GEOPHYSICS, PARTICLE PHYSICS, OR SOMETHING ELSE: WHAT IS MUOGRAPHY AND WHAT COULD BE ITS APPLICATIONS FOR SCIENCE AND INDUSTRY?

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A loved child has many names, many applications and great support, at least among the developers themselves. So it is also with cosmic-ray muon based imaging. Other names relating to this particular research methodology are muography, muon radiography and muon tomography [1]. In the present work, we discuss the nature of the muography as a research field and give some examples of its most promising applications [2].

The use of cosmic-ray muons for density observation and monitoring has its first steps taken already a century ago. Albeit the long history, muography is still in its early stages when evaluated in the context of industrial applications and general acceptance as a method/technique comparable to widely known geophysical methods, e.g. EM and gravimetry, or more traditional imaging methods such as X-ray and ultrasound. A workshop jointly organized by the Kerttu Saalasti Institute of the University of Oulu, Finland, and International Muography Research Organization of the University of Tokyo, Japan, worked on some issues relating to the future of this adolescent science. The meeting was accompanied by 22 researchers from Finland, Japan, Italy, England, Hungary and Chile.

The questions were planned to map participants opinions and viewpoints about, for example, how to market muography to non-muographers, what needs to be done to have it more recognized and accepted, and what applications it has or could have. As it was quickly learnt, even the participants who were at least familiar with muographic techniques (and some were top researchers in this field), faced trouble to find a consensus on what muography is. Opinions on this matter varied, but it became obvious that most participants regarded

muography as a geophysical and particle physics method. It became equally clear that what muography is, at least for now, depends on the context (e.g., for the developers it is a particle physics method, but for the appliers, e.g. mining companies, it is a geophysical method).

For most geophysicists, muography will remain a particle physics method until it has reached a higher level of maturity. It was agreed upon that the challenges are not limited to the muography field alone but also to the evaluators of grant proposals, investors, and even possible end-users. However, it is the responsibility of any new science to educate outsiders and prove the doubtful wrong. Some decisions made in the workshop are likely assisting in this huge work ahead. Regarding the applications, the most famous and widely document showcases of muography are in archaeology (the pyramids of Giza, Egypt [3]) and volcanology (e.g., Mt. Etna in Italy and Mt Sakurajima, Japan)[3-4]. Industrial applications include geological and infrastructural mapping [5], including applications in mineral exploration, CO_2 geostorage monitoring [6], and monitoring of high-density materials (e.g., Fukushima reactor imaging and nuclear contraband monitoring [7]). In the workshop above, also tunnel safety monitoring, borehole applications, space mining, and smelter imaging were highlighted. More applications will be shown in our presentation.

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