**The Great Devonian Controversy**

*The Shaping of Scientific Knowledge among Gentlemanly Specialists*

*M.Rudwick*

August 31 - September 4, 2012

There is a difference between facts and theories. The former are inescapable constituencies of our world, while the latter are mere speculation. Francis Bacon famously claimed that knowledge is developed by the accumulation of facts, unsullied by prejudiced theories. Only if one has a blank mind, i.e. free from extraneous preconceptions, is one able to read Nature as it is. We now consider this a rather naive view, even if it still permeates the public conception of science. For one thing it is very hard to give examples of facts which are not to some extent so called theory laden.

In the present book a very detailed story of the resolution of a geological controversy is narrated chronologically. The resolution was very successful hence the underlying controversy is forgotten. Hence one may think of this as a passing episode in the history of science, hardly worth such attention. However, the author wants to illustrate the process of the shaping and development of science, in particular to exhibit on one hand the vision of Truth, without which scientific activity would be pointless, and on the other hand the very human failings that characterizes this activity. There is rivalry, intrigue and upmanship, based on personal vanity, as well as down-right political maneuvering. The question of truth is of course of paramount importance, but so are petty concerns with priority and personal recognition. Scientists are not equal, there is a well-developed hierarchy based not only on scientific merit and standing but also, especially in 19th century England, on social standing. Science is not an individual enterprise, it is a social one, in which the arguments and opinions of different individuals crash. Yet, and that is an important lesson of the book, science may be a social enterprise, with all that goes with it, but that does not mean that its findings are arbitrary, although some seem more arbitrary than others, but constrained by the 'facts' so to speak. Science is constructed socially, but no mere social construct. Fashionable post-modernist theories are over-simplifications revealing a deep ignorance of the scientific endeavors.

Now the period under study is a perfect one to put under the microscope, because it is so well documented. The major means of communication beyond that of the personal conversation was the letter. Educated people at the time were in general excellent letter-writers. Considering that they also took the craft seriously and tended to preserve its products and furthermore that in addition the same people also took the time to maintain personal diaries, we are hence able to appreciate that there is an embarrassment of riches when it comes to detailed documentation. Personal memories, however charming, do not qualify as historical documents. The British philosopher and historian Collingwood, is quite firm on that issue. The reason being that unlike letters and other written documents, personal memory is not situated in the past, they are reconstructions of the past in the present, and appropriately changed and continuously modified according to the precepts

of hindsight. Just as you cannot step into the same river twice, you cannot recall the same memory a second time, every recollection changes it. Thus we are in the somewhat paradoxical situation that we are better able to reconstruct a process that took place almost two-hundred years ago than one that took place merely twenty years back in the past. And it is this reconstruction based on bare documentation - the facts so to speak, rather than suitable recollection, that allows the necessary level of fine-grained resolution.

Geology as a science was under its way in the 17th century. It was based on a study of rocks using the basic principle, first enunciated by the Danish Steno, that which was situated below was necessarily older than that which was on top. In this way the rocks told a sequential story. In principle this is simple but in practice quite complicated. For one thing, rocks do not come layered horizontally all the time, in fact that is almost an exception, instead they have been folded, sometimes into vertical layers, and then it is not so easy to know what is up and down, and sometimes they have been laid upside down, thus the naive view becomes misleading. In order to know what is up, you need to correlate layers from one location to another. This is a time-consuming business and it is made difficult by the fragmentary evidence. Most of the rocks are covered with vegetation, and it is not feasible for geologists to remove it, but they have to look for places where the removal has already been done, so called exposures. It could be a river that has eroded a gully and left steep banks, or an ocean that has done likewise along a beach. Furthermore it is not feasible for a geologist to drill through the rocks and get deep samples of the various layers, as those could be several kilometers thick. But what makes the exercise so complicated, the folding that has been going on, also makes it possible. The vertical layers are to be inferred from the lateral exposure, thus a two-dimensional picture of the different layers allows you in principle to infer the 3-dimensional and to reconstruct those layered sequence a drill-hole would in principle have revealed[1]. Hence mapping in geology is of paramount importance, because only by having a more global picture are you able to infer the underlying structure, which as has been noted is a key to ordering the past in a time-sequence. But mapping takes time and for a long period such had been going on. Mapping is not so straightforward as the exposure is very intermittent and rather daring interpolations have to be made. Thus the business becomes one of acquired skill and informed opinion, and hence in the absence of hard checks, something not quite that of an exact science.

By the early 19th century there was nevertheless a basic consensus among serious geologists. The uniformitarianist principles already enunciated by the Scot James Hutton and made almost into a dogma by his successor the Scottish lawyer Charles Lyell, (incidentally the mentor of Charles Darwin), taught that geological change proceeded along the very same process that are still present today, and was not the result of intermittent catastrophes. As those processes were very slow, it was a general understanding that the geological time-scales were very long, and that one may very well be talking in terms of hundreds of millions of years. Scriptural evidence played no role at all, none of the serious geologists paid any literal heed to the Bible, which of course presented no impediment to personal piety to flexible minds. Many of the geologists supported themselves in ecclesi-

[1] We have a 3-dimensional structure of layers upon layers, through which a slice has been made. The boundaries of the layers will show up as contourlines on the slice.

astic occupations and saw no hypocrisy in that state of affairs. On the contrary the study of nature could easily be seen as a celebration of its creator. In that regard terrestrial science was not that different from celestial, and in the idyllic times before hard specialization, there were people who pursued one and dabbled in the other. The great astronomer Herschel was an enthusiastic collector of fossils and certainly had a good eye for the geological formations, as did incidentally Goethe, who peppered his travel reports from Italy by geological observations as well as that of flora and fauna. Interest in natural history was indeed widespread among educated classes. Just as to be able to play an instrument, compose a piece of poetry and to draw passably well were considered as part of expected accomplishment, so was an ability to name plants and classify fossils. It is hard not to suspect that people of today lead far less intellectually stimulating lives. Education may be more wide-spread but it certainly does not go deeper.

The notion of a scientist had just been coined at the time, and many of the participants refer proudly t that status as well as extolling the practice. But few people actually made a living as scientists. Of course there were university positions, but universities were few, in England still basically only Oxbridge[2], and the chairs were scant. At the time in England we are talking only about Sedgwick and Buckland at Cambridge and Oxford respectively, but Sedgwick also had assumed ecclesiastical duties in Norwich to increase his income. Then there were ad hoc appointments by the Government, one of the actors De la Beche, supported himself as a surveyor. Otherwise there were many amateurs, either clergymen out in the countryside[3] or men of independent means. Murchison, one of the main protagonists in the story was one such gentleman, as was incidentally Darwin, who appears peripherally in the wings of the story. There was also learned societies who had regular meetings all over the country. The British Association for the Advancement of Science, was one such institution, in which geology played an important role. Such meetings were open to the public, and the geological section was the most popular, and drew attendances of several thousand people[4] The Geological Society of London was mainly intended for the experts but welcomed also serious amateurs. Presidentships were rotated on a biannual basis, as were the holders of offices. Meetings were held several times during the year, during which big maps and drawings were exhibited, along with specimen. Discussions followed, and abstracts of talks were published. Then there was also other avenues of publications, academic of course, but also more wide-spread journals catering to a general but informed public. Intellectual life was vibrant and also international, with a lot of communication with predominantly French and German scientists, but when it came to Geology, Britain seems to have had an edge.

The life of the geologist was a practical one appealing to gentlemen who wanted to combine outdoor living with intellectual pursuit. What better excuse than to roam the countryside looking for outcrops and exposures, identifying outliers and inliers. It did beat hunting, although as in the case of Murchison it did not exclude it either. The season was

[2] Durham was the third to be founded in England, but that was only at the beginning of the 19th century, Edinburgh in Scotland had of course a much longer pedigree

[3] Being a parson was of course a sinecure, but as many of them were drawn from a pool of intellectually gifted and curious persons, there was opportunity to make good use of the free time

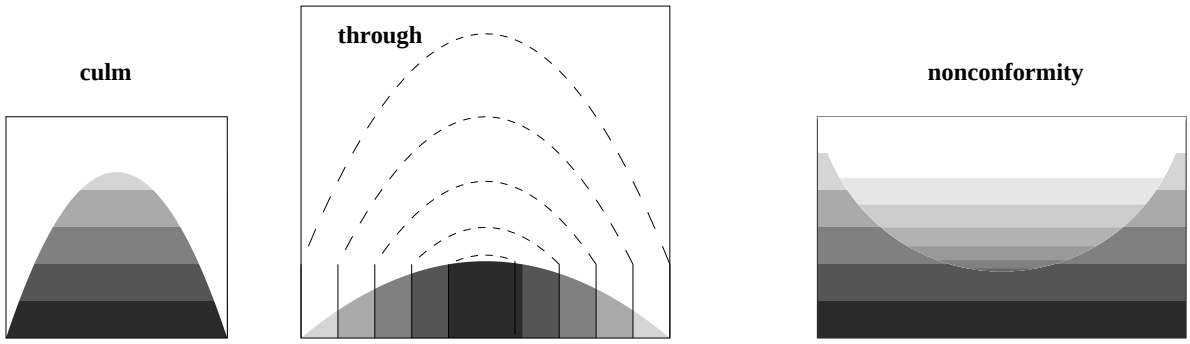
[4] Contemporary drawings reveal that women made up a large part of the audience.

short, however, and confined to the summer. Then the geologist armed with a hammer took to his feet. Travel to more distant locations was difficult and expensive, but already in the late 1830's the railway started to make this more feasible albeit to a limited choice of destinations, and thus for most geologists they had little option but to be reduced to the status of local experts, but giving invaluable assistance to the more global ones such as Sedgwick and Murchison. Most of the transportation was by walking, and walk they did, some thirty miles of bushwhacking in the terrain was considered normal. Reading about it all it seems so idyllic, who would not have loved to live then, at least if comfortably off.

The controversy started back in 1834. The surveyor De la Beche doing work in Devon decided that a certain deposit - the Culm north of Dartmoor, was old but still contained fossils that were typical for the later carboniferous age. The gentleman geologist Murchison challenged this. It was impossible. The culm must be of much more recent vintage, as fossils found in carboniferous strata could only be found in contemporary ones. De la Beche took exception. The idea that a theorist who had not even set foot in Devon should out of hand dismiss careful fieldwork on the basis of some speculative theory was preposterous. What De la Beche had found was facts on the ground. One could as well doubt that he (De la Beche) had a nose[5]. The slighted surveyor sought the assistance of hot-shot geologists such as Sedgwick and Greenough, who were sympathetic to his case. What was at stake? On the scientific side it was the supremacy of fact over speculation, on the private side, far more urgently, it was a case of reputation. Would it come to the ears of the people in government that De la Beche was an incompetent geological survivor, he would of course lose his livelihood, which he had secured by lobbying, and be forced to return to his plantation in Jamaica. Later on Sedgwick and Murchison went to Devon to look for themselves, as they had been challenged to do by De la Beche, and decided that the surveyor had made a mistake. The culm he had identified as lying low in the rocks, when it in fact was a through, and was lying on top, no doubt resting on an unconformity. The unconformity they could not find, but nevertheless they assumed there was one.

So what does that mean? Was De la Beche incompetent? (and at this stage of the narrative we feel for him), or was the matter just one of opinion, and if so whose opinion would in the end prevail (if so, the prospects for De la Beche seemed not so good, Sedgwick his former ally had defected to the camp of his adversary). Now what is a through, and what is an unconformity? The latter reflects that fact that the geological record has local gaps, part of it is eroded away, and then later on a new sedimentation is layered above. And a through means that a particular rock-layer is surrounded on both sides by rocks of the same age (see figure below)

[5] On the frontispiece of the book there is a caricature by the hand of the affronted surveyor himself, showing himself pointing at his nose, while a group of fancily dressed gentlemen looking through tinted glasses (i.e. seeing things through a theory) deny the fact.




Who is right? It is hard to read the geological record, and there is hence a certain latitude for reading what you want to read. Murchison wanted the culm to be young, hence it had to be on top of all the other old layers, referred to by the German term Greywacke[6] and preferably separated from them by an unconformity. De la Beche on the other hand had no such theoretical preconceptions, thus he considered himself to be the more impartial observer. In principle if all the top vegetation is removed and holes are drilled, one could in principle by unobstructed pure stratigraphy settle the issue, which means that there is an ultimate Truth to the question[7]. But one can only base an opinion on what is at hand, and with the accumulated progress of science, more and more will be at hand, and there will be an asymptotic approach to the Truth. Now due to the spotty record, one would like to have some shortcuts in identifying rocks laid down at the same time, one such fingerprinting was given by the presence of fossils. This was a shortcut that had dawned upon geologists and surveyors, and the acclaimed geological map by a certain William Smith, had in fact been based upon this assumption, a principle uncritically adopted by Murchison and Lyell. We are clearly looking at a case of induction here, a fact noticed repeatedly and hence elevated to a general law. But is it justified? De la Beche claimed, and his opinion was shared by most geologists, that structural geology, i.e. dating based on stratigraphy took precedence over fossils. If the two datings were in conflict, the one exploiting fossils based as it was on a mere hypothesis had to give. In order words, strutural stratigraphy being the most basic and logically inescapable, could serve as a falsifier[8]. Now, at the time there were good arguments against fossile-dating. Who could claim that faunas were correlated with time all over the world? This was, if so, rather something to be verified empirically, rather than to assert *a priori*. His own discovery seemed to show on the other hand that it was not so, and what could be more natural than to assume that a particular fauna and flora is due to specific circumstances rather than to time. This is a very reasonable assumption, especially at what was known

[6] Grauwacke, referring to old strata transitionally between the primary and the secondary stratas. The term is an old German mining term which had achieved wide-spread usage.

[7] even better to have been present during the time when sediments were laid down.

[8] Dawkins, whose grasp of such philosophical matters, is hardly firm, claims in his book - The Greatest Show on Earth, that evolution is a fact (meaning supposedly that it cannot be denied), and then claims that if fossils would be found in the wrong order it would make it collapse. Evolution is not a fact, it is theory laden, a hypothesis like all scientific laws and could hypothetically be falsified (or at least its supposed course), say according to the scenario he just sketched.

at the time[9].

One may at this stage insert a slight digression. What was really known about fossils at the time, and how were they thought of? I guess that it was universally accepted that fossils were remnants of once living animals, and not just particular mineralogical structures with no organic provenance. It was then clear that the types of fossils changed with time. The kind of fossils left in the uppermost layers - the Tertiary, were very close to those of now living animals and plants, while there were no fossils to be found in the Primary with the fossils of the Secondary were stranger. Thus there was a feeling that life had arisen on earth a long time ago, and that this event could be correlated with the geological record. Thus one would think that the stage would be set for an unproblematic acceptance of Darwin's transmutability of species, but the transmutation of species is not the same thing as a transformation of collections of species. The latter can accommodate the idea that species are being created as well as going extinct, and if fact the French adhered to an idea that geological periods were natural, being delimited by revolutions in which one set of species was replaced by another one. The idea of a progression was not clear either, and many geologist could conceive of a cyclical story. Still the idea of evolution in the sense of species transforming was breached already in the 18th century as one possible interpretation of the fossil record. Lamarck even gave a plausible explanation for it. But such ideas were very speculative and beyond the ordinary geologists concern for getting the facts straight.

Now Murchison was proposing his theory both for personal reasons but also for reasons of elegance and beauty. The first having to do with prestige, the second with scientific taste and intuition. Of course both were intimately connected. To use fossils as markers for layers would be very convenient and greatly simplify and speed up the process of geological identification. Fossils were the clue, not mineralogy. In particular it would have definite practical values, as it would give a quick way to check whether or not a particular location carried coal-bearing seams if any. The argument being that the existence of coal being identified with remnants from a very particular time-period. The practical value of geology, not very much apparent in this account of a scientific controversy, definitely played an important role in its popularity and its ease to get funding from governmental agencies[10].

Now the failure to find an unconformity was an embarrassment, and something on which De la Beche hang onto during his time of humiliation after having been forced to concede the new reading of the record of the culm being in a through, and hence locally the youngest layer[11]. Then Murchison got the brilliant idea to accept the lack of unconformity and simple elevate the underlying rocks to a younger age, by proposing a new era between the Silurian[12] and Carbonferious, to a large extent based on the fossil remains, which seemed to be intermediate between the two. The great challenge was to show that this

[9] The notion of a progressive evolution was not universally accepted and its implication of historical contingencies.

[10] It is dafe to assume that nowadays most people graduating in geology are industrially employed.

[11] He was able to jeep his surveying position though due to the intervention of powerful allies such as Greenough

[12] Murchison had in fact written a major treatise on the 'Silurian system'

made sense and that it was not only a local phenomenon but had relevance way beyond the limits of Britain. He managed to get Sedgwick on the boat as a co-author, while the latter was rather dubious and only reluctantly accepted to go along, grumbling occasionally about the lack of evidence. The interchanges between the two give a very good picture of two collaborators not really being in synchronization with each other, but who nevertheless decide to go along together due to the advantages of a joint effort. What Murchison had to do was to identify the layers more globally and get incontestable stratigraphic evidence of his Devon sediments being sandwiched between the two other. That indeed would be to give a logical proof in the spirit of Euclid, the kind of ideal rigor to which any science should strive. For that purpose he went on fieldwork for two summers, once in Germany, mostly along the Rhine, and later to Russia, where he was able to clinch matter. His identification of the Devon strata did in the end depend on fingerprinting by fossils, having established a typical Devon fauna, which he was able to find in faraway Russia and thus establishing that it was no mere local phenomenon. In fact his earlier daring identification of his Devon stratas with Old Red Sandstone had been an embarrassment as there were no fossils that made them appear contemporary, while in Russia he got conclusive evidence that they were correlated[13]. Later on Devon-type fossils were also discovered in the States and his triumph was more or less assured. It had taken six years of hard work before a consensus was formed. Now, this consensus was it a case of a social agreement or had it anything to do with external truth? Rudwick appends his detailed history with a detailed discussion of what was actually going on.

Let us first consider the final conclusion. How was it reached? It was team-work, a giving and taking. De la Beche had one interpretation which was countered by Murchison and Sedgwick, who claimed that De la Beche had failed to identify a through or to find an unconformity. De la Beche conceded the issue of a through but denied that there was an unconformity, while on the latter point both Murchison and Sedgwick had to back down. This presented still a problem for Murchison who then decided to upgrade the whole set of strata lying under the contentious culm. Ideas were being wollied back and forth on letters and at formal meetings, none of the participants, unlike the case of Darwin many years later, had the leisure and peace of mind to develop their theories in isolation. Still Murchison was the driving force, bringing with him a part-time reluctant Sedgwick and often having to deal with the opposition on his own, his co-author bogged down by other obligations. Gradually more and more people came around to his case. In the end there was a consensus. The consensus was very much dependent on there being a hierarchy. There were the experts, whose opinions carried a lot of weight. Among the experts, special attention was paid to those who had engaged themselves personally in the controversy. When all the experts had agreed to agree, the controversy was shelved. So was it just a social construction? And what had really been really accomplished? The naming of a geological epoch is of course just a convention, but not an entirely empty one. Many of the geologists expressed indifference to what it was called, but not Murchison. He very much fought for the retainment of the name - Devonian. As he wrote as a response to an alternative terminology of the Palaeozoic involving simply Lower, Middle and Upper

[13] The difference in faunas were later explained by the different circumstances, one set corresponded to sediments in the sea, the other on land.

*The perpetuity of a name affixed to any group of rocks through his original research is the highest distinction to which any working geologist can aspire.*

to which he added *It is in truth his monument*. Then we have the issue of the Epoch itself, to what extent is it natural? Is it not like the unnatural borders of a nation state, lines drawn on a map, because lines have to be drawn? The French adhered to a sequence of catastrophes, each catastrophe wiping the slate clean. This would of course give a meaning beyond mere convention to a partition into different periods. Murchison following the lead of Lyell opposed such a scenario, and more careful analysis by experts in fossils disclosed that there had indeed been a gradual change. Anyway, although not canonical, the epoch nevertheless was a convenient one, issuing the emergence of terrestrial animals, including the early vertebrates. But the most momentous consequence was of course that fossil dating became the norm, and the fact that this has not so far led to any inconsistencies with the structural approach illustrate the Popperian thesis of no falsification. It has proved convenient and no one has felt the need to challenge it. As a real contribution to knowledge it is less momentous, but with it, the grand plan of epochs following each other had finally been established, before that there was great confusion among the Palaezonic rocks.

Rudwick takes exception to the grand theories of Kuhn and Popper, spending more time on the former. He points out that there was no real revolution, instead there were a gradual change within the paradigm itself. Nor was this change brought about by some disembodied Popperian falsification tests, but by real people, being driven by all too human motivations. As against the post-modernist social construction view, one should invoke Popper. When Murchison went on his field trips he had no idea what he was going to find. What he found was to some extent conditioned upon his expectations and wishes, but far from fully as he had to admit defeat at times. Science, although given a large latitude as to formulation of theories is constrained by having to comply with the facts. And facts can be hard, especially on the ground. Practical applications of science should be seen primarily in this light and not in an economical one. And geology has a lot of practical applications as we have already mentioned. By championing his principles, one would be in a good position to be able to rule out large areas as possible location for coal seams[14]. If on the other hand plants could occur at any time period, there would be no such constricting laws.

Now the advantage of presenting the chronological narrative is to give flesh to the bones. In a way the subject is as engrossing as any that is feed for a novel. Clearly a novel could have be made of it, as it is the author is constricted to what can be factually confirmed which makes the story a bit more tedious than it would otherwise have had the potential to be. Still the personages come out vivid enough. At center stage is Murchison. He is a gentleman scientist and a former solider. He loves the outdoors, not only fieldwork, and he loves to live the high life, to which his marriage to a wealthy heiress eventually makes possible. He is driven by ambition and to be acknowledged as a scientist among his social peers. He is jealous of his reputation and sees De la Beche as not only a rival, but also

[14] Murchison during his visit to Russia had the privelige to meet with the Czar Nicholas I advising him not to look for coal in the north of Russia

as a threat being government supported[15] he could as a professional usurp the legitimacy of being expert for himself and his colleagues to the detriment of the independent scholar who would be then marginalized. Not surprisingly Murchison is short on his temper and has a problem holding his fire, sometimes to the detriment of his cause. And how is the campaign conducted? It is a campaign along military lines in which you have to have ammunition and shoot well and sink the arguments of your opponent. Sometimes metaphors taken from the world of sports are invoked but more often than not the language of the court is employed, and that is very natural, because the quest for truth is battled over at a court, not a legal one but a scientific one. A court in which the towering experts act as judges and jury, while accomplished people are brought in as witnesses, the weight of their testimonies given according to their perceived competence. The conflicting parties furnish their briefs, exaggerating the strengths of their cases and passing over the weaknesses. And the notion of precedent is very important, as justice means invariance over time. And for that reason De la Beche makes a big point of examples elsewhere, in Ireland as well as in Brittany, shwing the same kind of supposed anamolies[16]. A court of law is not necessarily out to get the Truth, it is out to get an informed judgment on the basis of the testimony presented. This is all they can do. The difference between science and a court is that in the latter case a verdict has to be made within a finite amount of time, while in science the case is potentially open indefinitely. The fact that a consensus was made in the early 1840's does not mean that the accomplishments of Murchison was established once and for all, the future may bring as of yet unknown anomalies, the resolution of which may lead to rethinking. Court cases designed to come to some closure permeate all sciences, even mathematics, which is commonly thought of as exempt. Deductive chains are so complicated that purely mechanical ways of verification are no longer feasible, but matters of taste and informed opinion must come into play.

Now what strikes the modern reader is the modernity of the whole controversy. The actions and emotions of the main players are exactly what you might expect today, if not as elegantly expressed. Therein lies is of course the charm of history, to be able to identify with the actors while those are being placed in to us unfamiliar circumstances. Circumstances which strike the modern reader as quaint and idyllic, as already remarked. The wealthy protagonists with free time at their hands can afford to travel in style. They go by coach or steamer. The introduction of railways lends a modernistic touch, which almost seems anachronistic. In a novel, much more of the sense of time and place could have been conveyed, and the relentless technical description be leavened with more mundane matters of more general interest.

This is microhistory, a hermeneutic exercise bound to take a lot of time and effort and hence only undertaken at critical junctures. Rudwick has decided that the Devonian controversy, just because of its mundane aspects, provides an excellent specimen from the past, whose study can reveal much more than the ostensible subject would be expected

[15] De la Beche would have preferred to be a gentleman scientist, but his plantation in Jamaica was not doing well, so he had to lobby for governmental grants and commissions, as already noted.

[16] The case of Ireland made by Weaver was later dismissed, as Weaver felt compelled to retract his original claims. That brought Sedgwick over to the side of Murchison and eventually to the total collapse of Weavers reputation for competence.

to. Rudwick tries to stir a middle ground, between the naive proponents of straightforward science driven by facts and observation and the wooly tales of convention and social construction. There are of course much that is a drama on the purely human level, even if the protagonists themselves give witness to exalted visions of science and the search of truth, but there are constraints, most of them hidden and tacit, and hence in need of being clearly revealed, which maybe not quite the case. Our wishes and dreams as individuals are always frustrated by the conflicting demands of society. But there are also demands that go beyond society and impinges on inescapable physical restrains, many of them so well incorporated in our daily lives that we give them little thought.

September 4-5, 2012 **Ulf Persson:** *Prof.em, Chalmers U.of Tech., Göteborg Sweden* ulfp@chalmers.se