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AUSTRALIAN GROUND STONE HATCHETS:
THEIR DESIGN AND DYNAMICS

Abstract

The general purpose tool of the Australian Aborigines, usually known as a stone axe, is more correctly termed a hatchet since it conforms to the design requirements of a tool made for one-handed use. Similar implements not so conforming appear to be special purpose tools.

A geometrical feature common to all these tools and perhaps to other types is the 'median plane' which determines the position of the edge and governs some of its operational properties.

Some dynamical features of stone hatchet heads, the design of handles for them and their security of mounting are examined and compared with the features of modern steel hatchets.
Among the stone tools of the Australian Aboriginals the ground edge hatchet was the most versatile and was used over an area covering more than three quarters of the continent. A noted ethnologist of the last century, one of those still in a position to make first hand observations, wrote:

A man never leaves his encampment without his hatchet. With its help he ascends trees almost as rapidly as the native bear can climb. He cuts a notch for his toes, and placing the hatchet between his teeth, so as to set free his arms, ascends one step, cuts another notch, and so on until the height he desires to reach is attained. The rapidity with which he climbs and his dexterity would surprise a stranger. With the stone axe he cuts open limbs of trees to get opossums out of the hollows; splits open trunks to take out honey or grubs or eggs of insects; cuts off sheets of bark for his mia mia or for canoes; cuts down trees, and shapes the wood into shields or clubs or spears; cuts to pieces the larger animals of the chase, if necessary; and strikes off flakes of stone for inserting in the heads of spears and for skinning beasts and cleaning the skins. With an old tomahawk he will shape from the rough block of stone a new tomahawk. Its uses are so many and so various that one cannot enumerate them. It is sufficient to say that a native could scarcely maintain existence in Australia if deprived of this implement. (Brough Smyth 1878:1:379)

Being a wood-working tool, the hatchet has a distribution coinciding largely with the distribution of trees, the sources of raw material used in its manufacture and the habitat of the arboreal creatures which were important sources of food. The areas in which ground hatchets are not found are the treeless deserts, a part of Western Australia where an unground tool was used, and the island of Tasmania (Davidson & McCarthy 1957:426).

Ground stone technology in continental Australia is ancient, the oldest known hatchet heads, from Arnhem Land, having an age of some 20,000 years (C. White 1967). There are however, very large gaps in the chronological record and the use of ground tools may not have spread to the southern parts of the country earlier than about 5000 years ago (Mulvaney 1975:194). Dating depends on discoveries in sufficiently well stratified contexts and no one has been
able to exhibit a chronological series of forms even for a restricted region. The ancient Arnhem Land specimens are developed forms and presumably there is a remoter ancestry behind them.

While there are some regional variations in form these are neither positive nor exclusive enough to permit reliable identification of provenance. It is possible to have hatchet heads from sites 2500 km apart which can be distinguished only by petrological analysis. The range of sizes is large and, in most parts of Australia, varies from 150 g to 1500 g while in some districts there are ground heads of 2500 g and more. The variations in dimensions and shape are equally large.

In the face of such variability it seems important for any serious study to look for underlying features transcending temporal, geographical and cultural influences. Any such features would be of a functional nature, governed by the purposes the tool was made to serve and its modes of use. A prerequisite for such an investigation is to discard certain facile but misleading terms and ideas to which we have become accustomed.

In the first place it is wrong in scientific discourse where one has an obligation to be precise to talk of Aboriginal stone axes even though it is customary to do so. The Australian Aborigine did not make axes, but hatchets, which differ from axes in both construction and mode of use. An axe is a long-handed implement designed for two-handed use whereas a hatchet is intended for one-handed use with a quite different action. Neither tool is satisfactory for use in the manner of the other, as shown by simple trial. The correct name, hatchet, was regularly used by earlier writers (Collins 1798:2:586), and sometimes the name tomahawk (Curr 1886:147). The last term was taken into the English language in the 17th century and, while widely used, still carries some connotation of a fighting weapon whereas the Australian hatchet was ill suited for a weapon and was almost exclusively a utilitarian tool for daily use.

Our present misuse of the word axe is compounded by using it for the stone head alone, giving rise to the tautological term 'hafted axe' for a complete hatchet. The word haft is in any case inappropriate. Reference to a dictionary shows that it is the name for the handle of a tool such as a knife, a chisel or a gouge where the handle and blade are in line and the tool is operated under pressure. For axes, hatchets and hammers, if any name more specific than handle is needed, the correct word is helve, proper for a tool that is swung and operates by impact. This misuse of terminology can give rise to pseudo-problems as in a case
where it appeared to be a puzzle that hatchets were provided with handles 20,000 years ago but putting handles on knives and chisels did not come until some 12,000 years later (Mulvaney 1969:151; 1971:374). The problem really arose from the indiscriminate use of the word haft by archaeologists at large. There is in fact no technological coupling between helves and hafts to make one the precedent for the other.

The term 'polished' is one which should be very carefully used. A polished surface is smooth and brought to so fine and glossy a finish that it exhibits specular reflectivity. Many European and American celts were ground all over and polished to some degree as were New Guinean axe heads, but very few Australian hatchet heads were ground beyond the bevels necessary to form the edge. Despite Davidson's claim that the 'completely polished axe' is of widespread distribution in eastern Australia (Davidson 1938), Mulvaney is correct in saying:

It is rare in Australia for axes to have been ground all over and polished forms, so common in Melanesia, are virtually unrecorded. (Mulvaney 1975:194)

Though many of the kinds of stone used by the Australian Aborigines can be polished, those commonly so treated in other parts of the world, flint, obsidian and nephrite, were rare or not available at all. Australian hatchet heads were made from a wide variety of igneous and metamorphic rocks ranging from microcrystalline to coarse grained structures.

A typical collection labelled 'Stone Axes' comprises a number of pieces of stone which have one important feature in common: a ground edge. By way of descriptive classification one can set up arrays of measurable traits, to the limit on one-specimen classes, and make sophisticated statistical analyses. Whether the result is anything more than a feat of technical prestidigitation depends on the possibility of constructing a meta-system of feature significances behind it (Spaulding 1953; Whallon 1972). In respect of 'axes' Tugby (1958) has claimed that Australian typologies, particularly his own, are functional. He did not, however, relate traits to operations that would demonstrate their functional quality and far from the 'perceptual unity of the whole in the eyes of the artefact maker' he reverted to the eyes of the archaeologist (p.24):

The traits used are, in fact, those which are conceived by the archaeologist on general grounds such as the known manufacturing techniques for axes ....
The techniques of manufacture would indeed be functional in a study of grinding technology but it is the finished edge that is functional in a hatchet head, not the method by which it was formed. In fact the other so-called functional typologies (Kenyon & Stirling 1900; Mitchell 1949) are not wholly functional, even at the first and broadest levels.

The functional traits of an implement are those which make it fit and proper for the purposes for which it was made. They show why the thing was made as it was and the tests for presumed functional traits are clearly operational tests. Those traits which reveal the techniques of manufacture in the finished product are accidental in that they reflect the features of the raw material and the methods the tool maker chose to deal with them. Selection is the first stage in manufacture, picking the most promising blank that the stream-bed, the quarry and good luck provide. To a large extent the ultimate measurable traits are more accidental than contrived. For a trait to be called functional it is not enough for it to be compatible with operation; it must be shown to be operationally required.

Underlying these typological schemes is an assumption that we can always recognise the objects as members of the class of so-called 'stone axes'. While often true, this is not guaranteed. A particular ground stone may have been a hatchet head, a hand-held chopper, a wedge, a chisel or adze or some combination of these. These possible uses correspond to a considerable extent with those of American celts as described by Sonnenfeld (1962:56) from his own observations and those of earlier investigators, with similar problems in determining function. In fact the only specimens for which we can be certain are hatchets complete with head and handle, though we can be reasonably sure that a putative hatchet head has been one at some time if it has suitably placed gum still adhering or a groove worked round it.

So important and persistent a tool as the stone hatchet warrants a study going deeper than mere descriptions of superficial features. An investigation of the dynamics of its operation may reveal necessary functional features transcending accidental and stylistic traits and, if so, such features will be dynamically significant. A hatchet in use is part of a dynamical system which includes the user and the workpiece. It follows that, in the case of a stone hatchet head, any functional features will be those of a component, not of a complete tool.

Most ground stone hatchet heads have an edge which is curved in plan but straight in profile. The curvature in plan is a natural result of the grinding process, as shown in my earlier work (Dickson 1972). It is rather difficult to grind an edge which is curved in plan and it is a disadvantage in normal use. Seen in profile the edge of most stone hatchets is
straight, that is, the two ground bevels of the blade, which are surfaces of compound curvature, meet in a plane. If the edge is appreciably curved in profile, the hatchet head in use will be subjected to strong forces tending to break it in the direction of least strength, its thickness, and specimens with such curvature are commonly found broken.

The straightness in profile, unlike the curvature in plan, does not come naturally in the grinding process but requires some special effort to produce it. While investigating the technique of grinding I found that one does not only take care to grind the edge straight but also, apparently by instinct, to ensure that it is in a particular position. A little thought shows that this position does not relate to a line axis in the stone but to a definite plane. This plane, in which the edge lies, is highly significant and so deserves a name. According to the dictionary I may call it the median plane. It is not just a plane in which the edge happens to lie but rather it is a pre-existent determining plane to which the edge is adjusted. A well made hatchet head will be mass-symmetrical about the median plane and the ground bevels will make equal angles to it, though it may be necessary to do more grinding on one side to achieve this, resulting in a greater bevelled area on that side. The plane intersects the butt nearly centrally. For good balance it ought not be displaced by more than a quarter of the thickness of the butt and then only so much where there is extra mass on that side lower down to help the balance. When a head is mounted to a helve the plane is parallel to and close to the centre line of the helve which places the edge in its proper orientation. Because of the dynamic working of a hatchet and the impulsive forces on impact, serious deviation from any of these relations with the median plane will result in a tool bad to handle and to use with precision.

So far, after examining close to a thousand Australian hatchet heads and several hundred New Guinean axe heads, I have not seen any in which the position of the median plane could not be determined. The vast majority conform closely to the plane whereas those that did not were ill-made and most of them fractured due to curvature of the edge out of the plane.

For a hatchet maker with some experience it is easy to locate the median plane in a blank. If the disposition of the stone about it is promising then the blank will almost certainly make a good head. It also enables the maker to determine how much dressing may be needed to bring the blank into sufficient conformity. With practice, the position of the median plane in a blank can be determined with reasonable precision, often within 2 mm. I have not yet closely examined other kinds of tools in terms of the median plane but I have observed conformity to it in several bifacially flaked choppers from North Queensland. In passing, we may
notice that in selecting a blank for a ground stone adze the median plane is equally significant but in this case what will be the distal face of the butt should coincide with the plane and the blade end should be of a shape such that the edge, lying in the plane, will have the bevels at unequal angles. For best operation the blade of an adze is highly biassed so that the proximal bevel, if any, is essentially flat and lies in the plane.

Still looking at a stone hatchet head in profile, we see that the included angle between the bevels of the blade, normally bisected by it, is usually between 60° and 90°. Since the bevels are normally curved, the angle is measured close to the edge where it is most significant. It is arbitrary but convenient to define 'close' as 5 mm from the edge. This is very obtuse compared with the fine blade of a steel hatchet with its angle of 25°. In technical language, a fine blade is one which has a small angle like a knife or a well ground chisel. Fineness and sharpness do not mean the same thing and have nothing to do with one another nor do obtuseness and bluntness. A sharp edge is one where the surfaces that form it meet with a vanishingly small radius. One can make a very sharp edge with a large included angle. A sharp edge of 120° will cut a piece of paper laid on a hard surface just as cleanly as one of 20° but, of course, the penetration is small compared with that of a fine edge. On this basis the statement of Sonnenfeld (1962:59):

... the smaller the edge angle or the larger the taper radius the sharper the edge ...

is seen to be a misconception of what is really an elementary matter of engineering.

The edge of a stone hatchet is obtuse because stone is a brittle material. It is quite possible to make a stone hatchet with a blade as fine as 25° but it would be foolish to do so knowing that it would be shattered by a couple of smart blows on a piece of wood. The Aborigines learned long ago to make a working compromise between fineness and durability. A recent investigation of knife edges has shown the dependence of durability upon obtuseness (CSIRO:1971).

These basic features of stone hatchet heads permit wide variations in shape, size and weight. There is no question of an ideal hatchet, for the Aborigines were not making standard products but things to chop with, from such materials as they could procure. For what they had to do, a poorly shaped hatchet or one lighter or heavier than one might wish was infinitely better than no hatchet at all.
Fig. 1. Hatchet head 146 x 104 x 36 mm, weight 1035 g. Profile shows relation toMedian Plane.

Fig. 2. Hatchet head with edge curved out of Median Plane, fractured in use.

Fig. 3. Action of stone hatchet normal to wood and at an angle.
It is now appropriate to consider how a stone hatchet operates in its dynamical system. Very few of us have any experience in the use of a stone hatchet but many have used, after a fashion, a steel one. It will accordingly be helpful to exhibit some similarities and contrasts between the two in chopping wood. Steel hatchets are highly standardised tools mass produced to now traditional dimensions with a 12" helve and a 1½ lb head. In metric countries they are made with 30 cm helves and 700 g heads, a wholly insignificant difference. This traditional design is an empirical consequence of the usual build and musculature of modern Homo sapiens. They have edges curved in plan and fine blades of 25°. In swinging a hatchet the wrist is kept straight and the main centre of motion is the elbow joint, with a smaller component of motion from the shoulder, except in heavy chopping, when the shoulder becomes the main pivot. In either case the swing seldom exceeds 90°. The action of the muscles is to accelerate the hatchet head from rest at the top of the swing to its maximum velocity at impact. At the instant of impact the work of the muscles is done but they cannot be suddenly switched off and are still taut so, with hard wood, we feel a shock transmitted through the rigid handle as the head abruptly decelerates. A very light springy handle would withstand the load of acceleration and would absorb the shock as is indeed the case with a typical stone hatchet handle. A steel hatchet, however, can bite deeply and stick fast in the cut. That is why it is provided with a rigid handle of deep section, to withstand the heavy load of heaving the blade out of the cut, in which process most of the breakage of handles occurs.

It is to minimise this tendency to stick fast that the edge of the steel tool is curved and its fineness set at 25°, anything finer is almost certain to stick while a greater angle would unduly reduce the depth of cut. In a typical blow directed transversely across the grain and at 45° to it longitudinally, the edge severs the wood fibres and the blade acts as a wedge compressing them against the bulk wood on one side and forcing them outwards on the other, breaking their longitudinal cohesion. The mechanical advantage of a wedge is 1/sin θ where θ is the included angle, which clearly shows the benefit of making the blade as fine as possible without danger of sticking. Energy is consumed in both severing and wedging the wood fibres but, for a steel hatchet, frictional resistance absorbs the greatest share. Friction increases rapidly with the depth of cut, because of the increasing area of the blade in contact with the wood and is further increased by the tendency for resinous matter to adhere strongly to the blade, effectively reducing the slipperiness of its smooth surface.
Now in a stone hatchet the obtuse blade has a very poor mechanical advantage as a wedge and the angle of attack is severely limited. If we strike at a large angle with a 60° blade most of the available energy is expended in compressing wood fibres with shallow penetration and little cutting. It is often said that a stone hatchet works by bruising its way through the wood and this is true for such a brute force approach (Dunbar 1943). A skilled user, however, can do better than that by striking at the smallest angle that does not result in a glancing blow. Thus in a blow with a 60° blade directed at 40° to the grain the inner face of the blade is at 10° to the wood and the outer face at 70°. The sharp edge will slice the fibres better at this low angle while the outer face of the blade prises up the fibres at 20° less than a right angle. The result is the lifting of wood as fairly long thick parings. In this way a trunk can be severed in a manner similar to the use of a steel hatchet but the gash in the trunk will necessarily be wider and it will take longer to complete the operation. Once again energy is expended in cutting, wedging and in friction. Because of the small penetration and smaller blade areas involved friction is not so great a factor as with a steel blade, even though the stone surface is not normally as smooth.

A stone hatchet does not bite deeply enough for the blade to stick in the cut, hence the handle need not be very rigid. Surviving examples and earlier accounts show that the handles were usually rather flexible and springy (Mitchell 1839:2:343), from which two advantages accrue. The shock on impact is largely absorbed in flexing of the handle which is better for the user and secondly the stress on the bond between head and handle is minimised. In fact, unless it has been badly executed or weakened through age and long use, a gum or beeswax bond with good lashing is remarkably secure, even without grooving the head. Our experience with steel hatchets tends to make us over-estimate quite largely the strength of bond needed for a stone hatchet.

The use of a hatchet produces characteristic wear marks on the ground bevels, ranging from the fine scratches to deep scours often 10 mm or more long. Scours are not often produced in replicative experiments, whereas in the real case there was always a prospect of sand or grit finding its way into the work. Such marks are usually at an angle, perhaps as large as 20° to the axis of the head, a consequence of the curved path when swung and are more or less tangential to the arc of swing. A large angle indicates a long swing and correspondingly vigorous operation whereas a small angle suggests short chipping strokes. It is possible to tell which way round the head was mounted to the handle as the upper ends of the scratches are directed away from it.
The next consideration is the kinetic energy expended in chopping. As said before it is supplied by the muscles and stored, mainly in the hatchet head, by its acceleration to a high velocity. From the well-known expression \( E = \frac{1}{2} m v^2 \), where \( m \) is the effective mass of the tool and \( v \) its velocity on impact, it is clear that the energy can be increased in two ways, by increasing either \( m \) or \( v \). There are, however, factors limiting what can be done either way. The handle is an extension of the arm, and the typical 12 inch or 30 cm handle effectively doubles the length of the forearm so that, for a given angular velocity of swing the linear velocity of the head is doubled compared with a chopper held in the hand, quadrupling the energy. With a 700 g head on a 30 cm handle an impact velocity around 4 m/sec can be achieved. Doubling the handle length, however, will not generate a proportionately greater velocity because, owing to its mechanical disadvantage, greater effort is required for the same angular velocity and this is simply not available. Both the strength of muscles and the speed with which they can contract are limited. Not only is there little to be gained from a long handle in respect of kinetic energy, there is a loss of directional control over the point of impact.

The energy increases as the first power of the mass for a given terminal velocity but a heavy head in sustained work cannot be accelerated as smartly as a lighter one so that there is relatively little to be gained by a large increase in head mass. It comes back to the question of how fast the arm can turn about its joints under given loads. Apart from heavy work like felling trees, a fairly light head will serve for many purposes.

It seems reasonable to suppose that much of the work done with light weight hatchets was chipping rather than chopping. Thus a head of only 140 g on a 29 cm helve proved very suitable for debarking and pointing a digging stick or for hollowing out a broad piece of wood, its narrow 44 mm blade and fine 52° edge being advantageous for such work. On the other hand it took half an hour to chop through a 75 mm section of hard sapling and the work was very tiring.

The use of an axe can fairly be called a whole-body performance. The two-handed grip with one hand initially far up the helve but sliding back to the other as directional control is established, enables the 80 cm helve, the extended arms and flexing body to provide a large radius of swing. During this long swing of some 120° there is time for the combined power of many muscles to impart a high velocity to the head, perhaps twice that of a hatchet despite the greater mass. Steel axe heads come in weights of 3½, 4, 4½ and 5 lb or their near metric equivalents. The five-pounder is a tool for skilled and strong-muscled axemen; the axe-makers tell me that there are few today who really use it.
No so-called Aboriginal axe can be used in such a manner because the handle is short and not made for a sliding grip. Complete stone hatchets are rare compared with heads but the 75 specimens I have been able to measure have an average helve length of 29.7 cm. Of these three were exceptionally long at 42, 42.5 and 46 cm. They are still considerably shorter than the 60 cm helve of what is technically called a half-axe which has a 2½ lb or 1100 g head. The split helves and bindings prevent these specimens from being used with a sliding grip; they are indeed hatchets and the handles are still of a length for them to be conveniently carried about stuck inside the waist-band in typical Aboriginal style.

From the well-known wide range of sizes, it is clear that Aboriginal hatchet heads differ greatly in mass. With the exceptions of the giant types from Cape York (Wolston & Colliver, 1973), and very small specimens that may have been mounted chisels, there is a range of about 12:1 in mass from 250 g to 3000 g. Measurements of 503 specimens and the weights of 173 made available to me by Dr I. McBryde, give a median weight in the range 600 g to 700 g. The distribution, which has not yet been analysed, is obviously skewed, with 280 heads between 250 g and 500 g.

The large proportion of low mass heads is consistent with the dynamical considerations discussed above, but represents more strongly another design criterion combined with a natural phenomenon. Field observation suggests that blanks of desirable form are most readily obtainable in the smaller sizes. From the tool maker's point of view these have a marked advantage over the massive blanks. In an experimental case, to make a head of 980 g it was necessary to grind away 103 g of stone while for one of 302 g only 20.8 g was removed. In direct mechanical terms only one fifth as much work had to be done but in dynamics of grinding the advantage is even greater as the smaller area of contact results in higher grinding pressure for a given effort.

As might be expected on both dynamical grounds and from the relative scarcity of large favourably shaped blanks, heads between 1500 and 1800 g are rare. There does, however, appear to be a group ranging from 2500 g to 3000 g. According to Howitt, in the Cooper's Creek region, massive heads were used held in the hand (Howitt 1876). Hand choppers of 900 g to 1500 g can be used single-handed with the blade parallel to the arm or nearly at right angles. The former position is more suitable for splitting and the latter for paring in an adze-like manner. Neither mode necessitates positive design features, only that the butt shall not be excessively tapered. As Sollas quoted:

... it is not so much the flint that fits the hand as the hand that fits the flint.
(Sollas 1924)
2. Hatchet collected by K. Akerman near Derby, Western Australia. Dolerite head, appr 930 g, handle 23 cm long. Light binding with fiber ring and main bond of beeswax loaded with red ochre.

7. One of the author's replica hatchets for experimental use. Grooved basalt head weighing 680 g, split can handle 27 cm long. This hatchet cut through a 12 cm Eucalyptus sapling in 7 min.
The heavier heads of 2000 g to 3000 g call for two-handed use and there is no way to hold the tool with its edge parallel to the arm. Mechanically, there is a preference for a butt tapering in breadth so that the hands are inclined towards each other as this gives a distinctly better grip. Whether one-handers or two-handers such stones are neither hatchets nor axes but hand choppers and tools in their own right.

However, Brough Smyth claims the massive heads of 4 lb to 6 lb were provided with helves and used for splitting hollow trees to get possums (1878:1:369). Some trials with heads of 2260, 2330 and 2350 g with helves of 36, 33 and 35 cm respectively, show that these must be used two-handed. The action, however, is not really that of an axe because of the short helve and the effective swing is limited to about 90°. While certainly useful for splitting a hollow trunk with a few centimetres thickness of wood they are poorly suited for other work, being too heavy and clumsy for comfortable use. They appear to have been designed for this special purpose and might better be described as splitters than as hatchets or axes.

Reference has already been made to the flexibility of Aboriginal hatchet handles as contributing to the security of the bond with the head. A commonly used form of handle was a stick about 25 mm or a little more in diameter split lengthwise, bent around the head and tightly bound. Alternatively a similar piece might be cut from a trunk. In either case it was not a deep section like the handle of a steel hatchet. In general bending the handle round the head was achieved by heating the green stick over a low fire or in hot ashes and sand, heating, bending and reheating progressively until the stick is doubled round the stone head. Not every kind of wood can be so bent and, even with the more amenable species, a thickness of 12 to 15 mm is about as large as can be bent without excessive fibre breakage on the outside.

Even though tightly bound a handle is not secure enough for serious work without additional means of bonding which can be had in two ways, from the shape of the head or the use of adhesives. If the head tapers in thickness to the butt, impact tends to wedge it tighter into the handle. Tapering in width is less effective unless there is a marked change of shape, as when the head is 'waisted' or 'shouldered' to provide a definite mechanical lodgement preventing the head from being driven through and out of the handle. Another way to produce positive lodgement is by forming a groove around the head on one or both sides into which the handle fits. This is certainly a very ancient method as is shown by the grooving of 20,000 year old specimens from Arnhem Land. It may well be more ancient than the use of adhesives.
From a technological point of view the use of adhesives is more sophisticated than modifying the shape of the head. Grooving and waisting are simple in principle and execution, though often tedious. Successful application of gums and resins requires a detailed knowledge of their properties and considerable skill in heat treatment at moderate temperatures. The resin itself often calls for elaborate preparation to put it into a form and consistency suitable for application to the joint. While it may be that the Aborigines learned about grooving hatchet heads before they arrived in Australia, it seems probable that the use of resins from indigenous plants like *Xanthorrea* and *Tridá* was not discovered until a later stage in their occupation of the continent.

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