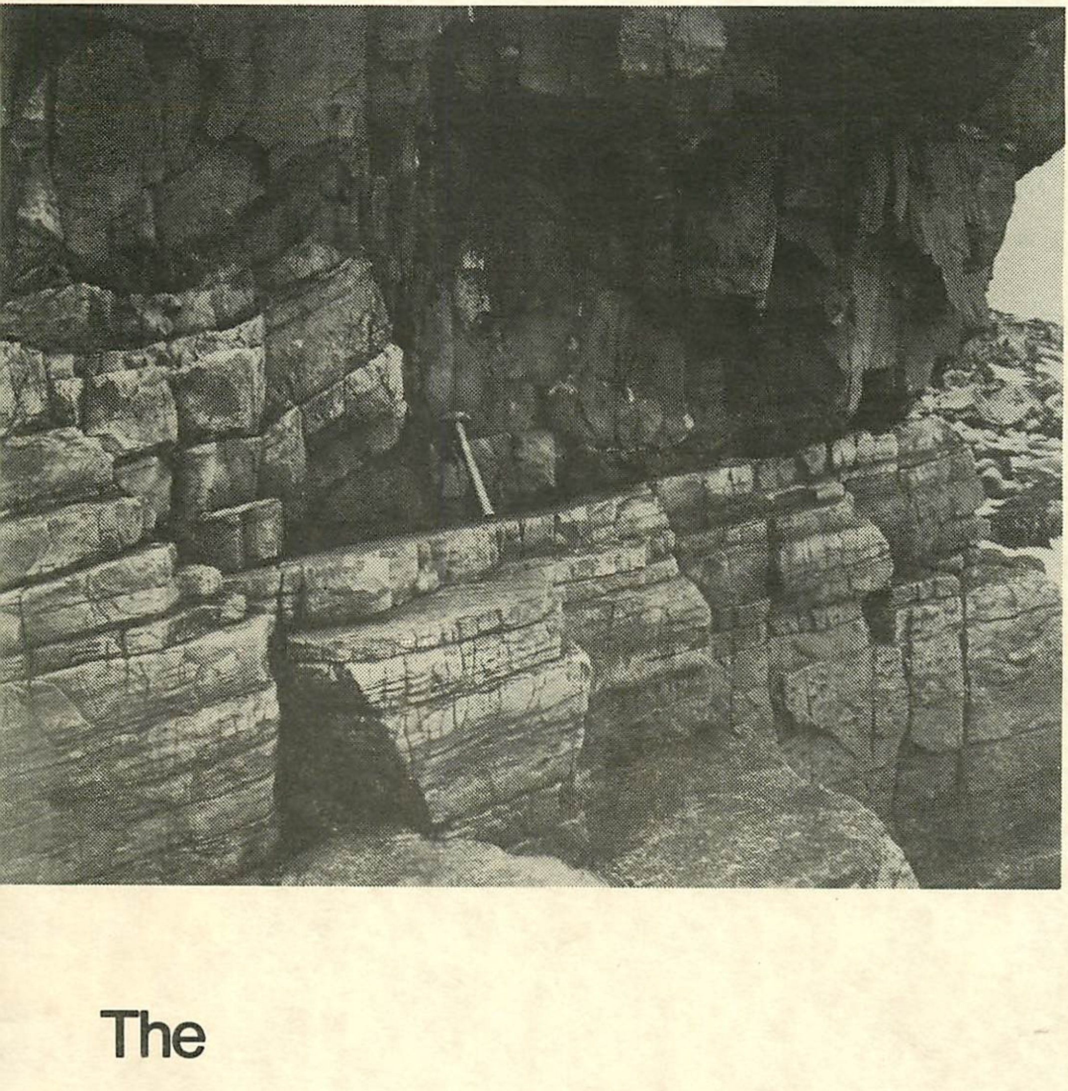

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Cover illustration: A Geological Survey photograph (D1917) of the quartz-dolerite sill at Hound Point, near South Queensferry.

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EDITORIAL

What's in a Name?

On January 1st the Institute of Geological Sciences underwent a name change. Now, this organisation whose aggregate age under various titles is just less than that of this Society, is called the British Geological Survey, the name reflecting perhaps more accurately the nature of its task than did the word 'Institute'. The B.G.S. remains a component of the Natural Environment Research Council, the latter a mere youngster which came of age last year. In the 'good old days' everyone knew what the G.S.G.B. meant but, of course, a reversion to 'Great' would hardly be tolerated today. On the other hand, it is good that the word 'Survey' has been re-introduced. Let us hope that its meaning continues to be put into practice. A month before this momentous event, the staff were introduced to a new form of management know in polite circles as the 'matrix'. Our President, who, many will know ferrets out of books the most amazing pieces of information, discovered that matrix as defined by the *Shorter Oxford English Dictionary* 'is the rock-mass surrounding gems'. We shall see.

Preparations.

Well, the Society's 150th is nearly upon us and your hard working Council has been conjuring up numerous ideas on how best to recognise the date. An exhibition of geological maps is planned for this year's Edinburgh Festival. The City has kindly offered to undertake a Motif on the Mound from 3rd to 10th September. A meeting on geological conservation, arranged by the Scottish Wildlife Trust and the Society, will take place on 6th October. It is also Council's hope that a number of meetings will be arranged jointly with other organisations. In addition various souvenirs will be produced and excursions to historical localities arranged.

Anticipating next Session's events an unusual excursion will take place this June, involving the re-enactment of a visit by train to Burntisland – the first excursion of this kind was not undertaken until 1867, but who minds as long as all goes well and the party is not left behind at Waverley to examine rail ballast.

As far as the magazine is concerned, we would like to think that a bumper issue could be produced in the autumn, but this prospect is dependent upon contributors. We invite contributions which should reach us, not verbally but on paper, by the beginning of October at the latest. We'll take it from there.

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THOLEIITE SILLS OF THE MIDLAND VALLEY AND TASMANIA COMPARED

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The abundant dolerite sills of Carboniferous-Permian age in the Midland Valley fall into two main petrological groups, namely alkaline and tholeiitic. In Fife and West Lothian they occur in close proximity and this may explain why, for many years, the important difference in their magnitude went unnoticed. Whereas the alkali-dolerites tend to be relatively localized, the tholeiites form a single complex, the Midland Valley Sill, extending for 1600 km^2 beneath much the eastern part of the Region (Fig. 1). The greater volume of tholeiitic magma available for intrusion is not peculiar to Scotland and may owe something to its generation from higher levels in the mantle than the alkaline material. Whether for that reason or not, it is evident that all the great dolerite sills of the world – and they occur on every continent – are tholeiites. Thus as a preliminary to making a direct comparison between one of the greatest – that of Tasmania – with its Midland Valley counterpart, it might be useful to examine first what such sills have in common everywhere as well as some recently revised concepts on emplacement mechanism based on the Scottish evidence.

Features in common are firstly a low aspect ratio, that is to say that thickness is always a very small fraction of the lateral extent. Secondly intrusions are invariably emplaced into thick (1.5 to 6.0 km) sequences of sediments which are not much older than the sills, are not much deformed at the time of intrusion, and are underlain by crystalline basement. Thirdly the sills are disposed in saucer-like shapes, or more commonly a complex of saucers linked at their rims. Fourthly they cut across bedding planes discordantly in "step-and-stair" fashion. Fifthly they are associated with dykes which are of similar composition and which in some cases are demonstrably linked to the sills as part of a feeder system.

Over a century ago the American geologist G.K. Gilbert offered a

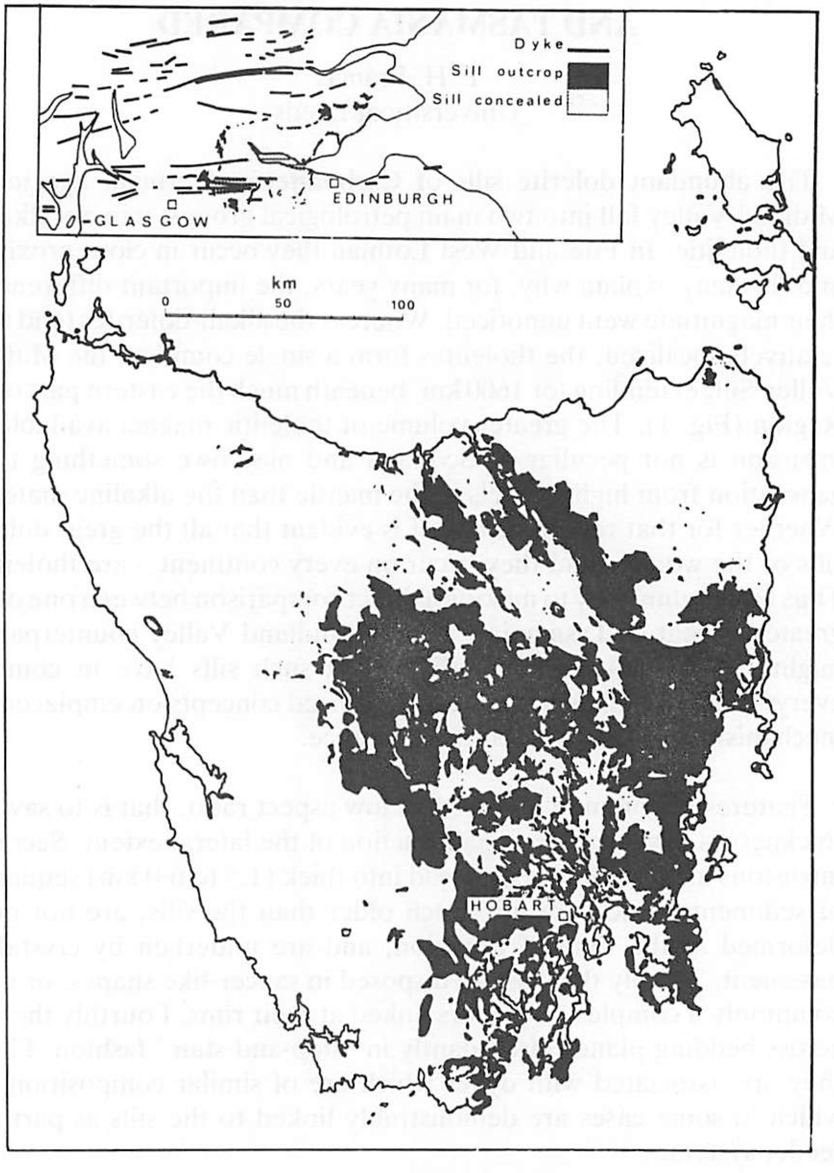


Figure 1 Maps of the Midland Valley and Tasmanian sills drawn at the same scale for comparison of magnitude.

general explanation, still accepted, as to how sills are propagated. Columns of magma ascend through fissures under the lithostatic pressure exerted by the weight of superincumbent rocks. As these rocks are progressively less dense towards the surface, particularly where they are sedimentary, there is assumed to be a level at which they are, effectively, unable to support the weight of the column and the difference in pressure between magma and wall rocks is then such as to lead to lateral intrusion rather than to eruption at the surface. Initiation of sills by this means is easy to visualise. A more difficult and controversial question is to account for the continuation of the process so as to emplace such enormous volumes of tholeiites rapidly enough to forestall crystallisation, bearing in mind the pressure needed for insertion along bedding planes ("roof-lifting") as well as the relative ups and downs implied by saucer shapes and "step and stair".

Understandably, theories to explain this have assumed forcible injection particularly as they have started from the premise that the host sediments were generally horizontal and of even thickness at the time of intrusion. We are nowadays well aware, however, that controls over differential subsidence give rise to lateral variations in thickness, so that layering which is approximately horizontal at the time of deposition at the surface, becomes inclined often at progressively higher angles as it is buried (Fig. 2). The importance of this to sill interpretation is obvious; transgression of bedding, for instance, does not necessarily imply magma movement up or down relative to the horizontal, though this has traditionally been assumed. Proper understanding of the sediment-sill relationship is thus possible only if the attitude of the sediments at the time of intrusion can be reconstructed. It requires three-dimensional data such as is provided by exploratory boreholes and mining records; for its wealth of these the Midland Valley may well be unique.

Analysis of the Scottish data has revealed several unexpected relationships. Firstly, structural contours of the sill correspond closely with sedimentary isopachs, so that when the distribution of dips at the time of intrusion is reconstructed (using for horizontal datum Skipseys Marine Band as a reasonable proximation to the surface at the time of

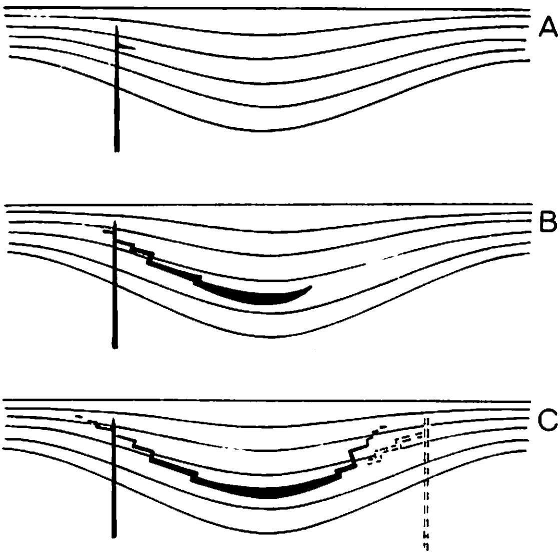


Figure 2 Diagram to illustrate the mechanism of sill intrusion. A, dykes or fault intrusion to 0.5–1.0 km from the surface and above optimum level for lateral flow. B, lateral intrusion under head leading to gravitational flow down dip (accompanied, perhaps, by step-down under load) and accumulation at bottom of syn-sedimentary basin. C, to achieve hydrostatic equilibrium ascent of magma from basinal bottom with step-up via fractures propagated by advancing extension space and with *en echelon* fingering to leading edge. Broken lines indicate variation inherent in multiple dyke sources.

emplacement c. 295 million years ago) it becomes apparent that in the course of intrusion the sill approximately followed the saucer-like attitudes of the bedding in the lower parts of the basin. Even more surprising is an equivalent correspondence between isopachytes of sill and sediments, implying that the dolerite is thickest at the bottom of the basins. There is no evidence, geophysical or otherwise, of feeders below these low centres of thickness. By contrast the literature, including published maps, clearly indicates that some dykes, such as the Lenzie-Torphichen dyke, acted in such a capacity.

The explanation now offered to account for these features is that the tholeiitic magma ascends along fissures (now dykes), most of them marginal to the sedimentary basins, reaching levels up to 0.5 or 1.0 km above the optimum level of potential wall rock collapse due to differential density. This is assumed to provide a head of pressure which, after collapse, would naturally drive magma down bedding planes into the bottoms of basins under the force of gravity. At the bottoms, magma accumulates until hydrostatic balance is achieved; continuing flow thereafter merely drives the magma up-dip away from source (Fig. 2).

An envelope of gas (partly steam from pore water in the sediments) around and ahead of advancing magma has often been invoked in sill literature assuming forcible injection as an instrument which helps to overcome resistance to splitting and fracture along bedding planes. If this concept is valid as many engineers believe, it is even more applicable to intrusion under gravity. Resistance in that event may well be overcome to the extent that flow down bedding planes becomes comparable to subaerial "free-air" flow of lavas down slopes. Although this supposition may appear at first sight to be revolutionary it should be borne in mind that the only natural phenomena of the same order of magnitude and aspect ratios as the world's big tholeiite sills are the world's great plateau basalts, such as those of the Deccan in India.

Those plateau basalts form part of the large outpourings of tholeiite magma - perhaps the largest in the geological record – released by the break-up of the southern Supercontinent, Gondwanaland, early in the Mesozoic. Other tholeiites of that time are the Karroo dolerites of South Africa and more importantly for the purposes of this article, the sill complex of Tasmania.

The Tasmanian complex was emplaced during the Jurassic into a virtually undeformed sequence of Permo-Triassic sediments which rest in turn on a basement of Lower Palaeozoic rocks. The boundary between the Tasmanian Permian and Triassic is problematic within a sequence which is alternatingly marine and glacial below and freshwater above. Each of these two main divisions is said to be about 1 km thick, but there is little information as to lateral variation in those measurements. Indications that the sedimentary pile may have been twice as thick at the time of intrusion is provided by the mineralogy of the zeolites in the dolerites at outcrop, which indicates original burial to depths of 2 km. If that much cover has been removed by erosion, its seems possible that some of it may have been of Jurassic sediments, though none is still preserved; the only superincumbent rocks are local pockets of Tertiary basalt lavas.

Similarities shown by the dolerites to those of the Midland Valley include their petrography, the presence of pegmatitic zones one third down from the tops, and the "step-and-stair" geometry whereby sills transgress sedimentary bedding. There is a difference in scale, however. As shown in Fig. 1 the Tasmanian complex is much more extensive. Moreover, the original difference was almost certainly even greater, for whilst the zero isopachs calculated in Scotland indicate that the area of the sill there was probably never much more than it is now, the Tasmanian dolerites represent only a part of an even larger complex, the remainder of which is now to be seen in Antarctica. Thicknesses, too, are greater, with records in excess of 300 m as compared with a maximum Scottish thickness of 150 m drilled near Glenrothes. In consequence the total volume of dolerite in Tasmania has been calculated at some 8000 km^2 as compared with only 125 km^2 in the Midland Valley.

Thickness calculations in Scotland are simplified by the reasonable assurance that the sill-complex was emplaced as a single magmatic pulse. For many years, therefore, it has been known from measurements in mines that in any given neighbourhood the total dolerite thickness remains the same whether the sill is in one "leaf" or several. The same principle has been demonstrated to obtain over much of Tasmania, though in some areas such as around Hobart, it is complicated by the evidence of more than one intrusive pulse in the form of later dolerite chilling against earlier. It is a phenomenon which ought to be expected in view of the enormous volume of magma intruded in what must have been a very short time in geological terms.

Mechanisms proposed to explain dolerite emplacement in Tasmania predate the recent re-interpretation of Scottish data and are thus essentially based on traditional views of forcible injection. Analogies formerly drawn with ring dykes have been abandoned, though a generally upward drive and transgression from multiple feeders is still assumed. The feeders are believed, mainly on the evidence of gravity measurements, to include pipe-like bodies, though these are said to be difficult to distinguish from dykes in some places. Their identification is clearly critical if the Scottish and Tasmanian systems are to be regarded as having been similarly emplaced, for as already noted there is no indication of such bodies under the thickest parts of the Scottish sills at the bottoms of the sedimentary basins. Neither are they mapped cutting basement at erosion levels below the dolerite in Tasmania. Even more important, perhaps is the mechanical problem inherent in the "pipes" interpretation, for though vertical cylindrical bodies of basalt are commonplace as plugs filling volcanic conduits it is generally accepted that such pipes have first to be drilled out by a process of gas-ash fluxion or convection leading to explosive eruption at the surface. Neither in Scotland nor in Tasmania is there evidence of related subaerial activity, nor is there any mechanism in the literature for propagating cylindrical conduits by movement of magma alone.

Does this mean that both pipes and forcible injections can be rejected in favour of gravity down-dip flow mechanism in Tasmania as in Scotland? The presence of multiple intrusive pulses in the former as compared with only one in the latter would not be inconsistent with such a view. The analogy with extensive superficial lavas needs merely to be extended by pointing to the abundance of composite flows in most eruptive piles. It has to be said, however, that the essential Scottish evidence for gravitational flow is simply not available in Tasmania. There is no relevant mining and all too few boreholes to provide the basis for the construction of isopachs or structure contours where there are sediments or dolerites. Thus neither the present relationship between the two, nor their crucial relationship at time of intrusion can be reconstructed. Until the time as such reconstruction becomes possible (perhaps through seismic traverse) the fairest verdict might be "not proven".

THE GEOLOGY OF EDINBURGH AND ITS ENVIRONS: CASTLE HILL

Charles MacLaren

Just over 150 years ago, Charles MacLaren, Editor of *The Scotsman*, contributed a series of newspaper articles on the geology of the city. He later revised these articles and published them in his book *A sketch of the Geology of Fife and the Lothians including detailed descriptions of Arthur's Seat and Pentland Hills*, 1839. Later, as President of the Society in 1864-65, he dedicated the 2nd Edition to its Fellows. In the first of an occasional series we reproduce from the 1st Edition his account of the geology of Castle Hill, which first appeared in *The Scotsman* on 29th January 1834. We acknowledge with thanks the cooperation of the Editor of *The Scotsman* for allowing us to reprint MacLaren's writings.

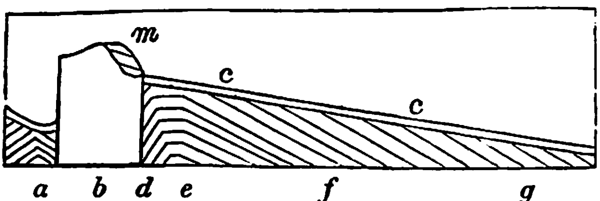
THE CASTLE HILL.

The hill on which the Castle stands is a mass of basaltic clinkstone. about 900 feet in length from north-west to south-east, and about 700 in breadth in the transverse direction. It is a remarkably bold picturesque rock, bounded by craggy cliffs on all sides, except at the south-east angle, where it joins the ridge on which the old town stands by a narrow neck. The mass of clinkstone is surrounded on all sides by sedimentary strata; and its relations indicate that it had been protruded from below in a solid state after the strata were deposited; that in its ascent it had pierced, fractured, and disturbed them; and that the part of it visible may be considered as the summit of a vast column, reaching probably to a considerable depth downward. The rock is of a blue colour and fine grained, and contains a few grains of pyrites. Its numerous parallel fissures, chiefly in a direction approaching to the vertical, exhibit a semblance of stratification; but the appearance is merely superficial.

and due probably to the mode in which it cooled from a state of fusion.

The following section shows its relations to the rocks on the east, forming the ridge on which the old town stands :—

FIG. 23.



b, The column of basaltic clinkstone.

e f g, The strata under the High Street, extending a mile eastward, and dipping to the east (more correctly E. by N.,) at an angle of 15°.

m, A portion of the strata adhering to the trap under the half-moon battery.

A part of the strata *e f g*, are laid bare on the New Approach under the Esplanade; and the crest of a portion of them was exposed in 1833, in opening a trench for gas-pipes from the Tron Church to the Castle Hill. I examined it several times; and from ocular inspection, and questions put to the workmen, I learned, that nearly the whole consisted of red and blue slate clay. At the Esplanade also, four-fifths of what is visible are of the same soft and feebly coherent substance, with only a very few beds of sandstone intermixed; and we can thus the more easily comprehend how it would be cut away by a powerful current, till it assumed the form of a long narrow ridge, protected at the head by the column of basalt *b*.

c c, A bed of alluvium of variable thickness covering the ridge.

The mass of basaltic clinkstone, as already observed, is about 900 feet long from S.E. to N.W., and 700 feet broad in the transverse direction. The subjoined diagrams are sections, No. 24 in the direction of its length, No. 25 in that of its breadth.

FIG. 24.

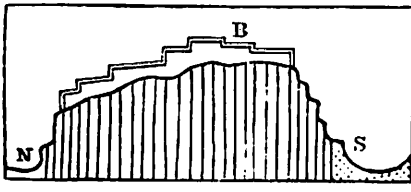
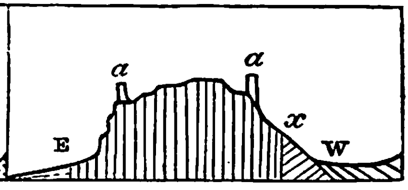


FIG. 25.



N, The north end of the trap rock, which rises in a vertical precipice about 100 feet above the surface of the gardens in the North Loch. The soil under N, consists of clay and debris.

S, The south end of the rock, which rises nearly 250 feet above the road at the king's stables, and 150 above the west approach. The soil here consists of debris. The double line along the head, is meant to show how the castle walls rise by successive steps to B.

B, The highest part of the rock is under this letter, near the chapel. It is 434 feet above the sea, and 287 feet above the surface of the gardens in the North Loch at N.

Fig. 25, is a transverse section of the Castle rock passing through the new barracks and the governor's house.

E, The east side, within the gardens.

W, The west side, also within the gardens, and near the new bridge.

a a, The walls of the castle.

The sedimentary strata are not visible at E; but their existence here may be inferred from their appearance a short way eastward.

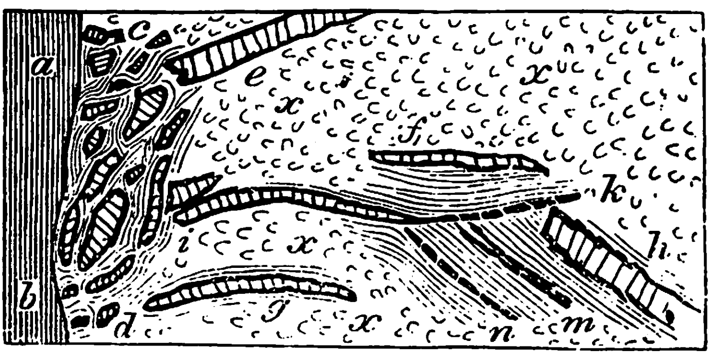
On the north-west side the strata are seen at a seat in the gardens, dipping northward and eastward, (or in towards the trap.) About 120 yards westward from this, they dip north-west at 45° or 50°. Thus, at a point near the Castle, probably 80 or 100 yards from it, the dip of the strata is reversed. This is shown at W, and above *a*, in Fig. 23. Something analogous is seen on the south-east side. Nearer the bridge, on the west side, the strata are seen in contact with the trap. They consist of sandstone, and dip north-west at a pretty high angle, presenting their edges to the trap, neither inclined from, nor towards it. The sandstone has a deep red colour, is hard, and, at the point of junction, presents the appearance of vertical laminæ, parallel to the surface of the trap, leaving us in doubt whether it is not really a mass placed on edge, and the traces of a northern dip a delusion. The trap, also, is discoloured to the distance of a foot from the junction.

The sedimentary beds at W, rise to a point *x*, about 80 feet above the cart-road passing under the bridge. They are thickly covered by the debris of the trap, except at the two points where they have been artificially laid open.

I have stated that the sandstone at W, and the trap in contact with it, are both discoloured. The inference is, that the trap was hot when it was protruded from below. It would seem also to have been *soft*, perhaps *viscid;* for Lord Greenock remarks that "within the Castle walls, fragments of sandstone are imbedded in it;" * yet it certainly was not *liquid*, at least in the exterior parts, for if so, we would have found veins proceeding from it, at the fine section under the half-moon battery, (Fig 26,) where the ruptured fragments must have presented many interstices, into which a fluid could easily have penetrated. Indeed, the groovings on the surface of the trap here, prove that it had been moved after consolidation. But the exterior parts, being in contact with the cold strata, must always have consolidated first, and hence an intruding mass of trap might be firm, but still hot, while the internal parts were liquid. The curious phenomena of metallic veins, however, lend some countenance to the idea that igneous and sedimentary rocks placed in contact, may undergo a mutual change of constitution from the influence of electricity, or some analogous agent.

FIG. 26.

SECTION UNDER THE CASTLE GATE.



This very interesting section is on the new approach, under the south end of the half-moon battery.*

a, b, The basaltic clinkstone, the eastern boundary of which consists of a slightly waving vertical plane, running north and south.

c, d, A confused mass of large blocks and fragments of sandstone, intermixed with blue and red slate clay. The blocks

* Transactions of Royal Society, Ed., Vol. xiii. p. 41.

* The diagram is roughly sketched from a hasty inspection of the locality. A very correct drawing of the section is given in Lord Greenock's paper, on which I could not lay my hands when it was wanted.

of sandstone are of all sizes, up to 10 or 12 feet in length. The fine lines represent the laminæ of the slate clay. The space occupied by these fragments, from the trap *a b*, to *i*, is about 25 feet in breadth, and may be considered as a great fissure produced by the rending of the strata, and afterwards filled by broken materials falling in from above. The entire height up to the Castle wall, is nearly 100 feet; but that of the part shown in the Figure is only about 70 or 80 feet.

e, A portion of a bed of sandstone six feet thick. There is another in a parallel position, three or four yards above it.

f, A bed of sandstone, two feet thick.

i, *k*, A bed of sandstone parallel to *f*, about two feet thick at the west end, and thinning off on the east.

g, A bed of sandstone, two and a half feet thick.

h, A bed of sandstone, about six feet thick.

m, *n*, Very thin beds of the same.

x, *x*, *x*, *x*, Soil and herbage.

The fine lines represent the slate clay, and show the direction in which its laminæ extend. It will be observed that those between *n* and *h*, are transverse to those between *i k*, and *f*. Various explanations have been given of this phenomenon, which, however, I shall not stop to examine.

From *b*, to the bed *h*, the distance is about 250 feet. The section is not vertical: the surface is inclined at an angle of about 50°.

The beds *h m n*, show the position of the strata under the old town; these strata extend nearly one mile to the eastward, and all dip to east, at various angles from 12 to 20, averaging perhaps about 15°. The beds *e*, *i k*, and *g*, have a western dip where they approach the trap, and are nearly level farther east. This unconformable position is evidently caused by the upheaving of the clinkstone, the disturbing influence of which has extended 250 feet to the east. The general effect of this arrangement of the rocks is represented in Fig. 23, at *d e*, divested of the details. On entering the outer gate of the Castle, a portion of strata, some yards in thickness, will be seen about 100 feet to the left of the guard-house, under the south end of the half-moon battery, having the same dip as *e*, in the preceding Figure, and presenting their raised and truncated ends to the east. On the right of the guard-house, however, under the north end of the same battery, a mass of strata, (*m*, Fig. 23,) is exposed dipping to the east. These seem to consist of portions of the strata borne up with the trap, and adhering to it, without changing their position; while the other, which either incline to the trap, or are horizontal, had been shaken, bent, and shifted, by the disturbing movement, of which we have such striking evidence in the fragments filling the space between *i* and the trap rock *b*.

At *b*, close to the road, some yards of that part of the surface of the trap are exposed, which had been in contact with the sedimentary rocks. It is smoothed, and marked with grooves which are nearly vertical, suggesting the idea, that in its ascent from below, it had been abraded by the fractured ends of the sandstone strata.

Since it appears that the strata on the opposite sides of the Castle rock (neglecting the small portion in contact with it) dip in opposite directions, those on the east side eastward, and those on west side westward, the question arises, whether the intruding trap, in ascending from below, moved them into this inclined position? That it was the agent by which the change was in part effected, seems probable. If we assume that the original position of the strata was horizontal, and that the clinkstone mass, pushed up in the solid state, broke and pierced them, we would expect to find the fractured strata, if not afterwards disturbed by other causes, leaning against the trap, and dipping away from it on all sides. We might also account for the anomalous position of the portions of the beds nearest the trap, (at *a* and *d*, Fig. 23,) by supposing that the column was hot when it ascended, and having afterwards cooled, it shrunk, as all bodies do in the process of refrigeration, and, in subsiding, carried the adhering ends of the strata down with it. According to Mr Adie's very careful experiments, the linear contraction of a column of Ratho greenstone, in cooling through 1000 degrees of Fahrenheit's scale, (namely, from a red heat to that of our climate,) would be about 4½ feet for every 1000. Supposing this to be the amount of the change of temperature, and the ends of the strata to be bent downwards 20 feet, the column of trap would require to be 4400 feet, or four-fifths of a mile in length, to account for the change of position. That the trap was hot when it ascended, may be inferred from the discoloration it has communicated to the sandstone, and undergone itself, at the point of contact; and that in cooling it would contract both in length and breadth, is certain; but our knowledge of all the facts is too limited to enable us to arrive at positive conclusions. We are ignorant of the length of the trap column, and its temperature at the time of its ascent, and as for the altered position of the sandstones *e*, *i k*, and *g*, it may be the simple effect of disturbance.

The position of the strata in the southern districts is precisely the same as under the High Street. This was shown by openings in Nicolson Street, near Surgeon's Hall; in Lothian Street, at the foundation of the Catholic Chapel; behind Brown Square, at the foundation of George IV. Bridge, and elsewhere. The E.N.E. dip of the rocks, 1500 feet south from the High Street, and 2000 feet from the Castle, could not be the consequence of the upheaval of the mass of basaltic clinkstone; for if so, the inclination should have been S.E., that is, nearly at right angles to what we find it. At Keir Street, again, 1000 feet south from the Castle, the dip is slightly north, of course the reverse of what it should have been. At the deep opening 500 feet south-west from the Castle, intended for a street, (marked Grindlay Street in Kirkwood's map,) the dip is not S.W., that is, away from the trap mass, but N.W., at 10° or 12°.

It thus appears that the arrangement of the rocks all round the Castle, is not such as the simple action of the mass of trap upon horizontal strata, which it pierced and upraised, would produce; yet the appearances in the section, Fig. 26, clearly show that it did alter the position of the strata to some extent. Besides a thousand geological facts prove, that trap has been a chief, though not the sole agent, in throwing the sedimentary rocks into the infinitely varied positions in which we find them. Perhaps the most legitimate conclusion is, that the trap rocks visible, are to some extent the *cause*, but to a greater extent the *sign*, of disturbing movements, which had their origin at a depth under the surface. Trap is abundant in the district, as will appear from the following enumeration of beds and veins independent of those in Arthur Seat, the Calton Hill, and the Castle.

The great vein of greenstone, 60 feet broad, passing through Drummond Place, Broughton, and by Quarry Holes, to Lochend.

Two thin beds in Lothian Street, exposed in 1817.

A bed in Merchant Court, Cowgate, at the foundation of Geo. IV. Bridge.

A bed abound three feet thick, was found in sinking a well in Mr Berwick's brewery, Canongate. It is perhaps a continuation of St Leonard's bed, which is seen at St John's Hill, 1000 feet southwards.

A thick bed at Bell's Mills, at the bridge. Two veins at the Mineral Wells at Stockbridge, which, by their numerous fissures, serve as conduits for the mineral water. The one is about 12 feet broad, the other 6.

A bed behind Bread Street, at the cutting made for Grindlay Street.

A vein was met with by Mr Jardine in tunnelling betwixt Watson's and Heriot's hospitals for the Waterworks.

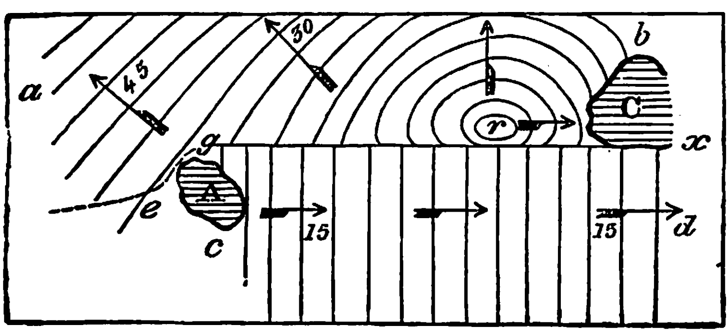
A vein was found in the east part of Canonmills in cutting a drain, and one westward of the village, in Mr Eyre's ground, (Mr Jardine.)

Considering how small a part of the surface has been exposed since geology was studied here, we may safely assume that the trap beds and veins observed, bear a very small proportion to the entire number existing. I have applied the term *beds* to those masses which lie conformably among the strata, though they may with equal propriety be considered as *veins*, since they have generally, if not universally, been *injected* among the strata, instead of being laid down upon them, as one sedimentary rock is deposited above another. In one respect, however, they differ from vertical veins cutting across the strata, such as those at the Mineral Well, and the great vein at Lochend, as the latter have probably in some cases been filled from above, or from a mass of liquid trap at one of their extremities. The matter of the great vein, for instance, has been supposed to have flowed from the trap of Corstorphine Hill, into the fissure where we now find it. The erupted traps, therefore, namely, the Castle rock, and the various beds and veins, may be considered as extravasated portions, belonging to a larger mass now, or once existing, at a certain depth below, and affording clear indications of its disturbing agency.

The strata under the High Street were exposed in 1835 from Niddry Street to the head of the West Bow, a distance of 1500 feet. A very few beds of sandstone were found, from one to four feet thick; but nine-tenths, or more, consisted of alternations of blue and red slate clay, which were generally very soft. The same sort of rocks were found at the Gas-Works in New Street, at Mr Berwick's Brewery in Wilson's Court, Canongate, and there is little doubt that they extend to the Abbey. No trap was found in any part of the line, except the three feet bed at Mr Berwick's; and, as not unconnected with this absence of trap, I may observe, that the disposition of the strata is extremely regular. They uniformly dip to the east, or more correctly E. by N., and at an angle averaging probably 15°. The distance from the Castle to the Abbey being almost precisely one mile, the true thickness of the beds will be about 1200 feet, and the number of alternations of blue slate clay, red slate clay, and sandstone, estimating them at 18 inches on an average, will be 800. Of the entire series, the sandstone probably does not constitute one-tenth. There is perhaps a little limestone and clay ironstone, though I did not observe them. It is this absence of firm rocks which had enabled the diluvial current to cut the strata away so closely on each side, and form so sharp a ridge.

I have no doubt that a deep fissure, or FAULT, *extends along the hollow of the North Loch;* for the strata under the New and the Old Town are placed in positions altogether dissimilar. Owing to a thick bed of diluvium which covers much of the site of the New Town, the rocks are rarely seen; but the strata were well exposed last year at the New Club-Room; and I am indebted to the kindness of Messrs Grainger and Miller for notices respecting those in the line of the Newhaven Railway. From these I find, that the strata under the east side of St Andrew's Square are horizontal about the middle, but decline a little to the south on the south side, and to the north on the other. Of 66 feet pierced, more than nine-tenths was slate clay. At Queen Street lane, the dip is 1 in 4 or 5 to the north. At the New Club-House in Prince's Street, the dip was north-west, at angles from 30° to 40°, and nearly the whole, in the space of 60 feet, was blue and red slate clay. At the West Church Manse, beds of slate clay were exposed 100 feet thick, dipping north-west at 45° or 50°. At Rutland Street, the strata dip north-west at 45°, but here sandstone abounds. In Melville Street, and at the west end of Maitland Street, the dip is the same. Thus, speaking generally, we may say that the strata under the New Town, from St Andrew's Square westward, dip north-west at a very high angle; while those under the Old Town, placed parallel to them at a distance of 700 or 1000 feet, dip uniformly to the east. This will be rendered more intelligible by the subjoined diagram: it is a ground-plan or horizontal section.

FIG. 27.



A, The trap rock of the Castle.
C, The trap rock of the Calton Hill.

a, b, The strata under the New Town.
c, d, Those under the Old Town, eastward from the Castle.
g, x, The supposed fissure or *fault,* running along the hollow separating the New and Old Town, called the North Loch.
r, The point in St Andrew's Square where the strata are horizontal, and from which they decline in all directions.

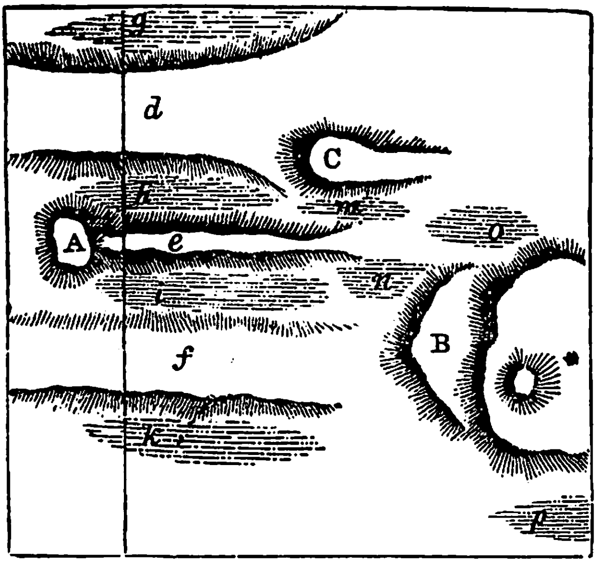
The lines mark the *direction* of the strata, or the appearance their outcrop edges present on the horizontal plane; the arrows show the point of the compass to which they dip; and the accompanying numbers, the degrees of inclination, so far as known. The eastern dip between *r* and C is merely inferred, the strata not being visible.

The strata on the west side of the Castle, perhaps as far as Portsburgh, agree with those of the New Town, in dipping to the same point; but a sudden and great change in the degree of inclination takes place between Grindlay Street and the ground at the Unitarian Chapel near *e,* which leads me to think that the supposed fissure in the North Loch takes a bend here in the direction of the dotted line *g, e.* I am aware of the numerous inflections which the strata often undergo without fractures; but the difference of position here, betwixt the rocks under the Old and the New Town, seems to me too abrupt and too great, to be accounted for without supposing a rupture of continuity. The cause of a change so complicated, however, cannot be explained, without the assumption of various upheavings and subsidences, a full discussion of which would be out of place in this Sketch.

DILUVIAL AND ALLUVIAL PHENOMENA.

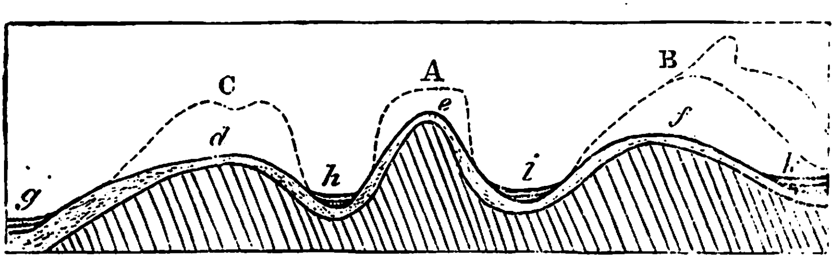
The coat of clay, sand, and gravel, which covers the solid rocks, except at a few points, presents some interesting objects of inquiry. It is, like the sedimentary rocks, generally the product of causes no longer in action, (at least on the dry land;) but as it is the latest product of these causes, its origin, and the peculiar circumstances which attended it, should be more within the reach of investigation. In this district it consists of three descriptions of matter: 1. A stiff blue or red clay, with rolled stones, the "older alluvium," which I call *diluvium;* 2. A softer clay, with rolled stones; 3. Sand, or sand mixed with gravel. The two latter constitute the "newer alluvium," which I call simply *alluvium.* Older and newer alluvium are unquestionably the more suitable terms; and my sole reason for preferring " diluvium and "alluvium," is their greater brevity and distinctness. I need scarcely add, that the former term is not used with any reference to the deluge recorded in the Scriptures. The general opinion of geologists now is, that there have been many local deluges, some of them since the appearance of man on the globe, but no universal deluge ; and it is evident that a deluge, submerging all the parts of the earth inhabited in the age of Noah, would attain the object for which that catastrophe was sent.

FIG. 28.



In this miniature map, A is the Castle; B, Salisbury Crags, with Arthur's Seat behind them; C, the Calton Hill. The city stands on *three ridges, d, e, f,* separated and bounded by the four swampy hollows, *g, h, i, k.* This will be better understood from the section below, which runs south and north along the line *g k* in the map. The letters in the map and section correspond.

FIG. 29.



The section shows the three ridges in connexion with the trap hills C, A, B, to which they apparently owe their existence. The figures under the letters *g, d, h, e,* &c., denote the various elevations of the ridges and hollows, in feet, above the level of the sea. The part marked by oblique lines represents the rocks; and the narrow belt of dotted space over this, is the alluvial matter. The horizontal distance from *g* to *k* is about 2300 yards, or 1⅓ mile. The elevations are a little exaggerated.

g, The meadow extending from Silvermills to Canonmills. There is a great depth of sand here, probably 30 or 40 feet: under this lies a bed of clay, which, northward at the Botanic Garden, attains a depth, I believe, of 80 or 100 feet.

d, The ridge on which the New Town is built.

C, The Calton Hill in outline, which stands at the eastern termination of the ridge *d*.

h, The North Loch. It was formerly a lake, and constituted the best defence of the town on the north side, in early times. The bottom is still marshy, and there is a great depth of alluvial matter in it.

e, The sharp ridge on which the Old Town stands, about 100 yards east from the Castle.

A, The trap rock of the Castle in outline, which is at the west extremity of the ridge. It rises about 280 feet above *h*, the marshy surface of the North Loch.

i, The hollow occupied by the Grassmarket, which is continued eastward by the Cowgate. It was once a marsh; for a black substance, of the nature of moss, was found at various depths from six to fifteen feet, below the level of the Cowgate, at one of the piers of George IV. Bridge, and at the foundation of the New Courts, south side of the Parliament Square. At the latter a remnant of the city wall, erected in 1450, was laid bare; and in the mossy soil below it, about three or four feet under the foundation, were found a number of entire skeletons, showing that the ground had been used as a burying-place long before the wall was built.*

f, The ridge on which the Southern Districts are built.

B, Salisbury Crags and Arthur's Seat in outline, which are situated near the east end of this ridge.

k, The surface of the Meadows, a hollow filled with alluvial matter.

A little reflection shows that the three ridges *d, e, f*, owe their

* An account of these relics was given in the *Scotsman* of 13th April 1833.

existence to the denuding action of a powerful current of water flowing from the west, and impeded in its course by the three trap hills A, B, C. The ridge *e*, on which the Old Town stands, affords a beautiful example of what Sir James Hall termed "Crag and Tail." The column of firm trap A, is about 900 feet long by 700 broad; and its summit projects about 80 feet above *e*, the highest part of the strata forming its tail. These strata, which, as formerly observed, are very soft, sink lower and lower as we proceed eastward, (see Fig. 17.) The marshy surface of the North Loch *h*, is about 280 feet below the summit of A, and the rock is perhaps 30 or 40 feet lower still. The ground on the west side of the Castle is probably 260 feet below A; and the Grassmarket, *i*, about 230 feet. Immediately eastward of the Castle, the sides of the tail ridge *e* are steep, and laterally as well as vertically quite within the shelter of the column of basalt. As the ridge recedes from this protecting column, its crest sinks lower and lower; its sides become flatter, and it loses itself in the general level at the Abbey, about a mile from its head.

If we place a mass of tenacious clay, with a stone in the middle of it, in the current of a brisk stream of water, it will assume exactly the form of the ridge we have been describing. We shall find a ridge or tail of clay in the comparatively still water behind the stone, and tapering off, and losing height, as it recedes from the protecting object: on the opposite side of the stone also, where the stream is checked by its resistance, we generally find a lower and flatter ridge; but close in front, where the water, accumulated as it were, seeks a passage laterally, there is a hollow, and on each flank of the stone the clay is swept entirely away. The Castle rock in this case represents the stone, and the ridge under the High Street the tail. The valley which the Castle Bridge crosses, is the hollow worked out by the pressure of the water in front; and the North Loch on one side, with the Grassmarket and Cowgate on the other, which were once marshes, are the deep channels excavated on the flanks of the resisting object. The ridge in front is wanting, but we find it in connexion with the other heights.

The long swell *d*, on which the New Town stands, owes its existence to the Calton Hill, (C, Fig. 28,) which, checking the current of water in its progress eastward, protected the rocks from its more violent agency. There is a higher and sharper ridge on the east side of the hill, extending fully half a mile from the trap. Arthur's Seat and Salisbury Crags (B, Fig. 29) would in the same way occasion an abatement in the action of the current in front of them; and the protection thus afforded to a portion of the strata directly west from them, seems obviously the cause of the long swell *f*, between the Cowgate and the Meadows, on which the Southern Districts of Edinburgh stand, and which abuts, as it were, against the hill. The cavity of the Hunting Bog, between the hill and the crags, in the first place, and that between St Leonard's and the crags, in the second, would be hollowed out by the arrested current seeking a vent laterally.

The action of the current in hollowing out a cavity immediately in front of the resisting object, is shown in the diagram below.

FIG. 30.

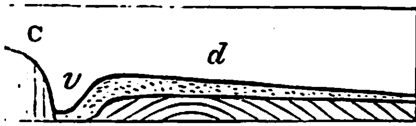


FIG. 31.

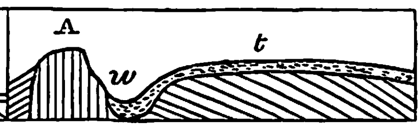


Fig. 30 is a section lengthways (east and west) through the ridge on which the New Town stands. C, the Calton Hill; *v*, the hollow in front of it; *d*, the ridge of the New Town. We see the protecting influence of the hill even in the thickness of the alluvium, marked by a dotted space. At Melville Street and Maitland Street, fully one mile west from the hill, it is only two, three, or four feet thick; at the New Club-Room, half a mile from the hill, it is six or eight feet thick; at the south-east and north-east corners of St Andrew's Square, 300 yards from the hill, I learn from Messrs Grainger and Miller, that the thickness is no less than twenty feet.

Fig. 31, a section east and west through the Castle. A, the trap rock of the Castle; *w*, the hollow in front of it, the bottom of which is about 100 feet below *t*, the swell of the ground towards the south end of the Lothian Road. The alluvium is very thick in the hollow *w*: on the west side it consists of soil and stones; on the east, of the debris of the trap. When the new bridge was building here, peat, with some small branches of trees, were found about 17 feet below the surface, showing that the morass of the Cowgate and North Loch had extended completely round the west side of the Castle.

The great current, acting of course with double violence on the flanks of these hills, tore up the strata to a greater depth; and there accordingly we find, in each case, either marshes or low grounds. Thus, Arthur's Seat has on one side the marsh *n*, (Fig. 28,) called the King's Meadow, 102 feet above the sea, and of unknown depth, which had evidently been continued at one time by *o*, to the Watering-Stone at the east end of the hill. On the south side it has Duddingston Loch *p*, the surface of which is 120 feet above the sea. The North Loch *h*, must in the same way have extended at one time along the North Back of the Canongate, by *m*. At the College Church it is 130 feet above the sea, and 70 feet below Prince's Street. Directly in front of the hill, we have a hollow which descends suddenly about 40 feet below Prince's Street; and even at this depth the alluvium is swept away, and the rock laid bare. Passing round the north flank of the hill, where the current had a clear sweep, it has hollowed out a cavity behind Greenside Place, about 100 feet lower than Prince's Street. The Castle is flanked by the North Loch *h*, and the low ground *i*, from the King's Stables to the Cowgate, which, as already stated, was once a marsh. Each of these depressions of the soil is extremely well marked, and the flanks of the hills above them are steep and bare, showing in the most distinct manner that these were the spots where the force of the current acted with the greatest energy.

The hollows of the North Loch and Cowgate are what the English geologists call "valleys of denudation;" but in reasoning on such cavities, scooped out by great currents of water, we must not forget that they are complex results, depending on local inequalities in the hardness of the rocks, as well as on the force and direction of the current.

We have other and even more palpable proofs of the existence of a great current from the west. In the Prince's Street Gardens, east as far as the Mound, masses of the trap of the Castle rock are found strewed over the surface, of all sizes up to two or three cubic yards. Hundreds of similar boulders are unquestionably buried in the soft silt of the North Loch. In opening up a deep drain at the east end of the esplanade, on the south slope, in 1830, six or eight blocks of the trap, from three to four feet in diameter, were found amidst the clay, within a very limited space. A large stone of the same species lay for many years near the door of the old Gaelic Chapel. In cutting away the soil behind the Advocates' Library, eight or nine years ago, two huge blocks were exposed, one of them a cube of six feet, which must have weighed about 16 tons. This was 1500 feet east from the Castle gate. Now, all these belonged to the basaltic clinkstone of the Castle rock; and the characteristic fact is this, that *while numbers of these masses are strewed over the surface to the eastward, none of any notable size are found to the westward*, beyond the line to which fragments falling from the rock, in the progress of disintegration, are carried. When deep trenches were cut, and spaces opened for streets, on the slope between *t* and *w*, about seven or eight years ago, I examined the ground repeatedly, and never saw a mass of the Castle rock equal to half a cubic yard, though travelled fragments of greenstone exceeding this size, from distant localities, and many large angular blocks of sandstone, were met with.

Distinct marks of the action of the current can be traced on the precipice which forms the north end of the hill, (at N, Fig. 24, page 54.) At various places, from 20 feet above the level of the garden, up to the Castle wall, the surface of the trap rock may be observed curiously smoothed and polished, and sometimes scratched horizontally. These *dressings*, as Sir James Hall termed them, can be seen to best advantage about three or four o'clock in a bright day, by the observer stationing himself on the cross walk, near the stone pillar, so as to catch the reflected light. In dull weather they escape notice; but when the light is strong, they are so distinct that every doubt is removed, and the experienced observer is instantly led to conclude, that the rock had been exposed to abrasion to the height of 100 feet above the surface of the gardens, and that this abrasion must have resulted from the motion of stones, gravel, or sand, borne along horizontally. As the rock is subject to disintegration, and portions fall off from time to time, these marks, of course, are only to be seen at particular parts, and not along the whole surface. On the south end of the rock, a few feet under the level of the King's Bridge Road, a projecting portion of the rock was laid bare, exhibiting the same traces of abrasion.

The currents of which we are speaking must have been *oceanic* currents, and the rocks in this quarter seem to have been exposed to their denuding action in two different directions. The first, from the north-west, had stripped off much of the upper strata, which were shattered and disrupted by *faults* and intruding veins and masses of trap. We see its effects in the humbled and rounded form of the north end of the Castle rock, (see Fig. 24,) which, as most exposed to its violence, has been worn down to the extent of 80 or 100 feet beneath the level of the south end: we see, too, that the strata have been torn away from its north-east side, (at E, Fig. 25,) where a westerly current could scarcely affect them: finally, we observe that the isthmus of sedimentary strata, connecting the Castle rock with the ridge under the Old Town, which should have been at the middle of its east side, if the denuding current had come only from the west, is in reality at its south-east corner. When this current ceased to act, the strata on which the New Town stands probably formed one irregular inclined plane to the esplanade, and prolonged again from the esplanade to the site of

Heriot's Hospital. A second current, at a later period, from west, or west by south, scooped out the North Loch, and the hollow of the Grassmarket and Cowgate; and to the latter, the *dressings* on the face of the rock, the deposit of clay on the surface, and the distribution of the trap boulders, may be attributed.

REVIEW

A Dinosaur in the family

Reprinted by kind permission of *New Scientist*, 1 December 1983

How to Keep Dinosaurs

by Robert Mash, Andre Deutsch, pp. 72, £4.95

Every dinosaurophile from the age of about five must have wondered what it would be like trying to keep a dinosaur as a pet. All the basic information on size of egg clutch, the best diet, how long they lived etc, has been available in museums, to say nothing of dinosaur books. What has been lacking was something more practical. This omission has now been rectified: Robert Mash has provided us with just such a guide.

Where the author has had personal experience of keeping dinosaurs he is excellent, but there are one or two parts where his account is based on hearsay, and serious damage could be caused to either owner or dinosaur if his advice is followed uncritically.

The unwary purchaser could come up with a few nasty surprises and some suggestions seem unnecessarily cruel. The 1-metre tall *Fabrosaurus* is cold blooded and hence does not have any stamina at all; it is, therefore, quite heartless to make it follow long cross-country walks. It is remiss not to warn the impending owner of the bone-head *Stegoceras* of its propensity for head butting. If you bend down to pick up something from the floor, or even to put its food bowl down, you are likely to end up with a fractured skull. To omit this information verges on the irresponsible. The matter of house training need not present any undue problems: all dinosaurs, like modern reptiles, are regular in their sanitary habits and perform in much the same place the first thing every morning. Once your dinosaur has chosen its preferred site, it is an easy matter to place a plastic sheet with a sprinkling of sand over the spot. It is important to remember that dinosaurs are not warm blooded as Robert Mash believes. They really do need centrally heated living quarters and the heating bills can be prohibitive.

Riding the *Ornithormimus* is more hazardous than the author realises – certainly they do not bite, but they have a very vicious peck, and it is simply not true to say that they do not have claws that catch. They are not averse to snatching up and devouring cats and small dogs; in this they are not unlike *Coelophysis*, which the author notes is partial to small lap dogs.

It is a great relief to read of *Deinonychus's* propensity for disembowelling: it may well be useful for police work but surely not in this country.

Robert Mash recommends dinosaur eggs, but do remember that one is the equivalent of 100 hen eggs and would be more than adequate for a normal family breakfast. I have the suspicion that the author has never actually tackled a dinosaur egg. He cannot be serious with his elaborate ritual with a glass cutter – a swift sharp tap with a tablespoon is all that is required.

It is very pleasing to be reminded that such dinosaurs as *Triceratops* have a FDH (flock dominance hierarchy) and that they are happier kept in groups. The old policy of keeping then alone or in twos was unkind. Mash reminds us that the male of such placid beasts are prone to fighting in the spring.

This handbook is highly recommended for Christmas reading, but I do suggest that with so many Christmas pets being abandoned after the festivities, parents should think very seriously before adding a dinosaur to the family.

Beverly Halstead

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No. 10	Autumn 1981	No. 14	Autumn 1983
No. 11	Spring 1982	No. 15	Spring 1984

Authors of Articles, Reviews and Poems

Subjects of Articles

Books Reviewed

Poem titles

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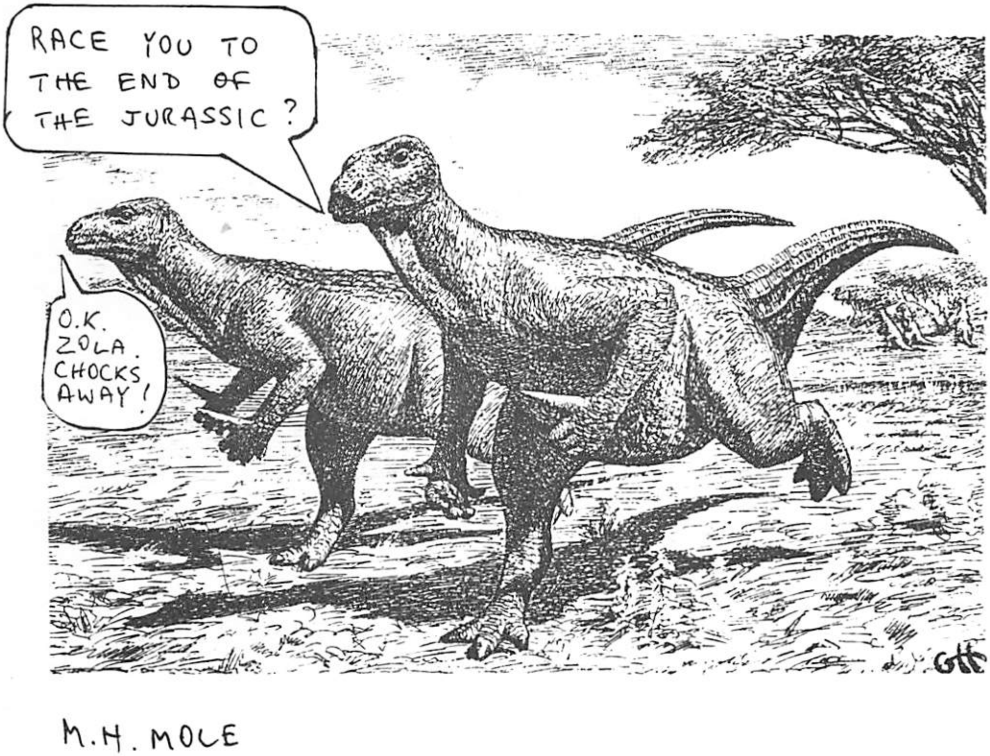
Dr. John Horne	B. Lightfoot	Mar 1979, 10-11.
The Caithness Peat	Anon.	No. 11, 9-11
Ode to the Long Excursions	M.C. Hogarth	No. 12, 21-23.



M.H. MOLE

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