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High Temperature and Pressure impact on Volume of Ore Deposits; Itagunmodi Gold Deposit, South West Nigeria as a Case Study.

Adetoyinbo A.A., Bello A.K. and Hammed O.S.

Abstract An understanding of the Earth's interior depends on information about the behavior and properties of matter under high pressures and temperatures. An equation of state that connects pressure (P), volume (V), and temperature (T) is very important. This work examines the impact of high temperature and pressure on the formation and maturity of sediment-hosted disseminated gold (SHDG) deposits in Itagunmodi, Osun State, Nigeria located in the clayey soil types derived from variably migmatised gneiss, biotite-and-biotite-hornblende-gneiss and weathered amphibolites respectively.The melting temperatures of gold were determined by differential thermal analyses. After application of appropriate correction for the effect of pressure on emf of thermocouples, the melting curves are linear with the isothermal volume of the melting solid to within the precision of the measurement. This melting point of gold at variable high temperature and pressure, if extrapolated could be used as a primary standard for measurements.

Key words Pressure, Temperature, Volume, thermal analyses, thermocouple

Introduction

A correct pressure scale is fundamentally important for interpreting geophysical observations using laboratory experimental data obtained at high pressure and temperature. Accurate determination of pressure at high temperature is more difficult because of large uncertainty in calculating thermal pressure. Gold (Au) has been extensively used as an internal pressure standard in high-pressure and high-temperature experiments. .Although, some investigations have been carried out on their geological and geochemical characteristics in general, most of the studies were based on limited database. The source and the nature of the gold in the deposits are still not clear, and these have been the major objectives of this study. This research work centered on sediment-hosted disseminated gold deposits in Itagunmodi Osun State, Nigeria.

Epithermal deposits of gold (± Ag) comprise veins and disseminations near the Earth's surface (≤1.5 km), in volcanic and sedimentary rocks, sediments, and, in some cases, also in metamorphic rocks. The deposits may be found in association with hot springs and frequently occur at centres of young volcanism. The ores are dominated primarily by precious metals (Au, Ag), but some deposits may also contain variable amounts base metals such as Cu, Pb, and Zn.

Epithermal Au deposits are a type of lode deposit [1] ; [2] consisting of economic concentrations of Au (± Ag and base metals). These deposits form in a variety of host rocks from hydrothermal fluids, primarily by replacement (i.e. by solution and reprecipitation), or by open-space filling (e.g. veins, breccias, pore spaces). The form of deposits originating by open-space filling typically reflects that of the structural control of the hydrothermal fluids (planar vs. irregular fractures, etc). The deposits are commonly young, generally Tertiary or Quaternary. They may be of similar age as their host rocks when these are volcanic in origin, or (typically) younger than their host.

'Epithermal' Au deposits are regarded to be primarily associated with continental volcanism or magmatism, although similar processes of ore deposition occur in other, near-surface environments

Adetoyinbo A.A.
Department of Physics, University of Ibadan, Nigeria

Bello A.K., and O.S. Hammed
Department of Physical Sciences, Bells University of Technology, Ota, Nigeria

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(e.g. seafloor volcanogenic massive sulphide (VMS) deposits, submarine volcanic arc systems, and non-volcanic vein deposits; see [3] ; [4]. These other deposits, especially those with similar characteristics from marine environments, may also be considered epithermal deposits in a broad sense. Many extensive reviews of epithermal deposits, among them [5], [6], [7], [8], [9], [10], [11], [12]and [13] have provided a wealth of background information.

Epithermal Au deposits are distinguished on the basis of the sulphidation state of the sulphide mineralogy as belonging to one of three subtypes: (1) high sulphidation (previously called quartz-(kaolinite)-alunite, alunite-kaolinite, enargite-Au, or high sulfur: [14]; [15]; (2) intermediate sulphidation [16]; or (3) low sulphidation (previously called adularia- sericite). High-sulphidation subtype deposits usually occur close to magmatic sources of heat and volatiles, and form from acidic hydrothermal fluids containing magmatic S, C, and Cl. Low-sulphidation subtype fluids are thought to be near-neutral, dominated by meteoric waters, but containing some magmatic C and S. In addition, some geologists also refer to 'hot-spring' deposits as an additional subtype of epithermal deposit that may form as surface expressions of hydrothermal systems, typically of the low-sulphidation subtype sometimes associated with acidic, steam-heated alteration zones. [17] , [18], [8] , [15] , [19] and [20]for discussions and original definition of these terms. [16] is recommended for a more recent and very comprehensive summary of current usage, classification, and deposit characteristics.

The study area is Itagunmodi, Osun State, southwest, Nigeria. It is located in the clayey soil types derived from variably migmatised gneiss, biotite-and-biotite-hornblende-gneiss and weathered amphibolites respectively.

The geology of the area is Precambrian basement complex gneisses, migmatites and Schist associated with amphibolites.

Location

Itagunmodi is located on latitude (DMS) $7^0 31'60''$ longitude (DMS) $4^0 39'0''$ and altitude (meters) 347 the time zone is east (est). The approximate population for 7km radius from this point is 12655. Itagunmodi is a town very close to towns such as: Ile-Ife, Ilesa and Modakeke all in Osun State, Nigeria.

The following figures 1(a-g) were some of the mining sites

Figure 1a: one of the mining sites

Figure 1b: one of the mining sites

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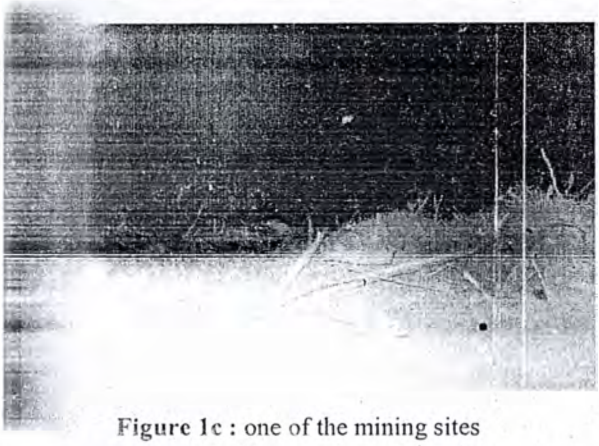

Figure 1c : one of the mining sites

Figure 1d: one of the mining sites

Figure 1e: one of the mining site

Figure 1f: one of the mining site

Figure 1g: one of the minig sites

Methodology

Determination of volume, temperature and pressure using fast capacitor-discharged circuit

Gold samples were placed in a new improved high-pressure vessel, which is part of a fast capacitor – discharged circuit and in which a static pressure above 600mpa can be reached with distilled water and pressure transmitting medium. The samples were self-heated resistivity by a current pulse. The voltage drops across it and the temperature were recorded as a function of time. The radial expansion of the sample was determined with a CCD camera. When the critical pressure was exceeded, no liquid gas phase transition

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was gained. The difference of the initial volume (V_0) and the final volume (V_1) of the sample was recorded at a particular temperature and time. The room temperature (T_0) and the final temperature (T_1) are equally noted as the temperature increased with time. The initial pressure (P_0) and the final pressure (P_1) are equally recorded. The intervals between the initial and the final values for volume, temperature and pressure was determined and recorded respectively. The samples was run three rounds at different temperature and time.

Note: T_0 and T_1 are the initial and final temperature respectively

Bulk modulus B in N/m² is further expressed as:

$$B = pressurex\frac{Vinitial}{Vchange} \quad \text{-------- (1.1)}$$

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

$$T_m = T_m^{\ 0}\{1 + C[\Delta V / V_c]\} \quad \text{------------ (1.2)}$$

Where C is the specific heat capacity of gold. The melting temperatures as a function of pressure have been determined to be 1064°C at a pressure of 530mpa by differential thermal analysis. The precision of the results is high. The determinations of these values at a given temperature agree within ± 2°

Results and Discussion

Physical Data

Mass of first sample -0.89g
Atmospheric pressures= 760mmHg
Appearance and color- yellow solid metal
Specific gravity-19.4
Odor –none
Melting point of sample-1064°C
Boiling point of sample=2967°C
Voltage drop-380V at 3.3 KW

Table of Values

Table 1 Values of Temperature, Volume and Pressure for Three Runs for First Sample

RUNS	TIME(HR)	TEMPERATURE (°C)		VOLUME ($m^3 kg^{-1}$)		PRESSURE (mpa)	
		T_0	T_1	$V_0 x10^{-3}$	$V_1 x10^{-3}$	P_0	P_1
1	18.00	42.00	1573.00	0.15	0.05	0.00	530.00
2	23.00	600.00	2928.00	0.15	0.05	0.00	545.00
3	28.00	626.00	4110.00	0.15	0.05	0.00	564.00

Table 1 represent the results of the analysis carried out on the first sample
T_0=42.00, P_0=0.00, V_0=0.150

Table 1a values of temperature, volume and pressure for 1st run (first sample)

Time (hr)	T (°C)	V x10^{-3}	V/V_0	P (mpa)
14.00	1223.40	0.138	0.920	412.20
15.00	1310.80	0.126	0.840	441.70
16.00	1398.20	0.110	0.733	471.10
17.00	1485.60	0.080	0.533	500.60
18.00	1573.00	0.050	0.333	530.00

T_0=600.00, P_0=0.00, V_0=0.150

Table 1b values of temperature, volume and pressure for 2nd run (first sample)

Time (hr)	T (°C)	V x10^{-3}	V/V_0	P (mpa)
19.00	2418.80	0.134	0.893	450.00
20.00	2546.10	0.122	0.813	473.90
21.00	2673.40	0.106	0.707	497.60
22.00	2800.70	0.100	0.667	521.30
23.00	2928.00	0.050	0.333	545.00

T_0=626, P_0=0.00, V_0=0.150

Table 1c values of temperature, volume and pressure for 3rd run (first sample)

Time (hr)	T°C	V x10^{-3}	V/V_0	P (mpa)
24.00	3522.90	0.130	0.867	483.40
25.00	3669.60	0.118	0.787	503.60
26.00	3816.40	0.108	0.720	523.70
27.00	3963.20	0.102	0.680	543.90
28.00	4110.00	0.050	0.333	564.00

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Table 2 Values of temperature, volume and pressure for three runs for second sample
Mass of second sample=0.95g
Table 2 represent the results of the analysis carried out on second sample

RUNS	TIME(HR)	TEMPERATURE(°C)		VOLUME($m^3 kg^{-1}$)		PRESSURE(mpa)	
		T_0	T_1	$V_0 x10^{-3}$	$V_1 x10^{-3}$	P_0	P_1
1	18.00	42.00	1575.00	0.16	0.06	0.00	535.00
2	23.00	600.00	2930.00	0.16	0.06	0.00	548.00
3	28.00	626.00	4115.00	0.16	0.06	0.00	565.00

T_0=42.00, P_0=0.00, V_0=0.160

Table 2a Values of temperature, volume and pressure for 1st run (second sample)

Time (hr)	T (^{0}C)	V x10^{-3}	V/V_0	P (mpa)
14.00	1225.00	0.148	0.925	416.10
15.00	1312:50	0.136	0.850	445.80
16.00	1440.00	0.120	0.750	475.60
17.00	1487.90	0.090	0.560	505.70
18.00	1575.00	0.060	0.375	535.00

T_0=600.00, P_0=0.00, V_0=0.160

Table 2b Values of temperature, volume and pressure for 2nd run (second sample)

Time (hr)	T (^{0}C)	V x10^{-3}	V/V_0	P (mpa)
19.00	2420.40	0.145	0.906	452.70
20.00	2547.80	0.132	0.825	476.50
21.00	2675.20	0.115	0.719	500.35
22.00	2802.60	0.110	0.689	544.80
23.00	2930.00	0.060	0.375	548.00

T_0=626, P_0=0.00, V_0=0.150

Table 2c Values of temperature, volume and pressure for 3rd run (second sample)

Time (hr)	T^{0}C	V x10^{-3}	V/V_0	P (mpa)
24.00	3522.90	0.130	0.867	483.40
25.00	3669.60	0.118	0.787	503.60
26.00	3816.40	0.108	0.720	523.70
27.00	3963.20	0.102	0.680	543.90
28.00	4110.00	0.050	0.333	564.00

Table3 Values of temperature, volume and pressure for three runs for third sample
Mass of third sample=0.92g
Table 3 represent the results of the analysis carried out on the third sample

RUNS	TIME(HR)	TEMPERATURE(°C)		VOLUME($m^3 kg^{-1}$)		PRESSURE(mpa)	
		T_0	T_1	$V_0 x10^{-3}$	$V_1 x10^{-3}$	P_0	P_1
1	18.00	42.00	1584.00	0.155	0.055	0.00	532.00
2	23.00	600.00	2929.00	0.155	0.055	0.00	546.00
3	28.00	630.00	4112.00	0.155	0.055	0.00	565.00

T_0=42.00, P_0=0.00, V_0=0.155

Table 3a Values of temperature, volume and pressure for 1st run (third sample)

Time (hr)	T (°C)	V x10^{-3}	V/V$_0$	P (mpa)
14.00	1224.20	0.143	0.923	413.80
15.00	1311.70	0.131	0.845	443.30
16.00	1399.10	0.115	0.742	472.90
17.00	1486.60	0.085	0.548	502.40
18.00	1574.00	0.055	0.354	532.00

T_0=600.00, P_0=0.00, V_0=0.155

Table 3b Values of temperature, volume and pressure for 2nd run (third sample)

Time (hr)	T (°C)	V x10^{-3}	V/V$_0$	P (mpa)
19.00	2419.60	0.139	0.896	451.00
20.00	2547.00	0.128	0.826	474.80
21.00	2674.30	0.111	0.716	498.50
22.00	2801.70	0.105	0.674	522.30
23.00	2929.00	0.055	0.355	546.00

T_0=626, P_0=0.00, V_0=0.155

Table 3c values of temperature, volume and pressure for 3rd run (third sample)

Time (hr)	T°C	V x10^{-3}	V/V$_0$	P (mpa)
24.00	3524.60	0.135	0.871	483.40
25.00	3671 40	0.123	0.794	504.50
26.00	3818.30	0.113	0.729	524.60
27.00	3965.10	0.108	0.697	544.80
28.00	4112.00	0.055	0.355	565.00

Table 4 values of temperature, volume and pressure for three runs for forth sample
Mass of forth sample=0.86g
Table 4 represent the results of the analysis carried out on the forth sample

RUNS	TIME(HR)	TEMPERATURE(°C)		VOLUME(m^{3}kg^{-1})		PRESSURE(mpa)	
		T_0	T_1	V_0x10^{-3}	V_1x10^{-3}	P_0	P_1
1	18:00	42.00	1570.00	0.145	0.045	0.00	528.00
2	23.00	600.00	2926.00	0.145	0.045	0.00	540.00
3	28.00	628.00	4100.00	0.145	0.045	0.00	562.00

T_0=42.00, P_0=0.00, V_0=0.145

Table 4a values of temperature, volume and pressure for 1st run (forth sample)

Time (hr)	T (°C)	V x10^{-3}	V/V$_0$	P (mpa)
14.00	1222.70	0.133	0.917	410.70
15.00	1310.00	0.121	0.834	440.00
16.00	1397.23	0.105	0.724	469.30
17.00	1484.70	0.075	0.517	498.70

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3.00	1572.00	0.045	0.310	528.00

0.00, P_0=0.00, V_0=0.145

4b values of temperature, volume and pressure for 2[nd] run (forth sample)

me (hr)	T (^{0}C)	V x10^{-3}	V/V_0	P (mpa)
9.00	2417.10	0.129	0.890	446.10
0.00	2544.30	0.118	0.814	469.60
1.00	2671.60	0.101	0.697	493.00
2.00	2798.80	0.095	0.655	516.50
3.00	2926.00	0.045	0.310	540.00

=628, P_0=0.00, V_0=0.145

4c values of temperature, volume and pressure for 3[rd] run (forth sample)

ime (hr)	T^{0}C	V x10^{-3}	V/V_0	P (mpa)
4.00	3514.30	0.125	0.862	481.70
5.00	3660.70	0.113	0.799	501.80
6.00	3807.10	0.103	0.710	521.90
7.00	3953.60	0.097	0.669	541.80
8.00	4100.00	0.045	0.310	562.00

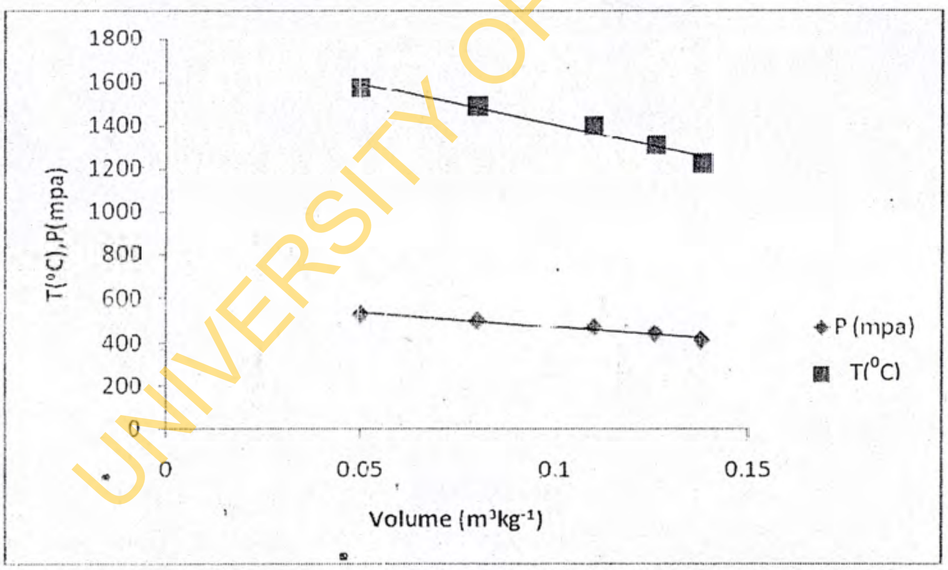

Figure 2 Graph of T,P against Volume for 1[st] run (first sample)

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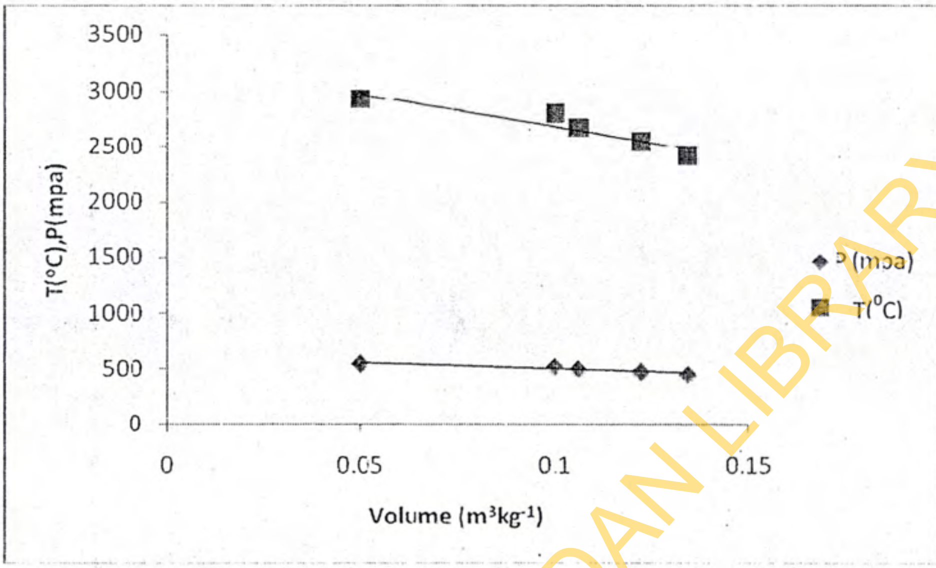

Figure 3 Graph of T,P against Volume for 2nd run (first sample)

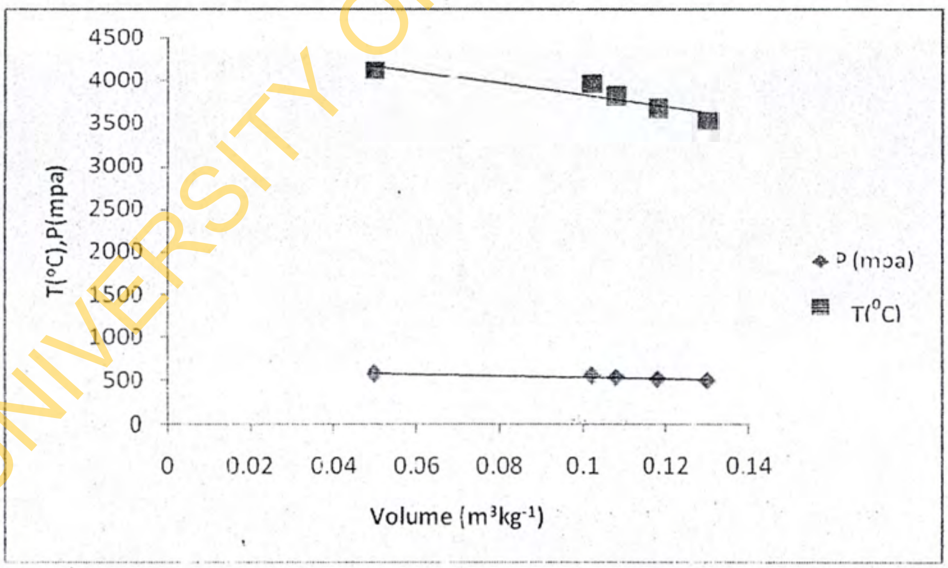

Figure 4 Graph of T,P against Volume for 3rd run (first sample)

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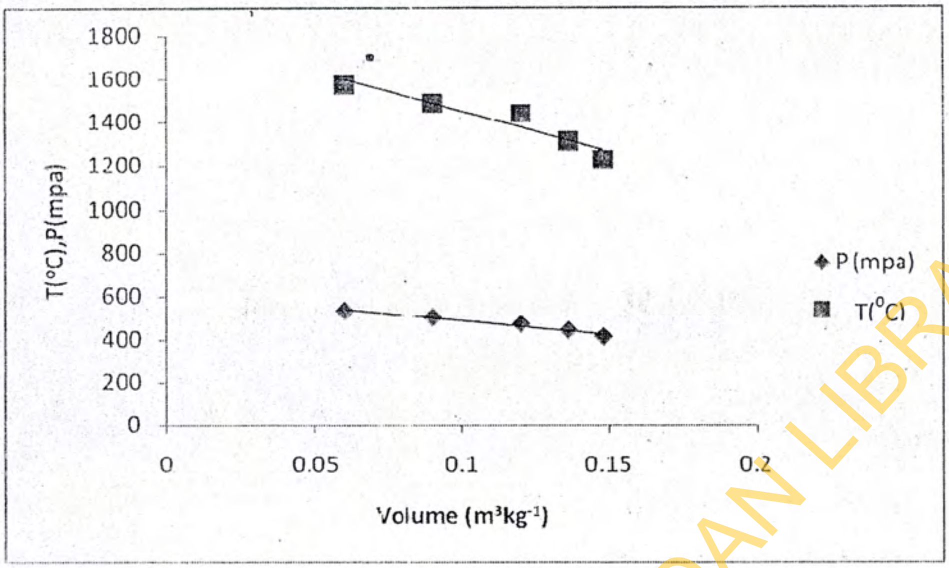

Figure 5 Graph of T,P against Volume 1st run (second sample)

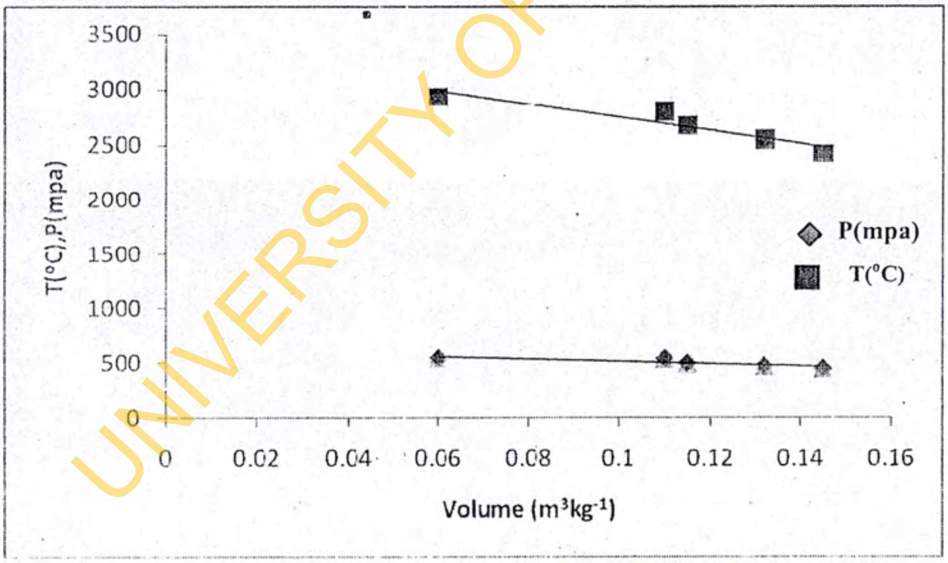

Figure 6 Graph of T,P against Volume for 2nd run (second sample)

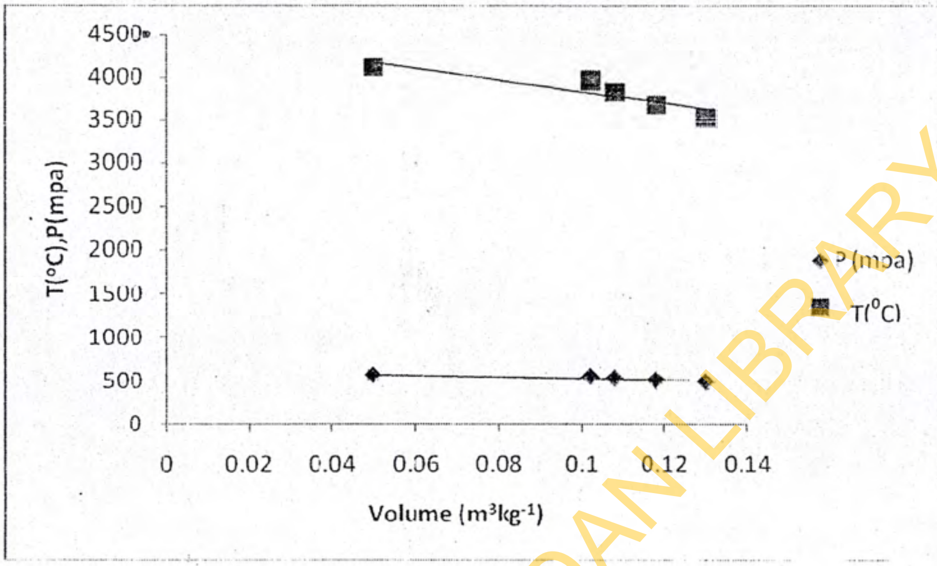

Figure 7 Graph of T,P against Volume for 3rd run (second sample)

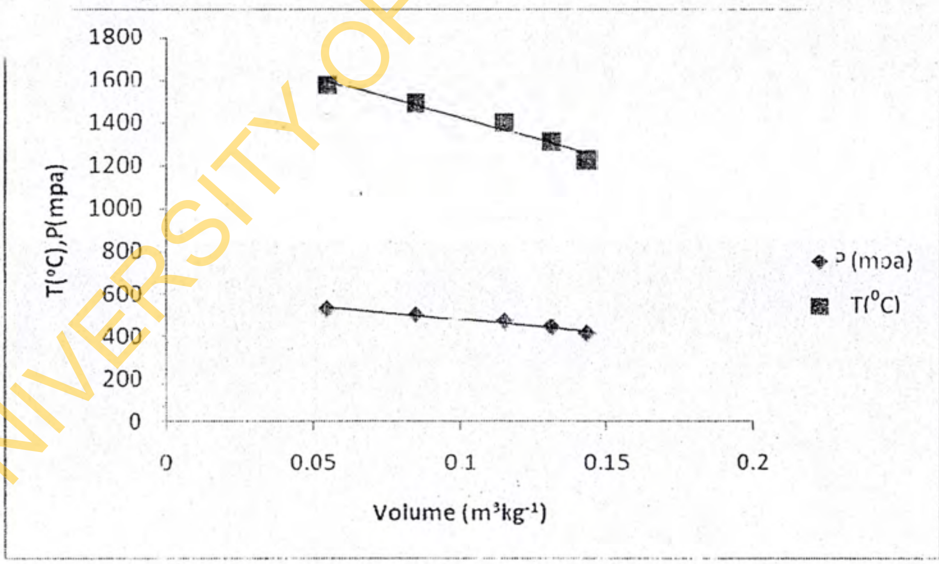

Figure 8 Graph of T,P against Volume 1st run (third sample)

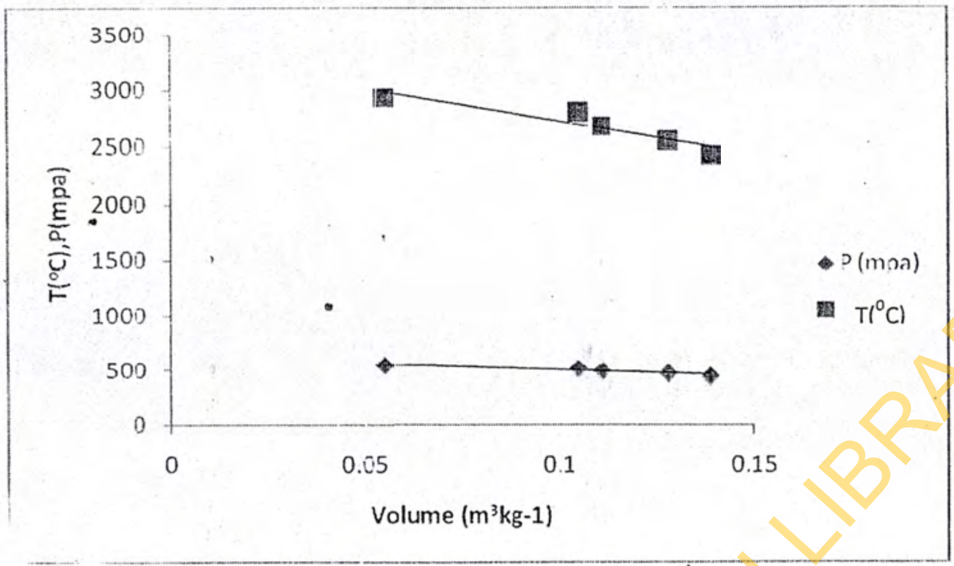

Figure 9 Graph of T,P against Volume for 2nd run (third sample)

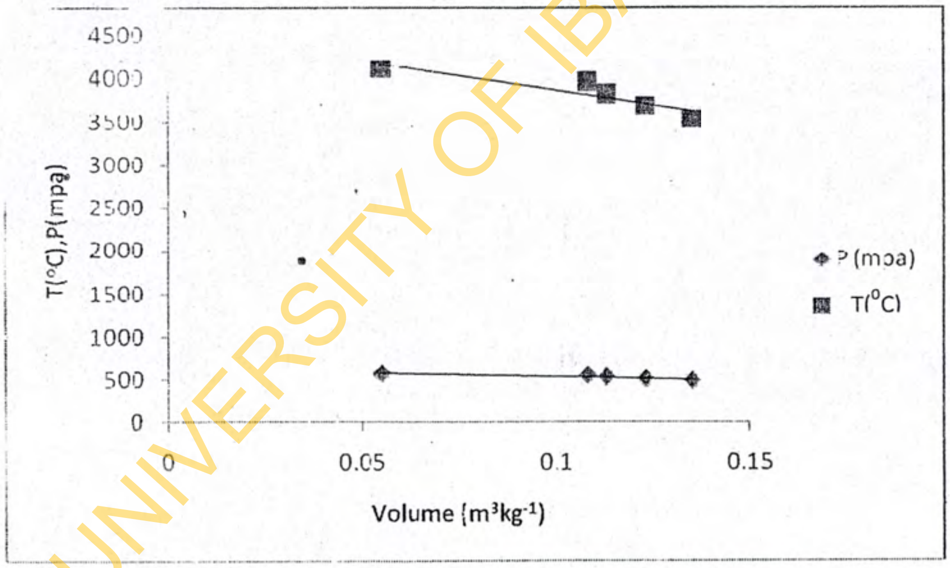

Figure 10 Graph of T,P against Volume for 3rd run (third sample)

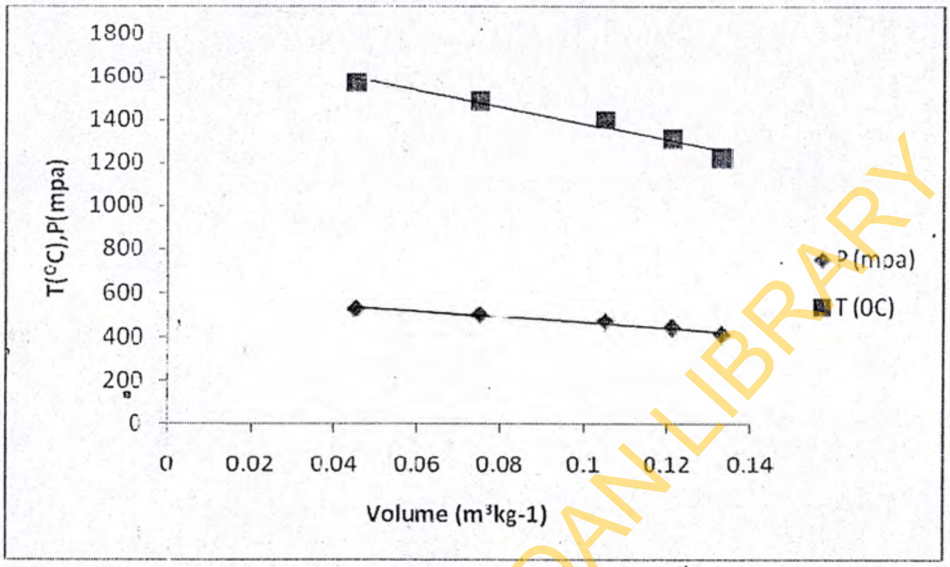

Figure 11 Graph of T,P against Volume for 1st run (forth sample)

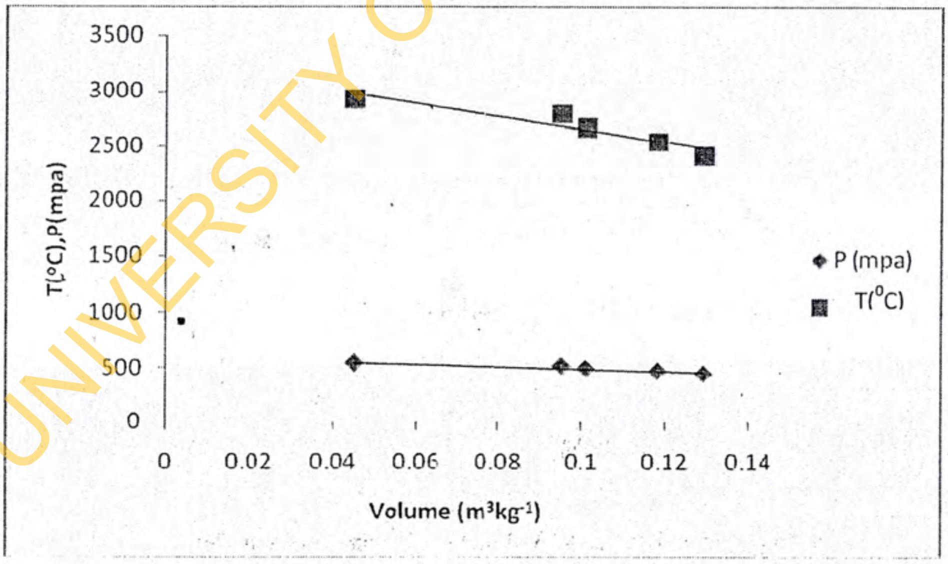

Figure 12 Graph of T,P against Volume for 2nd run (forth sample)

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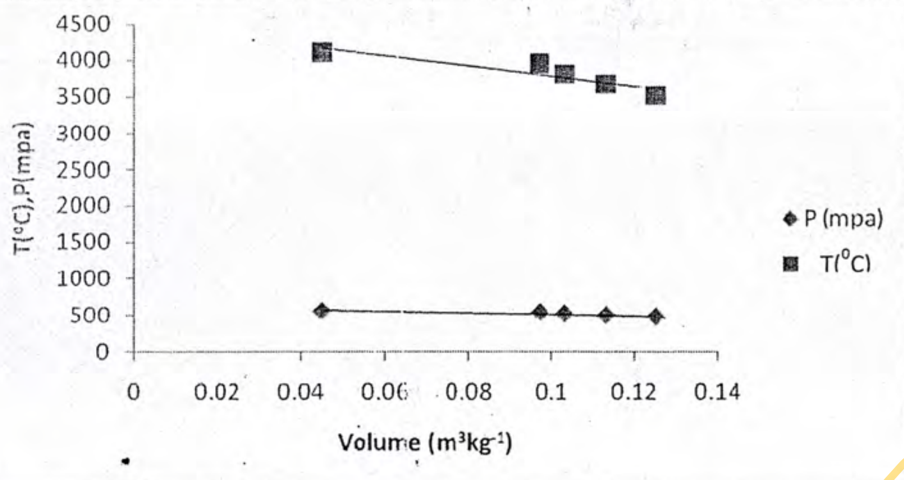

Figure 13 Graph of T,P against Volume for 3rd run (forth sample)

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1e melting point of the sample is 1064.0°C; the mental scatter of the determination was very about 2°C. The result is in agreement with the g point of pure gold.

t 1-atmospheric pressure, the melting point that served for the samples was 1064.0°C, whereas cepted melting point as given by [21] was °C. The approximately 1°C deviation between ults and the accepted results at 1-atmosphere is ly a measure of the temperature gradient in our nental apparatus, as well as calibration errors in couple emf, sample contamination, etc.

om laboratory analysis, the graphs of ature and pressure (T,P) against volume in (2,3 ,4) and (5, 6, 7) , (8, 9, 10) and (11, show that when the values of temperature and increases, there was a gradual depression in of the samples (i.e. samples:1-4).

sion

results show that there is decrease in volume at high temperature and pressure. This could of the reasons why gold found in that area is in nation and not in solid form as in some places.

In Itagunmodi, the results of the analysis carried out on gold samples collected from four different locations in the town exhibits similar properties in such a way that high temperature and pressure reduced the size of gold in all the locations. Hence both temperature and pressure are likely the major factors that contributed to the state of the dissemination of gold in the area.

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