

Introduction

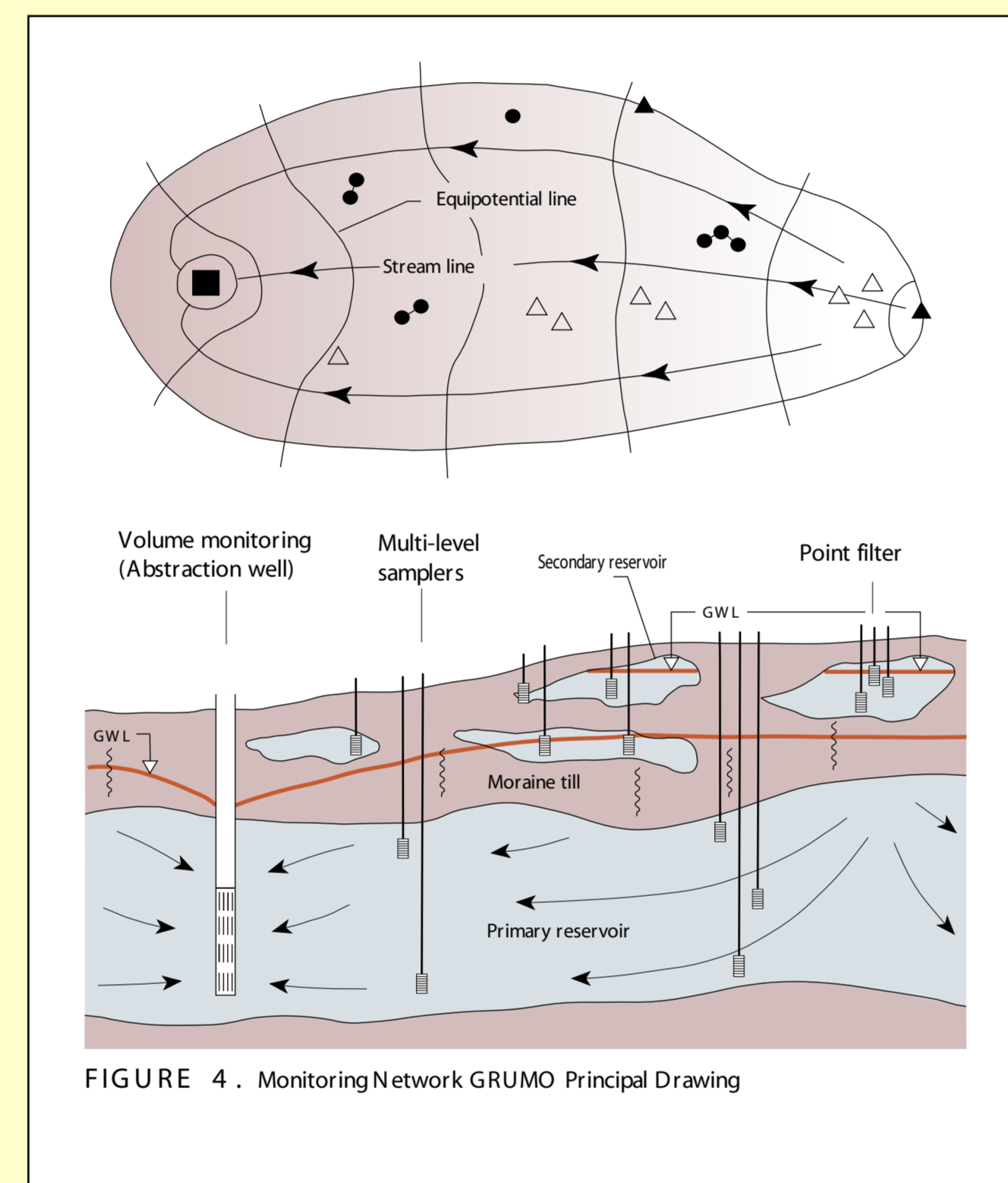
Groundwater monitoring in Denmark is based on information from groundwater monitoring areas (Grumo), agricultural watersheds and water supply wells. Problems arising from intensive land use e.g. pollution from pesticides and nitrates have been increasing during the last 50 years. Understanding groundwater age is thought of as an parameter in understanding the current state of pollution. Eggerslevmagle (Grumo area in a moraine geological environment) in the Eastern part of Denmark has been subject to investigations of travel pathways and age distribution (including residence time) of pesticides.

The residence times in different redox environments have a large impact on the fate of pesticides in aquifers. How important is the detailing and resolution of geological faices? In order to address this question three geological models of different complexity and based on different interpretations are defined and introduced in a 3-D numerical groundwater model in order to predict the spatial distribution of groundwater age.

Measurements of CFC and Tritium as well as redox state have been carried out in all Grumo areas in order to provide age information. The age distribution for an aquifer might be used to explain flow features as mixing ability and protection capability. In classical solute transport theory increasing geological complexity enhance mixing (often accounted for in hydrological modeling by increasing dispersion). In this case study for Eggerslevmagle, the effect of different conceptualizations on calculated age distribution is investigated under natural hydrological conditions.

Grumo Factbox

Continuous measurement of head in 55 filters, some are line monitored (Multi level sampler) and some are point monitored (point filters) (See Figure 4)
Sampling program for 16 filters (12 sampled for CFC and Tritium)
Abstraction 700.000 - 1.000.000 m³/year
Hydrological catchment for Eggerslevmagle 50 km²
The hydrological catchment of model is 300 km²
Well log archive have app. 1000 well logs or app. 3 per km² for model catchment



Geological Complexity and Age Simulation

Three different conceptual models are set up. The basis for defining the three geological models is in all cases an extensive well log archive with typical hydrogeological information.

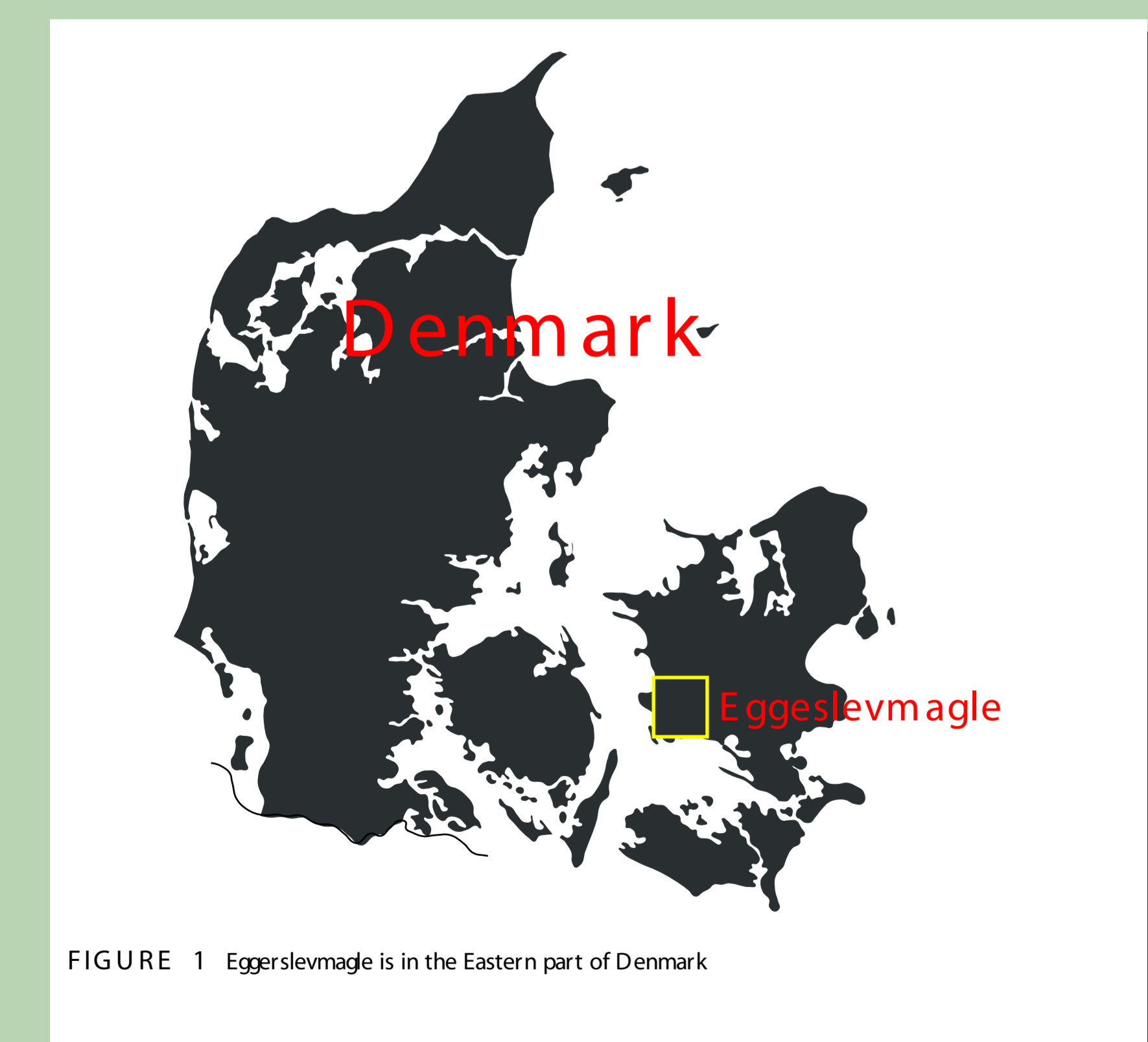
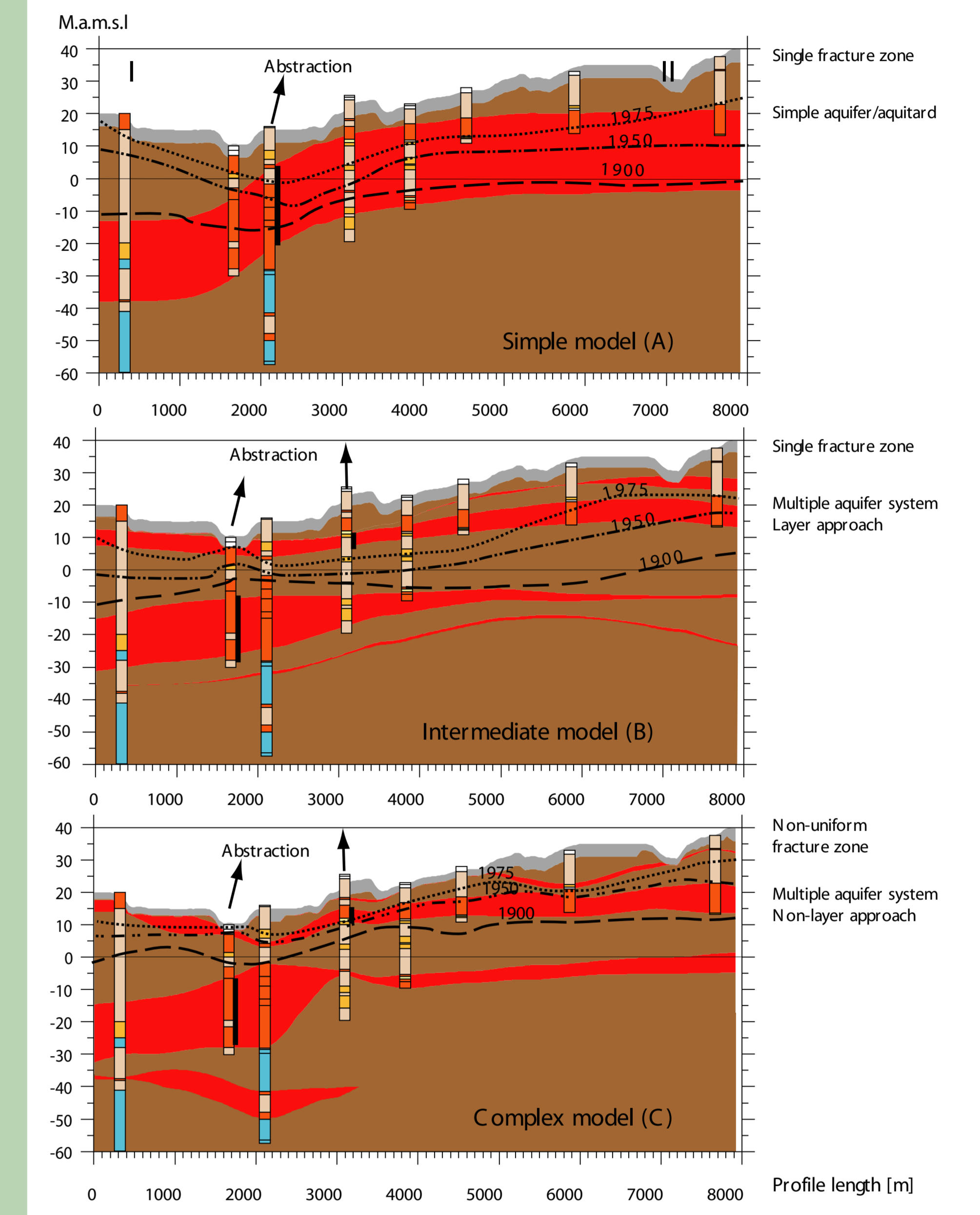
- The "simple" geological representation is an aquitard aquifer model based on simple interpolation of data from the well log archive and using a zonation approach. Conceptually it is assumed that minor sandlenses and different sand layers can be described as one aquifer with uniform thickness (25 meter). This aquifer is covered by a layer of moraine till. The thickness of the moraine till is the depth to the primary aquifer (the upper first aquifer with abstraction filters taken from the Well Log Archive).
- The model of "Intermediate complexity" is a multi-layered aquifer based on regional trends and soft information on depositional history. The top layer of the model is a mixture of moraine till and minor sand lenses lumped together.
- The most "complex" model, the geological interpretation includes identification of different geological facies based on studies of local geomorphologic features. Conceptually it is a multiple aquifer system (sand layers) with an additional minor local aquifer (buried river valley). An important difference between model A. and B is the identification of a secondary flow system situated 5-10 below land surface and zones of fractured till at different depths in the upper moraine till. The zones of fractured till have been identified in a detailed study of redox conditions, fracture intensity and geomorphology (Figure 2).

Uniform parameterization of sand, moraine till and fractured zones was applied for all three models. The transmissivity of the individual layers was assumed to depend solely on layer thickness. Each of the three models was discretized in 250x250 m grid using a finite difference model. Model setups are deterministic in a sense that all parameter zones are defined only by geological.

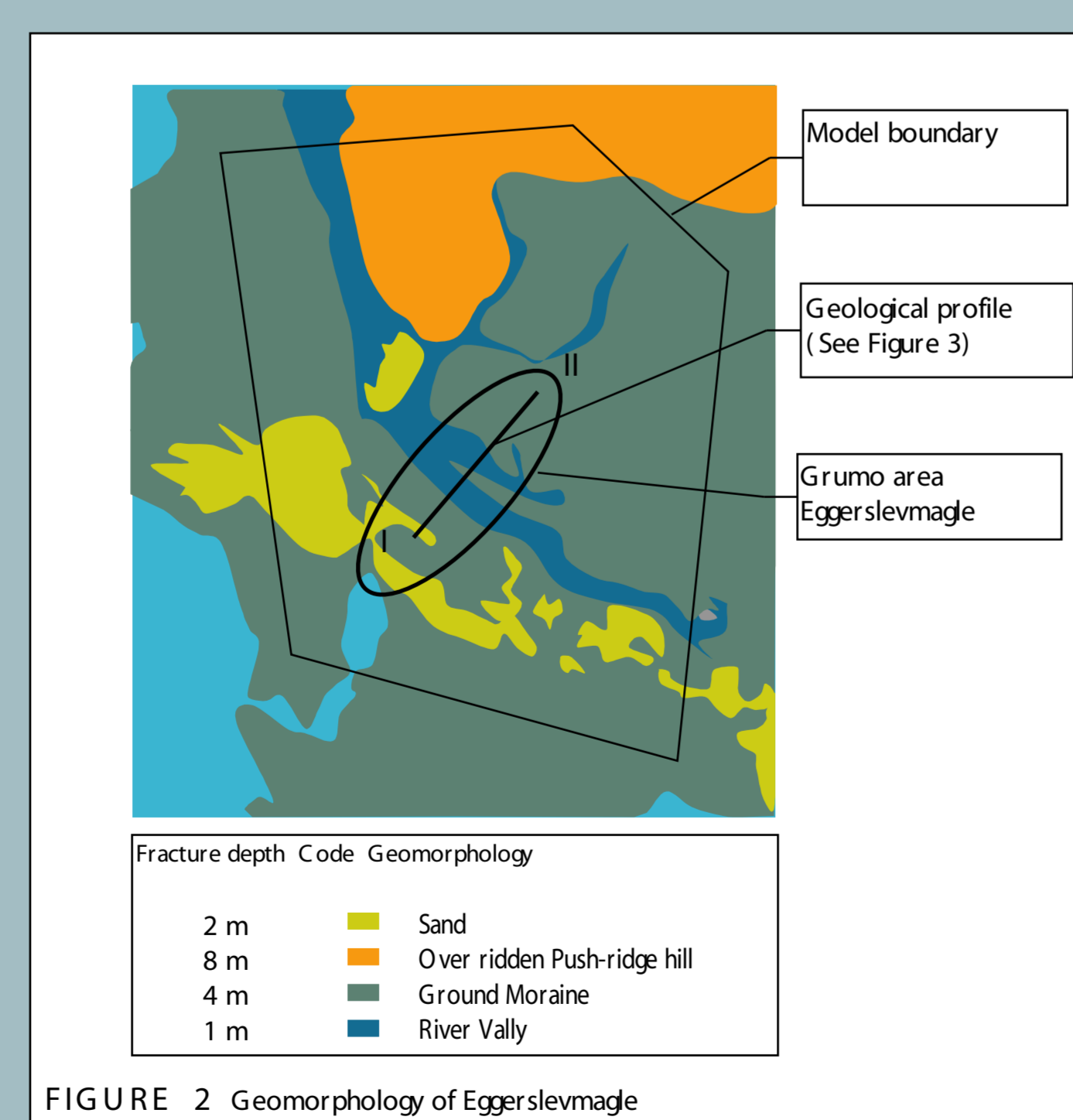
Calibration of the models were performed with using inverse calibration (UCODE). There were 3 to 5 free calibration parameters depending on the conceptual model. The groundwater models were inverse calibrated against head measurements

Numerical simulations of groundwater age were carried out using a particle tracking model CFC and tritium concentrations were compared with groundwater ages simulated for all three numerical models. In the particle tracking simulations uniform porosity were presumed. Particle tracking was simulated for a period of 1000 simulation years based on a steady state flow simulation. Each time step (1year) new amounts of particles were released at surface, thus the traveltime of each particle can be interpreted directly as groundwater age.

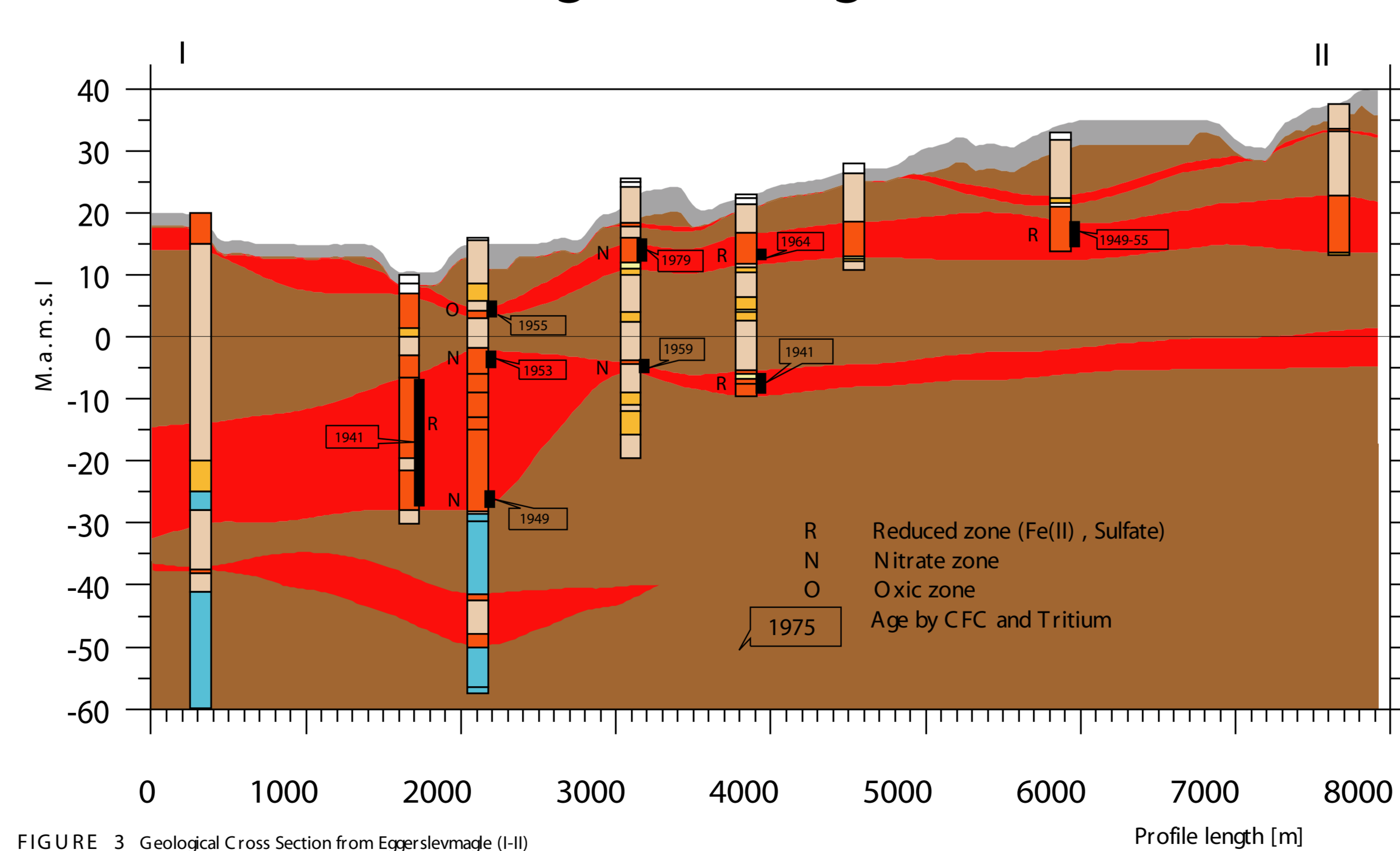
Simulated Age Distribution



Eggerslevmagle Model Area



Measured Age Dating and Redox State



Results

The age distribution for a cross section shows a steeper age gradient with increasing model complexity (Figure 5). The modeled age of the shallow aquifer varies from 50 years "Complex" (C) to 25 years for the "Intermediate" (B). In the deeper aquifer the intermediate (B) and complex (C) shows a water age more than 100 years.

The simple case (A) simulates a larger variation in age. The mean age of the abstracted water (Figure 6) is: 225 years case (A), 250 years case (B) and 300 years case (C). This gives a timespan of 75 years depending on model complexity. Direct measured age (CFC, Tritium Figure 3) suggest an aquifer with a very limited age difference between upper and lower parts of the system (20-40 years).

Conclusion

The case study of Eggerslevmagle shows the importance of incorporating local secondary flow systems at regional scale. Increased model complexity seems to increase partitioning between shallow and deep flow systems.

