

Dosimetry simulations based on the Geant4 toolkit : do it yourself with DosiVox

Norbert Mercier ^{1*}, Loïc Martin¹, Sébastien Incerti ^{2,3}

¹ IRAMAT-CRP2A, UMR 5060 CNRS - Université Bordeaux Montaigne, Maison de l'Archéologie, 33600 Pessac, France

² CNRS, IN2P3, CENBG, UMR 5797, 33170 Gradignan, France

³ Université de Bordeaux, CENBG, UMR 5797, 33170 Gradignan, France

* norbert.mercier@u-bordeaux-montaigne.fr

Introduction

There is an obvious recurrent need in paleodosimetric dating methods to evaluate the doses delivered in various situations, for instance, when calibrating a source, calculating attenuation factors or directly determining dose-rates, etc ... and these evaluations are never simple and numerical simulations can then be of some help.

For that purpose, we developed a flexible dosimetric tool named **DosiVox**.

This software is based on the general purpose Geant4 Monte Carlo toolkit developed by an international collaboration for simulating particle-matter interactions. This tool allows to model a large variety of complex cases relevant to luminescence and ESR dating techniques and to perform dose-rate calculations useful for age determination. The user can create a model of the sample and its environment using a graphical interface which generates a pilot text file containing all the information relevant for the simulation. No skills in C++ programming or with the Geant4 libraries are then required.

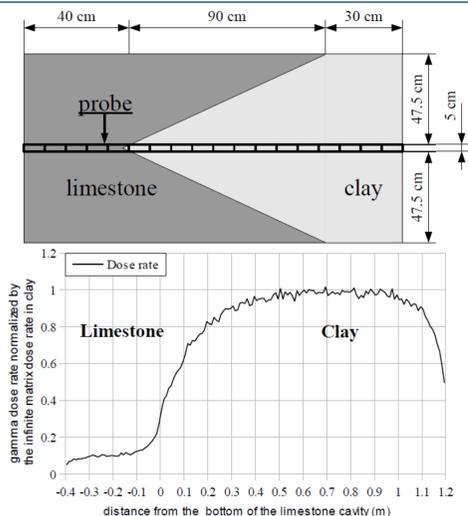
DosiVox characteristics

- The « World » contains a 3D grid of voxels whose X, Y, Z dimensions, material and radioactive contents are user-defined ;
- 3 detectors defined in « parallel » worlds are superimposed on this grid :
 - a segmented vertical probe
 - a random packing of spheres (modeling grains) in a rectangular prism
 - a sub-voxelised voxel allowing to import 3D data (3D scans or 3D drawings)

Modeling a limestone cavity filled with a clay sediment and calculating the gamma dose rate from potassium :

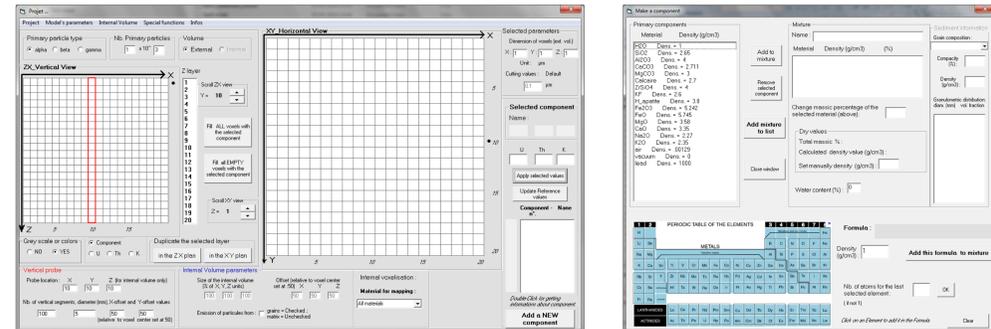
- geometry, materials and radioactive contents defined with the graphical interface
- probe located at the centre of the cavity

- materials composition :
 - clay : SiO₂ (55% in mass) Al₂O₃ (35% in mass) Fe₂O₃ (10% in mass), density 2.0 g.cm⁻¹, water content: 15% in mass
 - limestone : CaCO₃ (70% in mass), MgCO₃ (30% in mass), density 2.7g.cm⁻¹, water content: 10% in mass

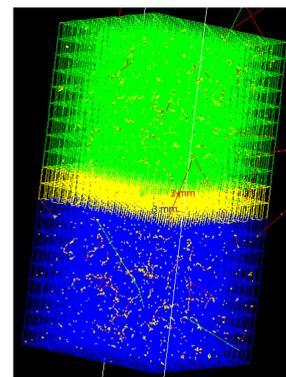


Material for simulation

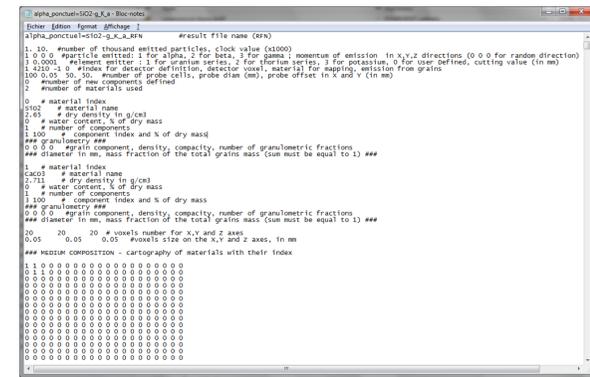
- a PC or Mac running a Scientific Linux 6.4 virtual machine (free download at <http://geant4.in2p3.fr/spip.php?rubrique8&lang=en>)
- Geant4.10-p01 (available freely at www.geant4.org) installed on the virtual machine
- the DosiVox software will be available at <http://lascarb.labex.u-bordeaux.fr/Outils-de-la-recherche/DosiVox,i1991.html>



Graphical interface allowing to create the pilot text file controlling the simulation.



World containing the 3D grid of voxels.



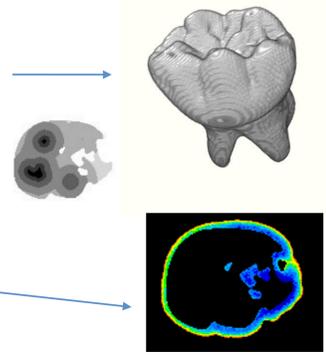
Header of the pilot text file.

Mapping the beta dose rate in a tooth whose geometry was obtained from a 3D micro-scanner tomography :

The 3D scan was converted into a stack of slices (text files in grey levels) read by the graphical unit.

Materials and radioactive contents were then associated with the different grey levels.

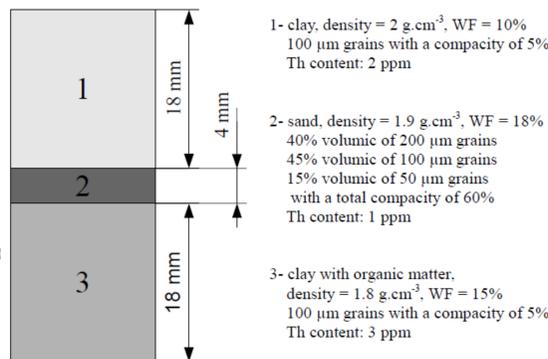
After calculation, the 3D image showing the beta dose distribution in the enamel was constructed with the free ImageJ software (<http://imagej.nih.gov/ij/>).



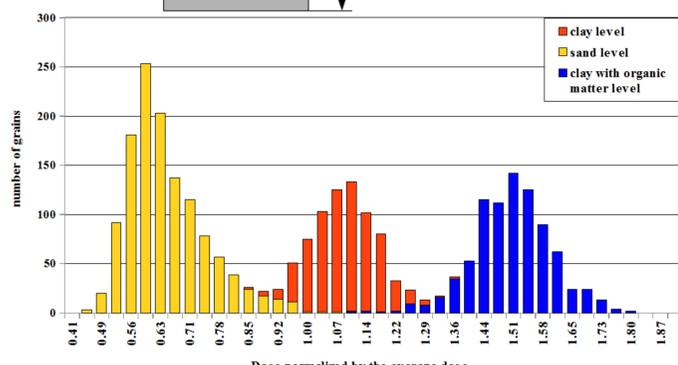
Beta micro-dosimetry in a stratified sediment :

We simulated with the graphical interface a stratified sediment composed of three levels (see below for their composition) :

DosiVox was used to calculate the beta dose from the Th series to which have been exposed all the 100 μm grains, whatever their location in the three defined levels.

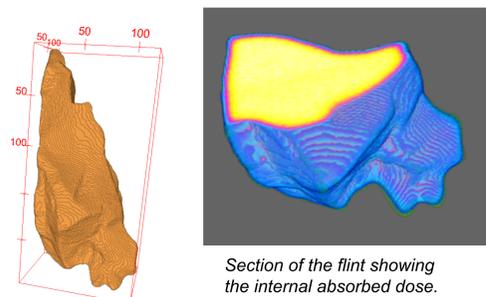


As shown on the graph below, the differences in composition and in radioactive contents of the three levels induce a large scatter of the beta dose received by the 100 μm grains.



Beta dose rate in a flint sample :

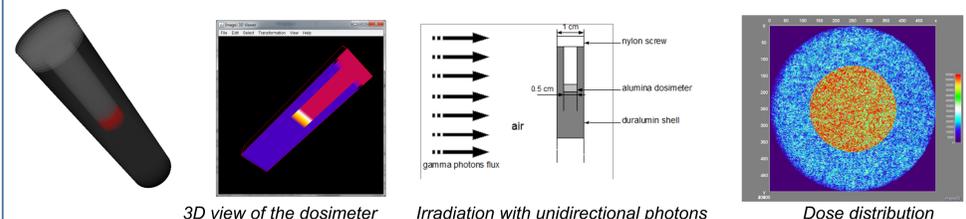
A voxelised 3D scan image of a flint was loaded in DosiVox and the spatial distribution of the internal beta dose rate from the U-series has been simulated.



Irradiation with Cs-137 gamma photons of a dosimeter used for source calibration :

Energies of alpha, beta and gamma particles are stored in text files read by DosiVox. Changes in these files can then easily be done by the user. Here, we defined 661.7 keV photons for simulating a Cs-137 source.

DosiVox allows simulating the emission of particles in all directions (4π steradian), or in a single direction chosen by the user as it was done in this case.



Simulating bursts of alpha and beta particles from the Th series in clay :

A cubical 3D image made of 100x100x100 voxels, containing a single grey tinted voxel defining the emission point was constructed with the ImageJ software and loaded into the sub-voxelised voxel of the graphical interface.

A unidirectional emission was chosen, and the dose deposited in the detector recorded as a 16 bits 3D image.

Notice the distribution of the alpha dose due to the 3.8 ; 6.8 and 8.8 MeV emissions.

