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Our Legacy and our Future

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PRESIDENTIAL ADDRESS

The Earth Sciences: Our Legacy and our Future

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INTRODUCTION

The motto of the 2011 Ottawa Annual General meeting of the Geological and Mineralogical associations of Canada, "Navigating Past & Future Change", was intended to highlight our commitment, as a scientific community, to the exploration of both the science and societal significance of the Earth Sciences. What I intend to do in this Presidential Address is to turn the motto around and restate it as a question: What is the scientific and societal significance of the Earth Sciences? This is not an idle question. Many of those attending the Ottawa GAC–MAC meeting are dependent upon a government paycheque, either because we work in universities or for government labs and surveys. In addition, much of our research is funded by government grants, most notably through the NSERC Discovery grants program. In other words, our jobs and our research are dependent upon public recognition of our contribution to society.

So what is the scientific and societal significance of the Earth Sciences? To answer that question I want to go back to a remarkable time in our history, the late 1700s, and in particular to three key developments of that time. Those developments were nothing less than 1) Hutton's discovery of deep time; 2) Smith's invention of the modern geological map; and 3) the realization that humans are a component of the Earth system. These three intellectual leaps all occurred at the exact moment that atmospheric CO_2 concentrations started their inexorable and ongoing rise. As the scientists most responsible for finding the coal, oil, gas and mineral resources on which modern society is built, we can take a great deal of pride in the role that geology and the Earth Sciences have played in civilization's evolution over the past two hundred and fifty years. The prosperity of modern society is rooted in the discovery of deep time and the invention of the geological map: that is our legacy. It is, however, in addressing and understanding our role in the Earth system that our future scientific and societal significance is to be found.

HUTTON AND THE DISCOVERY OF DEEP TIME

The year is 1788. Three Scottish gentlemen clambered into a 'wee' boat and headed down the east coast of Scotland. These three were the physician and experimental farmer James Hutton, the mathematician John Playfair and the naturalist James Hall. They made a precarious landing at Siccar Point, where Hutton was able, for the first time, to convincingly demonstrate his discovery of deep time. Anyone who has ever tried to read Hutton knows that had he not managed to enlist Playfair as an advocate, appreciation of the significance of his discovery may have been very much delayed, for Hutton was not an eloquent writer. Playfair was. And so, despite the familiarity of Playfair's description of that momentous day at Siccar Point, it is so beautifully written that it bears repeating:

"We felt ourselves necessarily carried back to the time when the schistus on which we stood was yet at the bottom of the sea, and when the sandstone before us was only beginning to be deposited, in the shape of sand or mud, from the waters of a superincumbent ocean. An epoch still more remote presented itself, when even the most ancient of these rocks, instead of standing upright in vertical beds lay in horizontal planes at the bottom of the sea and was not yet disturbed by that immeasurable force which has burst asunder the solid pavement of the globe. Revolutions still more remote appeared in the distance of this extraordinary perspective. The mind seemed to grow giddy by looking so far into the abyss of time; and while we listened with earnestness and admiration to the philosopher who was now unfolding to us the order and series of these wonderful events, we became sensible how much farther reason may sometimes go than imagination can venture to follow."

I am struck by a couple of prescient aspects of Playfair's rendering of that day on Siccar Point. The first is his reference to deformation of the crust as being attributable to an "*immeasurable force which has burst asunder the solid pavement of the globe."* In those few words Playfair came as close to plate tectonics as anyone would for another 150 years. The second is found in Playfair's description of how he and Hall sat listening "*with earnestness and admiration"* as Hutton explained the significance of the rocks before them. I could not help but think that these words still adequately describe geological field trips: while none of us will ever participate in such a significant field trip, we all have benefitted from the earnest and admirable efforts of field trip leaders.

Deep Time! Without Deep Time and the intimately linked concept of uniformitarianism, there could be no Charles Darwin and no evolution.

Without Deep Time there could be no understanding of the immensity of the universe as we know it, for Deep Time is a requirement of light having travelled interstellar distances. And of course there would be no plate tectonics without first understanding the Deep Time available for the movement of plates. So unfathomable is Deep Time, so far removed is Deep Time from human experience, that none of us can fully grasp its scale. That Hutton, Playfair and Hall realized even a fraction of the implications of their discovery is a staggering, amazing achievement.

WILLIAM SMITH AND INVENTION OF THE MODERN GEOLOGICAL MAP

The second major act of the late 1700s was played out near Bath in southwestern England. William Smith, who made his living building canals to transport coal, drew up his first geological map showing the geology of the Bath region. It was one of the first maps by which it was recognized that the Earth's crust consisted of a sequence of layers that always occurred in the same order. He also realized that fossils were unique to each layer, and that there was an evolution in certain types of fossils from one layer to the next. And it was based on that map that William Smith later constructed cross-sections in which he was able to reveal, indeed to predict, not only the structure of the Earth at depth, but also to show the crust that had already been removed by erosion; the cross-sections showed that once continuous layers of rock had been eroded away and great masses of rock removed.

As anyone who has ever attempted to make a geological map will know, it is a beast. It is neither pure data, nor an outright model. A geological map is the product of observational (not experimental) science, but any and all attempts to map in a purely observational fashion are doomed to produce the lousiest of maps. If you do not believe me, I invite you to come teach field school with me sometime.

William Smith was, by 1815, able to publish a geological map of most of Great Britain. He did not manage this by visiting every outcrop. What he did was develop a model!! Smith's model was nothing more than the recognition that the crust underlying Great Britain was characterized by a set stratigraphic sequence that had subsequently been folded and faulted. Using his model, together with the sparse data available from outcrop and canal-cuts, he then produced a predictive map that he was subsequently able to test against the rocks exposed in each new canal. This was the leap. This was the invention of the modern geological map. Smith's geological map of Britain is, like all good geological maps, a mixture of observation and model. It is neither 'stamp collecting', to use a phrase oft employed to describe observational sciences, nor is it the product of repeatable experimentation. There is nothing quite like the geological map in any other science. The map is what distinguishes us, and William Smith's map of Great Britain, which proved to be remarkably accurate, is justifiably recognized as a great scientific achievement.

HUMANITY AS A GEOLOGICAL AGENT

Finally, I turn to the third major development of the late 1700s: the realization that man was an active component of the Earth system. We need to first step back to 1763, the year that James Watt invented his 'efficient' vacuum steam engine. Watt had a working engine by 1765, and in 1776, the year of the American Revolution, the Watt steam engine was made widely available. This was the golden age of the Industrial Revolution, complete with the urbanization of Great Britain, and the first development of large-scale coal mining – coal that was used to generate the steam required by Watt's engines. You can imagine the change in the landscape: there was the widespread development of high-density urban areas that proliferated across formerly pastoral landscapes; there were the coal mines, the canals (constructed by William Smith) needed to deliver the coal, and the pollution stemming from burning of the coal. It was, in 18th century Great Britain, impossible not to realize that humans were reshaping the face of the Earth.

It was Robbie Burns who perhaps best captured that realization with his poem 'To a Mouse' (see inset box page 150). The poem, published in 1786, a scant two years before Hutton, Hall and Playfair visited Siccar Point, is ironic: in the face of the onrushing industrialization, Burns turned his eye instead to the seemingly benign practice of pastoral farming, farming as it had been practiced for centuries. And what Burns cleverly showed was that even farming comes at a cost. Implicit in the poem is the question 'if farming comes at a cost to the Earth, what then is the cost of industrialization?'

The poem is a eulogy to a mouse whose nest is turned up by Burns as he ploughs his fields. There is much debate over whether Burns ever laid his hands upon a plough as he is now commonly portrayed as an almost mythical layabout, womanizer and drinker (no wonder he is so revered). Regardless, what Burns does is to use the mouse and its nest as an analog for the natural world; it is an intricate system that is part of, and has evolved in response to the Earth's system. And then along comes man, embodied in Burns' plough (the 'cruel coulter'), and in a geological instant, everything is changed. Burns speaks directly to industrialization in the second stanza:

I'm truly sorry man's dominion
Has broken Nature's social union

But Burns also sees the quandary:

I backward cast my e'e
On prospects drear!
An' forward, tho' I canna see,
I guess an' fear!

Burns recognizes that you cannot go back to the poverty (prospects drear) that characterized too many lives before industrialization. But he also looks upon the changes wrought by industrialization and though he cannot tell the future, he fears it. He fears it because, unlike farming, whose cost was known and understood, the cost of industrialization was unknown. And he fears it because, to return to the most famous line of the poem, "*the best laid plans o' mice and men, gang aft agley.*"

OUR FUTURE

There is now broad and growing concern that the best laid plans may indeed have gone awry. We are now

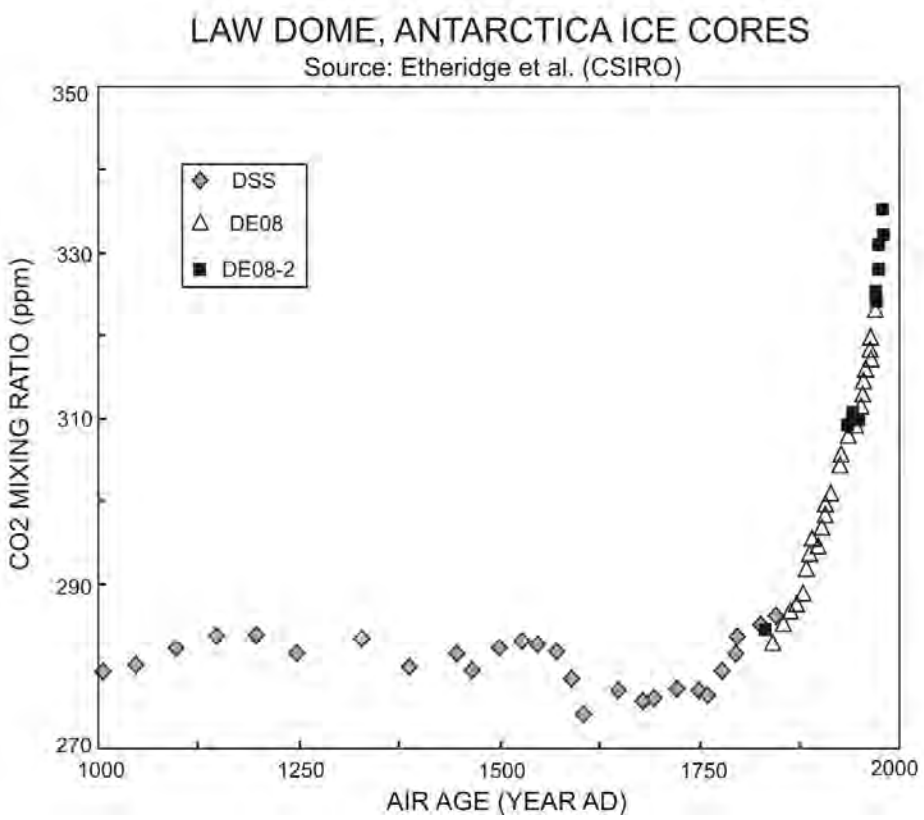

Figure 1. CO_2 vs. time. (Note: the 'air age' is younger than the age of the ice from which the air was extracted due to continued interchange with the atmosphere for a limited time after snow deposition and its subsequent conversion to ice. The CO_2 mixing ratio is the number of molecules of CO_2 relative to the total number of molecules per unit volume of the air extracted from the ice, and is reported as ppm by standard convention). Modified from Etheridge et al. (1998).

incomparably rich compared to even the richest 1% of all people living in the late 1700s. And geologists have had a great deal to do with our enrichment. The recognition of deep time has provided the backdrop for a vast array of scientific advances, from biological engineering to nuclear physics. Geological maps have been instrumental in the finding and exploitation of the coal, gas, oil and minerals that form the foundation on which our prosperity, health and longevity has been built. But as with 18th century pastoral farming, prosperity is not without a cost, and the 'cost' is CO_2, the main byproduct of industrialization (Figure 1).

It may be ironic that the discovery of deep time, the invention of the geological map, and the realization that man is a geological agent of change, all lie together right at the start of the modern rise in the concentration of atmospheric CO_2. It may be ironic, but it surely is no coincidence. And so we are, like Friedrich's 'Wanderer Above a Sea of Fog' (Figure 2), left with little in the way of choice regarding where we go from here. We cannot descend back into the fog of ignorance, nor the poverty of 'prospects drear' that preceded industrialization. And as huge as the role of the Earth Sciences has been in bringing about the health and prosperity we enjoy today, our future scientific and societal contribution is going to have to be equally significant, if not more so.

What is the challenge before us? We need to understand the role played by humans in bringing about the ongoing changes in the Earth system, and we need to know the magnitude and scope of the changes facing us over the next 250 years. To do this we must understand how Earth has worked in the past. Geological maps and our understanding of deep time

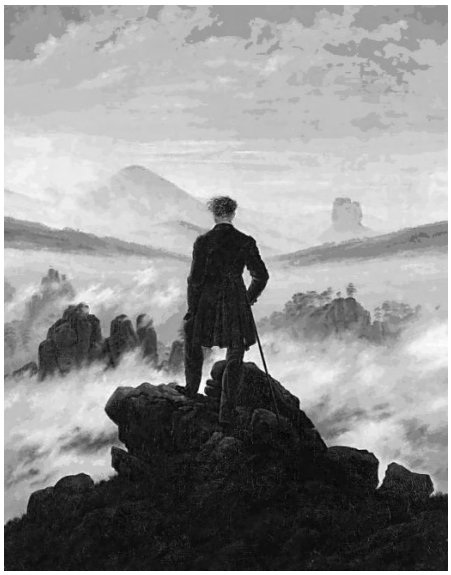

Figure 2. Friedrich's 'Wanderer Above a Sea of Fog'.

are our legacy, but they are also the tools that we must use to remain societally and scientifically relevant. Rocks are a repository of information on the processes responsible for changes in the biosphere, hydrosphere, atmosphere and solid Earth. And we cannot even begin a conversation regarding the significance of increasing atmospheric concentrations of CO_2, far less what to do about it, if saddled with a woefully incomplete understanding of how the Earth system has responded to changes of this nature and magnitude in the past.

I give the last word to John Playfair who, when faced with the concept of Deep Time, said so well "*we became sensible how much farther reason may sometimes go, than imagination can venture to follow.*" The message to take from Playfair's words is this: it is not good enough for us, as Earth Scientists, to come to a conference, give a scientific talk and then return to our offices, laboratories and field areas to continue our research. That is only half of our work. The only way that society is going to support us is if they too can reason. We have to educate the public. Outreach cannot be the spare time pursuit of the minority of Earth scientists. Outreach has to be central to our science, for a public ignorant of the basic workings of the Earth and of the depth of Earth history, will never be able to imagine the substantial challenge that humanity currently faces.

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To a Mouse
Robert Burns

Wee, sleekit, cow'rin', tim'rous beastie,
O what a panic's in thy breastie !
Thou need na start awa sae hasty,
Wi' bickering brattle !
I wad be laith to rin an' chase thee
Wi' murd'ring pattle !

I'm truly sorry man's dominion
Has broken Nature's social union,
An' justifies that ill opinion
Which makes thee startle
At me, thy poor earth-born companion,
An' fellow-mortal !

I doubt na, whiles, but thou may thieve;
What then? poor beastie, thou maun live !
A daimen-icker in a thrave
'S a sma' request:
I'll get a blessin' wi' the lave,
And never miss't !

Thy wee bit housie, too, in ruin !
Its silly wa's the win's are strewin;
And naething, now, to big a new ane,
O' foggage green !
An' bleak December's winds ensuin'
Baith snell an keen !

Thou saw the fields laid bare an waste
An' weary winter comin' fast,
An' cozie here, beneath the blast,
Thou thought to dwell
Till, crash! the cruel coulter past
Out thro' thy cell.

That wee bit heap o'leaves an' stibble
Has cost thee mony a weary nibble !
Now thou's turn'd out, for a' thy trouble,
But house or hald,
To thole the winter's sleety dribble
An' cranreuch cauld !

But, Mousie, thou art no thy lane
In proving foresight may be vain:
The best laid schemes o' mice an' men
Gang aft a-gley,
An lea'e us nought but grief an' pain,
For promised joy.

Still thou are blest, compared wi' me !
The present only toucheth thee;
But, Och ! I backward cast my e'e
On prospects drear !
An' forward, tho' I canna see,
I guess an' fear !