Siccar Point and Teaching the History of Geology

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ABSTRACT

The concept of the rock cycle and the "indefinite" length of geologic time were outlined first by James Hutton before he had ever seen an unconformity. Hutton drew general support of his theory from existing observations of unconformities from accounts in French, which he re-interpreted in light of his own ideas. Hutton then found his own field examples to test his ideas before coming upon Siccar Point. In summing up his evidence, which included wide-ranging observations on the geology of SE Scotland, Hutton himself did not cite Siccar Point. Inaccuracies concerning the role of Siccar Point in the development of James Hutton's ideas remain as entrenched as ever in many physical geology textbooks. A more balanced appraisal of all contributions to Hutton's work is warranted, particularly the contributions of French writers. Finally, an accurate presentation of Hutton's method can contribute to students' understanding of the nature of historical theories and in meeting the challenges of creationists.

Keywords: Geological education, history of geology, Hutton, misconceptions, Siccar Point, creationism

> Young-Earth Creationists persist in attempts to persuade the public that historical theories such as evolution are not scientific: "You can't apply the scientific method to evolution. It's never been observed. You can't repeat the experiment" (CNN, 1999); consequently, "Historical science . . . is theoretical in nature . . . [it] does not . . . merit the same regard as repeatable science" (CSAMA, 1999).

Darwin had to deal with exactly this form of criticism, not from Creationists but from scientists who were his contemporaries, who viewed "method" in science from a purely empirical-inductive perspective: Adam Sedgwick, Darwin's friend and President of the Geological Society of London, complained to Darwin that he "had departed from the true inductive track" (quoted in Hull, 1973, p.6). In his own defense, Darwin argued:

> . . . the change of species cannot be directly proved, and . . . the doctrine must sink or swim according as it groups and explains phenomena. It is really curious how few judge it this way, which is clearly the right way" (quoted in Hull, 1973, p.13).

In parallel to this, not surprisingly, Young-Earth Creationists today also take offence at James Hutton's famous reasoning for landscape evolution, which is often quoted as an example of the uniformitarian method:

> There is not one more step in all this progress, (of the summit of the solid mountain forming earth and stones, and traveling to the sea) that is not to be actually perceived, although it is only *scientifically* that man, who reasons in the present moment, may see the effect of time which has no end" (Hutton, 1795b, p.327-329).

Thus a section on "Patterns of Cumulative Change," including "continental drift, which is part of plate tectonic theory, fossilization, and erosion" was struck from the Kansas Science Education Standards in 1999 through the work of a Creationist group (CSAMA, 1999). The section was reinstated in 2001, but Creationists continue to attack it, ostensibly on the same grounds (IDnet, 2001).

There are various possible ways of addressing these matters in geological education. Wise (2001, p.34) argued, "Scientists need to spread a bigger tent which includes the bulk of the American public by emphasizing that scientific findings preclude only the most extreme fundamentalist interpretations [Young Earthers, Diluvialists, Progressive Creationists] and that evolution is compatible with most major American religions" (see also Kelly, 2000). Zen (2001, p.8) has "found that [classroom] discussions with 'old-earth' evangelical Christians can be fruitful and stimulating. Such conversations can clarify ideas, resolve misunderstandings, and define common ground . . . they can reveal where my own convictions might be based on prejudices."

It would help if students, especially in an introductory class, were provided with knowledge that could place these debates in a broad historical context and help them understand how narrow such claims are of what constitutes "science." It would help, for example, if they had accurate knowledge of how James Hutton, as a scientist and philosopher, worked and reasoned. Yet, textbook accounts of the development of geology, if anything, have declined over the past twenty years, and abbreviated discussions focus almost entirely on the angular unconformity at Siccar Point in southeast Scotland, which is said to have a "particular significance in geology" (Chernicoff, 1999, p.217; see also Davidson et al., 1997, p.16).

Curiously, despite this stated significance, many textbooks transmit various misconceptions concerning this field site and Hutton's work in general. For example, Marshak (2001, p.372) has us imagine Hutton watching the waves below deposit sand and suddenly realizing the significance of this for the strata he was studying; both Skinner and Porter (2000, p.8) and Dolgoff (1998, p.28) have Hutton visiting the site and concluding something he actually wrote 3 years before (there being "no vestige of a beginning, no prospect of an end" to the Earth's geological cycles); Hamblin and Christiansen (1998, p.174) have Siccar Point as the first unconformity Hutton studied, as do Skinner and Porter (2000, p.8, caption Figure 1.3); Thompson and Turk (1997, p.6) attribute Playfair's famous allusion to the "abyss of time" to Hutton; finally, Dolgoff (1998, p.26) states Hutton "jumped up and down in delight" upon finding Siccar Point — something he is actually reported to have done in Glen Tilt upon finding Granite veining 3 years earlier (Playfair 1805, p.68-71).

It is implied often that Hutton's ideas on the rock cycle were derived from Siccar Point inductively (or, in a moment of blinding insight):

> It was here ... that James Hutton realized that severe upheavals had tilted the lower rocks and formed mountains that were worn away and covered by younger, flat-lying rocks." (Monroe and Wicander, 2001, p.225-226; see also Marshak, 2001, p.372; Dolgoff, 1998, p.26, Figure 1.1 caption)

More generally, at Siccar Point, James Hutton is said to have become the first scientist to interpret the meaning of unconformities (e.g. Hamblin and Christiansen, 2000, p.182 caption, Figure 8.1; see also Monroe and Wicander, 2001, p.225; Skinner and Porter, 2000, p.8, caption Figure 1.3; Renton, 1994, p.46).

This article will first discuss the sources of Hutton's ideas that lead, eventually, to the famous Siccar Point expedition reported by Playfair (1805). It will then consider how much knowledge Hutton drew from the Siccar Point site as compared to other sites he visited. It will assess the accuracy of textbook accounts. The article will then discuss the value of a broader perspective on Hutton's work in the education of our students.

HUTTON'S FIELD OBSERVATIONS AS "THEORY-LADEN"

Historical fact belies any textbook notion that Hutton's methodology was primarily inductive. Hutton's method in working out his theory was generally hypothetico-deductive, based upon chemical and geological knowledge allied with strong Deistic theological assumptions — what Gould (1987, p.76) termed the "paradox of the soil:"

> This globe of the earth is a habitable world; and on its fitness for this purpose, our sense of wisdom in its formation must depend . . . a soil is necessary . . .
>
> IF the vegetable soil is . . . constantly removed from the surface of the land, and if its place is thus to be supplied from the dissolution of the solid earth, as here represented, we may perceive an end to this beautiful machine; an end, arising from no error in its constitution as a world, but from that destructibility of its land which is so necessary in the system of the globe, in the oeconomy of life and vegetation" (Hutton 1788, pp.209-215).

This Deistic context never draws a mention in textbooks: religion, if presented at all, is generally viewed as antagonistic to the development of geology (e.g. Hamblin and Christiansen, 2001, p.181) even although Hutton took care to place his theory within its fold: "with respect to human observation, this world has neither a beginning nor an end" (Hutton 1785, p.280; present author's emphasis). If mentioned at all, textbooks equate Judeo-Christian views in the late Eighteenth - early Nineteenth Centuries only with Catastrophism (e.g. Chernicoff, 1999, p.8; Dolgoff, 1998, p.26).

The exclusion of religious belief in historical science did not happen until long after Hutton (Gillispie, 1996, p.217-228) and many of the most prominent British geologists in the first half of the Nineteenth Century had church affiliations (Rudwick, 1985, p. 44): "the conflict was not so much one of religion versus science, but of religion within science," and in particular the role of Divine Providence (Rupke, 1996, p.vi). By examining with our students the relationship between the religious beliefs and the science of James Hutton, at the time of the emergence of modern geology, we can do much to explore directly the issues of compatibility between the two.

Popper (1959) argues that scientific observations are "theory-laden," being conditioned by ideas we already hold. Almost exactly one hundred years before, Darwin had advised a young scientist, "Let theory guide your observations" (quoted in Hull, 1973, p.10). Hutton's reading of the existing literature in French and his Jedburgh discovery, both of which preceded Siccar Point, were conditioned in exactly this manner. These will now be reviewed.

HUTTON'S PRIOR KNOWLEDGE OF ANGULAR UNCONFORMITIES IN FRENCH

Contrary to the implication in some textbooks, Hutton was certainly not first in identifying and considering the geological issues posed by angular unconformities. Steno (1669, p.67-75), for example, inferred "changes which have taken place in Tuscany" from the contrasting inclinations of the strata. Hutton does not discuss Steno, but he recognized that angular unconformities reported in French in the Continental literature supported his ideas concerning the rock cycle. For example, he quotes a contemporary observation by an un-named author travelling in Switzerland (likely Jean-Benjamin de la Borde, judging by the title provided by Hutton, 1795a, p. 419):

> Ici c'est une roche de schiste bleautre, dure et compact . . . Cette roche s'élève a une hauteur prodigieuse, est presque verticale, et ces couches sont à quatre-vingt degrés d'inclination. . . . Apres avoir monté . . . on trouve cette roche de schiste surmontee d'autres rochers fort hauts qui sont calcaires, et dont les lits sont fort horizontaux."
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> [Here is a rock of blueish schist, hard and dense . . . This rock rises up to an extraordinary height, almost vertically, and these beds are at an angle of eighty degrees. . . . After having climbed . . . one finds that sitting on the schist are other extremely high, calcareous rocks, whose strata are strikingly horizontal."]

Contributions such as this were important to Hutton's argument, although Hutton did not assist readers by translating or abbreviating the quotations — the above quote is taken from almost three pages that are largely travelogue. Yet the only French author discussed in any physical geology text is Georges Cuvier, and he is dismissed (unfairly) as a simple Young-Earth Catastrophist (Hamblin and Christiansen, 2001, p.181).

Hutton believed that such field reports from the Alps generally confirmed his belief that the lower strata had been "twice subjected to the mineral operations" (1795a, p.427) and that this, rather than any novel processes in

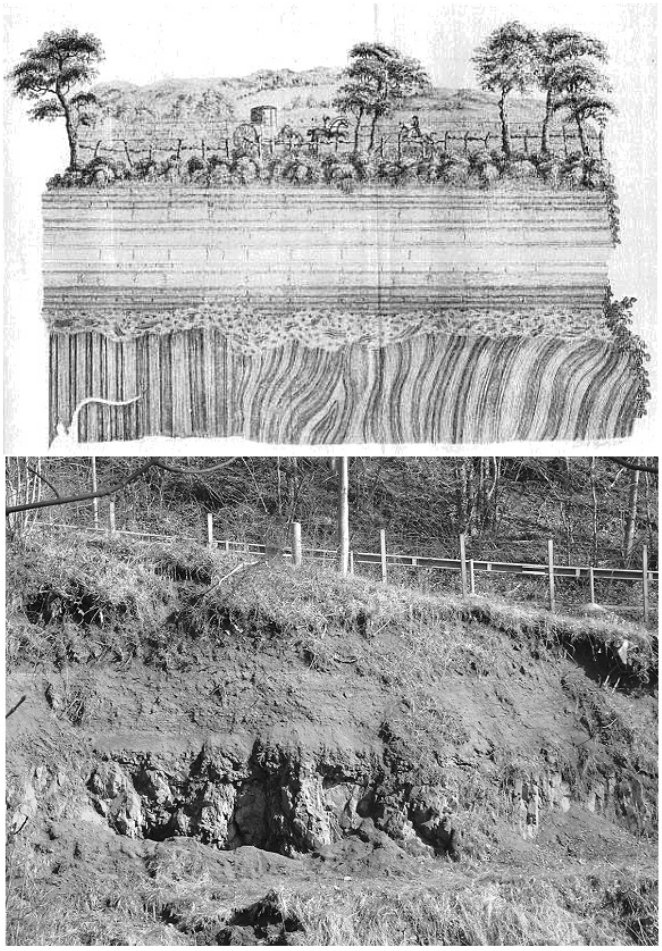

Figure 1. Top: John Clerk of Eldin's famous conceptual rendering of the Jedburgh unconformity from 1787 (Hutton, 1795a, Plate III). The view is looking east across the River Jed, 0.2 miles south of the Abbey Bridge, which is near the center of Jedburgh. The road today is the A68. The people are not so much for scale (which is inaccurate) as to contrast the present world with Hutton's "former worlds" represented by the Devonian Upper Old Red Sandstone overlying the vertical greywacke of the Silurian (with Hutton's "puddingstone" in between). The intrusion in the lower left has been added from another exposure mentioned by Hutton (1795a, p.438) a half-mile upstream at Allar's Mill (to the right — see McAdam, 1993, for a description of this site). Bottom: The unconformity as it appears today (March 2003), having been washed clean recently by the local fire brigade. The property is owned by the owner of Inchbonny Braes house, 200 yards upstream (right), from whom permission must be obtained to visit the site. Plans are afoot to build a viewing platform and interpretive plaque that can be accessed directly from the road above — obscuring this excellent view from across the river!

the past, accounted for the general differences in the nature of these beds. However, he did not think that these accounts were conclusive without further evidence or "particular marks" of the relationship between the two rock layers (1795a, p.420). Therefore, Hutton sought evidence for himself, and this is the context of his descriptions and analyses of unconformities in Scotland:

Figure 2. Detail of the unconformity (Figure 1) viewed from the opposite (west) bank of the River Jed. Here the lower beds contain a prominent fold to the right of center. The conglomerate layer, clearly visible above the fold and running across the exposure, is approximately 1 ft. thick.

"having given what was my opinion . . . I am now to treat of this subject from observations of my own, which I made since forming that opinion" (1795a, p.421; present author's emphasis).

HUTTON'S FIRST UNCONFORMITIES AND THEIR "PARTICULAR MARKS"

In 1787, on the Isle of Arran, two years after his Theory was first presented (Hutton, 1785), Hutton discovered his first unconformity (Hutton, 1795a, p.429; Hutton 1899, p.235; Playfair, 1805). However, he thought the exposure here did not enable him to conclude what state the lower strata had been in when the upper strata had been laid (1795a, p.430). As he saw it at the time, this was partly because the upper strata were not horizontal, and partly because the exposure was so limited (also Hutton, 1899, p.235-237).

It was only after discovering a second angular unconformity, at Jedburgh later in 1787 (Playfair, 1805, p.71) that Hutton was prepared to write:

> [I] rejoiced at my good fortune in stumbling upon an object so interesting in the natural history of the earth, and which I had been long looking for in vain" (1795a, p.432).

Figures 1 and 2 illustrate this location. Any implication in textbooks that Hutton came upon this feature, let alone Siccar Point, unprepared and reached conclusions inductively is certainly incorrect.

At Jedburgh, Hutton had found an angular unconformity in which the upper strata were perfectly horizontal and it seemed difficult "to suppose that the upper strata had been deposited before those below had been broken and erected" (1795a, p.433). This was carefully confirmed by Hutton, who noted a conglomerate layer between the lower and upper beds that contained boulders from the lower beds as well as other, more distant rocks (p.435-438). These "particular

marks" were conclusive of the relationship between the lower and upper layers.

It is interesting to read Dean's (1997, p.236) account of the Arran unconformity: this was the example that Hutton dismissed as an inadequate test of his ideas. Dean opines that in all respects "it is as perfect an unconformability as could be desired" (see also Tomkeieff's description, 1963, p.398-399). This perfection includes the fact that the upper rocks "may be seen wrapping round the denuded ends of the older strata" and "further evidence of a complete break between the two formations is supplied by the fragments of schist contained in the [intervening] breccias." Perhaps if Hutton had come across this site after having seen the way things "ought to look" at Jedburgh, he might have "seen" it differently; interestingly, after Jedburgh, he does not think to mention the lack of horizontality of the upper strata at Siccar Point.

OTHER CONFIRMATION FROM EXISTING LITERATURE IN FRENCH

Hutton realized that observations equivalent to those of his Jedburgh conglomerate layer already existed in the French language literature from the continent. He used these reports to lend global support to his ideas (1795a: de Saussure p. 389, 448; de Luc p. 416; Voigt p.445; and Schreiber p. 450-452). For example, from Schreiber:

> Mais ce qu'il y a de remarquable, c'est que le gneis ne participe en rien de la pierre calcaires quoiqu'il n'en soit separe que par une couche d'une pouce d'epaisseur de terre arguilleuse et calcaire, tandis que le rocher calcaire renferme beaucoup de fragmens de granit et de gneis, dans le voisinage de cette reunion." (1795a, p.451-452).
>
> [But what is remarkable is that the gneiss does not include any part of the limestones though it is separated only by a layer an inch thick of argillaceous and calcareous material, while the limestone contains many fragments of granite and gneiss, in the vicinity of this contact.]

In contrast to Hutton, Schreiber interpreted this granite and gneiss to be "primary formations," which was an issue that Hutton, the Plutonist, dealt with elsewhere in his work.

SICCAR POINT AND HUTTON'S SOUTHEASTERN FIELD WORK

On his return journey home from Jedburgh, Hutton again found the Jedburgh sequence in Teviotdale (1795a, p.443-444). He conjectured that where the horizontal strata are found one could reasonably suppose that the conglomerate and vertical strata underlay them and, equally, where only the vertical strata are be found, that the horizontal cover had been removed by denudation. Although he believed this conclusion to be a reasonable one, he desired "more evidence to be found by which the probability may be increased or diminished" (1785a, p.444).

At this point in his work, Hutton's interpretation and speculation upon the regional geology and his Theory of the Earth had, naturally, become one and the same, and the famous title of Chapter VI, Section II (p.453) — "The Theory confirmed by observations made on purpose to elucidate the subject" — could equally well be referring to his Theory of the Earth or to his ideas concerning the regional geology. It is a pleasure to read how his field program (including the discovery of Siccar Point) is driven by deductions from his Theory (1795a, p.453-467). And so, while Hutton had tested and successfully resolved his ideas in large part prior to the discovery of the Siccar Point unconformity, the Siccar Point discovery represented a very impressive prediction to certain of his friends who were only familiar with his ideas as "theoretical speculations" (i.e. Playfair, 1805, p.72).

Hutton pondered where else "we might most probably succeed in finding the junction of the low country strata and the alpine schistus" (p.453). A suggestion from a friend led him, in spring 1788, to take a field trip south of Edinburgh with John Playfair.

Hutton first found the junction in the valley of the Tour and Pease Burns, and Hutton reports it was comparable in nature (but not quality) to Jedburgh (p.456-457). By sea they found the junction first at St. Helen's, "But, at Siccar Point, we found a beautiful picture of this junction washed bare by the sea" (p.458 — compare this to his reaction at Jedburgh). They found the same junction at Red-heugh (p.458) and a lesser example on another day at Ey[e]mouth (p.467).

However, Hutton made other, arguably more important discoveries farther along the coast, discoveries that he described in highly satisfactory terms. They found some excellent sections of the vertical beds that contained strong ripple marks ("a waved figure," p.460); Hutton states that he had previously supposed these strata to have been water laid and originally horizontal, but this was the first time he had seen such clear evidence of this. Not surprisingly, such a discovery "could not fail to give us great satisfaction" (p.460). Later, at Lumesden Burn, Hutton was "no less gratified" to find folded, younger strata that suggested to him how the vertical strata were raised and that the processes were much the same in both instances (p.460). Together, he describes both these finds as "remarkable examples" (Hutton 1795a, p.459).

Equally important, in Hutton's judgment, later in the trip they found the conglomerate at the highest altitudes; this demonstrated to Hutton the full extent of erosion of both the lower strata and the subsequent erosion of the conglomerate and secondary strata upon it: in following the trail of geological clues to this discovery, Hutton states with a clear sense of wonder that "we never should have dreamed of meeting with what we now perceived" (p.463).

SICCAR POINT IN PROPORTION

Regarding the Siccar Point discovery Bailey (1967, p.56) infers that Hutton was "not overwhelmed, having already been feasted in Arran and near Jedburgh," and that his account of Siccar Point was only "adequate" and contains "signs of blaséness."

Laudan (p.128, 131) credits Davies (1969), Dott (1969), and Porter (1977), among others, with helping us to appreciate the larger context of Siccar Point, yet little of this scholarship seems to inform present textbook accounts of Hutton's work. Textbooks appear to inaccurately equate his actualistic ("uniformitarian") philosophy with inductive reasoning.

Hutton's own writing is clearly more effusive concerning other exposures on the same trip, from which

he certainly added more new information to his geological store of knowledge than he did at Siccar Point. In fact, while reviewing the work they had just completed he makes no mention of Siccar Point (p.464-465, 471)! It is clear that the "Observations" Hutton set out to make in the southeast include a vastly greater corpus than Siccar Point alone, and extended "from one end to the other, and on both sides of that range of mountains which run from sea to sea in the south of Scotland . . ." (p.467).

In his own conclusions, from all this work (from "the composition of the mountains, which occupy the south of Scotland," p.469) Hutton makes clear he has satisfactorily tested his ideas: "By thus admitting a primary and secondary in the formation of our land the present theory will be confirmed in all its parts" (p.471). How much Siccar Point added to this is debatable and at the point of these conclusions, Hutton still was to write two and a half volumes laden with field observations pertaining to many geological matters.

WHAT COULD BE STATED BRIEFLY ABOUT SICCAR POINT IN TEXTBOOKS

Siccar Point: James Hutton's Deistic religious views predisposed him towards thinking that Earth's continued habitability depended upon a rock cycle that renewed its soil, and that Earth had been so designed. He tested his idea of a rock cycle against extensive field observations he made throughout Britain. He knew from reading many geological reports written in French by continental geologists that unconformities existed, although he disagreed with how they were interpreted. Upon finding this particular site in 1788, one of the last unconformities he discovered, James Hutton greatly impressed his companions with his naturalistic interpretation of the events and the span of time that could be inferred from its strata. One these companions (the mathematician John Playfair) became his biographer and through his writings this locale has come to symbolize Hutton's Theory and the birth of modern geology in the English-speaking world.

More could be added about Hutton and the development of his ideas, but this seems to sum up Siccar Point and place it in good context.

DISCUSSION AND CONCLUSIONS

Most current physical textbooks continue to reverse the relationship between Hutton's ideas and his fieldwork through an excessive emphasis on Siccar Point as an icon of blinding scientific insight. The broad impact of this is to present an excessively narrow, empirical-inductive view of geological science that diminishes the creative brilliance, depth of preparation and background knowledge, and imaginative insight that lead to the development of Hutton's theory (and that lead his group to Siccar Point that day). James Hutton's fieldwork at sites such as Siccar Point and Glen Tilt confirmed ideas he had already deduced from chemical and geological knowledge allied with strong Deistic theological assumptions (the latter of which never elicits a mention in textbooks). As discussed by McIntyre (1999) and [a]engör (2001), among others, Hutton's theory was born in the context of ideas and debates of the Scottish Enlightenment in Edinburgh and to which he contributed. In most textbooks, Hutton's life's work is taken entirely out of intellectual context, including his knowledge of Continental field workers and theorists: modern geology is presented entirely as an invention of the English-speaking world on one fine spring day.

Although space is at a premium in textbooks, for students who are majors or who are in the liberal arts there is much poverty in presenting advances in science as the inevitable outcome of a robotic method: serendipity, personal insight, and imagination have always contributed in a significant way. Textbooks often do a good job of presenting Plate Tectonics in this way, but the lack of attention to the critical period in the relationship between religion and science in late Eighteenth and Nineteenth Centuries is regrettable: at the very least, however minimal, what we present in texts ought to be correct. Given the continued attacks upon historical science by Young-Earth Creationists in Alabama and Oklahoma, for example (Dawkins, 1997), it is important that our students be given the opportunity to appreciate fully the historical context of the discipline and its scientific reasoning in all its historical diversity.

The absence of a broad understanding of science in a society as democratic as the United States will make it very difficult to evaluate and agree upon the choices we face, for example, in environmental policy, in energy planning and global atmospheric change. Introductory textbooks must necessarily simplify a great deal. However, much of value is lost when the history of science is simplified too much: we loose a wonderful opportunity to provide students with the tools necessary for critical appraisal of active socio-political debates affecting science education.

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