The Barometric Driven Xenon-Tracer Transport of the Non-Proliferation Experiment Simulated By Finite Volume – Finite Element Higher-Order Accurate Modeling

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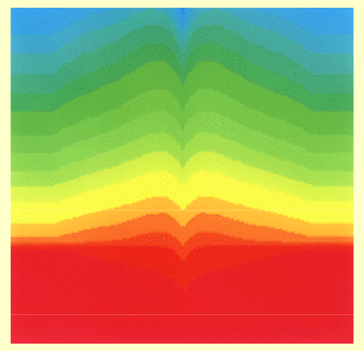
Introduction

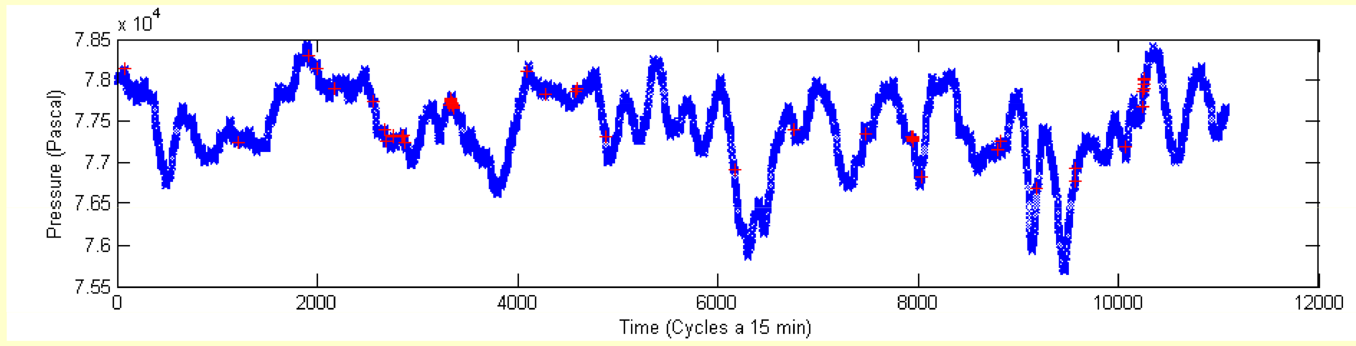
Calculations on arrival times of the four CTBT-relevant radioxenon isotopes and their surface concentration levels depending on weather patterns are critical in narrowing down the on-site inspection activities like soil gas sampling according to the CTBT provisions. A better understanding of the distribution of surface concentration levels can support optimized soil gas sampling schemes

Non-Poliferation Experiment

In the Nineties an Experiment was conducted on verifying compliance with respect to the Comprehensive Nuclear Test Ban Treaty (CTBT). This Non-Proliferation Experiment was located at the Nevada Test Site and demonstrated the detectability of an underground nuclear explosion with a clandestine setup. A chemical explosive of approximately 1 Kt TNT- equivalent was detonated in a cavity located 390 m deep in the Rainier Mesa (Nevada Test Site) in which two tracer gases were emplaced. No surface fracturing was visible. In this experiment SF_6 was first detected in soil gas samples taken near fault zones after 50 days and ^3He after 325 days, which indicates advective dominant transport. [1]

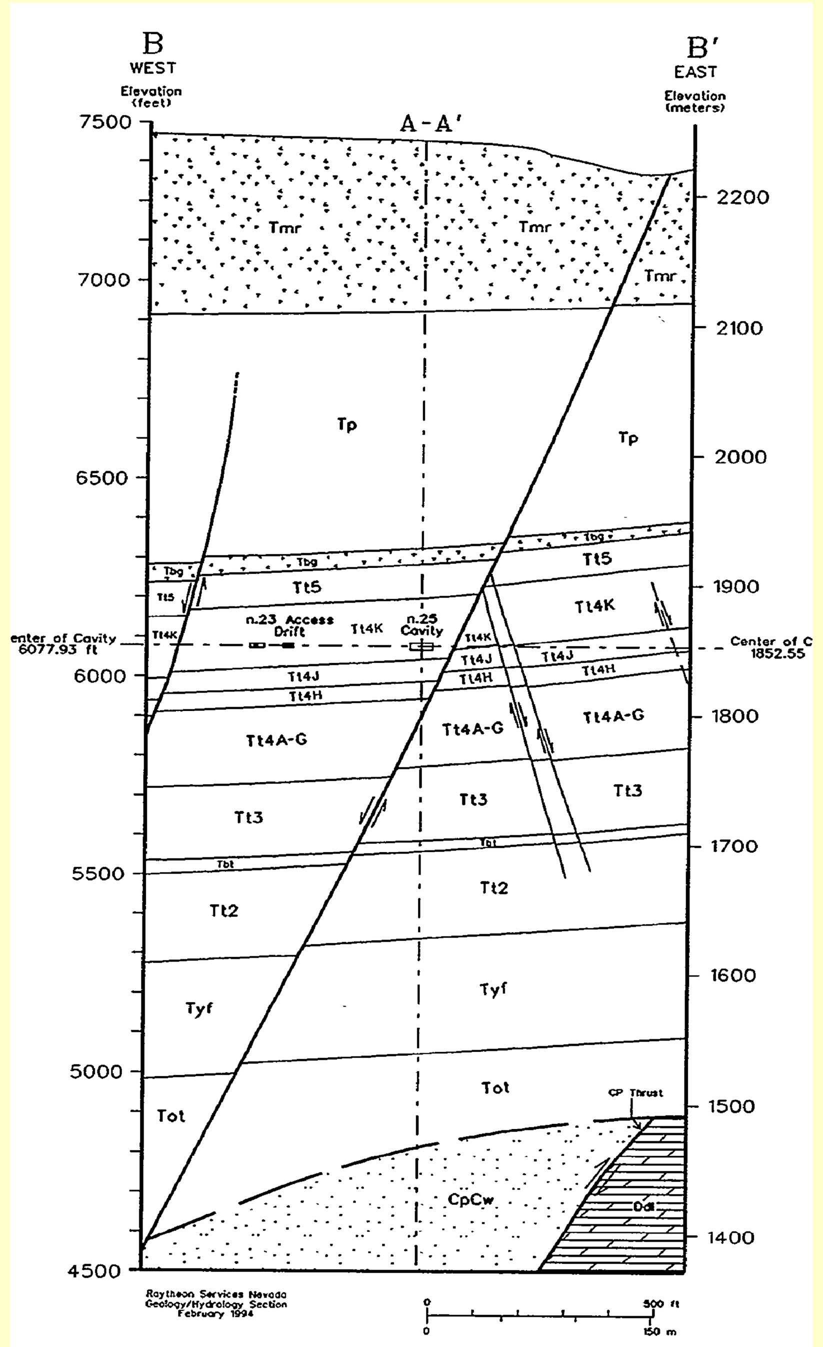


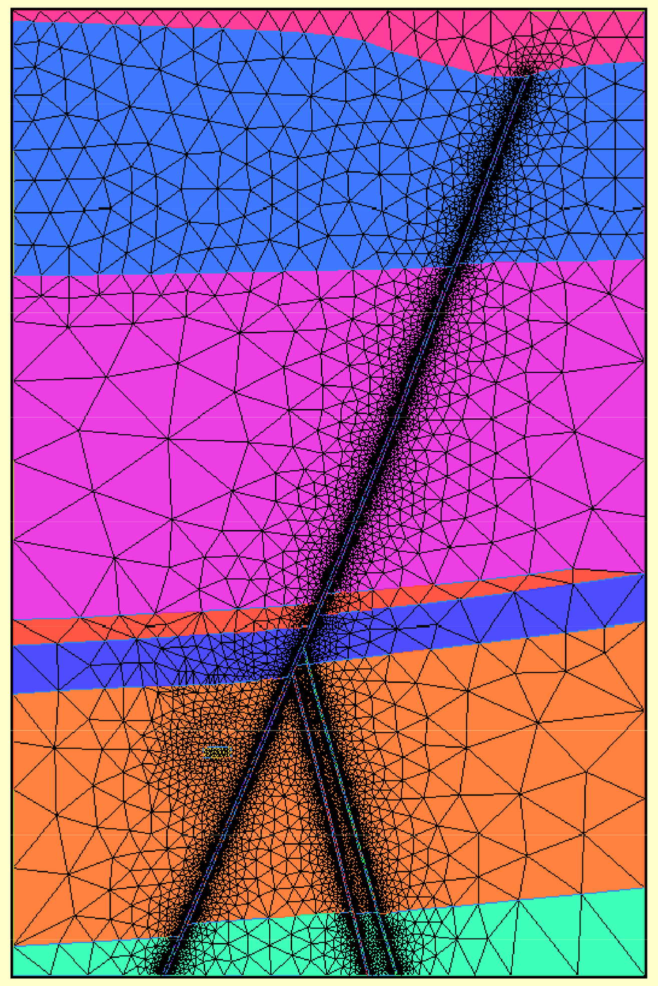
Barometric Pumping



In well connected and highly permeable fractured systems like Rainier Mesa or Yucca Mountain with its arid climate, surface pressure variations due to weather patterns can result in a dominant-driven tracer transport leading to a upward migration. [2]

Geological Model I





(Above)
A mesh with 40.642 finite elements and 18.373 nodes. The model accounts for single phase flow and transport with gravity and dispersivity effects, is owing to the fractured media.

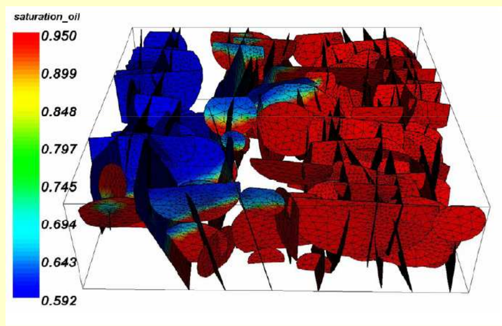
Geological Model II

We resolve the geological structures by using advanced CAD-software (Rhinoceros 4.0). The Non-uniform Rational Bi-Spline (NURBS) curves in Rhinoceros allows us to recreate the complexity of the Rainier Mesa. The geometry (see left) is discretised for the numerical simulations into 40.642 finite elements using the commercial software ANSYS ICEM. Datas on gas-filled porosity and permeabilies are shown in table right [5,6]

Families used in geometric model

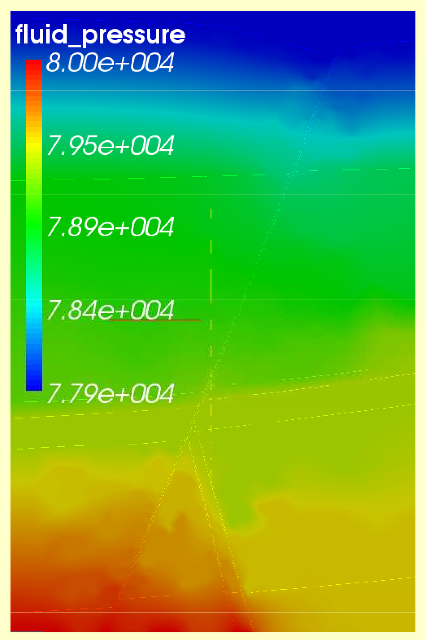
Unit	Depth (m)	Gas filled porosity	Permeability (m^2/s)
Tmr	0 - 130	6.6e-3	5.2e-16
Tp	- 316	2.9e-2	9.1e-14
Tbg	- 328	2.5e-2	1.1e-14
Tt5	- 352	9.8e-3	1.6e-15
Tt4	- 489	6.6e-3	1.6e-15
Tt3	- 542	1.1e-2	1.6e-15
Faults	various	1.0e-1	1.0e-12

Complex System Modeling Platform CSMP++



CSMP++ is a state-of-he-art simulator for modeling fluid flow and transport in structurally complex reservoirs. It uses a higher-order accurate transport schemes, which allows to predict the arrival times and concentrations with greater accuracy. The combination of finite volumes and finite elements allows for better geometric flexibility. Hence, tracer transport in more complex but geologically more realistic fracture models can be studied to evaluate how the predictions change compared to the highly idealized case of a single fracture transectioning a uniform porous media [4]

Ongoing Results

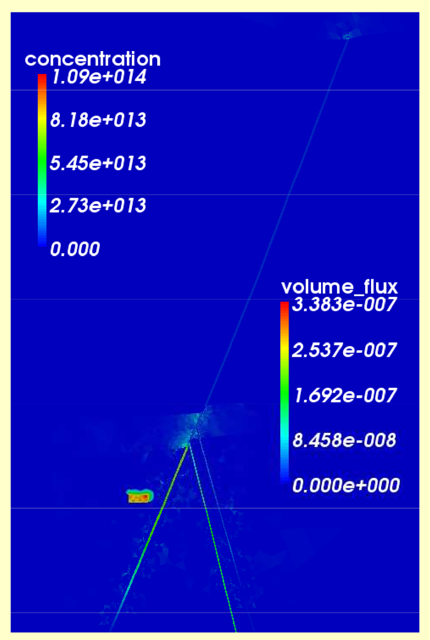


(Left)

Pressure Response after 240 hours with a neumann condition of 0.0 (no flux) on the bottom boundary

(Right)

Uncalibrated result from parameter study of tracer transport assuming a point source with a diffusivity of 1.24 * 10^(-5) after 474 hours



Summary

- **Modeling of complex geological situations with sophisticated software can be done nowadays on desktop computers within hours to days provided that appropriate geological datas are on hand**
- **The effect of barometric pumping on tracer transport in geologically complex situations has not been studied yet, neither its implications on migration the four radioxenons owing to their different diffusivities leading to an potential bias in source discrimination**
- **Our parameter study indicates that an initial tracer distribution limited to cavity geometry gives lower surface concentrations than presented in [3] in accordance to the previous work.**

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