ANALYSIS OF ROCK-GEOLOGICAL MATERIAL FROM PLACES IN TANZANIA BY WAVELENGTH DISPERSIVE X-RAY FLUORESCENCE SPECTROMETER

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ABSTRACT

A number of precious stones and minerals in Tanzania are found either just on the ground surface or unexplored inside the earth. Principally those found at the surface differ in their source of origin from those found inside the earth. Some of these stones are coming from the rocks in their present locations (primary deposits) while others are transported from other places (secondary deposits). The mechanism of transportation may be rivers, sea or wind. The distribution of these valuable stones is geographically irregular in Tanzania and in some of the regions the deposits are higher compared than others. In several parts of the country such information is completely unavailable and in many cases unexplored. In order to provide this information to the decision makers and investors, Wavelength Dispersive X-ray Fluorescence (WDXRF) Analysis has been used with objective of identifying the composition of some of these stone and rock samples. The samples identified and reported in this paper include: Iron ore, Green Aventurine, Amethyst, Red Garnet, Sapphire nuts, Green Opal, Blue Kymete, Black Tormaline, White opal, Aquamarine and Granite. The samples were prepared as pellets after mixing with boric acid or fused as discs for analysis. Typical results for the Iron Ore in % are SiO_2(0.97), Al_2O_3(0.57), Fe_2O_3(77.5), MnO(0.35), MgO(0.35), CaO(0.16), Na_2O(<0.01), K_2O(0.04), TiO_2(19.1), P_2O_5(<0.01), SO_3(0.14) and that of the Amethyst SiO_2(97.8), Al_2O_3(0.11), Fe_2O_3(1.37), MnO(<001), MgO(<0.01), CaO(<0.01), Na_2O(<0.01), K_2O(<0.01), SO_3(0.33). The results show that Tanzania is a very rich country in minerals but are currently unexplored either because of lack of information or investment capital.

INTRODUCTION

Principally gemstones differ in their sources of origin. Some are formed out of the magma (magma tic), sedimentation (sedimentary) and some re-formed from other rocks (metamorphic) deposits. While some of the

rocks in Tanzania are in their original places of formation as primary deposits, others were actually transported from other places (secondary deposits). In primary deposit cases the stones have a relationship with the host rocks at the same location. The secondary deposits have their place of formation far away from the place where the deposit is found and thus harder crystals become rounded and softer ones made smaller or simply destroyed because of the hardness of transportation. The transportation mechanism may be by river, sea or by wind. Distribution of gemstones over Tanzania is irregular with some regions more favored than others. In several areas no information on such distribution are available especially some of the unexplored places in the country. The reason for this is the high cost required for exploration and investments.

Gemstone miners in Tanzania identify the precious stones by their colors, hardness, chemical composition, specific gravity and refractive indices. Carat is the weight used in the gemstone world to mean 0.2 g and the hardness value refers to the resistance of mineral to scratch with pointed testing object. The hardness value varies from the soft most (1-6) to the hard most (7-10).[1] Dispersion is the split of white light when passing through a crystal, which result, into the different colors. This is due to individual colors having different wavelengths bending differently when passing through different crystals and thus used for identification.

Wavelength Dispersive X-ray Fluorescence (WDXRF) analysis has been in use for geological application for many years. The advantage of the method is due to its ability to measure most of the elements up to very low atomic number with good precision. The objective of this work was to identify the composition of rock-geological samples of Tanzania. The result will accelerate exploration processes by determining which mineral rocks are available and their locations. In many cases elemental composition may tell us what to expect after investment. Prior to this work Some Tanzanian Scientist in cooperation with some foreign companies are working on geographical map for deposits in Tanzania.[2,3]

EXPERIMENT

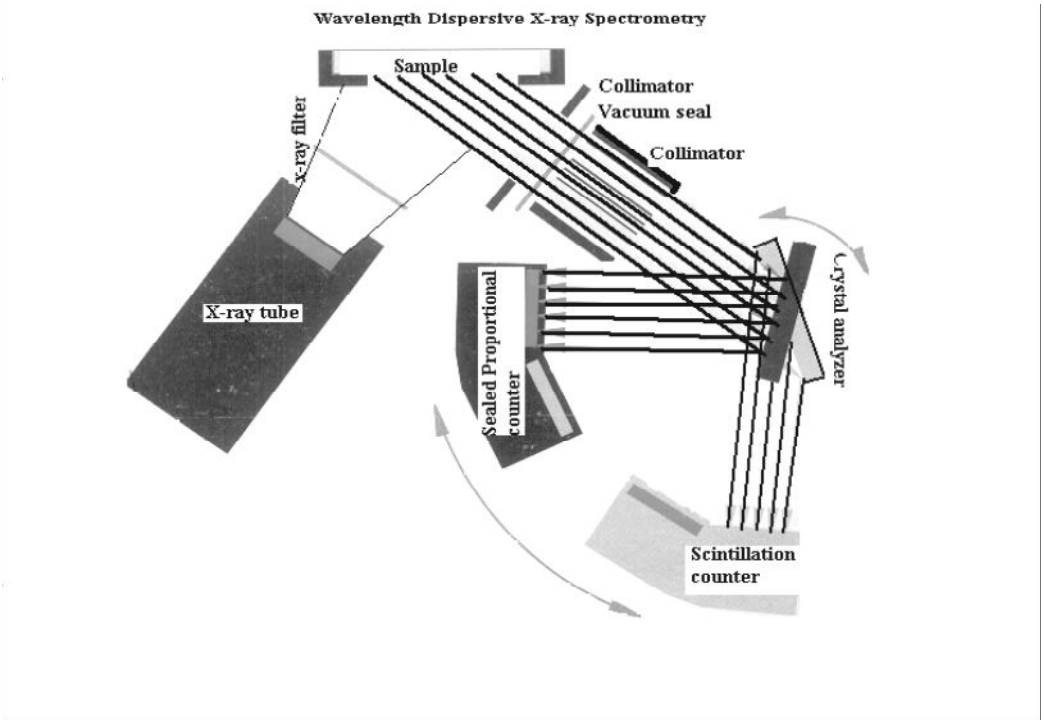


Fig. 1 Typical radiation formation in WDXRF

In fig. 1 the wavelength dispersive x-ray spectrometer is shown, composed of an x- ray tube and the sample holders were the sample in pellet form are placed. Characteristic x-ray from the sample after strict collimation is made incident on the crystal analyzer, which disperses the radiation according to their wavelength. The rotating detector is searching for these various wavelengths. The signals for elements of various wavelengths are collected on a multichannel analyzer installed in a computer. The details of the experimental conditions are articulated in a handbook of x-ray spectrometer.[4]

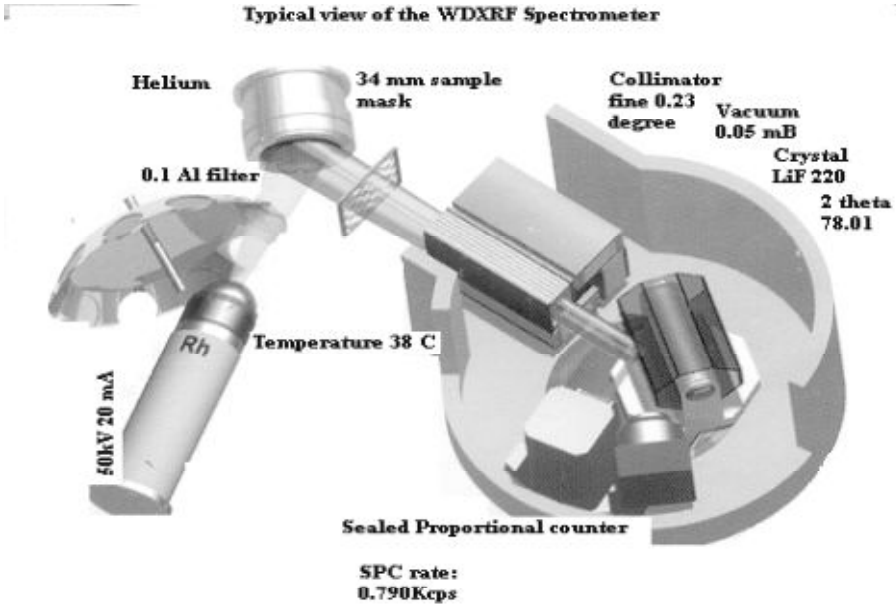


Fig. 2 Typical view of components in WDXRF spectrometer in Dar es Salaam(SEAMIC)[6].

In Fig. 2. the Rh anode operating at a 50 kV, 20 mA has x-ray filtered by a 0.1 mm Al filter. The sample is mashed by a 34 mm Al holder and excited in a vacuum atmosphere. After collimation the fluorescent radiation arrives in a LiF crystal. Sealed proportional counter, prop4^{TM}, is used to detect radiation at a rate of 790 counts per second. However, apart from LiF(220) and LiF(200) other crystals like PET, OVO55, and OVO160 are also used and the count rate vary depending on the nature and concentrations of the sample.

SAMPLING

Table 1. The locations where rock-geological samples measured on the WDXRF spectrometer were collected

Sample ID	Name	Location	Identified area
UD-1	Iron ore	Dodoma,Iringa	Mpwapwa,Liganga
UD-2	Green aventurine	Morogoro	Kilosa
UD-3	Amethyst	Tanga,Rukwa	Handeni,Sumbawanga
UD-4	Ruby	Arusha, Morogoro,Tanga	Longido, Matombo
UD-5	Corundum(Al_2O_3) (sapphire nuts)	Ruvuma,Tanga	Tunduru,Umba river
UD-6	Green opal	Arusha	Mirerani,Longido-Mundarara

UD-7	Blue kyanite	Dodoma,Arusha	Mpwapwa,Longido Mundarara,Mireran
UD-8	Black tourmaline	Ruvuma,Morogoro	Tunduru
UD-9	White and brown Opal	Ethiopia and Kenya	-
UD-10	Aquamarine (blue)	Tanzania	Many regions
UD-11	Granite	Tanzania	Many regions
UD-12	White opal	Tanzania	Many regions
UD-13	Yellow opal	Taanzania	Many regions
UD-14	Feldspar	Dodoma,Morogoro,Tanga	Mpwapwa,Kilosa, Umba river
UD-15	Brown garnet.	Arusha,Morogoro,Tanga	Mirerani,Longido, Umba river

RESULTS AND DISCUSSION

Table 2. Analysis of 15 geological samples by WDXRF

Sample ID	Name	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	MnO %	MgO %	CaC %	Na_2O %	K_2O %	Ti_2O %	P_2O_5%
UD-1	Iron ore	0.97	0.57	77.5	0.13	0.35	0.16	<0.01	0.04	19.1	<0.01
UD-2	Green aventurine	96.4	1.40	0.52	<0.01	<0.01	0.15	<0.01	0.64	0.05	<0.01
UD-3	Amethyst	97.8	0.11	1.37	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
UD-4	Ruby	38.1	59.7	1.75	<0.01	<0.01	0.06	<0.01	0.03	<0.01	<0.01
UD-5	Corundum (Al_2O_3) (sapphire nuts)	13.8	76.6	2.47	0.02	0.83	1.59	0.36	1.40	0.15	<0.01
UD-6	Green opal	82.9	0.54	6.20	<0.01	0.52	0.50	<0.01	0.03	<0.01	<0.01
UD-7	Blue kynite	36.4	20.8	24.7	0.48	13.6	3.19	<0.01	<0.01	0.13	<0.01
UD-8	Black tourmaline	51.5	0.66	7.45	0.05	14.0	24.5	1.48	<0.01	0.06	<0.01
UD-9	White and brown Opal (Ethiopian)	86.5	3.54	3.48	0.05	0.16	0.41	0.93	4.17	0.24	<0.01
UD-10	Aquamarine (blue)	74.3	19.9	4.32	0.04	0.24	0.06	0.29	0.04	<0.01	<0.01
UD-11	Granite	63.1	18.1	0.30	<0.01	<0.01	0.25	2.40	14.5	<0.01	<0.01
UD-12	White opal	66.1	17.9	<0.01	<0.01	0.30	1.11	14.0	0.48	<0.01	<0.01
UD-13	Yellow opal	92.2	0.29	<0.01	<0.01	0.36	0.15	<0.01	<0.01	<0.01	<0.01
UD-14	Feldspar	60.5	22.7	0.47	<0.01	<0.01	6.67	8.34	0.66	<0.01	<0.01

UD-15	Brown garnet.	37.9	13.5	10.0	0.99	0.20	36.5	0.08	0.02	0.53	0.04

Most of the analyzed samples 1-15 in table 1 form an ore from which gems are obtained. They are all rich in Si except iron ore which has 77.5% Fe. Iron ore mainly found in areas of Mpwapwa, Dodoma region compete in composition to similar ores found in Liganga, Iringa region with more than 98% Fe. Certainly this could form a basis of heavy metal industry incase investors show interest to harvest these resources.
The rest of the gemstones rich in Si have also Fe, Al and Ca in its major composition. The various contents of these determine the color of the gem. While the Si provides for its glass transparent part, the variation of hardness from one gem to another shows how tough one is when it gets scratched by another. The weakest in the scratch test has a hardness value of 1 and the hardest have exceed 6 towards 9 to10 (table 2).

When light goes through some of these transparent gems their refractive indices are measured as shown in table 2. Absorption of different wavelength colors by some implies that the remaining colors mix to form a beautiful color after going through the gem. The data on the determination of color, hardness, specific gravity, crystal system, chemical composition, transparency, refractive index and dispersion for the analyzed rock samples are provided in table 2.

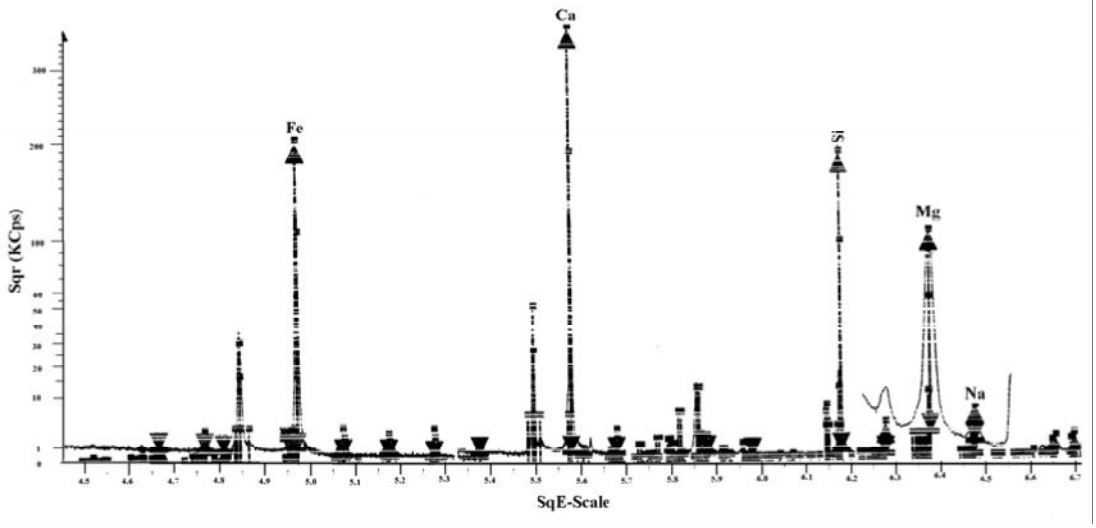


Fig 3. Typical spectrum of geological material by WDXRF.

Table 2. Other observed characteristics of the 15 samples.[1,5]

Sample ID	Name	color	hardness	Specific gravity	Crystal system	Chem.. composition	transparency	Refractive index	dispersion
UD-1	Iron ore								
UD-2	Green aventurine	green	7	2.65	Hexagonal(trigonal); crypto-crystalline	Silicon dioxide	Transparent, opaque	1.554-1.553	0.013
UD-3	Amethyst	Violet	7	2.63-2.65	Hexagonal(trigonal); hexagonal prisms	Silicon dioxide	transparent	1.544-1.553	0.013
UD-4	Red garnet/ ruby	red	9	3.97-4.05	Hexagonal(trigonal);hexagonal prisms or tablets, rhombohedrons.	Aluminum oxide	Opaque, transluscent, transperent	1.766-1.774	0.018
UD-5	Corundum(Al_2O_3) (sapphire nuts)	purple	9	3.99-4.00	Hexagonal (trigonal); dipyramidal, barrel-shaped, tabloid-shaped.	Aluminum oxide	Transparent, opaque	1.766-1.774	0.018
UD-6	Green opal	green	5.5-6.5	1.98-2.20	Amorphous; kidney or grape-shaped aggregates	Hydrous silicon dioxide	Transparent, opaque	1.44-1.46	none
UD-7	Blue kymeta	blue	6-7	3.65-3.69	triclinic	Aluminum silicate	Transparent, translucent	1.715-1.732	0.020
UD-8	Black tourmaline	black	7-7.5	3.02-3.26	Hexagonal(trigonal); usually long crystals with triangular cross section and rounded sides, definite striation parallel to main axis, often several prism grown together	Aluminum borate silicate, complicated and changeable composition.	Transparent, opaque	1.616-1.652	0.017
UD-9	Opal (Ethiopian)	White	5.5-6.5	1.98-2.20	Amorphous; kidney or grape-shaped aggregates	Hydrous silicon dioxide	Transparent, opaque	1.44-1.46	none
UD-10	Aquamarine	Light blue	7.5-8	2.67-2.71	Hexagonal (trigonal); long prisms.	Aluminum berylliu m silicate	Transparent to opaque	1.577-1.583	0.014
UD-11	Granite								
UD-12	White opal	White	5.5-6.5	1.98-2.20	Amorphous; kidney or grape-shaped aggregates	Hydrous silicon dioxide	Transparent, opaque	1.44-1.46	none
UD-13	Yellow opal	yellow	5.5-6.5	1.98-2.20	Amorphous; kidney or grape-shaped aggregates	Hydrous silicon dioxide	Transparent, opaque	1.44-1.46	none
UD-14	Feldspar								
UD-15	Brown garnet.	brown	-	-	Isometric; rhombic, dodecahedron, icositetrahedron.	-	Transparent, translucent	-	-

Table 2. Discusses the physical characteristics of the 15 samples observed which are also discussed below.

Amethyst is the most highly valued, highly compact formation stone in the quartz group. Heat treatment between 878-1382^0F (470-750^0C) produces light yellow, red brown, green or colorless varieties. Some Amethysts lose some color in daylight. Source deposits are found in Tanzania at Handeni in

Tanga region as well as Sumbawanga in Rukwa region. It has the following characteristics: Chemical composition: SiO_2, silicon dioxide. Si (97.8%), Fe (1.37%), Al (0.11%),It is used for beads, cabochons and ornaments.

Opal is divided into groups of the opalescent precious opal, the yellow-red fire opals. The color of the stone may be white, gray, green, orange. In our case we have green opal and white opal. Its Chemical composition is, hydrous silicon dioxide. Opal always contains water, the content varies but it can have as much as 30% water. It can happen that in the course of the time it looses water, results into cracks and the opalescence diminishes. This can temporarily be restored by spraying with oil or water. The aging process is avoided and the opalescence increased when stored in moist absorbent cotton (cotton wool) not to evaporate water. In the present analysis yellow opal had Si 92.2%, Fe 0.01%, Mn 0.01%. Green opal had Si 82.9%, Fe 6.2%, Mn 0.01%, White opal had Si 66.1%, Fe 0.01%, Mn 0.01% .The iron and Mn contents determines the color.

Aquamarine together with emerald and beryl belongs to the beryl group. It has sea dark blue water color. The lower qualities are heated to $752^0F/400^0C$ to change them to the desired aquamarine blue. It has a chemical composition of $Al_2Be(Si_6O_{18})$ Aluminum beryllium silicate. The analysis shows high presence of Si (74.3%), Al (19.9%) and Fe (4.32%).The concentration of these elements determines the good color of Aquamarine deposits in Tanzania.

Tourmaline samples analyzed in this experiment were black.The current stone show high level of Si (51.5%), Fe (7.45%), Mg (14%), Ca (24.5%), and Na (1.48%). By heating and subsequent cooling, as well as by applying pressure i.e. by rubbing, a tourmaline crystal will become electrically charged. One end becomes negative; the other becomes positive and attracts dust particles as well as some pieces of paper. These deposits are found in Tanzanian at Ruvuma and Morogoro regions.. By heating to 842-1202^0 F $(450-650^0C)$,small color change can be produced.[1]

Ruby Corundum is red in color. Ruby, as well as sapphire was recognized as belongings to the corundum group. The coloring pigment is chrome and for brown lines, some iron is also found. The red color varies with the individual deposits, so it is not possible determine the source area from the color, as each deposit yields various tones due to chemical composition. It is

characterized by varying red color. Important deposits in Tanzania were being exploited at small scale and has produced a decorative green rock. Recently some rubies have been found in the Umba river (north East of Tanzania in Tanga region) as well as in Longido at Arusha region and Matombo in Morogoro. They are purple to brown-red and has Si (13.8%), Al (76.6%) and Fe (2.47%).

Aventurine is a dark green with metallic iridescence caused by fuchsite (green mica) inclusion; the red and brown are caused by iron-mica inclusions. Important deposits are in Tanzania at Morogoro region but unexplored. It used for cabochons and ornamental objects, it is very popular in Tanzania small miners and can not be confused with aventurine fieldspar which is brown.The x-ray analysis shows presence of 96.4% SiO_2, 1.4% Al_2O_3,0.52% Fe_2O_3, others are 0.15% CaO, 0.64% K_2O, 0.05% Ti_2O.

Sapphire-Corundum group: Very similar to ruby, sapphire is gem varieties of corundum. The corundum of all colors is called sapphire except red are called rubies. There is no definite demarcation between ruby and sapphire. The coloring pigment in blue sapphire is iron and titanium and in violet stones, Vanadium. Small iron content results in yellow and green tones. Chrome produces pink. The most desired color is pure cornflower blue. It is very much in abundance in Tanzania at Umba river in Tanga, Mererani in Arusha and Tunduru in Ruvuma. It is transparent with refractive index: 1.766-1.774.

Kyanite: The color is often in irregular streaks. Has a vitreous luster. The crystal are difficult to cut because cleaveage. Can be confused with aquamarine and sapphire. The Main characteristics are:Color: blue-green, Moh's hardness: 4.5 along axes, 6&7 across axes.Specific gravity: 3.65-3.66.Crystal system: triclinic. It has a refractive index: 1.715-1.732. In Tanzania it is found at Mpwapwa in Dodoma region,|Mirerani and Longido in Arusha region.

Garnet: This is a group of differently colored minerals, in grain size of the rounded crystals. Garnet, in the popular sense, is understood to mean red "garnet", almandine and pyrope, the stone is in white color with rhombic, isometric, crystal configuration. There are also green, brown and other garnets depending on the color. Garnet is mainly found in at Arusha, Morogoro and Tanga in Tanzania.

Feldspar: There are two main groups mainly found in Tanzania at Arusha, Morogoro and Tanga.: potassium feldspar as orthoclase (varieties- adularia with moon stones, sanidine) and microcline (variety- amazonite); and calcium feldspar (called plagioclase) with albite (variety – peristerite), oligoclase (variety –aventurine feldspar) andesine.

CONCLUSION

The 15 samples of rock-geological materials were analyzed using wavelength dispersive x-ray fluorescence analysis. The iron ore was dominated by about 77% Fe. This is indicator of a number of rocks which may be exploited for heavy metal industry in Tanzania. Certainly higher percentage Fe rocks may be found in the other places in Tanzania like Linganga at Iringa region which contains 98% Fe. Other 14 remaining samples have gemstone value rich in Si which provide for its glass part. The contents of other elements like Fe, Zn, Mn, Cu determines the color of the stone. The heat treatment may change the gemstone from one color to another.

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