

SUPPLEMENT

**The Royal Society of Edinburgh, James Hutton,
the Clerks of Penicuik and the Igneous Origin of Granite**

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Figure 1 Clerk of Eldin's watercolour – Old Bridge of Tilt.

1. John Clerk of Eldin's watercolour, Blair Atholl, 1785

Mauna Kea in Hawaii is the world's tallest mountain – about 1000 m taller than Mount Everest (*Science*, volume 313, 22 September 2006, p. 1732). Near the summit, at an altitude of 4092 m, is the James Clerk Maxwell Telescope (JCMT) – the largest astronomical telescope designed to operate in the sub-millimetre wavelength region of the spectrum. In 1987 the JCMT was dedicated by HRH Prince Philip, Duke of Edinburgh, and named for the physicist James Clerk Maxwell (1831–1879). Sir John Dutton Clerk of Penicuik Bt, CBE, VRD, DL FRSE (1917–2002) represented the family.

On his way to Hawaii, Sir John stayed with us at our home in California. Kind, and generous, he brought thoughtful gifts, including a watercolour by John Clerk of Eldin, James Hutton's invaluable 'friend and coadjutor'. Both Hutton (1726–1797) and Clerk of Eldin (1728–1812) were founding Fellows of the Royal Society of Edinburgh and Members of its first Committee.

The watercolour (Fig. 1) shows distant rectangular fields, which in 2007 are still visible from the village of Blair Atholl.

[The Duke's title '*Atholl*' is spelled with two 'l's. According to Derick S. Thomson, Editor of *The Companion to Gaelic Scotland* (1983, p. 231), '*Atholl* is derived from *Athphodla* (New Ireland) – significant as a genuine early Gaelic name in what had been Pictland). The name is recorded in the Irish Annals in 740.' Gaelic remained the language of the area through the 1880s, but was much reduced during the First World War.

As the area was formerly Pictish, the name has sometimes been considered of Pictish origin and spelled with a single letter 'l' or 'le.' According to *The Encyclopaedia Britannica* (1929, vol. 2, p. 627): 'The district (Atholl or Athole) is said to have been named Athfotla (Athol) after Fotla, son of the Pictish king Cruithne, and was under the rule of a Celtic *mormaer* (thane or earl) until the union of the Picts and Scots under Kenneth Macalpine in 843.'

It is also suggested that the various spellings possibly came about by interpretation of the spoken word by a writer or scribe. It is also possible that individual characters in the hand-written word could be mistaken: e.g. a lower case 'l' could look like an 'e' – so that a double 'll' might become 'le'.]

On a path in the wooded foreground a man looks towards the bridge that spans the gorge of the River Tilt. On the reverse John Clerk of Eldin had written 'Bridge of Tilt, Blair in Atholl'. Sir John explained that he had chosen this picture because I had told him that Hutton had found granite veins below a bridge in Glen Tilt. Although the Dail-an-eas Bridge ['Waterfall' Bridge] – where Hutton found granite veins – is seven miles up the Glen, and now destroyed (Fig. 2), the scene is consistent with Hutton's account, and it seems clear that the watercolour was painted in 1785 when Hutton and Clerk were guests of the Duke of Atholl.

I have been privileged to take three generations of the Clerk of Penicuik family to the spot where their artistic kinsman had worked. In 2007 the bridge in the painting still carries the road over the Tilt to Old Blair and Blair Castle. A footpath from the Castle passes through woodland and crosses the road by a private arched foot-bridge that leads to the path in the foreground. Hutton called the scene 'the woody dean within the policy, above the house of Blair'. In Scotland 'Dean' is a small or deep wooded valley; 'policy' (often 'policies') refers to planted and embellished pleasure grounds beside a country seat or mansion house.



Figure 2 Dail-an-eas [Waterfall] Bridge, Glen Tilt – the bridge is now in ruins.

A man – presumably representing Hutton – stands at an easily identified bend of the path. I first knew this path in the 1930s, when as children we were warned that it was strictly for the private use of the Duke and Duchess and their guests. In 1785 Hutton and Clerk were guests at the House of Blair.

2. 'Blair Castle' [today] versus the 'House of Blair' [Hutton]

Blair Castle is the seat of the Duke of Atholl. During the 1745 Rising, James Murray (the 2nd Duke) supported the Hanoverian Government while his elder brother (William) and two younger brothers (Charles and George) were prominent Jacobites [supporters

of Prince Charles Edward Stuart]. In 1745 the Duke fled, leaving his attainted older brother, William, to take possession of the Castle. When the Prince led the Jacobite army south, Blair Castle was garrisoned by Hanoverian soldiers. The youngest brother, Lord George Murray, Lieutenant-General of the Jacobite army, laid siege to the Castle – it was the last time a British Castle was besieged. William was one of the seven men who accompanied the Prince from France, and was privileged to unfurl the Prince's flag at Glenfinnan. William was betrayed by a false friend and died in the Tower of London in 1746.

The Duke later remodelled the building, removing the battlements and turrets to transform the castle into a house; so that when Hutton and Clerk stayed there they called it 'the house of Blair'. In 1868 the 7th Duke restored the Castle to something like its former appearance.

Lord George Murray's son, John, succeeded his uncle as the 3rd Duke, and when Hutton and Clerk visited in 1785, their host was the 30-year-old 4th Duke, John Murray (1755–1830) who had succeeded his father in 1774. It is interesting to reflect that Hutton was entertained by the grandson of Prince Charles' Lieutenant-General. Two years after Hutton's visit, Robert Burns spent two nights at 'Athole-House'. The Duke was away, and Burns was welcomed by the Duchess. Although Burns' poem *The Humble Petition of Bruar Water* is written about the Falls of Bruar on the Atholl estate, it is thought that some of the images may have been suggested by the River Tilt. William and Dorothy Wordsworth visited Blair Atholl in 1803. Before going on to Bruar, they rested on the same seat overlooking the Tilt where Burns had sat five years earlier.

3. John Clerk of Eldin's *Journey to the North, August 1779*

A hand-written notebook records the author's observations as he travelled north via Stirling, Callender, Killin, and Taymouth, to Dalnacardoch (15 km WNW of Blair Atholl), where he recorded that 'The **River Garry** has **cut a run or Trough** over the **mettals** [*sic*] which run right **across**. At this place a Granite dike with smooth red spots runs across the River SW making a Water Fall. Took a specimen.' [The words in bold-face were later repeated by Hutton.]

Leaving Dalnacardoch, Clerk travelled north to Inverness and east to Portsoy, where he collected graphic granite. These specimens convinced Hutton that granite was igneous – and granite veins later provided confirmation. Hutton concluded that quartz and feldspar had crystallised from a molten mixture (*Theory of the Earth*, 1795, vol. 1, pp. 104–110). Graphic granite is, in fact, the result of roughly simultaneous crystallisation, although this was not demonstrated in the laboratory until 200 years later (Fenn 1986).

It may have been either on this journey in 1779, or with Hutton in 1785, that Clerk sketched the porphyry sill at Dalnacardoch and the porphyry dyke below General Wade's bridge at Dalnamein, 4 km ESE of Dalnacardoch. (Fig. 3; See Dennis Dean's edition of Hutton's *Theory of the Earth*, Vol. 3, opposite p. 22.)



Figure 3 Dalnacardoch vein discovered by Clerk of Eldin – this led to Hutton's visit to Glen Tilt. Width of view = c. 70 cm.

4. Hutton on Granite

Hutton believed that all layered or stratified rocks, including the greywackes of the Southern Uplands and the schists of the Highlands, were formed by the consolidation of debris from older rocks, but he was unsure about granite. The generally accepted

view was that granite was the oldest of all rocks, precipitated from a primeval ocean under conditions unlike any prevailing today.

‘When Hutton’s first sketch of his *Theory of the Earth* was read to the Royal Society [of Edinburgh] in the spring of 1785 he had never seen granite in place save cursorily at Peterhead and Aberdeen.’ (Archibald Geikie: Editorial Note on Hutton, Vol. 3, 1899 Note p. 1)

In Hutton’s words he ‘had travelled every road from Northumberland . . . to Edinburgh, and every spot from sea to sea . . . from Edinburgh . . . to the Pentland Firth without seeing one block of granite in its place. . . . It is true, I met with it on my return by the east coast, when I just saw it and no more, at Peterhead and Aberdeen; but that was all the granite I had ever seen [in situ] when I wrote my *Theory of the Earth*’ (Vol. 1, pp. 213, 214)

Hutton’s recognition of the igneous origin of granite was discounted because he had seen so little of it in the field. But John Clerk of Eldin had collected *graphic granite* at Portsoy in August 1779, and his specimens convinced Hutton that it was igneous:

‘The species [of granite] now to be examined comes from the north country, about four or five miles west from Portsoy, on the road to Huntly. I have not been upon the spot, but am informed that this rock is immediately continuous with the common granite of the country. This indeed appears in the specimens which I have got; for in some of these, there is to be perceived a gradation from the regular to the irregular sort. . . . But what I would here more particularly represent is the transverse section of those longitudinal siliceous bodies. They have not only separately the forms of certain typographic characters, but collectively give the regular lineal appearance of types set in writing. . . . Upon the whole, therefore, whether we shall consider granite as a stratum or as an irregular mass, whether as a collection of several materials, or as the separation of substances that had been mixed, here is sufficient evidence of the body having been consolidated by means of fusion, and in no other manner.’ (*Theory of the Earth*, Vol. 1, 1795. pp. 104–109; figs 1–10)

Hutton was convinced that granite was igneous, although it was another 200 years before graphic granite resulting from roughly simultaneous crystallisation was demonstrated in the laboratory (P. M. Fenn 1986).

5. Opposing views about The Origin of Granite

Because granite is commonly found in mountainous terrain, it was thought to be the oldest rock. Indeed on Hutton’s extensive journey through Scotland he saw almost no granite outcrops – for the simple reason that granite forms hills (e.g. the Cairngorm Mountains) that roadways avoid.

Hutton argued that if granite is the oldest rock, fragments might be found in adjoining, younger rocks; but if granite is an igneous intrusion veins of granite might be found penetrating adjacent older rocks. If Hutton’s conjecture is correct ‘some confirmation of it must appear at those places where the granite and the strata are in contact, or where the former emerges from beneath the latter. In such situations, one might expect veins of the stone which had been in fusion to penetrate into the stone which had been solid; and some imperfect descriptions of granite veins gave reason to imagine that this phenomenon was actually to be observed. [John Clerk of Eldin discovered granite veins in the River Garry in 1779.] Dr Hutton was anxious that an *instantia crucis* [crucial instance] might subject his theory to the severest test’. (Playfair 1805, p. 67)

6. Hutton’s Methodology

When experimentation is not possible, we must judge between two conflicting conjectures by predicting possible observations that would be consistent with the one and inconsistent with the other, and then selecting sites where such observations might reasonably be supposed to be made. This is what Hutton meant when he headed a section of his book: ‘The Theory confirmed from Observations made on purpose to elucidate the subject’ (Hutton, *Theory of the Earth*, 1795, Vol. 1, p. 453)

Revisionist historians who condemn Hutton’s methodology fail to do him justice and are, in my opinion, mistaken. Stephen Jay Gould, for example, asked rhetorically whether Hutton based his theory on observations, ‘as the usual story goes’. Gould’s response is: ‘Hutton’s countryman, the great Scottish geologist Sir Andrew [sic! – should be ‘Archibald’] Geikie, gave this common myth its strongest support in his 1905 volume, *The Founders of Geology*. . . . Geikie’s heroic Hutton gathered his facts by the method that provides both the strength and mystique of geology – field work’.

Gould continues: ‘This Hutton matches the idealized image of geology presented to generations of students, but it bears little relation to the original. To be sure, Hutton did not remain perennially in his armchair. He made excursions and saw many things. His observations no doubt inspired and instructed him; but we can show, also without doubt, that fieldwork was not the source of his theory. For his two key observations, the chronology of the official myth is backward. Hutton saw his first angular unconformity after he had presented his full-blown theory in public. Moreover, by his own admission, he had observed granite in only one uninformative place before publishing his theory. Fieldwork, at best, provided confirmation for a theory developed elsewhere.’ (Gould 1984, p. 89.) Gould was apparently ignorant of Hutton’s study of the Portsoy graphic granite.

Herries Davies is confident about Geikie’s motivation:

‘It was Geikie who misled us, and he misled us deliberately, because when he penned his account of Hutton, Geikie was far less concerned with historical truth about Hutton than he was with the elevation of Hutton to the status of being Scotland’s national geological hero. Being himself a Scot, Geikie was delighted to find in Hutton a fellow country man whose praises he could loudly sing . . .’ (Herries Davies 1985, p. 387)

In support of his case, Herries Davies pointed out that both Hutton and Geikie were raised and educated in Edinburgh. It is therefore appropriate that the author of this paper should admit to being a Scot, born (like his parents) in Edinburgh and educated at school and University in that city. Moreover he is probably the only person who stood by Hutton’s grave in Greyfriars (Edinburgh) in both the anniversary years 1947 and 1997 (150 and 200 years after Hutton’s death).

[Of all the great contributors to the Scottish Enlightenment, Hume, Hutton, and Walter Scott are the only ones who were born and educated in Edinburgh. Hume and Hutton also died there.]

Playfair put it fairly:

‘The truth, indeed, is, that in physical inquiries, the work of theory and observation must go hand in hand, and ought to be carried on at the same time, more especially if the matter is very complicated, for there the clue of theory is necessary to direct the observer. Though a man may begin to observe without any hypothesis, he cannot continue long without seeing some general conclusions arise; and to this nascent theory it is his business to attend, because, by seeking either to verify or to disprove it, he is led to new experiments, or new observations. He is led also to the very experiments and observations that are of the greatest importance, namely, to those *instantiae crucis*, which are the *criteria* that naturally present themselves for the trial of every hypothesis. He is conducted to the places where the transitions of nature are most perceptible, and where the absence of former, or the presence of new circumstances, excludes the action of imaginary causes. By this correction of his first opinion, a new approximation is made to the truth; and by the repetition of the same process, certainty is finally obtained. Thus theory and observation mutually assist one another; and the spirit of the system, against which there are so many and such just complaints, appears, nevertheless, as the animating principle of inductive investigation. The business of sound philosophy is not to extinguish this spirit, but to restrain and direct its efforts.’ (Playfair 1802, pp. 524–525, paragraph 457)

‘Of a geological theory that has stood this double test of the analytic and synthetic methods, Dr Hutton has furnished us with an excellent instance, in his explanation of granite. The appearances which he observed in that stone led him to conclude, that it had been melted, and injected while fluid, among the stratified rocks already formed. He then considered, that if this is true, veins of granite must often run from the larger masses of that stone, and penetrate the strata in various directions; and this must be visible at those places where these different kinds of rock come into contact with one another. This led him to search in Arran and Glen-tilt for the phenomena in question; the result, as we have seen, afforded to his theory the fullest confirmation, and to himself the high satisfaction which must ever accompany the success of candid and judicious inquiry.’ (Playfair 1802, pp. 526–527, paragraph 458)

7. Searching for Granite Veins. Why Glen Tilt?

It is commonly supposed that Hutton realised that granite was igneous after seeing granite veins in Glen Tilt. On the contrary, Hutton went to Glen Tilt because he expected to find granite veins there (Fig. 4).



Figure 4 Red granite veins, Glen Tilt. Width of view = c. 70 cm.

Hutton’s account:

‘Knowing that in the sources of the River Dee there were great granite countries, and that in most of the sources of the Tay nothing is to be found but the alpine schistus, I considered the country between those two rivers as the most proper for discovering the relative state of these two bodies. Having also observed in the bed of the Tay abundance of gravel

formed of granite and porphyry, I doubted not of finding something of what I desired in the north-eastern branches of that river. Mr Clerk of Eldin and I being therefore on a visit to the Duke of Athol [sic] at Blair this harvest [1785], I expressed to his Grace my desire to examine the minerals of his deer-forest, and to visit the mountains from whence the granite rolling in the river came. The Duke willingly entered into our views, and Mr Clerk and I, being nobly supported by the most kind and hospitable assistance, made an agreeable party of pleasure of a thing which would otherwise would have been incommodious and painful.' (*Theory of the Earth*, Volume 3, 1899, pp. 9–11)

Playfair's account:

'When they had reached the Forest Lodge, about seven miles up the valley, Dr Hutton already found himself in the midst of the objects **which he wished to examine**. In the bed of the river, many veins of red granite, (no less than, indeed, six large veins in the course of a mile), were seen traversing the black micaceous schistus, and producing, by the contrast of colour, an effect that might be striking even to an unskilful observer. The sight of **objects which verified at once so many important conclusions in his system**, filled him with delight; and as his feelings on such occasions, were always strongly expressed, the guides who accompanied him were convinced that it must be nothing less than the discovery of a vein of silver or gold, that could call forth such strong marks of joy and exultation.

Dr Hutton has described the appearances at this spot in the third volume of the *Edinburgh Transactions*, p. 79 and some excellent drawings of them were made by Mr Clerk, whose pencil is not less valuable in the sciences than in the arts. On the whole, it is certain that of all the junctions of granite and schistus which are yet known, this at Glen Tilt speaks the most unambiguous language, and most clearly demonstrates the violence with which the granite veins were interjected among the schistus.' (Playfair 1805, pp. 68–69)

John Clerk of Eldin's Account Book for 1785 refers to the 'Expence of a journey to Blair in Athol'. The journey apparently took place after September 10 and before October 8:

'The general direction of those porphyry dykes being east and west, and **from what Mr Clerk had seen upon a former occasion**, there being good grounds to find them traversing the Garry between Blair and Dalnacardoch, where this river runs in a trough cut in the solid rock and in a direction across the stretching of the porphyry, we set out upon this expedition, taking the falls of Bruar in our way. We found among those cataracts a bed or dyke of porphyry but being willing to pursue our chief object, which was the Garry, we proceeded westward; and there we had the satisfaction to discover no less than eleven or twelve of those porphyry dykes intersecting the strata, but sometimes so obliquely, that it is difficult to distinguish them from a parallel bed.' [Bold-face added] (Journey to the North, pp. 22–23)

8. The Woody Dean Within the Policy

[Hutton's *Theory of the Earth*, Vol. 3, pp. 20–23]

[Bold face added for emphasis: words underlined were used by Clerk in his *Journey to the North*, 1779]

'... we found a bed of porphyry eight or ten feet deep, running parallel with the [strike of the] strata of alpine stone in the mountain. This was sufficient information with regard to that subject, for I had before discovered several beds of both grey and red porphyry **in the woody dean within the policy, above the house of Blair**; but as these beds of porphyry at Blair are perfect dykes and veins breaking and traversing the strata, and not running parallel with them, ... We must therefore conclude that besides the granite which has been made to flow in breaking and displacing the strata of the alpine stone, there have been also masses of fluid porphyry interjected among those elevated strata. ... The general direction of those porphyry dykes being east and west, and **from what Mr Clerk had seen upon a former occasion [1779]**, there being good grounds to find them traversing the bed of the Garry between Blair and Dalnacardoch, where this river runs in a trough cut in the solid rock and in a direction across the stretching of the porphyry, we set out upon this expedition.'

John Clerk of Eldin was obviously Hutton's source, for he collected *graphic granite* at Portsoy in August 1779 – This evidence convinced Hutton that granite was igneous, and moreover it was John Clerk's discovery of granite veins at Dalnacardoch that brought Hutton to Glen Tilt.

Professor John Playfair put the relationship well [Bold type added]:

'Mr Clerk [John Clerk of Eldin or Eldin], perhaps from the extensive property which his family had in the coal-mines near Edinburgh, was early interested in the pursuits of mineralogy. ... The interest he took in studying the surface no less than the interior of the earth, his extensive information in most branches of natural history; a mind of great resource, and great readiness of invention; made him, to Dr Hutton, an invaluable friend and coadjutor. **It cannot be doubted that, in many parts, the system of the latter has had great obligations to the ingenuity of the former, though the unreserved intercourse of friendship, and the adjustments produced by mutual suggestion, might render those parts undistinguishable even by the authors themselves.** Mr Clerk's pencil was ever at the command of his friend, and has certainly rendered him most essential service.' (Playfair 1805, p. 97)

9. Clerk of Eldin's sketch map of Tarf and Tilt (Fig. 5)

Sir John asked me to turn the watercolour over in order to read the title in Clerk of Eldin's hand on the back. Doing so I saw a capital Z and other faint pencil marks. Rotating the sheet, Z became N [for North] and I realised that the faint lines formed a sketch-map of the upper reaches of the Rivers Tilt and Tarf. This is the 'remote country' Hutton and Clerk explored in 1785.

This being prime deer-stalking country, it is not readily accessible. I therefore consulted Charlie Pirie, who spent 36 years with the Atholl Estates, the last nine years as head game-keeper at Forest Lodge, the isolated dwelling in Glen Tilt where Hutton and Clerk stayed as the Duke's guests. Mr Pirie generously contributed two large boulders (with granite veins cutting Dalradian schist) for the

memorial at the site of Hutton's Edinburgh home. When Mr Pirie saw the sketch-map he quickly identified the Tarf Bothy [NN926788] on the Feith Uaine Mhor burn that drains into the Tarf.

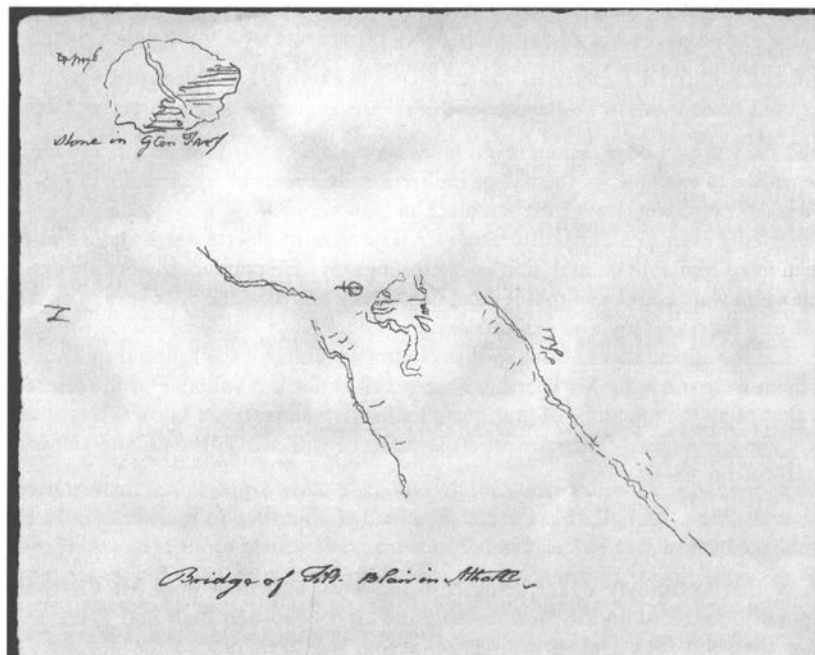


Figure 5(a) Reverse of watercolour, showing title in John Clerk's handwriting and a pencil drawing of 'Stone of Glen Tarf'.

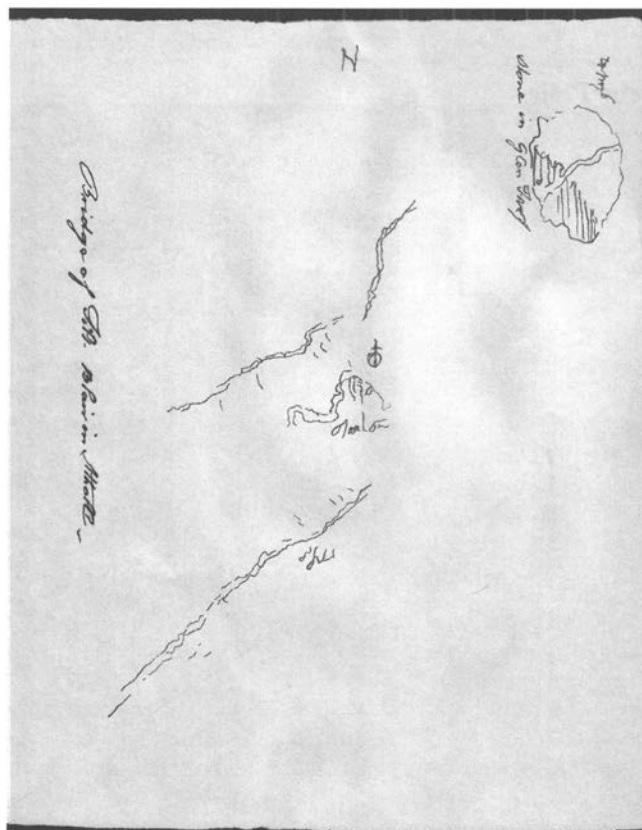


Figure 5(b) Reverse of watercolour turned through 90 degrees to reveal the sketch map, with 'N' for North at the top, of the rivers Tilt and Tarf. The location of "Hutton's boulder" is marked with a cross.

A Glen Tarf boulder as a record of post-granite intrusion

'In this valley of Tarf we had also the satisfaction to find many tumbled stones, composed of broken schistus including granite; . . . One of those pieces of stone had also this particular, of containing a vein which traversed both the mass of granite and broken schistus; consequently here is the proof of another operation subsequent to the fracture of this schistus and the injection of the granite.' (Hutton, *Theory of the Earth*, vol. 3, Chapter IV, p. 19)

As 'The Lost Drawings' were at hand, we were able to confirm that this newly discovered image was the original of *Lost Drawings* (p. 30 Fig. 6 left-hand image) – and that Clerk of Eldin had mistakenly written that it came from the Tilt when in fact it had come from the Tarf. As the Tarf is reckoned a tributary of the Tilt, this may be a fine point, but it is important to know which boulder supports Hutton's claim to have proof of a significant operation 'subsequent to the injection of the granite'. Figure 7 of *The Lost Drawings* (p. 30) [copied in Dennis Dean's augmented reprint of Hutton's Third Volume (1997, opposite p. 19)] is an image of a boulder from the Tarf with the caption 'containing a vein which traversed both the mass of granite and broken schistus; consequently here is the proof of another operation subsequent to the fracture of this schistus and the injection of the granite'. But, despite the assertions, neither source provides evidence of a *post-granite* event. In fact the only evidence of such an event is Hutton's description quoted above and Clerk's drawing on the reverse of his watercolour.

Several attempts were made to get a reproducible image of Clerk's faint markings. In 1992 I took Professor Daniel F. Merriam (Kansas) and Dr Lee Gerhard (then Director of the Kansas Geological Survey) to Glen Tilt. They kindly arranged for Roy R. Mullen, Associate Chief, National Mapping Division, US Geological Survey, to record the image reproduced here. In 2005 Roy Mullen (a fighter pilot during World War II) was selected one of 25 Honorary Members of the American Society for Photogrammetry and Remote Sensing (ASPRS). While with the USGS he was Chief of Photogrammetry, Office of Research and Technical Standards, and was acknowledged as 'leading the agency into the digital era.'

10. Granite Veins in Glen Tilt (Figs 7–11)

Playfair's Biographical Account, 1805, pp. 68–9

'... Dr Hutton having mentioned these circumstances to the Duke of Athol [sic], was invited by that nobleman to accompany him in the shooting season into Glentilt, which he did accordingly, together with his friend Mr Clerk of Elden [sic], in summer 1785.

The Tilt is, according to the seasons, a small river, or an impetuous torrent, which runs through a glen of the same name, nearly south-west, and deeply intersects the southern ridges of the Grampian Mountains. The rock through which its bed is cut is in general a hard micaceous schistus; and the glen presents a scene of great boldness and asperity, often embellished, however, with the accompaniments of a softer landscape.'

Hutton's account: post-granite intrusion, Vol. 3, 1899: pp. 10–26 *passim*

'It is particularly in Glen Tilt that this most interesting part of natural history is to be seen. This glen is a long narrow valley, running in a straight line between two mountains, the sides of which are as steep as is possible for earth and stones to lie. The River Tilt that runs in this valley, discovers in many places the solid rock, which being cut and polished by the stream, presents here and there the most interesting picture or section of the strata. The direction of the valley is almost due SW and NE; the strata, therefore, which stretch in this direction, and present their edges in the bed of the river, are only traversed by the natural windings of the water-course in the valley, or by the irregularities of the strata themselves which are very subject to particular disorders.

On the south side of the glen, the strata are composed of alpine schistus, particularly of granulated quartz and micaceous limestone; and these strata dip into the hill in descending to the south. On the other side of the glen, the steep face of the hill is all covered with lumps of beautiful red granite, not a particle of which is to be seen upon the south side. Here therefore we are in the very spot which we desired, and fortunately for our researches, the river lays bare enough of the solid parts to give the most satisfactory view of what had been transacted in a former period, probably at the time the strata, which were originally horizontal, had been broken and displaced. It must be recollected that the present question regards the granite, how far it is to be considered as a primary mass in relation to the alpine schistus; in that case, fragments of the granite might be found included in the schistus, but none of the schistus in the granite. But besides this point to be ascertained, I had in a preceding part of this work drawn a very probable conclusion concerning the natural history of granite, so far as those masses might be considered as analogous to basalts, or subterraneous lava, in having been made to flow. [See vol. 1, p. 318] We have both those points now perfectly decided; the granite is here found breaking and displacing the strata in every conceivable manner, including the fragments of the broken strata, and interjected in every possible direction among the strata which appear. This is to be seen, not in one place only of the valley, but in many places, where the rocks appear, or where the river has laid bare the strata. . . .' [Hutton's footnote: The Plate exhibits one view of this. It is immediately above the bridge at the Duke's Lodge.]

'In matters of science, curiosity gratified begets not indolence but new desires. We now wished to see the extent of that granite which we had found; and whether it were one continued mass of granite to the River Dee, where perhaps nothing but granite mountains are to be found, at least where chiefly these abound. We had hitherto made the Duke's hunting-lodge in Glen Tilt our headquarters.

His Grace now proposed to remove us farther into the wilderness, and also to entertain us with the deer-hunting in his forest. We travelled up the Tilt, crossed the Tarf which runs into the Tilt, and came to the other hunting seat of Fealar [NO009799], the most removed, I believe, of any in Britain from the habitations of men.' [Note: In Scotland a 'forest' is an extensive tract of unenclosed wild land reserved for deer.]

'Here we were near the summit of the country, where the water runs into the three great rivers, Tay, Spey, and Dee. The Duke was successful in killing three harts and one hind, all in excellent condition; and our curiosity was gratified in finding both the granite and alpine schistus in this summit of the Highlands, between Glen More and Glen Beag.

The Duke's party proposed returning through the forest by the hills which are to the north of Glen Tilt, and we willingly accompanied them, as this was the chief part remaining to be surveyed. We walked up Glen Tarf, one of the highest glens



Figure 6 The author at SE side of Dail-en-eas Bridge near Forest Lodge, 1975 – photograph taken by Professor James Secord (then newly graduated!). Black areas are potholes. Fine veins are being pointed out. Hutton would have crossed the bridge, but to reach the site now it is necessary to wade across the river immediately above the waterfall. This can be dangerous and is often impossible.

in Scotland, running almost parallel to Glen Tilt, for the water of Tarf, running from west to east, turns round at last to the south, and empties itself into the Tilt, which then carries this stream from east to west.

Upon the south side of this ridge, which separates these two parallel valleys of Tilt and Tarf, we have already seen that the alpine strata were at the bottom of the hill superincumbent upon the granite which composes the body of the mountain; here again upon the north side we found a similar appearance, so far as the strata discovered by the Tarf, though stretching east and west as usual, are reclined in the opposite direction to that in which they are found upon the south side of the mountain; so that, as far as we may judge from this appearance, we ought to conclude that on the north, as well as on the south side of this mountainous ridge the alpine strata are superincumbent on the granite mass.

But here we are to draw a very different conclusion from other naturalists, who, seeing the schistus on each side of this ridge of mountain, superincumbent on the granite, would necessarily conclude that the stratified schistus had been formed upon the granite, and in its present place. On the contrary, the schistus strata having been originally formed in a horizontal direction, the granite, certainly interposed among these broken and displaced strata, must be considered as posterior to those strata, notwithstanding that these are found superincumbent on the granite.

In this valley of Tarf we had also the satisfaction to find many tumbled stones, composed of broken schistus including granite, but this granite was in general different from that of Glen Tilt, which is the **most perfect red granite** I ever saw, **whereas that here found [i.e. in the Tarf] is white. One of these pieces of stone had also this particular, of containing a vein which traversed both the mass of granite and broken schistus; consequently here is the proof of another operation subsequent to the fracture of this schistus and the injection of the granite.** [Bold emphasis added]

Clerk of Eldin's 'Lost Drawings' includes engraved images of three boulders (page 30 and facsimiles). The first and second (Fig. 10), said to be from the River Tilt, are dark *Shistus* [sic] cut obliquely by white granite, and the first is subsequently cut obliquely by a vein of *Red Porphyry*. In my opinion there is no doubt that this boulder is the one from the Tarf described by Hutton as evidence of post-granite intrusion.

The third (Fig. 11), which is said to be from Glen Tarf, shows a boulder of schist intersected by a network of irregular, branching granite veins. The accompanying modern text asserts that: 'This stone is the one from Glen Tarf referred to in Volume III, 19: stone . . . containing a vein which traversed both the mass of granite and broken schistus.' This interpretation was accepted in Dennis Dean's augmented edition of Hutton, Vol. 3, opposite pages 10 and 19.

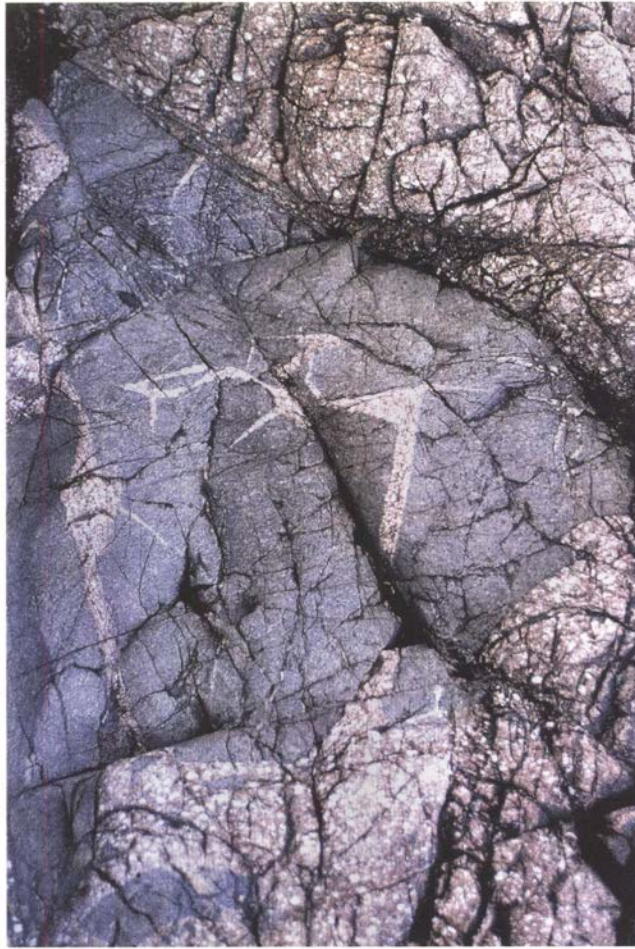


Figure 7 Red granite veins cutting black schist at Dail-an-eas Bridge site. Width of view = *c.* 35 cm.



Figure 8 Red granite veins. Width of view = *c.* 50 cm.



Figure 9 Detail of Figure 8 showing contact of granite with schist.

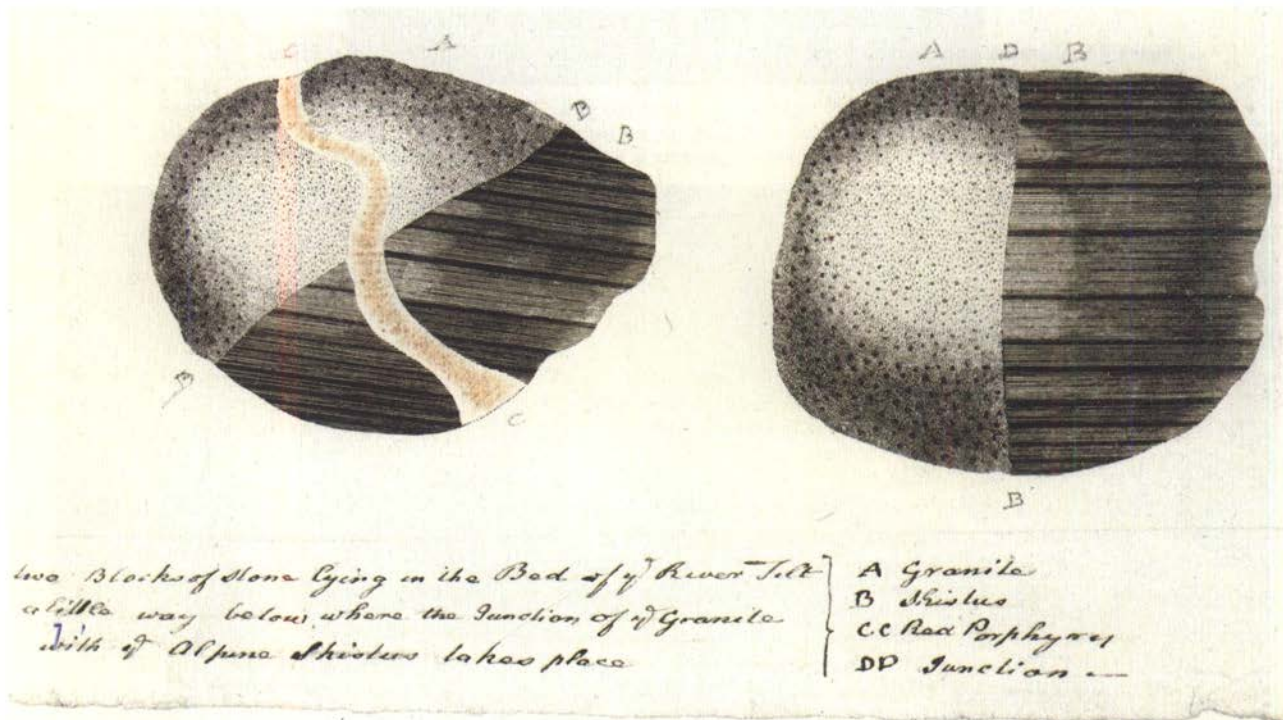


Figure 10 Two boulders drawn by Clerk of Eldin and reproduced in *The Lost Drawings*. The boulder on the left matches “Hutton’s boulder from Tarf” incorrectly referenced by Clerk and *The Lost Drawings* . . . “here is the proof of another operation subsequent to the fracture of this schistus and the injection of granite”.

Hutton rightly described the boulder on the left as ‘proof of another operation subsequent to . . . the injection of the granite’. Another boulder from the Tarf was mistakenly identified as the boulder Hutton described [see Dean’s edition of Hutton’s third volume, opposite p. 19].

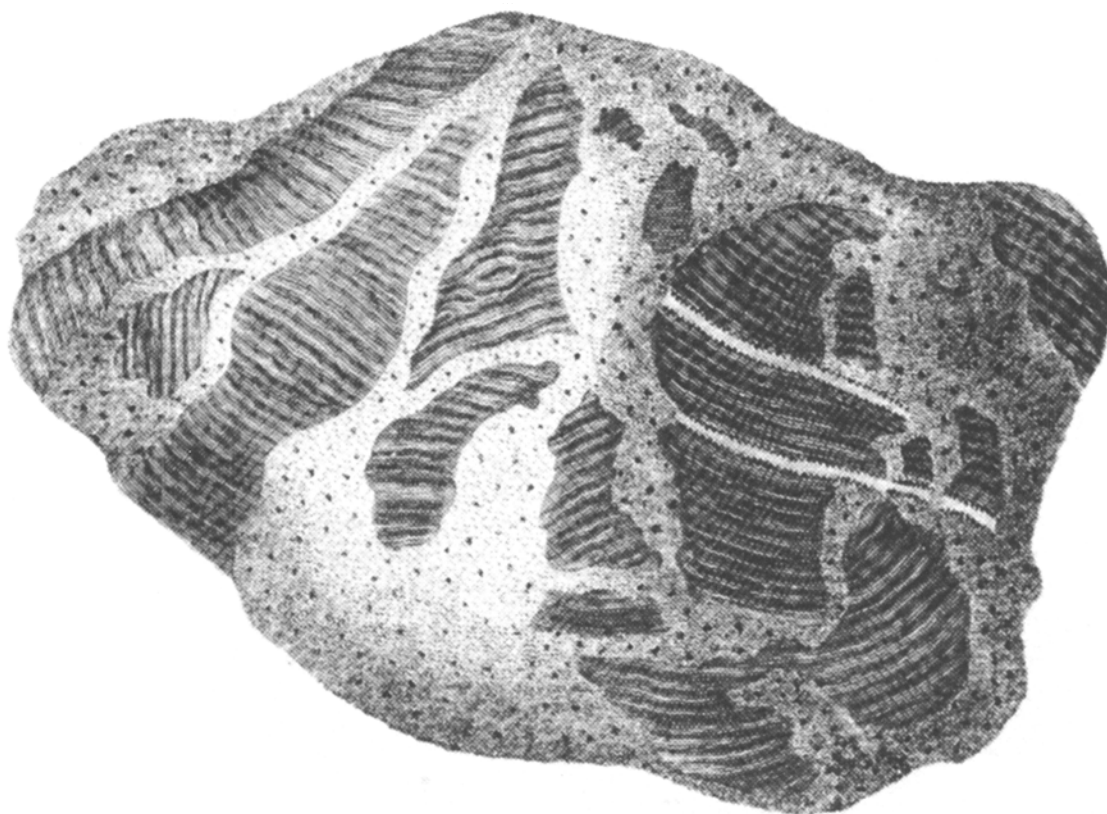


Figure 11 Third boulder incorrectly referred to in *The Lost Drawings* and again in Dennis Dean's augmented edition of *Hutton's 3rd Volume* (opposite p. 19). The reason for these errors is that Clerk ascribed his drawing to the Tilt instead of the Tarf. Hutton's own account of the boulder says [as I have quoted in the present text] that the boulder (a) came from the Tarf, and (b) is evidence of an intrusive event **subsequent** to the intrusion of granite.

11. Hutton (1726–1797), the Clerks of Penicuik and the Royal Society of Edinburgh

James Hutton, John Clerk of Eldin, and George Clerk-Maxwell were Founding Fellows, 17 November 1783.

John Clerk (Lord Eldin) was elected FRSE 26 January 1784.

John Clerk of Eldin (1728–1812)

John Clerk of Eldin provided the graphic granite from Portsoy that convinced Hutton of the igneous origin of granite. His discovery of granite veins at Dalnacardoch led Hutton to Glen Tilt, and he accompanied or followed Hutton on his historic journeys to Glen Tilt (1785), Galloway (1786), and Jedburgh (1787). His field drawings remain valuable tools for geology students.

‘Several years before the time I am now speaking of, he had completed the great outline of his system, but had communicated it to very few; I believe to none but his friends Dr Black and Mr Clerk of Elden [sic]. Though fortified in his opinion by their agreement with him, (and it was the agreement of men eminently qualified to judge), yet he was in no haste to publish his theory; for he was one of those who are much more delighted with the contemplation of truth, than with the praise of having discovered it.’ (Playfair 1805, p. 51)

‘The interest he took in studying the surface no less than the interior of the earth; his extensive information in most branches of natural history; a mind of great resource, and great readiness of invention; made him, to Dr Hutton, an invaluable friend and coadjutor. It cannot be doubted, that, in many parts, the system of the latter has had great obligations to the ingenuity of the former, though the unreserved intercourse of friendship, and the adjustments produced by mutual suggestion, might render those parts undistinguishable even by the authors themselves.’ (Playfair 1805, p. 97)

Sir George Clerk-Maxwell (1715–1784)

John Clerk of Eldin's older brother and 4th Bart. of Penicuik; married his Uncle's daughter, Dorothea Maxwell, and took the name George Clerk-Maxwell. Their great grandson was James Clerk Maxwell (1831–1879).

‘From this time [1754] till about the year 1768, he resided for the most part on his farm, visiting Edinburgh, however, occasionally. The tranquillity of rural life affords few materials for biographical description; and an excursion to the North of Scotland, which he made in 1764, is one of the few incidents which mark an interval of fourteen years, passed mostly

in the retirement in the country. He made this tour with Commissioner, afterwards Sir George, Clerk, a gentleman distinguished for his abilities and worth, with whom Dr Hutton had the happiness to live in habits of the most intimate friendship.

They set out by way of Crieff, Dalwhinnie, Fort Augustus, and Inverness; from hence they proceeded through East Ross into Caithness, and returned along the coast by Aberdeen to Edinburgh. In this journey Dr Hutton's chief object was mineralogy, or rather geology, which he was now studying with great attention. . . . about the year 1768 he left Berwickshire entirely, and became resident in Edinburgh, giving his undivided attention from that time to scientific pursuits.' (Playfair 1805, pp. 45–46)

Anyone as interested in geology as were Hutton and George Clerk would be struck by the prominent basaltic dyke a mile and a half south of Crieff [For a photograph see McIntyre & McKirdy 1997/2002, pp. 26–27]. This is the dyke 'on the road to Crieff' that Hutton refers to in *Theory of the Earth* (Hutton 1788, pp. 278–279). To the east it might be seen to resemble a disused railway embankment, while to the west the driveway to Drummond Castle runs along the top of the dyke.

It seems likely that as early as 1764 Hutton and George Clerk made at least some of the observations that Hutton recorded 24 years later:

'A fine example of this kind may be seen upon the south side of the Earn, on the road to Crieff [25 km west of Perth]. It is twenty-four yards wide, stands perpendicular, and appears many feet above the surface of the ground. It runs from that eastward, and would seem to be the same with that which crosses the river Tay, in forming Campsy-lin [Campsie Linn] above Stanley, as a lesser one of the same kind does below it. I have seen it at Lednoc [Lynedoch, at Dalcrue bridge] upon the Ammon [Almond], where it forms a cascade in that river, about five or six miles west of Campsy-lin. It appears to run from the Tay east through Strathmore, so that it may be considered as having been traced for twenty or thirty miles, and westward to Drummond Castle [4 km south of Crieff], perhaps much farther.' (Hutton 1788, p. 278)

'The origin of this form, in which the trap or whin-stone appears [as dykes] is most evident to inspection, when we consider that this solid body had been in a fluid state, and introduced, in that state, among strata which preserved their proper form. **The strata appear to have been broken, and the two correspondent parts of those strata are separated to admit the flowing mass of whinstone.**' In these words Hutton and George Clerk recognised the igneous origin of dykes – thereby preparing Hutton to consider an igneous origin for granite. (1788, p. 278) [Bold emphasis added]

'Two small veins of the same kind, only two or three feet wide, may be seen in the bed of the Water of Leith, traversing the horizontal strata, the one is above St Bernard's well, the other immediately below it. But, more particularly, in the shire of Ayr, to the north of Irvine, there are to be seen upon the coast, between that and Scarmorly [Skelmorlie], in the space of about twenty miles, more than twenty or thirty such dykes (as they are called) of whinstone. Some of them are of a great thickness; and, in some places, there is perceived a short one, running at right angles, and communicating with other two that run parallel.' (Hutton 1788, pp. 278–279)

John Clerk, Lord Eldin (1757–1832)

Elected FRSE 26 January 1784 and wrote his Uncle's Obituary for the Royal Society of Edinburgh. Following their discovery of granite veins in Glentilt in 1785, Hutton and Clerk of Eldin had a successful exploration of Galloway in 1786, and intended a study of the granite of Arran in 1787.

James Hutton:

'In August 1787, I set out for Arran. Mr Clerk [of Eldin] could not go at that time, and Mr John Clerk, *junior*, was so kind as to accompany me.' (Hutton 1794, pp. 77–81)

Hutton's report on the geology of Arran shows that John Clerk, *junior*, was an able field assistant and draftsman. He inherited skill with pen and brush from his mother, Susannah Adam – daughter of William Adam and sister of Robert Adam, the famous architects.

12. The lost Hutton manuscript

The manuscript of Hutton's *Theory of the Earth* Volume 3 was long lost, but found by chance by Frank D. Adams in the Library of the Geological Society [*Nature* No. 1354, Vol. 52 (10 October 1895) p. 569]. The volume was subsequently edited by Sir Archibald Geikie and published by The Geological Society in 1899. [In the 1940s I bought a copy from the Society for 2 shillings]. Dennis R. Dean edited an excellent edition with the title *James Hutton in the Field and in the Study* (Dean 1997).

13. Acknowledgements

The late Sir John Dutton Clerk, Bt, CBE, VRD, FRSE, of Penicuik who graciously gave me the Clerk watercolour and granted permission to quote from Clerk of Eldin's drawings and manuscripts. Having completed my study of the watercolour, I returned Sir John's gift for safe-keeping in the family archives. Sir Robert Clerk, Bt, OBE, BSc, FRICS, DL of Penicuik, for permission to quote from Clerk of Eldin's drawings and manuscripts. Professor Dan F. Merriam, Geology Department, the University of Kansas, and Dr Lee C. Gerhard, formerly Director, Kansas Geological Survey, who persuaded Roy R. Mullen to reproduce Clerk of Eldin's faint pencil markings on the back of the watercolour. Roy R. Mullen, formerly Associate Chief, National Mapping Division, US Geological Survey. I am also indebted to Professor Colin Graham FRSE (Edinburgh) who in 2006 arranged for a computerised scan of both sides of the watercolour. Charlie Pirie, who knows the Tilt and Tarf rivers better than anyone else. Mrs Jane Anderson, Archivist, Blair Castle. Charles Sievwright, E-computers Perth, for the loan of his professional camera to photograph the

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