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Volcanic Eruption Trends in the Five-Years Pre-Eruption Era[1]

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Abstract—Predicting volcanic eruption and magmatic transports is a global research. In this study, the temperature deviation curve model and temperature polynomial expansion scheme was used to calculate the time-scale of an active pre-eruption process. Satellite imagery within the timescale was harvested to further corroborate the findings.

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INTRODUCTION

The mechanism of volcanic systems are highly unpredictable [1] because of the different features of the earth crust at each volcanic zones, shape and sizes of the magma reservoir. There are numerous hypotheses or models for detecting and predicting volcanic prone regions but salient parameters have been ignored. The main hypotheses are centered on the geophysical, geothermal and geochemical techniques. They include the Failure Forecast Method (FFM) [2] and Thermal remote sensing (TRS). FFM and TRS have been used to predict eruptions at short notices i.e. within hours or days. The diversity of research has shown that dependence on one technique may be unreliable at the moment [3–7]. This suggests that more multidisciplinary efforts are required to proffer accurate prediction.

Volcanic zones are characterized by many factors but the major is the magmatic features. Magma stored in chambers/mushes is surrounded by crustal rocks. Magma bodies are open systems or self-organized dissipative structures that exchange material and heat with their surroundings under far-from-equilibrium conditions. The massive magma chamber transmits heat flux by conduction through the crust rocks to the ascending soil layer and by convection through the conduits via the pores/cracks of the soil layer. The transmitted heat flux via different media creates series of surface pattern. An advanced heat flux accumulation about a region-having a homogenous media, leads to ground inflation [8]. Heat flux pattern depends on the sizes and number of magma chambers; it acts like a photographic film that captures series of events in the high temperature geothermal fields close to the magma reservoir [22]. Therefore, it is scientifically valid to propose that heat flux pattern from within the earth-crust differs due to thermal conductivity of the soil layer. The long wave radiation from the earth is ignored because of its non-uniformity within regions of equal climatic signatures. The gas flux is an advanced stage of the heat flux transmission within the eruption timescale. Ultimately, the gas flux ejection determines the most prospective conduit for eruption.

In our model, Soil heat flux is the major factor used for calculating the timescale of pre-eruption era. Different techniques-both theoretical and experimental have been employed to estimate soil heat flux and its implication at different magnitude. Among the reliable theoretical methods for estimating soil heat flux is the Temperature Deviation Curve Model (TDCM). The TDCM has been used to predict the susceptibility of Abuja metropolis to soil compaction [9]; determine the annual amplitude of the surface soil temperatures of the same region [9]; estimate soil heat flux from both short and long-term remotely sensed surface temperature [10]; monitor earthquakes [11]; derive the temperature polynomial expansion scheme for sensible heat flux [12]; forecast hydrological disaster [13].

So far, literatures have only accounted for conductive heat transport from the top soil to the subsurface [14–16]. The reverse seem to be difficult because we have to account mathematically a conductive model-capable of transmitting within several kilometers from the magma chamber to about fifteen meters below the top soil. In this paper, we propose via an in-depth mathematical experimentation that the duration between the heat flux and the gas flux is about five years; and the duration between the gas flux ejection and eruption is about a year. Our main objective is improving on the geothermal technique to forecast volcano eruption at longer notices.

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[1] The article is published in the original.

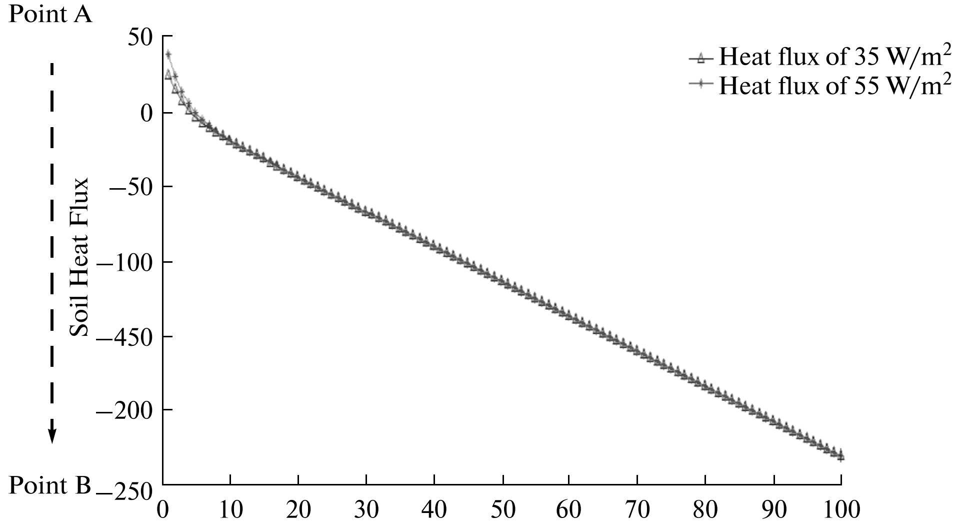

Fig. 1. Soil heat flux trend within multiple soil layer.

MATHEMATICAL DERIVATION OF THE TIMESCALE PRE-ERUPTION MODEL

In this section, the objective is to calculate the timescale from the point of eruption to the point the magma contents are excited within chamber. To do that, we start with the climax-before eruption (point A) to about 10 km below the earth crust (point B). At point A, the eruption is characterized with volcanic-tremor [15] or earthquake [16]. The magnitude of the earthquake with respect to the behavioral component of the soil properties [6] had been estimated to be

$$M = \frac{2}{3}\log\left(\frac{k^2}{2\omega}\right)\left(\frac{\rho_s}{\rho_b}\right)^2 - 7.87, \tag{1}$$

where K is the hydraulic conductivity, M is the magnitude of the earthquake, ρ_s is the soil particle density, ρ_b is the soil bulk density, ω is the circular frequency and k is the thermal diffusivity.

Between point A and B, are soil layers, rocks, aquifer e.t.c. which are subject to changing temperature. We therefore introduce the temperature deviation curve model [9] to account for the thermal instability. It is written as

$$\Delta T = A_0 e^{-\rho_s/\rho_b}\sin\left(-\frac{\rho_s}{\rho_b} - \frac{\pi}{2}\right), \tag{2}$$

where ρ_s = soil particle density which is a approximately 2.66 g cm^{-3} by Gupta et al. [17], ρ_b = soil bulk density. Since the change of the temperature is with respect to time, equation is written as

$$\frac{\partial T_1}{\partial t} = A_0 e^{-\rho_s/\rho_b}\sin\left(-\frac{\rho_s}{\rho_b} - \frac{\pi}{2}\right). \tag{3}$$

Earlier, the heat flux had been reported [10] to follow a polynomial trend in a uni or multi soil layer.

$$\begin{cases} G_n = \dfrac{2^n}{3}G_0 \quad \text{for} \quad n \le 1 \\ G_n = \left(\dfrac{2}{3}\right)^n G_0 - \dfrac{7}{3(n-1)} \quad \text{for} \quad n \ge 2. \end{cases} \tag{4}$$

The more the soil layer, the lower the soil heat flux. This idea is in line with common physics principles. Therefore, Eq. (4) shall be used in calculating an assumed 100 layers. The numerical analysis when G_0 = 35 W/m^2 at the 100th layer showed the highest positive heat fluxes i.e. G_n = 23.45, 13.38, 5.86, 0.053 W m^{-2}. Figure 1 shows that the magnitude of the heat flux transport at the magma chamber flows at a peculiar—trend regardless the boundary barriers within the earth crust. However, due to the implications of Eqs. (1) and (2) the heat flux varied due to densities of the earth crust content and attenuations from atmospheric net radiation impact. The uneven arrival of the heat flux at point B gives the pictorial patterns of occurrences within the crust.

The downward propagating temperature signal as a function of time (t) and depth (z) is given by Carslaw and Jaeger [18] as

$$T(z, t) = Ae^{-Kz}\cos(\omega t + \epsilon - Kz). \tag{5}$$