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Radiometric Survey of River Osun-Osogbo in Osun State of Nigeria

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Abstract: Survey for radiometric minerals has become important over the last few decades because of the demand for alternative to present common source of energy. Radiometric survey is one of the geophysical techniques in use in exploration for geothermal energy, which is generated mainly from the decay of long-lived radioactive isotopes. Ten fresh rock samples were collected from Osun-Osogbo river. This is to determine their radioactive heat production and the contribution of each radionuclide content. The radiogenic heat production was determined in the laboratory using NaI(Tl) gamma-ray spectrometer. The results shows that the contribution and rate of heat production of ^{40}K, ^{238}U and ^{232}Th in the samples vary significantly with lithology. (rock type) and rock samples OS4 (mica) is associated with high heat production uranium.

Key words: Radiogenic heat, radionuclide, gamma-ray spectrometer, photopeaks, geothermal energy

INTRODUCTION

The Earth's internal heat derives from several sources but there are 2 main sources. One of the sources is the cooling of the Earth since its early history, when internal temperature were much higher than they are now. The other source is the heat produced by the decay of long-lived radioactive isotopes. This is the main source of the Earth's internal heat, which in turn, powers all geodynamic processes (Philip, 2005). The Earth is constantly losing heat from its interior, which is many times larger than the energy lost by other means, such as the changes in Earth's rotation and energy released in earthquakes. The interior of the Earth is losing heat viz geothermal flux at a rate of about 4.4×10^3W, which is which is equivalent to 1.4×10^{21}Jyr^{-1}.

Geophysical methods play a key role in geothermal exploration. The geophysical surveys are directed at obtaining indirectly, from shadow depth, the physical parameters of the geothermal systems. The various geophysical techniques in use in exploration for geothermal energy include subsurface (Shallow) temperature measurement (Lachenbrunch and Sass, 1977; Kintzinger, 1956; Lee, 1977; LesSchach and Lewis, 1983; Ranmingwong *et al*., 2000); Geochemical thermometric method (Sigvaldason, 1973; Rajver, 2000). Electrical methods (Bandwell and MacDonald, 1965; Anderson and Johnson, 2000; Pertamina, 1997; Tripp and Ros, 1997); Magnetolluric methods (Johnson, 1992; Ushijima *et al*., 2000); Gravity method (Johnson, 1995; Sumintadireje *et al*., 2000) Aeromagnetic and magnetic surveys (Reynolds *et al*., 1990; Salem *et al*., 1999, 2000); Sesmic Method (Keller, 1981; Rajver *et al*., 1996) and Radioactive Method (Pasquale *et al*., 1997; Louden and Mareschal, 1996). Each of these methods has its own advantages and disadvantages. Some lack the maturity under difficult conditions while others become less useful for deep exploration because of lack of sensitivity. Considering the limitations of the various methods, it is probably necessary to use an integrated geophysical approach employing a wide variety of techniques.

Non renewable energy sources like the fossil fuels (Crude oil, natural gas, coal, coke, etc) are daily depleting fast. As a matter of expediency, there is a strong need to replace non renewable energy sources with alternative renewable sources. This is the strong impetus for this current study on geothermal exploration.

In this study, we use the radioactive method, which involves measuring the concentration of radioactive elements: Potassium (^{40}K), Uranium (^{238}U) and Thorium (^{232}Th), using Gamma-ray spectrometer. The gamma-ray spectrometry method is widely use in Earth's Sciences for the determination of naturally occurring radioactive materials. Heat produced by radioactive decay in rocks is of the fundamental importance in understanding the thermal history of the Earth and interpreting the continental heat flux data (Chiozzi *et al*., 2000, 2007).

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Theory: Energy released by short-lived radioactive isotopes may have contributed to the initial heating, but the short-lived isotopes would be consumed quite early. The heat generated by long-lived isotopes has been an important heat source during most of Earth's history.

In order to be a significant source of heat a radioactive isotope must have a half-life comparable to the age of the Earth, the energy of its decay must be fully converted to heat and isotope must be sufficiently abundant. The main isotopes that fulfill these conditions are ^{238}U, ^{235} U, ^{232}Th and ^{40}k. The isotope ^{235}U has a shorter half-life than ^{238}U and release more energy in its decay.

The heat Q, produced by radioactivity in a rock that has concentrations C_u, C_{Th} and C_K, respectively, of these elements is

$$Q = 0.00348C_K + 95.2C_U + 25.6C_{Th} \text{ (Rybach } et\ al.\text{, 1988)} \qquad (1)$$

Heat can be transported by three process: Conduction, convention and radiation; conduction and convention require the presence of a material; radiation can pass through space or a vacuum. Conduction is the most significant process of heat transport in solid materials and thus it is very important in the crust and Lithosphere. However, it is an inefficient form of heat transport and when the molecules are free to move, as in fluid or gas, the process of convention becomes more important. Although the mantle is solid from the standpoint of the rapid passage of seismic waves, the temperature is high enough for mantle to act as a viscous fluid over long time intervals (Philip, 2005) consequently, convection is more important form of heat transfer than conduction in mantle. Convection is also the most important form of heat transport in the fluid core.

MATERIALS AND METHODS

Ten fresh rock samples were collected from different location of Osun-Osogbo river in Osun State, Nigeria. The rock samples were crushed to fine grains to minimize self-bsorption and to have geometry and matrix. Each sample was carefully packed in a 391 g plastic container, sealed and weighed. They were then left for thirty days in order for gaseous members of Uranium and Thorium series reach secular equilibrium before counting.

Natural radionuclide of relevance for the radiognic heat production are mainly ^{40}K and gamma-ray emitting nuclei in decay series of ^{238}U and ^{232}Th Gamma radiation analysis allows various gamma emitter to be distinguished and the quantitative content of potassium. Uranium and thorium to be calculated. Concentration of ^{40}k, ^{238}U and ^{232}Th are determined in the laboratory through spectrometry of emitted gamma rays using a cylindrical NaI(TI) scintilator. The detector used is 7.6 by 7.6 cm NaI(TI) detector (model No 802 series) by Canberra Inc. the gamma rays, which interact with the scintillator are converted into quanta of visible light, which can be detected with a photomultiplier produces voltages pluses with height proportional to the energy of the gamma rays. These pluses are amplified and fed to a multichannel analyzer (Canberra series 10 multichannel analyzer). All the samples were counted for 18000 sec, as this was considered adequate for measurement of the low activity of the samples. The efficiency and quantitative calibration of the apparatus was determined using a standard material prepared from Rocketdyne laboratories. Califonia, USA. The photopeak area values were converted into concentration in Bqkg^{-1} and then later to part per million (ppm). These concentrations in ppm were used for determination of the radiogenic heat production was calculated using Rybach (Eq. 1) where C_U C_{Th} and C_k are concentration in ppm of uranium, thorium and potassium, respectively. Multiplying the radiogenic heat production values by the rock density gives the radiogenic heat generated in cubic meter of the rock (Wm^{-3}).

RESULTS AND DISCUSSION

The total heat production represents the summation of the three isotopes for each sample and is a comprehensive parameter to reflect the rate of radiogenic heat rock samples (Table 1).

The radiogenic heat contribution of the isotopes ranges from 0.04 to 3.35×10^{-6} Wm^{-3} for ^{40}k, 0.13-5.26×10^{-6} Wm^{-3} for ^{238}U and 0.04-2.75 Wm^{-3} for ^{232}Th (Table 2). Overall result shows that uranium has the highest radiogenic heat contribution, which is in support of (Stacey, 1994; Stacey and Loper, 2007) results.

Mica (OS4) has the highest radiogenic heat production with the highest contribution from the isotopes. This is in support of the earlier work carried out by Alabi (2007) on rock samples from three different rivers of different location in Osun State. It is also observed that Mica is associated with high radiogenic heat contribution from uranium. Mica is closely followed by amphibolites, however, Mica has greater radiogenic heat production than amphibolites with approximately multiple of three folds.

Quartz is expected to have the highest radiogenic heat but it is found to ranked ninth, this is likely due to geological location because radiogenic heat contributions are unequal and different in the ocean and continent (Bott *et al.*, 1982).

Table 1: Isotopic concentrations and radiogenic heat production in samples collected from Osun-Osogbo River

		Concentration (ppm)			Heat production (10^{-11}Wkg^{-1})			
Sample code	Lithology	^{40}K,	^{238}U,	^{232}Th	Potassium	Uranium	Thorium	Total
OS1	China clay	3428.72	0.79	0.87	11.93	74.81	22.29	109.03
OS2	Glauconite	462.07	0.17	0.30	1.61	15.96	7.71	25.28
OS3	Shale	2007.75	0.05	0.77	6.99	4.71	9.82	31.52
OS4	Mica	34370.56	1.97	3.83	119.61	187.41	98.08	405.10
OS5	Pegmatite	24764.86	0.50	0.15	86.18	47.85	3.80	137.83
OS6	Muscovite	31529.80	0.22	0.10	109.72	21.30	2.65	133.83
OS7	Quartz	1208.74	0.20	0.05	4.21	19.31	1.30	24.82
OS8	Synite	728.18	0.38	1.00	2.53	35.99	82.84	121.36
OS9	Amphibolite	28778.73	0.34	1.26	100.15	32.13	32.21	164.49
OS10	Mica	8504.87	0.81	0.24	29.60	77.03	6.02	112.65

Table 2: Radiogenic heat production in samples collected in micro watts per meter cube

			Heath production (10^{-6} Wm^{-3})			
Sample code	Lithology	Density (Kgm^{-3})	Potassium	Uranium	Thorium	Total
OS1	China clay	2750	0.33	2.06	0.61	3.00
OS2	Glauconite	2700	0.04	0.43	0.21	0.68
OS3	Shale	2710	0.19	0.13	0.54	0.86
OS4	Mica	2800	3.35	5.25	2.75	11.35
OS5	Pegmatite	2740	2.36	1.31	0.10	3.77
OS6	Muscovite	2700	2.96	0.58	0.07	3.61
OS7	Quartz	2900	0.12	0.56	0.04	0.72
OS8	Synite	2700	0.07	0.97	2.24	3.28
OS9	Amphibolite	2640	2.64	0.85	0.85	4.34
OS10	Mica	2800	0.83	2.16	0.17	3.16
		Total	12.89	14.30	7.58	34.77

CONCLUSION

The concentration and radiogenic heat production by the 3 isotopes for each sample vary significantly. Highest concentration and heat contribution is recorded in Mica. Mica has greater heat production than Quartz, which is contrary to expectation; this might be as a result of geological location. Thus, Mica rock samples from the river produce more heat than any other rock type and they are associated with high heat contribution from uranium isotope.

REFERENCES

Alabi, O.O., 2007. Radiogenic heat production of Rocks from 3 Rivers in Osun State of Nigeria. J. Applied Sci. Pak., 7 (12): 1661-1663.

Anderson, D.L. and G.R. Johnson, 2000. Application of the Self Potential Method to Geothermal to Geothermal Exploration in Long Valley, California, Geophysics, 38 (6): 1190-1190.

Bott, M.H.P., G.A.L. Johnson, J. Mansfield and J. Wheilden, 1982. Terrestial Heat Flow in North-East England. Geophys. J. Astr. Soc., 27: 277-288.

Bandwell, C.J. and W.J.P. MacDonald, 1995. Resisitivity Survey in New Zealand thermal areas. Eight Commonwealth mining and metallurigical Congress, Australia and New Zealand, New Zealand Section, pp: 1-7.

Chiozzi, P., V. Pasquale and M. Vedoya, 2000. Ground Radiometric Survey of U, Th and K on Lipori Island, Italy. J. Applied Geophys., 38: 207-217.

Chiozzi, P., V. Pasquale and M. Vedoya, 2007. Radiometric Survey for Exploration of Hydrothermal Alteration in Volcanic Sites. J. Geophys., 93: 13-20.

Johnson, D.J., 1995. Gravity Changes on Mauna Loa Volcano in Mauna Loa Revealed Structure, Composition, History and Hazards, Geophysical Monograph, 92, Rhodes J.M. and John. P. Lockwood (Eds.). AGU, Washington, D.C., pp: 127-143.

Johnson, J.M., L. Pellirin and G.W. Hohmann, 1992. Evaluation of Electromagnetic Methods for Geothermal G Reservoir Detection. Geothermal Resources Council Translation, 16: 241-245.

Keller, G.V., 1981. Exploration for Geothermal Energy. In: Fitch, A.A. (Ed.). Developments in Geophysical Exploration. Method-2 Applied Sci. Publ., pp: 107-150.

Kintizinger, P.R., 1956. Geothermal Survey of hot ground near Lordsburg. New Mexico: Sci., 124: 629-630.

Lachenbruch, A.H. and J.H. Sass, 1977. Heat flow in the United States and thermal regime of the Crust, the earth's crust, its nature and physical properties. Heaecock, J.G. (Ed.). AGU Monograp., 20: 626-675.

Lee, T.C., 1977. On Shallow-hole temperature measurements. A test study in the Salton Sea Geothermal Field: Geophysics, 42: 572-583.

Leschack, L.A. and J.E. Lewis, 1983. Geothermal propspectin with Shallo-Tem Surveys. Geophysics, 48 (7): 975-996.

Louden, K.E. and J.C. MaresChal, 1996. Measurements of radiogenic heat production on basement samples from sites 897 and 900. In: Whitmarsh, R.B., Sawyer, D.S., Klaus, A. and Masson, D.G. (Eds.). College Stattion, Tx (Ocean Drilling Program). Proc. ODP, Sci. Results, 149: 675-682.

Pasquale, V., M. Verdoya, P. Chiozzi, R. Cabella and D. Russo, 1997. Thermo physical properties of the Lapari lavas (Southern Tyrrherian Sea). Annal Di. Genocidal, XL (6): 1493-1503.

Pertamania, 1997. Liporan Mingyuan Pemboran Sumur. Report for Geothermal Division, Jakarta, pp: 1-4.

Philip, A.O., 2005. An Introduction to Geophysical Exploration. Mc Graw-Hill, New York, 70: 63ND-89ND.

Rajver, D., 2000. Geophysical exploration of the low enthalpy Krsko Geothermal Fields, Slovenian. Proceeding W.G.C., Japan, pp: 1605-1607.

Rajver, D., A. Gosar and M. Zivanoric, 1996. Geothermal Energy Resources in Triassic. Aquifers in the Krsko-Brezice basin. Report for the Ministry of Science and Technology, Ljubljana (In Slovenian), pp: 22-22.

Ramingwong, T., S. Lertsrimongkol, P. Asnachinda and Praservdigai, 2000. Update on Thailand Geothermal Energy Research and Development. Processing W.G.C. Japan, 30: 29-68.

Reynolds, R.L., J.G. Rosenbaun, M.R. Hudson and N.S. Fishman, 1990. Rock Magnetism, the distribution of Magnetic Minerals in the Earth's Crust and Aermagnetic anomalies. In: Hanna, W.F. (Ed.). Geologic Applications of Modern Aeromagnetic Surveys: U.S. Geol. Survey Bull., 1924: 24-45.

Rybach, K., R. Hokrick and W. Eugester, 1988. Vertical Earth Heat Probe Measurements and Prospects in Switzerland in Communication and Proceedings, Paris, 1: 367-372.

Salem, A., A. Elsirafi and K. Ushihima, 1999. Design and Application of high- resolution aeromagentic survey over Gebel Duri area and its extension, Egypt. Memories of the Graduate School of Engineering, Kyushu University, 59 (3): 201-203.

Salem, A., K. Ushijima, A. Elsirafi and I. Mizunaga, 2000. Spectral Analysis of Aeromagnetic Data for Geothermal Reconnaissance of Quesri Ara, Northern Red Sea. Egypt. Proc. W.G.C. Japan, 4: 873-876.

Sigvaldason, G.E., 1973. Geochemical method in geothermal exploration. UNESCO., pp: 49-49.

Suminatadireja, P., S. Sudarman, H. Mizunaga and K. Ushijima, 2000. Mise-al-masse and Gravity Data Surveys at the Kamojang Geothemal Filed, Proceedings. W.G. Japan, pp: 1777-1780.

Stacey, F.D., 1994. Modes of Mantle Convection and the removal of Heat from the Earth's interior. J. Geophys. Res., 87: 4682-4696.

Stacey, F.D. and D.E. Loper, 2007. Physics of the Earth and Planetary Interiors. Science, 16: 13-18.

Tripp, A.C. and H.P. Ross, 1997. SP modeling U.S. Department of Energy, Geothermal Energy Technical Site, pp: 234-239.

Ushijima, K., K. Tagomori and W.H. Relton, 2000. 2D Inversion of VES and MT data in Geothermal Area. Proceedings W.G.C. Japan, pp: 1909-1914.