To Björn Dverstorp, SSM, for the NEA review team of experts, IRT

At the IRT presentation of "status of review" on Friday the 16 of December, I posed a question.

I have a question with respect to what you said about *"What can happen if anything goes wrong"* and *"the treatment of uncertainties",* because in your review you only talked about the material presented by SKB. So my question is:
What do you do with material that opposes and contradicts the statement given by SKB?
In science, we may have different opinions and interpretations. Observational facts that have been repeatedly published in peer-reviewed international journals can, in my opinion, not be neglected: they have to be considered.
SKB has taken as a rule, it seems, to neglect material that does not fit their scenarios. They have even said *"SKB does not need to consider extreme ideas"*. What I am talking about is by no means "extreme ideas", rather boundary science.

- **all the key sites have been visited by over 100 international experts at excursions in 1999, 2008, 2008 and 2011.**
- **our findings have been presented in 38 peer reviewed paper in international journals (plus a number of additional papers); 26 of them in the last 20 years listed below – can be ordered.**
- **our studies have been performed as a team work including several international top-experts.**
- **bedrock deformation, sediment deformation and magnetic characteristics of liquefaction have been covered by 3 Ph.D. projects at the department of Paleogeophysics & Geodynamics at Stockholm University (which I headed 1991-2005).**
- **my monograph "Paleoseismicity of Sweden – a novel paradigm (2003) describes 54 paleoseismic events in details (today we have a documentation of 59 events) – can be ordered (via SSM).**
- **the methodology of "multiple criteria" was recently described in Quaternary Research (vol. 242, 2011, p. 65-75).**

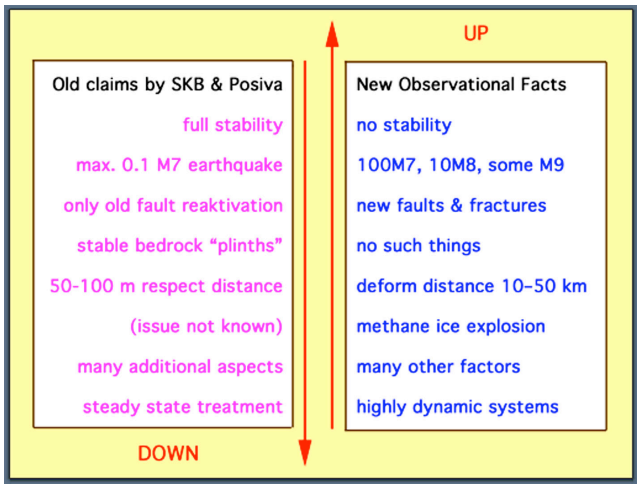
To ignore all this is neither acceptable nor scientifically ethical. Still, this is just what SKB has done despite the fact that we have called attention to it in review after review through the years.

The main questions were presented in a letter of December 10, attached below. Today, I add some problems with respect to the method used and the place chose + a reference list of the last 20 years.

Till SSM:s Internationella Expertgranskningsgrupp

Geological, Geodynamic & Paleoseismic considerations

The KBS-3 method proposed for the storage of high-level nuclear waste in the bedrock under "safe" conditions for a minimum time of 100,000 years was proposed and in the 1970s and coined in 1983.
The basic assumption for this was an old concept of an exceptional bedrock stability of the Fennoscandian Shield, and it was firmly stated that this was the basic requirement for the method proposed.
Today, in the light of modern achievements in geology, geodynamics and Paleoseismology, this stability concept fundamentally revised.
Therefore, one must talk about a paradigm shift, or an "conceptual fault" as illustrated in the below picture (from *Detta Eviga Avfall*, Mörner, PQR-kultur, 2009).



(1) The Earthquake scenario

SKB (and Posiva) limit their analyses to data from seismology and a few historical events, and make predictions for 100,000 years.
Modern Paleoseismology provides a totally different picture, however. This applies both to magnitudes (up to M >8) and frequency (7 events in 102 varve years).
At present 59 events are recorded, 17 of those were linked to significant tsunami events (of up to 20 m wave height).
Over a time period of 100,000 years, this implies a totally different seismic environment than that proposed by SKB. The difference in energy release is in the order of 10^{12}, which seems to invalidate the proposed "safety" of the KBS-3 concept.

(2) The "respect distance"

SKB claims that the canister can be placed as close at 50–100 m from regional fault-lines and fracture zones. SKB claims that this is the safe "respect distance" they can rely on.
Observational facts violate this proposal in most sites investigated. At the 10,430 BP event in the Stockholm region, a 6-8 m lateral fault was formed 1 km from the primary fault. At the 9663 BP event, strongly fractured bedrock is recorded (some 100 sites) at least up to 40 km from the epicentre.
This implies that there is not bedrock volumes enough for a KBS-3 repository.

(3) New faults

SKB claims that all of the postglacial faults are reactivated pre-existing faults.
Reactivation is an important factor, especially when it concerns the deglacial faults, but there are several observations of new fault both in Sweden and Finland.

(4) Explosive methane venting tectonics

SKB and Posiva do not consider this factor.
Our group have documented and described this novel factor where methane hydrate in the bedrock is explosively transformed into methane gas. This is recorded geochemically in the varved sediments. It is also recorded as violent bedrock tectonization when the ice explosively is transformed into gas. The last event occurred as late as 2000 BP, and it set up a 20 m high tsunami wave.
This factor seems to invalidate all talk about a safe deposition of high-level waste according to the KBS-3 concept.

Finally, because these modern findings have been extensively documented and presented in peer-reviewed scientific articles in well-known international journals, and because they all are fundamental for the risk assessment of the proposed KBS-3 repository at Forsmark, they have to be considered by SKB as well as SSM and "kärnavfallsrådet".

Nils-Axel Mörner, December 10, 2011

The Method chosen and the DRD alternative

In response to the problems reviewed above we have proposed an alternative method, the so-called DRD-method (Dry Rock Deposit). It means that one chose a high bedrock relief and drain a suitable bedrock unit by surrounding it by artificial fracture zones. Those fracture zones serves both as a mode of draining the rock, and as an efficient barrier against seismic deformation. The repository will be effectively closed against unwanted intrusion. The repository will be placed in tunnels at a suitable depth depending upon the bedrock height; 100 to 300 m seems feasible. In a DRD repository the waste will remain accessible for the bad (reparation) as well as for the good (future utilization, destruction or relocation). At the same time as the waste will become safely stored underground, it will provide us freedom of action awaiting future technological innovations.

A DRD-repository can be built in many different ways:
1. **as temporary storage of SFL-type**
2. **as temporary storage of high-level nuclear waste (substituting Clab and NPP storage)**
3. **as a final repository of high-level waste at a place of no glacial effects (e.g. the Ivö region)**

We have over and over again proposed that this alternative should be given money for a detailed presentation of its function, building and design (lastly 2010-03-01 to the Minister of Energy).

The Place chosen and better alternatives

It would be quite remarkable if the best sites for a KBS-3 repository really should be at the two NPP sites at Forsmark and Oskarshamn. Those sites were not chosen because of extra favourable geological conditions, but rather for the municipal acceptance.

One may note and consider that Forsmark lies in a wide shear zone. At least 5 paleoseismic event have been documented in this region. Therefore, it seems (at least for me) reprehensible when SKB claims that the seismic risk for a M 7 event in the next 100,000 years is only 0.1.

In fact, there exists many much more suitable sites in Sweden (as discussed on p. 68, 76-78 in my book *"Detta Evia Avfall",* PQR-kultur 2009). The most interesting alternative site discussed, is the Åsen-Ivå region in southeast Sweden. This region seems to have remained "in the shadow" between the main ice lobes in the Baltic and over SW Sweden during all the Quaternary glacial movements. This is evident from the occurrence of undeformed deltaic beds (sand and clay) directly underlying the Quaternary cover, and leading their origin in the Upper Cretaceous about 80 million years ago (as recorded by pollen, macrofossils and paleomagnetics).

This is just one example of a much more geologically favourable location of a repository. SKB has not even considered those alternatives.

Even more interesting it the fact that this might also be an ideal site for a DRD-repository. A steep bedrock hill rises from the sedimentary plain at +20 m to a crest height of +161 m. Draining a suitable rock unit in this hill by artificial fracture zones would establish excellent conditions for a DRD-repository with a roof of about 150 m bedrock and a deformation potential that seems to be almost zero (judging from the underformed sedimentary beds for 80 million years). This means that one may here even establish conditions allowing us to talk about a final repository, which in our opinion would at least be safer than a KBS-3 repository at Forsmark.

This needs, of course, to be tested, discussed and described in details. We have asked for support to undertake such studies, but been refused to obtain this.

One thing is for sure; there are alternative methods and alternative sites.

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Bold = recommender reading for the IRT members

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