Journal of the Nigerian Association of Mathematical Physics
Volume 40, (*March, 2017*), pp 151 – 156
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Determination of Stress-Bulk Modulus in the Lithosphere and the Peak Particle Velocity with regards to Sediment-Hosted Disseminated Gold Deposit

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Abstract

The tectonic activities happening within the subsurface has led to a huge trapped pressure within the plate boundaries looking for escape through the weakest points to the surface. This has led to deformation in the lithosphere which was greatest at the plate boundaries. In recent time, sediment-hosted disseminated gold deposits had been an important ore mineralization. From research it was suggested that gold,a material from subsurface derived from the core-mantle region passes through different regions of different densities, pressures and temperatures. Bulk modulus, an important parameter determined from the thermodynamic properties was investigated to the depth of the lithosphere. The ground movement was also determined with a view to ascertain the save distance and precautions when handling explosives as tools in underground mining.

Keywords: Bulk Modulus, Deformation, Lithospheric Stress, Ground Movement.

1.0 Introduction

The Earth is divided into three regions namely crust, mantle and the core, this research work was focus on the lithosphere which is the brittle portion of Earth's interior it behaves as a non-flowing, rigid material. The lithosphere is the concrete basement in form of plates that carries all loads/overburden. It has two layers, the crust and mantle.The mantle portion is denser than both the overlying crustal portion and the underlying asthenosphere.The brittle condition of the lithosphere causes it to fracture when strongly stressed. This deformation near the Earth's surface is concentrated along the boundaries.There are weak plate margins(regions of high deformation) and strong plate interiors(regions of little deformation). The rupture produces an Earthquake or Tsunami. Hence, no place on earth is free from this hazard.

1.1 Measurement of Ground Movement

When carrying out the study on handling of explosives in mining, the aspect of prediction of distance of ground movement is necessary as this will safeguard the environment from undesirable occurrence, especially in most of the rural areas where mining activities turn out to be devastating due to lack of awareness on safety precaution. It was established that the ground vibrations at any point away from the explosion depends on the distance of the point of measurement from the point of origin and maximum charge weight [1]. Based on past studies in [1], the United State Bureau of mines concluded that if one or more of the mutually perpendicular components (L, V, T) of vibration in the ground near the structures have peak particle velocity (PPV) in excess of 50mm/s, there is a fair possibility that it may cause damage to structure and conversely less damage if the components have peak particle velocity less than 50mm/s. Due to extensive complains by the public, the office of surface mining of the United state lowered the safe blasting criteria for surface mine operations to 25mm/s [2]. It has also been established that if miners exceed 50.8mm/s peak particle velocity as recommended by the United States Bureau of mines, structural damage may likely occur [3]. Building damage related to blasting vibrations has been under investigation since 1927 [4]. Research efforts have been concentrated on determining what parameter of the ground motion is closely related to building damage.

1.2 Gold Deposits in Itagunmodi

The deposits in Itagunmodi were identified as sediment-hosted disseminated gold (SHDG). Other deposits that have been identified include those at the Mercur deposit, Utah, U.S.A., which have been mined since the last century [5]. The Carlin

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Trend, including past production and resources, forms the largest and most prolific accumulation of gold deposits in the North America. Deposits have also been reported elsewhere, and these include some so called Carlin-like gold deposits which are genetically associated with magmatic activity, i.e., in China, Hungary, Ukraine, Iran Slovakia, Indonesia, Malaysia, Philippines, Greece, Spain, Mongolia, Peru, Italy, and Canada [6-12].

The gold in SHDG deposits in this ore mineralization is believed to originate from the crust or both the crust and the mantle where the Lithosphere, Mesosphere and the Astenosphere were found.In the near surface the materials are relatively brittle, but plastic deformation becomes more significant with depth. As a result earthquakes occur predominantly in the top 15 km above the brittle–ductile transition.Gold is most commonly deposited in areas open to circulation of liquids such as fracture zones along faults, the zones is contain in the Lithosphere that lie between the crust and the upper Mantle ranged between 0-150km thick.

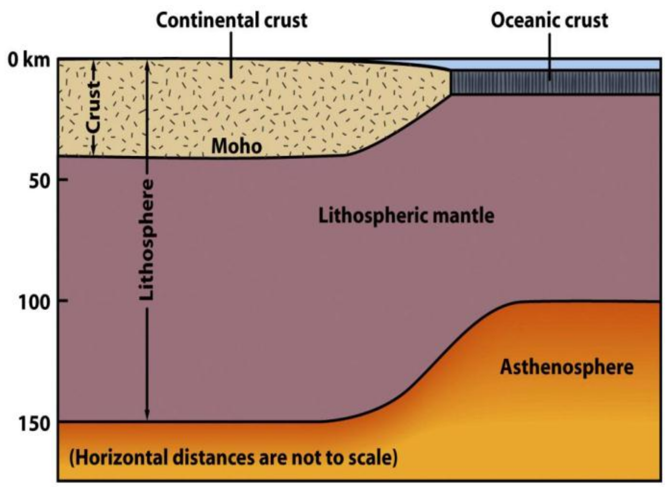


Figure 1a: Picture showing the oceanic and continental crusts

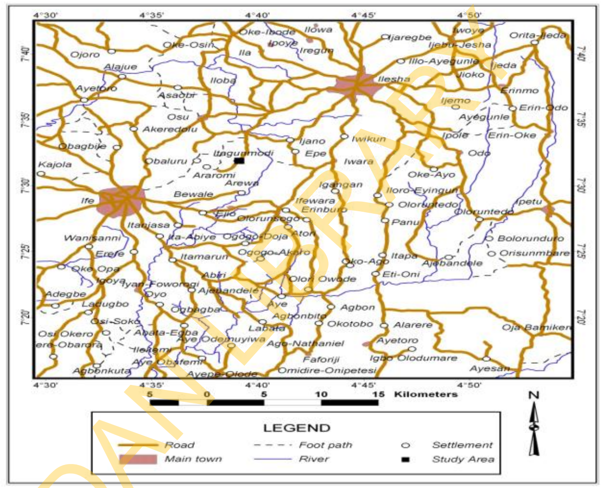


Figure 1b: Map of the study area

In part of Southwestern Nigeria the disseminated form of gold deposits are found in abundance, the geophysical analysis of SHDG deposits in this part of Southwestern Nigeria was carried out and the work was extended to the investigation of the stress in the lithosphere of the Earth from mining area.

1.3 Geology of the Study Area

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. The town is very close to towns such as: Ile-Ife and Ilesa in Osun State, Nigeria.

The geology of the area is Precambrian basement complex of the south-western, Nigeria and it is composed of gneisses, migmatites and Schist associated with amphibolites

2.0 Methodology

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.Mie-Gruneisen equation of state (equation 1) was applied to determine pressure (P) and the bulk modulus (K) in the lithosphere, the model:

$$\left(\frac{\partial P}{\partial T}\right)_V = \alpha K_T \quad \text{-----------------------} \quad (1)$$

Integration of (eqn.1) at constant volume yields:

$$\Delta P_{Th} = \int_{T_1}^{T_2} \alpha K_T dT \quad \text{-----------------------} \quad (2)$$

$$\frac{\Delta P_{Th}}{K_T} = \frac{\Delta V}{V} = \alpha \Delta T \quad \text{----------------------} \quad (3)$$

$$\frac{\Delta V}{V} = \alpha (T - T_0) \quad \text{----------------------} \quad (4)$$

$$\frac{\Delta P_{Th}}{K_T} = \alpha \Delta T \quad \text{----------------------} \quad (5)$$

The volume strain is given the relation:

$$\Delta\eta = 1 - \frac{V}{V_0} \qquad \text{--------------------} \qquad (6)$$

The lithospheric stress throughout the Earth's crust is governed by the expression

$$P(z) = \int_0^Z \rho(z) g dz = \rho g z \qquad \text{----------------------} \qquad (7)$$

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.

The ground movement is determined using the relation below:

$$PPV = K_s * (SD)^{-M_s} \qquad \text{----------------------} \qquad (8)$$

Where SD is given by

$$SD = \frac{R}{\sqrt{W}} \qquad \text{----------------------} \qquad (9)$$

Where PPV is the peak particle velocity, SD in m/Kg, the scale distance, R, the distance from source to the point of measurement in m, W, maximum instantaneous charge weight per delay in Kg. K_s and M_s are rock energy transfer coefficient and specific geological constant respectively.

PPV (mm/s) = K_s *$(SD)^{-Ms}$ if log K_s=3.56 and M_s= 1.60

$$PPV = 3600(SD)^{-1.60}$$

3.0 Results and Discussion

Table 1: Stress-bulk computation in the lithosphere (0 - 150 km depth)

Depth (Km)	Temperature ^oC	Temperature K	Stress (Mpa)	Bulk Modulus (Gpa)
0	0.00	273.00	0.00	0.00
10	265.00	538.00	274.68	36.47
20	530.00	803.00	549.36	48.86
30	795.00	1068.00	824.04	55.11
40	1060.00	1333.00	1098.72	58.87
50	1325.00	1598.00	1618.65	72.35
60	1590.00	1863.00	1942.38	74.47
70	1855.00	2128.00	2266.11	76.06
80	2120.00	2393.00	2589.84	77.30
90	2385.00	2658.00	2913.57	78.30
100	2650.00	2923.00	3237.30	79.11
110	2910.00	3183.00	3561.03	79.91
120	3180.00	3453.00	3884.76	80.36
130	3445.00	3718.00	4208.49	80.85
140	3710.00	3983.00	4532.22	81.28
150	3975.00	4248.00	4855.95	81.65

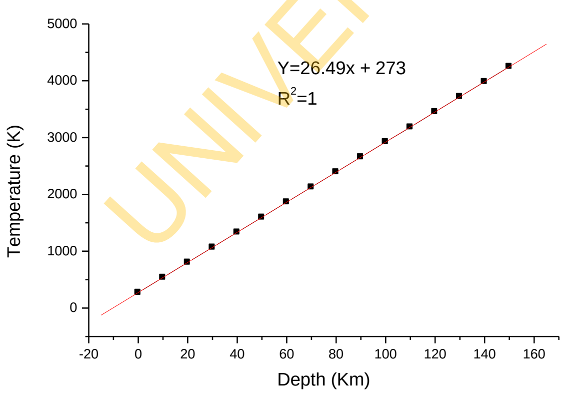


Figure 2: Temperature against Depth

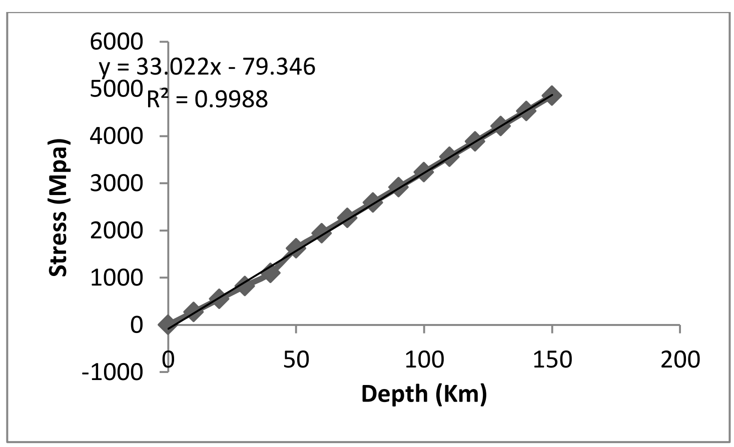


Figure 3: Stress against Depth in the Lithosphere

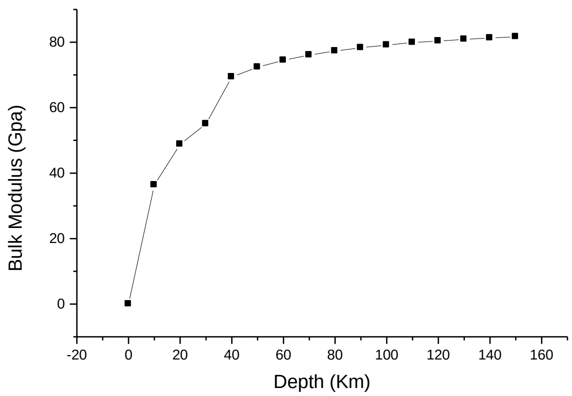


Figure 4: Bulk Modulus against Depth in the Lithosphere

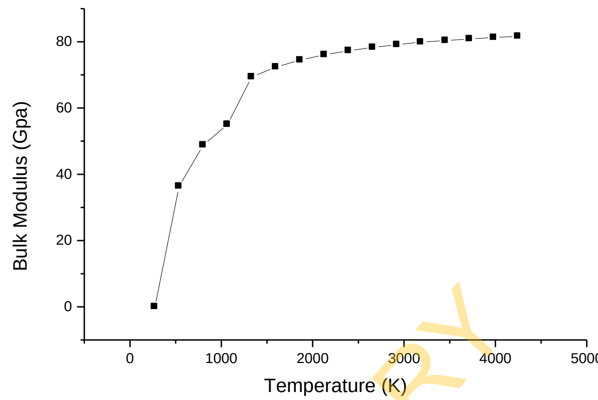


Figure 5: Bulk Modulus against Temperature in the Lithosphere

Table 2: Computed values of Peak Particle Velocity and Scaled Distance withvaried charge weight

R(m)	W(Kg)	$SD = \frac{R}{\sqrt{W}}$	PPV(mm/s)	Log SD	Log PPV
300	500	13.416	56.505	1.128	1.752
350	500	15.652	44.154	1.195	1.645
400	550	17.056	38.485	1.232	1.585
450	550	19.188	31.875	1.283	1.504
500	600	20.412	28.872	1.310	1.460
550	650	21.573	26.427	1.334	1.422
600	675	23.094	23.698	1.363	1.375
650	700	24.568	21.464	1.390	1.332
700	725	25.997	19.607	1.415	1.292
750	750	27.386	18.040	1.438	1.256
800	775	28.737	16.703	1.458	1.223
850	800	30.052	15.549	1.478	1.192
900	850	30.870	14.895	1.490	1.173
950	900	31.667	14.300	1.501	1.155
1000	950	32.444	13.756	1.511	1.139
1250	1000	39.528	10.029	1.597	1.001
1300	1050	40.119	9.794	1.603	0.991

Table 3: Computed values of PPV (mm/s) and SD (m/Kg) for fixed charge weight

R (m)	W (kg)	PPV (mm/s	SD (m/Kg)	Log PPV	Log SD
250.0	0.5	16.817	353.553	1.226	2.548
300.0	0.5	15.351	424.264	1.186	2.628
350.0	0.5	14.213	494.975	1.153	2.695
400.0	0.5	13.295	565.685	1.124	2.753
450.0	0.5	12.534	636.396	1.098	2.804
500.0	0.5	11.891	707.107	1.075	2.849
550.0	0.5	11.338	777.817	1.055	2.891
600.0	0.5	10.855	848.528	1.036	2.929
650.0	0.5	10.429	919.239	1.018	2.963
700.0	0.5	10.050	989.949	1.002	2.996
750.0	0.5	9.709	1060.660	0.987	3.026
800.0	0.5	9.401	1131.371	0.973	3.054
850.0	0.5	9.120	1202.082	0.960	3.080
900.0	0.5	8.863	1272.792	0.948	3.105
950.0	0.5	8.627	1343.503	0.936	3.128
1000.0	0.5	8.408	1414.214	0.925	3.151

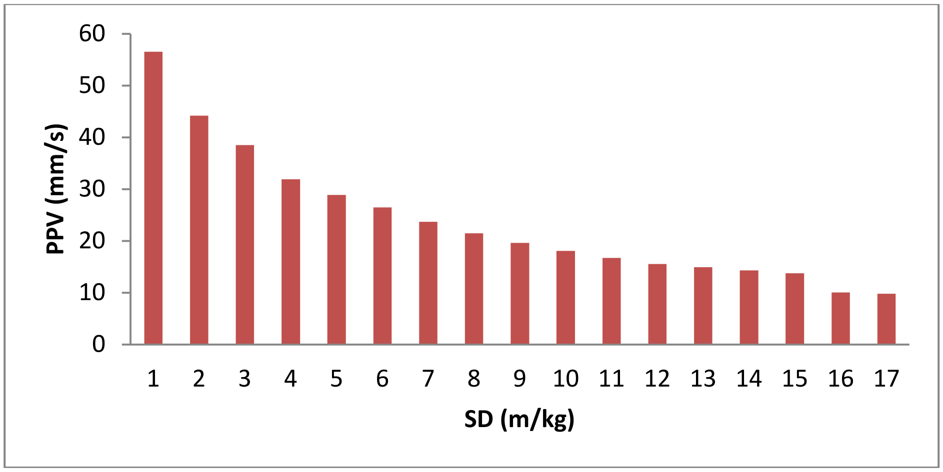


Figure 6: Peak Particle Velocity against Scaled Distance(varied charge weight)

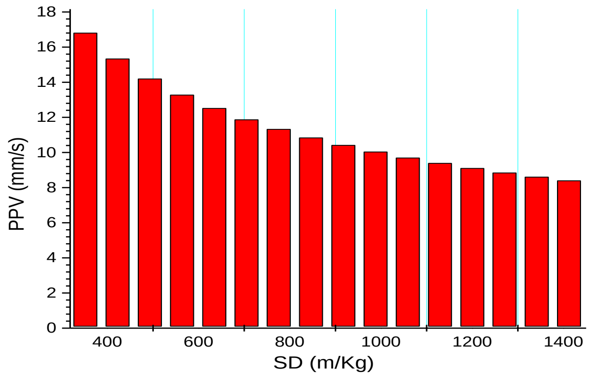
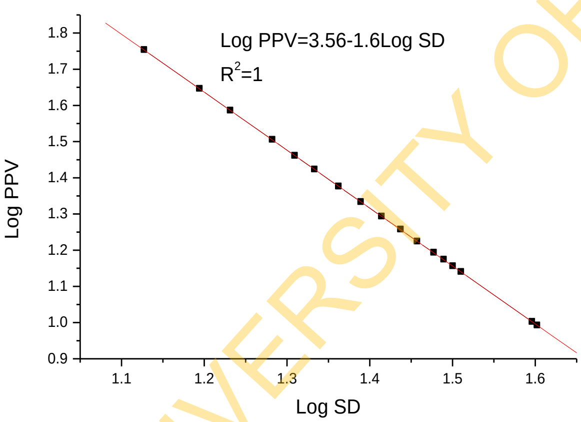


Figure 7: Peak Particle Velocity against Scaled Distance (fixed charge weight)



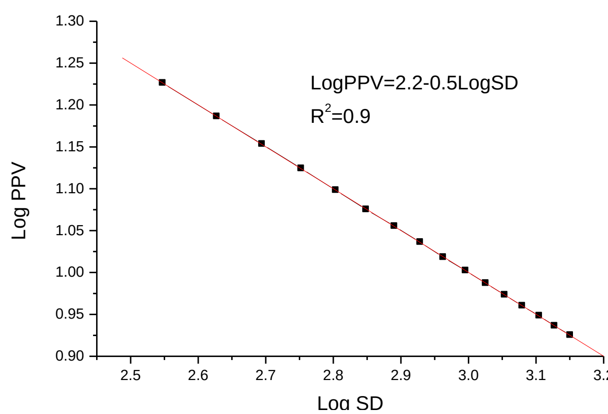


Figure 8: Graph of log PPV against Log SD (varied charge weight)

Figure 9: Graph of Log PPV against Log SD (fixed charge weight)

4.0 Discussion

The temperature increase at the rate of about 26.5K /Km in the lithosphere as shown in figure 2, it is linear because the temperature and pressure increases with depth.The bulk modulus increases with depth because as we go deeper in the lithosphere, density, temperature and pressure increases due to compositional and phase changes. If the bulk modulus in any part of the lithosphere is lower, it means a lower stress force can cause instability (e.g. structures collapse,) at that region although, the deformation produced will not be permanent. The stress field in the mantle means that stress increases down the lithosphere at the rate of 33Mpa/Km as shown in figure 3, which means the rate of increase in stressis 1.25Mpa per Kelvin temperature.In figures 4 and 5, there is discontinuity along the boundary between the crust and mantle (i.e. beyond 40 Km depth and temperature above 1300K), it represent region of compositional changes and changes in mineral structures (phase changes).

In figures 6 and 7, Peak Particle Velocity decreases as the distance from source increasesfor varied and fixed charge weights while figures 8 and 9 represents the linear graphs of $\log PPV$ against $\log SD$ that gives the values of $\log K_S$ on vertical axis and M_S on the horizontal axis.The scale distance increases as the distance from shot increases, and conversely, the peak particle velocity (PPV) decrease with an increase in scale distance (R). The peak particle velocity must be within the safe limit of 50.8mm/s recommended by USBM but because of extensive complain the United State has lowered the safe blasting criteria for surface mining to 25mm/s [2]. In order to prevent Earth threatening occurrence, those handling explosives should restrict to using lower value of charge weight and maintain large distance from physical structure for safety assurance. The damage decreases as the vibration level decreases below 50mm/s. It is better to maintain peak particle velocity of 25mm/s.

5.0 Conclusion

The bulk modulus increases at the rate of 13.9Mpa/K in the lithosphere**.** In the lithosphere, the bulk modulus increases at the rate of 379Mpa/Km down the depth, the bulk modulus increases at 0.014Mpa/K. Hence, when the lithosphere becomes unstable, there will be shake up whose result will be devastating. The recommended peak particle velocity is 50.8mm/s, a safe scale distance must also be considered as well for a safe environment. Hence, all hands must be on deck in monitoring all activities going on in the subsurface.The lithosphere is brittle.Hence, mining activities taken place on Earth should be monitoredbecause illegal mining and haphazard drilling of water boreholes are not friendly to the environment. Also, civil engineers or building engineers should work with geophysicists and geologists to study the nature of soil before structures are erected.The strength of the lithosphere is reduced along the boundaries, areas far from the boundaries should also have their activities checked since tectonic motion is universal, that is, plate motion is a continuous process.

6.0 References

[1]. Nicholls, H. R., Johnson, C. F., Duvall, W.I., 1971. Blasting vibrations and their effects on structures, Bureau of Mines, Bulletin 656.

[2]. Dick, R. A. 1979. A review of the Federal surface coal mine blasting vibrations, proc. Fifth Comference on Explosives and Blasting Technique, St Loius, Miss (Society of Explosives Engineers, Wilm.)

[3]. Adetoyinbo A. A, Popoola O. I, Hammed O. S, and Bello A. K 2010; An assessment of quarry-blasting vibration impacts in Ibadan and Abeokuta, Nigeria

[4]. Rockwell, E. H., 1927. Vibration caused by quarry blastings and their effect on structures, Rock products, 30:58 – 81.

[5]. Jewell, P. W., and Parry, W. T. 1987. Geology and hydrothermal alteration of the mercur gold deposit, Utah. Economic Geology, 82(7): 1958-1966.

[6]. Turner, S. J., Flindell, P. A., Hendri, D., Hardjana, I, Lauricella, P. E, Lindsay, R. P., Marpaung, B., and White, G. P. 1994. Sediment-hosted gold mineralisation in the Ratatotok District, North Sulawesi, Indonesia. Journal of Geochemical Exploration, 50(1- 3): 317-336.

[7]. Shumlyanskiy, V. O., Ivantishina, O. M. 1998. Prerequisites to a search of the Carlin gold deposit type in the Carpatho-Dinar region. Geological Journal, no. 1-2: 258-269.

[8]. Knesl, J. and Kneslova, A. 1999. Gold mineralizations types in Slovakia and possibilities of their utilization. Mineralia Slovaca, 31(3-4): 171-174.

[9]. Korpas, L. and Hofstra, A. H. 1999. Potential for Carlin-type gold deposit in Hungary. In: Carlin gold in Hungary. Edited by Korpas, L. and Hofstra, A. H. Geologica Hungarica, Série Geologica, 24: 133-135reduction by light hydrocarbon gases in deep carbonated reservoirs. Nature (London), 333: 415-419

[10]. Asadi, H. H., Voncken, J. H. L., Kiihnel, R. A., and Hale, M. 2000. Petrography, mineralogy and geochemistry of the Zarshuran Carlin-like gold deposit, northwest Iran. Mineralium Deposita, 35: 656-671.

[11]. Cluer, J. K., Enkhtuvshin, K., and Robertshaw, P. 2000. Sedimentary rock-hosted gold mineralization at Zalaa Uul, Khentii Range, northeastern Mongolia. Mineraliu. Deposits, 35: 587-597