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26 October 2011

West Cumbria MRWS Partnership
Copeland Borough Council
WHITEHAVEN
Cumbria
CA28 7SJ

Dear Sir/Madam

REQUESTED RESPONSE TO PROFESSOR SMYTHE'S PAPERS

In an e-mail of 19 October 2011, you requested my views specifically as to the extent to which there is either agreement or disagreement with Professor Smythe's belief (as stated in MRWS website reports M and N; Refs 1 and 2) that we know enough about West Cumbria's geology and hydrogeology to rule it out of the search for a potential repository site. You also wished to know if Professor Smythe has raised any issues that should lead the Partnership to alter its initial opinions as expressed in the Geology chapter of the draft Consultation Document (Ref. 3).

In keeping with previous responses I shall restrict my comments to the specific questions asked by the Partnership, and so I will not be providing any "substantive comment" on the various other issues raised by Professor Smythe. Also, in adherence to the Geological Society's Chartership Code of Conduct, I will respond only to issues within my stated areas of expertise in geology and hydrogeochemistry.

Two regions in particular have been highlighted by Professor Smythe in his original report of 12 April 2011 (Ref. 4), to which I responded. These are the Eskdale Granite (Page 10; Ref. 5) and the Solway Coastal Plain (Page 9; Ref. 4). In Document N (Ref. 2), Professor Smythe's comments on the Eskdale Granite include "it has now been suggested by Dr Dearman of FWS Consultants Ltd. as a *"potentially suitable repository host rock"*" is misleading on two counts; I am NOT Dr Dearman, and in my response I stated "Professor Smythe also reviews the geological potential of the Eskdale Granite which he dismisses....". My response was therefore to an issue he initially raised, not one I suggested.

Since these two specific regions have already been highlighted and discussed at some length by Professor Smythe I will use them as examples as to why I consider there is currently insufficient information, in particular regarding hydrogeological data, to rule them out at the **CURRENT STAGE** of the search for a potential repository site in West Cumbria.

With regard to the Mercia Mudstone Group [MMG] (also known as the Stanwix Shales), this is indeed a Secondary B aquifer, which lies between the Sherwood Sandstone Group [SSG] (Principal Aquifer) and the Penarth Group [PG] (also a Secondary B aquifer). Previous

Environment Agency (EA) nomenclature would describe both the MMG and PG as a NON-AQUIFER. The reader is referred to the EA website for a precise definition of a Secondary B aquifer but in summary they are "predominantly lower permeability layers which may store and yield limited amounts of groundwater due to localised features such as fissures, thin permeable horizons and weathering. These are generally the water-bearing parts of the former non-aquifers."

Professor Smythe asserts (in summarised form) that:

1. The area lies with in a region of high topography.....even though the gradient due to the Cumbrian Mountains may only be half of that on the western coastal strip
2. The MMG is a Secondary B aquifer with dozens or more water abstraction wells within the outcrop area of the MMG, some penetrating to more than 100m. Based on this and the presence of the underlying SSG, the MMG should have been excluded on the basis of intrusion risk and loss of future groundwater resources
3. MMG comprises laminated mudstones and subordinate siltstone and calcareous sandstone which are not "suitably impermeable formations"
4. MMG cut by NNW-SSE faults (throws up to 100m)
5. The chemistry of the MMG *implies* (my italics) an oxidising environment

Therefore:

1 The area has a LOWER hydraulic gradient than the former Longlands Farm site and therefore has a characteristic that is better than Longlands Farm (one of Professor Smythe's criteria in his argument that Longlands Farm was the least unsuitable site in the whole of West Cumbria and therefore if there was nothing better then it must follow that the whole of West Cumbria is unsuitable).

2 The MMG, like the BVG, is classified as a Secondary B aquifer. These two units have very different properties making them Secondary B aquifers – the BVG has overall low hydraulic conductivity and some fracture flow allowing groundwater transport whilst the MMG has variable hydraulic conductivity layers (mudstones, siltstone and sandstones) plus flow along faults and joints. It is NOT an aquifer *per se*, it is a low permeable rock that contains isolated groundwater. At depths in excess of 500m any groundwater present will most likely be saline and thus does not represent a potable groundwater resource. This is why the BGS Screening study uses 500m depth as the cut-off for excluded areas.

3 It should be noted that hydraulic gradient is a measure of the potential energy that may be imparted to groundwater to transport it from areas a to b. It is not the same as the hydraulic conductivity which is a measure of the rate of flow. Groundwater will follow along the path of least resistance when flowing down-hydraulic gradient. This will be through the geological units with a higher value of hydraulic conductivity. Intuitively to a hydrogeologist this will be the sandstone layers within the MMG, and possibly within any faults present. There are just over half a dozen locations in the Solway region for which hydrogeological data are available regarding the MMG, and a total of only 25 measurements in total. From this meagre source of hydrogeological data Professor Smythe asserts the whole of the MMG is not a suitably impermeable formation. By assuming the hydrogeological properties of the MMG in the Midlands or Cheshire (where more measurements are available) are the same (both in ranges and in distribution) as those in West Cumbria, and thus have the same mean value, he assigns an implied hydraulic conductivity for the MMG of 10^{-6} to 10^{-7} ms^{-1}. Until we

understand better the variability of the geological units that make up the MMG, thier respective hydrogeological parameters and the distribution and hydrogeological properties of any faulting or jointing, for example, we can only speculate on the hydraulic conductivity of the MMG as it affects its potential as a suitable host rock lithology.

4 The MMG is cut by faults which can provide higher flow pathways. However, much depends on the nature of material infilling these faults/fractures/joints. Not all faults act as high hydraulic conductivity pathways. I don't believe there is a detailed hydrological study of these faults available to make this interpretation.

5 I assume Professor Smythe means that, as the MMG is generally red in colour due to the iron being in an oxidised state, this implies an oxidising environment. This is not true. The deposits were laid down in an oxidising environment but also contain grey reduced patches (known as reduction haloes, frequently containing a carbonaceous core). The interstitial groundwater at depths in excess of 500m (the proposed minimum depth for any potential repository facility) will be reducing as any oxygen from recharging groundwater will be consumed through biogeochemical reactions. It will also most likely be saline. Again, this is not based on any measurements to confirm the geochemical characteristics of the deep groundwater. My PhD studies on radionuclide mobility in reduction haloes within red-beds from both Switzerland and the UK indicated radionuclide transport in these reduction haloes of the order of a few centimetres maximum over time periods of around 1 to 2 million years (Refs. 5 and 6). Thus the international requirement for a geological setting to inhibit movement of radionuclides could be achieved within the MMG, subject to further research and confirmation of these characteristics.

Patrick (Ref. 7) states the Stanwix Shales are similar to the St Bees and Eden Shales and form confining aquiclude over the Kirklington Sandstone. Limited water movement will probably occur within them, as in the St Bees Shales, but faulting is never sufficiently intense to provide a breach.

Professor Smythe suggests the most recent BGS review of the geology of the Solway Basin, based on numerous and recent lines of evidence (including more than 40 years worth oil industry data) already provides "a proper evaluation" of the Solway Basin. This opinion is not shared by BGS. It is also worth mentioning that following 40 years of exploration there are no oil/gas production fields identified in this area and thus it was not excluded by the BGS on the grounds of intrusion risk.

Regarding the Eskdale Granite, Professor Smythe states:

1. The Eskdale Granite is "clearly" heavily faulted and fractured, in contrast to "normal" granite bodies
2. The Eskdale Granite will contain "extremely high permeability" zones, in the same way as the Weardale Granite, as a consequence of the present day stress field (and attributing this to my colleague Dr F W Smith)
3. There is strong evidence for oxidising groundwater flow, both in the past and today

There is no clear evidence that the Eskdale Granite is as heavily faulted as Professor Smythe states. His statement is based on the *assumption* that this pre-orogenic intrusion will be as heavily faulted as the sediments to the east, despite a lack of exposure or any other scientific evidence to confirm or even support these assumptions. This may prove to be the case, but without further work on the acknowleded 80% of the intrusion that is unexposed, this "evidence" remains an unproven assumption. High permeability zones were reported on in the Weardale Granite, and commented on by my colleague Dr F W Smith. The high permeability zones he attributes to a lack of infilling of hydrothermal fractures during mineralisation in a known vein fissure, and **NOT** to the present day stress field as claimed by Professor Smythe.

The "strong" evidence presented to support the argument that groundwater in the Eskdale Granite is oxidising, namely the speculative statement by the BGS that elevated uranium in stream sediments over the outcrop of the Eskdale Granite is from scavaging (although it should be noted not necessarily from the Eskdale Granite itself which is low in uranium), is **NOT** "strong" evidence. The presence of haematite mineralisation does not indicate the presence of modern day oxidising groundwaters at depths of up to 1km within the Eskdale Granite. At a depth in excess of 500m it is highly unlikely that potable, oxidising groundwaters will be present in the Eskdale Granite.

Based on the above, I would re-iterate my earlier statement that I feel it is more Professor Smythe's personal opinion, and not the opinion of the wider geological community, that the entire MRWS Partnership area is geologically unsuitable, and should not progress to the next stage of the current evaluation process to identify a potentially suitable radioactive waste repository site in the UK. On this basis I believe it does not raise any issues that should lead the Partnership to alter its initial opinions as expressed in the Geology chapter of the draft Consultation Document.

Yours faithfully

On behalf of FWS Consultants.

Dr J P L DEARLOVE
PRINCIPAL CONSULTANT

DR F W SMITH
DIRECTOR

REFERENCES

1 Smythe, 2011. Response from Professor Smythe to FWS Consultants. 16 September 2011.

2 Smythe, 2011. Letter from Professor Smythe regarding the unsuitability of the Eskdale Granite. 6 October 2011.

3 West Cumbria MRWS Partnership, 2011. Geological disposal of radioactive waste in West Cumbria? Public consultation document. November 2011 to March 2012.

4 Smythe, 2011. Why a deep nuclear waste repository should not be sited in Cumbria: a geological review. 12 April 2011.

5 Dearlove, 1989. Analogue studies in natural rock systems: Uranium Series radionuclide and REE distribution and transport. Unpublished.

6 Ivanovich, Dearlove and Lever, 1886. Uranium series disequilibrium profiles from reduction haloes in Permian red-beds of Northern Switzerland. Harwell Industrial Report AERE-G 4194.
7 Patrick, 1978. Hydrogeology *in* The Geology of the Lake District Edited by F. Moseley. Yorks. Geol. Soc. Occasional Publication No. 3.