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THE WEDGE-EFFECT IN FIRESETTING OF A SARSEN STONE AT OVERTON, NEAR AVEBURY, WILTSHIRE

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Abstract: Following a method described in the mid 18th century, a sarsen stone of the type used in the Avebury stone circles was split using firesetting. This demonstrated it was a feasible method of destroying the large stones whether found in the local fields, or erected as monuments, which were, in earlier and more robust times, considered as inhibiting agriculture and best recycled for building purposes.

INTRODUCTION

The experiment was carried out as part of a BBC Scotland programme for BBC 2, *Time Flyers*, in April and was broadcast in November 2002. This edition was presented by Professor Mark Horden of Bristol University and Dr Jo Caruth of the University of East Anglia. The programme mainly concerned the nearby Avebury stone circle and avenues, particularly as seen from the air but, since research had revealed firesetting had been used to destroy substantial numbers of stones as originally erected (and, no doubt, also stones lying in the fields), a simple experiment was devised based on original 17th and 18th century descriptions for the area and the writer was commissioned to demonstrate it, to a proposal prepared by BBC researchers.

THE BRIEF FOR THE EXPERIMENT

The brief for the experiment, *Turning Sarsens into Building Materials*, using documentary sources, described first, firesetting in 1663, "make a fire on that line of stone, where you would have it crack; and after the stone is well heated, draw over a line of cold water, & immediately give a knock with a smyth's sledge and it will break like the collets at the Glass-House".

William Stukeley (Bodl.MS Gough Maps 231 f5 is cited) in 1724 illustrated the process showing pointed sledge hammers, large jugs, presumably for water and large timbers for levers and a further note describes it as "a barbarous massacre".

In his work of 1749, Stukeley described Tom Robinson of Abury (Avebury) as eminent in this kind of execution. The method was to dig a pit to fell the stone, which was as much as 18 feet long 13 broad and 6 thick. The collapse crushed stone laid to receive it, and timbers 20 foot long were then used to raise it, by the help of twenty men. The timbers often broke.

For the burning, a hollow was made under the stone, like a glass-house furnace or baker's oven and straw and faggots were used in the fire. Archaeological evidence, from 1999 and 2000 excavations at Avebury, at sites of missing stones on the line of the Beckhampton Avenue, showed layers of burnt and flaked sarsen material within a matrix of burnt straw and charcoal.

The experiment was to determine the practicality of firesetting so described, and to answer questions about the temperatures raised, the length of time required and the condition of the stone produced. Finally the site was to be left and after a suitable interval, re-excavated for comparative purposes. An outline of the procedures was provided, which was much as the actual procedures carried out and described below. A further, but unstated, objective, was to have a dramatic film of events.

THE BARBAROUS EXPERIMENT

The chosen stone for breaking had, long previously, been dragged out of any natural or re-use position and was lying, partially buried, at North Farm, Overton, about three miles from the famous Avebury site. Stones of similar and larger sizes lie naturally nearby and this stone was originally, probably, derived from very close to the present site. It was about 2.4 m long, in the shape of a triangular prism or "boat-shaped with a deep rounded keel", lying approximately east-west. The rounded surface was probably originally uppermost but as found was buried, "lying on its side". The two long "sides" were each generally about 80-90 cm wide and very slightly curved. The third side was a nearly flat surface, facing north, which had, probably, originally been the lower-side, bedding plane, surface. This was again about 80-90 cm wide, reducing near (but not at) the western end to some 50 cm. The total weight was estimated to be somewhat under two tonnes. The lesser width, about 70 cm in from the western end was due to erosion of a deep groove, possibly a joint. It was decided to use this possible weakness to focus our firing efforts.

Sarsens are remnant stones of a former Eocene (early Tertiary) deposit, which originally lay (hereabouts) unconformably on top of an eroded Cretaceous chalk surface. The example here appeared to be a fine to medium grained, compact felspathic sandstone, probably cemented with silica. There was little evidence of iron content, either in the freshly broken stone, which had a "pepper and salt" appearance, or, as found later, in the "burnt stone". The stone has a reputation for toughness, and though edges can be broken-off reasonably easily using a lump hammer and chisel, large lumps are very resistant even to our 10 lb.sledge-hammer. Its toughness and, perhaps hardness, appears harder than the better quality, fine-grained, felspathic, Millstone Grit sandstones found in the Pennines.

To carry out the firing most effectively it was desirable to both raise the western end of the stone and to rotate the uppermost side towards the south (slightly uphill). This would bring the narrowest and flattest (originally bottom) surface of the stone to a horizontal top position, convenient for eventual striking with a hammer, with the erosion groove in a vertical position to help heat from flames to penetrate deeper into the rock. It would maximize the surface area available to the fire, make it easy to dig a trench for a flue under the stone, and satisfy the demonstration requirement that, as in earlier centuries, the stone be lifted using wooden levers.

WEATHER CONDITIONS

These were ideal. There had been no rain for a fortnight, it was cold but sunny, with a fairly stiff north-east wind blowing uphill and away from nearby farm buildings. The soil was thus fairly dry and raising the stone and digging the flue was done before lunch, firing during the afternoon, a schedule largely chosen to suit the camera crew who had other activities to film too.

RAISING AND FIRING THE STONE

For this four wooden poles, three metres long and about 100 mm diameter, barked and turned to expose the grain and any weaknesses, were purchased from a local sawmill and agricultural engineers, together with other shorter poles to act as fulcrums. Small holes were dug under the stone in two places, large enough to insert two poles in each. The fulcrums were placed as close as possible to the stone, each in a parallel shallow and narrow trench, about 40 cm from the pole working-end. One person could just make the end of the stone shift slightly, but our team of four required just a little outside help to free the bottom of the stone from the adhesive properties of the underlying loam, though subsequently four people could just manage the (rotative) lift. Raising was done in three stages: first an experimental lift to free the stone from the soil and to reassure the team the poles would both hold and be effective. After some repositioning of the levers the stone was then lifted a few inches and flat stones were inserted under the eastern end and central portion. Further pole repositioning gave complete confidence and a final lift was held with comparative ease whilst larger flat and wedge-shaped stones were emplaced to ensure the raised and rotated position was maintained. This left the lowest part of the western end of the stone just above the soil, which was useful in forming the flue under.

The fire-hole and flue was formed by digging a trench under the stone. The fire-hole was about 80 cm wide and 30-40 cm deep and angled so as to catch the wind. Under the stone the flue passed under the narrow section and was about 30 cm deep and 40 cm wide, emerging at a vertical hole of similar dimensions on the south side. To further channel the wind, a bank of stone, logs and soil was built about 70 cm high on the western side of the firehole and the south side hole was built-up to form a shaft or chimney in a similar way. All this was done very quickly and without problems.

Three types of fuel were used. Historically and archaeologically straw has been reported, and this was used to start the fire. On this were laid thin laths of pine offcuts (old pallets), the straw and wood filling the firehole and the flue under the stone. Subsequent fuel was elm sticks and logs derived from a dead elm cut down a year ago, and very dry.

The straw was very easy to ignite and its heat set the wood ablaze very rapidly. It quickly transpired that the firehole was not sufficiently large to continue burning straw: it and its loose ash blocked the flue thus preventing flames passing under and up the south or shaft side of the stone. Using wood, however, allowed a good under-draw to take place, with strong flames entering the chimney. It soon became clear that the chimney or shaft effect, in the strong wind, was insufficient to cause the flames to impinge sufficiently on the south side of the stone. Substantial long logs were then inserted vertically in the southside of the shaft or chimney to form a muffle, which, assisted by their own burning and probably by reverberation of the heat, had very much the desired effect.

Hooson's comment (1747) of firesetting as "the easiest work in mining, any young chap can do it" effectively describes our experience for the remainder of the afternoon. Less than an hour saw our fire burning very adequately, needing only a few sticks adding (and plenty of poking) every few minutes to maintain the heat. Within two hours thin layers of rock began to spall and at about two hours the first of several substantial lumps broke away from above the flue. They were very fragile, crumbling and breaking as they were removed by a spade. This operation caused the fire to slow and it was built up again using sticks and sawn logs. Once these were burning well, at about two and a half hours, the rock began to develop cracks, which widened slightly, spit the rock through and propagated, so that within minutes, the fired end of the rock had cracked into small blocky pieces. The west end being rather less affected, stayed whole. The process was spectacular, but usefully, there was no explosive spalling and consequent missiles.

The shaft and wind-bank were then pulled to pieces and allowed to damp the fire. Hooking a pick into the main crack allowed the end block (about 120 kg) to be pulled clear, and a gentle blow with the 10 lb sledge hammer caused the whole fired section to disintegrate. Gentle pouring of water (as used in earlier centuries but on this occasion more for the spectacle rather than necessity) on the adjacent side of the remaining rock caused existing cracks to open wide and to propagate vigorously.

Measurement of temperatures was done using a digital optical thermometer, with a laser spot. A probe attachment was not suitable to the task, and the intended probe hole was anyway partially destroyed by spalling. The temperature read-out fluctuated fairly wildly, and the following temperatures are no more than generalizations. On the windward side fire temperatures after an hour were between about 750° and 800° Celsius. In the shaft on the south side, with the muffle effect of the vertical logs, 850° and possibly 900° were later recorded. Rock temperatures reached about 750° and 800° respectively. The rock surface on the flat top, away from the sides and flames, reached about 150° (remaining surprisingly cool to the hands - due to the low conductivity of rock?).

OUR EXPECTATIONS

The main reactions which take place when rocks are fireset have been previously described by the writer (Willies 1994), and for surface quarrying of granite, Craddock (1996). Quartz is the most vulnerable mineral to fire, with felspar also easily, but less effectively, affected. The principle effects in a fire such as that described above take place at temperatures up to say 900°. Weakening of the rock strength is detectable above 100°, probably from interstitial moisture changing to steam and physically and chemically breaking down bonds. At higher temperatures, depending on the original formation temperatures of the minerals, expansion of fluid in inclusions begins to cause crystals to decrepitate (firesetting has been described as "anthropomorphic decrepitation). At about the same temperatures (say 300-400°) the quartz crystals will have expanded in volume by about 1%. The effect of this is further increased by expansion on the vertical crystallographic axis being some three times as high as on the horizontal axes. At about 573°, many varieties of quartz will undergo an atomic re-arrangement, with a volume expansion (from an original 20° state), of some 3%. Since the expansion of other minerals (e.g. felspar) is different, the overall effect on a felspathic rock is extremely disruptive. The effects have, fairly frequently, been described by contemporaries observing the use of fire in mines, and what was seen by us was reasonably as described by contemporaries around Avebury.

RESULTS

The stone used was at the smaller end of what may have, in the past, needed fire to break up. There is little doubt that use of rock chisels and hammers, or some technique such as plug and feather (wedge and chip; wedge and tare) could have adequately broken up the present specimen, and with far less wastage were the stone needed for building purposes. However, none of those who saw this demonstration would have any doubt that a suitably laid fire would cope easily with a much greater rock – certainly with any of those in the Avebury monument, should their destruction ever be so desired again.

The amount of fuel used was not monitored. Probably it was well under 200 kg, and this liberated perhaps 400 kg of rock with minimal effort. Considerably more fuel was used than was probably required (even allowing for large partially-burnt logs out of the total) and refinement of the flue and, perhaps earlier use of the hammer could both reduce the fuel needed and the amount of rock spoiled for masonry purposes. Our use of straw was limited, but it burnt very hotly, and with a larger flue, may well have been adequate by itself. It would certainly be useful for preheating with perhaps an addition of wood to raise the final temperature. It is possible that burning straw only would cause less loss of useful stone if carefully used, leaving more emphasis on hammering.

So far as raising the stone goes, this is, and was, a case of simple mechanics and appropriate tools and a disciplined and heavy enough team.

The most notable effect was that the rock split with a crack extending from bottom, where it was intensely heated, to the top, where it was not. This can possibly be attributed to the wedge-effect of expansion at the bottom and on a substantially larger rock it is possible that such a slit would extend through virtually unheated rock, resulting in much less loss of material to overheating than we experienced. This is perhaps an effect which takes place in the extraction of thin, layered, granite blocks in India, noted by Craddock (1996 p8-9) whereby a crack, generated by a heated chisel, is "chased" in the required direction by a small fire placed on the rock-surface. In a mine the effect would presumably similarly affect jointed rock some distance ahead of direct heating effects. As an effect, this does not seem previously have been specifically noted in the literature.

The rock from the heated zone was easily broken and very friable. It was almost white (the original "pepper" colouration almost gone), but with slight reddening in thin bands, perhaps representing iron oxide accumulation. The earliest spalled material was in thin curved sheets typically 15-20 cm across. Later spalled lumps were rounded. The material released by the final splitting (and light hammering to separate), was somewhat angular. On the major split, a 10 cm long clast of included flint had split across the length in the exact plane of the main split through the sandstone. This may have been the result of similar chemical compositions of the sandy matrix, silica cement and the flint.

The firesetting remains at the site were left *in situ*, with the aim of their subsequent excavation. It is hoped to demonstrate remains found in hollows on suspected standing-stone sites is consistent with firesetting as at the present site.

HEALTH AND SAFETY

There was a consciousness throughout of the possible risks, from both lifting and supporting the stone and the subsequent firing. Apart from the obvious risks, there was a high chance of fragments of hot rock being thrown in the air from spalling. Timber for lifting was carefully selected and placed, with the team (with other helpers to hand) under a single controller. Other tools such as hammers were checked for their safe condition and casual use avoided. Large amounts of water were kept close by (for quenching of both fire and personnel burns), clothes were of cotton or wool (avoiding inflammable and melt-able synthetics), with cotton towelling neck-chiefs, gloves, safety boots, helmets and full face-masks. The location was not accessible to persons other than those authorized.

CONCLUSIONS

The experiment effectively demonstrated the utility of the method for a wide audience, and has suggested a wedging-effect may be a very important factor in the overall effectiveness of firesetting. This does not appear to have been previously reported and underlines the value of carrying out experiments, even where, as here, the full range of scientific observations possible were not undertaken.

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