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Geoscientific Instrumentation Methods and Data Systems Discussions

Interactive comment on "Muographic data analysis method for medium-sized rock overburden inspections" *by* Hiroyuki K. M. Tanaka and Michinori Ohshiro

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Anonymous Referee #1

(A) comments from Reviewers A MS "Muographic data analysis method for medium-sized rock overburden inspections" by H.K.M. Tanaka and M. Ohshiro is suggested to very interesting subject: studying cosmic rays propagation through such interesting archaeological targets as Egyptian pyramids. The paper is logically constructed and well illustrated. Undoubtedly it will be interesting not only for specialists in this field, but

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Discussion paper

also to the wide circle of people interesting by intricate archaeological object. Only one remark. According to last infrared investigations in the Great Pyramid: "Thermal Scan of Egyptian Pyramids Reveals Mysterious Anomaly in the Great Pyramid" (November 2015) here several enigmatic thermal anomalies were revealed. How it is correlates with the authors' analysis? Such an addition will be very useful for the readers.

(B) author's response Thermal scan of the Egyptian pyramid revealed subsurface thermal anomalies in the Cheops pyramid. They might be reflected by some structural irregularities. However, the present re-analysis is based on the data that L. Alvarez collected in late 1960s in the Chepren pyramid and therefore, it is difficult to directly compare muographic results with their thermal scan.

(C) author's changes in manuscript Thermal scan provides us information on electric conductivity that is complementary to muography that gives us areal density along the muon's path lines. For this reason, we added a statement "A thermal scan technique provides us the spatial distribution of subsurface thermal conductivity that complements muography that gives us areal density distribution along various muon paths and therefore, a joint measurement between muography and thermal scan will provide us more comprehensive picture on structural irregularities inside a pyramid"

Anonymous Referee #2

(A) comments from Reviewers General Comments This paper addresses a data analysis method of muographic measurements for medium-sized rock overburdens. The authors found that there is a simple relationship between the transmitted muon flux and the areal density along the muon path, as long as the overburden thickness is thinner than a few hundred meters. They propose a new analysis method to cancel experimental conditions and determine the areal density along the muon path by taking a ratio of transmitted muon fluxes after passing through partial layers of the overburden and by combining the independently measured density information for one partial layer. The technique to cancel uncertainties in experimental conditions may be a method commonly used in the field of particle physics. However this proposed method certainly help make the job, the estimation of the rock overburdens, much easier. It may become a popular method widely used in the muographic measurements of medium-sized rock overburdens. This paper may, therefore, deserve to be published in GI. However there are several points which the authors should clarify before its publication. They are listed below. Specific Comments and Questions

(1) Page 5 L6: “Fig. 3" Probably there should be another figure, Fig. 0: CSDA range vs. E.

(B-1) author’s response We inserted a plot showing CSDA range vs. E.

(2) Page 5 L16: If there is a figure on the muographic observations of the rock overburden which is divided into two horizontal layers, readers may easily understand the principle of the method. Later, the numbers of muons (N0, N1) appear as measurable quantities. Please explain how you measure N0 and N1, respectively, in this figure. Where is the detector to be located for each measurement?

(B-2) author’s response We inserted a figure on the muographic observations of the rock overburden which is divided into two horizontal layers.

(3) Page 11 Table 1: How did you calculate the numbers of events without casing and back stones, N1? (I understood the numbers of muon events N in Alvarez et al. (1970). For example, N(72 − 75) = 1300 + 1290 + 1470 + 1482 + 1545 + 1352 + 1172 + 1087 = 10698. How about N1?)

(B-3) author’s response As shown in Fig 12 in the paper by Alvarez et al (1970), they showed the simulated value of the numbers of events without casing and back stones, which is indicated by the horizontal line showing ”deviation” of zero.

(C-3) author’s changes in manuscript We explicitly stated: “we employed the value simulated by Alvarez et al. (1970) for the numbers of events without casing and back stones” in our manuscript.

(4) Page 12 Table 2: How did you calculate the ratio, 0/1? The ratios, < I0 > / < I1 >, are missing? It would be better to have necessary information so that readers can follow the calculations and reproduce the results in this paper.

(B-4) author's response I0 (theta,phi) and I1 (theta,phi) were calculated and averaged over the range within an elevation angle range shown in Table 1 for theta (W-E direction) and 24-degree wide band centered on the middle of the pyramid for phi (N-S direction).

(B-4) author's response We inserted "In order to derive 0/1 from X0/X1, I0 (theta,phi) and I1 (theta,phi) were calculated based on the topography of the pyramid and the detector location and, averaged over the range within an elevation angle range shown in Table 1 for ïĄś (W-E direction) and 24-degree wide band centered on the middle of the pyramid for phi (N-S direction).

(5) Page 13 L9: How did you calculate the Pyramid's core density of "1.89 $\pm$ 0.20 gcm$-$3"?

(B-5) author's response Here in this manuscript, the pyramid consists of (A) Tura limestone, (B) back stone, and (C) core stone. A density of (A) is given by Arnold (1991). A density of (B) is given by Alvarez (1987). Therefore (C) can be calculated from muography.

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