The reasoning for low ground magnetic anomaly reveal by model numeric and data on the field

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Abstract. The current practice in earth science for ground magnetic survey interpretation is analogue model based on the evidence in the other region, and make a theory. The numerical model based on principle of magnetic physical laws apply on the model running on computer and will show the clear explanation for the phenomenon. The current progress is possible to make the effect earth magnetic field, their magnetic variant and material responsible to. All the model and magnetic response as flux is overlay under the topography in 3-D and make the slicing easy. Hence we can follow directly and nearly true in the theory and the facts in East Flores island of Indonesia. On-site, low magnetic anomaly is unique. Over there the field ground magnetic, coincidence with the hot water outpouring from fracturing region. The result showing the phenomena are coherently explainable both in theory, and the fact in the field, bring the numerical software as a powerful tools.

1. Introduction
The interpretation in geosciences needs combining imagination-knowledge and numerical aids calculation. In numerical calculation the geoscientist develop the tools to predict the subsurface image based on measurement in the surface. The technique is famous as forward modeling and inversion [1][2].

Sometimes, those techniques reduces the principal of basic physical features to understand. From here this article will regain the whole, beginning with understanding ending with practical computation for subsurface imaging.

The Phenomenon, is describing besides in calculation and idea, but also introducing the fact in the field for a clue. Hence, the whole process of nature could be linked in the earth and physical parameter. The case study is an area in East Flores Island where volcanic rock exposed distinctly [3]. An example of surface measurement is capture for a model. The model will make us understand and the explanation simpler.

2. The spot of Anomaly among the high
East Flores is part of volcanic arc in Nusa Tenggara Indonesia. The Island, is part of magmatic arc of Pacific's ring of fire, about 300 km from Indonesian subduction zone. The next to volcanic island is closed to the famous, Banda in East, and Bali-Lombok in west.
The island is surrounded by volcanic product with subtle topography [4] with pyroclastic Nangapada (Tmn) to Waihekap (Tmpw) as tuff, breccias, and maybe deep intrusion Wolowaru(Tmg) Formation of Middle Miocene age. In several parts in foot of volcano and between the volcano peaks, the nearly flat topography is sometimes found.

In Theory, the cooling magmatic product will show the high magnetic anomaly, due to magnetite mineral in solidified rock of andesitic-basaltic such as found in this area. But in facts, on several parts the fumaroles found in several sites. The field observation and morphology observation is
also predict the existence of fault zone passing by the fumaroles (hot water outpouring from earth) [4].

We note the low magnetic anomaly is nearly coincidence with the fault zone and fumaroles

On several geothermal areas, such as Kamojang geothermal field in west Java, the low magnetic anomaly is coincidence or interpreting for fumaroles activity [5] due to relationship between temperature to susceptibility or magnetic residual [8]. The current data acquire for subsurface imaging use the proton magnetometer with 500 - 1000 meter intervals.

The anomaly magnetic south to north section in equatorial southern latitude, the symptoms of negative or locally zero anomaly on the spot is based on normal behavior of positive anomaly come from susceptibility of volcanic rock. The dipole character will produce by beginning of negative curve follow to positive curve. Contrary to normal in volcanic rock, the negative anomaly is beginning by positive curve follow to negative curve. The illustration is present in figure 1.

**Figure 1.** The interpretation section of north south, providing the perturbation local High-low anomaly magnetic due to heating liquid and providing both by fumaroles(♂) manifestation and signaling low by reduction to pole analysis, (after [6]).

**3. Numerical magnetic modeling and forward modeling**

The magnetic field in this case is Magneto static. It could be solved using scalar magnetic potential, $V_m$. The earth magnetic field, $H$, background is change by the presence locally intrusion or volcanic rock making higher anomaly, and the spot of fumaroles making low anomaly, dependence of permeability, $\mu$, or susceptibility.

The general magnetic equation is beginning by magnetic field, $H$, and its relationship with flux density $B$ (dependence $\mu$ of medium where $H$ is dominance factor, and residual, $B_r$), with scalar potential $V_m$ as:

$$H = -V_m$$

(1)

$$\nabla \cdot (\mu \nabla V_m + B_r) = 0$$

(2)
The Potential magnetic is separating into external factor, $V_{\text{ext}}$, and internal factor $V_{\text{int}}$ (considering not influence or dissolve to $V_{\text{ext}}$). And flux density $B$, decompose to residual $B_r$, and background $B_0$, yield into the intensity, declination, and inclination value in the area. Assuming the current magnetic epoch is same for region, we adopt the value of Magnetic intensity $44476.3$ nT, inclination $= -33.083^\circ$, declination $1.983^\circ$ So the eq. 2 separating into:

$$\nabla \cdot \mu \nabla V_{\text{red}} + B_r + \mu \nabla V_{\text{ext}} = 0$$  \hspace{1cm} (3)

The flux density local, $B_r$, is proportional to B-magnetic by predicting presence permeability concentration material, say with percent (%) for magnetite or hematite equivalence.

The boundary condition for flux magnetic surrounding the box, is following Neumann’s boundary condition [7], meanwhile inside the body use continuation.

The following figure show the basic magnetic influence on surface due to body in subsurface and field intensity or flux result. See how the subtle anomaly due to fumaroles hence yields the low magnetic among the high one.

**Figure 2** The reduce magnetic field in near surface igneous rock representing by cylinder body. See the dipole effect (red high, blue low) and arrow indicate its vector

**Figure 3** The reduced magnetic anomaly in near surface due to both igneous (representing by cylinder) and crack fumaroles (representing by thin ellipsoid). Compare to figure 2, on sequence three phenomena : blue (low anomaly) and cyan (slightly high) and blue toward higher one

4. Low magnetic anomaly and the quantitative Interpretation approach

Figure [2] [3], two model body is representing the causative body of rock deformed by fracturing rock where fumarole manifestation and body mounted near the surface. The rock fracture filling in fumarole represent by an ellipsoid at depth about 300 meters. While, a body mounted represent by a cylinder at base 2 km depth.

The earth magnetic field, $H_0$, on this area is about $44437$ nT, and the contribution local Flux $B$, by combination of permeability, inclination (-30 degree) and declination (1.8 degree). All of this parameter is resulting perturbation of earth magnetic field. The local magnetic effect both the positive
is a cylinder of body due to high permeability value (20 percent equivalent magnetic), and an ellipsoid low permeability (2 percent equivalent magnetic). An estimation temperature we reduce the effect as low as 30% [8].

The Topography represent the area is coming from US Army Topography [9], digitize and formatting to apply in Comsol [7]. All is received and joint with numerical forming the magnetic effect of causative body and reformulating the basic parameter. The mesh generation using triangulation finite element like is producing as well by the program. The 3-D picture could maximize the observation and to see the result, figure [2] [3].

On figure [2] show the effect of magnetic field because of mounting body alone (left), compare with the combination with the crack (ellipsoid), at right. The Field magnetic show the change from positive amplitude, to wavy because of dipole effect of small ellipsoid model of crack. This effect is comparable to field observation of ground magnetic data (figure [3]). The field observation is also show the lineation zone, interpreting from Landsat, and evidence from fumaroles [4]. From here both approach show the coherence between field measurement to physical evidence, identified indirectly by cracking, fumaroles and numerical knowledge approach for the response of field magnetics curve.

5. Conclusion

The evidence of surface observation by the combination from indirect measurement of ground magnetic, surface expression, is explain by model causative body. The respond of magnetic field made by numerical-geosciences approach calculate the effect therefore comparable with the data. The numerical based geosciences is a powerful tools to overcome mystery in subsurface and a completed approach to current routine imaging

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