D8.10

EARB third annual project review

DELIVERABLE (D8.10)
Report

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EARB-Report

D6.1 The EARB considers that the report has been revised according to the adjustment and precision of WP6 deliverables, i.e. D6.1 chapter 3: Civil Society (CS) “Initial general observations on the project and scientific input to the overall analysis of the research to be done in the project” has been cancelled. Instead, an “enhanced work plan for CS dissemination efforts for years 2-4” was given.

Herewith, misunderstandings between WP6 participants and EU project management about the CS WP6 have been dispelled.

In **D5.5** “Specification for BEACON WP5: Testing, Verification and validation of models step 3” three experiments with initial and boundary conditions are described in order to allow their modelling. For two experiments the results are given, too, to allow modelers for calibrating their models. For the third experiments, blind predictions are request from the modelers for the experimental results. Such a procedure is a good method to test the developed models. The experimental set-ups are related to bentonite heterogeneity (layers of pellets and blocks) and fit well into the BEACON project. The experimental results show that models should have the capability to include micro and macro pore evolution during saturation in order to describe pellet and block evolution during saturation.

Another result that can be valuable for modelling efforts is that the swelling pressures after saturation are roughly the same whether the water is suppled under the condition of constant pressure or under the condition of constant flowrate, even though the development of pressure during saturation test differs significantly in the two cases.

It is observed in this study that some residue inhomogeneity, like those of the water content and dry density, remains even after what is considered to be full saturation. The EARB wonders if the claim of full saturation can be further substantiated, e.g. by comparing the total amount of water taken up by the sample and the sample’s void volume. If the full saturation is confirmed, this observation is of great importance for assessment of long-term performance of the bentonite barrier in a final repository.

In **D3.2** “Description of the improved constitutive models and their implementation and verification” a summary of model development is given on the individual model level. It is stated that the large diversity of approaches and formulations present at the start of the BEACON project is maintained. Developments follow inner logic of the model development rather than from an explicit need arising from the applications to WP5 cases. This seemed to be a problem (or a no go) to the EARB.

The EARB understand that convergence towards a unique modelling approach is a hard task to pursue since the starting point of each team is different (improvement of already existing constitutive models developed by each team for past applications). An interesting alternative could be the identification (at a certain stage of the project) of the essential features to be considered in a constitutive model to be able to reproduce and predict correctly bentonite transient and long term behavior (e.g. double structure vs single porosity models ?; hysteresis vs single water retention models?, …).

In the double-structure model in Annex B the formulation of water retention curve has been improved. The previous representation gave zero-order continuity of the relation between logarithm of saturation and logarithm of suction. This representation is reformulated to eliminate the discontinuity of the derivative of the curve. The EARB considers that the improvement is ingeniously performed by having eased the numerical difficulty in handling derivative discontinuity while not compromising the essential properties of the retention curve.

It is not clear from the reporting in Annex B how the double-structure model will be implemented to model the homogenization process. For example, will the initial heterogeneity caused by layered pellets and compacted blocks be represented as initial conditions with different initial ratios of the macro part to the micro part in the pellet layer and layer of compacted blocks?

In **D5.1.2** the "synthesis of results from task 5.1" presented. In the synthesis of results it is mentioned that five from nine modelers introduced "some friction" for the modelling of these small scale experiments, where friction might not that important for large scale experiment (lower surface to volume ratios). Generally, it is mentioned that some modeled results are close to the experiments, but "some" is just one or two. In the discussion, the large discrepancy for several parameters is mentioned (water content, dry density, total stress) which is also valid for the calculated duration of the transient phase. Reasons are mentioned as for example, modelers did not use the same assumptions for parameters (friction angle between 7-20 degrees); another difficulty was to associate a saturation state to the friction processes.

In the synthesis it is stressed that the "simple" tests were relevant to repository conditions, that 11 groups participated, that a large variety of different constitutive models have been used, …. However, EARB is wondering why there are still that large differences calculated for these "simple" tests especially that for the most relevant transient phase for repository conditions the largest discrepancies have been calculated. Also the fact that a gap is the most difficult situation to be modelled, and gaps will present at repository conditions for sure, there was no recommendation or common agreement on how to deal with gaps in the modeling.

EARB proposed, if not already done, to investigate in more detail, why there is such a large spreading of the results calculated by the different codes. Did the individual teams do a sensitivity analysis on their model parameters to identify most relevant parameters influencing their calculated results? Are the presented results already "best fits" of the individual model approaches, or a single calculation – we have not seen any parameter variation applied by the same code, although there might some parameters which are not really given (e.g. friction angle)?

It is mentioned that five teams introduced in their models some friction on the lateral boundary, allowing a difference of pressure between the top and the bottom. Actually, Difference of swelling pressure should be predicted if the model consider dry density inhomogeneity between the block and pellets part and then enhanced by introducing wall friction.

Most of the teams fail in predicting transient behavior and final state (fig 5.56) indicating that there is an essential key feature that is not taken into account by most of the models. This feature should be identified (e.g. initial inhomogeneous dry density distribution within the pellets part ?).
What are the needs to improve the predictions in terms of performance assessment?

The «discussions» sections as well as the «synthesis» of the report are discussing the capacity of the models to reproduce the test talking about "the models" as a whole without discussing the added value of the specificities of the models (e.g. the way to couple mechanical and hydraulic processes, the use or not of double structure/porosity mechanical/hydraulic/both, …). It is difficult to conclude from the synthesis what are the fundamental processes that need to be catch by the models to improve the prediction of the hydro-mechanical behaviour of the studied bentonite materials. It is also clear that discrepancies exist between tests and modelling. Are these discrepancies coming from the control of the tests conditions, from the models or both?

Figures 5-56 to 5-65: it is not clear from the figure caption, which tests results are presented. Figure 5-65 is not mentioned in the text.

In **D 4.3** the questions of creep in bentonite could be identified from natural analogue studies, i.e. whether data from natural bentonite deposits (vertical drill core) could be used to draw conclusions about slow mechanical processes (e.g. volumetric creep). Dry density of the core as a function of depth would indicate about a dry density gradient, which would indicate that long term creep is insignificant. Because no vertical drill core could be obtained from companies mining bentonite in Europe data from drill cores available from the Barra project in Spain (Villar et al 1996) were used, although no temporal evolution of dry density had been measured. In addition, data from the FEBEX experiments (18 years duration) were used for comparison, although such an experimental duration was identified as too short for long-term predictions.

It is clear that any data on bentonite dry density distribution and/or evolution are important for the long-term prediction of bentonite behavior (creep). However, as it is always the same with natural analog information, they can be used only as "additional indications", because initial conditions (dry density distribution for example) and perturbations over geological time spans are not known. From the available data from Serrata de Níjar a clear drop in dry density from the depth of around 5 m down to 10 m was observed. This could be seen as evidence that volumetric creep or other slow processes will have a negligible effect on homogenisation of bentonite even over geological timescales. But there are no other measurements from other boreholes available, i.e. no statistics and no identified common "history" (water availability at all depths for the Serrata de Níjar bore core). The conclusion that there is nothing in the data that supports the idea of disappearing density gradients with time in a saturated bentonite is supported just by single borehole data. And therefore, the pessimistic assumption will be that inhomogeneity will remain after barrier saturation and persist in time. Latter indicates that there will not be a full barrier saturation, also on the longer term. Moreover, the importance of predictive tools for mechanical evolution during the saturation process is emphasised because of "only indications” from natural analogs; however, the requested tools should be able to predict the transient phases… So far, there was a focus only on “final states” of experiments.

Concluding on the negligible effect of any long term mechanism on bentonite homogenization is not straightforward since the very initial state is not known.

Although, there is no safety requirements about complete homogenization of bentonite; the remaining dry density gradients and the induced differences in hydraulic conductivity should be considered in the evaluation of long term performance of bentonite barriers.

It is not clear in the report if the effect of samples unloading during dismantling and testing preparation was taken into account.

Table 1 comment on the saturation value at depth 10.8m should be added.

Background section: what NMR denotes for?

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ATTACHMENT 1

Response message to the Expert Advisory and Review Board, EARB, regarding comments in the third EARB report D8.10 with the title *EARB third annual project review report*, produced after the 3rd Annual Meeting of Beacon, M36

EARB: Frédéric Bernier (FANC), Jinsong Liu (SSM), Nadia Mokni (IRSN), Wilfried Pfingsten (PSI) and Klaus-Jürgen Röhlig (TU)

Respondents: Antonio Gens (UPC)(WP3), David Masin (CU), Klaus Wiezorek (GRS)(WP4), Jean Talandier (Andra)(WP5), Mary Westermark (MW)(WP8)(Coordinator)

The deliverables analysed in D8.X are:

- D6.1 Scoping the Beacon project
- D4.2 Creep in bentonite – a natural analogue
- D3.2 Description of improved constitutive models and their implementation and verification
- D5.5 (D5.3.1) Specifications of predictive test cases from task 5.3
- D5.2 (D5.1.2) Synthesis of the results obtained of test cases from task 5.1

No	EARB comment	Response
D6.1 Scoping the Beacon project		
1	D6.1 The EARB considers that the report has been revised according to the adjustment and precision of WP6 deliverables, i.e. D6.1 chapter 3: Civil Society (CS) "Initial general observations on the project and scientific input to the overall analysis of the research to be done in the project" has been cancelled. Instead, an "enhanced work plan for CS dissemination efforts for years 2-4" was given. Herewith, misunderstandings between WP6 participants and EU project management about the CS WP6 have been dispelled.	Johan Swahn (WP6 leader) and Mary Westermark (Coordinator): The amendment was not caused any misunderstanding between the project management and the WP6 participants, and no misunderstandings between these parts was perceived. The amendment was initiated and required by the Project Officer on behalf of the Commission. The change required was that the work programme of WP6 was not to be civil society interaction but only a dissemination effort to civil society.
D3.2 Description of improved constitutive models and their implementation and verification		
2	A summary of model development is given on the individual model level. It is stated that the large diversity of approaches and formulations present at the start of the BEACON project is maintained. Developments follow inner logic of the model	Antonio Gens (WP3): It is understandable that the statement has given rise to some disquiet in the members of the EARB because it does require some qualification. The statement does not say that that the modelling teams have ignored the results of the analyses performed in WP5. However, at the time of writing the contributions to

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	development rather than from an explicit need arising from the applications to WP5 cases. This seemed to be a problem (or a no go) to the EARB.	Deliverable 3.2 by the individual teams, only analyses within the first WP5 Step had been accomplished. As noted in the WP5 Deliverable 5.1.2, there were no glaring discrepancies between calculations and experimental results that required a complete overhaul of a particular model or models. Although differences between laboratory observations and computed results were certainly identified, they indicated more the need of a modification and/or adaptation of the model rather than its abandonment in favour of a radically new approach. In addition, as indicated by the Features Tables of Deliverable 3.1, most of the anticipated relevant characteristics of bentonite behaviour were already in place for most constitutive models. In this context, therefore, it is not surprising that development has been guided by the inner logic of model development. The EARB can rest assured that attention is paid and will be paid to the performance of the models in relation to experimental results throughout the project.
3	The EARB understand that convergence towards a unique modelling approach is a hard task to pursue since the starting point of each team is different (improvement of already existing constitutive models developed by each team for past applications). An interesting alternative could be the identification (at a certain stage of the project) of the essential features to be considered in a constitutive model to be able to reproduce and predict correctly bentonite transient and long term behaviour (e.g. double structure vs single porosity models ?; hysteresis vs single water retention models?, …).	This is an important issue that requires a careful consideration. Obviously, a model is always an approximation to reality and no model will ever exist that will reproduce precisely each and every one of the features of the mechanical behaviour of the bentonite; it would be too complex even if its development was feasible. It is also doubtful that there will be a single constitutive model that outstrips the others so much that it is the only one worthy of attention. In fact, it is far more likely that different modelling approaches may be quite appropriate to represent a particular instance of mechanical behaviour. A good example of this model variety is the existence of elastoplastic and hypoplastic formulations (both represented in the project) that have already proved quite suitable for reproducing many of the features of the mechanical behaviour of the bentonite. There is no compelling reason, at present, to prefer one approach to the other. In this context, the project is not aimed to reach a unique modelling approach. In fact, it is probably not even desirable. It is thought better to try to preserve a variety of approaches (a kind of genetic diversity) if a range of models are able to provide adequate representations of the observed mechanical and hydromechanical behaviour of the bentonite. In that way, we are better placed to address new observations and phenomena that may arise in the future. Only models that provide unreasonable outcomes and cannot be fittingly improved should be discarded and replaced. Another consideration is the fact that models that simulate successfully a particular experiment or sets of experiments may display quite different degrees of complexity. For instance, the Febex in-situ test has been successfully reproduced using both single

		and double porosity models. In that case, it seems reasonable to apply Einstein's overused (and probably inexact) quotation that we should use a model as simple as possible but not simpler. This is potentially another argument to preserve a range of suitable models. The identification of the essential features to be considered in a constitutive law to be able to reproduce and predict correctly bentonite transient and long-term behaviour is indeed a worthy goal, although it is likely to be case-dependent. The analyses of the modelling exercises of WP5 Steps 1, 2 and 3 as well as of Task 3.3 of WP3 should provide useful additional information in this respect that should constitute a significant outcome of the project. It should be stated, however, that it is unlikely that this issue can be completely settled over the lifetime of the project. This is a major undertaking and it will probably require a sustained effort over a longer period. After all, Beacon is only the first European project devoted specifically to the study and modelling of the mechanical behaviour of the bentonite. The likely requirement for further work underlay the idea of proposing a Beacon II project.
4	In the double-structure model in Annex B the formulation of water retention curve has been improved. The previous representation gave zero-order continuity of the relation between logarithm of saturation and logarithm of suction. This representation is reformulated to eliminate the discontinuity of the derivative of the curve. The EARB considers that the improvement is ingeniously performed by having eased the numerical difficulty in handling derivative discontinuity while not compromising the essential properties of the retention curve.	David Masin, CU: Thank you for your positive comment
5	It is not clear from the reporting in Annex B how the double-structure model will be implemented to model the homogenization process. For example, will the initial heterogeneity caused by layered pellets and compacted blocks be represented as initial conditions with different initial ratios of the macro part to the micro part in the pellet layer and layer of compacted blocks?	David Masin, CU: Essential state variables considered in the double-structure hypoplastic models are micro- and macro-void ratios with different initial proportions of the macro part to the micro part in the pellets and in the compacted blocks. Their relationship controls the overall swelling characteristics predicted by the model, such that for high macro-void ratios most of the swelling takes place internally (aggregates swelling into macropores), whereas for low macro-void ratios aggregate swelling imposes global swelling of the sample. A typical application of the model for predicting bentonite homogenization is the situation when two bentonite domains at different dry densities are in contact with each other. The model then predicts overall swelling of the high dry density (low macrovoid ratio) domain, which applies pressures

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		onto the low dry density (high macrovoid ratio) domain. These pressures impose compaction of the low dry density domain, such that void ratios of the two domains tend to equilibrate. In a similar way, the model can be used for predicting homogenization of block bentonite sample in contact with bentonite powder (filling technological voids) or in contact with pellet sample adopted to fill other part of the simulated geometry. It is to be said that convergence issues have been identified when simulating bentonite powder due to extremely high void ratios, for which the model has not originally been developed. Also, the model has to a certain degree limited accuracy for pellet sample due to its double-structure nature (pellets actually represent triple-structure system).
D5.5 (D5.3.1) Specifications of predictive test cases from task 5.3		
6	For the EARB it is clear from the experimental results that models should have the capability to include micro and macro pore evolution during saturation in order to describe pellet and block evolution during saturation.	We agree that the proposed method will really be relevant to test the models with a first step of calibration and a second step of blind prediction. It will also highlight how the models deal with micro/macro pore evolutions due to the initial differences of the material structure.
7	To EARB considers it potentially valuable for modelling efforts that the experimental results on swelling pressures after saturation are roughly the same whether the water is suppled under the condition of constant pressure or under the condition of constant flowrate, even though the development of pressure during saturation test differs significantly in the two cases. It is observed in this study, that some residue inhomogeneity, like those of the water content and dry density, remains even after what is considered to be full saturation. The EARB wonders if the claim of full saturation can be further substantiated, e.g. by comparing the total amount of water taken up by the sample and the sample's void volume. If the full saturation is confirmed, this would be of great importance for assessment of long-term performance of the bentonite barrier in a final repository.	One of the main issues of the Beacon project is to evaluate if the heterogeneities due to several origins (initial heterogeneities at the installation of the material, distribution of flow leading to local hydration or stress path) observed in the bentonite will persist after full saturation. In some experimental tests, it seems that even if the sample does not take water anymore and the mechanical deformation are stable, some heterogeneities persist in the bentonite plug. Comparison between the water taken up by the sample and estimations of the initial voids are done if possible and will be done here. It seems that at the time scale of observation, heterogeneities can't be avoided in the swelling clay. Concerning the link with long-term performance assessment, it has been observed that even if the material is not totally homogeneous, the specification expected are reached. For example, low water permeability or a swelling capacity. One question that should be investigated but which is not the purpose of this set of tests, is the long term evolution of the bentonite and the possibility of slow changes that could go in direction of a better homogenization.
D5.2 (D5.1.2) Synthesis of the results obtained of test cases from task 5.1		
8	In D5.1.2 the "synthesis of results from task 5.1" presented. In the synthesis of results it is mentioned that five from nine modelers introduced "some friction" for the modelling of these small scale experiments, where friction might not that important	The aim of the first set of tests was to confront the models developed or used by the different partners involved in the project to simple tests introducing in some ways heterogeneities in the bentonite. The idea was not to ask for the best fit of the experimental data, adjusting the numerous parameters of these coupling models but to assess the capacity of the tools to tackle the difficulties introduced by these tests. Consequently, this was to try to identify by each

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	for large scale experiment (lower surface to volume ratios). Generally, it is mentioned that some modeled results are close to the experiments, but "some" is just one or two. In the discussion, the large discrepancy for several parameters is mentioned (water content, dry density, total stress) which is also valid for the calculated duration of the transient phase. Reasons are mentioned as for example, modelers did not use the same assumptions for parameters (friction angle between 7-20 degrees); another difficulty was to associate a saturation state to the friction processes. In the synthesis it is stressed that the "simple" tests were relevant to repository conditions, that 11 groups participated, that a large variety of different constitutive models have been used, …. However, EARB is wondering why there are still that large differences calculated for these "simple" tests especially that for the most relevant transient phase for repository conditions the largest discrepancies have been calculated. Also the fact that a gap is the most difficult situation to be modelled, and gaps will present at repository conditions for sure, there was no recommendation or common agreement on how to deal with gaps in the modeling. EARB proposed, if not already done, to investigate in more detail, why there is such a large spreading of the results calculated by the different codes. Did the individual teams do a sensitivity analysis on their model parameters to identify most relevant parameters influencing their calculated results? Are the presented results already "best fits" of the individual model approaches, or a single calculation – we have not seen any parameter variation applied by the same code, although there might some parameters which are not really given (e.g. friction angle)?	partners where to improve the models in link with the activities conducted in WP3. Of course, some adjustments on parameters have been done by the modelers to be consistent with what it is needed by their models. On some parameters such as fiction at cell wall, there is a large uncertainty. Some partners made sensitivity analysis to see the role of these parameters on the results. See for example Figure 5 43 from ULG where different situations have been explored from a slipping condition (no friction) and sticking conditions. The second point was to identify where some efforts should be done to acquire some specific parameters in link with WP4. Among the parameters, the interactions between the micro and macro scale were identified as a key aspect of the problem and for some approaches represented in part by the interaction functions. **It has been proposed and accepted** by the partners that some tests from the task5.1 will be rerun at the end of the project to highlight the progress made. This step will be very interesting and instructive. Improvements in the models will be traced in the reports produced in WP3.
9	It is mentioned that five teams introduced in their models some friction on the lateral boundary, allowing a difference of pressure between the top and the bottom. Actually, Difference	The tests prepared in task 5.1 a large discrepancy of the results especially when a gap is included in the cell (test1a and test1b) or if there is a large difference of density has been introduced as an initial condition (test1c with a compacted block ~1.8g/cm3 compared to the pellets density about 0.9g/cm3). Those tests are interesting as underlined by EARB due to the

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	of swelling pressure should be predicted if the model consider dry density inhomogeneity between the block and pellets part and then enhanced by introducing wall friction. Most of the teams fail in predicting transient behaviour and final state (fig 5.56) indicating that there is an essential key feature that is not taken into account by most of the models. This feature should be identified (e.g. initial inhomogeneous dry density distribution within the pellets part ?). What are the needs to improve the predictions in terms of performance assessment?	fact that in repository context, this situation is likely to happen. An analysis of the physical processes shows that the two situations are quite similar with a significant rearrangement of bentonite microstructure during hydration. This point out where a part of the future effort should be focus to better handle this kind of situation and improve the predictions. In other hand, the results showed that when low level of heterogeneity is introduced in the system (first part of test1a and test 1b), the results obtained with the models are less spread out. On configurations that are more "conventional" (close to classical swelling tests), most of the models are able to give a good approximation of the observations which reveals that most of them integrate the main physical processes. Especially, the double structure approach retained by a majority of the partners, gives a good representation of the bentonite behavior during hydration.
10	The EARB considers that the «discussions» and «synthesis» sections of the report are discussing the capacity of the models to reproduce the test talking about "the models" as a whole without discussing the added value of the specificities of the models (e.g. the way to couple mechanical and hydraulic processes, the use or not of double structure/porosity mechanical/hydraulic/both, …). It is difficult to conclude from the synthesis what are the fundamental processes that need to be catch by the models to improve the prediction of the hydro-mechanical behaviour of the studied bentonite materials. It is also clear that discrepancies exist between tests and modelling. Are these discrepancies coming from the control of the tests conditions, from the models or both?	Certainly, in the discussion sections and in the synthesis part of the report, a better identification of how to improve the models in terms of fundamental processes and specificities of the models should have been added. The main difficulty is that this kind of element should be provided by the partners themselves and it was not asked at this stage. For the next tasks of WP5, this has been asked to partners and this kind of information will be included in the next synthesis reports and the discussion will be then improve in that way. Concerning the discrepancies between the models and the experimental results, a part is certainly coming from the models themselves, but another part is due to the experimental uncertainties. It is of course difficult to evaluate where it is coming from. In task 5.3, the repetition of the tests should bring some elements
11	Figures 5-56 to 5-65: it is not clear from the figure caption, which tests results are presented. Figure 5-65 is not mentioned in the text.	Figures 5-56 to 5-65 concern the test 1c.
D4.2 Natural Analogue		
	In D 4.2 the questions of creep in bentonite could be identified from natural analogue studies, i.e. whether data from natural bentonite deposits (vertical drill core) could be used to draw conclusions about slow mechanical processes (e.g. volumetric creep). Dry density of the core as a function of depth would indicate about a dry density gradient, which would indicate that long term creep is insignificant. Because no vertical drill core could be obtained from companies mining bentonite in Europe data from drill cores available from the Barra project in Spain (Villar et al 1996) were used, although no	

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	temporal evolution of dry density had been measured. In addition, data from the FEBEX experiments (18 years duration) were used for comparison, although such an experimental duration was identified as too short for long-term predictions.	
12	It is clear that any data on bentonite dry density distribution and/or evolution are important for the long-term prediction of bentonite behaviour. However, as it is always the same with natural analogue information, they can be used only as “additional indications”, because initial conditions (dry density distribution for example) and perturbations over geological time spans are not known.	In this particular case, a natural analogue could actually be used more than for “additional indications”. A slow long term homogenization would in general be a positive effect for repository performance. If studies of natural systems show remaining inhomogeneities, this would be a strong support to neglect these processes in safety assessments.
13	From the available data from Serrata de Níjar a clear drop in dry density from the depth of around 5 m down to 10 m was observed. This could be seen as evidence that volumetric creep or other slow processes will have a negligible effect on homogenisation of bentonite even over geological timescales. But there are no other measurements from other boreholes available, i.e. no statistics and no identified common “history” (water availability at all depths for the Serrata de Níjar bore core). The conclusion that there is nothing in the data that supports the idea of disappearing density gradients with time in a saturated bentonite is supported just by single borehole data. And therefore, the pessimistic assumption will be that inhomogeneity will remain after barrier saturation and persist in time. Latter indicates that there will not be a full barrier saturation, also on the longer term. Moreover, the importance of predictive tools for mechanical evolution during the saturation process is emphasised because of “only indications” from natural analogues; however, the requested tools should be able to predict the transient phases… So far, there was a focus only on “final states” of experiments.	It is true that it is a clear disadvantage that relevant data only is available from one single borehole. Borehole data from different locations is desirable to get better statistics on the involved processes.
14	Concluding on the negligible effect of any long term mechanism on bentonite homogenization is not straightforward since the very initial state is not known.	It is clear that there is a remaining dry density gradient in this particular borehole. Therefore, the initial conditions are of minor importance. This shows that homogenization is a very slow process under all circumstances. The statement above would however have been very relevant if no dry density gradient was found.
15	Although, there is no safety requirements about complete homogenization of bentonite; the remaining dry density	In the 1996 report about the boreholes drilling that I mentioned it is said that the cores were longitudinally cut just after extraction from the drilling tube. Only half of each

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	gradients and the induced differences in hydraulic conductivity should be considered in the evaluation of long term performance of bentonite barriers. It is not clear in the report if the effect of samples unloading during dismantling and testing preparation was taken into account.	sample core was taken and placed inside a PVC tube of diameter 72x75 mm. The lids of this tube were sealed with paraffin. So, I'd say that, while water content was very likely well preserved (the process was performed quickly with the aim of preserving water content), dry density changes cannot be ruled out, both during drilling and extraction of the cores and during storage. These changes would depend on plasticity, density and degree of saturation of the samples and also the storage time, so their assessment is not straightforward. Below is a picture of the cores where you can see at the bottom a half-sectioned core. The half missing would be the one taken to CIEMAT in the sealed PVC tubes.
		
		Response to 15 continued

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		If dry density had changed during storage (the samples were inside a PVC tube which could avoid evaporation, but not further stress release), it could be expected that the longer the storage time, the higher the relaxation and hence the lower the measured dry density (although stress release would be instantaneous, I do not think it keeps going on forever). The samples from borehole 2 were opened in the lab for dry density and water content determinations at different moments, as you can see in the report from which the dry densities and water contents were taken. Sample 1 (3.2 m depth) was sampled after 6 months, whereas sample 4 (11 m depth) was sampled after 12 months. The dry density of sample 4, sampled after longer, is the lowest. However, sample 2 (m. 5) which was sampled only a month before sample 4, has a density which is considerably higher than that of sample 4 and closer to sample 1. Hence, I cannot see a clear relation between sampling time and dry density decrease. This might be a reason against significant unloading effect (at least during storage). Concerning the degrees of saturation in Table 1, they would be higher for all the samples if some dry density decrease took place (which overall is very likely). Summarizing, unloading would probably decrease dry density, and hence the degrees of saturation computed would be lower than the actual ones. Nevertheless, the unloading effect should be more or less instantaneous and affect similarly all the samples.
16	Table 1 comment on the saturation value at depth 10.8m should be added.	±2 % is a normal precision in estimates of degree of saturation in bentonite. In this case the mineralogy may be slightly different at different depth, which means that the assumption of a constant particle density may be somewhat incorrect.
17	Background section: what NMR denotes for?	This was changed in the report to X-ray to be more consistent with the other work in WP4.