VI.

STONE CIRCLES: A NEW THEORY OF THE ERECTION OF THE MONOLITHS. By H. E. KILBRIDE-JONES, F.S.A.Scot.

It is now apparent that our prehistoric ancestors could very well think for themselves, and were not merely a race of barbarians living under clouded skies. On the other hand, our ancestors were just as active in mind as ourselves. It is true that they lived in small round huts when they might have built themselves palaces of stone or of brick; but that is no indication of mental inferiority. A people can be easily ridiculed when no tangible evidence remains regarding their powers of penetration and thought, their æsthetics, mental development, and religious ideals. Very often culture centres round religion; and religious ideals usually demand a certain initiative that might otherwise remain latent in the population. It often implies invention.

Any primitive race of people can easily erect a circle of rough boulders—very little talent is required for that: but when we observe that the monoliths have been split off from the living rock by the hand of man, and thereafter shaped, however roughly, to a definite and predetermined form, that implies invention. It implies, too, that these people who were responsible for shaping the monoliths were moving along a definite line of development to an ideal, now termed civilisation; because it is only when ingenuity, both individual and collective, is encouraged to serve humanity that the modern state develops. It spells organised society, and public recognition of genius in the individual.[1]

The theory about to be propounded is well known amongst modern engineers; but it was unknown before that the same theory also formed part of the equipment of the engineers who erected the Stone Circles in Scotland, and of those who erected Stonehenge in England. The modern engineer is careful to adopt the easiest method of raising a mass or a structure into position, as there is such a thing as overhead charges to be taken into consideration: the Bronze Age engineer was equally careful, although not, possibly, from a similar consideration.

[1] Whether stone circles were merely sepulchral, a permanent memorial to a famous man, or places of worship matters very little for present considerations. It is unity of purpose which led to their gradual development. However, it is questionable whether the big stone technique be a mere accidental convenience or not (*cf.* T. D. Kendrick, *The Axe Age*, chap. iv.). On the other hand, it seems to be the result, not of a spontaneity of conception, but of a deliberate and preconceived ideal, following a definite line of development.

Confronted by an enormous mass of stone, it was his place to contrive to discover the easiest methods whereby it might be raised into position; thereupon he either invented or developed the theory that is so well known to-day. I was fortunate in being present throughout the excavations undertaken by Professor V. Gordon Childe at the Stone Circle at Old Keig; and it was while I was watching the monolith Pm (fig. 1) being cleared of the earth that covered it, that its hitherto indeterminate shape suddenly conveyed a meaning the moment the base was fully exposed. The remaining monoliths displayed exactly the same characteristics.

Fig. 1. Old Keig Stone Circle: Stone Pm.
(Arrows indicate dressing.)

Most authors have been attracted to the problem of the erection of monoliths. Fergusson,[1] drawing a complete blank amidst a medley of useless data, dismisses the problem as "child's play." That, of course, is the most convenient method of attempting to solve any problem that is likely to prove too baffling. Peet dismisses the subject in one short sentence, without, however, even hinting at a method.[2] Later writers have been more thorough, and have attempted to explain away the problem in the crudest manner,[3] due to a belief in a supposed absence of intelligence on the part of prehistoric man, who has been credited with employing the most difficult and cumbersome methods to achieve his ends. In all cases these conclusions are the result of inattention to the form of the monolith, a matter which should be carefully studied prior to the form of the crater in which it has been placed.

[1] J. Fergusson, *Rude Stone Monuments*, p. 95.
[2] T. E. Peet, *Rough Stone Monuments and their Builders*, p. 9.
[3] Their theories will be referred to later, under the subheading "Stonehenge."

In regard to the monolith itself, the ideal form and mode of erection were probably due to insular ingenuity, and owed nothing to foreign influence.[1] Moreover, it shows that the Bronze Age peoples of these islands were as well acquainted with scientific engineering principles as were the Ancient Egyptians.

Observations and Measurements on the Monoliths at Old Keig.

Stone Pe,[2] *East Flanking Stone.*—This monolith is the tallest of the three examples chosen for the present paper; and it is the only stone remaining undisturbed in its original position (figs. No. 2 and No. 4, 1). It is an imposing monolith, standing 5 feet 11 inches above the turf level, and in extreme length from base to apex 9 feet. The maximum breadth is 4 feet 9 inches, and the thicknesses are as follows (reading from the base to the apex):—

	On curve (E. side).	On straight (W. side).
At 1 foot	12½ inches	13 inches
2 feet	12½ ,,	12½ ,,
3 ,,	13 ,,	19 ,,
4 ,,	11¾ ,,	20½ ,,
5 ,,	11¼ ,,	20½ ,,
6 ,,	12¼ ,,	21 ,,
7 ,,	13¼ ,,	23 ,,
8 ,,	14 ,,	20½ ,,
9 ,,	15 ,,	20 ,,

The greatest mass is, therefore, concentrated immediately above the pointed base. The stone has been quarried, and is comparatively smooth on both faces. Its evenness is at once apparent from the above figures. The form of the stone is not accidental: it has been carefully split to the required shape. The straight (west) side of the monolith would appear to have been trimmed by being roughly hammered, perhaps with a stone maul.[3] The curved side has been treated in the same manner. As far as it was possible to ascertain, the comparatively straight base seems to be the result of a single fracture.

[1] There seems to be little justification for assuming that the great stone monuments of the West were the result of a developed "Colonial" style (see Peake and Fleure, *The Way of the Sea*, p. 39); still less that the idea of the circle of stones was derived from chambered round barrows in Scandinavia (*ibid.*, p. 118). Since stone circles are more numerous in these islands than elsewhere in Europe (V. Gordon Childe, *The Dawn of European Civilisation*, p. 297), and since they are younger than most other megalithic monuments, it is probable that the Scottish, and perhaps the English, circles were an insular development. This theory has been dealt with by J. Graham Callander, *Archæologia*, vol. lxxvii. pp. 96–7.

[2] The notations used here correspond with those on the plan (to be published subsequently) prepared by Professor Childe.

[3] Stone mauls were used extensively to trim the trilithons at Stonehenge. Here the surfaces were dressed with rounded hammer stones of sarsen (see Frank Stevens, *Stonehenge To-day and Yesterday*, pp. 38 and 39).

The monolith has been maintained in its present position by three small blocks; and other stones were carefully rammed in around all sides of the base. The form and size of the cutting made into the virgin soil to receive the stone is worthy of note (see fig. 4, 1). Also, the three packing blocks just referred to are resting immediately upon the virgin soil, thus guarding against any risk of subsidence.

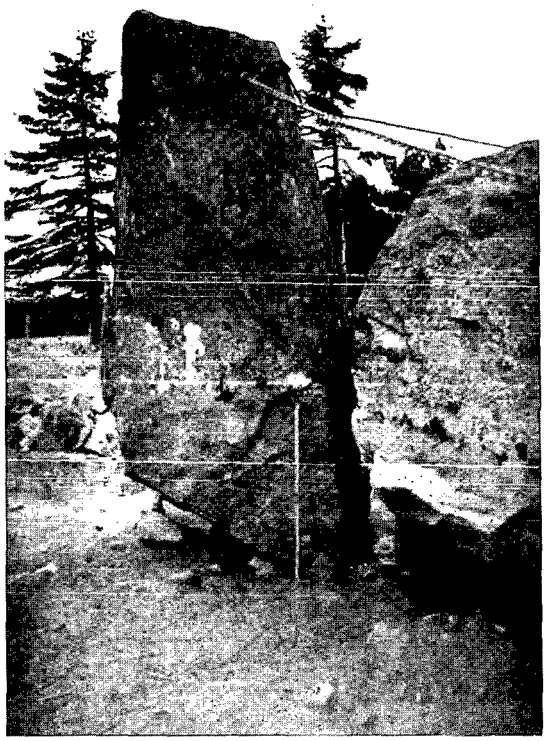

Fig. 2. Old Keig Stone Circle: East Flanking Stone Pe.

Stone Pm.—Although not so large as the above monolith, this stone is the finest example of the three (figs. No. 1 and No. 4, 3). It was found completely buried just without the outer limit of the bank. Its total length is 7 feet 7 inches, and maximum breadth 3 feet 8½ inches. The feature most worthy of note is its extraordinarily well-defined outline and form. More care than is usual has been expended on trimming it. It is of fairly even thickness, with the greater mass concentrated on the base, and on the straight side immediately above the

pointed base, as before. The four sides of the stone are comparatively straight, and its surface even; but the most remarkable feature is the careful tooling along the base (fig. 1), positive proof that the peculiar shape of the base was intentional, the result of a preconceived idea and plan, and not merely accidental.[1] The stone is a very regular trapezium. Its thicknesses are as follows (reading from base to apex):—

	On curve.	On straight.
At 1 foot	9½ inches	7½ inches
2 feet	8¼ ,,	8¼ ,,
3 ,,	9 ,,	9½ ,,
4 ,,	8½ ,,	8½ ,,
5 ,,	6 ,,	8 ,,
6 ,,	5¼ ,,	8½ ,,
7 ,,	6½ ,,	7 ,,

Stone Px.—This stone is, perhaps, the rudest of the three, yet it bears all the characteristics of the other two. It had been used as the

Fig. 3. Old Keig Stone Circle: Stone Px.
(Arrows indicate dressing.)

foundation of a dyke, and is undamaged. It is very irregular in shape, but, as seen from figs. No. 3 and No. 4, 2, it has been very roughly hammered into the standard form, and there is little difficulty in perceiving where the stone has been knocked away by the character of the irregular edges. The total length of the monolith is 8 feet 6 inches,

[1] This tooling seems to have been accomplished with a metal tool. This was probably of bronze, although copper might have been used. The use of copper is not so improbable as a first consideration might seem to suggest, since the Egyptians of the New Kingdom had nothing better, or more durable, than chisels of copper (*cf.* Somers Clarke and R. Engelbach, *Ancient Egyptian Masonry*, fig. 263). When an alloy such as tin is present, copper can be brought to a temper not far short of mild steel (*ibid.*, p. 25). Moreover, chisels were not unknown in Scotland during the Bronze Age, as the examples in the National Museum of Antiquities clearly demonstrate. The stones were probably trimmed at the quarry-face.

and the maximum breadth 3 feet 7 inches. Its thicknesses are as follows (reading from apex to base):—

	On curve.	On straight.
At 1 foot	13 inches	11 inches
2 feet	14 ,,	10 ,,
3 ,,	11½ ,,	9½ ,,
4 ,,	10¾ ,,	11 ,,
5 ,,	9½ ,,	12 ,,
6 ,,	10½ ,,	14¾ ,,
7 ,,	10 ,,	12½ ,,
8 ,,	10½ ,,	12 ,,

We thus observe that, although the monolith has been but roughly trimmed, the greater mass is still concentrated above the pointed base.

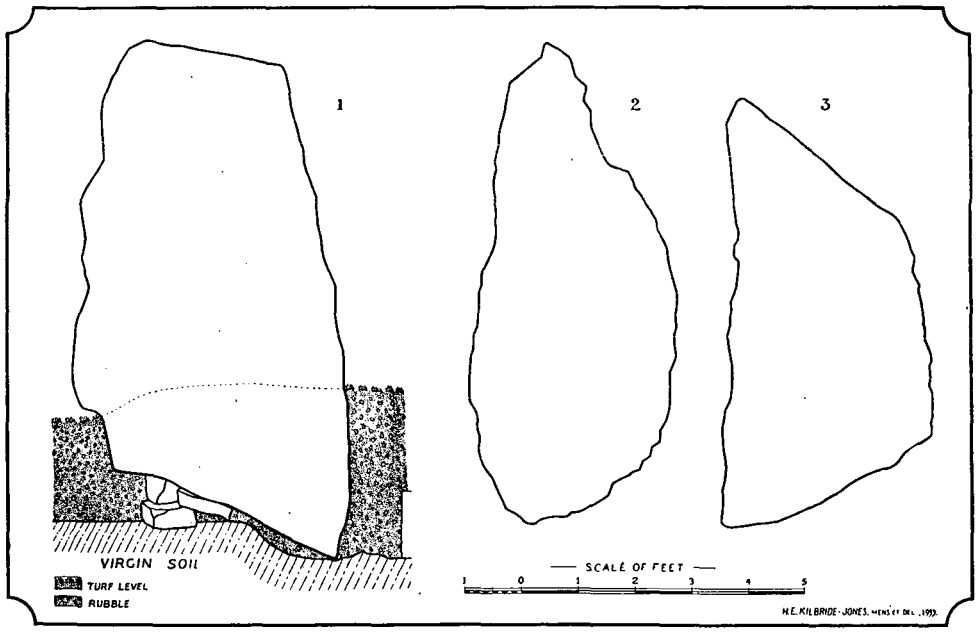

Fig. 4. Outlines of East Flanking Stone Pe and Stones Px and Pm.
(The numerous packing stones round Pe have been omitted.)

The Theory as applied to the Erection of the Monoliths.

The prehistoric stone circles of Great Britain have been described as being formed of simple unhewn blocks of stone.[1] Mindful of the stones at Old Keig, that statement appears to be quite erroneous when

[1] J. Fergusson, *Rude Stone Monuments*, p. 2. Also E. Herbert Stone, *The Stones of Stonehenge*, p. 34. The present paper proves the general idea to be ill-founded.

applied to stone circles collectively. Admittedly, there are circles composed of very rough stones; but many of the circles in Aberdeen, for example, show that a certain amount of care has been devoted to planning and shaping the monoliths, even to the extent of chiselling. The very evenness of some of the stones cannot be natural to them, and certain protuberances must, perforce, have been knocked off to give a rough uniformity of thickness, and this was probably accomplished with a stone maul. However, it must be admitted that careful trimming, such as that displayed on the base of Stone Pm, is the exception rather than the rule; but it does exist, as we have seen. In

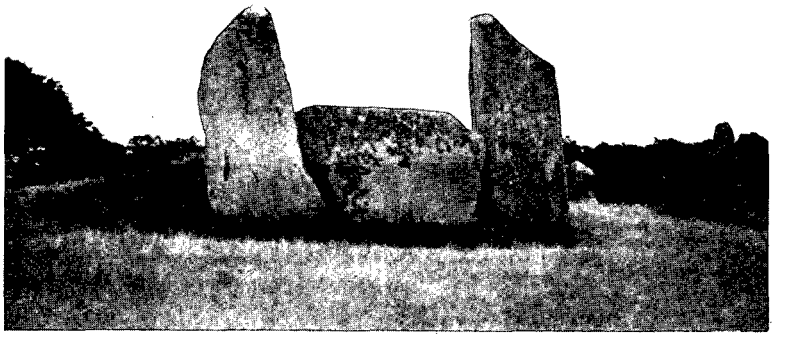

Fig. 5. Castle Fraser Stone Circle: Recumbent Stone, with Flankers.

the majority of circles the stones appear to have been roughly pounded into shape, although an exception here would seem to be the Stone Circle at Castle Fraser (fig. 5). The east flanking stone, in particular, is very even and smooth, and its outlines almost straight; and with the amount of care expended on its appearance it stands in marked contrast to the somewhat irregular monolith forming the west flanking stone.

To the casual observer, perhaps one of the most curious and remarkable features of many stone circles is the pointed appearance of the majority of the monoliths, where large stones have been utilised: and it is further noted that this apex is never immediately above the centre of the stone, but, instead, it is reminiscent of a right-angled triangle whose apex is in line with one of the vertical sides of the stone. This feature is particularly noticeable in the case of Stone Pm at Old Keig, and also in the case of the flanking stones at the circle at Castle Fraser.

Since this feature is noticeable in nearly every stone circle where large stones have been employed, it cannot have been merely accidental, and it must, therefore, possess some significance.[1] Actually, the object in so shaping the stone was a very real one, and is in accordance with certain engineering principles which will be touched upon later. Briefly, the whole scheme was originated to lessen the effort, or thrust, necessary for the erection of the monolith.

The excavations at Old Keig revealed the interesting fact that this pointed apex was vertically above a similar point at the base, although the latter is not so pronounced, generally speaking.[2] It was discovered that, in all cases, the bases had been thus shaped. On a first consideration, this might seem to be an undesirable feature, detracting from the stability of the monolith, especially when stability plays such a large factor in the lasting qualities of the monument. Knowing that stability would not be sacrificed without some other really important object in view, there was nothing left but to conclude that the peculiar shape of the base was intimately connected with the erection of the monolith, as indeed it was. The east flanking Stone Pe provided the solution. When the stone was fully exposed, the methods employed in its erection were at once obvious.

The whole process of erection may be described by taking Stone Pm as the monolith to be raised, each step in the process being considered separately.

The various stages in the erection would be as follows:—

(1) The monolith would be levered up on to its shorter side (fig. 7), termed previously in this paper "the curve."

(2) An excavation would thereupon be made in the ground to receive the pointed base, and of sufficient length and width to receive the stone comfortably.[3] It is interesting to observe the shape of this excavation. From fig. 4, 1, we observe that it must have been triangular in section, since it was only at the end intended to receive the pointed base that any cutting had been made into the virgin soil.

(3) After the completion of the excavation, the stone would be rolled into an upright position, using point C (fig. 7) as the fulcrum. To bring the stone to an upright position, a thrust would be applied as near to the apex as possible, and preferably at right angles to the line CD

[1] The Stone Circles at Callanish and at Stenness possess stones with apices pointed in the manner described.

[2] The same feature was observed at the Stone Circle at Castle Fraser, where two fallen pillar stones display the same pointed apex and base, after the manner of those at Old Keig.

[3] It is, of course, a debatable point as to whether the excavation was made at this stage or prior to the arrival of the stone. The former course seems to be the more probable, as this would obviate any damage to the sides of the excavation due to the monolith getting out of control, or due to people trampling around whilst moving it into position.

to be most effective. This thrust is represented by the force P in fig. 7.

This last step is the most important in the whole procedure. At the moment of applying the thrust we see, from Mr Regnauld's figures, that the force P required to raise the monolith is 1·575 tons (assuming the monolith to be of even thickness, and that its weight is 5 tons). As the stone rises into position, the thrust necessary decreases very rapidly, until, after an angle of 48° has been turned, the thrust becomes zero and the stone balances. This condition is due to the centre of gravity E having turned through an angle of 48°, until it is vertically above the fulcrum C. Thereafter, during the time the stone is turned through the remaining 42°, a restraining force will be required to prevent the stone from pitching forward. This restraining force would take the form of a rope, or ropes, fastened round the apex.

(4) Having raised the stone to an upright position, it now became necessary to wedge it firmly to make it secure for all time. First, the monolith was levered up slightly, and an excavation made in the humus to receive a number of wedges. In the case of the east flanking pillar Pe, the wedges were three in number, and they rested upon the virgin soil, to assure a sound foundation for them. The stone was then allowed to fall gently back upon the wedges, and, if correctly placed, the monolith should balance perfectly. Small stones and earth would then be rammed in between the monolith and the sides of the excavation, and the stone would thereafter be definitely secure.

During the process of raising the monolith, some means would be required to prevent it from pitching sideways. This may have been accomplished by driving a number of saplings vertically into the ground alongside the excavation: thus a temporary wooden buttress would be formed, which would keep the monolith from falling over whilst it was being made stable.[1]

Had the monolith been a symmetrical one, and presuming it to have been raised from a horizontal position, instead of having been placed on its side as our present theory demands, the conditions and the thrust required to raise it would have been very different. The centre of gravity would have been midway between the base and the top, and, at the moment of raising, a thrust equal to $2\frac{1}{2}$ tons would have been required. Moreover, it would have been necessary to apply a slowly decreasing thrust almost throughout an angle of 90°, instead of a rapidly

[1] This theory is fully considered later in the present paper under the subheading "Stonehenge." There was, however, no evidence to support this assumption at Old Keig; but the saplings may never have been driven into the virgin soil, and thus no evidence of a post-hole would remain.

decreasing thrust through an angle of 48°, which is all our new theory demands. Again, we see that, not only is there a saving of nearly 1 ton in the value of the thrust, utilising our method of erecting the stone, but the amount of work done is all but halved. The incongruity of asserting that the monoliths in stone circles were erected either from the interior, or exterior, of the circle is at once obvious. In any case, a cursory glance at the two flanking stones at the circle at Castle Fraser clearly demonstrates that they were never thus erected; for we observe that the west pillar is situated slightly behind the recumbent stone, whilst the east pillar is slightly in front of it.

Having ascertained the manner in which the monoliths were really erected, we can now understand the reason for adopting this peculiar standardised form. With a base of the form of the monoliths at Old Keig, the fulcrum C is brought nearer to the centre of gravity E, thus lessening the angle through which the stone would have to turn before the force P became zero. This enables the mass of stone to the left of the perpendicular CH (fig. 7) to give a pull in a downward direction, thus considerably lessening the necessary thrust. Another important factor in lessening the angle through which the stone must turn is the placing of the pointed apex vertically above the point of the base; an arrangement which serves the purpose of bringing the centre of gravity nearer to the vertical, or straight, side of the monolith than would otherwise be the case were the apex placed centrally, or to the opposite side; in other words, the ultimate result of this idea of form is to bring the centre of gravity vertically above the fulcrum C sooner than would otherwise be the case were the stone of any other shape. Then again, the straight side is always the thicker, lending added assistance in raising the monolith by bringing the centre of gravity still nearer to the vertical, or straight, side. This distribution of weight also provides a better balance when the monolith is in position, bringing the greater mass upon the point of the base, and easing the weight upon the wedges. The widening and thickening towards the base helps to preserve a better balance by keeping the centre of gravity as low as possible. The east flanking stone at Old Keig may not entirely agree with the standard form in regard to the apex, but this may have been a natural fracture, and to have fashioned the stone correctly would have materially lessened its height, rendering it unsuitable for such a position of importance.

The Theory as applied to Stonehenge.

Perhaps no stone circle has received more attention than Stonehenge. Much has been written; and while there is slight variation of

opinion, most authors are unanimous in their belief that the trilithons at Stonehenge were erected from a horizontal position.[1] In the case of one trilithon that theory could be true enough; but some of the monoliths have provided an unsolved problem in the past.

William Gowland was the first to consider the problem seriously, and he it was who probably started the theory cited above; for he concluded positively that Stone No. 56 had been raised from the interior of the circle.[2]

To anyone acquainted with the monoliths of the Aberdeen stone

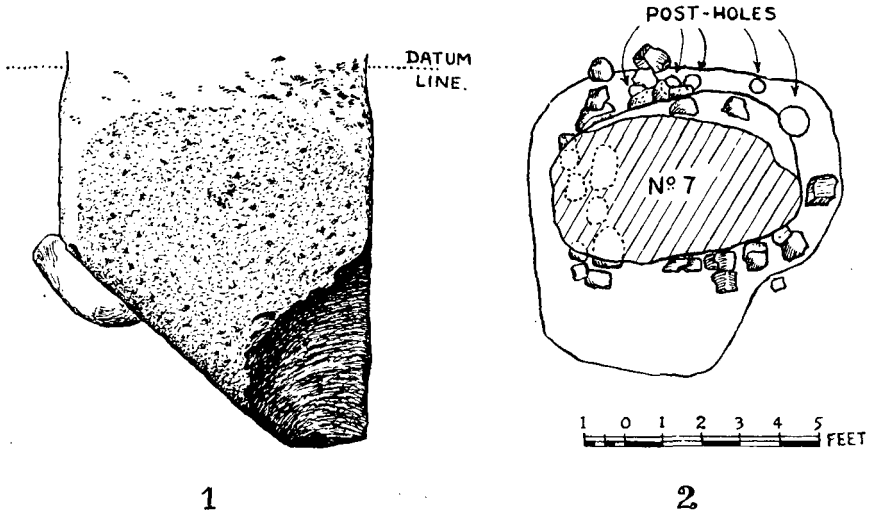

Fig. 6. Stonehenge: Stones Nos. 56 and 7.
(No. 1 after Gowland, *Archæologia*, vol. 58; No. 2 after Hawley, *Antiquaries Journal*, vol. i.)

circles, Stone No. 56 is perhaps the best example that could have been chosen. Professor Gowland is careful to base his assumption on the absence of chalk rock on the N.-E. side, and on the inclined plane existing there. However, when we consider the shape of the base of this trilithon (fig. 6, 1), the solution becomes apparent at once, from our knowledge of the standardised form of the Scottish monoliths: for, not only does the base conform to the standard, but it rests against a wedge in the same manner as the east flanking Stone Pe

[1] The details of this popular theory are given in succinct form in Frank Stevens, *Stonehenge To-day and Yesterday*. A more elaborate account is given in E. Herbert Stone, *The Stones of Stonehenge*, chap. vi. In regard to the latter, and probably both, the whole theory depends upon the monolith having a straight base, as witness Mr Stone's illustrations, yet most of the trilithons at Stonehenge possess pointed bases.

[2] William Gowland, "Recent Excavations at Stonehenge," *Archæologia*, vol. 58, p. 55.

at Old Keig. Undoubtedly, it was erected in the same manner. Professor Gowland is puzzled by the fact that the perpendicular face of the chalk had been cut away at the west corner (that next to the wedge).[1] This cutting probably was never intentional, but was caused either by the fulcrum slipping slightly as the stone was being raised or during the process of inserting the wedge.

Nothing could be more difficult than to raise the trilithon in the manner suggested by Professor Gowland. Had it been given a more or less regular, even base, upon which it could rest during the process of erection, there would be fewer objections to employing this crude and burdensome procedure: but, instead, with its present base, the stone would at once set up a rotary action, causing obvious difficulties and complications; and the energy required to prevent such an occurrence could be more profitably employed in erecting the trilithon. Once more the Bronze Age engineer is imputed to have possessed a complete lack of common sense.

In any case, Professor Gowland's theory is definitely disproved as a result of Lt.-Col. Hawley's excavations round Stone No. 1.[2] Col. Hawley is puzzled by the steepness of the crater, and is at a loss to know how the stone came to be erected. As he states, had the stone been tipped in according to Professor Gowland's assumption, the whole crater might have been ruined. On the other hand, had the stone been erected in the manner of the monoliths at Old Keig, the solution is not only obvious, but all danger of damaging the crater is avoided. In this case the stone tapers on both sides to a blunt point—a feature that was also noted in connection with Stones 29 and 30, and Stones 6 and 7.[3] It is only by tapering both sides to a point that damage is averted. Had the base taken the form of that of Stone 56, the point of the base would have struck the edge of the crater as the stone was brought into position, unless, of course, the crater had been materially lengthened. This idea might be thought to imply a refinement upon the stones at Old Keig; but when the process of erection is again considered, it will be seen at once that a certain amount of efficiency has been sacrificed, and a greater thrust will be required to raise the monolith.

Apart from the stones themselves, Stonehenge adds to our knowledge in another direction. Allusion has already been made[4] to a supposition concerning a wall, or buttress, of saplings, placed along one side to

[1] *Archæologia*, vol. 58, p. 82.

[2] "Second Report on the Excavations at Stonehenge," *Antiquaries Journal*, vol. ii. p. 38.

[3] Lieut.-Col. Hawley, "Stonehenge: Interim Report on the Exploration," *Antiquaries Journal*, vol. i., figs. 3 and 4.

[4] See page 89.

restrain the monolith from toppling over in that particular direction. At Stonehenge a curious phenomenon was noted by Col. Hawley: in the cases of Stones 7, 1, and 30, post-holes were observed, cut in the solid chalk, and flush with the broad face of the monoliths. Let us consider in detail the case of stone No. 7 (see fig. 6, 2). Here, it will be observed, are four post-holes, ostensibly placed in line, with another, much larger than the others, situated a short distance in from the others. Into the first four post-holes were inserted four saplings of goodly height, and these would necessarily be supported from behind by means of struts, or their equivalents. These saplings would thus form a steady barrier sufficient to prevent the monolith from toppling over. The remaining post-hole must have taken the trunk of a small tree by its diameter, and seems to have served the purpose of a check.

A glance at fig. 6, 2 shows that all the packing blocks resting underneath the monolith are to be found on the north side, indicating that the stone was erected from that side. This agrees exactly with the position of the post-holes. After the stone had been raised in the manner of our theory, the restraining ropes would be placed around the apex just as the centre of gravity was approaching the vertical: thereafter, when the centre of gravity had passed the vertical, a restraining force would be applied to the ropes in a direction slightly towards the barrier of saplings, thus causing the stone to brush against them. If the restraining force was in line with the axis of the stone, there would be a tendency for the monolith to topple over in both directions, with obvious danger to human life. The buttress of saplings would be useful for adjusting the stone to the correct position; for, while the stone itself has support to keep it upright, it could without difficulty be moved either to the left or right until it was at the correct distance from its neigbour to receive the lintel: that position attained, chalk, rubble, and stones would be rammed into the interspaces to firmly anchor the trilithon for all time. When this last operation was complete, it would be necessary to cut the saplings off at ground level, in order not to disturb the newly-rammed rubble. This would explain the finding of decayed wood in the post-holes around Stones 1 and 30. The reason for firing the wood in the post-holes by Stone No. 7 is not obvious.

We thus observe that our theory, as upheld by the monoliths of the stone circles of the north-east of Scotland, when applied to the problem of Stonehenge, reveals much that is interesting. The builders seemed, however, somewhat unfamiliar with the new form, a condition that can be understood when it is remembered that Stonehenge antedates

the stone circles of the north-east of Scotland by several centuries,[1] during which period the new form had time to become standardised. An absence of standardisation is seen in the variety of bases. Stone No. 56 is, perhaps, the sole attempt at the ideal, the remainder appear to be experimental. Apart from mere form, however, it is interesting to observe the efforts of a people to attain an ideal; and it needs but an ideal to encourage invention.

In conclusion, the author desires to express his thanks to Professor V. Gordon Childe for permission to make use of the data concerning the measurements of the monoliths at Old Keig, and of the photographs, figs. 1, 2, and 3; and to the Society of Antiquaries of London for permission to reproduce the drawings of fig. 6.

THE THEORY EXPRESSED IN MATHEMATICAL TERMS.

By A. REGNAULD, B.Sc.(Eng., Lond.), A.R.C.Sc., M.I.E.E.[2]

The stone is assumed to be of even thickness, and to weigh 5 tons. Considering the ground to be horizontal, and CH to be vertical, it will be found that the point D is 2′ 8″ above the ground, *i.e.* DG = 2′ 8″. The

[1] Apart from entering into any controversy in regard to the dating of the recumbent stone type of stone circle, which has of late been regarded as belonging to Iron Age A times (V. Gordon Childe, "Trial Excavations at the Old Keig Stone Circle," *Proc. Soc. Ant. Scot.*, vol. lxvii. pp. 37–53), attention may be drawn to the fact that, at the period of the erection of the circles in the north-east of Scotland, cremation was the general practice, most yielding burnt bones, and many urns of the cinerary type. Of stone circles with a recumbent stone, the following have yielded fragments of urns: Seanhinny (F. R. Coles, "Report on Stone Circles in Kincardine and Part of Aberdeen," *Proc. Soc. Ant. Scot.*, vol. xxxiv. pp. 139–98, No. 18), Castle Fraser, Hatton of Ardoyne (F. R. Coles, "Report on the Stone Circles of the North-East of Scotland, Inverurie District," *Proc. Soc. Ant. Scot.*, vol. xxxv. pp. 187–248, Nos. 4 and 21), and Candle Hill, Old Rayne (F. R. Coles, "Report on Stone Circles in Aberdeen, Inverurie, Eastern Parishes, and Insch Districts," *ibid.*, vol. xxxvi. pp. 448–581, No. 33). The circle at Burreldales, Rappla Wood, yielded a cinerary urn, possibly cordoned (F. R. Coles, "Report on the Stone Circles of the North-East of Scotland, Chiefly in Auchterless and Forgue," *Proc. Soc. Ant. Scot.*, vol. xxxvii. pp. 82–142). More definite evidence is forthcoming from the following circles: Tuack, Kintore, yielded three urns, one being of the overhanging rim type, and another cordoned (see Anderson, *Scotland in Pagan Times, the Bronze and Stone Ages*, p. 101); Crichie circle yielded two cinerary urns of late type (*ibid.*, p. 106). An encrusted urn was found within a circle at Glenballoch, near Blairgowrie (*Proc. Soc. Ant. Scot.*, vol. xiv. p. 90); while a circle at Tynrich, Ballinluig, yielded four large cinerary urns, "each of which was about 2 feet high" (Anderson, *loc. cit.*, p. 113). Fragments of cinerary urns were found in a circle at Kingcausie (*ibid.*, p. 113). A large urn full of burnt bones was found on the farm of Newton of Montblairy, during the process of demolishing a stone circle (*ibid.*, p. 115). Dr Cyril Fox believes this urn to be an intermediate form between the enlarged food-vessel and the encrusted urn (C. Fox, "An Encrusted Urn of the Bronze Age from Wales; with Notes on the Origin and Distribution of the Type," *Antiquaries Journal*, vol. vii. p. 115). Finally, an excavation at the stone circle at Balbirnie House, near Markinch, Fife, produced a number of broken urns of the cinerary type (Anderson, *loc. cit.*, p. 116). We thus see that the period to which the stone circles in the east of Scotland belong is the late Bronze Age. On the other hand, Stonehenge dates from the early Bronze Age (R. S. Newall, "Stonehenge," *Antiquity*, vol. iii. pp. 75–88).

[2] By courtesy of Alexander Russell, Esq., M.A., D.Sc., LL.D., F.R.S., M.I.E.E., Principal of Faraday House Electrical Engineering College, London.

magnitude of the thrust at D depends upon whether it is exerted in a direction perpendicular to CD, and it is questionable if human effort could be so exerted at a height of only 2′ 8″ from the ground.

Assuming, however, that the force P acts perpendicular to CD, taking moments about the point of contact with the ground, we get

$$P \times CD = W \times CF \quad \text{or} \quad P = \frac{W \times CF}{CD}.$$

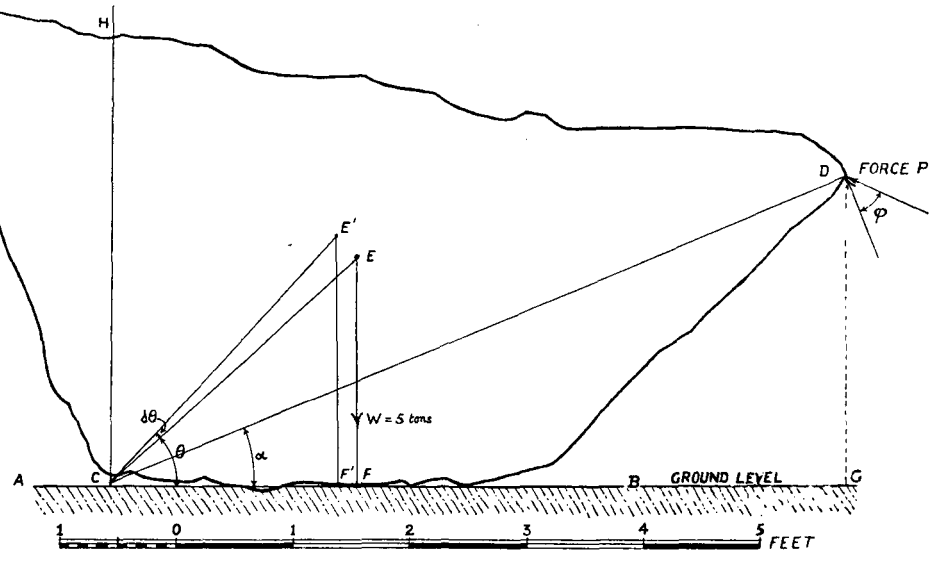

Fig. 7. Old Keig Stone Circle: Stone Pm.

From the diagram (fig. 7) CF = 2′ 1½″, and CD = 6′ 9″, so that putting W = 5 tons, we have

$$P = \frac{5 \times 2\frac{1}{8}}{6\frac{3}{4}} = 1{\cdot}575 \text{ tons.}$$

Thus, the thrust required to raise the stone about the point C is 1·575 tons. (N.B.—If P is not perpendicular to CD but at an angle ϕ to the perpendicular, the thrust will be increased to $\frac{P}{\cos \phi}$.)

As the stone pivots about C the angle θ increases, as also does the angle α, but still assuming that the thrust is exerted in a direction perpendicular to CD we get

$$P' \times CD = W \times CF' \quad \text{or} \quad P' = \frac{W \times CF'}{CD},$$

and since W and CD are constant, we have $P \propto CF$.

But $\frac{CF'}{CE'} = \cos(\theta + \delta\theta)$, so that $CF' \propto \cos(\theta + \delta\theta)$ or $P \propto \cos(\theta + \delta\theta)$, and when $(\theta + \delta\theta) = 90°$, $P = 0$.

From the diagram

$$\theta = \cos^{-1} \frac{2' \, 1\frac{1}{2}''}{2' \, 10\frac{1}{2}''} = \cdot 74, \quad \text{or} \quad \theta = 42°.$$

Thus, taking

$$P = \frac{W \times CE \cos(\theta + \delta\theta)}{CD} = \frac{5 \times 2' \, 10\frac{1}{2}''}{6' \, 9''} \cos(\theta + \delta\theta),$$

i.e. $P = 2 \cdot 13 \cos(\theta + \delta\theta)$, we get the values given in the following table:—

when $\theta = 42°$, $P = 2 \cdot 13 \cos 42° = 2 \cdot 13 \times \cdot 74 = 1 \cdot 575$ tons.
$\theta + \delta\theta = 50°$, $P = 2 \cdot 13 \cos 50° = 2 \cdot 13 \times \cdot 64 = 1 \cdot 36$ tons.
$\theta + \delta\theta = 60°$, $P = 2 \cdot 13 \cos 60° = 2 \cdot 13 \times \cdot 50 = 1 \cdot 06$ tons.
$\theta + \delta\theta = 70°$, $P = 2 \cdot 13 \cos 70° = 2 \cdot 13 \times \cdot 34 = 0 \cdot 725$ ton.
$\theta + \delta\theta = 80°$, $P = 2 \cdot 13 \cos 80° = 2 \cdot 13 \times \cdot 17 = 0 \cdot 362$ ton.
$\theta + \delta\theta = 90°$, $P = 2 \cdot 13 \cos 90° = 2 \cdot 13 \times 0 = 0$

It may also be noted that $\alpha = \sin^{-1} \frac{2' \, 7\frac{1}{2}''}{6' \, 9''} = \cdot 389$ or $\alpha = 23°$, and when CE is vertical, *i.e.* $\theta + \delta\theta = 90°$, $\delta\theta = 90° - 42° = 48°$, so that $\alpha + \delta\alpha = 23° + 48° = 71°$. The height of the point D above the ground will therefore be $6' \, 9'' \sin 71° = 6 \cdot 75 \times \cdot 945 = 6 \cdot 375'$, or $6' \, 4\frac{1}{2}''$. Thus, the question again arises as to whether the thrust exerted by human effort would be applied in a direction perpendicular to CD at this height above the ground, or even whether it would be applied at D at all, rather than at some point lower down, in which case the value of P given in the above table will again have to be increased. The thrust in any case will, however, be zero when the centre of gravity of the stone reaches the vertical line CH.