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DEVELOPMENT OF COMPREHENSIVE TECHNIQUES FOR COASTAL SITE CHARACTERISATION: INTEGRATED PALAEOHYDROGEOLOGICAL APPROACH FOR DEVELOPMENT OF SITE EVOLUTION MODELS

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ABSTRACT

Radioactive waste repository designs consist of multiple safety barriers which include the waste form, the canister, the engineered barriers and the geosphere. It is widely considered that the three most important safety features provided by the geosphere are mechanical stability, favourable geochemical conditions and low groundwater flux. To guarantee that a repository site will provide such conditions for timescales of relevance to the safety assessment, any repository site characterisation has to not only define whether these features will function appropriately today, but also to assess if they will remain adequate up to several thousand to hundreds of thousand years into the future, depending on the repository type.

The case study described here is focussed on the palaeohydrogeology of the coastal area around Horonobe in northern Hokkaido, Japan. Data from JAEA's ongoing underground research laboratory project is being synthesised in a Site Descriptive Model (SDM) with new information from the collaborating research institutes to develop a Site Evolution Model (SEM), with the focus very much on changes in the Sea of Japan seaboard over the last few million years. This new conceptual model will then be used to assess the palaeohydrological evolution of the deep geosphere of coastal sites of Japan.

INTRODUCTION

Radioactive waste repository designs consist of multiple safety barriers which include the waste form, the canister, the engineered barriers and the geosphere. In many waste programmes, it is considered that the three most important safety features provided by the geosphere are mechanical stability, favourable geochemical conditions and low groundwater flux [1]. To guarantee that a repository site will provide such conditions for the timescales of relevance to a safety assessment, any repository site characterisation has to not only define if these features will function appropriately today, but also to assess if they will remain adequate up to several thousand to hundreds of thousand years into the future, depending on the repository type [1].

In general, this is done by studying the palaeohydrogeological evolution of a site, defining temporal (and spatial) changes of various characteristics and processes [2]. These may include hydrogeology, geology, groundwater flow characteristics, groundwater chemistry and site tectonics, including uplift and erosion processes [3]. These key aspects are studied to build up a conceptual model for the overall site evolution over geological time, up to the present and this is used to define plausible future evolutions of the site and to assess if the main safety features will continue to function adequately.

The collaborative programme described here is focussed on the palaeohydrogeology of the coastal area around Horonobe in northern Hokkaido, Japan. Data from the Horonobe Underground Research Laboratory (URL) Project [4] is being synthesised in a Site Descriptive Model with new information from the Coastal Field Research Programme [4, 5] to develop a conceptual model of the site evolution, with focus very much on changes in the Sea of Japan seaboard over the last few million years. This new conceptual model will then be used to assess the palaeohydrological evolution of other sites on Japan's western seaboard, with the final aim of producing a

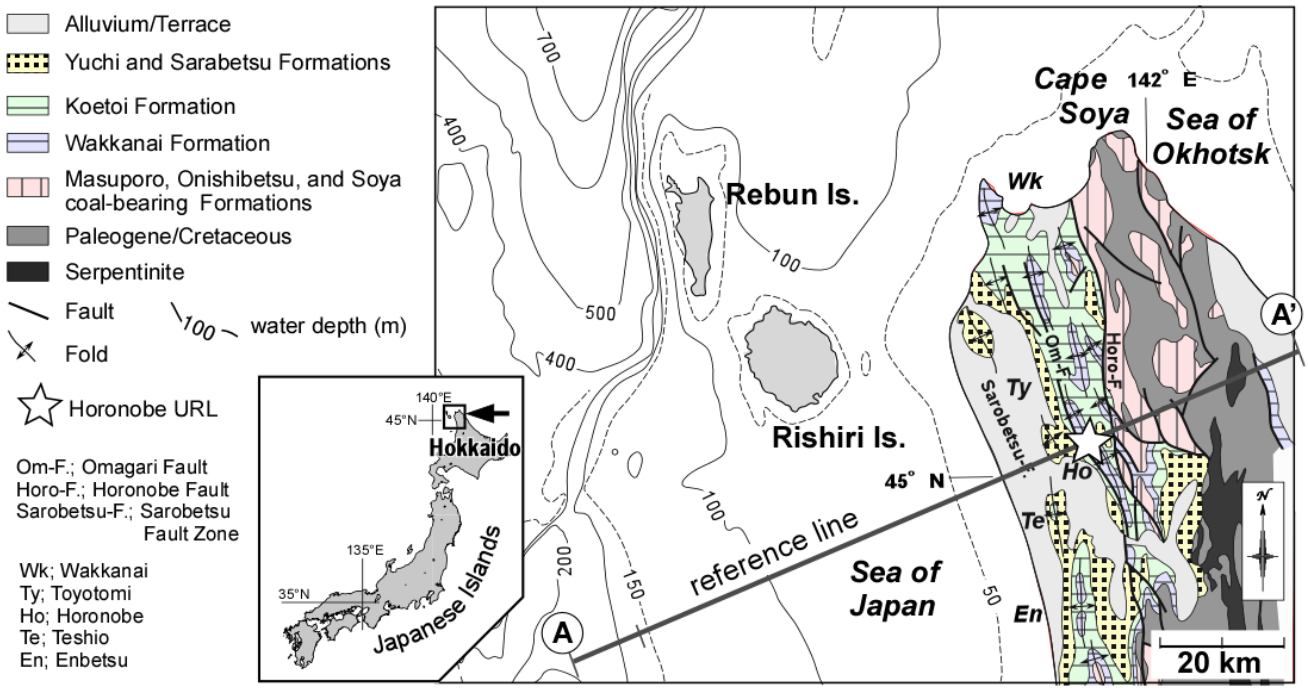

Figure 1. Reference line for construction of the geological evolutional model in the studied area.

regional understanding of the palaeohydrogeological evolution of the deep geosphere of all coastal sites on the Sea of Japan. This integrated understanding could then be used in the site characterisation and risk assessment of any future coastal nuclear facility on the Sea of Japan [6].

IDENTIFICATION OF HYDROGEOLOGICAL AND HYDROCHEMICAL IMPACTS CAUSED BY NATURAL EVENTS AND PROCESSES

The Horonobe area is situated in the northernmost part of Japan, referred to as the Tenpoku Sedimetary Basin. The target formations in terms of mechanical stability and low groundwater flux, the Wakkanai and the Koetoi Formation, have been affected by on-going thrust-fold tectonics (EW compression) constantly since the deposition of these formations [7]. Major tectonic activity refers to regional deformation after the Late Pliocene (ca 2.4Ma) in combination with deposition of the upper formations, i.e. the Yuchi and the Sarabetsu Formations [8]. As the Sarabetsu Formation is lagoonal and embayment sediments in comparison with the Yuchi Formation which is consist of shallow marine sediments [9], this area have been uplifted above the sea-level in part concurrently with deposition of the Sarabetsu formation (ca 1.3Ma). In essence, the sedimentary sequences in the Horonobe area are dominated by Neogene and Quaternary sedimentary rocks that were deformed by simple compressional deformation at shallow-crustal levels, prior to later exhumation to the current level of erosion.

In order to provide the boundary conditions for constructing the geological evolutional models of the Horonobe area, these areas were viewed in a broader geological perspective. For this purpose, attention has been focused on the geological reference line across the Horonobe URL from the eastern coastal boundary to the maximum regression level including some uncertainty (ca 200m) in the western sea area (Figure 1) since the beginning of the dominant tectonic event (i.e. 2.3Ma) to present. Furthermore, we narrowed the geological reference line down to approximately one-fourth which includes the present recharge and discharge areas [4], and shortened period considered to that from the when the site emerged from the sea (i.e. 1.3Ma) to the present for developing the palaeohydrogeological conceptual model reasonably.

Based on the existing information and current geological and geomorphological interpretation described above and those in [9], the most important geological events and groundwater flow processes within the defined time and spatial scale could be further focused on three points as below:

- Uplift and erosion: Based on the existing information [4], there is clear subsiding evidence in the shore area (Sarabetsu Lowland), while the URL area and the middle area (Sarobetsu Anticline) between the shore area and the URL area show uplifting trends (Figure 2). The uplift rate seems to be maintained nearly constant from 1.3 Ma to present, and there is an eastward increase in uplift rates from the middle area towards the URL area. It is therefore of special importance with regard to the hydraulic gradient that could be a driving force for porewater flushing and mixing of meteoric/surface water in the formations above sea level. The existing information indicates erosion rates are concordant with the uplifting rates in this area [4].

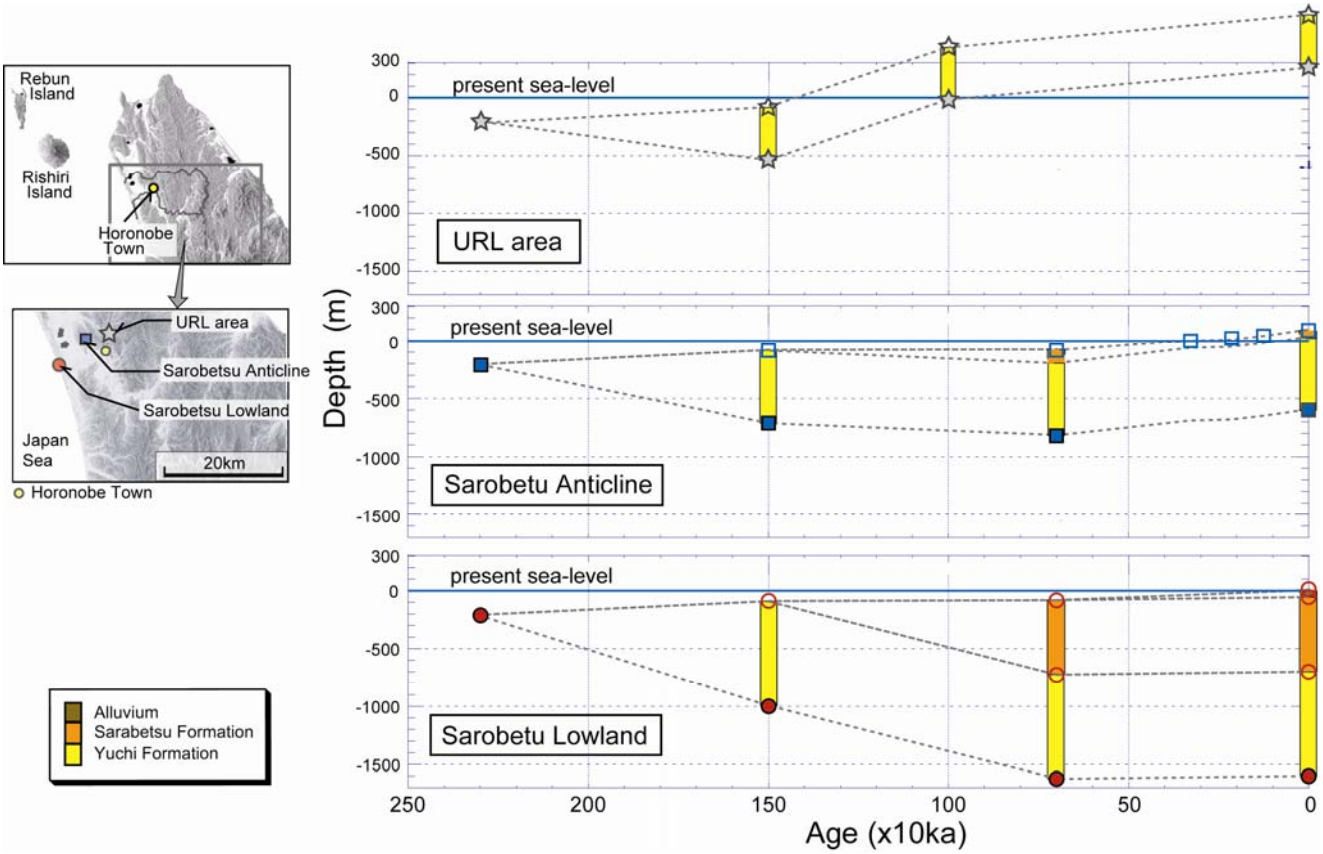

Figure 2. Uplift and subsidence history in the Horhobe area [4].

Erosion rates in the URL area are in the 0.66 to 1.79m/ky range, whereas in the middle area they are 0.21 to 0.86m/ky range [4].

- Sea-level changes: As the inferred sea level has changed periodically from +20 to –150m in comparison with the present sea level [8] on the defined time scale, shoreline displacement could be one of the major groundwater transport processes such as infiltration of the sea water and porewater flushing, particularly in the coastal area and the upper part of the formations. Though the depth of perturbation in each area are uncertain from the existing geological and geophysical data, the effect can be observed in the upper and unconsolidated formations such as the Sarabetsu formation. As the base of the Sarabetsu formation in the coastal area is approximately 700m below the sea-level [4], the one possible hypothesis of lowermost perturbed depth by sea-level changes is 700m below the sea-level. In the URL area, there are no unconsolidated formations and little effect of sea water intrusion and porewater flushing could have occurred above the lowermost sea-level (150m below the present sea-level). The depth from the ground level at the URL is roughly calculated as ca 210m from the current altitude (ca 60m).
- Porosity and permeability changes by tectonic fracturing and faulting: Since there is no big difference in the sedimentary regime from area to area before the defined time scale (i.e. 1.3Ma ~ present), the major process to alter porosity and hydraulic property could be tectonic fracturing and faulting due to the E-W compressional tectonics [8]. Since the wave length of the folds becomes much tighter to the east, porosity and permeability in the Koetoi formation and the Wakkanai formation in the URL area could be higher than those in the coastal area and the offshore area in a broader perspective.

CONSTRUCTION OF PALAEOHYDROGEOLOGICAL CONCEPTUAL MODEL

The surface-based investigations have shown that the groundwaters observed in this area have two different types, shallow Na-HCO_3 type and deep Na-Cl type [4], depending on the order of tectonic and shoreline displacement effects in the formations. In the coastal area, shoreline displacement is especially crucial for intrusion of the sea water into the rocks, as well as for the subsequent flushing processes in the upper and unconsolidated formation (i.e. Sarabetsu formation). However, there is a possibility that remnants of earlier and old groundwater can be preserved in localised clay layers of low hydraulic conductivity against natural perturbations over a long period of time.

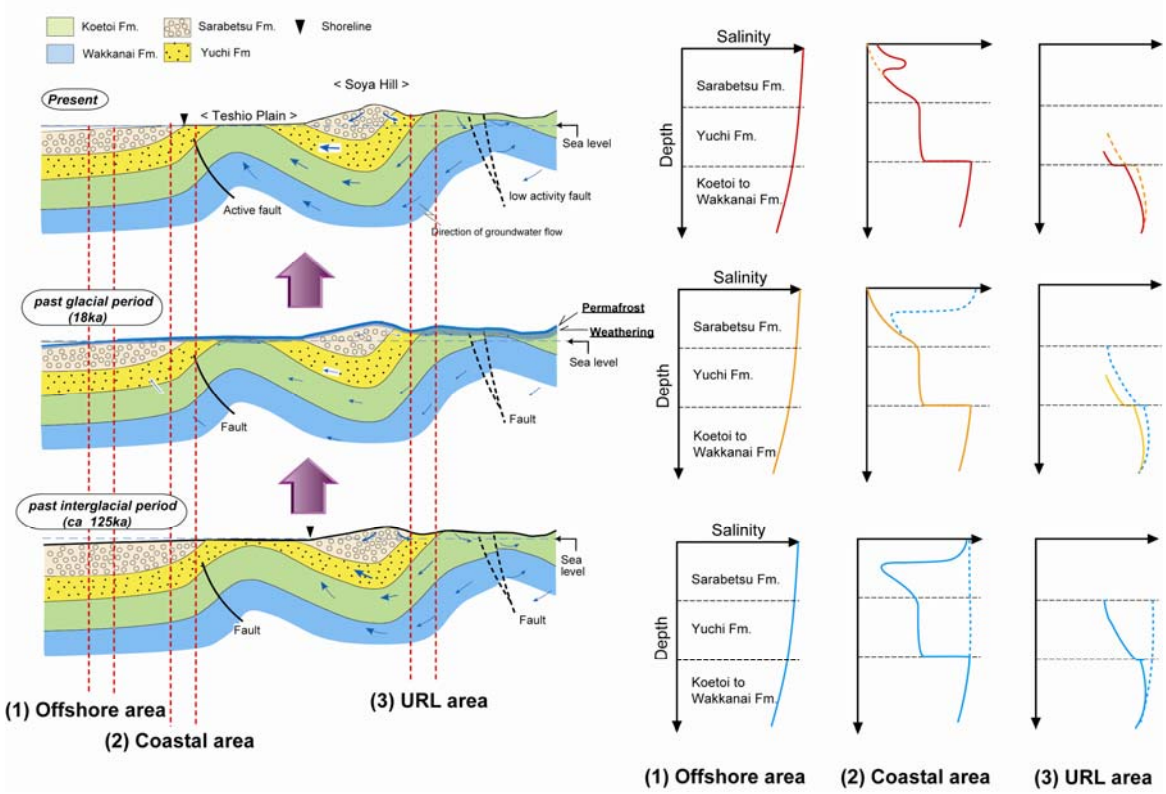

Figure 3. Palaeohydrogeological model in the Horonobe area.

Based on the current results and interpretation described above, a palaeohydrogeological conceptual model in the Horonobe area during the defined time scale, i.e. from 1.3Ma to present, is constructed in Figure 3. The palaeohydrogeological conditions in the area have changed continuously on an area-by-area and, as can be interpreted, the major driving force of groundwater is the shoreline displacement due to sea level changes and land uplift. A coupled geo-evolutional and hydrogeological model [10] is now under development to simulate long-term hydrogeological and hydrochemical conditions and to clarify remained uncertainties by comparison with actual borehole data such as salinity distribution of groundwater.

CONCLUSIONS

From the results of this study, a palaeohydrogeological conceptual model in the coastal area around the Horonobe URL was constructed based on the available existing information. Although this model might be primitive and hence with considerable uncertainty, major hydrogeological and hydrochemical impacts caused by natural events and processes were identified by focusing on a specific temporal and spatial scales. This could be information for putting forward a hypothesis to evaluate long-term geological stability in a realistic way, and to propose effective and efficient strategy of further surface-based investigations such as surface geophysics and borehole layout.

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