Arthur's Seat

O.S. 1:50000 Sheet 66 Edinburgh

B.G.S. 1:50000 Sheet 32E Edinburgh

B.G.S. 1:25000 Edinburgh Special Sheet

Route: (Map 3)

About a kilometre from the city centre, the remnants of the long-extinct volcano of Arthur's Seat rise from the low ground on which Edinburgh is built. Part of the volcano has been lost through erosion and part has been buried under younger rocks; enough, however, is exposed to allow us to study the vulcanicity in some detail, especially as the removal of much of the superstructure has laid bare the internal parts of the volcano. The largest volcanic remnant lies within the Holyrood Park where it culminates in Arthur's Seat (251 m), the hill from which the volcano takes its name. To the north and west smaller remnants build the Calton Hill and the Castle Rock (p. 52). The volcano was active in the Dinantian, early in the Carboniferous Period, and the products of its first eruption are taken to mark the top of the Cementstone Group. The lavas are covered by the oldest sedimentary member of the succeeding Lower Oil-Shale Group, the Abbeyhill Shales.

The first eruption of the Arthur's Seat Volcano was made into shallow water in which the rocks of the Cementstone Group had accumulated but early in the activity, the higher parts of the cone were raised above water-level and colonised by land plants. Their fossilised remains are found today in the ashes and agglomerates. The deposition of chemically precipitated limestone high on the cone in the middle stages of the activity, and the final burial of the entire volcano by waterlaid sediment indicates that the greater part of the cone was submerged during most of the volcano's life; this contention is supported by the presence locally of well-bedded ashes between most the lava flows. Thus, although the lavas were erupted subaerially, much of their descent of the cone was made below water. No trace of pillow structure, however, has ever been observed, but some of the higher lavas have been partially albitised and carbonated and are now transitional between normal basalts and spilites.

As exposed today, the Arthur's Seat Volcano consists of five vents (the composite Lion's Head and Lion's Haunch vents, the basalt-filled Castle Rock and Pulpit Rock vents and the agglomerate-filled Crags Vent), three portions of the cone (the Whinny and Calton Hills and an area near Duddingston) and a number of sills and dykes. The Salisbury Crags Sill and two small dykes were intruded long after the volcano became extinct.

Whinny Hill provides the most complete and accessible sequence of lavas. Lava 1, believed from petrographic evidence to have been erupted from the Castle Rock Vent, forms the Long Rowand, its northern downfaulted portion, the Haggis Knowe. Above the lava there lies a considerable thickness of mixed ash and sediment known collectively as the Lower Ash of the Dry Dam; this contains at least two bands of precipitated limestone, the lower containing irregular masses of chert. The ash, most probably derived from the Lion's Head Vent, is covered by Lava 2 which was erupted from the same orifice within which its feeding conduit is preserved. There followed the formation of a further bed of intermingled ash and sediment in which volcanic bombs are prominent - the Upper Ash of the Dry Dam. After the accumulation of the ash, a parasitic vent - the Pulpit Rock Vent - some distance down the northern slopes of the cone, emitted Lava 3. Later Lava 4 was erupted from the Lion's Head Vent at the apex of the cone and descended normally until diverted around the obstacle formed by Lava 3. Lava 4 is only seen on the southern part of Whinny Hill today, its northern continuation having been diverted out of the present plane of exposures by Lava 3. Lava 4 was the last flow to be erupted from the Lion's Head Vent for the residue of the flow remaining in the vent blocked the orifice on consolidation. All further activity of the Arthur's Seat Volcano was focused on the Lion's Haunch Vent from which the remaining nine lavas (5 to 13) of Whinny Hill were erupted. These flows lie in normal succession, one above another, the contacts of the flows being rarely marked by any considerable ash bed.

The remnant of the cone of the Arthur's Seat Volcano exposed on the northern shores of Duddingston Loch differs extensively from the remnant which forms Whinny Hill and, apart from Lava 1, the successions cannot be correlated with

any certainty. The Calton Hill succession (Locality 32) shows a general resemblance to that of the Whinny Hill.

Of the five vents of the volcano, that of the Lion's Haunch is by far the largest and most complex. It is filled chiefly by a red agglomerate consisting of a fine-grained red matrix of decomposed basaltic ash in which lie basaltic and sedimentary blocks up to 3 m in length. Within the agglomerate there occur at least seven small lava flows, of basalt or mugearite, which were erupted and confined within the crater walls. A common associate of these flows is a bedded red tuffaceous sandstone, pointing to the existence of temporary crater lakes during periods of quiescence in the vulcanicity. A mass of Dunsapie basalt forms the summit of the Lion's Haunch and partly rests on and partly cuts across the underlying agglomerate. This mass is the remnant of a one-time lava lake which probably once filled and blocked the Lion's Haunch Vent and brought the surface activity of the volcano to a close.

Several basaltic intrusions lie in the Lion's Haunch Vent. In the east there occurs the marginal intrusion of Dunsapie Hill, the type locality for Dunsapie basalt. In the west of the vent there crops out at Samson's Ribs an intrusion, again of Dunsapie basalt, which ascended along the wall of the vent and extended in a number of irregular tongues into the crater infilling.

The other three vents seen in the Holyrood Park are simpler in constitution. The Lion's Head Vent, now partly truncated by the later and larger Lion's Haunch Vent, appears to have been originally cylindrical in form and largely infilled by a fine agglomerate, through which penetrated the feeding conduits for Lavas 2 and 4; these conduits are now filled by Craiglockhart and Dalmeny basalt respectively. The Pulpit Rock Vent - the orifice of Lava 3, is a small plug of Craiglockhart basalt. The Crags Vent is filled with fine-grained agglomerate containing fragments of basalt similar to Lavas 1 and 2 of Whinny Hill. No higher flows have contributed fragments and it is probable that this vent ceased its activity shortly after the eruption of Lava 2. The intrusions associated with the vulcanicity, other than those in the vents, include a sill, which has been divided into three portions now forming the St. Leonard's Crag, the Dasses and the Girnal Crag. The probable feeder of the sill is situated at the Dasses where some dyke-like contacts may be seen. A second sill, known as the Whinny Hill Intrusion, occurs between Lavas 6 and 7.

Two intrusions of later date than the Arthur's Seat vulcanicity occur in the Holyrood Park. The larger is the well-known teschenite sill of the Salisbury Crags of Namurian age. To the north of the Cat's Nick the sill is cut by a later (Stephanian) quartz-dolerite dyke which contains a large strip xenolith of the sill rock.

After the final extinction of the volcano it was covered by thousands of feet of sediments. Earth-movements folded the strata and imparted to the buried Arthur's Seat Volcano a general eastward dip of between 20 and 30 degrees. Many faults cut the sediments and the volcanic rocks. The sedimentary cover of the volcano was removed by prolonged denudation which culminated in the distinctive erosion caused by the Pleistocene ice-sheet. The ice moved from west to east across the area; the hard rocks of the Arthur's Seat Volcano were left as high land while the soft surrounding sediments were more extensively planed away. The easterly dip of the volcanic rocks caused the ice-sheet to produce the present-day topography of westward facing cliffs backed by gentle easterly slopes. The famous crag and-tail structure of the Castle Rock and the High Street is the best known of these phenomena, but similar land forms have been produced at the Salisbury Crags and the Calton Hill. A fine roche moutonée has been preserved in the Queen's Drive and glacial striae can be observed at several localities.

The great majority of the geological phenomena to be seen on Arthur's Seat can he adequately appreciated without hammering the outcrops. As the area is intensively used by geologists for field studies, it is requested that visitors use their hammers as sparingly as possible. At a number of outcrops, including localities 3 and 15 below, hammering is strictly forbidden by the Park Authorities.

Four excursions are described in detail. These, with their approximate duration, are:

		Time
A	Salisbury Crags	2½ hrs
B	Whinny Hill	3 hrs
C	Lion's Head and Lion's Haunch Vents	3 hrs

D Calton Hill 1 hr

Holyrood Park lies to the centre of Edinburgh and Lothian Region Transport buses pass close to all three park gates. Ample parking for cars is available inside the Holyrood and Meadowbank gates and at Dunsapie Loch, but parking is difficult at the Park Road gate. The Park Authorities should be advised in advance of large parties. Prior permission is required to take coaches into the park and they may not park there. Note that the eastern half of the Queen's Drive, from Meadowbank Gate to Park Road Gate. has been converted to oneway driving.

Excursion A—Salisbury Crags (Figure 6)

Access to the Holyrood Park is gained by the Park Road Gate and localities 1 to 10 visited in succession. Alternatively from the Holyrood car park the localities can be visited in the order 8 to 10 followed by 1 to 7.

1. St Leonard's Crag

In a low interrupted line of cliffs to the south of the Queen's Drive the St Leonard's Sill is exposed. The central member of Dunsapie basalt, seen elsewhere, is absent and the sill, about 5 m in thickness, consists throughout of a brownish-red, markedly altered mugearite containing sparse plagioclase phenocrysts and small vesicles.

2. Queen's Drive: Cementstone Group

On the north side of the Queen's Drive white or pale red sandstones and marls are exposed. Several tons of rock were blasted from this exposure and removed for examination: several fish scales were found and were originally identified as *Holoptychius nobilissimus* suggesting that the strata were of Upper Old Red Sandstone age. Re-investigations have cast doubt on this identification and Mitchell and Mykura (1962) put forward strong evidence that the rocks seen in this outcrop belong to the Cementstone Group.

3. Salisbury Crags: Hutton's Section

The justly famous Hutton's Section of the base of Salisbury Crags Sill is found towards the south-eastern end of the escarpment, and provided Hutton and his followers with telling evidence in favour of magmatic intrusion in the great argument with the Wernerians in the eighteenth century. Beneath the sill lie well-bedded Cementstone Group strata, alternately red and white. The sill transgresses the bedding conspicuously in two places. At the first the sediment against the transgression is crumpled; at the other a wedge of teschenite has been intruded beneath a block of sediment, rotating it upwards from its original position and partly engulfing it in the sill. At the western end of the section, the teschenite immediately above the contact has been chilled to a glassy skin up to a centimetre thick, which has now been devitrified to a greenish material. Above the glass the teschenite is very fine in grain but coarsens markedly upwards. In the rock-face to the south-east of Hutton's section large rafts of sediment can be seen high in the sill. The rafts are not distorted and lie parallel to the strata below the sill. Still farther to the south-west, syenitic segregation veins up to 5 in thickness cut the sill.

4. Hutton's Rock

At the north-western end of the largest disused quarry in the Salisbury Crags Sill, a small isolated rock stands close to the path. Owing its preservation to the interest of Hutton, it is now known as Hutton's Rock. Here teschenite which has been extensively hematitised is cut by a vein of impure hematite several centimetres in thickness.

5. Sill-Sandstone relations

Here, at the foot of the Salisbury Crags, a mass of red sandstone is bordered above and on the east by the sill. Its other contacts are not seen and it is therefore uncertain whether it is a true xenolith or a tongue of the underlying sediments projecting into the sill. The intrusion of the sill has crumpled the sandstone and has locally produced slight faulting.

6. Cat's Nick: Fault, quartz-dolerite dyke

At the Cat's Nick a small east–west fault with a downthrow of a metre or so to the north cuts the Salisbury Crags Sill and the underlying sediments. The teschenite close to the fault is much decomposed and shows spheroidal weathering. A few metres farther to the north, a quartz-dolerite dyke traverses the sill. The dyke, about a metre in width, is much finer in grain than the sill and shows a distinct joint pattern. Just above the path it contains a large strip-xenolith of teschenite.

7. Sill: upper contact

In a prominent embayment into the line of the Crags, the upper contact of the teschenite sill is exposed. The teschenite decreases markedly in granularity and becomes vesicular as the contact is approached; the sediments above, white sandstones of the Cementstone Group, show little alteration other than a slight induration.

8. Camstone Quarries: Cementstone Group sediments

In the disused Camstone Quarries sandstones, shales and cementstones of the Cementstones Group dip eastwards at 25°. Well-developed sun-cracks, ripple-marks and worm-tracks occur and from the cementstones the small crustacean *Estheria peachi* has been obtained.

9. Crags Vent: agglomerate

A low mound marks the position of the Crags Vent and is bounded by a very broken scrap in which the fine-grained agglomerate of the vent is exposed.

10. Sill: upper contact, tachylyte veins

At the top of the main cliff of the Salisbury Crags, the teschenite sill very close to its upper contact is exposed and is seen to contain vesicles which, in places, are arranged in trains as a result of late magmatic movement. Patches of altered sediment, of Cementstone age, lie upon the teschenite a few metres east of the Crags and the teschenite here is locally cut by veins of dark tachylyte. To the south and east of this locality the sill splits up into a number of leaves separated by thin layers of intervening sediment.

Excursion 8—Whinny Hill

The approach to Whinny Hill for localities 11 to 20 is most easily made from the western end of St. Margaret's Loch which can be conveniently reached from either the Holyrood or Meadowbank Gates car parks.

11. Dasses Sill

The sill of the Dasses here forms a low westward facing cliff. Only a metre or so in thickness, it consists of highly altered Markle basalt transitional to mugearite. The top or the sill is well-exposed and shows a number of north-westγouth-east corrugations. representing casts of drag-folds in the overlying sediments caused by the movement of the magma. A few centimetres of very slightly indurated sediment can be seen above the sill and directly below the turf at the eastern margin of the outcrop.

12. Long Row: Lava 1

The Dunsapie basalt which forms Lava 1 is well-exposed at the northern termination of the Long Row, The base of the flow is not seen but the greater part of its thickness is exposed, The flow is sparsely vesicular throughout and the central part shows a crude columnar jointing. The irregular and slaggy top of the flow is exposed in the path leading to the Dry Dam almost where it joins the path uphill past St. Anthony's Well; the irregularities in the top of the lava are filled with basaltic ash.

13. St. Anthony's Well: Lower Ash of the Dry Dam

The Lower Ash of the Dry Dam is somewhat poorly exposed at this locality, Above the top of Lava 1 there crops out a bed of white limestone. a metre thick. The limestone contains cherty nodules and is associated with dark sandy shales containing plant remains. In the small scrape on the south side of the path leading past St. Anthony's Well, ashy and shaly beds are exposed and are overlain by another impure limestone. Lava 2, which overlies the Lower Ash, is not exposed at this locality on the south side of the St. Anthony's Fault.

14. St. Anthony's Well: Lava 2

This locality lies to the north of the path running to the east past St. Anthony's Well and is the lowest westward facing cliff on the slope below St. Anthony's Chapel. The well lies on the east-west St. Anthony's Fault so that Locality 14 is separated from Localities 13 and 12 by this dislocation; the fault has thrown the rocks down to the north by some 23 m. At Locality 14 Lava 2 crops out. The flow of Craiglockhart basalt is of no great thickness and is decomposed and vesicular throughout. At the south-western extremity of the exposure the flow has been gas-brecciated, the fragments now being cemented by calcite. The upper surface of Lava 2 is irregular the irregularities being filled with ash or sediment.

15. Lava 2: Upper Ash of the Dry Dam

The upper surface of Lava 2 forms a small ledge in the westward facing cliff below St. Anthony's Chapel. Above and to the east of the ledge the ash is exposed and is covered by the columnar basal portion of Lava 3. The metre-thick ash is well-bedded and contains occasional volcanic bombs up to 0.7 m in diameter. Near its base the ash carries numerous coalified plant fragments; a tooth of Rhizodus and remains of Eloniclzthys striatus and Callopristodus pectinatus have been found here.

16. St. Anthony's Chapel: Lava 3

Lava 3 is a basalt of Craiglockhart type and the lower part seen around the ruins of St. Anthony's Chapel, is markedly columnar, the individual columns being about 0.7 m in diameter and inclined steeply to the west. Some 5 m above the base of the flow the markedly columnar portion grades into an irregularly columnar portion which is exposed locally at the base of the cliffs to the east of the Chapel. This in turn passes very gradually upwards into the topmost zone of the lava-an assemblage of basaltic blocks lying in a matrix of identical composition. The blocky portion has a marked pyroclastic appearance and most probably originated by the brecciation of the cold crust of the lava by the movement of the still liquid interior. The blocky portion is about 15 m thick. The total thickness of the flow exceeds 25 m.

17. Pulpit Rock: basalt plug, lavas 2, 4

The small parasitic vent of the Pulpit Rock is occupied by a plug of Craiglockhart basalt which forms a prominent cliff high on the eastern slopes of the Dry Dam. Columnar jointing is well-developed, the columns being curved; in the centre of the mass they are more or less vertical but on being traced towards the margin the individual columns approach the horizontal indicating that they have been chilled against the vertical wall of the vent. To the south of the cliff the contact of the plug with Lava 2 is exposed, the lava being much altered in proximity to the junction. Lava 4, which to the south forms the cliff along the eastern wall of the Dry Dam, also comes into contact with the Pulpit Rock Vent but, being younger, naturally shows no increase of alteration at the contact. The connection between Lava 3 and its feeder-the plug in the Pulpit Rock Vent is still preserved and may be traced on the north side of the vent.

18. Dry Dam: Upper Ash, lavas 2, 4, 5, 6

At this locality the Upper Ash of the Dry Dam is exposed in a number of outcrops. Its base can be observed resting on Lava 2 and its top seen to be covered by Lava 4 which here forms the cliff immediately to the east of the Dry Dam. The ash here is coarse. especially in its upper part. and contains numerous ejected blocks and bombs of basalt. Between Localities 18 and 19, lavas 4, 5 and 6 can be examined. The foremost is a Dalmeny type basalt, the latter two are of

Jedburgh type.

19. Whinny Hill Intrusion

Whinny Hill Intrusion. a small sill, lies between Lavas 6 and 7. The two flows are microporphyritic Jedburgh basalts and present a strong contrast in appearance to the markedly macroporphyritic Craiglockhart basalt of the sill. The sill lies along a hollow between the dip slope of Lava 6 to the west and the scarp of Lava 7 to the east. The feeding pipe of the intrusion cuts Lava 5, another Jedburgh basalt. 45 m to the south-west of the northern extremity of the sill outcrop.

20. Whinny Hill: Lavas 7, 8–10

The return route from Locality 19 lies at first eastwards across the dip slope of Whinny Hill. Here exposures of Lavas 7 (Jedburgh), 8, 9 and 10 (all Markle) can be seen. On reaching the Queen's Drive the road is followed northwards and westwards; roadside exposures of the same flows can be examined in descending order.

The Park can be left either at the Meadowbank or the Holyrood gates.

Excursion C—Lion's Haunch and Lion's Head Vents (Figure 8)

21. Queen's Drive: Samson's Ribs Crater Lavas

The Samson's Ribs crater lavas, exposed in the Queen's Drive, dip towards the centre of the Lion's Haunch Vent. The lowest flow is brecciated throughout and has a slaggy top overlain by a foot of red tuffaceous sandstone. Above comes another lava, again with a slaggy upper surface, and this is in turn succeeded by a third flow. Above this uppermost flow lies the main mass of crudely bedded agglomerate of the Lion's Haunch Vent.

22. Roche moutonnee, glacial striae

From the retaining wall on the north side of the Queen's Drive there protrudes a roche moutonnée. The rock is striated horizontally. the striations tending to narrow towards the cast; some plucking of the eastern end of the mass has occurred. The direction and narrowing of the striations, and the plucking. all point to the existence of a stream of ice moving from west to east through the hollow now occupied by the Queen's Drive. A few yards to the east a slickensided surface occurs by the roadside and can be contrasted with the glaciated surface.

23 and 24. Samson's Ribs Intrusion, agglomerate

A small exposure of columnar Dunsapie basalt occurs on the north side of the Queen's Drive above the retaining wall. The columns, some 20 cm across, plunge southwards. The exposure marks the north-eastern termination of the Samson's Ribs Intrusion, which here cuts the agglomerate overlying the Samson's Ribs crater lavas farther to the west. The main part of the intrusion, which is markedly columnar in nature, is best seen in the cliff below to the Queen's Drive. The north side of the Queen's Drive is here (24) marked by a cliff of coarse agglomerate containing abundant basalt blocks and a lesser proportion of blocks of sedimentary rocks. The basalt blocks are of Dunsapie or Markle type. The matrix in which the blocks lie is a red decomposed basaltic ash.

25. Crater lavas and ash

In the cliff above the Queen's Drive a crater lava of Jedburgh basalt rests on a few metres of ashy sediment which, in turn, lie on agglomerate; the lava and sediment dip towards the north-east at a moderate angle. A small north-south fault repeats the slaggy top of the flow and its covering of agglomerate. Approximately 90 m farther to the north-cast, a crater of lava of mugearite is seen in the cliff above the Queen's Drive. This flow is covered by ashy sediments which are themselves overlain by agglomerate; the dip of the flow is again towards the north-cast. Several small north-south faults cut this mugearite flow.

26. Loch Crag: vent margin, Lava 1, limestone

The southern margin of the Lion's Haunch Vent is exposed above the retaining wall of the Queen's Drive where it can be seen truncating Lava I and the sediments and ashes above and below that flow. The lava forms a low southward facing cliff which can be followed upwards for a short distance from the road until it is cut across by the vent. The actual contact is not seen but can be fixed to within a metre or so. At this point the feeder of the Lion's Haunch Basalt occurs at the vent wall so that the contact is between the sparsely porphyritic Dunsapie basalt of the lava and the highly porphyritic Dunsapie basalt of the feeder. Sediments of the Cementstone Group have been seen below the lava; they are truncated by the vent and lie against agglomerate. Above the lava ash and sediments are visible; they are cut across by the vent which here also contains agglomerate. Blocks of a white limestone identical to a bed seen in situ some feet above the lava. are found sparsely throughout the agglomerates at this locality.

27. Dunsapie Hill: intrusion, mugearite lava

To the east of Dunsapie Hill, a mugearite lava forms a number of small outcrops. The rock is pale purplish-grey and is cut by numerous platy joints. It lies above a Markle flow exposed farther to the south. Both flows are cut by the Dunsapie Hill Intrusion within the Lion's Haunch Vent.

28. Lion's Haunch Basalt

The highly-porphyritic Lion's Haunch Basalt, the remains of a lava-lake resting on the agglomerate which forms the chief infilling of the Lion's Haunch Vent, is well seen in numerous exposures at this locality.

29. Lion's Head basalt, viewpoint

The summit of Arthur's Seat-the Lion's Head-is formed of a glacially moulded basaltic plug which acted as the feeder for Lava 4 and which, on consolidation, blocked the Lion's Head Vent. From the summit the chief geological features of the Lothians and Fife can be clearly seen.

30 and 31. Lion's Head Vent margin, agglomerate

This locality lies at the junction of the Lion's Head Vent and Lava 1. On tracing the lava southwards, it becomes shattered and altered close to the vent and its dip increases from less than 20° to 40°. The actual contact is not visible, but its position can be fixed within a metre. A dyke of Craiglockhart basalt, the feeder of Lava 2, lies within the vent at the junction. On the slope above the dyke the fine agglomerate of the vent is exposed. The agglomerate of the Lion's Head Vent is roughly bedded and has an inwards dip (31). It contains numerous small fragments of Dunsapie and Craiglockhart basalt but no fragments of Markle basalt occur. The small size of the fragments and the absence of Markle blocks distinguish this agglomerate from that of the Lion's Haunch Vent. A large gully, known as the Gutted Haddie, has been eroded along the line of contact between the Lion's Head and the Lion's Haunch vents; some 15 m to the north of this gully a small basalt dyke cuts the Lion's Head Vent.

The return from this excursion can be made either by the Hunter's Bog to the Holyrood Gate or through the low col between the Salisbury Crags and the Lion's Haunch to the Holyrood Park Road Gate.

Excursion D — Calton Hill

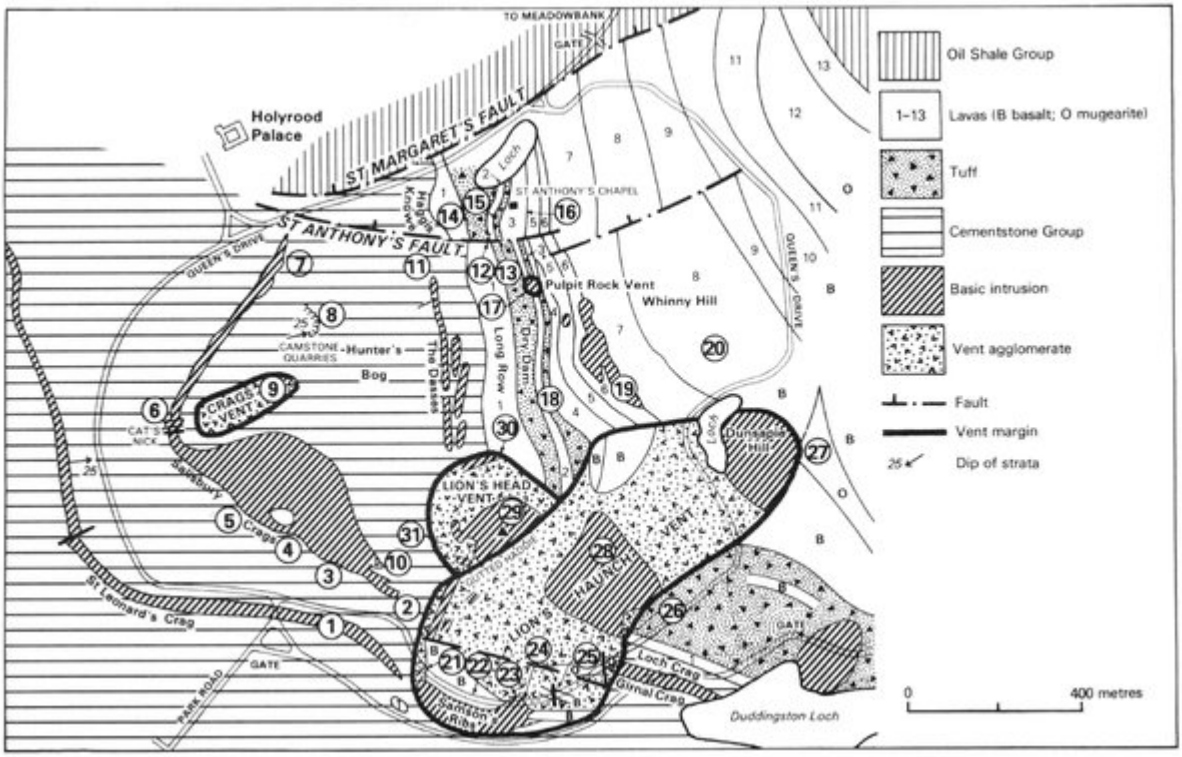
The Calton Hill succession may be easily followed by ascending the steps at the east end of Waterloo Place [NT 261 741] and proceeding eastwards over the hill.

32. Calton Hill: lavas and ashes

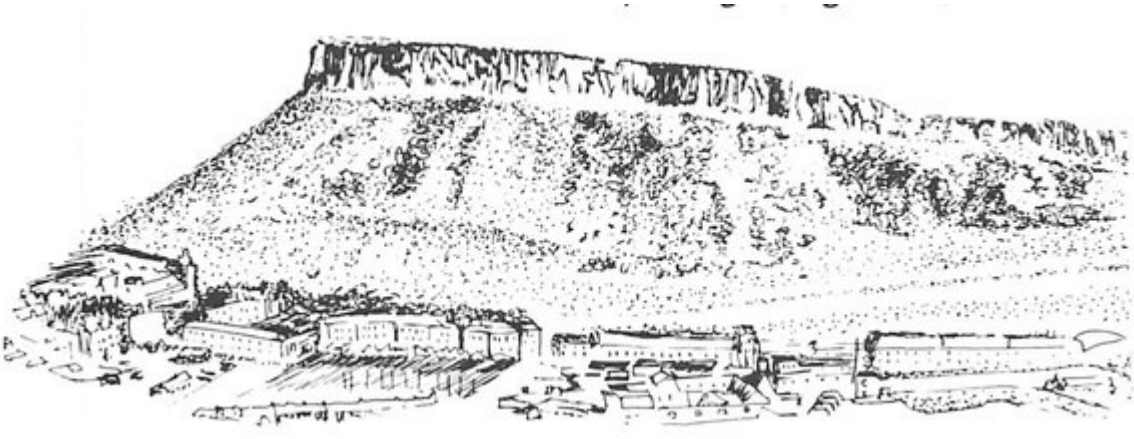
At the base of the succession alternations of ash and sediment occur. These represent the two ash beds of the Dry Dam, for the equivalents of Lavas 1 and 2 of the Whinny Hill are not found on the Calton Hill. Above the ashes lie two lavas of

Craiglockhart basalt, the lower closely resembling Lava 3 of the Whinny Hill. Lavas 4, 5, 6 and 7 of the Whinny Hill are not found, their temporal equivalent being a thick bed of ash containing an unsorted assemblage of boulders, blocks and bombs of basalt. Above this there lies a group of three lavas of Markle basalt separated by thin ash-beds—the local equivalents of Lavas 8, 9 and 10 of the Whinny Hill. On the highest Markle flow lies another ash-bed which, in turn, is overlain by a group of three mugearite lavas, again separated by ash-beds; these flows are the approximate equivalents in time of Whinny Hill Lavas 11 and 12. The highest mugearite lava of the Calton Hill is directly covered by the Abbeyhill Shales.

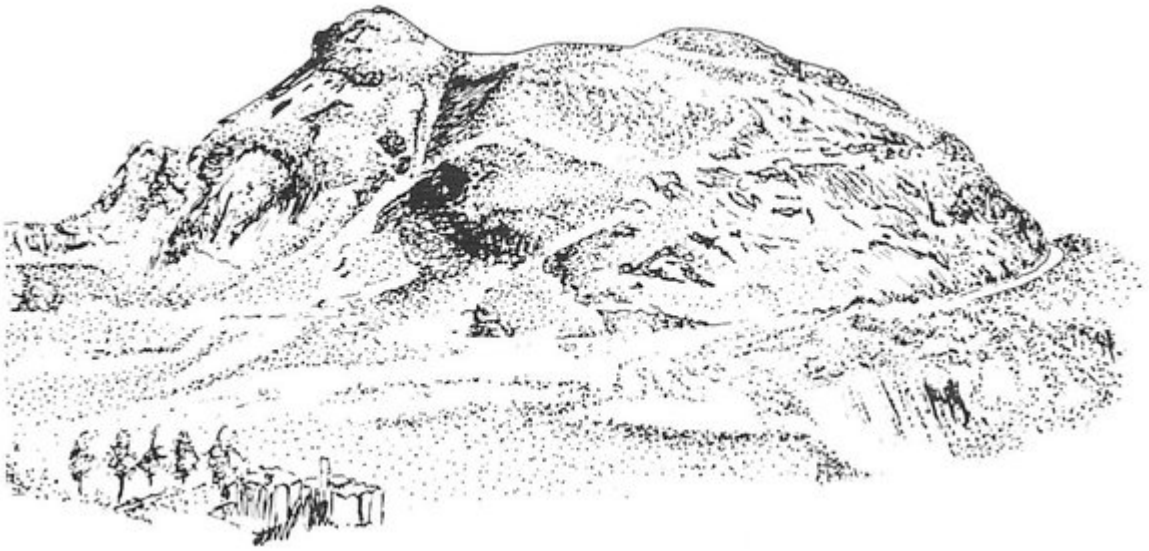
References



(Map 3) Arthur's Seat.



(Figure 6) Salisbury Crags, by C. Anderson.



(Figure 8) Arthur's Seat, by C. Anderson.