit more elaborate methods of manufacture and a greater variety of types, such as large choppers, bifaced tools, or stone projectile points.

The Chibcha cultures continued to make crude chert tool types, but a great variety of new artifacts and methods of manufacture were added. Thus, in the uppermost levels of the El Abra rock-shelters are sherds, ground stone celts, ground slate knives, stone mortars, and bronze poncho pins.

WESLEY R. HURT
Indiana University Museum,
Bloomington 47401

THOMAS VAN DER HAMMEN
Hugo de Vries-Laboratorium,
Universiteit van Amsterdam,
Amsterdam 4, Netherlands

GONZALO CORREAL URREGO
Instituto Colombiano de Antropologia,
Apartado Nacional 407,
Bogotá, Colombia

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Frequencies of Occultations of Stars by Planets, Satellites, and Asteroids

Abstract. Calculations show that several occultations of stars by the large satellites of the outer planets, Pluto, and the large asteroids could be observed each decade with existing equipment at Earth-based telescopes. A systematic program of occultation predictions and observations is urged in order to improve our knowledge about the atmospheres, sizes, shapes, topography, and positions of these poorly understood bodies, in support of forthcoming spacecraft missions to the outer solar system.

Every once in a while a planet passes in front of a star of comparable brightness. These occultation phenomena, though infrequent, arouse a great deal of interest among astronomers. From photoelectric light curves it is possible, in principle, to probe a planet's upper atmosphere in detail to obtain significant clues as to its temperature and composition (*1*); to detect the presence or lack of a very thin atmosphere; and to determine the diameter, shape, topography, and position of the planet with great accuracy. The recent occultation of Beta Scorpii C by Jupiter's satellite Io is a case in point. The upper limit to the pressure of Io's atmosphere has been lowered by several orders of magnitude to about 10^{-4} mb, and the precision in measuring Io's diameter, now known to within a few kilometers, has been improved by nearly two orders of magnitude (*2*).

The occultations that have been predicted and successfully observed in modern times are listed in Table 1 (*2–5*). From the shortness of the list we see that, for a given planet, these events are rare indeed. The question is, just how rare are they? Meeus (*6*) considered planetary occultations of the five brightest stars in the zodiac. His outlook was bleak: one occultation of Regulus by Venus and Mercury every 500 to 600 years, one occultation of Spica by Venus every 2000 years, and essentially no others.

No study has yet been made for fainter stars. In this report a recipe is provided for predicting the frequency of observable occultations of stars by all bodies of appreciable size in the solar system, other than the sun and the moon. This census includes those objects whose mean angular diameters exceed about 0.1 arc second, that is, the eight other planets, fourteen satellites of the outer planets, and the four asteroids for which accurate ephemerides are known.

These calculations are subject to a number of assumptions, and the final answers are not rigorously accurate. Nevertheless, they indicate the objects that are most susceptible to occultations and, therefore, the direction that prediction and experimentation ought to take. The frequencies are computed, first, by determining the area of the sky swept out by each object each year. Two general cases are considered: occultations observable in the night sky above a given site on the earth and occultations observable from somewhere on the earth. As seen from a given site, the area swept out is the product of the occulting object's mean angular motion and its mean angular diameter; as seen from some region on the earth—and it is just as likely to be New Guinea as Mt. Palomar—the area is the product of the object's mean angular motion and the sum of its angular diameter and twice its geocentric parallax. The mean motion and mean parallax for each planet are listed in Table 2. Once the area has been determined, one simply multiplies this by the mean number of eligible stars per unit area that are brighter than the appropriate magnitude (*7*) to obtain the frequency of occultations.

The calculations are subject to the following assumptions.

1) The near ultraviolet (about 3600 Å) is the best region for observing occultations. This is because most bodies in the solar system resemble late-type stars in having very red color indices. Thus, in most cases, observing in the ultraviolet minimizes the brightness of the planet with respect to that of the occulted star.

2) Counts of stars in a given magnitude range per square degree of sky are taken for photographic (blue) magnitude (*7*). Transforming these counts to the ultraviolet requires an adjustment in the ultraviolet − blue ($U - B$) color index which is negligible for most stars, that is, those bluer than spectral type K0 and redder than A0 (*7*). This transformation has been neglected.