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Determination of Source of Gold around Itagunmodi Southwest, Nigeria

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Abstract

The source of gold mineralization had been a subject of proposal in the past; some researchers suggested its original source to be the crust while some proposed the source as the mantle. In this study, the source of gold in Itagunmodi was the main objective. The melting temperature of gold and the variation of melting temperature with increase in pressures were determined from melting temperature equations and the values were correlated with the stress in the lithosphere to determine the source. At high values of pressures, the gold melts at higher temperatures. The melting temperatures ranged between $1064\ ℃$ to $1394.3\ ℃$ while pressure ranged between $2605.68 - 2931.39\ MPa$, $(i.e\ 26 - 29\ Kbar)$. When merged with the temperature and stress field in the Earth, its shows that the source of gold mineralization around the location is the mantle part of the lithosphere and this can serve as the baseline to the source of gold which was believed to originate from the mantle.

Keywords: Gold Mineralization; Melting Temperature; Pressure; Lithosphere

INTRODUCTION

There are several hypotheses that was proposed to describe the source of the mineral elements that form lode deposits as stated by Harold *et al.*, (1997. A lot of works has been carried out on gold which includes: Melting of gold using piston cylinder apparatus with a high-pressure cavity by Jagannaddham and George, (1971). Temperature effects on the universal equation of state of solids according to Pascal *et al.*, (1987), the determination of the Critical point of gold, using pressure vessel as studied by Boboridis *et al.*, (1999), their results for temperature, pressure and specific volume at the critical point are as follows: $T_C = 7400 \pm 1100\,K$, $P_C = 530 \pm 20MPa$ and $V_C = 0.13 \pm 0.03 \times 10^{-3} m^3.kg^{-1}$.Geochemistry of gold in Sediment Hosted Disseminated Gold (SHDG) mineralization was studied using Rock-eva analysis as studied by Zhiwei, (2001). Bello (2012) carried out electrical resistivity survey on area suspected to have gold deposit while Abdullah *et al.*, (2008) carried work on the effect of strain rate on ultra-fine gold wire. Colins (2014); construct stress-strain curves of gold thin films using force and displacement data and reported that the strain rates ranged from 10^{-6} s^{-1} to 10^{-3} s^{-1}. The stress-strain response of gold thin film was studied by Gudlavalletti *et al.*, (2002) while Espinosa and Prorok, (2003) carried out the studies on gold thin films. Also, Li (2003), reported the values for bulk modulus and yield strength on thin films gold. The measurement of strain rates for polycrystalline tantalum ranged from $10^{-4}\ to\ 10^{+4} s^{-1}$ was reported by Hoge and Mukherjee, (1977).The strain rate for copper and aluminum crystals using multiscale model was investigated by Shehadeh *et al.,* (2005).There is scanty information about temperature profile in the Lithosphere, the available temperature profile covers the depth from 100Km in the upper mantle to deeper depths. Among notable research carried out on stress include the origin of tectonic stress Bott and Kusznir, (1984), stress in the lithosphere as reported by (Zoback and Zoback, 2002) that in situ stress measurements and inferences based on topography and flexure suggested that shear stresses in the upper lithosphere are fairly large and are controlled by the frictional strength of the faulted crust. Michael *et. al.,* (2022) stated that when searching for gold in stream sediments, it is frequently more efficient to look for the geographical distribution of gold-associated mineral components rather than for gold itself, as gold is frequently found in association with other elements. Asubiojo et al., (2022) carried out controlled method of determine gold mineralization potentials in an unexploited area; a case study of Itagunmodi and Osu, Southwest, Most metallic ores occur as big solid minerals that can easily be mined, it was observed that the samples for the study were in form of grain that made the mining process to be stressful than the big solid rock mineral type. The mining process involves panning; these are used to separate gold from other mixtures such as Au-Ag, Cu-Au deposits. In this work the thermodynamic properties of gold deposits from Itagunmodi, Southwest Nigeria and the temperature profile in the lithosphere was used in the determination of its depth at the source.

The Geology of gold

Researchers have proposed various hypotheses to explain the source of solutions from which mineral constituents are precipitated in lode deposits. One widely accepted hypothesis proposes that many gold deposits, especially those found in volcanic and sedimentary rocks were formed from circulating ground waters driven by heat from bodies of magma intruded into the Earth's crust within about 2 to 5 miles of the surface. As the water is heated, it dissolves metals from the surrounding rocks. When the heated waters reach cooler rocks at shallower depths, metallic minerals precipitate to form veins or blanket-like ore bodies Harold, *et al.,* (1997).Another hypothesis suggests that gold-bearing solutions may be expelled from magma as it cools, precipitating ore materials as they move into cooler surrounding rocks Harold, *et al.,* (1997). This hypothesis is applied particularly to gold deposits located in or near masses of granitic rock, which represent solidified magma. A third hypothesis is applied mainly to gold-bearing veins in metamorphic rocks that occur in mountain belts at continental margins. This hypothesis suggests that when water is expelled from the rocks and migrates upwards, there is precipitation of ore materials as pressures and temperatures decrease Harold, *et al.,* (1997). The main aim of the work is to determine the source of gold deposits around Itagunmodi Southwest Nigeria using temperature profile.

Theoretical Background

Determination of melting curve temperatures

The melting temperature T_m and volume of a solid phase $\Delta V/V_0$ can be related by the equation:

$$T_m = T_m{}^0\{1 + C[\Delta V/V_0]\} \quad (1)$$

The melting curve temperature was obtained from the equation below:

$$t = t_0 + b_1 P + b_2 P^2 + b_3 P^3 \quad (2)$$

where b_1, b_2 and b_3 respectively are constants called melting-curve parameters. This show that the melting point of the materials increases with increase in pressure

Determination of Stress in the Lithosphere

The model proposed from Heim's rule that the assumption of a lithostatic state as we penetrate deeper into the Earth's crust was applied in calculation of stress from the surface to the depth of the lithosphere. The stress is given by the equation stated below:

$$P(z) = \int_0^Z \rho(z) g dz = \rho g z \quad (3)$$

Where g is the gravitational acceleration and z is the depth within the Earth's crust, while ϱ is the density of the layers of the Earth and P is the stress.

Results

The table below represent melting curve parameters that was used to determine the melting temperature of gold around Itagunmodi with variation in pressure

Table 1: Melting-Curve Parameters

b_1	b_2	b_3
$5.43561.0753 \times 10^{-2} - 2.4927 \times 10^{-4}$		

Where b_1, $b_2$and b_3 respectively are constants called melting-curve parameters after (Jagannadham and George, 1971).

The melting temperatures for gold around Itagunmodi area using equation (equation 2) with melting-curve parameters when varying the pressures are shown below;

Table 2: Melting Temperatures for Itagunmodi Gold at Varying Pressures

$\boldsymbol{P(Kbar)}$	T/ °C
0	1064.0
5	1091.4
10	1118.9
15	1147.1
20	1175.0
25	1202.7
30	1230.0
35	1256.7
40	1282.7

45	1307.7
50	1331.5
55	1354.0
60	1375.0
65	1394.3

Table 2 showed that the melting temperature of the unrefined gold from Itagunmodi increased within pressure which means a particular gold sample will melt at higher value whenever pressure is raised and vice versa. This means from the source where it originated from it exist in solid mass but due to transitional changes and hydrothermal fluid motion, the gold in this area were found in grained form. The table below shows the stress and temperature in the lithosphere

Table 3: Temperature Profile in the lithosphere

$Depth\ (Km)$	T (°C)	$P\ (MPa)$
0	27.0	0.00
10	127.0	275.30
20	227.0	550.50
30	327.0	825.70
40	795.8	1302.80
50	858.3	1628.60
60	920.8	1954.30
70	983.3	2280.00
80	1045.8	2605.70
90	1108.3	2931.40
100	1170.8	3257.10
110	1233.3	3582.80
120	1295.8	3908.50
130	1358.3	4234.20
140	1420.8	4559.90
150	1483.3	4885.70

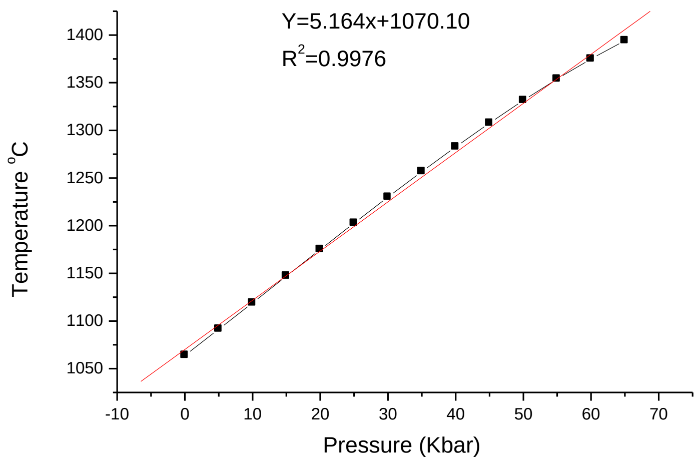

Figure 1: Melting Temperatures against Pressures for Gold from Itagunmodi

DISCUSSION

The melting temperatures for gold around Itagunmodi using the equation with melting-curve parameters, table 2, show that increase in pressure raised the melting point of this gold sample which means the gold sample will melt at higher temperatures and pressures. The melting curve equation show that the melting temperatures ranged between $1064\ ℃$ to $1394.3\ ℃$ in the pressure ranged between 0 to 65$Kbar$ (i.e. $0 - 6500\ MPabar$), The melting temperatures for gold using the equation with melting-curve parameters show that increase in pressure raised the melting point of unrefined gold as shown in Table 2, which means the metal will melt at higher temperatures with increase in pressures which show that the gold is in solid state at that depth in the mantle which was its original source in the mantle before they were brought to shallow depth in the subsurface by intrusion process. However, the hydrothermal fluid motion transport the metal to different location at various depth in the shallow region in the subsurface and as a result, this sample are found scattered in the form of fine grains in its new location.

After all the observations from the laboratory analyses and by examining the depth in the lithosphere, we can draw the inference that gold originated from the mantle, if we correlate the melting point of the gold samples $(1064\ ℃)$ with the temperature profile, it corresponds to depth ranged from$80 - 90\ Km$ in the upper mantle part of the lithosphere with pressure in the ranged $2605.68 - 2931.39\ MPa$, $(i.e\ 26 - 29\ Kbar)$, as shown in

Table 3, after this depth it was observed that the trend continues up to $150\ Km$.The melting point increased with rise in pressures, its effect will not allow the metal to be in another state of existence, the melting point also increase with increase in pressure and as a result, Itagunmodi gold existed as solid rock form at the depth from source. As a result of high pressure and temperature over time, the gold found in the area are being mine in the form of grained size.

CONCLUSION

The increase in pressure result to increase in melting temperature of gold, the material will melt at higher temperature which is greater than the laboratory melting temperature (1064°C). The stress profile in the lithosphere ranged between 0 – 49Kbar, the value falls within the pressure ranged for the melting temperature of the Itagunmodi gold deposits. In conclusion, when examining the depth in the lithosphere, we can draw the inference that the gold originated from the mantle.

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