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James Hutton's Geological Tours of Scotland: Romanticism, Literary Strategies, and the Scientific Quest

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| Abstract: | <p>Rather than focussing on the relationship between science and literature, this article attempts to read scientific writing as literature. It explores a somewhat neglected element of the story of the emergence of geology in the late eighteenth century - James Hutton's unpublished accounts of the tours of Scotland that he undertook in the years 1785 to 1788 in search of empirical evidence for his theory of the earth. Attention to Hutton's use of literary techniques and conventions highlights the ways these texts dramatise the journey of scientific discovery and allow Hutton's readers to imagine that they were virtual participants in the geological quest, conducted by a savant whose self-fashioning made him a reliable guide through Scotland's geomorphology and the landscapes of deep time.</p> |

**James Hutton's Geological Tours of Scotland: Romanticism, Literary Strategies, and
the Scientific Quest**

James Hutton's Geological Tours of Scotland: Romanticism, Literary Strategies, and the Scientific Quest

In this article I want to explore a somewhat neglected element of the story of the emergence of geology in the late eighteenth century – James Hutton's unpublished accounts of the tours of Scotland that he undertook in the years 1785 to 1788 in search of empirical evidence for his theory of the earth. While Hutton's genre – geological travel writing – can be seen as a hybrid between what we now distinguish as 'science' and 'literature', we need to remember, as Tim Fulford, Debbie Lee and Peter J. Kitson remind us, that these terms had very different meanings at the end of the eighteenth century and that 'scientific' discourses – natural history and natural philosophy – were as much part of 'polite literature' as poetry.¹ Yet, as Ralph O'Connor points out, most studies of the relationship between science and literature – even those which recognise that modern disciplinary designations did not apply in the eighteenth and early nineteenth centuries – tend to reiterate distinctions between these 'disciplines' by yoking them together with the conjunction 'and'.² O'Connor's *The Earth on Show: Fossils and the Poetics of Popular Science, 1801-1856* (2007) is a notable exception in its exploration of the way geological writing of the first half of the nineteenth century employed various kinds of literary strategy in order to gain cultural prestige and persuade readers to accept its extraordinary visions of the earth's past. O'Connor examines 'science *as* literature, rather than science *and* literature', thus restoring scientific writing to the broader notion of literature that prevailed at the time and bringing it within the remit of modern literary critics (*The Earth on Show*, p.15).

O'Connor stresses that reading 'scientific' texts as literature does not necessarily set out to 'expose scientific truth claims as illusory, or to assert that science can be somehow "explained" in purely literary or narrative terms' (p.15). Nor does such a reading imply that there were no perceived distinctions between the literary genres of natural philosophy and what we now call 'imaginative literature'. John Locke's attempt, at the end of the seventeenth century, to establish an absolute difference between philosophical language, whose aim was to 'speak of things as they are', and the deceptive use of figurative language in rhetoric and poetry, echoed the empiricist assumptions of the Royal Society and remained influential throughout the eighteenth century.³ O'Connor notes that 'The pejorative use of words like "poetry", "fiction", "romance", "dream", and "imagination" to denunciate the truth-values of

rival theories was a standard part of the rhetorical armoury of Enlightenment science’ (pp.449-50). Yet despite these rhetorical exclusions, elements of all these literary genres and modes ‘were also used paradoxically to raise geology’s public profile and claims to cultural authority’ (p.450). Given that geology’s claims ‘rested not on experimental demonstration, but on reconstructing the past from fragmentary evidence and developing plausible scenarios’, geological writers of the period ‘found it necessary to use stories to think about and communicate their ideas’. As a consequence, ‘The resulting tension between the repudiation and the cultivation of the poetic imagination can be traced right through geology’s literary history’ (p.450).

In this article I try to follow O’Connor’s lead – and that of the earlier forerunners that he acknowledges, such as Marjorie Hope Nicholson, Gillian Beer, and Noah Heringman – in order to read Hutton’s geological writing as a set of texts that use various literary techniques to persuade readers to accept their revolutionary account of the earth’s geological system. Hutton is particularly interesting in this respect because it has long been a given in the history of geology that his writing was so bad that his geological contributions remained unintelligible until they were transformed into lucid prose by John Playfair’s *Illustrations of the Huttonian Theory of the Earth* (Edinburgh, 1802). In what follows, I want to contest this assumption through a close literary analysis of Hutton’s unpublished geological travel writings that will relate them to recent discussions about the interconnections between geology, Romantic aesthetics and eighteenth-century travel writing.⁴ As Noah Heringman has shown, Romantic literature and geology can be seen as mutually constitutive discourses that emerged out of a shared cultural environment, which included topographic poetry, earth science, landscape aesthetics, travel writing, garden design, and other responses to landscape topography.⁵

In *Bursting the Limits of Time*, Martin Rudwick points out that written accounts of geological travel became newly important in the late eighteenth century as savants attempted to persuade readers to accept their theoretical claims by giving them a sense of contact with geological evidence that could not be brought back to museums:

The more the importance of firsthand field observation was emphasised, the more pressing was the problem of making that experience real and convincing to those who had *not* in fact witnessed what was being described. ... The real witness of certain features had to recount his experience in such a way as to make others ‘*virtual*

witnesses of it; he had to convince them that it was *as if* they too had seen it, so that they might also be persuaded to accept the interpretation or explanation offered for it.⁶

Geologists developed various ‘literary technologies’ for carrying their readers along with them, and often made use of illustrations – or what Rudwick calls ‘proxy pictures’ (*Bursting the Limits of Time*, pp.75-80). O’Connor develops Rudwick’s suggestion by showing how geological writings of the first half of the nineteenth century employed literary techniques and visual reconstructions in order to give readers a sense of being ‘virtual tourists’ who imaginatively shared geologists’ field trips into the landscapes of deep time. In doing so, geological travellers were following a more general tendency in accounts of scientific exploration. As Fulford, Lee and Kitson show in *Literature, Science and Exploration in the Romantic Era* (2004), scientific travel writing such as James Cook’s and Mungo Park’s enabled readers to experience an ‘imaginative participation’ in the journeys they read about and thus to become Romantic ‘mental travellers’ (pp.18, 90-107). In following Hutton’s accounts of his groundbreaking journeys, I will concentrate on the way their use of literary technologies and illustrations conveys the excitement and wonder of scientific discovery, giving readers the sense of being virtual tourists and virtual witnesses both of the geological formations in the field and of the stupendous processes that Hutton conjures up to explain them.

In *Making Natural Knowledge* (1998, 2005), Jan Golinski alerts us to the way the ‘constructivist’ history of science that has emerged in the last twenty years or so seeks to demonstrate that knowledge of the natural world is partly ‘made’ through the deployment of literary techniques and conventions – narrative strategies, genre conventions, figurative language, authorial self-fashioning, the manipulation of aesthetic categories, and so on.⁷ Golinski notes that some strands of the constructivist history of science have used the literary genre theory of Northrop Frye to highlight the literariness of scientific writing (*Making Natural Knowledge*, pp.192-94). The analysis of Hutton’s geological tours of Scotland that follows suggests that they can be read in terms of Frye’s account of quest romance. As we will see, these texts foreground the naturalist-explorer’s excited and arduous search for crucial evidence in the ‘wilds’ of Scotland’s mountainous landscape and repeatedly deploy the narrative dynamics of expectation, disappointment, and eventual success.⁸ Hutton’s narratives are structured as a sequence of minor adventures leading to the main adventure,

and Hutton figures as a heroic male adventurer in pursuit of the secrets of nature (in the form of buried treasure), battles against negative antagonists (other natural philosophers who hold contrary views about the natural world), overcomes difficulties to arrive at truth through a series of natural epiphanies, and brings back precious objects (rock samples and drawings of geological features) found on the quest.⁹ Metaphors of desire, hunting and the uncovering of nature's inner secrets shape the narrative of each tour and give particular resonance to common geological terms such as 'exposures' (places where key geological features are exposed to, or by, the geologist). Such language and strategies generate a vivid representation of the experience of scientific discovery, and enable readers to become virtual participants in Hutton's quest.

In his essay on 'Geological Travel and Theoretical Innovation' (1996), Rudwick offers another, related narrative model for understanding the geological quest – that of pilgrimage. He suggests that groundbreaking geological field trips typically fulfil certain conditions: they involve the geologist leaving behind the familiar intellectual and geological environment of 'home' by undertaking an often arduous journey to an unfamiliar 'liminal' place where he or she encounters new kinds of geological features in a context free from contact with other geologists who might reduce that new evidence to pre-existing paradigms. According to Rudwick, such transformative journeys are analogous to pilgrimages in that the physical and mental experience of travelling to places outside everyday experience can dispose the traveller to new spiritual or intellectual insight.¹⁰ As we will see, Hutton's manuscript accounts of his Scottish field trips foreground the experience of travelling off the beaten track in search of new kinds of geological evidence. His decisive field trips left behind an Edinburgh milieu that was not wholly sympathetic to his emerging theory and took him, with one or two supportive companions, into fairly remote Scottish landscapes where his discovery of striking geological features enabled him to develop his theory in innovative ways.

For Hutton, as for other writers of scientific travel writing, travel becomes both a means of, and a metaphor for, scientific exploration. Hutton's unpublished geological tours can thus be situated in the tradition of scientific travel writing represented by figures such as James Cook, Alexander von Humboldt and Charles Darwin.¹¹ Hutton's tours can also be related to the 'discovery' of Scotland that was undertaken by military surveyors, artists, writers and

travellers in the second half of the eighteenth century – by figures such as Paul Sandby, Thomas Pennant, and Samuel Johnson.¹² Like much of the period's travel writing about the mountainous regions of Scotland (by writers such as Sarah Murray and John Stoddart), Hutton's manuscripts record and evoke sublime experiences, but such aesthetic affects and responses are triggered not so much by the rugged topography itself as by the way his reading of its geomorphology opens up the 'dark abyss of time'.¹³ Hutton's texts thus add another dimension to established aesthetic responses to Scotland by locating spots of deep time in the Scottish landscape.¹⁴ Furthermore, Hutton's discovery of key geological sites in Scotland made those locations into places of geological pilgrimage, field centres and field trips. Scotland, in Hutton's narratives, becomes a core location of the geological history of the earth and the history of geology at one and the same time.

Hutton's Emerging Theory of the Earth

In 1785, Hutton began to make public the outline of a geothery that he had been developing over the previous twenty years or so. As Rudwick demonstrates, geothery was a genre which sought to develop a theoretical model that would explain the system and causal development of the earth's geomorphology in a way that would emulate Newton's theory of the solar system (*Bursting the Limits of Time*, pp.133-39). Most geotheries of the period were variants of 'Neptunism', whose characteristic assumption was that the rocks and landforms of the earth had been created beneath a primeval universal ocean and that most rocks, apart from those produced by the odd volcano, were chemical precipitates or sedimentary deposits whose sequence revealed the order of their formation. Rudwick calls this the 'standard model' (*Bursting the Limits of Time*, pp.172-80) and spends some time elaborating two of its most influential versions – Georges Buffon's 'Des époques de la nature' (1778), and Jean-André de Luc's *Lettres physiques et morales* (1779) (*Bursting the Limits of Time*, pp.139-58). Hutton's geothery broke with the Neptunist model in several fundamental ways. For Hutton, the primary agency in the production of rock materials was not oceanic precipitation but subterranean heat and pressure, and the landmasses had not emerged from the subsidence of the primeval ocean but had been raised (and were continually being raised) by the same subterranean forces. (The centrality of subterranean heat to Hutton's theory has led to him being labelled a 'Plutonist'.¹⁵) And while most Neptunist theories (excluding Buffon's in this respect) held that the oceanic formation of the

earth's rocks and geomorphology was completed in the recent or distant past and that the features of the earth were not subject to any further significant change, Hutton argued that rocks and landforms are continuously being eroded by weathering agents, carried by streams and rivers to the bottom of the oceans, consolidated or transformed by subterranean heat and pressure and then uplifted by those forces to become new landmasses. Such processes, he argued, have acted uniformly over a vast timescale and will continue to do so without prospect of an end. According to G.Y. Craig, Hutton's description of this 'geostrophic cycle' constitutes 'possibly the single most important concept in modern geology', and this is the primary reason why Hutton has often been championed as the founder of modern geology – a claim that has not gone unchallenged.¹⁶

Hutton first aired his theory in a paper read to the recently formed Royal Society of Edinburgh in March and April 1785. He then prepared an abstract of this paper – 'Abstract of a Dissertation ... Concerning the System of the Earth, its Duration and Stability' – to be read and discussed at a meeting of the Royal Society in July.¹⁷ Although Hutton's theory was partly based on empirical evidence that he had been gathering for twenty years or so, the 1785 Abstract relies entirely on a rational deduction about the formation of rock materials derived from the principles of physics and chemistry and on a 'moral' argument grounded in assumptions about the wisdom of nature in constantly producing 'a soil, adapted to the growth of plants ... in order to support the system of this living world'.¹⁸ Dennis Dean claims that Hutton failure to offer empirical evidence in this paper, along with its deistic tendencies and apparent suggestion that the earth was eternal, provoked hostility among at least some members of his audience.¹⁹ But although such criticisms appeared in print from 1788 onwards, and although the general tenor of natural history in Edinburgh in the 1780s was not receptive to abstract theorising, there is no direct evidence that Hutton's 1785 paper was criticised in the Royal Society for its lack of empirical evidence.²⁰ Yet it is notable that shortly after the presentation of his paper in July Hutton embarked on the first of a series of geological field trips in quest of evidence to support his theory. Between 1785 and 1788, Hutton explored Glen Tilt in the Highlands just south of the Cairngorms, the Southern Uplands of Galloway in south-west Scotland, the island of Arran in the Firth of Clyde, the Jed Water south of Jedburgh in the Borders, and Siccar Point on the coast of Scotland to the east of Edinburgh.²¹ Accompanying Hutton on these tours was a variety of friends and

colleagues, including Sir James Hall, John Playfair and John Clerk of Eldin, the latter of whom made a series of drawings of the landscapes and geological structures that they saw.

In addition to exploring the Glen Tilt region in the summer of 1785, Hutton found time to rewrite his Royal Society paper, which was published as an author's separate sometime after January 1786 with the new title of 'Theory of the Earth; or an Investigation of the Laws Observable in the Composition, Dissolution, and Restoration of Land upon the Globe' and then republished in the first volume of the *Transactions of the Royal Society of Edinburgh* in 1788.²² This article represents a significant development beyond the 1785 Abstract, offering a vision of the seemingly endless repetition of the geostrophic cycle that concludes with the most famous and controversial sentence Hutton ever wrote: 'The result, therefore, of our present enquiry is, that we find no vestige of a beginning, – no prospect of an end' (*TRSE*, I., 304). Yet Hutton's 1786/8 'Theory of the Earth' does not mention his tours of Scotland or the evidence he was beginning to gather on them. It wasn't until the publication in 1795 of the first two volumes of *Theory of the Earth, with Proofs and Illustrations* that Hutton made explicit use of some of the evidence from the Scottish tours.²³ Even then, however, he reserved the full accounts of his tours for a projected third volume of *Theory of the Earth*. Hutton's death in 1797 prevented that, thus allowing critics ever since to attack him for failing to support his theory with adequate empirical evidence.

Hutton's manuscript material for the third volume of *Theory of the Earth*, including three chapters devoted to his tours of Glen Tilt, Galloway and Arran, remained unpublished until 1899 when Archibald Geikie, Professor of Geology at Glasgow University, edited that material for the Geological Society of London.²⁴ Hutton had intended to use Clerk's drawings and watercolour sketches as illustrations for the third volume, but most of them went missing after Hutton's death and were not available to Geikie. Fortunately, the so-called 'lost drawings' were rediscovered in 1968 by John Clerk of Penicuik, one of Clerk's descendents, and published in 1978 in *James Hutton's Theory of the Earth: The Lost Drawings*. (The black and white reproductions given below of some of Clerk's images fail to do justice to the exquisite colouring of the originals, facsimiles of which can be seen in the folder that accompanies *The Lost Drawings*.) The availability of Geikie's edition of the material intended for the third volume of *Theory of the Earth*, together with Craig's edition of the 'lost

drawings', helps us to reconstruct Hutton's Scottish travel writings as he originally envisaged them.

In Quest of Granite Intrusions

Hutton initially undertook his tours of Scotland in order to find and examine places where the granite of Scotland's mountains was juxtaposed with other rock materials – especially what he called 'schistus'. As Geikie points out, 'Under the term "schistus," Hutton included not only what are now discriminated as "schists," but also all rocks associated with the schists and possessing a bedded character, such as quartzites and limestones. He also applied the same term to the highly inclined and contorted greywackes, grits and shales (Silurian) of the Southern Uplands of Scotland' (p.6, note). Hutton anticipated that exposed granite-schistus junctions would reveal granite veins running through the overlaying or adjacent stratified rocks. Such features would confirm, he believed, that granite is an igneous rock and that it had been forced into the surrounding rocks in a molten state by subterranean heat and pressure.²⁵ This would in turn support his theory that those forces were the main agents in the formation of rock materials and the uplift of landmasses. It would also, incidentally, undermine the Neptunist claim that granite was a primary sedimentary rock. Hutton, then, was in search of evidence to support a theory, and as a consequence his written tours are structured as quest narratives shaped by desire. As we will see, however, Hutton also found evidence that he was not expecting – junctions between stratified rock formations that exhibited 'unconformity' – and that allowed him to elaborate his theory in spectacular ways (for Hutton's account of unconformities, see below).

Observations Made in a Journey to the North Alpine Part of Scotland in the Year 1785

In the summer of 1785 Hutton and Clerk, as guests of the Duke of Athol, explored Glen Tilt and the surrounding area of north-east Perthshire in the Scottish Highlands. Hutton begins his written account of the tour, which was intended to form chapter four of the projected third volume of *Theory of the Earth*, by claiming that in the Grampian Mountains of north-east Perthshire 'is to be found everything requisite for establishing a natural history, not only of this, but of every other alpine country' (*Theory of the Earth*, vol. III, p.4). Hutton spells out why this part of the Highlands might be regarded as typical of the geological make-up of mountain

regions in general and how the evidence he found there reverses prevailing assumptions about the creation of mountains and the order in which different rock materials were formed:

the Highlands of Scotland, as well as the Alps of Switzerland, Savoy and other alpine countries, may be considered as composed of two things, mountains of schistus and mountains of granite. Some naturalists consider these mountains as being the primitive parts of the globe, or as having no origin from whence we may derive them in the operations of the globe; while others, here acknowledging a species of stratification, suppose them only to be primary in relation to other strata of which we certainly know the origin. In this case of primary and posterior, naturalists have thought to distinguish granite as being the primary in relation to the schistus mountains which they thus suppose as having been formed posterior to it; but as I have just now found evidence of the contrary in a journey which I have made to the Highlands, it will not be unacceptable to the public to know the state in which those things are found and to be informed of the place where any naturalist, who is willing to be satisfied from his own examination, may have an opportunity of gratifying his curiosity, and perhaps discovering something interesting to science and useful to those philosophers who enquire into the origin of things. (pp.8-9)

The place where any natural philosopher might find decisive evidence about the origin of things is the ‘long narrow valley’ in which the River Tilt ‘discovers in many places the solid rock, which being cut or polished by the stream, presents here and there the most interesting picture or section of the strata’ (p.11). Hutton and Clerk travelled with the Duke of Athol and a hunting party to Forest Lodge, about ten miles up Glen Tilt, where Hutton found abundant evidence in support of his theory that granite is a younger rock than schistus and of igneous rather than sedimentary origin:

We have both these 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. (p.13)

One of the things to note here is the suggestion that nature itself – here the River Tilt – sometimes ‘discovers’ or lays bare its secrets, willingly presenting ‘exposures’ to the naturalist. As we will see, Hutton’s written tours are shaped by the desire both to discover geological evidence that has been uncovered by natural forces (such as streams) and to remove the covering (such as moss) with which nature has concealed such evidence.

One of Clerk’s images of Glen Tilt (Figure 1) shows granite veins in the river boulders, but it also exaggerates the steepness and rugged nature of the mountain slopes on either side, thus

representing the glen as a sublime mountain wilderness and implicitly figuring himself and Hutton as heroic explorers:



Figure 1: View of Glen Tilt (John Clerk of Eldin, 1785).

Although Hutton is reporting his discovery of crucial evidence in support of his theory, his prose is notably restrained at this point. Yet he goes on to suggest that curiosity and desire play a central role in scientific exploration and that they are not satisfied but whetted by the discovery of apparently decisive evidence:²⁶

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 head-quarters. His Grace now proposed to move 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, the most removed, I believe, of any in Britain from the habitations of men. 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 Beg. (pp.16-17)

Hutton stresses that the hunt for the geological secrets of the earth, which is analogous to the hunting of deer, led them still ‘farther into the wilderness’ to the most remote hunting lodge in Britain. As Rudwick’s model would predict, in this liminal space, far removed from the physical and intellectual environment of Edinburgh, Hutton discovered evidence that challenged the fundamental assumptions of Neptunist geology.

Hutton’s finds in Glen Tarf revealed that granite is not the only rock that may be forced into schistus in a molten state under pressure. He notes, for example, ‘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’ (p.21). Hutton found a boulder in Glen Tarf, weighing about four hundred pounds (about 180kg), which contained ‘a vein which traversed both the mass of granite and broken schistus’ (Craig, *The Lost Drawings*, p.19) and had it transported to his house in Edinburgh; Clerk’s drawing (see Figure 2) would have allowed Hutton’s readers to see a proxy image of the evidence for themselves.²⁷

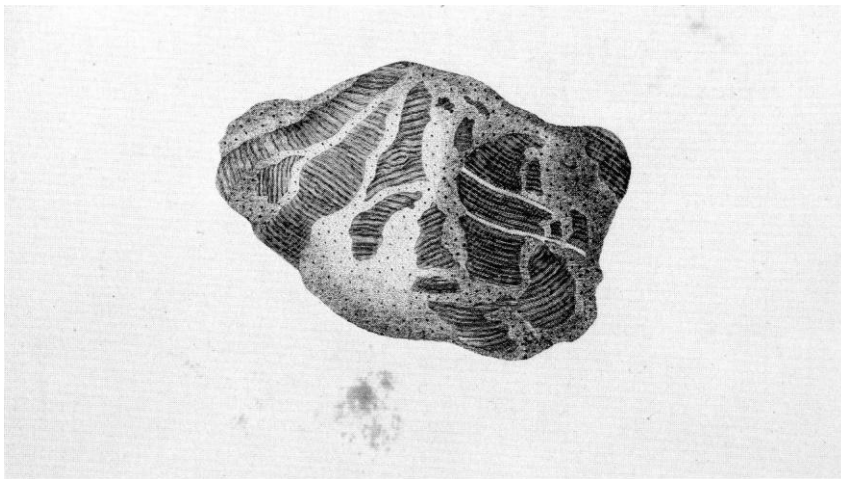


Figure 2: Boulder from Glen Tarf (John Clerk of Eldin, 1785).

Such finds enable Hutton to conclude that ‘our alpine country consists of indurated or erected strata of slate, gneiss, and limestone, broken and injected with granite and porphyry’ (p.24). He thus repeats with new confidence the conclusions he had arrived at in his 1785 paper. In the Highlands of Scotland, as in the rest of the world, ‘Nature acts upon the same principle in

her operations, in consolidating bodies by means of heat and fusion, and by moving great masses of fluid matter in the bowels of the Earth' (pp.25-26).

Hutton then turns his attention to another aspect of his theory – the claim that uplifted landmasses are gradually and continuously eroded by weathering agents over enormous periods of time and that the detritus is carried away by rivers and deposited on the sea bed (where it is eventually consolidated into new rock materials). Hutton's observation in and around the River Tay at Dunkeld of elevated river plains and rounded stones that could only have come from Glen Tarf is interpreted as

evidence of the long succession of time upon this elevated country, and great operation of water, in wasting and wearing the materials of this high land, in forming the valleys between the mountains, and carrying an immense mass of matter from the summits of those mountains into the sea. It must not be alleged that this is too great an effect for the operation of this river, which from the longest records of our history makes but trifling alterations upon its bed; neither must it be supposed that this had been the effect of some great catastrophe which may have happened to the globe (pp.28-29).

Hutton's tour of the Glen Tilt area in the summer of 1785 thus yielded what he took to be decisive evidence in support of two of the main aspects of his theory of the earth – the existence and operation of subterranean heat and pressure in forming igneous rocks and raising landmasses, and the slow-motion, long-term processes of erosion by the action of water. Although such exciting evidence is not mentioned in Hutton's 'Theory of the Earth' separate that was published a few months later in early 1786, it may well have influenced the confident manner in which Hutton's articulates that theory.

Observations made in a journey to the South Alpine parts of Scotland, in the year 1786

Hutton's account of his exploration of the Southern Uplands of south-west Scotland in 1786, intended as chapter five of the third volume of *Theory of the Earth*, begins by explaining that the evidence that he had found in and around Glen Tilt had stimulated rather than satisfied his desire to find further proof in other parts of Scotland:

Accordingly, in harvest 1786, I set out with Mr. Clerk of Eldin, who now entered warmly into the investigation; and having in view to examine also the granite of Arran, we went by Glasgow. But finding it too late in the year for exploring the mountainous region of that island we contented ourselves with making a circuit of the coast, from Glasgow round the shires of Ayr and Galloway. (pp.31-33)

This mention of Hutton's frustrated attempt to explore Arran is the first element of a narrative thread that runs through these manuscript chapters: the desire to visit the island is long-standing and heightened by several deferrals. When Hutton eventually fulfils his desire, as we will see, he finds on Arran a landscape whose geomorphology allows him to read the geological story of the whole planet across colossal time scales.

At the outset of their circuit of the coast of south-west Scotland, Hutton and Clerk were told at Newton Stewart that local people, even the overseers of mines, had not found granite in the region and could therefore offer them no help in their quest. Left to their own devices, Hutton and Clerk soon notice indications that they might find granite-schistus junctions on 'Cairns Muir, a great round mountain, exposed immediately to view from that part of the road upon the coast. Therefore being now determined, we put up our chaise at the village of Ferrytown, and procured horses and a guide to conduct us through the muir in pursuit of the object which we had in view' (p.44) In describing their exploration of this 700 metre mountain, Hutton emphasises that the geologist's desire to see and know is at once impeded and excited by the way nature sometimes resists and sometimes fulfils that desire:

To a naturalist nothing is indifferent; the humble moss that creeps upon the stone is equally interesting as the lofty pine which so beautifully adorns the valley or the mountain: but to a naturalist who is reading in the face of rocks the annals of a former world, the mossy covering which obstructs his view, and renders indistinguishable the different species of stone, is no less than a serious object of regret. Such was our case, in viewing a mountain which seemed as if cut asunder in order to gratify our particular desire. ... [H]ere we had the most desirable section exposed to our view, and had nothing to do but remove the thin veil with which the mineral face of nature was disguised. It was not without much pains and labour that we thus proceeded to investigate what could not appear at first sight; and it was not without some regret that we left so noble a section unfinished, or without a full delineation of an object so decisive in its nature and of such extent. We saw, however, enough to describe upon principle what we here had learned (pp.46-47).

The general naturalist is interested in all aspects of nature, including the moss that covers rocks and stones and trees. But to the geologist, anything that conceals rock sections and frustrates the attempt to read the annals of a former world is to be regretted and, if possible, removed. Although the mountain initially looks as if it has been 'cut asunder in order to gratify our particular desire', exposing 'the most desirable section to our view', Hutton and Clerk are forced, with much pains and labour, to 'remove the thin veil with which the mineral face of nature was disguised'. Even then, they are not able fully to satisfy their desire. One of

‘The drawings which Mr. Clerk took upon this occasion’ (p.47) is particularly interesting in the way it represents the relationship between these savants and this natural feature:



Figure 3: Granite veins exposed on Cairnsmore of Fleet (John Clerk of Eldin, 1786).

As well as providing a vivid proxy image of the geological feature, this drawing includes images of Hutton and Clerk working at and interpreting the exposure, whose size both overwhelms them and connotes their heroic labour on the mountainside. The figure at the centre of the image appears to stand at the threshold of deep time, reading the annals of a former world on what almost seems like a semi-transparent screen whose luminous glow hints at the subterranean fire at the core of Hutton’s theory. Hutton appears, indeed, to be about to penetrate the mountain, setting out on a journey to the centre of the earth.

Hutton’s figuration of geological exploration as driven by the desire to discover or uncover exposures that will reveal the secrets of the earth is part of a larger discursive formation in the period. The gendering of the natural philosopher’s quest was ubiquitous from the seventeenth to the early nineteenth century, from Francis Bacon’s *The New Organon* (1620) to Humphry Davy’s ‘Discourse Introductory to a Course of Lectures on Chemistry’ (1802). Davy, for example, rhetorically asked his audience at the Royal Institution ‘who would not be

ambitious of becoming acquainted with the most profound secrets of nature, of ascertaining her hidden operations, and of exhibiting to men that system of knowledge which relates so intimately to their own physical and moral constitution?’²⁸ Such attitudes are dramatised and criticised in Mary Shelley’s *Frankenstein* (1818, 1831), whose eponymous protagonist reports that ‘with unrelaxed and breathless eagerness, I pursued nature to her hiding places’ and eventually ‘succeeded in discovering the cause of generation and life’ after ‘days and nights of incredible labour’.²⁹ As Golinski puts it, ‘Images of nature as a female, unveiled by male researchers, had a pervasive ideological role’ in Enlightenment science.³⁰ Hutton’s writings, and some of Clerk’s drawings, thus serve not only to give the reader a sense of being a virtual witness or participant in the geological quest, but also fashion Hutton as a masculine explorer engaged in the heroic and laborious endeavour of exposing the inner secrets of a nature figured as female.

As they make their way along the southwest coast between Kirkcudbright and the Solway Firth, Hutton represents himself and Clerk as intrepid travellers on ‘a road which perhaps was never passed in a chaise before’ (p.54). Expectations are raised, apparently fulfilled, and then disappointed – granite and schistus outcrops are easily seen but the vital junction, which might reveal intrusions, remains hidden (pp.54-55). The explorers press on eagerly, anticipating that the sea at Solway Firth might have created the exposures they seek:

The road from Coend Kirk, if it may be called a road, leads to a little sandy bay of the sea, just within the limits or entry of the Solway Firth. Here it is common to ride on the sands when the sea has ebbed, in leaving the shore and making to Saturness [Southernness] Point near Arbigland, whither we were bound. The road was this way nearer, easier, and far more expeditious; but this was not our object; for now the rocky shore appeared, and we had every reason to expect to find something interesting in this critical spot. We therefore left the chaise, which we had for a long way attended on foot, to find its way up the hill, while we ran with some impatience along the bottom of the sandy bay to the rocky shore which is washed by the sea, it being then low water. We saw the schistus pretty erect, but variously inflected, as is usual, upon our right, where the land terminated in the sea. Upon the left again, we had the granite appearing through the sandy shore; and above, the granite hill seemed to impend upon the erected strata, if these reached so far into the land. We saw the place nearly where the granite and the schistus upon the shore must be united; but this place was bushy; and thus our fears and expectations remained for a moment in suspense. But breaking through the bushes and briars, and climbing up the rocky bank, if we did not see the apposition of the granite to the side of the erected strata so much as we wished, we saw something that was much more satisfactory, and to the purpose of our expedition. This was the granite superinduced upon the ends of those broken strata or erected schisti. We now understood the meaning of the impending granite which appeared in the hill above this

place; and now we were satisfied that the schistus was not only contiguous with the mass of the granite laterally, but was also in the most perfect conjunction with this solid rock which had been superinduced upon the broken and irregular ends of the strata. But even this view of things, decisive as it was, did not fill up the measure of our satisfaction, which was to be still further gratified with the only possible appearance which could now remain, in order to complete the proof with every species of evidence which the nature of things could admit of. For here we found the granite, not only involving the terminations of the broken and elevated strata, but also interjected among the strata, in descending among them like a mineral vein, and terminating in a thread where it could penetrate no farther. Mr. Clerk's drawing, and a specimen which I took of the schistus thus penetrated, will convince the most sceptical with regard to this doctrine of the transfusion of granite. (pp.55-59)

This remarkable passage is written with a breathless eagerness more reminiscent of the climax of a Romantic novel of the period than of a scientific report or perhaps even a travel narrative. Hutton's first-person account represents himself and Clerk as characters traversing a landscape suffused with desire, in quest of an exposure which the landforms repeatedly promise, satisfy in part, and only yield up at the climax. These characters run 'with some impatience along the bottom of the sandy bay to the rocky shore'; their 'fears and expectations remained for a moment in suspense' because the anticipated exposure is concealed by vegetation; breaking through 'the bushes and briers' they gratify their desire to know the meaning of the surrounding rock formations, only to gain further satisfaction when they view an exposure that 'complete[s] the proof with every species of evidence which the nature of things could admit of'.

The impression that this passage could easily appear in a Romantic novel is created not only by the way the characters pursue their quest through a landscape that both lures them onward and defers their satisfaction until the last moment, but also by Hutton's use of paradoxical deictic markers ('was-now') that override the normal distinction between 'we-are-now' and 'we-were-then':

but this *was* not our object; for *now* the rocky shore appeared, and we had every reason to expect to find something interesting in this critical spot ... We *now* understood the meaning of the impending granite which appeared in the hill above this place; and *now* we were satisfied ... our satisfaction ... *was* to be still further gratified with the only possible appearance which could *now* remain...

At the time Hutton was writing this passage, the use of 'was-now' formulations was being developed in third-person novels, though this technique would not become a dominant style

until Jane Austen's sustained use of empathetic narrative allowed readers both to participate in and criticise the inner experiential lives of third-person characters.³¹ Literary critics and theorists have paid a great deal of attention to third-person empathetic narration in the nineteenth- and early twentieth-century novel, but they have largely ignored the use of the 'was-now' paradox in first-person narrative.³² Yet, as Sylvia Adamson has shown, the 'she-was-now' formula introduced by the Romantic novel was made possible by an 'I-was-now' form developed in seventeenth-century Puritan conversion autobiographies, most prominently in John Bunyan's *Grace Abounding* (1666).³³ In carrying out the intense self-scrutiny of their sinful past lives that Puritanism demanded, writers like Bunyan employ the 'I-was-now' form most prominently in critical conversion moments in ways that collapse past and present into an illusion of experiential immediacy.³⁴ Bunyan uses the form throughout *Grace Abounding* in the retrospective narration of key moments when he realised his state of sin or received intimations of God's grace. Both kinds of insight are juxtaposed in the final, most intense epiphany:

At the apprehension of these things, my sickness was doubled upon me, for now was I sick in my inward man, my Soul was clog'ed with guilt, now also was all my former experience of Gods goodness to me quite taken out of my mind, and hid as if it had never been, nor seen: Now was my Soul greatly pinched between these two considerations. *Live I must not, Die I dare not*: now I sunk and fell in my Spirit, and was giving up all for lost; but as I was walking up and down in the house, as a man in a most woful state, that word of God took hold of my heart, *Ye are justified freely by his grace, through the redemption that is in Christ Jesus*, Rom. 3.24.

Now was I as one awakened out of some troublesome sleep and dream, and listening to this heavenly sentence, I was as if I heard it thus expounded to me ...

Now was I got on high; I saw myself within the arms of Grace and Mercy; and though I was before afraid to think of a dying hour, yet now I cried, Let me die; now death was lovely and beautiful in my sight.³⁵

In contrast to the concentrated uses of 'I-was-now' forms in *Grace Abounding*, other first-person early-modern narratives, such as the sea voyages collected in Richard Hakluyt's *Principal Navigations* (1598–1600), reveal a comparatively low percentage of was-now tokens. The key difference, perhaps, between Hakluyt's *Navigations* and *Grace Abounding* is that the former concentrates on external events, while the latter is concerned almost exclusively with intense internal experience.³⁶

It is striking that Hutton should employ first-person 'was-now' deictic markers, along with the other markers of subjective experience that we have noted, in a text intended to be

included in his major work of natural philosophy. We might expect, indeed, that Hutton's text would be more like Hakluyt's than Bunyan's in this respect. Adamson claims that scientific writing of the eighteenth century, partly in reaction to Puritan enthusiasm, sought to eliminate deictic markers of subjectivity in order to suggest that science was entirely a matter of objective experimental evidence.³⁷ Although Isaac Newton's *Opticks* (1704), one of the paradigmatic texts of eighteenth-century natural philosophy, does make use of 'was-now' deictics, it does so in a way that is crucially different from Hutton's usage. Out of about one hundred uses of 'now' as an adverb and conjunction in the fourth edition of 1730, eleven occur in adverbial form in relation to the past tense of the verb 'to be', always in reporting the results of experiments. The use of 'was-now' forms is most concentrated in Book II, part iv, Obs.11, where Newton reports his 'very strange and surprizing' 'Observations concerning the Reflexions and Colours of thick transparent polish'd Plates'. Notably, however, even in this flurry of 'was-now' formulations, the subject of the verb is almost invariably the natural phenomenon rather than Newton himself – as in the following: 'the first of those luminous Rings was now grown equal to the second of those dark ones'.³⁸ Although Newton does use the first person pronoun in *Opticks*, in the one instance where 'I' appears in a sentence with a 'was-now' form, the subject is still the phenomenon rather than the experimenter: 'Wherefore I covered that Part of the Glass with black Paper, and letting the Light pass through another Part of it which was free from such Bubbles, the Spectrum of Colours became free from those irregular Streams of Light, and was now such as I desired' (*Opticks*, p.88). While it is clearly not possible to generalise these findings without more extensive research, Newton's *Opticks* indicates that although the 'was-now' form does feature in reporting experimental findings in the natural philosophy of the period, Hutton's usage may be relatively novel in combining 'was-now' with first person pronouns.

It is particularly revealing that a scientific text of the late eighteenth century should present its intense moments of geological discovery in ways that echo the moments of spiritual self-discovery in seventeenth-century Puritan conversion narratives. Such Puritan texts represent the high point of the focus on subjective experience in the seventeenth century (anticipating the Romantic focus on internal experience at the end of the eighteenth century). Yet although Hutton is primarily concerned with the external events of his travels and the geomorphology of his findings, he is also concerned with the internal experience of the naturalist-traveller and it is when he records the most climactic moment of discovery that he reaches for the

paradoxical deictics of ‘was-now’. If ‘was-now’ markers occur most intensively at the critical conversion moments in seventeenth century Puritan autobiographies, in Hutton they occur at critical moments of epiphany when the long-expected revelation of decisive exposures seems about to occur and when crucial evidence about the natural history of the earth is about to be revealed.

One explanation of Hutton’s stylistic usage is that he is writing scientific travel literature rather than a treatise. A number of critics have argued that travel writing at the end of the eighteenth century underwent a shift from objective reportage to a more Romantic focus on the individual traveller’s inner and outer experience.³⁹ Nigel Leask questions this standard account by relocating the ‘disjuncture between scientific and literary travel writing in the decades *after* 1790-1820.’ ‘In the earlier decades’, he suggests, ‘travel writing struggled to integrate ... anecdotal personal narrative with “curious” or “precise” observation’.⁴⁰ Hutton, it might be said, succeeds in integrating scientific and romantic travel writing precisely in those moments of epiphany when the discovery of geological evidence is fused with the discoverer’s excited experience of that discovery.

It is also important to recall Heringman’s argument that geological writing had not yet fully distinguished itself from the network of other discourses and practices – travel writing, landscape aesthetics, topographic poetry, and so on – in which it developed. In addition, Rudwick’s suggestion that there are similarities between groundbreaking geological field trips and religious pilgrimages might lead us to expect that the parallels between Hutton’s and Bunyan’s climactic moments might be typical of scientific journeys of discovery in general. We also need to bear in mind, as Rudwick emphasises in *Bursting the Limits of Time* and as O’Connor demonstrates in *The Earth on Show*, that geological writers of the period attempted to persuade their readers to accept their theoretical claims by making them feel that they were ‘virtual travellers’ who shared in the journey of discovery and ‘virtual witnesses’ to the evidence in the field. One effect of Hutton’s use of ‘we-were-now’ forms in the above passage is to conflate the ‘now’ of the experience, the ‘now’ of the writing, and the ‘now’ of the reading, thus involving the reader in the plural pronoun and in the present tense experience of expectation, delay and eventual discovery. A climactic moment in Hutton’s discovery of the secrets of the earth’s formation is vividly shared by the reader, as if the difference between time present and time past had been collapsed. Such a manipulation of the

reader's experience of time is wholly germane to Hutton's geological project, which is to decipher the formative events of the earth's distant past in the now of the geological evidence – simultaneously opening up and bridging the unthinkable gulf between the awesome formative processes that must have taken place in deep time and their traces in the rock formations he discovers and interprets for the reader.

An Examination of the Mineral History of the Island of Arran

Hutton concludes chapter five by announcing that the geological features found 'in the south alpine region of Scotland' had finally confirmed his theory of the earth (pp.60-61). As before, however, confirmation served to whet rather than satisfy his desire to seek further evidence in other enticing locations in Scotland. As suggested earlier, Hutton's geological exploration of Arran gets a big build up in the projected third volume of *Theory of the Earth*. Hutton defers the account of his trip to Arran by inserting three chapters, taking up a hundred pages in Geikie's edition, in which he compares his findings in Scotland with those of geologists in other parts of the world, especially those in the volumes of Horace-Bénédict de Saussure's *Voyages dans les Alpes* (Neuchâtel, 1779-96) that had then been published. When he finally turns to his findings on Arran in chapter nine Hutton reveals that his desire to visit the island went back further than 1786, had been foiled several times, and had originally been stimulated by seeing it from more than fifty miles away:

The extremely alpine appearance of Arran from the continent of Scotland, even at the distance of the middle of the country, *i.e.*, from the Shott Hills, had long been a subject of admiration to me; and it was there that I had always expected to have the nature of mountains, that is to say, the steps of nature in their origin and decay, better investigated than any elsewhere. (p.193)

Arran, then, is an island of promise whose exploration will finally reveal the nature of mountains. When Hutton finally made the crossing to Arran in August 1787, he went with Clerk's son, 'Mr John Clerk junior' (pp.191-92). As Playfair notes in his 'Biographical Account of the Late Dr James Hutton' (1805), John Clerk junior took over his father's role by making 'several drawings, which, together with a description of the island drawn up afterwards by Dr HUTTON, still remain in manuscript'.⁴¹

Hutton announces that 'In setting out upon that expedition, I had but one object in view; this was the nature of the granite, and the connection of it with the contiguous strata' (p.193). Although the sixty-one year old Hutton had already gathered enough evidence in support of

his theory about granite, it is notable with what boyish eagerness he and Clerk junior searched for exposed granite-schistus junctions all over the northern part of the island, spurred on by repeated frustration (see pp.220-26). Hutton eventually found satisfactory exposures of intrusive granite veins in adjacent schistus on a solo foray into North Glen Sannox, and only after that did he and Clerk make similar finds on Glenshant Hill and in the Cnocan Burn. But Hutton found more on Arran than he had anticipated. Rather than remaining fixated on granite-schistus conjunctions, he turned to a consideration of the geomorphology and geohistory of Arran as a whole, beginning with a general overview in which he notes the island's division into a granite mountain range to the north and a lowland area to the south made up primarily of sedimentary rocks arranged in horizontal strata (pp.201-216). The fact that the Highland Boundary divides Arran in this way means that the island is often described as a Scotland in miniature, and this is one reason why it remains of special interest to geologists today.⁴² Hutton, indeed, views Arran as a geological microcosm of the whole planet that promises to reveal the secrets of the system of the earth itself, as well as of mountains (p.199).

One of the discoveries on Arran that allowed Hutton to begin to think of the island in these terms was an interface not between granite and schistus but between schistus and other stratified rocks. Once again, Hutton tells us that he had been searching for this kind of junction for a long time (though he had not mentioned this before):

The immediate connection of the alpine schistus with the strata of the low country is an object which I have long looked for, I may almost say in vain. I expected to have seen it in entering the Grampian mountains, ... but I was disappointed in my expectations. ... I have in like manner looked for it in both sides of the southern mountains of Scotland, and that in several places, without receiving any satisfaction upon that subject. In the island of Arran I have sought it carefully without finding it, in a place where I thought it was certainly to be found; and I found it, in a place where I had not thought almost of looking for it. (pp.230-32)

This passage raises our expectations regarding Hutton's eventual discovery of the now famous unconformity just north of Newton Point on the shore of Loch Ranza – the first unconformity to be discovered in Britain and now a place of pilgrimage and study for geologists and geology students:

Loch Ranza at the north end of the island, is properly within the alpine schistus; but, in tracing the shore, upon the east side of the loch or bay, we come to the extremity of this schistus district. Here the first thing that occurs is the immediate junction of the

inclined strata of schistus and the other strata which here appear to be a composition of sandstone and limestone; these strata are equally inclined with the schistus, but in the opposite direction. Those two different kinds of stratified bodies rise to meet each other; they are somewhat confused at the immediate junction; but some of the sandstone or calcareous strata overlap the ends of the alpine schistus. (p.235)

Hutton does not at this point appear to understand the full significance of this unconformity, or at least he does not explain its significance here. Within twenty pages or so, however, some of its implications begin to emerge in Hutton's speculations about the origins of Arran as a whole:

It must appear that the island of Arran was originally composed of stratified bodies, in which two species may be distinguished; on the one hand, the alpine schistus, much changed by fusion from its original state, and containing no visible mark of organized bodies; and on the other, strata probably of later formation, less changed by fusion, and containing marks of organized bodies. (pp.262-63)

Although it is true that Hutton exhibited little interest in the historical sequence of the fossil record,⁴³ he is clearly interested here in the possibility that the presence or absence of fossils might reveal temporal and causal differences in rock formation that correlate with the temporal succession indicated by the Loch Ranza unconformity. That the island consists of at least two kinds of stratified rock that have undergone different degrees of metamorphosis indicates that its basic building materials must have been formed under the sea in two separate phases over a very long time. The fact that these stratified materials have been intruded and broken up not only by the massive granite upwelling that formed the mountains of the northern part of the island but also by multiple intrusions of all kinds of rock material into the various stratified rocks over the whole island supports Hutton's assumption that Arran must have been created a very long time ago when the complex strata that had been formed under the sea were raised above sea level by subterranean heat and pressure.⁴⁴ The original size and shape of the Arran landmass cannot even be guessed at because the island's geomorphology indicates that it has been exposed to erosive forces over an enormous time period since it 'first [proceeded] from the bowels of the earth or bottom of the sea' (p.264).

Having conjured up these startling visions of Arran's complex formation under the sea, uplift above the sea by subterranean heat and pressure, and subsequent erosion over an enormous period of time, Hutton goes on to speculate about the island's past connections with the surrounding landmasses in ways that heighten the sublimity of his Arran story still further:

The great number of whinstone dykes upon the west coast in the shire of Ayr, opposite Arran, *i.e.*, from Scalmorly [Skelmorlie] almost to Irwin [Irvine] similar to those which we find in that island, give reason to conclude that these are continued under ground, or that they had proceeded originally from one mass. We thus are led to believe that the island of Arran and the shire of Ayr had been raised from the bottom of the sea at the same time, or in the operation of the same causes; and that therefore those two coasts were once continuous land, which was afterwards preyed upon by the water, and disjoined by the sea. (pp.265-66)

By observing the erosive forces of the sea on Arran and suggesting that the islands of Pladda and the Holy Island (and perhaps even Ailsa Rock) were once part of Arran, Hutton begins to open up his speculations to include the likely future of the planet:

By thus ascertaining the first step in our cosmological speculation, we advance with some degree of certainty into the annals of a continent which does not now appear; and in tracing these operations which are past, we foresee distant events in the course of things. We see the destruction of a high island in the formation of a low one; and from those portions of the high land or continent which remain as yet upon the coast and in the sea, we may perceive the future destruction, not of the little island only, which has been saved from the wreck of so much land, but also of the continent itself, which is in time to disappear. Thus Pladda is to the Island of Arran what Arran is to the island of Britain, and what the island of Britain is to the continent of Europe. (pp.261-62)

On the eve of the French Revolution, in a period when writers were concerned about the potential decline and fall of the British empire, and even of Britain itself, and speculating about the ruins of empires in general, Hutton's long geological perspective indicates that the very fabric of the British Isles is a relatively temporary product of the geostrophic cycle, destined to destruction not by sin, or loss of virtue or valour, or political corruption, but by the inevitable continuance of the geological processes that had formed it in the first place. Hutton's interpretation of Arran's geology and the story it tells about the past and future of the planet offers sublime glimpses of colossal processes taking place infinitesimally slowly over almost unthinkable time periods, and promises the eventual slow-motion destruction of everything we take to be solid and permanent. His vision is nonetheless an optimistic one in that he sees the destruction of cherished landscapes and landforms as a necessary process in that it provides the eroded materials needed for the geostrophic cycle to continue to produce new landmasses that will sustain life long after Scotland, Britain and Europe will have disappeared from the face of the earth. Such a long-term perspective enables Hutton to claim that his theory of the earth 'is confirmed from the natural history of Arran' (p.267).

Jedburgh and Siccar Point (1787 and 1788)

The manuscript intended to form the third volume of *Theory of the Earth* comes to an end with the chapter on Arran. We might think that the sublime epiphanies that Hutton experienced on the island would represent the completion of his quest, but instead he undertook two further expeditions in search of unconformities that would help him to substantiate and develop the vision of the earth's past and future that Arran had allowed him to glimpse. To complete the story of Hutton's geological tours of Scotland we need to turn to chapter six of the first volume of *Theory of the Earth* and to Playfair's biography of Hutton of 1805.

Hutton makes no mention in *Theory of the Earth* of his search for granite intrusions in Glen Tilt, Galloway and Arran and concentrates instead on his later quest for unconformities around Jedburgh in 1787 and where the Lammermuir Hills run into the North Sea in 1788. In chapter six of the first volume, Hutton briefly describes the unconformities on Arran, Siccar Point, and elsewhere, but bases his extended analysis on the Jed unconformity. He recalls that 'one day, walking in the beautiful valley above the town of Jedburgh, I was surprised with the appearance of vertical strata in the bed of the river, where I was certain that the banks were composed of horizontal strata. I was soon satisfied with regard to this phenomenon, and rejoiced at my good fortune in stumbling upon an object so interesting to the natural history of the earth, and which I had been long looking for in vain' (I, 432). What most interests Hutton, however, is that 'above those vertical strata, are placed the horizontal beds, which extend along the whole country' (I, p.432), and he spends the bulk of the first part of the chapter in thinking through how such a juxtaposition could have come about and what it means for his geology. The elder John Clerk made a drawing of the Jed unconformity (see Figure 4) which was later used for one of the six engravings in Hutton's *Theory of the Earth* (which indicates how central this unconformity became for Hutton):

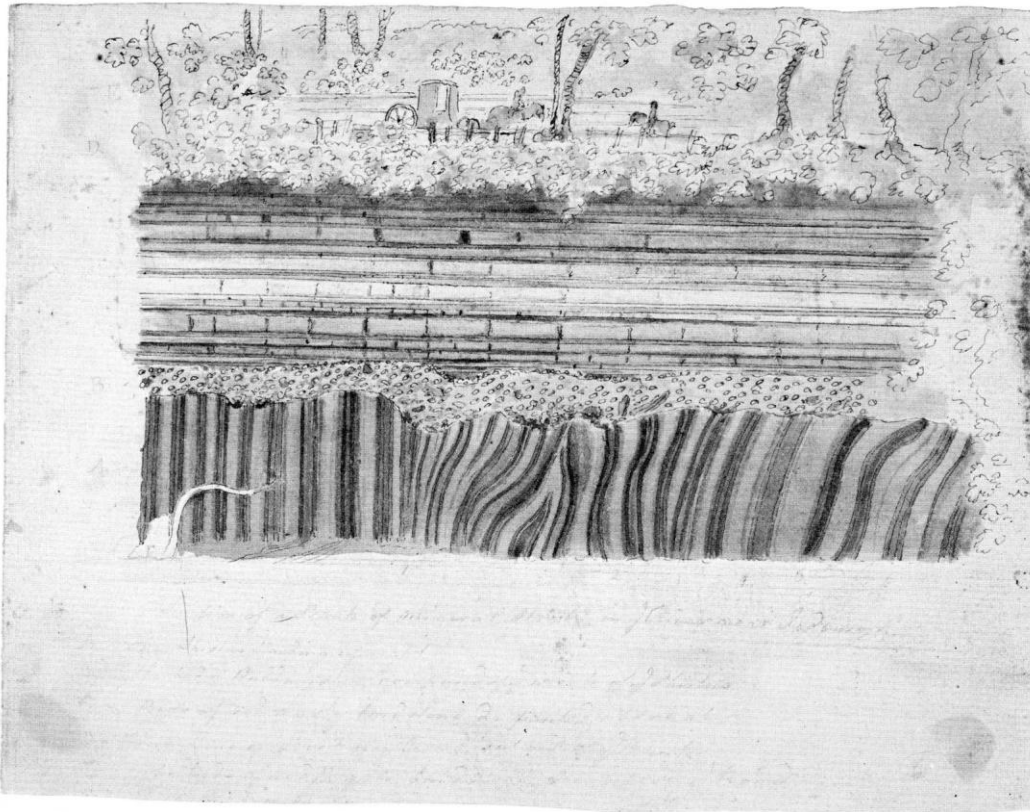


Figure 4: The Jedburgh unconformity: original drawing of the engraving for Plate III of *Theory of the Earth*, vol. I. (John Clerk of Eldin, 1787)

Hutton assumes that everyone will agree that the vertical schistus strata must have been formed in a horizontal orientation out of sediments gathered at the bottom of the sea. More controversially, he then proposes that subterraneous heat and pressure had hardened these strata, folded them into an upright orientation, and then raised them well above the surface of the ocean to produce an extensive mountainous area. A period of erosion then followed in which ‘the effects of either rivers, winds, or tides’ had washed bare ‘the surface of the vertical strata’. At a still later period, ‘this surface had been ... sunk below the influence of those destructive operations, and thus placed in a situation proper for the opposite effect, the accumulation of matter prepared and put in motion by the destructive causes’ (I, pp.434-35). The unconformity is complicated by the fact that ‘a certain pudding-stone’ is to be found ‘interposed’ between the vertical and horizontal strata (I, p.436), making up a complex structure that needed to be illustrated – Hutton refers the reader to the ‘view of this object ... from a drawing taken by Mr Clerk of Eldin’ (I, p.437, note; see Figure 4). The fact that the pudding stone is in a hardened state is taken by Hutton as evidence that the eroded schistus mountains had once more been subjected to the ‘indurating’ effects of subterraneous heat and

pressure (I, p.438). The horizontal beds of Old Red Sandstone must have been laid down upon the hardened pudding-stone at the bottom of the sea and then consolidated by Plutonic forces, after which the whole structure had once more been raised above the sea by those same forces and subsequently laid bare by the erosive effects of the river (I, pp.439-42).

Hutton's account of the Jed unconformity forms the core of the sixth chapter of the first volume of *Theory of the Earth* and he devotes only a paragraph to the unconformity at Siccar Point. But the Siccar Point unconformity has become much more famous in the history of geology because Playfair (along with Sir James Hall) accompanied Hutton on his last geological field trip and wrote an account of the expedition in his biography of Hutton that has been repeatedly quoted in scientific biographies, textbooks and field guides. Playfair recalls the boat trip to Siccar Point and describes the unconformity in similar terms to Hutton's account of the Jed unconformity (pp.71-72). He then claims that Hutton produced an on-the-spot analysis of the Siccar Point unconformity that had an overwhelming impact on his listeners:

Dr HUTTON was highly pleased with appearances that set in so clear a light the different formations of the parts which compose the exterior crust of the earth, and where all the circumstances were combined that could render the observation satisfactory and precise. On us who saw these phenomena for the first time, the impression made will not easily be forgotten. The palpable evidence presented to us, of one of the most extraordinary and important facts in the natural history of the earth, gave a reality and substance to those theoretical speculations, which, however probable, had never till now been directly authenticated by the testimony of the senses. We often said to ourselves, What clearer evidence could we have had of the different formation of these rocks, and of the long interval which separated their formation, had we actually seen them emerging from the bosom of the deep? We felt ourselves necessarily carried back to the time when the schistus on which we stood was yet at the bottom of the sea, and when the sandstone before us was only beginning to be deposited, in the shape of sand or mud, from the waters of a superincumbent ocean. An epocha still more remote presented itself, when even the most ancient of these rocks, instead of standing upright in vertical beds, lay in horizontal planes at the bottom of the sea, and was not yet disturbed by that immeasurable force which has burst asunder the solid pavement of the globe. Revolutions still more remote appeared in the distance of this extraordinary perspective. The mind seemed to grow giddy by looking so far into the abyss of time; and while we listened with earnestness and admiration to the philosopher who was now unfolding to us the order and series of these wonderful events, we became sensible how much farther reason may sometimes go than imagination can venture to follow. (Playfair, pp.72-73)

In Playfair's reconstruction, Hutton's rational analysis of the unconformity at Siccar Point carried his giddy listeners across the abyss of time to present them with events that

overwhelmed their imagination. Such effects precisely echo Kant's account of the mathematical sublime in *The Critique of the Power of Judgement* (1790, 1793) which was published almost contemporaneously with the expedition to Siccar Point.⁴⁵ If Hutton's attempt to read the earth's remote past in the now of the geological record generated sublime effects in his listeners, it is notable that Playfair, in recalling the climax of Hutton's endeavour, twice reaches for the paradoxical deitics of 'was-now' constructions – the second of which is in the third person ('the philosopher ... was now'). It may be, as I have suggested, that the 'was-now' paradox, with its disruptions of grammatical and temporal logic, best conveys (or produces) the experience of Hutton's listeners and readers as they 'grow giddy by looking so far into the abyss of time'. The technique also works, of course, at a time when Playfair was leading the struggle to get Hutton's theory accepted, to persuade readers of the explanatory power of Hutton's paradigm by inducing them to feel that they are sharing in the intense experience of those who listened to Hutton in front of the Siccar Point exposure, allowing them to becoming virtual witnesses not only of the evidence in the field but also of the ancient processes that it points to.

Conclusions

The publication of the two versions of Hutton's theory of the earth in 1786/88 and 1795 precipitated a heated controversy in which Hutton's Plutonism, apparent suggestion of an eternal earth, and seeming reliance on deductive theory, were all attacked. We can only speculate about the possible impact on this controversy if the projected third volume of *Theory of the Earth* had been published in 1795. Contemporary readers would have had a very different picture of Hutton's theory and the evidence for it. Yet prevailing paradigms and theories tend to shape the observation and interpretation of evidence even in those naturalists who claim to be inductive empiricists. The manuscripts of Hutton's Scottish tours were held by Playfair after Hutton's death, and C.J. Nicholas and P.N. Pearson have suggested that Playfair may have discussed them with Professor John Walker, his former teacher at the University of Edinburgh.⁴⁶ When Robert Jameson, also Walker's former student and one of the leading exponents of Werner's Neptunism in Edinburgh, explored Arran in the late 1790s it appears that he knew more about Hutton's findings on the island than are revealed in *Theory of the Earth*. Yet Jameson claimed not to be able to see the features that Hutton saw, or interpreted them to support the Neptunist theory.⁴⁷ Even today,

more than a century after their rediscovery and publication, Hutton's manuscript tours of Scotland have not been fully taken into account by historians of Romantic-period geology, many of whom perpetuate the assumption that Hutton was solely an armchair geologist whose theory of the earth had more in common with the tradition of speculative theories stemming from Thomas Burnett than with the empirical fieldwork that came to characterise geology in the nineteenth century.⁴⁸

A literary reading of Hutton's geological tours of Scotland helps us to speculate about their potential impact upon readers if not on the history of geology. Along with the 1786/88 paper and chapter six of the first volume of *Theory of the Earth*, the Scottish tours undermine the often-repeated assertion that Hutton was an inept writer. While some of the writing and organisation of the first two volumes of *Theory of the Earth* are confusing and opaque, the geological travel writing in the projected third volume is lucid and powerful and potentially generates the informed wonder that was the hallmark of Romantic science.⁴⁹ Attention to Hutton's use of literary techniques and conventions – narrative strategies associated with quest romance, figurative language, authorial self-fashioning, the manipulation of the sublime, the use of paradoxical deictics, and so on – highlights the ways these texts dramatise the journey of scientific discovery and induce the reader to participate in the dynamic experience of desire, frustration, fulfilment and awe. These written tours would have allowed Hutton's readers to imagine that they were virtual participants in the geological quest, conducted by a savant whose self-fashioning made him a reliable guide through Scotland's geomorphology and the landscapes of deep time. Indeed, it is possible to suggest that had they been published in 1795 Hutton's geological tours would have made a significant contribution to the tradition of scientific travel writing and the Romantic 'discovery' of Scotland.

¹. See Tim Fulford, Debbie Lee and Peter J. Kitson, *Literature, Science and Exploration in the Romantic Era: Bodies of Knowledge* (Cambridge and New York: Cambridge University Press, 2004), pp.2-4.

². Ralph O'Connor, *The Earth on Show: Fossils and the Poetics of Popular Science, 1801-1856* (Chicago and London: University of Chicago Press, 2007), p.446; for O'Connor's reflections on the reading of scientific writing as literature, see 'Introduction: Science as Literature' (pp.1-27) and 'Literary Criticism and the History of Science' (445-53).

³. See John Locke, *An Essay Concerning Human Understanding* (1689), ed. Roger Woolhouse (London and New York: Penguin, 1997), book III, especially ch. 10, para.34.

⁴. Marjorie Hope Nicolson, *Mountain Gloom and Mountain Glory: The Development of the Aesthetics of the Infinite* (Cornell: Cornell University Press, 1959). Also see Trevor H. Levere, *Poetry Realized in Nature: Samuel Taylor Coleridge and Early Nineteenth-Century Science* (Cambridge and New York: Cambridge University Press, 1981), Alan Bewell, *Wordsworth and the Enlightenment: Nature, Man, and Society in the Experimental Poetry* (New Haven and London: Yale University Press, 1989), John Wyatt, *Wordsworth and the Geologists* (Cambridge and New York: Cambridge University Press, 1995), and Dennis Dean, *Romantic Landscapes: Geology and its Cultural Influence in Britain, 1765-1835* (Scholars' Facsimiles & Reprints: Ann Arbor, 2007).

⁵. Noah Heringman, *Romantic Rocks, Aesthetic Geology* (Ithaca and London: Cornell University Press, 2004), pp.1-29, 138-160.

⁶. Martin J.S. Rudwick, *Bursting the Limits of Time: The Reconstruction of Geohistory in the Age of Revolution* (Chicago and London: University of Chicago Press, 2005), pp.74-75; Rudwick derives the notion of the virtual witness from Steven Shapin, 'Pump and Circumstance: Robert Boyle's Literary Technology', *Social Studies of Science* 14:4 (1984), 481-520.

⁷. See Jan Golinski, *Making Natural Knowledge: Constructivism and the History of Science*, 2nd edition (Chicago and London: University of Chicago Press, 1998, 2005), especially chapter four 'Speaking for Nature' (pp.103-32) and 'Coda: The Obligations of Narrative' (pp.186-206).

⁸. For a discussion of the way writings in the history of science variously employ the conventions of Romance, Comedy, Tragedy, and Satire articulated by Northrop Frye, see William Clark, 'Narratology and the History of Science', *Studies in History and Philosophy of Science* (1995), 26: 1-71, and Golinski, *Making Natural Knowledge*, pp.192-94.

⁹. See Northrop Frye, 'The Mythos of Summer: Romance', in *Anatomy of Criticism: Four Essays* (Princeton: Princeton University Press, 1957; London and New York: Penguin, 1990), pp.186-206.

¹⁰. See Martin Rudwick, 'Geological Travel and Theoretical Innovation: The Role of the "Liminal" Experience', *Social Studies of Science*, 26 (1996), 143-59.

¹¹. For essays on key examples of geological travel, see P.N. Wyse Jackson, ed., *Four Centuries of Geological Travel: The Search for Knowledge on Foot, Bicycle, Sledge and Camel* (London: The Geological Society, 2007).

¹². On the eighteenth-century 'discovery' of Scotland by writers and artists, see James Holloway and Lindsay Errington, *The Discovery of Scotland: The Appreciation of Scottish Scenery through Two Centuries of Painting* (Edinburgh: The National Gallery of Scotland, 1978); John Glendening, *The High Road: Romantic Tourism, Scotland, and Literature, 1720-1820* (New York: St. Martin's Press, 1997); Alastair J. Durie, *Scotland for the Holidays: Tourism in Scotland, c.1780-1939* (East Linton: Tuckwell Press, 2003); Katherine Haldane Grenier, *Tourism and Identity in Scotland: Creating Caledonia* (Aldershot and Burlington: Ashgate, 2005).

¹³. See Paolo Rossi, *The Dark Abyss of Time: The History of the Earth and the History of Nations from Hooke to Vico* (1979), trans. Lydia G. Cochrane (Chicago and London: University of Chicago Press, 1984), pp.113-20.

¹⁴. See Tom Furniss, "'Plumb-Pudding Stone" and the Romantic Sublime: The Landscape and Geology of the Trossachs in *The Statistical Account of Scotland* (1791-99)', in Christoph Bode and Jacqueline Labbe, eds., *Romantic Localities: Europe Writes Place* (London: Pickering and Chatto, 2010), pp.51-65.

¹⁵. For a more extended account of the controversy between ‘Neptunists, Vulcanists and Plutonists’ and between ‘Catastrophists and Uniformitarians’, see A. Hallam, *Great Geological Controversies* (Oxford: Oxford University Press, 1983).

¹⁶. G.Y. Craig, ed., *James Hutton’s Theory of the Earth: The Lost Drawings* (Edinburgh: Scottish Academic Press, 1978), p.5; the term ‘geostrophic cycle’ was coined by S.I. Tomkeieff, ‘James Hutton and the Philosophy of Geology’, *Transactions of the Edinburgh Geological Society*, 14.2 (1948), 253-76. For claims that Hutton was the founder of modern geology, see Dennis Dean, *James Hutton and the History of Geology* (Ithaca and London: Cornell University Press, 1992), D. B. McIntyre, and A. McKirdy, *James Hutton: The Founder of Modern Geology* (Edinburgh: National Museums of Scotland, 1997, 2001), and Stephen Baxter, *Revolutions in the Earth: James Hutton and the True Age of the World* (London: Phoenix, 2004). For criticisms of this claim, see Rudwick, *Bursting the Limits of Time*, pp.158-72, Roy Porter, *The Making of Geology: Earth Science in Britain, 1660-1815* (Cambridge and New York: Cambridge University Press, 1977, 1980), and Stephen Jay Gould, *Time’s Arrow, Time’s Cycle: Myth and Metaphor in the Discovery of Geological Time* (Cambridge, Massachusetts and London: Harvard University Press, 1987).

¹⁷. See G.Y. Craig, intr., *The 1785 Abstract of James Hutton’s Theory of the Earth* (Scottish Academic Press: Edinburgh, 1987).

¹⁸. *The 1785 Abstract of James Hutton’s Theory of the Earth*, pp.22, 28-29. On Hutton’s 1764 tour of Scotland, see Playfair, ‘Biographical Account of the Late Dr James Hutton’, *Transactions of the Royal Society of Edinburgh*, V (1805), 39-99 (45) and Dean, *James Hutton and the History of Geology*, pp.8-9; for the importance of Salisbury Crags to Hutton, see James Hutton, *Theory of the Earth, with Proofs and Illustrations*, 2 vols. (Edinburgh: William Creech; London: Cadell and Davies, 1795), I, 153-54, Craig, *Lost Drawings*, p.27, and Dean, pp.11-15.

¹⁹. See Dean, *James Hutton and the History of Geology*, pp.17-19.

²⁰. For early implicit criticism of Hutton’s deductive theorising, see John Walker, ‘Public Lecture anno 1788 on the Utility and Progress of Natural History, and Manner of Philosophising’, *Essays on Natural History and Rural Economy* (London and Edinburgh, 1812), pp.323-345 (336-37). Also see John Williams, *The Natural History of the Mineral Kingdom*, 2 vols. (Edinburgh, 1789), vol. I, pp.xxiii-lxii. The most extended early criticism of Hutton’s ‘Theory of the Earth’ is Jean André De Luc, four letters ‘to Dr. James Hutton, F.R.S. Edinburgh, on his Theory of the Earth’, in *The Monthly Review; or, Literary Journal, Enlarged*, vol. II (May-August, 1790), 206-27 and 582-601, vol. III (September-December, 1790), 573-86, and vol. V (May-August, 1791), 564-85. Also see Richard Kirwan, ‘Examination of the Supposed Igneous Origin of Stony Substances’, *Transactions of the Royal Irish Academy* 5 (1793?), 51-87; Kirwan’s *Geological Essays* (London, 1799) contains a critical essay ‘On the Huttonian Theory of the Earth’ (pp.433-499). Also see Robert Jameson, *An Outline of the Mineralogy of the Shetland Islands, and of the Island of Arran* (Edinburgh and London, 1798), and *Mineralogy of the Scottish Isles; with Mineralogical Observations made in a Tour through different parts of the Mainland of Scotland*, 2 vols. (Edinburgh and London, 1800). For an overview, see Dean, *James Hutton and the History of Geology*, pp.46-57, 79-101, 126-62, and Hallam, *Great Geological Controversies*, pp.1-28, 29-63. For the Edinburgh controversy between Wernerian Neptunism and Huttonian Plutonism in the early years of the nineteenth century, see Hallam, *Great Geological Controversies*, pp.18-23, and Gordon L. Davies, *The Earth in Decay: A History of British Geomorphology, 1578-1878* (London: Macdonald Technical and Scientific, 1968), pp.183-96.

²¹. See Playfair, ‘Biographical Account of the Late Dr James Hutton’, 67-73; also see Baxter, *Revolutions in the Earth*, pp.146-61, and Dean, *James Hutton and the History of Geology*, pp.15-46.

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- ²². James Hutton, 'Theory of the Earth; or an Investigation of the Laws Observable in the Composition, Dissolution, and Restoration of Land upon the Globe', *Transactions of the Royal Society of Edinburgh* I (1788), 209-304. For the suggestion that this article formulates a theory of the earth that we could call 'Romantic', see Furniss, 'A Romantic Geology'.
- ²³. See Hutton, *Theory of the Earth*, I, ch. 6 (pp.453-72).
- ²⁴. James Hutton, *Theory of the Earth, with Proofs and Illustrations*, vol. III, ed. Sir Archibald Geikie (London: The Geological Society, 1899, 1997). The text of Hutton's manuscript for the projected third volume of *Theory of the Earth* can also be found in Dennis R. Dean, ed., *James Hutton in the Field and in the Study: A Bicentenary Tribute to the Father of Modern Geology* (Delmar, N.Y: Scholars' Facsimiles & Reprints, 1997).
- ²⁵. See C.J. Nicholas and P.N. Pearson, 'Robert Jameson on the Isle of Arran, 1797-1799: In Search of Hutton's "Theory of the Earth"', in Wyse Jackson, ed., *Four Centuries of Geological Travel*, pp.31-47 (31). Also see James Hutton, 'Observations on Granite', *TRSE* 3:2 (1794), 77-85, which was read at the Royal Society of Edinburgh in January 1790 and August 1791.
- ²⁶. For a sustained discussion of the role of curiosity in the travel writing of the period, see Nigel Leask, *Curiosity and the Aesthetics of Travel Writing 1770-1840: 'From an Antique Land'* (Oxford and New York: Oxford University Press, 2002).
- ²⁷. Hutton's geological collection was dispersed and lost after his death, partly through Robert Jameson's neglect. See Jean Jones, 'The Geological Collection of James Hutton', *Annals of Science* (1984), 41:3, 223-44.
- ²⁸. Humphry Davy, 'A Discourse Introductory to a Course of Lectures on Chemistry' (1802), *The Collected Works of Sir Humphry Davy*, 9 vols. ed. John Davy (London: Smith, Elder and Co., 1839), vol. 2, pp.311-26 (320).
- ²⁹. Mary Shelley, *Frankenstein, or the Modern Prometheus* (1818, 1831), ed. Maurice Hindle (London and New York: Penguin, 2003), pp.55, 53.
- ³⁰. Jan Golinski, *Making Natural Knowledge*, p.66; see Ludmilla Jordanova, *Sexual Visions: Images of Gender in Science and Medicine between the Eighteenth and Twentieth Centuries* (New York: Harvester Wheatsheaf, 1989).
- ³¹. On the emergence of empathetic narrative and empathetic deictics, see Sylvia Adamson, 'Literary Language', in *The Cambridge History of the English Language*, 4, 1776-1997, ed. Suzanne Romaine (Cambridge: Cambridge University Press, 1998), pp.589-692 (671-73).
- ³². See Sylvia Adamson, 'Subjectivity in Narration: Empathy and Echo', in *Subjecthood and Subjectivity: The Status of the Subject in Linguistic Theory*, ed. Marina Yaguello (Paris: Ophrys, 1994), pp.193-208.
- ³³. Sylvia Adamson, 'From Empathetic Deixis to Empathetic Narrative: Stylisation and (de)subjectivisation as Processes of Language Change', in *Subjectivity and Subjectivisation: Linguistic Perspectives*, ed. Dieter Stein and Susan Wright (Cambridge: Cambridge University Press, 1995), pp.195-224.
- ³⁴. Adamson, in Stein and Wright, eds., *Subjectivity and Subjectivisation*, p.216

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- ³⁵. John Bunyan, *Grace Abounding, with Other Spiritual Autobiographies*, ed. John Stachniewski, with Anita Pacheco (Oxford and New York: Oxford University Press, 1998), paragraphs 211-213/257-259, p.73.
- ³⁶. Adamson, in Stein and Wright, eds., *Subjectivity and Subjectivisation*, p.209.
- ³⁷. Adamson, 'Literary Language', *Cambridge History of the English Language*, 4, p.662.
- ³⁸. Isaac Newton, *Opticks: or, A Treatise of the Reflections, Refractions, Inflections and Colours of Light*, 4th ed. (1730), ed. Sir Edmund Whittaker, I. Bernard Cohen and Duane H.D. Roller (New York: Dover, 1952, 1979), pp.289, 309.
- ³⁹. See George Parks, 'The Turn to the Romantic in the Travel Literature of the 18th Century', *Modern Language Quarterly*, 25 (March 1964); Charles Batten, *Pleasurable Instruction: Form and Convention in 18th Century Travel Literature* (Berkeley, LA, and London: University of California Press, 1978); Barbara Maria Stafford, *Voyage into Substance: Art, Science, Nature, and the Illustrated Travel Account 1760-1840* (Cambridge, Mass., and London: MIT Press, 1984); and Roger Cardinal, 'Romantic Travel', in *Rewriting the Self: Histories from the Renaissance to the Present*, ed. Roy Porter (London and New York: Routledge, 1997).
- ⁴⁰. Leask, *Curiosity and the Aesthetics of Travel Writing*, p.7.
- ⁴¹. Playfair, 'Biographical Account of the Late Dr James Hutton', 70); Craig suggests that 'there are reasons to believe that the drawings [of Arran] reproduced [in *The Lost Drawings*] are not by John Clerk, jnr., but by his father' (*The Lost Drawings*, p.53).
- ⁴². For the geology of Arran and the island's significance for geologists, see J.B. Whittow, *Geology and Scenery in Scotland* (Harmondsworth and New York: Penguin, 1977, 1979), pp.67-79; Con Gillen, *Geology and Landscapes of Scotland* (Harpenden: Terra, 2003), pp.161-3; and Alan McKirdy, John Gordon and Roger Crofts, *Land of Mountain and Flood: The Geology and Landforms of Scotland* (Edinburgh: Birlinn and Scottish Natural Heritage, 2007, 2009), pp.297-301.
- ⁴³. See Porter, *The Making of Geology*, p.166, and Gould, *Time's Arrow, Time's Cycle*, pp.86-88.
- ⁴⁴. G.W. Tyrrell, 'Hutton on Arran', *Proceedings of the Royal Society of Edinburgh*, LXIII, iv, 369-76.
- ⁴⁵. Immanuel Kant, *The Critique of the Power of Judgement* (1790, 1793), ed. Paul Guyer and trans. Paul Guyer and Eric Matthews (Cambridge and New York: Cambridge University Press, 2000), pp.131-43.
- ⁴⁶. See Nicholas and Pearson, 'Robert Jameson on the Isle of Arran', in Wyse Jackson, ed., *Four Centuries of Geological Travel*, pp.31-47 (33).
- ⁴⁷. In *An Outline of the Mineralogy of the Shetland Islands, and of the Island of Arran* (1798), Jameson explores Glen Sannox (which he calls 'Sanicks'), but is not concerned with granite-schistus conjunctions; in *Mineralogy of the Scottish Isles*, however, which repeats most of the earlier account of the exploration of Arran, Jameson adds an account of his exploration of North Glen Sannox ('Sanicks') in which he claims to have searched for signs of granite intrusions into adjacent schistus and failed to find any (see pp.71-74).
- ⁴⁸. See Gould, *Time's Arrow, Time's Cycle*, pp.61-97, and Porter, *The Making of Geology*, pp.184-96.

⁴⁹. See Richard Holmes, *The Age of Wonder: How the Romantic Generation Discovered the Beauty and Terror of Science* (London: Harper, 2008).