XXI.—*On the Calton Hill and its relation to the Rocks in the Neighbourhood.* By JOHN HENDERSON, Vice-President.

(Read 20th February 1896.)

My original intention was merely to bring before the notice of the Society a small section recently exposed in making a drain at the Low Calton, where the lowest portion of the traps of the Calton Hill was exposed, but seeing that a good deal of interest is centred on the hill at present owing to the making of the tunnel and other alterations going on in connection with the North British Railway, I have taken the liberty of calling attention to a few facts and theories connected with the hill.

The Calton Hill has not received so much attention from geologists as its larger neighbour, Arthur's Seat. This is no doubt due to the fact that its structure is much simpler than that complicated and puzzling series of rocks included in the Queen's Park. Still a number of well-known geologists have described its structure, and others have noted the minerals connected with it. Cunningham, in his "Geology of Midlothian," describes the rocks of the Calton Hill as a series of traptuffs and porphyries dipping to the east, and he seems to have considered them all intrusive. He also mentions certain sandstone strata dipping under the traps of the hill that were exposed in excavations made for the foundations of the Waterloo Bridge. He likewise calls attention to the stratified beds that overlie the trap at the eastern end of the hill. Maclaren, in his "Geology of Fife and the Lothians," gives a description along with a diagram of the Calton Hill, which, he explains, was mostly taken from a paper by a Mr Webster, a pupil of Professor Jamieson. He describes five beds of traptuffs and porphyry as forming the body of the hill, and shows them in the diagram dipping at a high angle to the east, and overlaid by a series of stratified beds, also dipping east. In the "Memoir of the Geological Survey for Midlothian" the Calton Hill is also described, but in a more detailed and perfect manner than had been done in any previous work. In it fifteen beds are enumerated as constituting the trap rocks of the hill. These are described as consisting of alternating beds of basalt, felstone, felspathic ash, porphyries, felsite porphyries, amygdaloidal felsites, stratified ash, &c. In this memoir a new and most important idea is brought out in connection with the geological history of the Calton Hill—viz., that it is a portion of the northern end of the volcanic rocks of Arthur's Seat brought into their present position in the Calton Hill by a fault. That a fault exists extending from the Castle along the south front of the Calton Hill and on towards the northern side of Arthur's Seat

there can be little doubt. It was first suggested by Maclaren, as far as I am aware, to account for the differences in appearance and position of the rocks underlying the Old Town and the New. The strata that underlie the Old Town from the Castle to Holyrood consist of a series of brown, grey, and greenish shales and thin bedded sandstones, dipping east-north-east. These beds, if prolonged in their line, strike northward, and if not interrupted by a fault ought to be found underlying all the New Town, from the west end of Princes Street to the east end of the Calton Hill; but, instead, we find from the west end of Princes Street to St Andrew Street a very different set of rocks dipping west-north-west. From St Andrew Street eastward the strata gradually arch over and dip to the east, showing an anticlinal bend between St Andrew Street and the Calton Hill. This easterly dip continues through all the rocks of the Calton Hill, and as far east as Lochend. But although this easterly dip coincides with the dip of the rocks on the south side of the town, yet none of the beds are prolonged unbroken from the one side to the other. For instance, if the rocks of the Calton Hill extended in their line of strike southward, they ought to be found all the way down the Canongate; but instead of the traps of that hill we find only the sedimentary beds already mentioned as occurring between the Castle and Holyrood, all evidence going to prove the existence of a fault between the Old and New Town. The fault, as figured in Maclaren's diagram, extended in a straight line from the north side of the Castle rock along the south side of the Calton Hill. In the map of the geological survey the fault is extended eastward in a nearly straight line along the north side of the Queen's Park to Restalrig. This extension of the fault eastward is put in, I expect, to explain the theory of the Calton Hill being a portion of the north end of Arthur's Seat, as its present position, nearly a mile to the west, could only be accounted for by a downthrow of the rocks to the north with their easterly dip. Of late I think I have been able to prove this extension of the fault eastward, although not in the same line as laid down in the Survey Map. In the year 1887 I read a paper before this Society on sections exposed in making a drain through the Queen's Park at Holyrood. In that paper I mentioned that a portion of the excavations were carried through the parade-ground to the east of Holyrood Palace grounds, where beds of brown, blue, and greenish shale, dipping north-east, were exposed, and at the south-east corner of the Palace gardens beds of black shale were cut into containing abundance of entomostraca and fish remains of well-known carboniferous species. Those black shales were exposed to

within a few feet of the whinstone of Salisbury Crags. The occurrence of black shales with the fish remains and entomostraca, so like those of the Wardie and Granton series, surprised me at the time, as, if continued in their line of strike south-eastward, they ought to be found immediately on the back of the whinstone of the Crag, but we know that a very different set of beds overlie the Crag at this place. At the time the excavations were going on I watched to see if any portion of the whin of the Crag would be exposed, but where it ought to have been met with the workmen came upon a great depth of loose watery sand, indicating that the Crag was truncated here. The conclusion I arrived at was that a fault existed here which had brought down a higher set of sandstones and shales against the rocks of Arthur's Seat. Now the question is, are there two faults running in the same direction—viz., the one laid down on the Survey Map extending from the south face of the Calton Hill to Restalrig, and this one running along the north-west portion of Arthur's Seat? I am inclined to think that the line of fault marked on the geological survey map is carried too far north, and that the great fault that has brought the rocks of the Calton Hill into their present position passes from the south face of that hill to the north end of Salisbury Crags, and in a north-easterly direction towards Restalrig, and I will give one or two reasons for thinking so. A number of years ago a bore was put down for water in Mr Robert Younger's brewery at Abbeyhill. The bore was made with the diamond drill, which brought up a nearly complete section of the rocks passed through in the shape of a core about 6 inches in diameter. The first beds passed through in this boring were of brown, grey, and greenish sandy shales, and one or two beds of black shale with entomostraca and fish remains nearly identical with those found in the section at the north end of Salisbury Crags. Now if the beds exposed in the Queen's Park were extended in their line of strike to the north-west they would pass over the ground where the bore was put down. And in that case the beds exposed in the parade ground would represent the beds that overlie the traps, conglomerates, and ash beds of the Calton Hill passed through in the Abbeyhill bore, but if the fault as marked in the Survey Map was correct this could not be, for the beds of the Arthur's Seat series would extend northwards to the north side of Holyrood and join the Abbeyhill beds there. Other evidence that the fault passes to the south of Holyrood instead of the north is to be found in the Abbey Brewery at the foot of the South Back of Canongate. Evidence of a great fault has been met with in the mines and wells there that have been made for water, and at Brown's Close, near the foot of the Canongate,

on the north side, porphyritic rock was exposed a number of years ago, which Rhind considered a portion of the beds of the Calton Hill. That the Calton Hill is a portion of the northern end of the volcanic rocks of Arthur's Seat, brought into their present position by a fault, I think there can be little doubt. To look at the position of the Calton Hill, lying about a mile west from the set of beds from which they are supposed to have been derived, we are apt to think it had got a great thrust to the west. But when the faulting took place the igneous and sedimentary beds of Arthur's Seat must have extended as far west, at least, as where the Calton Hill now stands, and having the same easterly dip we can see that a downthrow to the north and a denudation of the southern portion would bring the igneous rocks of the two hills into their present position. The extent of the fault might be roughly estimated by taking the dip 15° , and the distance nearly a mile; this would give a downthrow or upheaval in the fault at this place of about 1200 feet. Coming now to farther proofs of the origin of the Calton Hill, it was pointed out by Sir Archibald Geikie, who had done the work of the survey in this district when the memoir was published, that the lowest beds of the Calton Hill closely resembled the rock to the east of St Anthony's Chapel, known as St Anthony's Crag. I may say I have got a little farther proof of this in a section lately opened at the Low Calton. Here a portion of the lowest beds yet seen of the traps of the Hill was exposed. The rock is a remarkable looking basalt, containing cavities filled with crystals and other varieties of quartz, along with dogtooth spar and other forms of calcite and masses of jasper. And in examining the rock of St Anthony's Crag I found pieces of jasper in the rock of the same character as those found at the Low Calton, and I have not been able to find jasper in the same condition in any of the other beds either in Arthur's Seat or the Calton Hill. The other minerals found in the cutting at Low Calton I have also found in St Anthony's Crag but not in such abundance. In making the new road for the north back of the Canongate a fine section of nearly all the lowest beds of the Calton Hill is exposed, showing a series of basalts, traptuffs, felsites, and felsite porphyries, but to separate the beds of the hill in detail at this place I would not attempt. They get more porphyritic as they rise in the series, and the highest become both amygdaloidal and conglomeratic. This was proved by the deepest part of the bore in the brewery at Abbeyhill, details of which I gave in a paper before the Society some years ago. The lowest bed of trap yet observed is the one I have already mentioned as exposed in the cutting for the drain at the Low Calton, and at the south end of the

cutting brown shales were exposed dipping in towards the trap, but whether they passed under the trap or not I could not say. If the beds of the Calton Hill are a portion of the rocks of Arthur Seat from St Anthony's Chapel eastward, then the rocks that underlie those beds and extend westward in Arthur's Seat ought to be found to the west of the Calton Hill. These would include the traps that underlie St Anthony's Chapel, and the rock known as the Longrow and the Bog Craig, and all the sedimentary bed that lie between these and Salisbury Crags, along with that Crag, and in fact all the beds that underlie the Old Town as far west as the Castle. Now to the west of the Calton Hill we find a very different set of beds. Cunningham, in his "Geology of the Lothians," mentions sandstones being exposed in excavating for the foundations of the Waterloo Bridge as apparently dipping under the trap, and thick-bedded sandstones are at present exposed, lying nearly horizontal at the north end of the North Bridge. From there, westward, the beds gradually take a westerly and north-westerly dip throughout all the New Town, showing that an anticline bend exists between the Calton and St Andrew Square. Such being the case, if no other fault or interruption occurs, we might expect that all the beds of the Calton Hill would be repeated to the west of St Andrew Square, but no such beds occur there. The beds that underlie the New Town consist of brown, grey, and black shales with thick and thin bedded grey sandstones, mostly belonging to the Wardie and Granton series. Throughout these several vertical dykes of intrusive greenstone occur, but no bedded contemporaneous traps like those of the Calton Hill and Arthur Seat exist in the district. Now we have a different set of rocks and a different set of conditions lying to the west of the Calton Hill than that lying to the west of Arthur Seat, and we can only attempt to explain this by introducing another fault lying somewhere between the east end of Princes Street and the west face of the Calton Hill running in a northerly direction, and with a downthrow to the west, bringing the lower beds of the Granton series to a level with the traps of the Calton Hill or middle portion of the beds of Arthur Seat. In studying the various phenomena we cannot help wondering and speculating on the enormous changes the rocks of the neighbourhood have been subjected to since the early part of the lower carboniferous period. First we have that extensive series of reddish sandstones, grits, and conglomerates with brown, grey, and greenish shales that extend all over the south side of the town 2000 or 3000 feet in vertical thickness. Then these were interrupted by intrusions and outflows of igneous rocks only, portions of which can now be seen in Arthur Seat and the Calton Hill. The contemporaneous volcanic rocks

of these hills I consider were mostly produced under submarine conditions, judging from the number of sedimentary beds of ashy matter found among them, notably the bed of stratified ash, with both fish and plant remains, seen under the basalt of St. Anthony's Chapel. Then we can trace a gradual dying out of these volcanic conditions, as is shown by the boring operations in the brewery at Abbeyhill, where the felsites, felspathic ash, porphyries, and conglomerates gradually get overlaid by finer sandstones and shales of the Granton and Wardie series. It must have been after all the lower carboniferous rocks had been deposited, and even after all the carboniferous limestone and edgecoal series of the neighbourhood had been laid down, that the great faulting took place that threw up the Pentland ridge and the rocks of Arthur Seat, or threw down the rocks on each side of that ridge, as the two great faults that flank the Pentlands on each side show. One fault, extending from the Carlops to the sea at Portobello, has brought down the carboniferous limestones of Gilmerton against the lowest beds of the lower carboniferous at Craigmillar and Liberton, and must have had a downthrow in that district of 8000 or 9000 feet, as it has cut off all the lower carboniferous rocks, and all the carboniferous rocks to the south-east of this fault are tilted at a very high angle along the line of fault with an easterly dip. The fault on the north-west side can be traced from Currie down the Water of Leith to Colinton, and from there to the west side of Craiglockhart Hill and on to the north side of the Castle rock and south side of the Calton Hill, and from there to the north-west side of Arthur Seat. Though not so great or so extensive as the one that flanks the Pentlands on their south-east side, it is still a considerable fault. Its greatest downthrow, as far as I can make out, is somewhere about Craiglockhart. At the cutting made for the Suburban Railway to the north of that hill, shales belonging to the upper beds of the Granton series can be seen lying at a very high angle against the red sandstones of the lowest beds of the lower carboniferous, showing a downthrow here of at least 3000 feet. A finer example of a fault seen in open section could not easily be found. The effect of these faults, at whatever period they took place, would be to elevate a great ridge of land between the two great faults, including the Pentland Hills and all the district lying between there and Arthur Seat, also that hill and the district lying further north several thousands of feet above the land on each side of it, and bending the strata into synclines and anticlines. After the faultings, bending, and tilting of the strata had taken place, enormous denudation set in, reducing all those great inequalities to the condition we now find the district in.