PRINT ISSN 1119-8362
Electronic ISSN 1119-8362

Full-text Available Online at
https://www.ajol.info/index.php/jasem
http://ww.bioline.org.br/ja

J. Appl. Sci. Environ. Manage.
Vol. 23 (6) 1099-1101 June 2019

Determination of Temperature Profile of the Lithosphere between Zero and 150 km Penetration at Itagunmodi, Nigeria

[1]ADETOYINBO, AA; *[2]BELLO, AK

[1]Department of Physics, University of Ibadan, Ibadan, Nigeria
Email address: dejiade39@yahoo.com; Tel: 08071647268

*[*2]Department of Physical Sciences, Bells University of Technology, Ota, Nigeria*
**Correspondence Author Email address: akbellokazeem@yahoo.com; Tel: 08036803114*

ABSTRACT: In this work the temperature profile for the lithosphere was determined using data from radiogenic heat source and heat from other sources from 0 to 150 km depth was determined using a suitable mathematical expression. The temperature at the base of the lithosphere was given between $1200℃ \ to \ 1600℃$. The Fourier's law was applied and the results showed that the profile range from $27.0℃ \ to \ 1483.3℃$. These results compared favourably well with existing literature values.

DOI: https://dx.doi.org/10.4314/jasem.v23i6.16

Dates: Received: 27 April 2019; Revised: 22 May 2019; Accepted 11 June 2019

Keywords: Temperature Profile; Lithosphere; Radiogenic Heat; Heat Flux

Symbols

$A = Q_{MC}$, the heat flux from the mantle into the crust
$B = z_0$, the referenced temperature for crustal part of the lithosphere
$Q_{MC} = 25 \, mWm^{-2}$
$Z_0 = 8 \, km$
$Q_0 = 65 \, mWm^{-2}$
$q_0 z_0 = 40 \, mWm^{-2}$
$\dot{q}_0 = 5 \times 10^{-6} Wm^{-3}$
$B = z_0$
$z_M = 35Km$
T_M, is the referenced temperature for upper part of the mantle
Q_0, heat flow
q, radiogenic heat flux
$\dot{Q}_0$, mean value of continental heat flux
$\dot{q}_0$, mean value of radiogenic heat flux = $5 \times 10^{-6} Wm^{-3}$
$\dot{Q}_C$, total crustal heat = $65 mWm^{-2}$
K_C, crustal thermal conductivity = $2.5 Wm^{-1}k^{-1}$
K_M, mantle thermal conductivity= $4.0 Wm^{-1}k^{-1}$
$\dot{q}_M$, mantle radiogenic heat $= 1.8 \times 10^{-8} \ Wm^{-3}$
$\dot{Q}_{MC}$, mantle –to- crustal heat flux = $25 mWm^{-2}$

The temperature profile in the lithosphere requires the knowledge of the sources of the heat that is transported through the mantle region of the Earth's interior before the heat finally released at the surface. These include the original heat and those currently produced in the Earth. The major heat source is radioactivity and heat from other sources. The main source of heat through radioactivity is the decay of the radioactive elements that are present in the mantle which includes the principal radioactive elements such as; ^{235}U, ^{238}U, ^{232}Th whose decay finally gives ^{207}Pb, ^{206}Pb, 208Pb respectively, and ^{40}K whose decay gives ^{40}Ca and ^{40}Ar. Although, the heat production per unit mass of each element that are present in the mantle is well known, their concentration in the Earth is much less certain. One estimate leads to the approximate lower bound of 2.4×10^{13} W for the total radiogenic production of heat in the mantle, Verhoogen, (1980). The concentration of radiogenic heat production in continental material indicate that the continental roots may cool more rapidly than the underlying mantle because of radiogenic decay Chloe and Claude (2007). There was also a contribution from short-lived radioactive isotopes, today non-existent radioactive elements such as ^{26}Al. There are other sources of heat that is transported to the surface which include tidal dissipation in the solid Earth and latent heat released during exothermal phase transitions. However, in addition to secular cooling of the core, there exists a non-negligible contribution to the heat output of the core which is due to the latent heat released during crystallization of the inner core and the gravitational energy released as the fluid improved in light elements by crystallization of the inner core rises. The effect of pressure on conductivity is enough to be neglected in the crust and the topmost mantle, the measured values

**Correspondence Author Email address: akbellokazeem@yahoo.com; Tel: 08036803114*

of the conductivities of familiar rocks and minerals provide a reasonable estimate of the conductivity of the lithosphere. There is a range of values for different rocks and minerals as determined from the laboratory measurements. The value of the conductivity, K was given as 4.0 W $m^{-1}K^{-1}$ from measurements on minerals in ultramafic rocks to be representative of the topmost mantle Clauser and Huenges (1995), while a value of 2.5 W $m^{-1}K^{-1}$ was given for basaltic oceanic crust. The most accurately determined properties of the Earth's interior are determined seismically from both velocity and density profile respectively and therefore, most of the thermodynamic properties of the Earth's interior which includes temperature profiles of the Earth are derived in terms of these profiles. The existing evidence of temperature profiles covers the lower mantle and the outer core, these profiles were derived in terms of the parametric earth model (PEM) found from normal modes of the earth as Dziewonski *et al.,* (1975). In some of the previous work done by some researchers in the determination of temperature profile from the lower mantle to the core, some values were given for the base of the lithosphere. Among the authors includes Stacey, (1977); Jeanloz and Richter (1979); Anderson, (1980). The temperature profile in the upper mantle had their origin in heat flow data extrapolations. Among these notable authors, Anderson, (1980) gave the value of temperature inside the Earth at 100km as 1200ºC while Verhoogen, (1980) gave a value of 1000ºC. Stacey, (1977) estimated temperature at crust-mantle boundary using Lindemann's Laws of fusion was 277 ºC. The temperature ranged between (1199 -1400) ºC and (1200 -1440) ºC at depth between (100 - 140) km, Anderson, (1979 and 1980), At the base of the lithosphere, Watts, (2007) gave a value of 1330ºC, William, (2007), gave a value of 1280ºC for the base and Chloe and Claude (2007) gave a value of 1600ºC. The main aim of this work is to determine the temperature profile of the lithosphere between zero and 150 km penetration.

METHODOLOGY

The heat flux Q is not directly measured but its vertical component is obtained by the Fourier's law. The heat flux, Q_0 and radiogenic heating of surface rocks, q_0 are both variable, a correlation between these two variables leads to a simple model for the depth distribution of heat sources. The linear relationship that exists between the variables is stated in the relation below:

$$\dot{Q}_0 = A + B\dot{q}_0 \text{ --------------------- (1)}$$

By assuming an exponential variation of radiogenic heat with depth,

$$\dot{q}_0 = q_0 \exp(-z/z_0) \quad \text{------ (2)}$$

The total crustal heat, Q_C is the integral from the surface to the mantle–crust boundary at depth z_{MC} ,

$$\dot{Q}_C = \dot{q}_0 \int_0^{z_{MC}} \exp(-z/z_0)dz \text{ ----- (3)}$$

$$\dot{Q}_C = \dot{q}_0 z_0[1-\exp(-z_{MC}/z_0)] \approx \dot{q}_0 z_0 \text{ --- (4)}$$

The heat flux through a surface at depth z is given below; this equation is the Fourier's Law

$$\dot{Q} = k_C \frac{dT}{dz} = \dot{Q}_{MC} + \dot{q}_0 z_0 - \int_0^z \dot{q}dz \quad (5)$$

$$k_C \frac{dT}{dz} = \dot{Q}_{MC} + \dot{q}_0 z_0 \exp(-z/z_0) \text{ ----- (6)}$$

The temperature profile is calculated as stated in the equations below:

$$T(z) - T_0 = \frac{\dot{Q}_{MC} z}{k_c} + \frac{\dot{q}_0 z_0}{k_c} \int_0^z \exp(-z/z_0)dz \quad (7)$$

$$T(z) - T_0 = \frac{\dot{Q}_{MC} z}{k_C} + \frac{\dot{q}_0 z^2}{k_C} \exp(-z/z_0) \text{ -- (8)}$$

The mantle part is calculated using equation below:

$$T(z) - T_M = \frac{\dot{Q}_{AM} z}{k_M} + \frac{\dot{q}_M z_0}{k_M} \int_0^z \exp(-z/z_M)dz \quad 9$$

$$T(z) - T_M = \frac{\dot{Q}_{AM} z}{k_M} + \frac{\dot{q}_M z^2}{k_M} \exp(-z/z_M) \text{ --(10)}$$

Equation (10) is used to calculate the profile for the upper mantle part of the lithosphere such that $z_M = 35\ Km$.

RESULTS AND DISCUSSION

Table 1 show the values of the temperature profile. The temperature profile in the lithosphere covers the surface to depth of about 150 Km, the values ranged from $27.0°C - 1483.3°C$, it increases linearly until the discontinuity region at about 30km in the crust before the shift in direction in the mantle part of the lithosphere as shown in figure 1. The discontinuity occurred along the boundary between the crust and mantle, between (30-40) Km depth and temperature is above $825°C$, this is Mohorovicic discontinuity region, it represents region of compositional changes and changes in mineral structures (phase changes and the P-wave velocity increases at that boundary). In the crustal part, the temperature increased at $10.0°C$ per kilometer and the rate of increase in the upper mantle part is 6.3°C per kilometer.

Table 1: Values of Computed Temperature Profile in the Lithosphere

Depth, Z (Km)	0	10	20	30	40	50	60	70
Temperature, T °C	27.0	127.0	227.0	327.0	795.8	858.3	920.8	983.3

Depth, Z (Km)	80	90	100	110	120	130	140	150
Temperature, T °C	1045.8	1108.3	1170.8	1233,3	125.8	1358.3	1420.8	1483.3

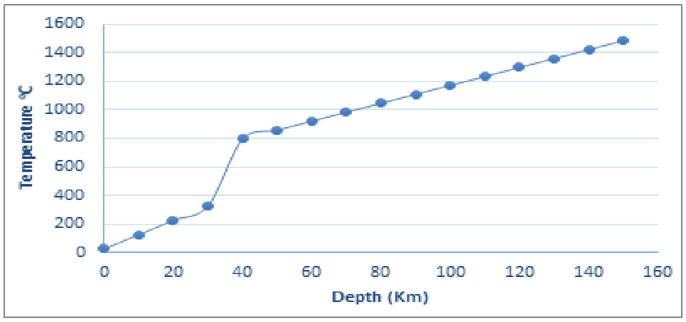

Fig 1: Temperature against Depth

The temperature at depths between (100 and 140) km ranged between $1170.8°C$ *and* $1420.8°C$ can be compared with the work of Anderson, (1980); Verhoogen, (1980) in which the temperature at depths between (100 and 140) km ranged between $1200°C$ *and* $1440°C$. The temperature at the base of the lithosphere in this work was $1483.3°C$, this value falls within the range $1280°C$ *and* $1600°C$ as given by Watt, (2007); William, (2007); Claude, (2007) respectively.

Conclusion: The past work had revealed the temperature profile for the lower mantle down to the core. In this work, the temperature profile for the lithosphere from the surface to depth of 150 km ranged between $27.0°C - 1483.3°C$. The results were within some standard values as stated in the literature.

REFERENCES

Anderson, OL, (1980). Temperature profile in the Upper Mantle earth. *Journal of Geophysics Research, volume 85, 7003 – 7010*

Anthony, BW, (2007). Crustal and Lithosphere Dynamics: Elsevier. Volume 6, Oxford University of Oxford, Oxford U. K.

Chloe, M; Claude, J (2007). Secular cooling and thermal structure of continental lithosphere: *Earth Planetary Sci. Let. 257 83–96*

Clauser, C; Huengens, E (1995). *Thermal Conductivity of rocks and minerals. In Ahrens pp 105 – 126*

Dziewonski, AM; Hales, AL; Lapwood, ER (1975). *Parametrically simple earth models consistent with geophysical data. Physic. Earth Planet Interiors 10. 12 - 48.*

Jeanloz, R; Richter, FM (1979). Convection, composition, and the thermal state of the lower mantle, *J. Geophysics Res. 84, 5497 – 5504*

Jean-Paul P (2000). The Physics of the Earth Interior Edition Cambridge University Press 2nd Edition Jean-Paul Poirier.

Stacey, FD (1977). A thermal model of the Earth. Phys. Earth Planet Int.

Verhoogen, J (1980). *Energetics of the Earth, Nat. Acad. Sci., Washington, D.C*

William, L (2007). Fundamentals of Geophysics second edition. Cambridge University Press.