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UNIVERSITY OF CALIFORNIA
ARCHAEOLOGICAL RESEARCH FACILITY

Number 8 June, 1970

MAGNETOMETER SURVEY OF THE LA VENTA PYRAMID AND OTHER PAPERS ON MEXICAN ARCHAEOLOGY

UNIVERSITY OF CALIFORNIA
DEPARTMENT OF ANTHROPOLOGY
BERKELEY, CALIFORNIA

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Department of Anthropology
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In connection with the La Venta pyramid project the authors also wish to acknowledge the assistance of Mr. Jose Benavente, graduate student in the Department of Materials Science and Engineering, who developed the special purpose computer programs for the interpretation models in this study. We are also indebted to Dr. J. Barcus, Physics Department, University of Denver, who very graciously and generously permitted us to borrow his rubidium sensor for this investigation. We acknowledge with thanks the assistance of the University's Computer Center (Berkeley) in providing the computer time and plotting for the interpretation. Mr. Eugene Prince, photographer in the Lowie Museum of Anthropology took the color photo from which Figure 6 is printed.

THE LA VENTA PYRAMID (FEBRUARY, 1968) LOOKING NNW

IV. PRECOLUMBIAN OBSIDIAN EAR SPOOLS:

AN INVESTIGATION OF POSSIBLE MANUFACTURING METHODS

Erich G. Thomsen and Harriette H. Thomsen

Antiquities are often interesting but not always esthetically satisfying. The obsidian ear spools of ancient Mexico are both; there are few important collections of precolumbian art that do not contain at least a single specimen of these fragile objects. Descriptions in the literature of obsidian ear spools, (sometimes called ear plugs) have dwelt on their beauty, their fragility, their sometimes paper-thin walls, but almost never on the significance of the technical know-how inherent in their manufacture.

The authors first became cognizant of their existence on a long-ago trip to Oaxaca, Mexico, where they pressed their noses against the vitrinas to admire the marvels of Tomb VII. Among the treasures of Tomb VII are ear spools of obsidian, rock crystal and amber, but it was the fashioning of those of obsidian which excited their interest; the technique which could have produced the apparently precise surfaces of revolution in so brittle and fragile a material.

Kidder (1947) made a summary of the then-available information on obsidian ear spools but hazarded no suggestion as to their manufacture, detailing only their fineness and delicacy. It will be seen in the subsequent pages of this paper that one of the characteristics of obsidian ear spools is their axial symmetry. It is this aspect which is the subject of the present preliminary study. The authors suggest a method for their manufacture which they prove feasible by experiments in generating such surfaces. No attempt has been made to replicate a complete ear spool, but only to demonstrate that their suggested method does in fact result in concentric surfaces of revolution yielding uniform wall thicknesses.

Ethnographic Information on Ear Spools

The usual procedure in attempting to analyze a prehistoric technique is to search for clues in the ethnographic literature. In the case of ear spools the obvious sources are the chronicles written mainly in the first century after the Conquest. If Bernal Diaz (1950) saw obsidian he does not appear to have been impressed by it, and Cortes' famous description of the Tlatelolco market (1962) in which he refers to the barbers' stalls "*donde lavan y rapan las cabezas*", (literally, "where they wash and shave the heads", but usually translated "where you can have your hair washed and cut"), is occasionally extrapolated to an interpretation that the cutting was done with obsidian razors (MacCurdy, 1900). Neither of these contemporary observers of the Conquest indicate any interest in how the material was processed, although Diaz (op.cit., p. 353) does have one brief comment on stone knives (*navajas de pedernal*). Sahagun (Dibble and Anderson, 1954, 1959, 1963; Seler, 1938), Duran (1964), Beaumont (1932, Torquemada (1723a), however, sophisticated men, not soldiers, reported randomly on the native arts. Beaumont has several references to the use of obsidian (in tarascan = tzinapo or tizinapu) in Michoacan, but no description of their manufacturing techniques, referring the reader to Torquemada. Torquemada, for his part detailed a widely-cited description of the making of obsidian blades; Torquemada's description should read in the light of discussions by Semenov (1964), Crabtree (1968) and others.

Sahagun, whose chapters on casting, lapidary - and feather work are justly famous, does not include a description of the working of obsidian. He was, however, aware of the use of obsidian in the making of ear spools. He attributes the art of the lapidary to certain deities: "Their creations were lip pendants, lip plugs, and ear plugs, ear plugs of obsidian, rock crystal, and amber; white ear plugs; and all manner of necklaces; bracelets; the manner of designing, of inlaying, with green stone; and the drilling, the polishing" (Dibble, 1959, 79-82). When Sahagun goes on to detail the methods whereby precious stones were prepared for adornments, he deals only with rock crystal, amethyst, green stones and emerald-green jade, bloodstone, Mexcian opal and several turquoises. No reference is made to the method used in the shaping, the drilling nor the polishing of obsidian; nor, in fact, to the method of manufacture of ear plugs from any of the materials.

In Sahagun's description of the costumes worn by the Aztec rulers in their various activities he describes only golden ear plugs (and a great variety of lip and nose ornaments), and a great warrior as adorned with leather ear plugs, but he describes the women as wearing "amber ear plugs, white crystal ear plugs; golden ear plugs; silver ear plugs; white obsidian ear plugs" (Anderson, 1954, 47). By indirection, therefore, we have a kind of evidence that Sahagun associated the wearing of obsidian ornaments with the female sex.

Of these three chief sources, each illustrates the role of ethnography when applied to the recreation of lost techniques: as stated, Torquemada must be viewed in the light of more modern commentators. Beaumont tells us little of practical value in the working of obsidian but some of his descriptions of funeral customs among the Tarascans have been borne out archaeologically (Rubin de la Borbolla, 1941, 1944, 1946; Moedano, 1941). It appears that obsidian ear spools were part of the grave goods in one of the multiple male burials at Tzintzuntzan[1]. Sahagun left us a heritage of immeasurable value but he gives us no clue to the making of obsidian ear spools. Only a few modern writers such as Orchard (1927, 216-221), Linne (1934, 151-2) Mirambell (1968) have speculated on the methods used in the manufacture of these remarkable objects.

Are we to conclude that the objects were well-known at the time of the Conquest but that the technique of manufacture was a lost art? The

1. Of the nearly 700 burials excavated at Tlatelolco, 5-6% contained obsidian ear spools. Since Tlatelolco was a temple precinct and ceremonial center the burials were generally males. The rich offerings imply that many were of warriors. (Contreras, personal communication, 1969).

little knowledge that we have of their provenience indicates that the preservation of most specimens has been in burials; are we then to assume that their use was conbined to ceremonials and interments of important people, or were they worn commonly but destined to destruction because of their fragility and brittleness?

Technology of Obsidian Ear Spool Production

A study of the processing technology of obsidian ear spools, fashioned by pre-Conquest Mexcian Indians, might well include an examination not only of the geometrical forms but also of texture and surface finish.

Obsidian is a volcanic glass primarily consisting of approximately 75% of SiO_2, 13-15% Al_2O_3, with smaller amounts of CaO, MgO, Na_2O, K_2O, and some trace elements (Stross et al., 1968; Weaver et,al., 1965; Heizer et.al., 1965) and less than 1% of H_2O. Its melting temperature is above 1100°C and it owes its glassy texture to the prevention of crystallization during rapid cooling. Its viscosity varies during solidification over a range of temperatures. The impurities and fine dispersion of small crystallites throughout the mass make it opaque to light when in massive section. If the sections are thin enough, however, say one millimeter in thickness as is often found with ear plugs, the obsidian becomes transparent to light and takes on the glass-like appearance of window or bottle glass. The color depends on the source from which the obsidian comes and shades of brown, green, gray, red, etc., are found (Jack and Heizer, 1968).

There appears to be no reason to accept nor discard the idea that molten glass could have been cast into suitable molds to form the initial semi-finished blank for an ear plug. Its further processing could have been by polishing with fine abrasive materials. The indigenous peoples of the High Culture area of Mexico had the capability of melting glass-like materials and could construct baked clay molds, coated with carbon to prevent fusion with the mold. Sahagun (Dibble, 1959, 73-78) gives a classic description of their casting technology of metallic objects, especially gold and silver. The fact that glass artifacts have not been found may be a clue that the casting of glass was not used.

Our own laboratory observations of volcanic glass, i.e. obsidian, confirm the general knowledge that when heated to 1100°C gases are liberated, transforming the obsidian to a pumice-like material. As far as we know there is no method by which it can be returned to its original structure, unless melted under pressure[2]. Until more information is available we will

2. Rubin de la Borbolla (1941) cites a fragment of an obsidian ear plug as burned and bent by the effects of fire (p. 10), and also fragments of obsidian knives twisted by the heat (p. 16); blades curved presumably by the heat of cremation were found in Tlatelolco (Contreras, personal communication, 1969). We cannot know the temperatures achieved in the cremations but we must assume that they were below 1100°C. Our own experiments on Tlatelolco obsidian specimens indicate the beginning of softening at a temperature of approximately 980°C and the initiation of liberation of gases at 1050°C.

assume that the ear plugs under study are made from the original obsidian solid by mechanical processing.

If an ear plug is produced by mechanical means, it would appear, considering the tool materials available, that only two methods could have been used by the ancient lapidary for external material removal. The first method is based on the propensity of glasseous substances to fail by brittle fracture. This requires a well-placed impact with a material having sufficient hardness and mass, such as flint, or a concentrated force applied in a small region causing a high stress. In either case cores of various shapes could be produced in this manner by chipping to form rough blanks for ear plugs. Mirambell (1968, 63-69) describes the geometrical evolution of ear plug blanks as they might have been removed from the original rock. Because of the brittleness and hardness of obsidian (6-7 on the Mohs scale), it is unlikely that substantial material removal could have been achieved with harder stones such as flint by chip removal, except by pressure or impact chipping, and it must be assumed that a second method, abrasion, was the only avenue available for further material removal.

Semenov (1964) stresses the point that an examination of the surface may reveal something about the manufacturing and use of stone tools made by early lapidaries. This, even today, holds true for identifying manufacturing methods. But now, as then, it is only the last contact marks of a tool and abrasive, or wear marks, which can be observed. All previous marks imparted during the removal of substantial amounts of material will have been obliterated. Thus, fine finishing marks on a completed article may give a clue to the final process employed, but may throw little or no light on what went on before. The examination of the finish marks on ear plugs may give us some clues to the final polishing process, but will tell little about the sequence of previous operations and these must remain in the realm of speculation.

We shall now explore the possibility that the geometrical form reveals some peculiarities to use which may suggest a processing method. In order to do this the authors examined a number of ear plugs in museums located in New York, Washington, and others, examples of which are shown in Plate Ia and Ic. They found that the general form and dimensions varied and might be grouped as shown in Figure I. Inasmuch as the provenience of many of the U. S. museum pieces is not precisely known, and that they are identified only as coming from central Mexico, the authors examined and measured ear plugs in the Museo Regional de Oaxaca (Tomb VII) and in the Estado Museo Michoacan in Morelia, in order to ascertain that similarities existed.

The Mesoamerican ear plugs examined in the course of this study can be put into five classes as shown in Figure I, differing slightly from those classifications given by Mirambell (1968)[3]. Of the various ear plugs

3. Mirambell's study dealt with a larger sample of ear plugs made of skarn, marble, gneiss and obsidian (14 specimens). Extensive studies of the manufacture of jade ear plug components can be found in Kidder _et al._, (1946), Smith _et al._ (1951), Lothrop (1955) and Foshag (1957).

examined, the length l, diameters d_o and d_i, and thickness t are given as examples only. Furthermore, the flange diameters d_o were sometimes of equal size but frequently varied from one side to the other. The flange thicknesses of the ear spools as well as the thicknesses of the cylindrical or conical portions were remarkably uniform and often varied by a few 0.001 inch (0.025 mm). Similar symmetry was observed in the diameters of the surfaces of revolution which show remarkable concentricity and by today's standards could be regarded as precision parts.

In the following it will be seen that this remarkable concentricity poses the problem of how such precision surfaces could have been generated by preconquest artisans. It suggests that there are two possibilities to be considered: (a) the technology was sufficiently advanced to permit the construction of equipment capable of generating precision surfaces having rotational symmetry, or (b) the method used was a primitive one which produced such surfaces and such symmetry but requiring only simple technology and skillful craftsmanship.

In the absence of archaeological evidence it is not possible to come to a positive conclusion about the process at this time. However, similar accuracies obtained in contemporary grinding and lapping processes requires equipment which must impart rotation to the workpiece about a fixed center. Such equipment, capable of retaining for sustained periods a fixed center of rotation, requires appreciable sophistication in method and material, which was apparently not available to the precolumbian lapidary of Mexico. Consequently, we shall discard the fixed-center of rotation idea and turn to one which we might call the floating-center process. The floating-center is not a new idea and is occasionally used even today in some manufacturing methods. Its principle consists of the rotation of an object in space and its subjection to dynamic forces.

Since we are going to apply the floating-center principle to the making of ear spools we shall assume that the original blank cut from the rock by chipping, string-cutting or the like, can be perforated by a drilling or grinding operation. This method consists of rotating a tubular tool such as a hollow bamboo stem or more preferably a copper tube between the outspread palms of the hands pressed together against the drill. Alternating movements of the palms moved past each other in first one direction and then the other, imparts alternating rotary motion to the drill. A similar alternating motion was used by the California Indians when rolling the drill shaft over the thigh with the palm of the flattened hand.

The end of the drill could have been provided with a dry abrasive or with abrasive and water. The removal of material consists of abrasion combined with local crushing of the surface. The rapidity of material removal depends on the factors of: relative velocities between work and tool; hardness of the tool, type of workpiece and abrasive; and among others, the pressure applied to the abrasive through the tool. This method of drilling, using abrasive materials, has been well described in the literature by the early chroniclers. Their abrasives apparently were a variety of hard powders classified under the common name of esmeril which may or may not have any specific relation to the modern natural abrasive known as emery (Sahagun, 1963, pp. 237-238).

The accuracy of the resulting perforation in large part depends on the method and the hole could have been tapered if drilled from one side and biconical if the hole were drilled from both sides. The attainment of tapered holes is a natural consequence of the use of a powdered abrasive, combined with the rotation of an inaccurately centered drill. This is undoubtedly the reason why so many of the ear plugs show biconical surfaces or concave surfaces with the inner bore being smaller at the center than at the two ends. In the few cases measured where a nearly perfect cylindrical surface was attained, it is suggested that the taper in the hole was removed by the use of a stick such as bamboo coated with abrasive. The string drive to be discussed later may also have been the method employed.

The authors believe that the rotational symmetry could have been achieved by the two-string floating-center method. This method is illustrated in Figure 3. The process consists essentially of the two elements: providing a simple drive and automatic attainment of concentricity. The obsidian blank, which has been provided previously with a central perforation, is mounted on a mandrel or shaft, as shown in Figure 2. The blank must be secured to the shaft; this could be accomplished with an adhesive such as a pitched string around the shaft at the two ends.[4] The rotation of the shaft can then be achieved by wrapping two suspended strings once or twice around the ends of the shaft and placing a weight at the bottom. Figure 3a illustrated the way in which the operator could clutch the spindle through a lap and set it in rotary motion by moving his hand up and down. The split lap held in the operator's hand surrounds the perforated obsidian blank and is provided with abrasive for the material removal action. The lap could be of wood or of a metal such as copper. A copper lap withstands tool wear better than wood and can be used for a longer period. The lap need not be close-fitting but must be replaced during the material removal process as the diameter of the workpiece decreases. A possible alternate position, utilizing a backstrap device is shown in Figure 3b. If the driving effectiveness is not good enough with the set-up shown in Figure 3a, improvement could be achieved by placing larger driving cylinders over the two ends of the shaft. This reduces the rotational speed for a given up-and down-movement, but increases the torque for overcoming lapping resistance. Furthermore, if the string has a tendency to slip during the upward motion of the operator's hand because of the reduced torque, which is due to a well-known principle in mechanics, then a teeter-totter arrangement could be provided as shown in Figures 3c and 3d. The single weight is replaced by two equal weights. This permits the weights to be lifted alternately so that one is suspended in air while the other is touching the ground, assuring equal driving torque in both directions for the lapping movement. The idea of two

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4. From the literature to appears that some or all of the following adhesives were available in precolumbian Mexico: pitch (Duran, 1964, p. 131); asphalt (Clavijero, 1958, p. 56); rubber and bitumen (Vaillant, 1944, p. 130); bat dung (Cabrol, 1932, quoting Hernandez).

suspended strings appropriately weighted down could have come from the weaving techniques known to have been practiced early by aboriginal peoples[5].

The second important feature of the suggested technique is that the process tends toward the production of concentricity through Newton's second law of motion, one of the important principles in dynamics. In simple terms, it states that a mass in motion (rectilinear or rotary) will persist in motion until acted upon by gravity or inertia forces. Applying this principle to the manufacture of ear spools, assuming a balanced mass system, we see that the ear spool and shaft, if rotating at, say, constant speed, would be acted upon by gravity forces and the operator's push as he moves the assembly up and down. The material removal on the outer surface of the spool would be uniform and there is high probability that initial concentricity will persist. However, if the center perforation of the spool is not initially concentric with the outer surface in contact with the lap then a small but sufficient centripetal or radial force will be produced because of the unbalance of the rotating mass. It is assumed that both the rotating spool and the stationary lap have sufficient masses to cause such a force, which will tend to abrade the eccentric portion of the surface more rapidly than it does the other. The important feature is that the correcting process is self-terminating once concentricity will have been achieved.

Experimental Procedure

The hypothesis of the early use of the two-string floating-center method described in the foregoing has little value unless it can be demonstrated to achieve the characteristics observed in preconquest ear spools. Consequently, the authors demonstrated the method experimentally.

In order to be certain of using materials similar to those suggested by early chroniclers to have been the raw materials of the native lapidaries, the authors collected obsidian from out-croppings at Zinopecuaro, State of Michoacan, Mexico. Ear plug blanks of the general geometry of Figure 1 (2) were arbitrarily selected for experiment. They were prepared by facing a rough block and removing specimens by core drilling. Diamond saws and core drills were used to facilitate the process. The outside and inside diameters were respectively 1.05 inch

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5. Gayton (1962, 543-552) says that ancient Mexico relied on the back-strap loom, that they may have had the fixed vertical loom, but that there is no archaeological evidence to confirm its use. MacNeish (1967) concludes that true loom-weaving was practiced in the Tehuacan Valley possible as early as 1500 B.C. (Early Formative Ajalpan period) and assumes that from about 200 B.C. (Palo Blanco period) all the major procedures of backstrap loom-weaving were undoubtedly well-known. Sahagun's list of weaving components (1954, 49) must certainly reflect the Spanish influence on techniques and equipment.

   It should be pointed out that in Arizona, Woodbury (1954, 153-156) found archaeological evidence of the use of loomblocks in excavations of (Late?) Pueblo III date (1200-1400 A.D.).

(26.6 mm) and 0.5 inch (12.7 mm), and a length of 2 inches (50.8 mm). These dimensions have no significance and were chosen because of the availability of core drills. The center perforation for each blank was drilled eccentrically in order to test the hypothesis of automatic center correction during the process. The abrasive used was Boron carbide of 280 grid size. Laps of cast iron, copper and wood were used.

An example of the results obtained is shown in Plate Ib. On the right side of the photograph is seen a blank prepared by modern sawing and drilling; on the left, a specimen lapped by the two-string floating-center method. The reduction in diameter was from 1.05 inch (26.6 mm) to 0.80 inch (20.32 mm), at a rate of 0.001 inch per minute (0.025 mm per minute). In addition, two other specimens were prepared with somewhat smaller reductions.

The experimental results lead to the following conlcusions:

1. The proposed method works satisfactorily for the production of cylindrical ear spools (Type: Figure I (2).)
2. A copper split-shell type lap gave satisfactory accuracy without requiring a close fit of the lap.
3. Dimensional accuracies over a length of 2.0 inch (50.8 mm) of $\pm$ 0.002 inch (0.05 mm) and a roundness of $\pm$ 0.001 inch (0.025 mm) could be maintained without special precaution.
4. An improvement of concentricity of 10% was achieved for a reduction of approximately 10% in diameter. The masses to achieve this result need not be large (i.e. a lap of one or two pound weight at rotary speeds of approximately 10 rev./sec.). When large reductions in diameter are required, several laps should be used in order to improve or maintain concentricity.

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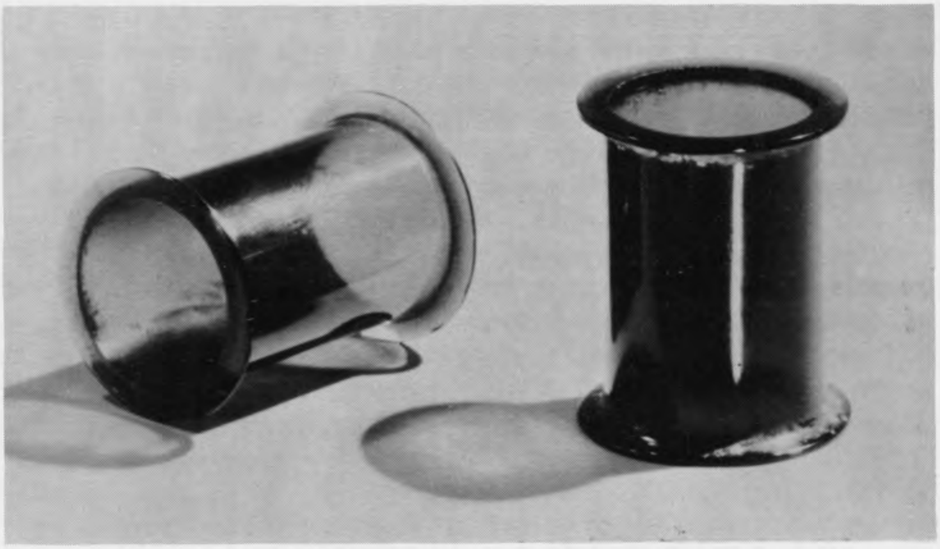
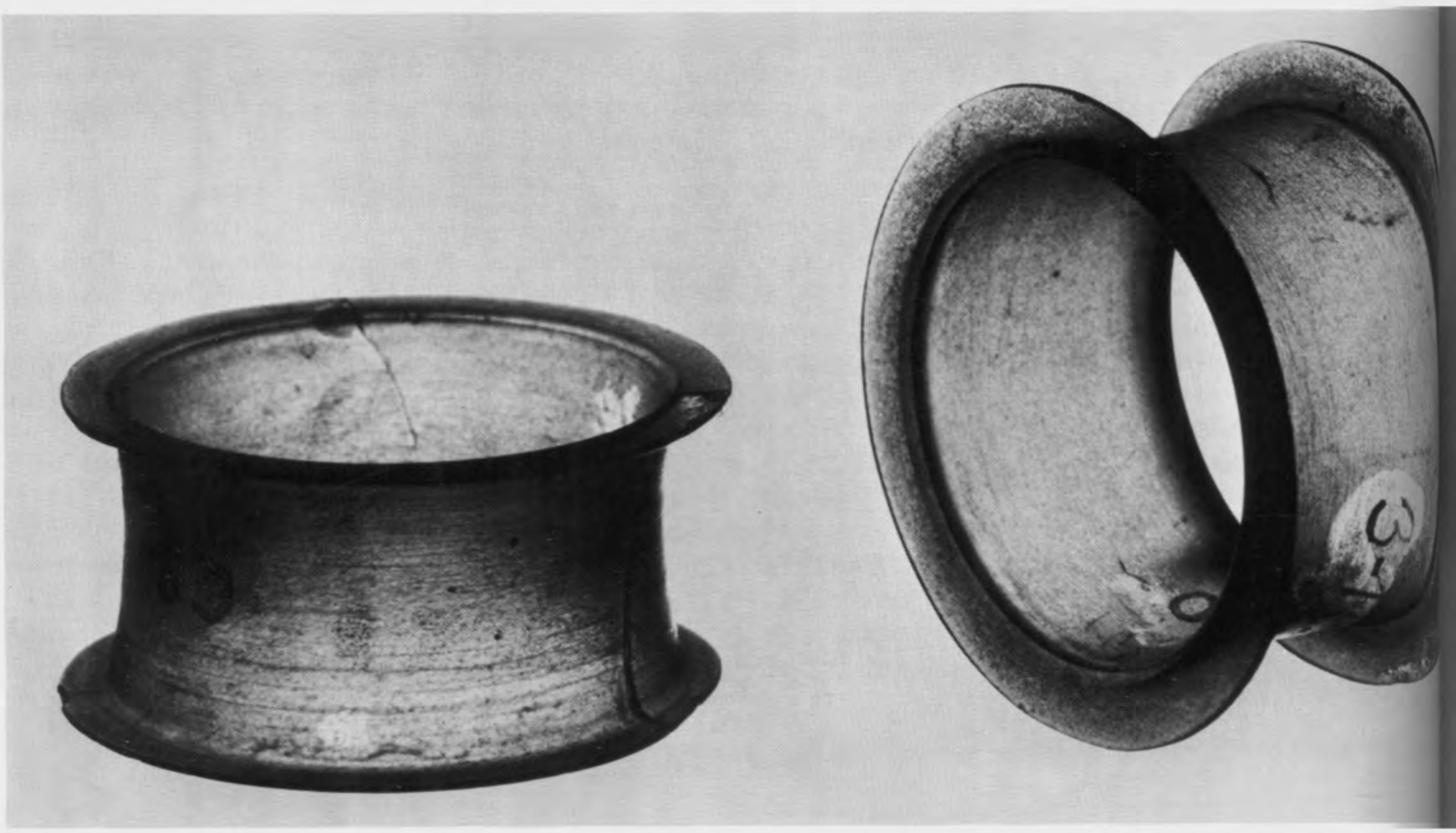
List of Illustrations



a

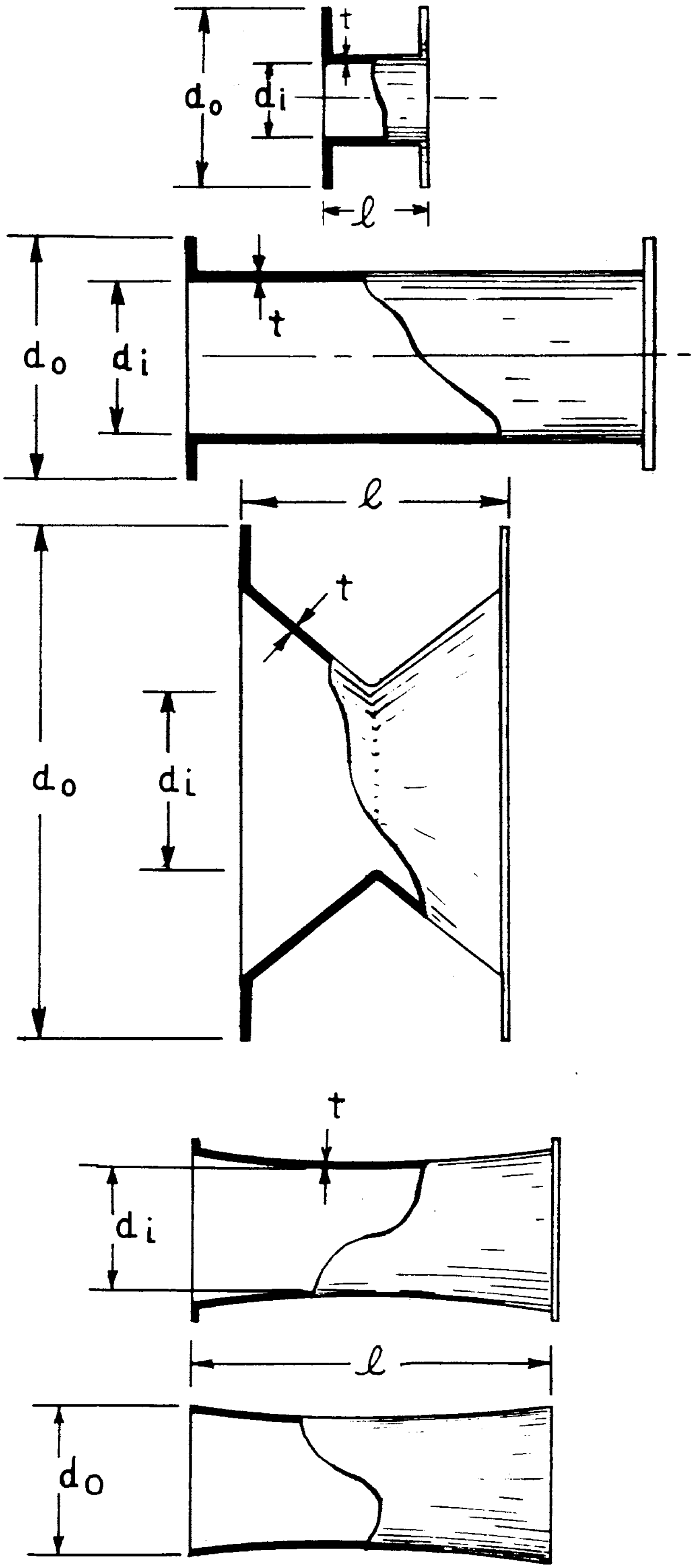
b



c

Plate I

Types of Ear Spools
(not to scale)



Typical Measurements
mm

	d_o	d_i	ℓ	t
(1)	17.0	7.5	7.8	1.0
(2)	27.5	20.0	34.5	1.0
(3)	57	31	23	1.1
(4)	—	54	—	1.1
(5)	24	—	25	1.5

(Measurements of fragment) [printed under row (4)]

FIG. 1

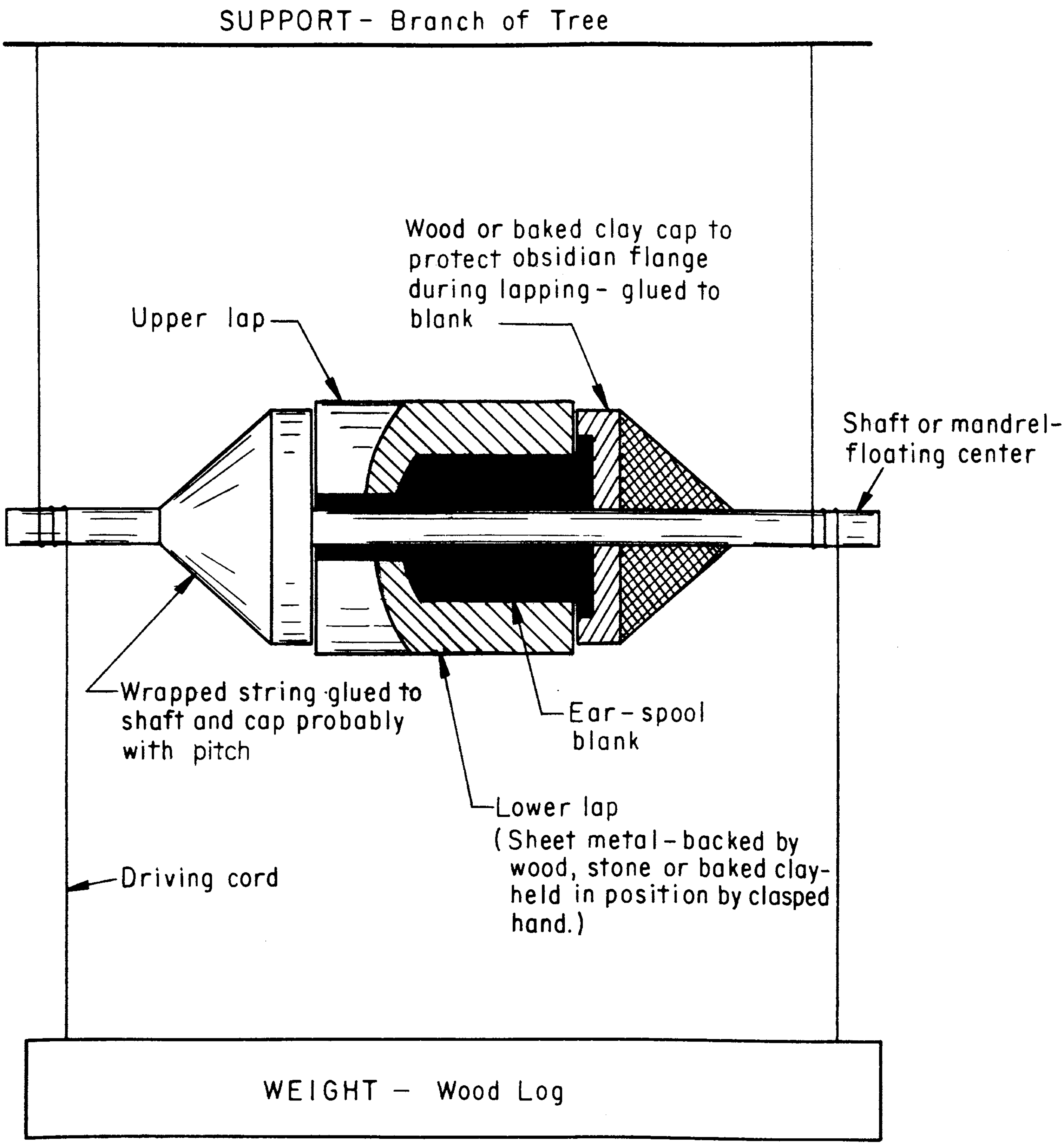

SUPPORT - Branch of Tree
Wood or baked clay cap to protect obsidian flange during lapping - glued to blank
Upper lap
Shaft or mandrel- floating center
Wrapped string glued to shaft and cap probably with pitch
Ear - spool blank
Lower lap
(Sheet metal - backed by wood, stone or baked clay- held in position by clasped hand.)
Driving cord
WEIGHT - Wood Log

FIG.2

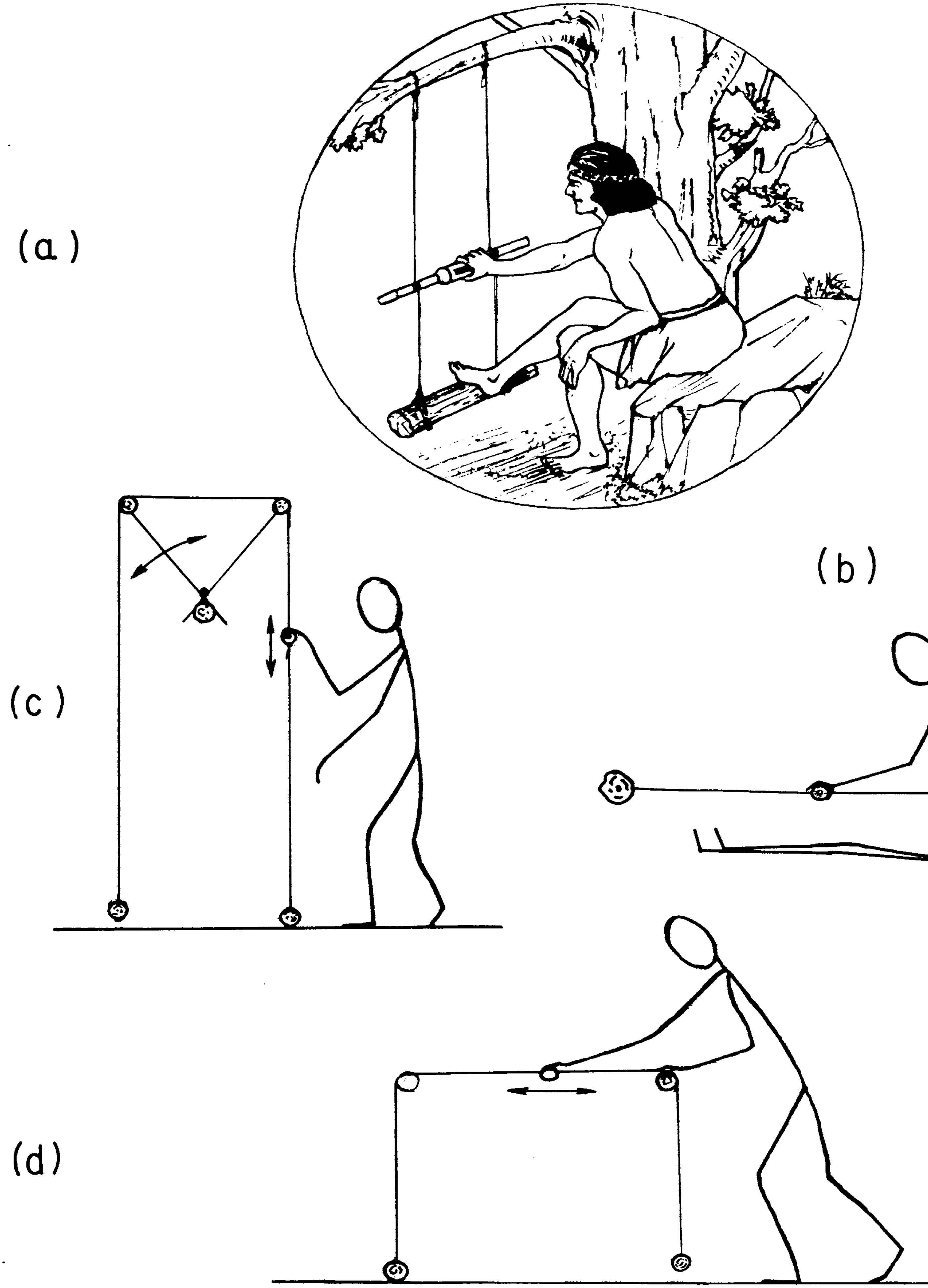


FIG. 3

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