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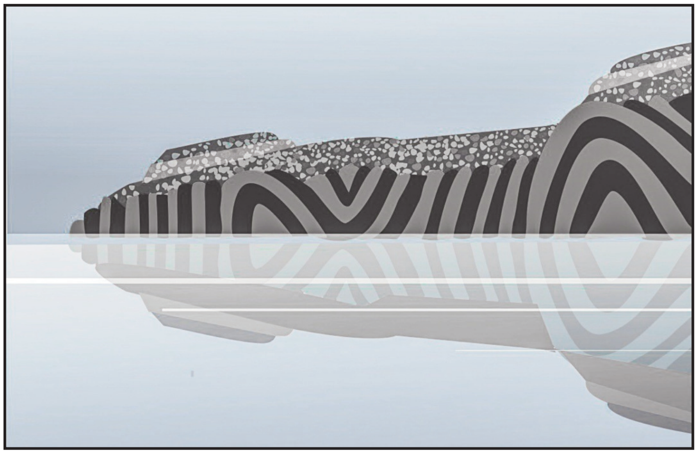

Classic Rock Tours 1. Hutton's Unconformity at Siccar Point, Scotland: A Guide for Visiting the Shrine on the Abyss of Time

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SUMMARY

The angular unconformity at Siccar Point in Scotland is one of the most famous localities in the history of geology. At this spot, steeply dipping, folded turbiditic sandstone of early Silurian age is clearly overlain by subhorizontal red conglomerate, breccia and sandstone of late Devonian age. Siccar Point was not the first unconformity ever to be described or illustrated, but it is unquestionably one of the most spectacular and informative that geologists are likely to see. In June of 1788, a famous excursion by James Hutton, John Playfair and Sir James Hall first discovered this striking evidence for the cyclic nature of geological processes and the probable antiquity of the Earth. Contrary to myth, it was likely not the inspiration for Hutton's famous phrase *no vestige of a beginning, no prospect of an end*, but Playfair's metaphor of *looking so far into the abyss of time* is forever associated with this place. Siccar Point influenced many other geologists, including the young Charles Lyell, who would eventually bring the ideas of James Hutton together with those of William Smith, to build the uniformitarian paradigm that founded modern geology. Lyell's writings would in turn influence the young Charles Darwin in his search for the reality and causes of evolution. Siccar Point is easy to visit from the historic and vibrant city of Edinburgh, and such a pilgrimage is easily combined with other sights of geological or cultural interest. Visiting the shrine involves a short coastal hike in one of the most beautiful parts of Scotland. This article combines practical advice for would-be pilgrims to Siccar Point with some historical context about its pivotal role in the development of geological ideas in the enlightenment of the late 18th and early 19th centuries.

RÉSUMÉ

La discordance angulaire de Siccar Point en Écosse est l'une des localités les plus célèbres de l'histoire de la géologie. À cet endroit, un grès turbiditique plissé à fort pendage du début du Silurien est recouvert de conglomérats rouges subhorizontaux, de brèches et d'un grès de la fin du Dévonien. Siccar Point n'est pas la première discordance qui ait été décrite ou illustrée, mais c'est sans conteste l'une des plus spectaculaires et révélatrices que les géologues puissent voir. En juin 1788, avec leur célèbre excursion, James Hutton, John Playfair et Sir James Hall ont découvert cette preuve frappante de la nature cyclique des processus géologiques et de l`ancienneté probable de la Terre. Contrairement à ce qu'on croit, ce n'est probablement pas la fameuse phrase de Hutton « aucun vestige d'un début, aucune perspective de fin », mais la métaphore de Playfair « voir si loin dans l'abîme du temps » qui est à jamais associée à ce lieu. Siccar Point a influencé de nombreux autres géologues, y compris le jeune Charles Lyell, qui a fini par réunir les idées de James Hutton et celles de William Smith qui ont défini le paradigme uniformitariste, devenu le fondement de la géologie moderne. Les écrits de Lyell influenceront à leur tour le jeune Charles Darwin dans sa recherche de la réalité et des causes de l'évolution. Il est facile de se rendre à Siccar Point depuis cette ville chargée d'histoire et dynamique qu'est Édimbourg, et un tel pèlerinage se combine facilement avec d'autres sites d'intérêt géologique ou culturel. La visite de ce « sanctuaire » implique une courte randonnée côtière dans l'une des plus belles régions d'Écosse. Le présent article combine des conseils pratiques pour les visiteurs potentiels à Siccar Point et présente un historique de son rôle central dans le développe-

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ment des idées géologiques à la fin du XVIIIe siècle et au début du XIXe siècle.

Traduit par le Traducteur

PROLOGUE

In introductory geology classes, I often use images of the Grand Canyon as symbols for the immensity of geological time. Impressive as it is, the canyon is really not the original shrine to our knowledge of Earth's antiquity. The true *shrine on the abyss of time*, as I call it here, lies instead on the temperate coast of eastern Scotland. It was first encountered on one of the most famous field trips in the history of geology – a boat excursion by James Hutton, John Playfair and Sir James Hall in June of 1788. Siccar Point is a place of pilgrimage for geologists and all others who love the mysteries of the Earth, and it seems an appropriate place to begin this new thematic series in *Geoscience Canada*.

James Hutton's archetypal unconformity is easy to visit and enjoy. The scenic hike along the coastal path can be as short as a 3 km round trip, although it can be made longer if you wish. Siccar Point itself reveals one of the clearest and most instructive unconformities that I have ever seen, and its influence in confirming and connecting the ideas that Hutton (1788) expressed in his *Theory of the Earth* is easy to comprehend. On this rocky headland, the first salvo in the great debate about the age of the Earth was fired, creating cracks in a religious dogma that accorded geologists only 6000 years to explain the history of an entire planet. Those fractures would propagate over a century or more, until Arthur Holmes published a famous book that marked the start of modern geochronology (Holmes 1913). Siccar Point is much more than a field locality, so this article includes not only the rocks and how to see them, but also explores the context of those times and the ways in which this singular place influenced subsequent geological thinking.

This article contains no original research. It is built instead from the published scientific record, several books on James Hutton and his contemporaries, and other public-domain sources. The observations, photographs and practical suggestions come from my own visits in March 2016, and the references given at the end should be the primary source for any citations. I commence with some simplified regional and local geology, followed by information for safely and respectfully visiting the site, and some descriptions of rocks and relationships. I then take an historical turn, by recounting some early descriptions and thoughts from 1788, and discussing how Siccar Point might have influenced later geologists. Hutton's insights were undeniably prescient, but their presentation was often disorganized and muddled, and it took the work of others to mould them into a paradigm for physical geology. Knowledge of this wider historical context certainly is not essential to take a beautiful walk to a famous place, but I firmly believe that it can enrich the experience.

LOCATION AND REGIONAL GEOLOGICAL CONTEXT

Siccar Point is located in eastern Scotland, between the city of Edinburgh and the English border, within the historical county of Berwick, now included within the 'Scottish Borders Unitary Region.' It is close to the A1, a main trunk road leading to Berwick-upon-Tweed. If you are willing to walk a few extra kilometres, you can get there using public transport. The site is a coastal headland and some low-relief outcrops that form part of a wave-washed platform on the North Sea coast, situated below steep but negotiable slopes. Other coastal outcrops that form part of a well-known Devonian and Carboniferous section can also be visited in this general area, to make a full-day hiking excursion.

This region is part of the Caledonian orogenic belt, which makes up most of the pre-Carboniferous bedrock of Scotland, England and Wales, aside from older Precambrian areas in northwest Scotland (Fig. 1). Most readers will know that the Caledonian and Appalachian orogenic belts were contiguous prior to the Mesozoic and record the closure of the early Paleozoic Iapetus Ocean and its related basins. The overall geological progression from north to south in Britain is similar to the northwest to southeast progression seen in the Canadian Appalachians, although there remains debate about the exact location of key features. For example, the 'Iapetus Suture' (the limit of Laurentian and peri-Laurentian crust in the orogen) is placed in a more southerly ('outboard') location in Britain than in most interpretations for Newfoundland and elsewhere in Canada (e.g. van Staal et al. 1998). In southwestern England and in south Wales (Fig. 1), Paleozoic rocks are variably affected by Carboniferous deformation (termed Variscan or Hercynian), which is less prevalent in Canada. Some distal effects of Variscan deformation are also recognized north of the Variscan Front (Fig. 1). Central and southeastern England consist of late Paleozoic to Cenozoic sedimentary rocks that form a largely undisturbed southeast-younging and southeast-dipping sequence. On the south coast of England, some of these younger sedimentary rocks are affected by distal deformation caused by the formation of the modern Alpine orogenic belt. It was in southeastern England that the principles of stratigraphy were first elucidated by William Smith, who shares with James Hutton the title of 'the father of geology.' Smith is best known for having constructed the first true regional geological map (e.g. Winchester 2001; Sharpe 2015), whereas Hutton first voiced the idea that geological history might be explained by modern day processes operating over immense periods of time, amongst many other ideas. Hutton's ideas would eventually lead to the well-established doctrine of uniformitarianism (e.g. Lyell 1874) which persists today, albeit with some modifications.

Siccar Point is located within a few kilometres of a major structure known as the Southern Upland Fault (Floyd 1994; Figs. 1, 2), which separates a region dominated by lower Paleozoic rocks (the Southern Uplands) from a region dominated by Devonian and Carboniferous rocks (the Midland Valley of Scotland). The Midland Valley represents a rifted basin that also contains volcanic rocks, and it developed following the closure of the Iapetus Ocean (e.g. McKirdy et al. 2007). Devonian and Carboniferous sedimentary rocks also occur within the Southern Uplands, where they form thinner sequences that sit unconformably upon older deformed and

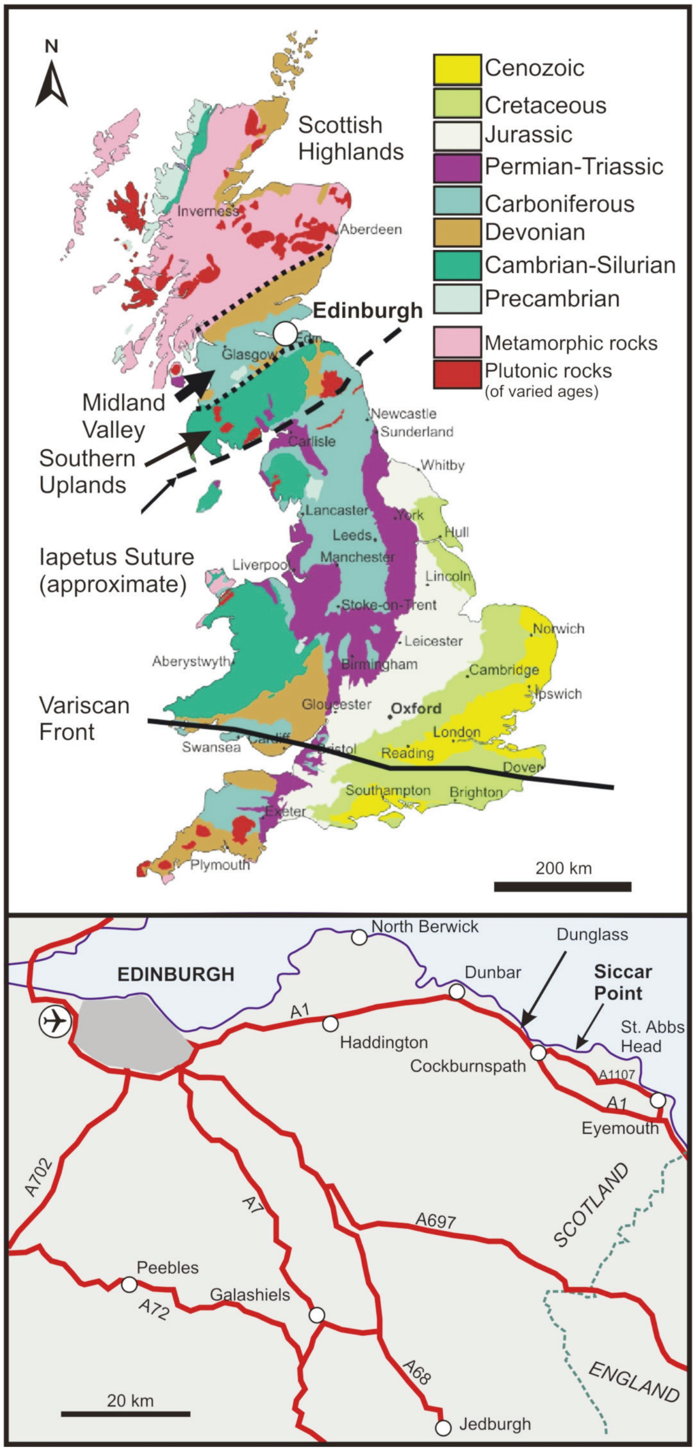

Figure 1. A. Simplified geology of England, Wales and Scotland, showing the location of the area near Edinburgh covered in this paper and some important geological features. B. The location of Siccar Point in relation to local towns and major roads in the area. The geological map in (A) is modified from one published online by the British Geological Survey.

metamorphosed sedimentary rocks. Siccar Point is the classic expression of this regional unconformity, but it was not the only such site examined by Hutton in the late 18th century. The Southern Uplands Terrane is considered in Britain to be of peri-Laurentian affinities, and to represent an accretionary wedge formed as the last vestiges of the Iapetus Ocean were subducted (e.g. McKirdy et al. 2007; Stone 2012; Stone et al. 2012). Rocks occupying the same relative position in eastern Canada are considered to be of peri-Gondwanan affinity (e.g. van Staal et al. 1998), but of similar tectonic setting. The paleogeographic setting of the Southern Uplands Terrane was recently reassessed by McConnell et al. (2016), using detrital zircon to establish sediment provenance. This debate, although interesting, is not relevant to the story of Siccar Point, other than to illustrate that discussion of the geology continues and probably always will.

The regional and local geology are summarized in a recent article by Archer et al. (2017) and also in more general publications from Scottish Heritage and the British Geological Survey (notably MacAdam and Stone 1997; source of Figure 2). A more detailed summary is provided by Barclay et al. (2005) as part of an extensive review of "Geological Conservation Review Sites," some of which are designated or suggested as Sites of Special Scientific Interest (SSSI) in the United Kingdom. The area lies within the Eyemouth Sheet (1:50,000) of the British Geological Survey, first published in 1982, with an accompanying Memoir (Grieg 1988). In the area east of the town of Dunbar, there is a westward progression from Silurian sedimentary rocks, through Upper Devonian and Carboniferous sedimentary rocks, towards the Southern Upland Fault (Fig. 2). The local geology of the area around Siccar Point is depicted in Figure 3, modified after Grieg (1988) and Barclay et al. (2005). The oldest rocks are the turbiditic sandstone, siltstone and mudstone of the Silurian Gala Group, which are overlain by Devonian terrestrial sandstone of the Stratheden Group, which then passes up into the more varied Carboniferous rocks of the Inverclyde and Strathclyde groups (Fig. 3). The sedimentary rocks of the Gala Group are assigned to the Llandovery stage based on fossil graptolites (Stone et al. 2012). The Devonian rocks belong to the sequence traditionally known as the 'Old Red Sandstone' in Britain, as distinct from the 'New Red Sandstone,' which is of Permian to Triassic age. These red-bed sequences represent post-orogenic 'molasse' cover rocks linked to the Caledonian and Variscan orogenies, respectively. Fossil fish remains from the lower Stratheden Group indicate a late Devonian (Fammenian) age (Barclay et al. 2005).

None of these familiar stratigraphic terms existed at the time of James Hutton's explorations, and there was no geological time scale as such. Indeed, most of the concepts that we now take for granted were not developed until well into the 19th century. In the time of James Hutton, the questions about geology were of a much more fundamental nature, i.e. how and when were rocks formed, and what did they mean?

PRACTICALITIES AND LOCAL GEOLOGY SIGHTS

There are published descriptions of the local geology and the Siccar Point site, most recently by Archer et al. (2017) and in some previous excursion guides by Craig (1960, 1986), which are less easily accessible. There is also a summary suitable for self-guided excursions in an excellent book on the geology of Scotland (McKirdy et al. 2007). Several books about James

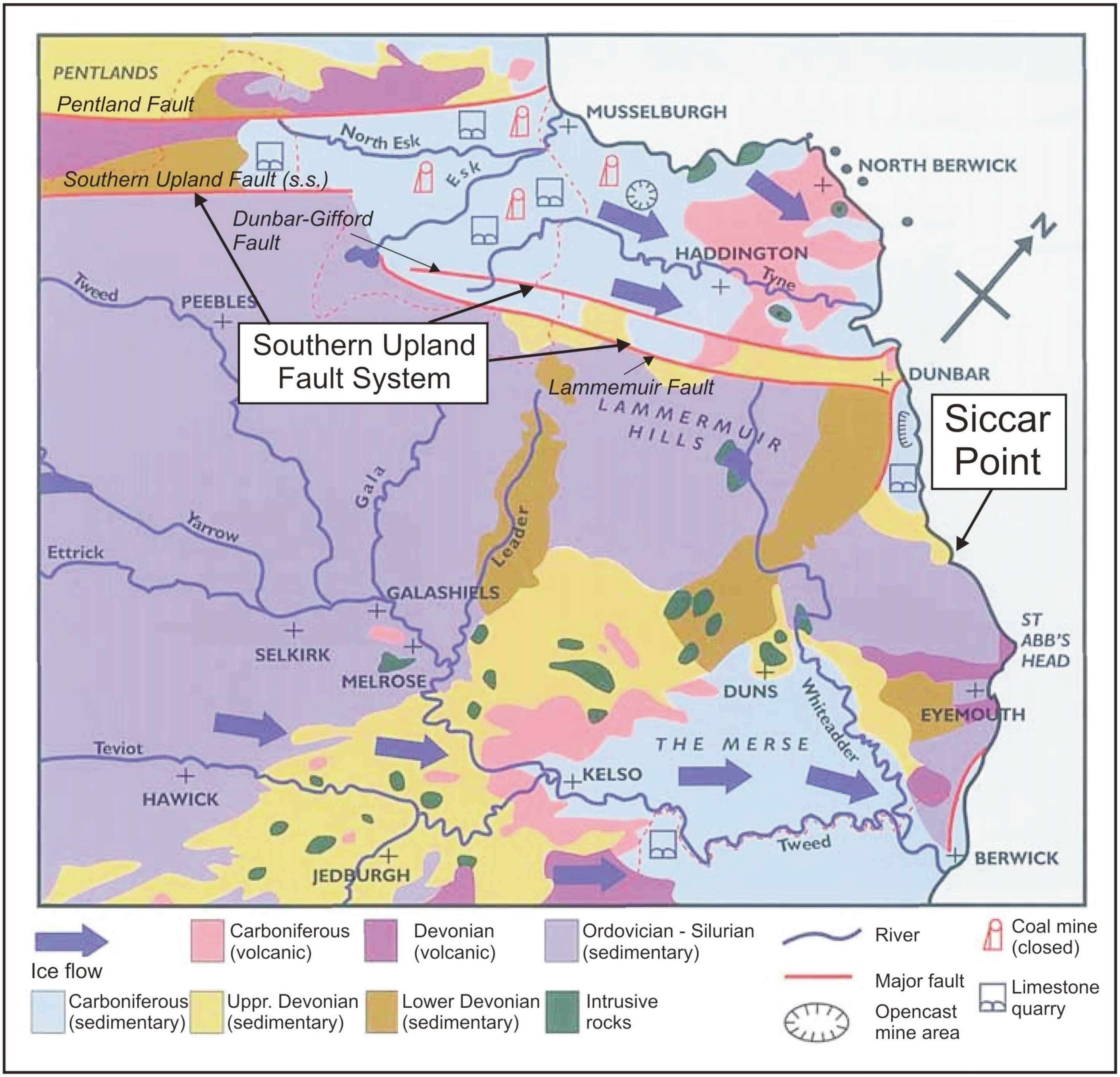

Figure 2. Simplified geology of the area east of Edinburgh and including the area around Siccar Point. From MacAdam and Stone (1997) with some slight modifications and additions. Base geological map from report used with permission of the British Geological Survey and Scottish Natural Heritage.

Hutton also provide discussions of the initial visits by Hutton and his colleagues (e.g. Baxter 2003; Repcheck 2003). Montgomery (2003) provided an illuminating discussion of Siccar Point in the context of teaching the history of geology, emphasizing it as an example of the scientific method. In this section, I integrate some of these sources with my own observations to simplify matters for the travelling geologist. Readers should note that references to landmarks, although current as of early 2016, may become obsolete, and also that odometer readings for vehicles in the UK are given in miles, rather than kilometres.

Safety, Security and Conservation

Siccar Point is accessed via a coastal hiking trail that is well-defined and maintained for the most part, but its condition may vary seasonally, and it may be muddy and uneven in places. In some areas, it is situated close to the edges of steep slopes or vertical cliff faces. Sturdy footwear is important,

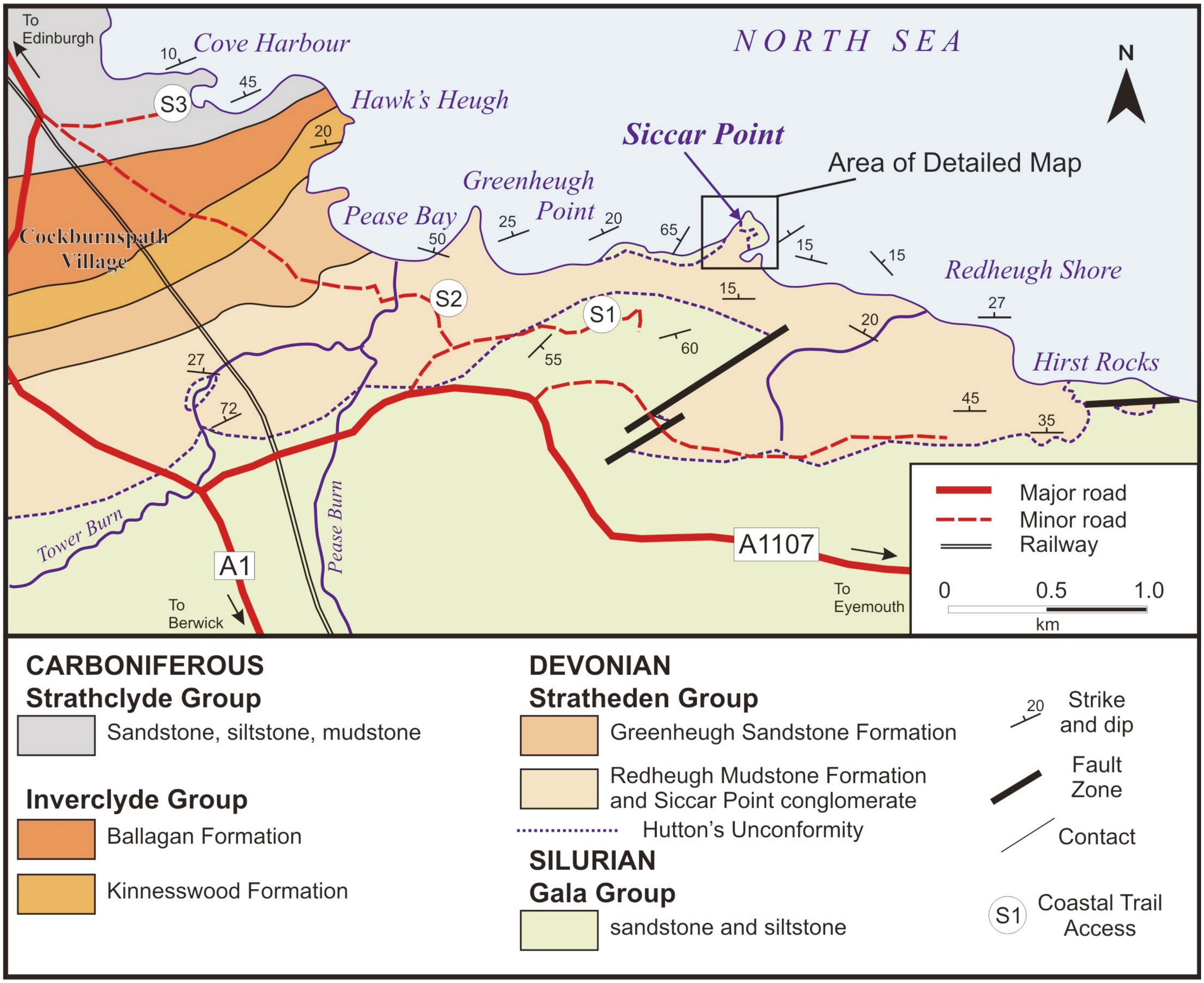

Figure 3. Simplified geological map of the area around Pease Bay and Siccar Point showing the access roads and entry points to hiking trails. From the British Geological Survey map (Grieg 1988); compare Barclay et al. 2005. Note that there is extensive outcrop in the intertidal zone along this coast, which is omitted for the sake of clarity.

preferably with good support for the ankles, and care should be exercised at all times. The weather in eastern Scotland is just as unpredictable as it is in Newfoundland or Nova Scotia, so walkers should be prepared for wind and rain as well as sunshine and everything else in between. The descent from the path to the coastal outcrops at Siccar Point is the steepest and most challenging part of the excursion. However, this path is well-trodden and follows a comforting fence. The unconformity site consists of coastal outcrops, which are uneven, and from which there may be vertical drops to the cold waters of the North Sea. Part of the area is a wave-cut platform across which larger waves may travel if sea conditions are rough. Visitors should monitor wave activity carefully before descending, and determine which areas might be dangerous, and should stay well away from the water or any areas that appear wet. Note that any excursion or activity described here is conducted *entirely* at your discretion, and that neither the author nor the Geological Association of Canada accepts any responsibility for injury or loss that might occur. Geoscientists visiting this area should follow all the safety protocols that they would normally employ in their professional work.

Siccar Point is designated as a Site of Special Scientific Interest (SSSI) and it is protected; the collecting of samples and removal of material is prohibited, as is any hammering or defacement of outcrop surfaces. There is no need to even bring a hammer. There are codes of conduct that apply to outdoor activities (the Scottish Outdoor Access Code), and these can be consulted at www.outdooraccess-scotland.com. Scottish Natural Heritage even publishes a specific 'geological code,' which can be found on their website at www.nature.scot. Visitors are urged to consult these guidelines.

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Getting to the Siccar Point Area

The easiest and most flexible way to visit the area is with your own vehicle, but it is also possible via public transport. Driving in metropolitan Edinburgh is not for everyone, as the streets are narrow and congested, and parking is expensive and elusive. It is currently possible to arrange a guided tour to the site through *Geowalks* (www.geowalks.co.uk), which represents an easy solution, including transportation. If you have a rental vehicle and are staying in central Edinburgh, it may actually be cheaper to leave the car at long-term parking at the airport and use the excellent tram service for city centre access. If travelling from Edinburgh by road, the A1 is the route out of the urban area to the village of Cockburnspath, where there is a roundabout with a left turn signposted for Pease Bay, just before the road crosses the path of the railway. The looming bulk of the Torness Nuclear Power Station (on the left) provides a useful marker around 5 km before the roundabout. If this turn is missed, take the later left turn on the A1107, signposted for Eyemouth. The Siccar Point area can then be accessed via the minor road on the left, a few hundred metres past the bridge over Pease Burn. These roads are all shown on the local geology map (Fig. 3).

Public access is via the bus service linking Edinburgh and Berwick-upon-Tweed (England) which is provided by Borders Buses (www.bordersbuses.co.uk). Currently, the service is numbered 253, and it runs approximately once an hour; note that the last return bus (as of February 2018) to Edinburgh from Cockburnspath departs at 16.49 (weekdays) and just after 17.00 on weekends. Be sure to check the latest schedules, and to leave Edinburgh early to ensure enough time for hiking. From Cockburnspath village, walk along the road to Pease Bay, as shown in Figure 3. Note that the road lacks a pedestrian walkway, and that drivers may come around corners at high speeds. Care should be exercised and you should face the traffic at all times.

There are several choices for an excursion to Siccar Point, depending on how far you wish to walk. The shortest option is to drive through the Pease Bay Caravan Park (Plate 1), through the ford on Pease Brook, and then take the side road on the left that leads into the Drysdale's farm property. The company has thoughtfully provided a small parking area for geologically minded visitors (Point S1 on Fig. 3). Alternatively, park at the junction of the Drysdale's farm road, and walk a short distance back towards the Caravan Park, to connect to a hiking trail clearly signposted for Siccar Point (Plate 2; Point S2 on Fig. 3). This will lead eventually to the same parking area at Point S1, but provides a scenic diversion. The longest and most adventurous route is to take the short access road on the left from the Pease Bay Road, about 200 m after the roundabout on the A1. This leads to Cove Harbour, from where the coastal path can be accessed at Point S3 and then followed all the way through Pease Bay to Siccar Point. However, remember that you will have to retrace your steps to return, or walk back on the roads, and that parking is limited around Cove Harbour. The full hike provides a walk down-section from Carboniferous into Devonian rocks and terminating at Hutton's unconformity. The higher part of the stratigraphic section is also well-known for superb exposures of fluvial and aeolian sedimentary rocks, and also important fossil fish localities (Barclay et al. 2005). Note that these sites are also SSSI, with the same protection criteria as Siccar Point itself. Although I have not completed the walk from Cove Harbour to Pease Bay, there is a useful description provided in an informal report by the Glasgow Geological Society that describes a 2016 field excursion (Hollis 2016).

Plate 1. View of the large caravan park at Pease Bay. You will pass through this en route to Siccar Point.

Plate 2. View of Pease Bay from the road leading towards Siccar Point, where it intersects the Berwickshire coastal path.

The Coastal Hike to Siccar Point

From Pease Bay, the path leads along the coast, but not on the clifftops, and then rejoins the farm access road that leads to Point S1. A signboard here provides some background information on the Siccar Point locality. The trail from here leads northward toward the coast, and first passes the ruins of St. Helen's Chapel. Like many older buildings here, and most of the stone walls that bound fields, this is constructed from local

Plate 3. The ruins of St. Helen's Chapel, which the trail passes. Note the mixture of red and grey-green stone blocks used in construction.

Plate 4. Dry-stone wall not far from Siccar Point on the hiking trail. Note the almost equal proportions of red (Devonian) and grey-green (Silurian) stones.

Plate 5. Coastal view en route to Siccar Point. The low outcrops in the water are gently dipping Devonian sandstone.

stone blocks (Plate 3). In this case, there is a striking colour contrast between most of the stones (grey or pale green sandstone of Silurian age) and a smaller number of orange-red blocks (Devonian sandstone). It is noted on the signboard that the mixture of sandstone types used in construction alerted James Hutton to the possibility that the contact between the 'primary' and 'secondary' sedimentary series that he had already defined might lie in this general area. This is not mentioned in other sources, but it certainly makes sense as a useful observation. Indeed, the dry-stone walls near Siccar Point itself contain almost equal proportions of the two sandstone types (Plate 4).

Beyond the chapel, the trail meets a stone wall that runs parallel with the cliff edge and follows this wall eastward towards Siccar Point. The wall can be climbed in places, although care must be taken to avoid the barbed wire. The coastal side of the wall allows sufficient space for safe walking, and provides better coastal views, but it places walkers close to the cliff in some places. There is really no need to climb the wall, as there is a gate providing access closer to the point. Views of the coastline here reveal the outcrop pattern of gently dipping Devonian sandstone, protecting sand and gravel beaches (Plate 5), and then provide views towards Siccar Point (Plate 6). The latter provides an illustration of the three-dimensional topography of the unconformity surface. The steeply dipping grey beds in the lower section of the slope are the older Silurian rocks, and the largely unexposed upper section conceals subhorizontal red sandstone. However, the offshore rocks in the far distance, close to Siccar Point, also represent the basal surface of the Devonian section, which is essentially at sea level, because it sits within an incised paleochannel (see below).

Above Siccar Point, the trail is marked by a second sign board, which provides some additional information on unconformities and their significance. The point is clearly visible below, and the colour contrast between the grey Silurian strata and the red Devonian strata is obvious even from above.

Descending to the Siccar Point Outcrops

The view of Siccar Point from the clifftop (Plate 7) suggests that this is a steep descent, and it is, but it is easier than it

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Plate 6. Approaching Siccar Point on the coastal path. The steeply dipping grey beds in the middle are Silurian greywacke, but the upper part of the slope (unexposed) consists of subhorizontal Devonian sandstone. The rocks in the distance are part of the Siccar Point outcrop, where the unconformity is essentially at sea level.

Plate 7. View of the Siccar Point outcrops from the clifftop, showing the route down to the locality following the fence line. Devonian sandstone visible in right of photo, underlain by subvertical Silurian greywacke. The reddish outcrops on the left are Devonian sandstone and breccia sitting on the Silurian rocks in an incised paleochannel, which extends northward below sea level.

appears. This is because a sturdy fence leads almost all the way down and provides secure hand-holds and guidance. Previous visitors have also created a series of eroded steps parallel to the fence, which also helps, but be wary of slippery red mud if there has been recent rain. The steepest part of the descent is close to the bottom, and this should be avoided. About two-thirds of the way down there is a double fence post; from here, turn to the left and descend diagonally across a gentler grassy slope, and then double back towards the outcrops. The ascent follows the same course, and is actually somewhat easier than the descent, if more tiring. This section of the hike is definitely unsuitable for children or for anyone who is uncomfortable with heights, but it will not intimidate most field geologists. However, good footwear and caution are essential, and a hiking stick is a valuable accessory.

As seen from above, the southeast side of Siccar Point contains a slot-like channel backed by vertical cliffs (Plate 7), and the descent provides a spectacular view back towards the unconformity surface, which is high in the cliff face (Plate 8). This view also shows the way in which the contact cuts down sharply into the older rocks, which here strike almost parallel to the cliff face. This is because the area of Siccar Point itself is an incised channel beneath a regional unconformity surface that is more planar, but still topographically complex (Craig 1986; Barclay et al. 2005; Archer et al. 2017).

Geological Relationships and Sights at Siccar Point

In my time as a field geologist, I have not seen an unconformity as accessible and informative as Siccar Point. James Hutton and his colleagues were indeed lucky to have found such a clear and instructive example in June 1788.

The geology of Siccar Point is described by Archer et al. (2017) and in previous accounts by Craig (1986), Grieg (1988), Barclay et al. (2005) and McKirdy et al. (2007). The local geology is illustrated in Figure 4, modified after Grieg (1988). The outcrop is in three parts; to the west, well-bedded grey sandstone and siltstone dip towards the south at 45° or more. These same rocks in the southeast dip more steeply to the north, suggesting tight folding; according to Grieg (1988) bedding is locally overturned in this area, although access to these outcrops is not easy. In the central part of the outcrop, and on some offshore reefs, red sandstone and basal breccia dip gently to the north. The younger rocks are draped over steeply dipping Silurian rocks, and resistant sandy beds locally protrude through the unconformity surface to emerge as tiny inliers on the outcrop surfaces. Similarly, patches of the basal breccia facies sit in low-lying sections of the outcrops, forming complementary outliers. The angular discordance between Silurian greywacke and Devonian sandstone is clearly seen and there is

Plate 8. View of the unconformity in the cliffs, about halfway down the fence line. The Silurian greywacke beds are steeply dipping in the plane of the photo. Note how the elevation of the unconformity surface descends at the right side of the photo, illustrating the paleotopography on the surface.

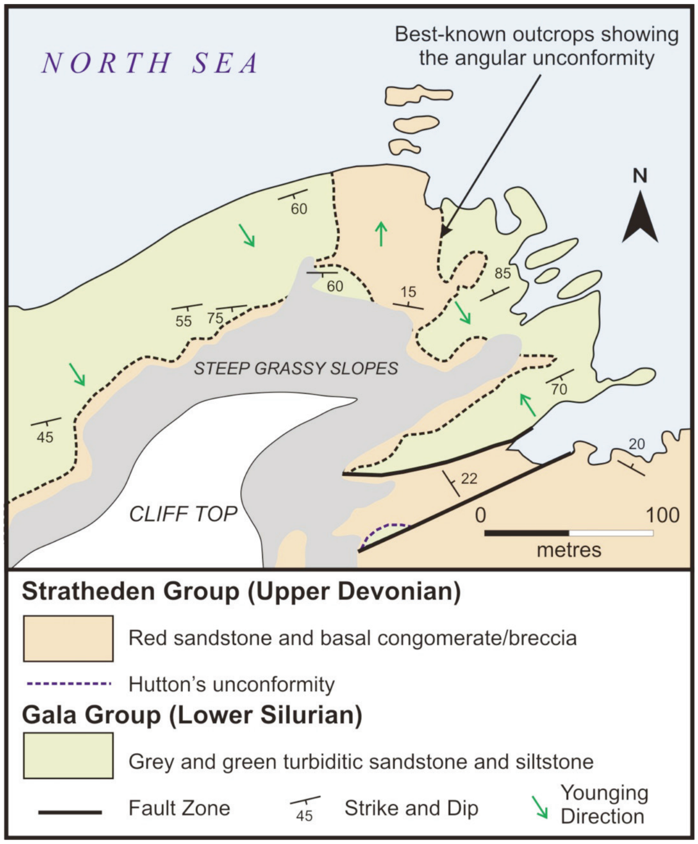

Figure 4. Geological sketch of the Siccar Point locality (Hutton's unconformity). Simplified slightly from Grieg (1988) and Barclay et al. (2005).

Plate 9. This is the classic view of the unconformity seen in many other sources. The unconformity surface is just above the hiking stick. Note how the surface is draped over the resistant Silurian sandstone unit at the left of the photo.

essentially no sign of disturbance by later faulting. The most famous section of the outcrop is indicated in Figure 4, and Plates 9 to 15 highlight some of the relationships.

All descriptive accounts of Siccar Point emphasize the marked paleotopography of the unconformity surface, which is seen on scales from centimetres to tens of metres (Craig 1986; Grieg 1988; Barclay et al. 2005; Archer et al. 2017). Regional studies of the Devonian sedimentary rocks imply that they were deposited in erosional valleys that overlapped in time and space, and the Siccar Point exposures are interpreted as an incised gully formed in an arid climate, which experienced periodically intense water flow. The most detailed account of sedimentological features is provided by Barclay et al. (2005), drawn from earlier and more detailed studies of the Devonian rocks. The central part of the outcrop contains most of the breccia, and the clast population is dominated by angular plate-like chunks of older greywacke, along with pieces of quartz (likely from veins). The imbrication of clasts, and information

Plate 10. A closer view of the unconformity surface shown in Plate 9, showing the angular discordance, which here is almost 90°. The basal conglomerate and breccia unit sits between the older rocks and the red sandstone, but is only a few centimetres thick. Note a possible tight fold closure in the older rocks to the right; this was not confirmed in my field notes, so it could be an optical illusion caused by inclined fracture surfaces.

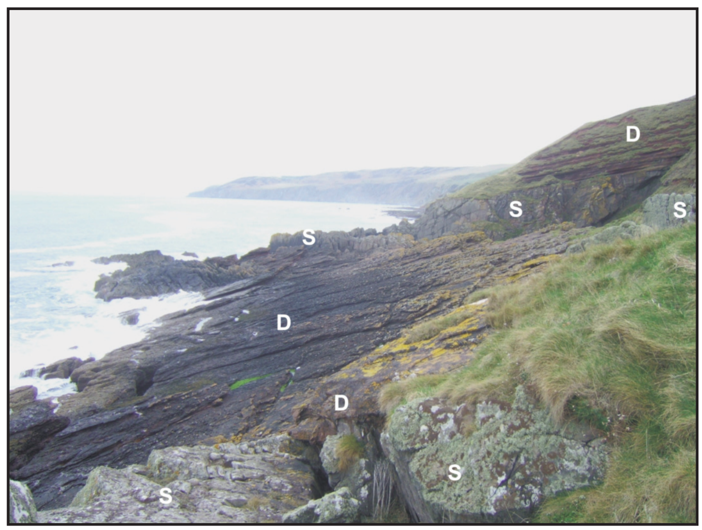

Plate 11. A view of the entire unconformity surface, showing the channel containing conglomerate and breccia (tilted to left, flow direction to right), resistant Silurian outcrops (centre and upper right) and gently dipping sandstone sitting directly on the Silurian greywacke (top right) outside the incised channel feature (S-Silurian, D-Devonian).

Plate 12. A view across the bottom of the paleochannel that contains much of the Siccar Point unconformity surface. The breccia and conglomerate in the foreground dip gently to the right (north) but the paleocurrent direction is to the left (south). This gives the slightly disorienting sense of an uphill water flow. The massive grey rocks in the middle are resistant Silurian greywacke, which would have formed islands in the Devonian channel or gully. The breccia passes upwards into red sandstone that eventually filled the channel (see centre of photo) but has now largely been eroded. This part of the outcrop is especially evocative.

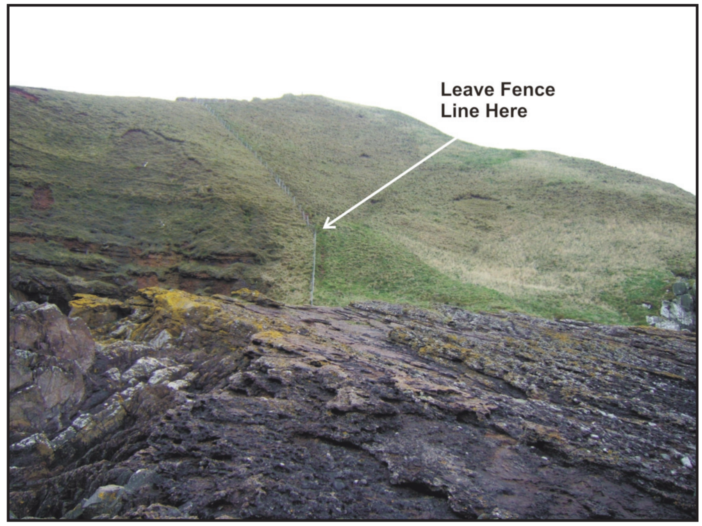

Plate 14. A view looking up from Siccar Point towards the access route along the fence line. This also shows the unconformity surface and north-dipping breccia and conglomerate in the channel floor at right. The white-weathering steeply dipping beds at left are the older Silurian greywacke. In the left distance is the red sandstone that sits above the basal unit, but which is largely eroded from the coastal outcrops. Note the inflection point in the fence line, marked by a double fence-post. The route down to the point diverges from the fence line at this point, as shown to cross the gentler grassed slope to the right.

Plate 13. Part of the unconformity surface and basal breccia unit shown in oblique plan view; steeply dipping greywacke at left, with red sandstone matrix to breccia infilling the less resistant areas.

Plate 15. A close-up view of the conglomerate and breccia unit that marks the unconformity surface almost everywhere at Siccar Point. Note the poorly sorted matrix (the 'arenaceous cement' of John Playfair), and the wide range of clast sizes and shapes. A clast of probable white vein quartz is at top left.

from cross-bedding foresets in younger sandstone, imply that the paleocurrent in the channel flowed towards the south or southeast (Grieg 1988). Standing within this area, at the bottom of a Devonian gully, it is easy to imagine the cobble and boulder-choked watercourse, with rocky resistant outcrops of older greywacke beds standing up as islands within it (Plates 11 and 12). Cross-bedded sandstone overlies breccia and conglomerate, showing the change in depositional environment. Due to the regional northward tilting of the unconformity surface the paleocurrent appears now to be flowing uphill, which is somewhat disorienting, but the sense of stepping back in time and walking in an ancient riverbed is palpable, and it will strike visitors who have little geoscience knowledge.

The amount of missing time represented at the Siccar Point unconformity surface is not measured directly because the sedimentary rocks are not amenable to radiometric dating. The older rocks are of Silurian age, in the Llandovery Stage (~ 444 Ma to 428 Ma) based on regional correlations and graptolite data. Loose blocks of Devonian sandstone from Siccar Point contain fossil fish remains indicating an upper Devonian (Famennian) age of ca. 370 Ma (Barclay et al. 2005 and references within). Thus, the unconformity does not by itself closely constrain the timing of the deformation and low-grade metamorphism of the Silurian rocks. In addition to its value in teaching the essential principles of geology and science (Montgomery 2003), Siccar Point is also relevant as an end-member of a spectrum of unconformable and paraconformable surfaces involved in traps for petroleum resources (Archer et al. 2017). For more details on the local geology and related matters, see Archer et al. (2017), its contained references and the other sources cited above. After visiting the site and spending some hours exploring it (including a leisurely lunch) I can only express my agreement with the views of McKirdy et al. (2007):

> *"If you go nowhere else to see the geological gems of Scotland, go to Siccar Point"*

Taking a Virtual Tour

A virtual tour of this locality is available online. The British Geological Survey has produced an excellent video using drone photography, appropriate music and a well-conceived commentary intended for non-geologists. Find the video at: https://www.youtube.com/watch?v=JCEDCcHcpYE, or by searching keywords. The production is an excellent model for what we could do in Canada for important geological sites, but it is no substitute for visiting Siccar Point in person.

SICCAR POINT AND GEOLOGICAL THOUGHT

For most classic geological localities, there are elements of history to consider, but Siccar Point is unique, as it played a key role in changing ideas about the age of the Earth and influenced subsequent thinking. A visit to this place is thus also a chance to contemplate and appreciate the origins of modern geology. For more complete accounts of the lives and accomplishments of James Hutton and his acquaintances, see several biographies (Bailey 1967; Dean 1992; Repcheck 2003; Baxter 2003). The latter reference has my strongest recommendation for easy and informative reading and also for giving some glimpses into the human side of Hutton. I attempt here only to highlight some key points within the wider context of 18th century geological thought. It is also interesting to revisit original descriptions and famous words that the site inspired, although these certainly appear in other accounts, and the most famous phrase of all even made its way into rock music. I cannot resist mentioning the irony of Hutton's words being used in a song by an American punk rock band named *Bad Religion*. I suspect that one of the band members must at the very least have taken an introductory geology course, but have found no documentary evidence.

The Age of the Earth: Genesis Versus Science

We have all grown up with the knowledge that the Earth is around 4.6 billion years old, as demonstrated from U–Pb isotopic studies of meteorites, but the road to this insight was not straight or smooth. In 1788, when Hutton and his friends boarded a boat at Dunglass, the age of the Earth was accepted by almost all at around 6000 years, based on biblical interpretation by James Ussher, Bishop of Armagh (1581–1656), who in turn derived it from previous scholars. Similarly, the idea of divine creation was questioned by very few, and even then only at their peril. James Hutton was one of the first to propose that the Earth's origin was far more distant in time. In 1785, three years before visiting Siccar Point, his ideas were first expressed in a paper read to the Royal Society of Edinburgh (Hutton 1785). Although this was only an outline of his concepts, it remains one of the clearest, leading to suggestions that much of it was actually written with assistance from more lucid friends, either John Playfair (Bailey 1967) or William Robertson (Dean 1992). Hutton's (1785) 'abstract' contained the memorable phrase:

> "*...with respect to human observation, this world has neither a beginning nor an end...*"

These words are nowhere near as famous as the sentence that closed the later 1788 edition of "*Theory of the Earth*," but they are perhaps more accurate, as they are qualified. Unfortunately, Hutton's critics did not appreciate these terms of reference and castigated him for suggesting that the Earth was eternal. To the pious, this was atheism and heresy, because only one entity could truly be eternal. Hutton was actually not an atheist, but a *deist* – he believed in creation, but not as depicted in Genesis, and he saw no divine role in the routine workings of the world, on any time scale. His ideas began the 'Age of the Earth Debate,' during which views directly based on theology, or developed to be consistent with theology (e.g. 'catastrophism') would be superseded by the concept of uniformitarianism, which demanded that the Earth be very ancient. The 1788 visit to Siccar Point was undoubtedly an important influence on such ideas, but it was not the *source* of such a concept, because it came later than its first presentation. Siccar Point was also not the first unconformity that Hutton had visited during his explorations, although it is undoubtedly the clearest (e.g. Montgomery 2003).

Three Men in a Boat

In 1788 James Hutton and two colleagues embarked on a boat excursion from Dunglass, located to the west of Cockburnspath (Fig. 1). This is probably the most famous field trip in the history of geology, so it is fitting to introduce the characters and reflect upon their words and other depictions of the time. Three visual illustrations, chosen to represent their probable appearance ca. 1788, appear in Figure 5. There is little choice of subject material when it comes to Hutton, for the portrait by Henry Raeburn, completed around 1775, seems to be the only image that we now possess.

The name of *James Hutton* (1726–1797) is familiar to every geology student, but few know more than this and his status as one of the 'fathers of geology.' Hutton was a wealthy man, interested initially in chemistry, who later went on to qualify as a medical doctor. He never actually practised medicine, but instead took to farming, introducing 'modern' agricultural methods at his Berwickshire farm. For full biographical accounts, see Baxter (2003) and Repcheck (2003). Hutton's ideas about earthly processes reputedly came from his obser-

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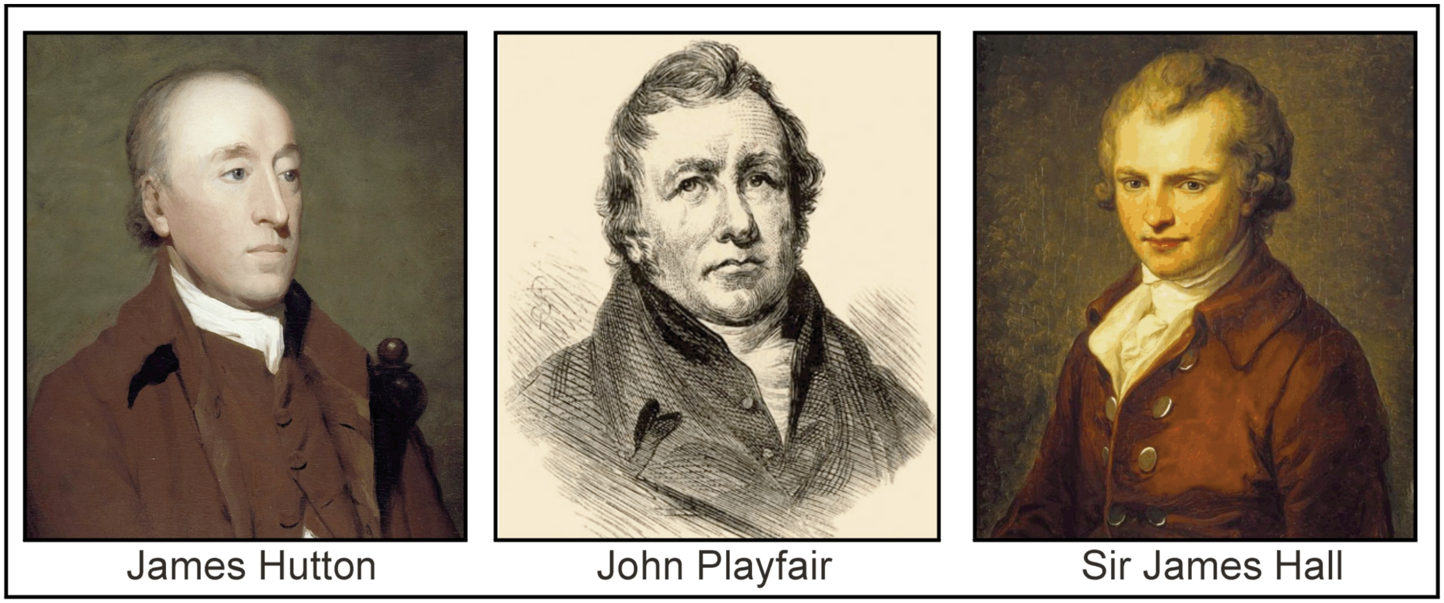

Figure 5. The protagonists of the Siccar Point story, namely James Hutton, John Playfair, and Sir James Hall. The images are chosen from limited selections in order to correspond roughly with their likely appearance in 1788, when they embarked on the famous field trip from Dunglass, west of Pease Bay. Portrait of Hutton by Henry Raeburn (1756–1823), around 1775, now located in the Scottish National Portrait Gallery. Engraving of John Playfair, obtained from ClipArt ETC (Florida Centre for Instructional Technology) and featured in the Amadeus Grabau's "*Textbook of Geology*," published in 1920. Details of the date and artist proved difficult to establish. Portrait of the young James Hall by Angelica Kauffman around 1785, now located in the Scottish National Portrait Gallery.

vations as a farmer. He saw that soil was slowly but steadily removed by erosion and transported by rivers to the sea. He reasoned that there must be an opposing process, by which material deposited in the seas was somehow returned to the land, to begin the cycle again. This represents the 'rock cycle' taught in every school today, and he suspected that long expanses of time were essential. He had other prescient ideas, notably that granite and other igneous rocks were once molten, rather than crystallized from some early 'universal ocean.' He argued that vast internal heat was responsible for raising rocks from the ocean basins to form mountains that would then be eroded. He is even credited with the first thoughts that the Earth might be likened to a vast machine that maintains a habitat for life, a concept that would later expand into the 'Gaia Hypothesis' of the 1970s, minus the element of design (e.g. Lovelock 1988). Gaia is still with us, but is unfortunately now covered by the far less imaginative term 'Earth System Science.' Baxter (2003) speculated that some of Hutton's ideas about thermal energy and the workings of machinery came from his close friendship with James Watt (1736–1819), the inventor of the steam engine. I myself wonder if Hutton's Gaia-like ramblings had some connection to the economic theories of another friend, Adam Smith (1720–1790), with their checks, feedback loops and balances. Hutton, Watt, Smith and other well-known intellectuals were all part of what is now known as the 'Scottish Enlightenment,' when Edinburgh gained the unlikely nickname of "The Athens of the North". In 1788, Hutton was 62, and not as strong and fit as he once had been. He had abandoned active farming and returned to live in Edinburgh and was a prominent (if eccentric) member of the city's intelligentsia. Later that year, the first edition of "*Theory of the Earth*" would be published, and much if not all of its text was already completed. A two-volume expanded edition was published in 1795, but his health was by then frail and additional volumes remained uncompleted when he died in 1797.

The name of *John Playfair* (1748–1819) is less familiar than that of Hutton, but he was in large part responsible for the impact of Hutton's ideas. He began his career as a church minister and was then known as a mathematician who wrote a landmark textbook on geometry. He also dabbled in physics, which led him into the natural sciences. Playfair was a keen observer, a logical thinker and a lucid writer; this latter quality differentiated him from Hutton, whose writing was at times impossibly convoluted, long-winded and multidirectional. "*Theory of the Earth*" was dubbed one of the "*least read most important books in the history of science*" (Bill Bryson 2003), although it likely has some competitors for that honour. John Playfair commented on its turgid and confusing prose and, as he was a close friend and admirer of Hutton, we can only assume that he erred on the side of generosity in stating:

> *"The great size of the book, and the obscurity that may justly be objected to many parts of it, have probably prevented it from being received as it deserves".*

Following Hutton's death, Playfair became his loyal advocate, and in 1802 he published "*Illustrations of the Huttonian Theory of the Earth,*" which outlined Hutton's ideas in an ordered and clear treatment. This book is not exactly short, and is perhaps misnamed because it lacks any true illustrations, but the wider recognition and discussion of Hutton's concepts in the 19th century came from Playfair's efforts. Interestingly, Playfair's exposure to geology was largely through John Walker

(1731–1803), a professor of Natural History at the University of Edinburgh. Walker was a noted follower of 'neptunism,' the idea that all rocks, including what we now see as igneous and metamorphic types, were crystallized from primordial ocean waters, and he would later become one of Hutton's fiercest critics, along with the Irish scientist Richard Kirwan. Some accounts (e.g. Repcheck 2003) suggest that both Playfair and Sir James Hall (see below) were initially skeptical of Hutton's 'plutonist' ideas, which were directly opposed to what they had been taught by Walker.

The third man on the June 1788 excursion was *Sir James Hall of Dunglass* (1761–1832), a young aristocrat who had recently inherited this local estate and title; he would later become president of the Royal Society of Edinburgh. Then only 27 years old, his scientific interests lay largely in chemistry, but he was also influenced by John Walker's view of natural history. James Hall went on to have a very important career in geology, as the pioneer of experimental petrology, and his work was instrumental in refuting neptunism. He placed mixtures of minerals or powdered rocks in sealed rifle barrels and subjected them to high temperatures and pressures in blast furnaces. Among his achievements was proving that limestone could be converted to marble without losing carbon dioxide and that basalt could be melted and recreated as a coarser grained rock if cooled slowly. Wyllie (1999) discussed his many contributions to our knowledge. Like Playfair, Hall became a lifelong defender of Hutton's view of the Earth and he continued to live at the estate in Dunglass. It is likely that he took many other early 19th century geologists to Siccar Point, and I like to think of him as the 'keeper of the shrine' through much of his life, although there is no written support for this fanciful view.

A Day Not Soon to be Forgotten

The field trip in June 1788 took place in fair weather, which allowed them to 'sail' close to the shore. It seems unlikely that they would have been driven along solely by the wind and one account suggests that they were accompanied by 'several sturdy farmhands,' who provided at least some motive power. They progressed past the red cliffs and fine sands of Pease Bay, then unblemished by hundreds of box-like caravans. Biographical works (Repcheck 2003; Baxter 2003) both commence with 'fictionalized' reconstructions of this trip, which is in itself an indication of its importance. Many undergraduate geology texts mention it, and some include embellishments, such as Hutton watching the waves move sediment and actually deposit it. Others portray the landing at Siccar Point as a moment of epiphany in which Earth's antiquity suddenly struck Hutton, much as the displacement of water reputedly struck Archimedes in his bathtub in ancient Syracuse. Montgomery (2003) provided an interesting summary of varied reconstructive accounts and comments on their inconsistency with the historical record. Siccar Point is also sometimes depicted as the first recognition of an unconformity, although there are accounts in earlier French literature concerning the Alps, and Hutton had actually made references to these (Montgomery 2003). Furthermore, Hutton himself had previously visited two other unconformity locations in Scotland since presenting his theory in 1785, but neither was as striking as the one he would encounter on that day. His own description (here taken from McKirdy et al. 2007) seems in many respects rather mundane:

> *"Having taken the boat at Dunglass Burn, we set out to explore the coast. At Siccar Point, we found a beautiful picture of this junction washed bare by the sea. The sandstone strata are partially washed away, and partially remaining on the ends of the vertical schistus; in many places, points of the schistus are seen standing up through among the sandstone, the greater part of which is worn away. Behind this, we have a natural section of the sandstone strata, containing fragments of the schistus. Most of the fragments of the schistus have their angles sharp; consequently they have not travelled far, or been worn away by attrition."*

John Playfair's description of the field relationships is clearer and is actually a good model to show students. It is certainly better than most of the ramblings found in my own notebooks.

> *"It is here a micaceous schistus, in beds nearly vertical, highly indurated, and stretching from SE to NW. This schistus has a thin covering of red horizontal sandstone laid over it, and this sandstone, at a distance of a few yards farther back, rises into a very high perpendicular cliff. Here, therefore, the immediate contact of the two rocks is not only visible, but is curiously dissected and laid open by the action of the waves. The rugged tops of the schistus are seen penetrating into the horizontal beds of sandstone, and the lowest of these last form a breccia containing fragments of schistus, some round and some angular, united by an arenaceous cement"* (Playfair 1802).

Note that the term 'schistus' was then applied to almost any deformed or weakly metamorphosed sedimentary rocks, and that the Silurian rocks beneath the unconformity are not schist in our modern sense of the word. The profound message of Siccar Point, where relationships show that one group of sedimentary rocks first must have been deposited, then twisted and uplifted and then eroded, before being submerged and buried by a second series of very different sedimentary rocks, and then together uplifted and tilted for a second time to be eroded anew, is most eloquently delivered by John Playfair (1802). His words are repeated in many textbooks:

> *"On those of us who saw these phenomena for the first time, the impression made will not soon 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 that separated their formation, had we actually seen them emerging from the bosom of the deep?"*

Playfair's description continues in a similar vein, with an imagined trip to a time when the older rocks were still accumulating on the sea floor, and then to *"epocha still more distant in time"*, before with a short sentence that has become justly famous:

> *"The mind seemed to grow giddy by looking so far into the abyss of time"*

These words are what most geologists associate with Playfair, but his contribution to geological thinking was far greater than one memorable phrase. He was a keen observer and a gifted communicator, who promoted the ideas of Hutton and also modernized them. He continued to gather firm evidence, not just for the depth of his abyss of time, but for the nature of plutonism, folding, metamorphism and all manner of things that would come to define the dynamic Earth. He initiated an effort to locate and describe other unconformities, understanding their great importance in reconstructing geological history. But his words on Siccar Point are probably not the most famous uttered by early geologists. That honour goes to Hutton himself who closed the 1788 edition of "*Theory of the Earth*" with a phrase that has echoed through the centuries:

> *"The result, therefore, of our present enquiry, is that we find no vestige of a beginning, no prospect of an end"*

There is an implication in some texts that Hutton's famous words were inspired by or even came to him at Siccar Point, but this is probably not so, because the text of the book was complete by then, and it makes no mention of the excursion (Montgomery 2003). Hutton already had in his mind the concept of an unconformity, having recognized the differences between what we now know to be Silurian and Devonian strata. He had visited two other examples and read other descriptions that fitted his hypothesis. Siccar Point provided a dramatic example of the cyclicity of geological processes, and the immense time periods involved, but it was the *test* of a concept, not the inspiration for it. Rather than a moment of epiphany on a rocky shoreline, the Siccar Point excursion was a successful application of the scientific method. Montgomery (2003) advocates that it should be taught as such, and I now do this.

Unconformities – Observations, Hypotheses and Proofs

The Siccar Point location is one of three unconformities in Scotland that bear Hutton's name. The first location that he visited, in 1786, is near the village of Lochranza, at the northwest end of the Island of Arran, in the Firth of Clyde, southwest of Glasgow (Fig. 1). Hutton was fond of Arran, which contains striking geological and scenic diversity for so small an island – it has long been referred to as 'Scotland in Miniature.' The location preserves the contact between metamorphic schists of the Dalradian Supergroup, likely of late Neoproterozoic age, and Carboniferous strata. Far more time is missing at this site, as much as 300 million years, and descriptions (Barclay et al. 2005) suggest that it is not as clear or as dissected as Siccar Point. In 1787, Hutton visited and described a location in the town of Jedburgh (Fig. 1) where vertical Silurian greywacke is juxtaposed with horizontal red Devonian sandstone. This is a small and inconspicuous outcrop located on private property and not easily viewed; it is designated as a SSSI, and the landowner reportedly struggles to clear creeping vegetation on an annual basis (Baxter 2003). I have not visited it, but the outcrop is the subject of a famous engraving by John Clerk of Eldin, a close friend of Hutton's who later would provide illustrations for the never-completed later editions of "*Theory of the Earth*." Eldin's surviving illustrations of geological localities are now considered highly valuable, and his work in documenting 18th century Scotland is justly famous (Craig 1978; Bertram 2012). The engraving, completed in 1787, clearly depicts the conglomerate and breccia horizon developed at the unconformity surface (Fig. 6a). This is probably the first visual representation of an unconformity, but an equally famous sketch of Siccar Point created by the young James Hall in 1788 (Fig. 6b) is likely more accurate in terms of scale and geological relationships. Photos of the actual outcrop in Jedburgh (*in* Montgomery 2003) suggest that it is far smaller than Clerk's lovely artistic depiction. It is unfortunate that Clerk's talents were never applied to Siccar Point itself. A website offering reproductions of his drawings for sale lists the locality, but the drawings in question actually appear to be those of James Hall (see above).

The Later Influence of Siccar Point

There is no visitor's book at Siccar Point, but perhaps there should be one, because it must have seen many famous visitors. Arthur Holmes, the father of modern geochronology, would have been among them, for he spent many years at the University of Edinburgh. In his iconic textbook "*Principles of Physical Geology*," Siccar Point is extensively described and illustrated (Holmes 1944). I have long wondered if there was ever any connection between James Hutton and the younger William Smith. There seems to be no record of a meeting and given their age difference, this seems unlikely. However, in the year of Hutton's death (1797), Smith himself described an angular unconformity in underground mine workings in Somerset. Smith may also have been the first to use the modern term, as he commented on "the unconformableness of some of the other strata" (as noted in Woodward 1911). In this case, the coal-bearing (Carboniferous) rocks sat *below* the unconformity, rather than above. Instead of a sub-Devonian unconformity, as at Siccar Point, Smith had defined a younger unconformity, because Somerset lies south of the limit of Variscan deformation (Fig. 1). Thus, within a decade, Hutton and Smith had each recognized an important gap in the stratigraphic record, recording the two main orogenic cycles that built most of the British Isles. But if Hutton and Smith never met, did the older man influence the younger through his written work? Again, there seems to be no record of this in material about Smith (e.g. Winchester 2001), so perhaps he was unaware of the "*Theory of the Earth*." Smith himself claimed that his work was "*unincumbered with theories*" (sic) and Woodward (1911) suggested that his knowledge of scientific works was 'meagre.' There were many theories of the Earth in those early days and

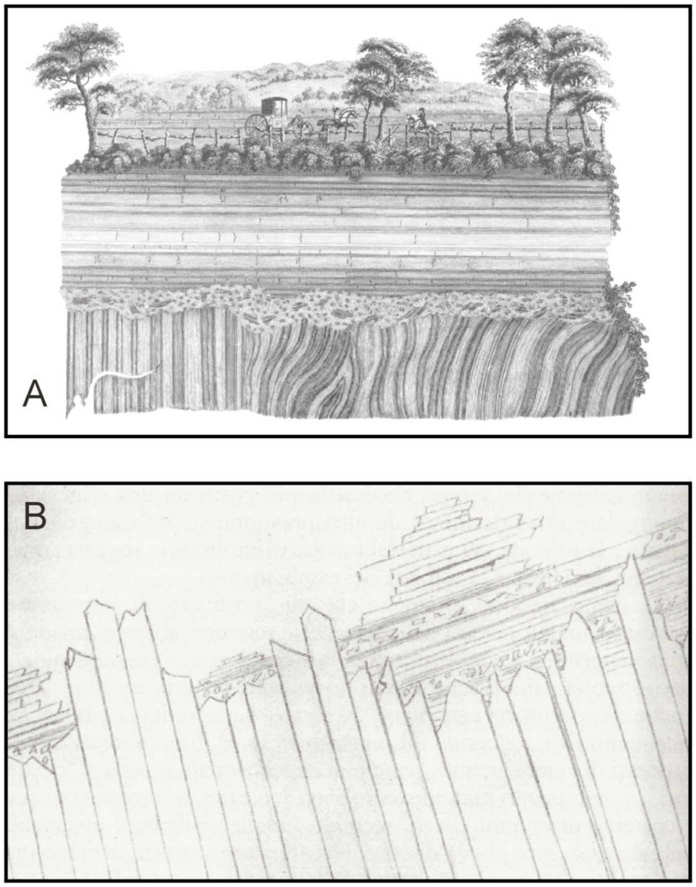

Figure 6. A. The famous engraving by John Clerk of Eldin, depicting the unconformity at Jedburgh visited by Hutton in 1787, before the Siccar Point visit. This image is found in many books and papers. Note the conglomeratic unit shown just above the unconformity and also the depictions of folds and intrusive dykes in the older rocks. The illustration has considerable artistic license, as the actual outcrop is very small and inconspicuous. B. Part of an equally famous field sketch of the relationships at Siccar Point drawn by the young James Hall following their visit. This has also been widely reproduced, most recently by Archer et al. (2017).

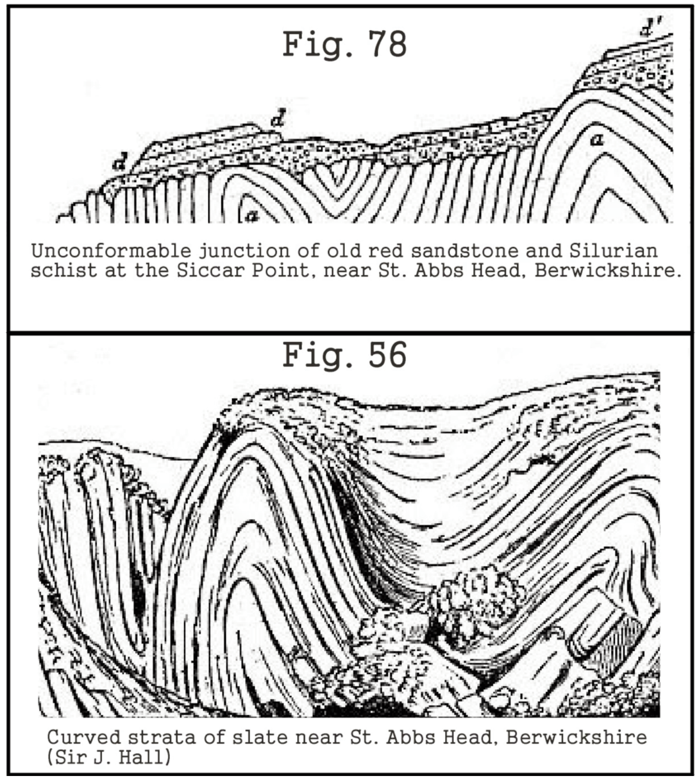

Figure 7. Two illustrations taken from the author's copy of Charles Lyell's "*Student's Elements of Geology*," first published in 1874. One is of Siccar Point and the other depicts folded Silurian rocks at nearby St. Abb's Head, as illustrated by Sir James Hall. Both illustrations also appeared in Lyell's famous textbook "*Principles of Geology*." Note that the original text in the images was replaced digitally to improve clarity.

Hutton's work remained contentious, even after Playfair had wrung clarity from its obscurity, so perhaps Smith drew his conclusions independently. A connection between Playfair and Smith seems more of a possibility, but again there seems to be no record of any meeting or influence. Smith's 1815 map extends to Berwickshire, but does not discriminate strata in the Siccar Point area. I cannot resist some speculation about how the evolution of geological science might have differed had these men had the opportunity to share their ideas and collaborate. However, as is clear from the biography of Winchester (2001), the stratification of society in those times was just as marked as that of the rocks, much to Smith's disadvantage, and could have impeded such connections.

In 1824, Siccar Point had a young visitor who would later go on to merge the ideas of Hutton and Smith. Charles Lyell (1797–1875) was born in the year of Hutton's death and certainly knew of Smith's map; by this time Playfair's efforts to disseminate the ideas of Hutton had at least partially succeeded. Lyell grew up in England, but was born in Scotland and had many connections there. The new offices of the British Geological Survey in Edinburgh are today known as the Lyell Centre. He came as a guest of Sir James Hall of Dunglass, who was by that time elderly and distinguished. Lyell mentions his visits to see coastal geology in rather matter-of-fact terms in correspondence with family members, but the visit to Siccar Point surely had a profound impact upon him and his concept of uniformitarianism. Lyell's own discussion of unconformities makes reference to Siccar Point, and it is illustrated along with nearby localities (Fig. 7; Lyell 1874). Lyell combined the threads woven by Hutton and Smith into a single tapestry that would in turn influence a young man named Charles Darwin who became the natural scientist aboard H.M.S. Beagle. It is not clear if Darwin ever visited Siccar Point, although he did spend several years in Edinburgh, but its testimony of near-endless time was critical for his ideas. Curiously, James Hutton was a friend of Erasmus Darwin, Charles' grandfather, and some believe that the "*Theory of the Earth*" contains vague concepts that resemble later ideas about evolution. Was there perhaps another branch in the tangled tree of thought that connected these defining ideas?

EPILOGUE

Unconformities are a key concept in historical geology, defining multiple cycles of geological evolution and reinforcing the great antiquity of our planet. Siccar Point may not be where such ideas truly *began*, but it is surely where they first came to be clearly understood. It is indeed a shrine on the abyss of time, worthy of our pilgrimage, but also deserving of our protection. Many might think that the Age of the Earth debate is long concluded in an age of ion probes and mass spectrometers, but that would be naïve. If you search 'Siccar Point' on the internet, you will quickly find accounts that seek to discredit its testimony. For example, at www.creation.com, you will find a page dedicated to the Siccar Point trail, claiming that all features described here can easily be explained by the violence of the biblical flood. 'Young-Earth Creationists' take particular aim at John Playfair, perhaps because of his church background. It is tempting to dismiss such ideas with amusement or disdain, but there have been several attempts to insert such thinking into educational curricula (Montgomery 2003) and they visibly compete with more 'factual' sources such as Wikipedia. It is therefore important not only to preserve remarkable locations such as Siccar Point, but to use them at every opportunity to promote scientific reason.

James Hutton has a reputation for difficult and confusing language, but he seemed to compose memorable phrases to close his works. The final statement of his original 1785 written summary, as recounted by Monro and Crosbie (1999) reads as follows:

> *"...there is opened to our view a subject interesting to man who thinks; a subject on which to reason with relation to the system of nature; and one which may afford the human mind both information and entertainment"*

I think that says it all.

ACKNOWLEDGEMENTS

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