To track: *Simulation tools and studies*

Muography and geology - Does it matter which continent you stand on?

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The literature concerning muography has steadily increased in recent years, but so far very few publications have taken into account the true complexity of rocks in different continents, each continent having a different history and hence different geological features. The same is also valid for the question how deep underground muography can be applied. This is not straightforward because of rapidly reducing muon rate. Furthermore, we keep in mind that most people working in these fields are geologists, geochemists, geophysicists, and mining engineers.

In order to demonstrate the wide spectrum of different types of geological domains in the layered earth structure, we conducted a series of extensive simulations to be able to understand the differences in conducting muographic measurements in different parts of the world. Our simulations are based on the geological fact that different geological environments have different bulk rock compositions and density variation profiles.

Consequently, the present work introduces five continental geological models that differ from each other in terms of their density and rock chemistry. Clearly, both density and chemistry have a clear impact on the muon survival as it is known well that the attenuation of muons depends mostly on the density of the material the muons pass through before ceasing to exist.

We discuss the basic principles that must be taken into account while considering the maximum depth muography can be applied, but also highlight the key issues why this simple question is far from trivial, and why the answer always has some constraints that must be considered before planning and conducting muographic measurements deep underground.

The studied continental geological models were 1) upper continental crust, 2) bulk continental crust, 3) lower continental crust, 4) oceanic crust, and 5) oceanic upper mantle. In the latter two models, the oceanic rocks are tectonically thrust on the continental crust. The chosen five models differ from each other by both rock chemistry and density. Furthermore, water and standard rock were used as a reference as those are more familiar materials among astroparticle physicists. The simulation tools were Geant4 (attenuation) while the muon rate estimates were based on CORSIKA, Guan et al. (2015) (modified from Gaisser, 1990), Chirkin and Rhode (2016) (MMC code) and on the experimental data of Enqvist et al. (2005) extracted in the Pyhäsalmi mine, Finland.

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