

## Response to letter submitted to MRWS:Cumbria by Dr J. Dearlove

David Smythe  
16 September 2011

This letter is in response to the letter submitted to MRWS: Cumbria by Dr J. Dearlove on 13 May 2011. His letter is a commentary on my critique ‘*Why a deep nuclear waste repository should not be sited in Cumbria: a geological review*’, dated 12 April 2011. I have abstracted the text of the letter, numbered the paragraphs for reference, and appended it below.

### Points of agreement

Dr Dearlove says:

*“I agree that the more complex the geology, the more uncertain the results of any modelling exercise. Our current understanding of the geology associated with the former Longlands Farm site indicates it is indeed complex (structurally, lithologically, geochemically and hydrogeologically).”* (Para. 2.2)

*“I would agree, in general, with Professor Smythe that the MRWS Stage 4 technical criteria for the selection of areas for further investigation is lacking in detail.”* (para. 4.2)

*“It could be argued, as Professor Smythe does, that the original generic geological settings put forward by Chapman *et al.* in the 1980's could be used.”* (para. 4.3)

*“The current volunteerism process constrains selection to less than ideal sites.”* (para. 5.1)

*“I would agree with Professor Smythe that the criteria set out in his Figure 2 are too vague”* (para. 5.2)

*“I feel it is necessary to acknowledge that it is true to say that the Sellafield B site is not/was not, sensu stricto, a Basement Under Sedimentary Cover (BUSC) scenario (as per the original prototype through the coastal plain of Maryland, USA).”*(para. 5.4)

*“Groundwater flow in hard rock systems is undeniably complex.”*(Para 6.5)

So we are in agreement that:

- West Cumbria is complex and “*less than ideal*” as Dr Dearlove puts it;
- The NDA table 4.1 (my figure 2) is vague;
- Valid criteria do exist for choosing geological settings in the UK;
- The Sellafield B / Longlands Farm sites did not conform properly to one of the BGS-predefined geological settings.

### Complexity

Dr Dearlove admits to the complexity of both the geology and the resulting groundwater flow (paras. 2.1, 2.2, 2.3, 6.3, 6.5), but contends that it is nevertheless possible to model (and therefore predict) the groundwater flow. He also adds that the international guidelines regarding the undesirability of complexity are mere preferences and not requirements (para. 4.4).

## Failure of logic

Dr Dearlove summarises me correctly (para. 2.3) in that:

*Statement 1.* The area in question is well understood, and too complex in its geology and hydrogeology to be considered once again as a region within which a waste repository could be located.

But he then goes on to say that this “*suggestion*”, as he terms it, is no more or less valid than the counter-claim he proposes:

*Statement 2.* We currently do have a sufficient level of understanding of the groundwater flow and flowpaths consistent with the safe disposal of intermediate-level nuclear waste.

Leaving aside the error that a *high-* as well as *intermediate-level* waste geological repository is what is now being sought, his attempt to juxtapose the two statements as having equal validity is false. He is appealing to an *argumentum ad ignorantiam*, by putting my Statement 1 (with the status of a mere suggestion) beside his Statement 2, then claiming that we do not know enough to refute either statement.

But in order to make *Statement 1*, I have studied and presented for discussion the local and regional geology and hydrogeology. Therefore if Dr Dearlove wishes to refute *Statement 1*, then he needs to refute, category by category and locality by locality, all my evidence. He has not done so.

In contrast *Statement 2* is mere assertion, added as a debating tactic. It follows from *Statement 1* that:

*Statement 3.* We currently do have a sufficient level of understanding of the groundwater flow and flowpaths to be able to say that they will be so complex and unpredictable that a safety case will never be made.

In other words, *Statement 3*, which is the opposite of *Statement 2*, is founded upon sound evidence. *Statement 2* is nothing more than a denial of my *Statement 1*, put there in lieu of a detailed refutation.

*Statement 3* is supported by the outcome of the Longlands Farm Planning Inquiry, since the site in question was the “least unsuitable” (my phrase) volume of rock to be found in the coastal strip of West Cumbria.

## No comment

Dr Dearlove makes no substantive comments on various detailed issues I raised, including:

- The removal from the NDA website of the vast bulk of Nirex documents, so that there is no record of the 1995-96 Planning Inquiry (section 3).
- The fact that Cumbria is an exceptionally well-understood region, geologically (section 4.1)
- The flawed, politically skewed, site selection process of the late 1980s (section 4.2).
- The unsuitability of the coastal zone south of the Esk estuary and west of the Lake District Boundary Fault (section 4.3 and figure 5).
- The fact that the Longlands Farm site, which I describe as the ‘least unsuitable’ site in West Cumbria, is highly complex, highly constrained on four sides, and with unpredictable hydrogeological flow (section 4.3, figures 6-8).
- The stillborn attempt by Nirex to argue that had the Nirex97 set of science documents been available in time, the outcome of the Inquiry might have been different (section 4.3).

- The discussion (section 4.4, figures 9, 10) of the extensive oil exploration and wealth of resulting seismic and exploration well data in the onshore Solway Basin, much of it interpreted and published by the BGS (see the section below on the Mercia Mudstone Group).
- The essential three-dimensionality of the limestone belt as an illustration of what I mean by ‘complexity’ of geology (section 4.4, figs. 12, 13).
- The unsuitability of any hard rock site within the National Park, such as the Eskdale granite (section 4.5).
- The fact that the increase in computing power since 1995 does not imply greater accuracy in modelling (section 5.1).
- My synthesis of EU and international guidelines for deep geological disposal, together with the Inquiry Inspector’s observations, that all agree on the desirability of both low hydraulic gradients and simple geology (section 5.3).

### **High hydraulic gradient**

Dr Dearlove states, in the context of the Eskdale granite as a possible host rock:

*“It should be noted that a number of radioactive waste research facilities were located in areas of high hydraulic gradient (for example, Grimsel in the Swiss Alps)”*. (para. 6.5).

The mention here of Grimsel, the hard rock underground laboratory developed by Nagra in Switzerland, is misleading. It was located in the heart of the Alps as a way to bore horizontally from a public road into crystalline rock below 400 m of mountain cover rock. This is far more convenient and cheaper than sinking 400 m deep shafts, then tunnelling horizontally. The site is explicitly designed for research, and will never be used as a waste repository, precisely because of the high hydraulic gradients due to the mountainous topography.

No other potential waste repository sites internationally are located in areas of high hydraulic gradient.

I shall provide more evidence elsewhere as to the unsuitability of the Eskdale granite as a host rock.

### **Mercia Mudstone Group**

Dr Dearlove discusses the Solway Plain and Solway Firth, identified by the BGS in the 1980s as an area of “potentially suitable sedimentary formations” (para. 6.2). He goes on to say that:

*“Whilst there is a suggestion it may be structurally complex, this requires proper evaluation and is insufficient grounds to reject it”*.

In fact I nowhere imply that the Permo-Triassic of the Solway basin is structurally complex. Its geology has been thoroughly studied and published by the BGS in several recent papers, which make good use of the ample oil industry information to which I alluded. This work includes a re-evaluation of the small inlier of Jurassic. So the “*proper evaluation*” that he demands has already been done by the BGS. The geology of the basin is quite simple – a syncline cut by normal faults, and confirmed by an oil well bored right through to the Carboniferous. There is nothing new left to discover here regarding potential repository host rocks and their structural setting.

He accepts my conclusion that the St Bees Evaporite Formation (a potentially suitable host rock) is absent in northern Allerdale (as proved by the Silloth-1A well drilled in 1983), but goes on to state that the Mercia Mudstone Group (MMG) is now being considered, according to his “*brief discussions with the BGS*”, as an alternative potentially suitable host rock (para. 6.3). Therefore, according to him, CoRWM’s position (that suitable host rocks remain to be found) remains tenable.

Dr Dearlove does not mention that three sites within the Solway Basin were investigated by the BGS in the 1980s as part of the nationwide site search, but were then rejected on grounds of geological unsuitability. These are:

| <b>Site</b> | <b>Environment</b>  | <b>OS grid square</b> | <b>Easting</b> | <b>Northing</b> |
|-------------|---------------------|-----------------------|----------------|-----------------|
| Anthorn     | sedimentary coastal | NY 1758               | 317300         | 558100          |
| Longton     | sedimentary inland  | NY 3567               | 335100         | 567300          |
| Eastriggs   | coastal             | NY 2664 [inaccurate]  | 324100         | 565100          |

I have corrected the erroneous grid square reference to Eastriggs in the Pieda documents. The most relevant of these sites is Anthorn, a former airfield. It lies in a zone not excluded by the BGS in 2010, and is about 6 km NE of the Silloth-1A well. The site is representative of the deeper basinal Permo-Triassic geology (including the MMG) in the non-excluded area running from Abbeytown in the south to Bowness-on-Solway in the NE. The Solway Basin, and Anthorn in particular, was initially considered by the BGS because of the possible presence of thick anhydrites at appropriate depths for a host rock. But the outcropping MMG was never thought of as a potentially suitable host rock within the Carlisle – Solway area. That is why I did not consider it further. Had it been so, then additional areas of MMG outcrop would have been marked on the BGS regional map of the late 1980s, for example on either side of the Severn estuary, and a much wider area of the Staffordshire Basin than was depicted.

So if the area (and indeed the MMG in general outside the areas where thick halite is present) was rejected by the BGS in the late 1980s, why is it now apparently being considered? I consider it to be *a priori* an unsuitable repository host rock formation, for the following reasons:

1. The area lies within a region of high topography and hence high hydraulic gradient, even though the gradient due to the Cumbrian mountains may only be about half of that on the western coastal strip.
2. It is a Secondary B aquifer. There are a dozen or more water abstraction wells within the outcrop area of the MMG. Some of these penetrate to more than 100 m. The combination of this fact, together with the presence of the underlying Sherwood Sandstone Group (a Principal Aquifer) implies that the MMG should be excluded on the grounds both of intrusion risk and of loss of future groundwater resource.
3. The MMG comprises laminated mudstone and subordinate siltstone and calcareous sandstone. In the Solway basin area there are thin beds and stringers of gypsum and/or anhydrite, but too thin to be considered as a host rock formation. The Preesall Halite Formation was encountered in the Silloth-1A well at about 180 m OD, but is only 7 m thick.
4. The MMG is cut by faults with throws of up to 100 m, trending NNW-SSE; therefore it cannot be compared with unfaulted flat-lying geologically simple claystone formations currently being considered as potential host repository rocks elsewhere in Europe. The continuation of the Crummock Fault, downthrowing to the E, runs north to the coast, flanking a narrow horst block lying just east of the well. To the west of this block the base of the MMG is at a maximum of 500 m depth; to the east the base of the MMG forms a circular basin with a maximum depth of about 400 m.
5. Mudstones and siltstones with subordinate sandstones and halites do not comprise a suitably impermeable formation, unlike claystones.
6. Their chemistry implies an oxidising environment, a highly undesirable attribute for a host rock.

Within the boundary of Allerdale District Council there are two outcrops of MMG outwith the excluded area. The small area to the east, centred on (OS grid coordinates 332, 551) can be discounted because the MMG is at less than 300 m depth. The larger area, to the west, runs northwards from Pelutho, through Seaville and Silloth, and NE past Moricambe Bay and then through Anthorn to Bowness. At Anthorn the MMG is at about 200 m depth, thinning out northwards; so the area north of the bay can be discounted. That leaves the Silloth – Seaville – Pelutho area to the south of the bay – the area cut by the large faults.

Hydraulic conductivity measurements of the MMG from various locations in England range from as low as  $10^{-5}$  to  $10^{-9}$   $\text{ms}^{-1}$ . BGS reports quote a mean of  $10^{-6}$  in one case and  $10^{-7}$  in another. In contrast, the Opalinus Clay currently being considered as a host rock by Nagra in Switzerland has laboratory measurements of conductivity from shallow boreholes below 20 m depth in the range  $10^{-10}$  to  $10^{-11}$   $\text{ms}^{-1}$ , plus good evidence for *in situ* conductivity of  $<10^{-13}$   $\text{ms}^{-1}$ . The Lower Cretaceous Gault Clay of England has a laboratory-measured conductivity of  $10^{-11}$   $\text{ms}^{-1}$ , although this may be larger *in situ* by an order of magnitude, due to the presence of fractures. Put simply, the MMG has a hydraulic conductivity ranging from ten thousand to millions of times higher than other potentially suitable claystone host rocks. This is not surprising, as it is an aquifer. The city of Leicester's water supply used to come from the MMG.

It is misleading of the 2010 BGS screening report to have cited the Borrowdale Volcanic Group (BVG) as the example of a Secondary B aquifer under the new Environment Agency definitions (table 4). The BVG has a conductivity of the order of  $10^{-10}$   $\text{ms}^{-1}$ , that is, three to four orders of magnitude smaller than the MMG. The MMG is a good example of a Secondary B aquifer. Therefore under the screening criteria it should have been excluded.

In the East Irish Sea Basin it is reported that at least 600 m of MMG is required for it to be an effective hydrocarbon seal there, due to the inversion uplift. This effect will also apply to the Solway Basin. However, the MMG is an effective seal in the Wessex Basin, where 300 m of MMG caps the oil of the Wyth Farm field, together with another 200 m of Liassic mudstone above. The difference in the latter case is that the Tertiary uplift has never taken the MMG into the brittle tensional strength regime, which is the reason for the higher hydraulic conductivity in the Irish Sea region.

The Preesall Halite Formation is far too thin to act as a seal, not least because any fault cutting it with a vertical throw of  $>7$  m will place the mudstones above and below the halite into direct contact.

In conclusion, the MMG is quite unsuitable as a host rock *per se*, and in the locality available for consideration it is in fact exploited as an aquifer. Lastly, the shallow depth available and the large-scale normal faulting in the centre of this locality would rule it out even if it did have properties more appropriate to a claystone host rock.

Therefore, Dr Dearlove's statement:

*“the conclusion must be that the Solway Plain within the West Cumbrian MRWS Partnership area remains, on geological evidence, an “area of potentially suitable sedimentary formations”.* (para. 6.3)

is invalid, and his logical follow-on statement *“This clearly supports CoRWM's position”* is therefore also invalid.

In conclusion, given that my previous statement on the unsuitability of the Solway basin area is clearly confirmed by the discussion above, there is no area which I have considered in depth in West Cumbria (the so-called partnership area) which remains to be investigated.

## **Summary and conclusions**

*Complexity:* Dr Dearlove seems to be content that international guidelines be disregarded, as well as the UK-derived criteria for suitable geological environments. In effect he accepts the current NDA evaluation process, even though he clearly has misgivings about certain aspects of it. I, in contrast, am challenging the whole process, inasmuch as West Cumbria is being targetted (I am not against UK final geological disposal in principle).

*Existing knowledge:* Dr Dearlove has used a debating tactic to argue that we do not know enough about the areas in question to be able to say whether or not they are suitable. In contrast, I argue that we do know enough, both about the region and about the supposedly most suitable (or least unsuitable) locality, after an expenditure of some £400M on research in the region by Nirex up to the mid 1990s.

*Mercia Mudstone Group:* I have presented more detailed evidence than hitherto regarding this supposedly potential host rock, given that the BGS is apparently now considering it (but had ruled it out 25 years ago). I confirm that it remains unsuitable.

There is no magic bullet. There is no as-yet unknown volume potentially suitable rock volume that remains to be discovered. The work has been done. The BGS correctly summarised the position in the late 1980s during its national site search.

By proceeding to Stage 4 in West Cumbria, despite the evidently insuperable difficulties of geology and hydrogeology, the NDA and the local authorities may run the risk of legal challenge.

## **References**

All the factual statements made above are backed up by reference to various BGS reports, peer-reviewed papers and reputable on-line presentations (e.g. from Nagra, NDA, BGS, etc.). I assume that Dr Dearlove is already familiar with them.

**Appendix**  
**Letter to West Cumbrian MRWS Partnership**  
**By Dr. J. P. L. Dearlove**  
**[Paragraph and sub-paragraph numbering added by DKS]**

**OVERVIEW OF PROFESSOR DAVID SMYTHES REBUTTAL OF CoRWM'S VIEWS**  
**13 May 2011**

1.1 As requested, I have undertaken a review of Professor Smythe's document "Why a deep nuclear waste repository should not be sited in Cumbria: a geological review". I have focused my review on the two key questions you asked, which are "In your opinion, to what extent is David Smythe expressing a view held by the wider geological community?" and "Which issues, if any, warrant further follow-up by the Partnership at this stage in the process?"

2.1 Starting with the first question, in terms of my own professional field of hydrogeology and contaminant transport geochemistry, I would contest the assertion by Professor Smythe that it is not possible to model adequately the complexity of groundwater flow and radionuclide transport in the geological sequences likely to be encountered within the West Cumbrian MRWS Partnership area. I prefer to use this description for the entire geographical area under consideration in this review (rather than "area", "region", "West Cumbria" or any other term used to describe the geographical area of interest where a potential repository may be sited).

2.2 I agree that the more complex the geology, the more uncertain the results of any modelling exercise. Our current understanding of the geology associated with the former Longlands Farm site indicates it is indeed complex (structurally, lithologically, geochemically and hydrogeologically).

2.3 However, it is a considerable leap to go from this position to then suggest that the geological complexity of the "coastal strip of West Cumbria" is already sufficiently well understood to allow us to draw the conclusion that it should be rejected as being potentially suitable for a repository site. This statement has as much validity as the counter-claim that we currently have a sufficiently robust level of understanding in groundwater flow and flowpaths consistent with the safe disposal of intermediate-level nuclear waste. *I feel it is more Professor Smythe's personal opinion, and not the opinion of the wider geological community, that as a consequence of the MRWS Partnership area having complex geology and hydrogeology, the area should not be considered potentially suitable for a geological repository.*

3.1 It is also true to say that a region with a lower hydraulic gradient would be *preferable*, but the current site selection process does not allow for much choice. Undertaking investigations in areas of low hydraulic gradients (i.e. Norfolk/The Wash) may be preferable but this is a political and not a scientific decision that lies outside the remit of the West Cumbrian MRWS Partnership.

4.1 I would like to try and derive a positive contribution to the current debate from what appears to be a rather negative document produced by Professor Smythe through looking at the second question you posed.

4.2 I would agree, in general, with Professor Smythe that the MRWS Stage 4 technical criteria for the selection of areas for further investigation is lacking in detail. I believe it may be this uncertainty in the Stage 4 evaluation criteria that exacerbates the current disquiet as to whether or not the MRWS Partnership should proceed to Stage 4 and the fear that, irrespective of past events, the former Longlands Farm site will emerge on the potentially suitable site list at Stage 4, possibly at or near the top in terms of priority.

4.3 It could be argued, as Professor Smythe does, that the original generic geological settings put forward by Chapman *et al.* in the 1980's could be used. However, the opportunity to evaluate

potential sites in the UK, as a whole, against these ideal criteria was lost when Sellafield B and Dounreay were selected as the sites on which to undertake further work.

4.4 Professor Smythe also cites the current/updated IAEA guidelines which, it should be noted, indicate *preferences* regarding geological complexity, not *requirements*.

4.5 I believe it is the absence of any clear criteria against which the UK should evaluate potentially suitable sites at MRWS Stage 4 that leaves the discussion on the geological suitability of West Cumbria to host a repository open to a significant range of interpretations.

5.1 The original search process in the 1980's allowed for the selection of a site with as close to ideal geological and hydrogeological characteristics as possible. The current volunteerism process constrains selection to less than ideal sites.

5.2 I would agree with Professor Smythe that the criteria set out in his Figure 2 are too vague, although I cannot agree with his subsequent highly personal derisory comments.

5.3 It would be potentially very beneficial to the MR WS Partnership to follow-up with a request to the NDA to initiate a process by which specific criteria to be used at Stage 4 can be identified by the close of Stage 3. This might follow a similar methodology to that which derived the screening criteria for the BGS report.

5.4 It is a matter of some debate to suggest that the PRZ at the Longlands Farm site was selected by a scientifically irrational process. Since a large proportion of Professor Smythe's review focuses on the selection of the Sellafield B site, I feel it is necessary to acknowledge that it is true to say that the Sellafield B site is not/was not, *sensu stricto*, a Basement Under Sedimentary Cover (BUSC) scenario (as per the original prototype through the coastal plain of Maryland, USA). However, this does not mean it then ceases to be a potentially suitable repository host rock.

5.5 The current selection process requires a review at Stage 4 (against clearly identified selection criteria) to determine its potential suitability. This may then provide the evidence (in particular from a structural geology perspective) to support Professor Smythe's claim that "the geology of this district is evidently unsuitable for considering a repository site".

6.1 I think Professor Smythe is wrong to refute the CoRWM statement.

6.2 Based on Professor Smythe's own report, one area, first identified by the original BGS study for potential low- and intermediate-level waste repository sites back in the 1980's, remains potentially suitable. Professor Smythe's figure 3 shows geological environments considered to have the potential for repository development. The area of the Solway Plain and Solway Firth is shown on this map under the heading "Areas of potentially suitable sedimentary formations". This is an area of thick Triassic and older rocks.

6.3 Professor Smythe notes that the "general geological advice given to government by BGS has not subsequently been found by any later detailed investigation to be flawed". Professor Smythe highlights the potential wealth of oil industry seismic data within this region. Whilst there is a suggestion it may be structurally complex, this requires proper evaluation and is insufficient grounds to reject it. Professor Smythe considers this area is geologically unsuitable, and outlines his reasons in the paragraph preceding section 4.5 on Page 9. The St Bees Evaporite Formation is dismissed as a consequence of its absence onshore in northern Allerdale. However, I understand from brief discussions with the BGS that the Mercia Mudstones within this area would also form part of the BGS's "potentially suitable sedimentary formations". Thus the conclusion must be that the Solway Plain within the West Cumbrian MRWS Partnership area remains, on geological evidence, an "area of potentially suitable sedimentary formations". This clearly supports CoRWM's position.

6.4 The discussion by Professor Smythe on the Carboniferous Limestones in this region is largely irrelevant as it is stated in Table 5 of the BGS screening report that these are excluded between 200 and 500m below ground level, and subsequently that the isolation of any facility from exploitable water resources will be a major issue regarding the potential suitability of any proposed site.

6.5 Professor Smythe also reviews the geological potential of the Eskdale granite, which he dismisses on the grounds of a higher than desirable hydraulic gradient and its proximity to the Lake District Boundary Fault (LDBF). It should be noted that a number of radioactive waste research facilities were located in areas of high hydraulic gradient (for example, Grimsel in the Swiss Alps). Groundwater flow in hard rock systems is undeniably complex.

6.6 It is probably insufficiently understood at present by the International hydrogeological community to permit its evaluation to the level necessary to satisfy the current UK regulatory agencies, particularly in consideration of its proximity to the LDBF. However, until it has been reviewed under the current evaluation process, it remains a potentially suitable repository host rock.

7.1 In conclusion, Professor Smythe fails to adequately refute CoRWM's position, and to some extent inadvertently even appears to support it. The issue of identifying suitable criteria for the selection of potentially suitable repository host rocks for implementation at Stage 4 should be followed-up by the West Cumbria MRWS Partnership.