KIREHE SANDSTONE DEPOSIT

STUDY FOR A POSSIBLE GLASS FACTORY

RWANDA NATURAL RESOURCE AUTHORITY
GEOLOGY AND MINES DEPARTMENT

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0. INTRODUCTION

Since the 1970's, the idea of initiating and promoting glass manufacturing projects has been existing at the Ministerial level. This is due to good quality sand that exists in the country. Based on Karega Schwarzbock in « Recherche des matières premières pour la création d'une bouteillerie au Rwanda », 1976) the main raw material in glass production is sand silicas which is occurred in many places in Rwanda as it will be discussed along this document.
Looking also how the country is continuingly growing economically especially in house construction which implies high needs in glass products has reinvigorated the idea of assessing the potentiality of evaluating the available raw material, its quality and quantity for setting up a glass factory in Rwanda

0. 1. Objective of the study

The current study which is focusing on Kirehe Sandstone deposit is serving to exhibit the high potential (quality and quantity) of raw materials in glass manufacturing and will show also the high needs of such factory in Rwanda.
The high needs is in building construction in towns, more buildings owners are highly interested in modern constructions by minimizing spaces (Highest floors) which implies high consummation of glass materials.
It is in that light this study aims also to encourage whoever would be interested to invest in this domain as this will be matching with the Rwandan government goal of reducing imports and promotes exports.

0. 2. Location of Rwanda in Africa and its climate

Whereas Rwanda is so called "*the country in the heart of Africa*", it is located in Central East of Africa at 1^0 2' 44" and 2^0 50' 24 **S** and $28^0$51'40"**E**. Bordering in North with Uganda, Tanzania in East, Burundi in South and DRC In west. Rwanda has a temperate climate with temperatures not often climbing above 25^0C and the max can't normally go over 31^0C. The long dry season is from June to September and there are two annual rainy seasons, the first from mid-March until the beginning of June and small rains from mid-September to December and annual rain fall ranging between 900 and 1600 mm.

Figure 1: Localization of Rwanda on Africa Map

0. 3. Geographic location of Kirehe Sandstone

The area of study is located astride the Nasho, Nyarubuye and Mushikiri sectors of Kirehe District, Eastern Province (Figure 1).

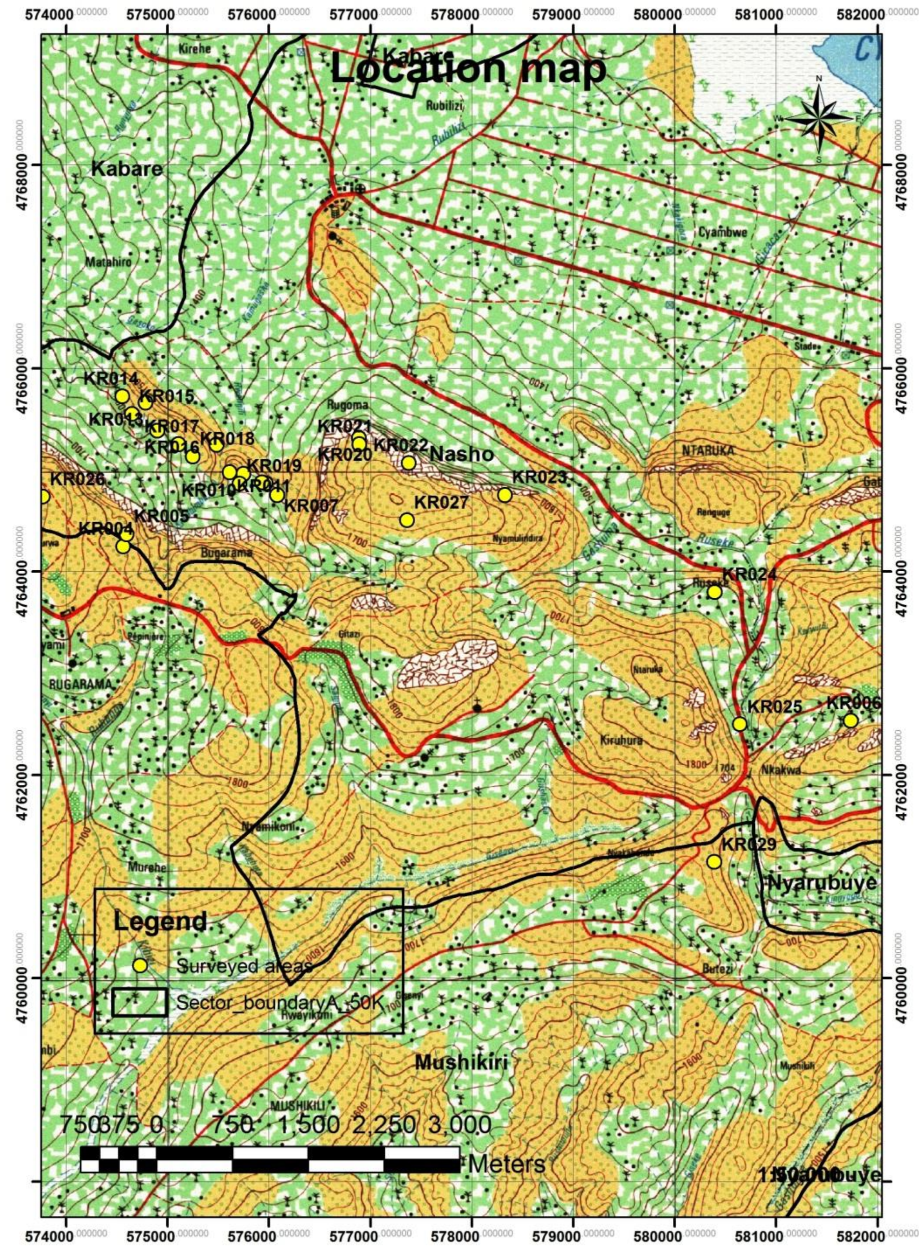

Figure 2: Location map of Kirehe sandstone deposits.

The site is accessible via the asphalt road from Kigali to Kibaya via Ngoma District location and the gravel road from Kibaya to Rugarama via Rukira.
The topography of the study area is moderate to rugged (Figure 1), consisting of hilly and flat terrains where the elevations range between 1456m and 1872m asl.

1. DEFINITION AND UTILIZATION OF SANDSTONE

Sandstone is a metamorphic rock which is primarily formed by quartz grains. It is formed by recrystallization of quartz-dominated sandstone by thermal or regional metamorphism.
Quartz is one of the most abundant minerals in the Earth's crust and is the common constituent of hyothermal veins. It occurs as an essential constituent of many igneous, sedimentary and metamorphic rocks. Quartz is a colorless and transparent tecto-silicate. It is characterized by the lack of cleavage, visible twinning, low relief, weak birefringence and vitreous luster. Some varieties of quartz are colored because of the presence of impurities.

Sandstone rock is as well utilized in the construction industry especially in various domains: as stones for building and civil works, making of reinforced concrete and general concrete works, as a decorative material for floors, stair steps, walls, roofing tiles. Sandstone is as well used as a stone for stabilization along the railroad tracks. When sandstone is packed in between the rails and tiles, it facilitates drainage and prevents the growing vegetation. Furthermore, quartzite/sandstone is the raw material for sands which are utilized in the glass making.

1. 1. Geological setting

Figure 2 shows a geological map of the Nasho area. A systematic verification of the stratigraphic units was made during the field work.
The details of the stratigraphic units are described below, from the oldest to the youngest geological formation:

1. **Rusumo complex** (Rs on Figure 2): The oldest regional geological formation which corresponds to a complex geological formation formed by highly sheared mica-schists, layers of quartzite etc.
2. **Gitwe formation** (Gi on figures 2 and 5): Gitwe formation is dominated by hard massive quartzites, sandstones and schists. This meta-sedimentary set is equivalent to the Bwisige formation in the stratigraphic sequence of the central Rwanda.

Figure 3: Photo showing the quartzite of Gitwe formation. Parallel thin layers are shown by the top of the geologic hammer.

3. **Rukira formation** (Rr): Comprises metapelite - dominated packages of thinly stratified and laminated layers of schists with locally black shales: tourmaline chlorite schists and whitish to dark beige sericite schists underlying dark, ferruginous and silicified schist, fine-grained sandstones and siltstones.
4. **Quaternary** (Ho): represented by undifferentiated Holocene and Pleistocene with several tens of meters of recent alluvial sediments deposited by rivers and/or erosion.

1. 2. Mesoproterozoic magmatic complexes vis-a-vis structural geology

Structurally, the Nasho area is situated East of an important NE-SW oriented anticline adjacent to the Kibungo syncline in the W: the Rwinkwavu anticline. The regional geology is dominated by two major parallel alignments of intrusive granites: the axis of Sake -Mugesera- Rwamagana-Rugarama-Nyagatare and Rusumo–Ihema granitic complexes. These granitic intrusions are complex and heterogeneous, syn- to post-Kibaran and comprise whitish granites, often pegmatitic and undifferentiated granites, granitoids and granites with two micas. Moreover, the study area exhibits, locally, sparse lenses of layered mafic to ultra-mafic sills and dykes (Figure 3).

Figure 4: Photo showing a cracked gabbro-diorite near the office of Ntaruka Cell (KR026 on the geology map).

Those mafic rocks are composed of quartzite diorites, quartz and amphibole-rich diorites, amphibolites and gabbro-diorites out-cropping on the far Eastern part of the Rwinkwavu anticline, in the vicinity of lakes Rwehikama and Nasho (Figures 2 and 3). Those dark minerals-dominated mafic rocks consist of two elongated and parallel E-W trending units of mafic to ultra-mafic rocks separated by thick layers of recrystallized quartzite. The origin of these mafic to ultra-mafic suites is up to now unknown.

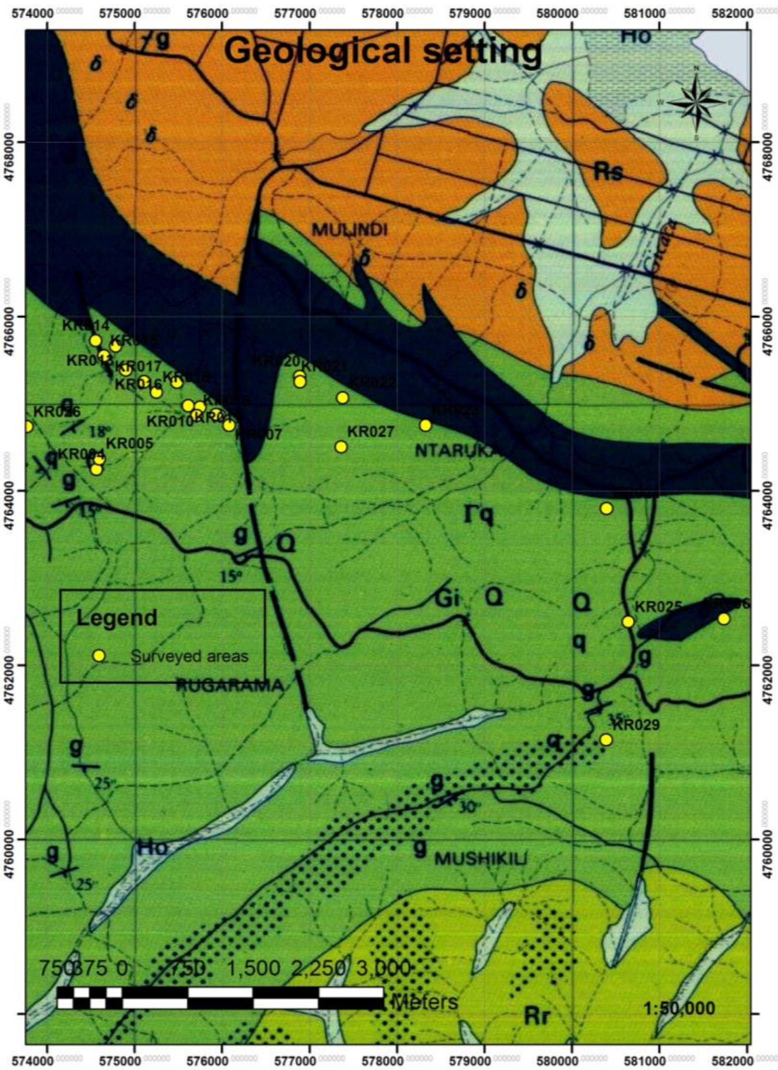

Figure 1: Geological map of the surveyed area.

2. METHODOLOGY

2. 1. Sampling

In Nyarubuye area, the sampling of sandstone was done at each 200m interval but due the size of the area and limit time, we reduced the sampling frequency to routine sampling. 500 to 1000g of sandstone were collected from field. 250g were crushed using a geological hammer. A GPS, shovels and a tape measure were as well used for the field work. Each collected sample was kept in an appropriate bag. For each sample, the coordinates, elevation and distance between two samples were recorded. The samples were collected on the foot on the hills and on the top of them in conformity of systematic procedure of sampling. All collected samples were fresh and recrystallized sandstone.

No	Sample	Northing (m)	Easting (m)	Elevation (m asl)
1	RK3N002	575932	4764877	1463
2	RK3N003	575748	4764964	1471
3	RK3N004	574783	4765664	1496
4	RK3N005	575249	4765132	1569
5	RK3N006	575710	4764866	1550
6	RK3N007	576892	4765256	1582
7	RK3N008	578325	4764755	1546
8	RK3N009	573769	4764737	1872
9	RK3N010	577360	4764507	1790
10	RK3N011	577520	4762929	1783
11	RK3N012	582358	4761419	1683

Figure 6: table of showing samples location

2. 2 Sample preparation

The sample preparation was done in the RNRA/GMD laboratory. After the registration of the samples in a logbook, the sample was crushed and grinded. Representative samples were stored in appropriate bags and then, labeled.

2.3 *Sample analysis*

Preliminary physical and chemical analyses were completed in the GMD laboratory. The target of these analyses was to cross-check whether the sandstone extracted from Nyarubuye-Nasho area might constitute a raw material for production of glasses or can be used for other industrial purposes.
This study comprises laboratory measurements and assays. One rock sample was collected from the mafic rocks. Furthermore, eleven (11) fresh quartzite samples were collected from different locations across the study area in order to determine the density of the samples using Archimede's principle. The mass of each sample was determined using a balance. The mass was used to measure the volume. The volume inside the measuring cylinder was known before suspending the sample inside the cylinder. The final volume was calculated as the volume of the sample.
The height of the quartzite resources was determined using a Global Positioning System (GPS)-garmin focusing on the difference of altitudes. The area size was estimated using ArcGIS software (Figures 6 and 10).

3. DISCUSSION OF THE RESULTS

3.1. *Density calculation*

The density of each sample is measured using the following formula: Density = Mass/volume.
The following results were obtained:

Waypoint	**Sample number**	**Type of rock**	**Color of pulverized powder**	**Hardness on Moh's scale**	**Calculated density (g/cm^3)**
KR006	RK3N001	Dark minerals-dominated rock: gabbro-diorite	Dark grey	?	?
KR009	RK3N002	Recrystallized sandstone	White	7	2.6270
KR010	RK3N003	Recrystallized sandstone	Rose	7	2.6738
KR013	RK3N004	Recrystallized sandstone	White	7	2.6499
KR018	RK3N005	Recrystallized sandstone	Rose	7	2.7038
KR019	RK3N006	Recrystallized sandstone	White	7	2.6702
KR021	RK3N007	Recrystallized sandstone	White	7	2.6543
KR023	RK3N008	Recrystallized sandstone	Rose	7	2.6594
KR026	RK3N009	Recrystallized sandstone	White	7	2.6573
KR027	RK3N010	Recrystallized sandstone	White	7	2.6597
KR028	RK3N011	Recrystallized sandstone	White	7	2.5004
KR029	RK3N012	Recrystallized sandstone	White	7	2.5934
Average density					**2.6408**

Figure7 : table of samples density

The average density is ca. 2.6408g/cm^3 which is equivalent to 2640.8kg/m^3.

3.2. Volume and tonnage determination

There is a huge resource of quartzite in Kirehe District in the sectors covered by the Gitwe geological formation. Few rock samples were previously collected, taken to commercial laboratories in Indonesia. The results of analyses were good. The investigated areas were in the surroundings of the previously sampled zones (Figure 8).

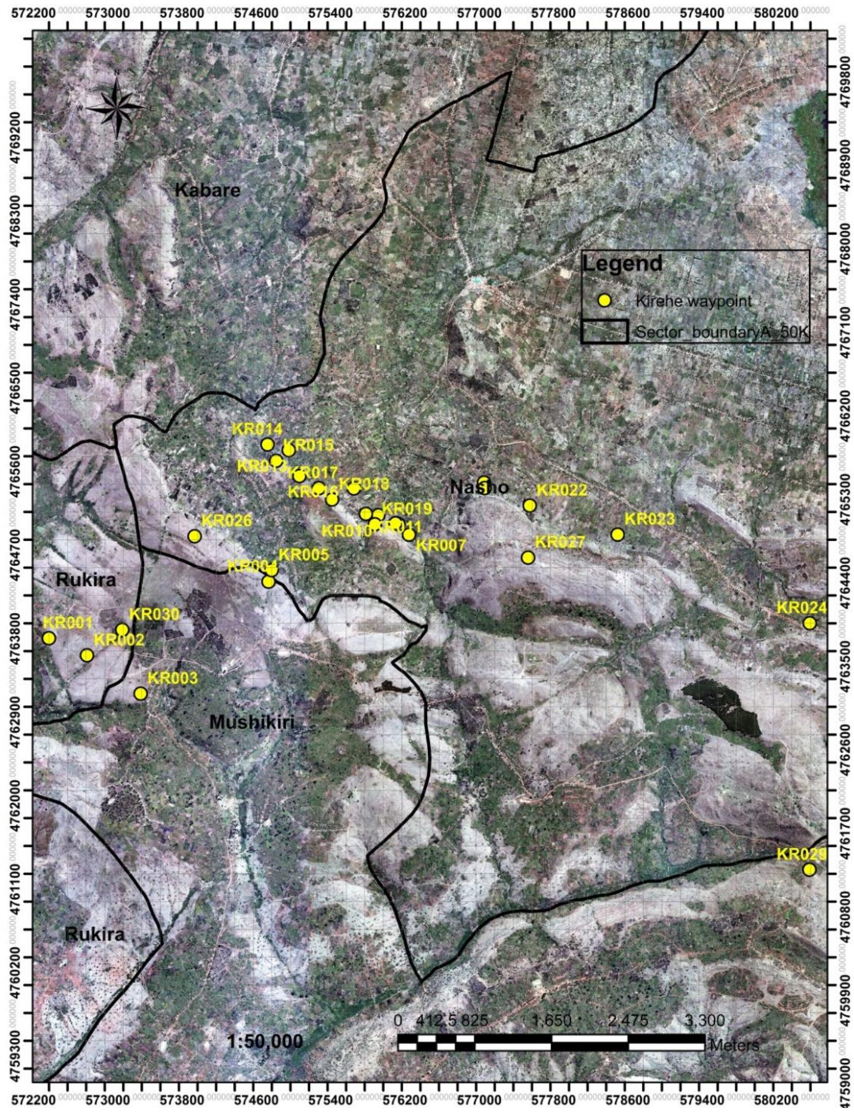

Figure 8: Aerial photo showing two (2) investigated quartzite bodies (KR14-KR007&KR007-KR024).

Resource estimation was done on two blocks situated in the Nasho Sector for the following reasons:

- Shallow and easily exploitable resource;
- Favorable topography;
- Water resources (near the lakes of Akagera National Park);
- Access roads in good conditions;
- Electricity supply not very far;

- The land is used only for agriculture, so no housing will be compensated during the project implementation;
- A big part of the land is for the district of Kirehe;

3.2.1. JYOGIRE BLOCK: sandstone reserves estimate

Figure 9: Photo showing how the height of the Nasho quartzite was measured.

sandstone reserves estimation in the Jyogire area
Lower block
Measured surface (using ArcGIS software) = 2,587,570m^2.
Height of the block = 97m (altitudes difference),
Volume of the quartzite = 2,587,570m^2*97m = 250,994,290m^3
Upper block
Measured area (using ArcGIS software) = 2,343,614m^2; Height of the sub-block = 307m
Volume of the quartzite resource = 2,343,614m^2*307m = 946,820,056m^3.
Total volume = 250,994,290m^3+946,820,056m^3 = **1,197,814,346m^3.**
Weight = Volume*density = 1,197,814,346m3*2640.8kg/m3 = 3,163,188,124,916.8kg = **3,163,188,125 Tonnes.**

Figure 10: Aerial photo of the Western-most part of the assessed quartzite resource.

Figure 11: Aerial photo of the middle part of the surveyed quartzite.

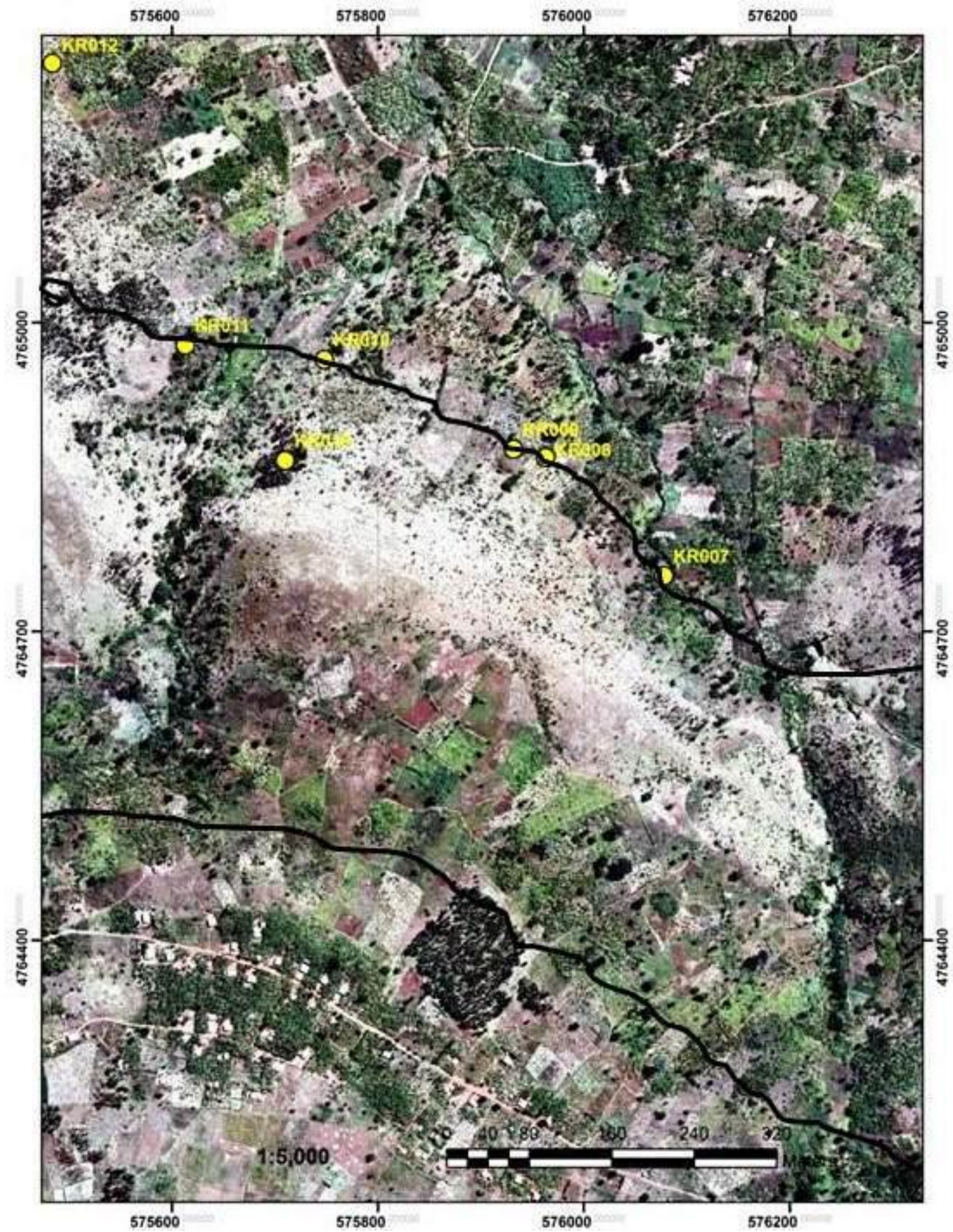

Figure 2: Aerial photo of the Eastern-most part of the surveyed quartzite (Jyogire area).

3.2.2. NYAMURINDIRA RANGE BLOCK

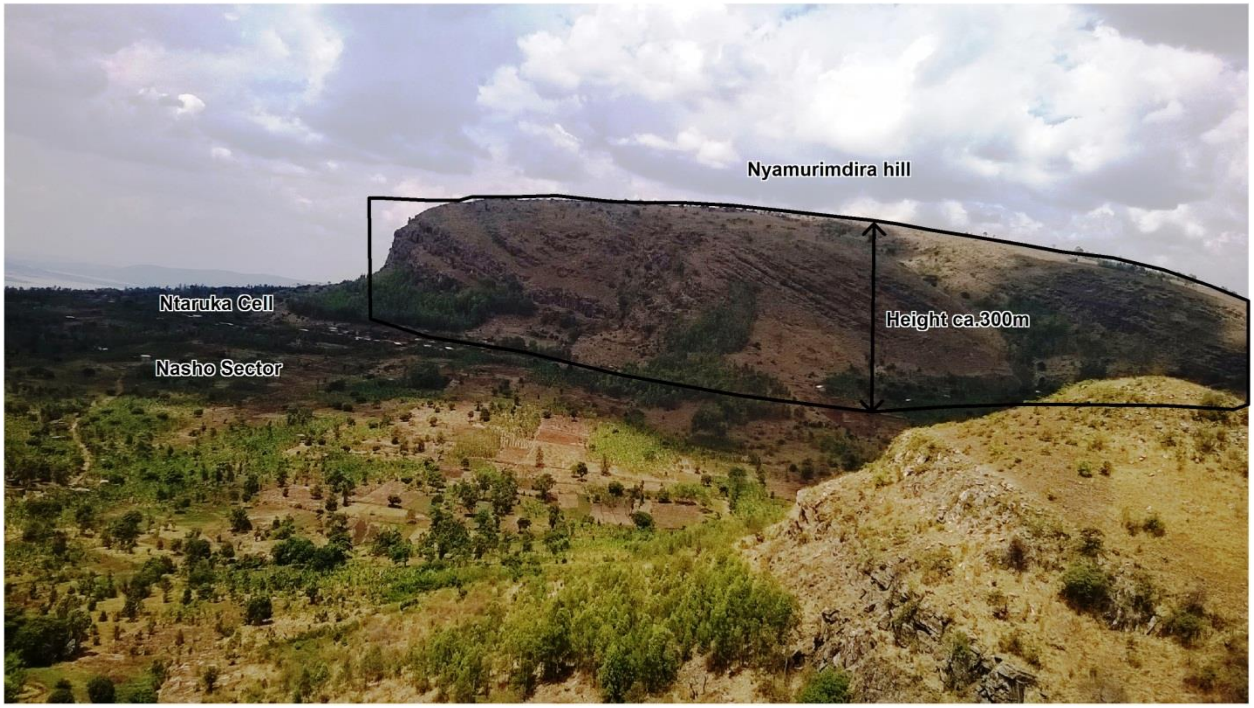

Figure 13: Western side of Nyamurindira quartzite located between Nyarubuye and Nasho sectors (Kirehe District).

Area of Nyamurindira quartzite (determined using ArcGIS) = 2,220,857m^2.
Estimated height (GPS) = 320m
Volume of quartzite = 2,220,857m^2*320m = 710,674,240m^3.
Weight of the quartzite resource = Volume*density = 710,674,240m^3*2640.8kg/m^3 = 1,876,748,532,992kg.
The targeted quartzite resource for the Jyogire area is ca.**1,876,748,533 Tonnes**.

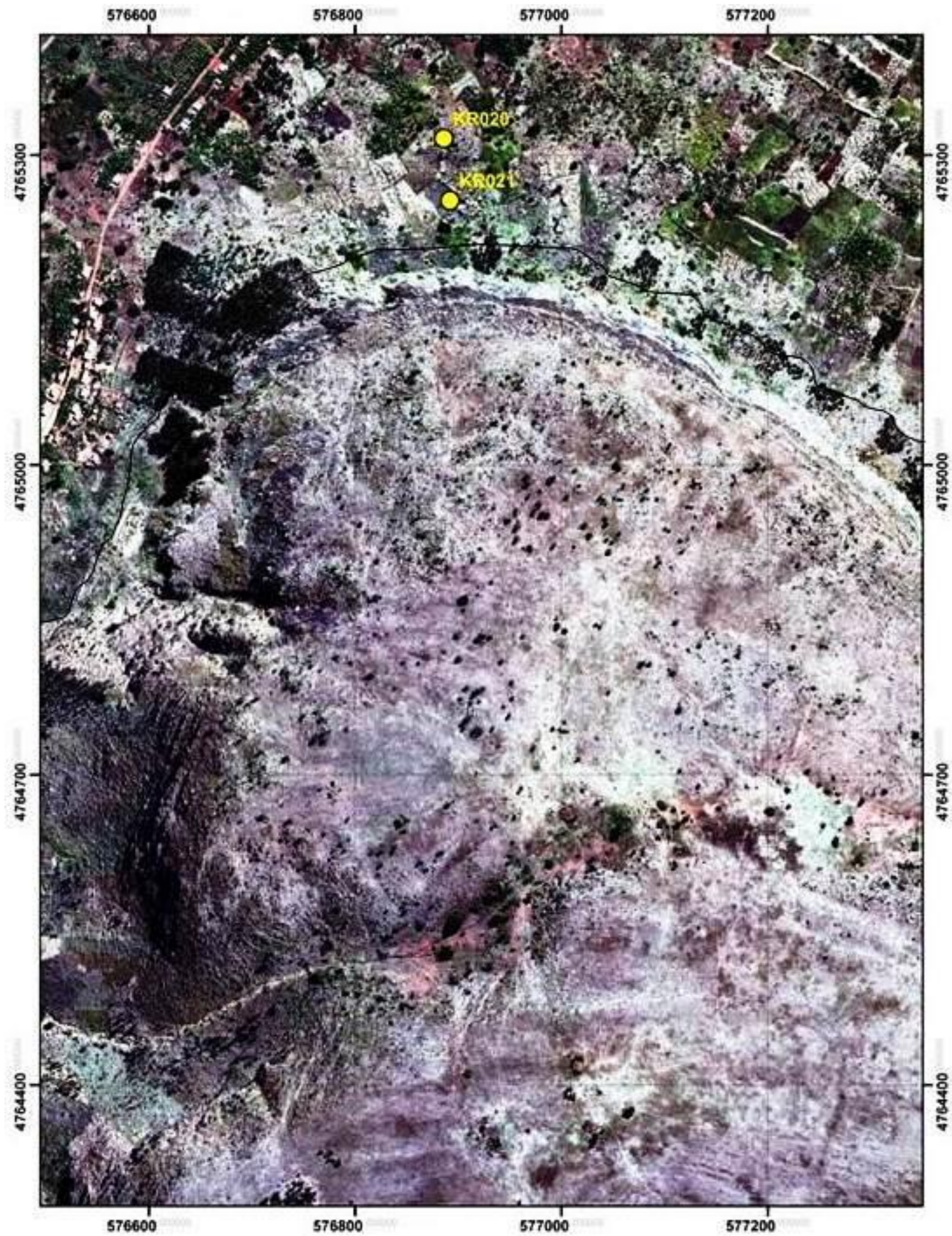

Figure 14: Aerial view of Nyamurindira hill corresponding to the block of the surveyed sandstone).

Figure 15: View of the middle part of the Nyamurindira sandstone.

Figure16: Aerial view of the Eastern-most part of the Nyamurindira quartzite resource.

Total reserves = 3, 163, 188,125 Tonnes + 1, 876, 748,533 Tonnes = 5, 039, 936,658 Tons.

3.2. Chemical analysis (Major oxides)

No	Sample name	%SiO_2	%TiO_2	%Fe_2O_3	%Al_2O_3	%P_2O_5	%CaO	%MgO	%Na_2O	%K_2O	%MnO
1	RK3N002	92.77	-	0.9326	-	-	-	-	-	-	-
2	RK3N003	81.8	-	0.8919	-	-	-	-	-	-	-
3	RK3N004	93.5	-	0.8437	-	-	-	-	-	-	-
4	RK3N005	95.62	-	0.8375	-	-	-	-	-	-	-
5	RK3N006	94.87	-	0.7647	-	-	-	-	-	-	-
6	RK3N007	91.3	-	1.039	-	-	-	-	-	-	-
7	RK3N008	93.35	-	0.6409	-	-	-	-	-	-	-
8	RK3N009	92.5	-	0.7253	-	-	-	-	-	-	-
9	RK3N010	92.65	-	0.8249	-	-	-	-	-	-	-
10	RK3N011	95.88	-	0.8345	-	-	-	-	-	-	-
11	RK3N012	95.89	-	0.7716	-	-	-	-	-	-	-

Figure 17: Table showing chemical analysis of major oxides from the samples taken

Although we preferred to measure major oxides, for one sample we additionally measured some minor oxides for getting the whole picture of the Nyarubuye sandstone quality:

No	Sample name	%SiO_2	%Fe_2O_3	%Al_2O_3	%Na_2O	%K_2O	%MnO
1	RK3N000	97.3	0.4	0.2	0.064	0.049	-

Figure18: table showing analysis results of minor and major oxides from one sample

4. NYARUBUYE SANDSTONE AS RAW MATERIAL

Considering their chemical composition, hardness, area occupied by the resource stone and environment around that area, the sandstone of Nyarubuye-Nasho-Mushikiri area can constitute the raw material for the glass industry. The sandstone can be used to produce the ferrosilicon, industrial silica, silicon and silicon carbide. They can also be used as construction materials or used as electric and electronics, solar panels and heat resistant fabrics.

Due to the reason why a 100% of the glasses of Rwanda are still imported, the glass production is more suitable for our country. The glass making by float methods is necessary for buildings and it can help the country to upgrade the development of our country creating new jobs and reduce imports of glass products. The other alternative use of the sandstone of Nyarubuye area is the manufacturing of optical fibers.

4.1. Required raw material in grass making and its availability in Rwanda

A part of the sand silica (SiO_2) which is available in Kirehe and that will be used at more than 75 percentages there are other essential raw materials that are available in the Country:

- ***CaO and MgO that are extracted from Limestone***

Rwanda has enough reserves of limestone from travertine with almost 40 to 49% of CaO which is mined in many places of Western Province of Rwanda.
Rwanda has also some outcropping rocks of dolomite in some places of Karongi district. A sample of the Karongi dolomite has shown up to 45.056% of MgO in its composition.
At the same time Karongi district disposes a deposit of Marble at Mbabara Island. This marble contains 51.78% of CaO.
Main of these limestone deposits are accessible via the tarmac road along Kivu Lake.

- **Al_2O_3 that can be extracted from feldspar**

Rwanda is mainly underlain by granites with different ages (13 to 9,5Ma) and the latest granites which mainly expressed as pegmatites or followed by pegmatites are rich in feldspar. The big field of such pegmatites is located in the South Central to the Central and central west of the Country and some of the pegmatite rich in feldspar can have 20Km length out of 1km of width.

- **F_2O_3 that can be mined in some places in Rwanda**

The good deposits of Iron are found mainly found in the North party of Rwanda in Burera and Bicumbi Districts. In that places Iron contents can rich more than 66%.

- **Soda ash**

The only raw material that may be imported is Soda ash which may be found not so far from the site location. Lake Nitron in Arusha which is locate at around 900 Km from the sandstone site has a good quality(highly rich in Sodium carbonate). Also soda ash can be found in Kenya.

5. NEEDS OF GLASS PRODUCTS IN RWANDA

Rwanda is among of the Countries of Africa with high and stable economical growth rate averaged at 7.73% from 2000 to 2015.

Figure18: Graphic showing average annual growth *rate*

This economic trend encourages high investment especially in the sector of houses construction and all types glass material as accessories and according to the plan of cities in Rwanda, they are building houses going height which also implies using lightweight materials especially using glass products.

Houses recently constructed in Kigali Central town Planned houses to be soon constructed

If we look on the housing demand only in Kigali City by 2022, it will be required to construct 458,265 new buildings from social housing to premium housing (Kigali City report in housing Study, 2012).
More on the needs in glass for construction, Rwanda also is increasingly importing various products of glass products which were in 2014 estimated at around 3,4bilion of Rwandan Francs.

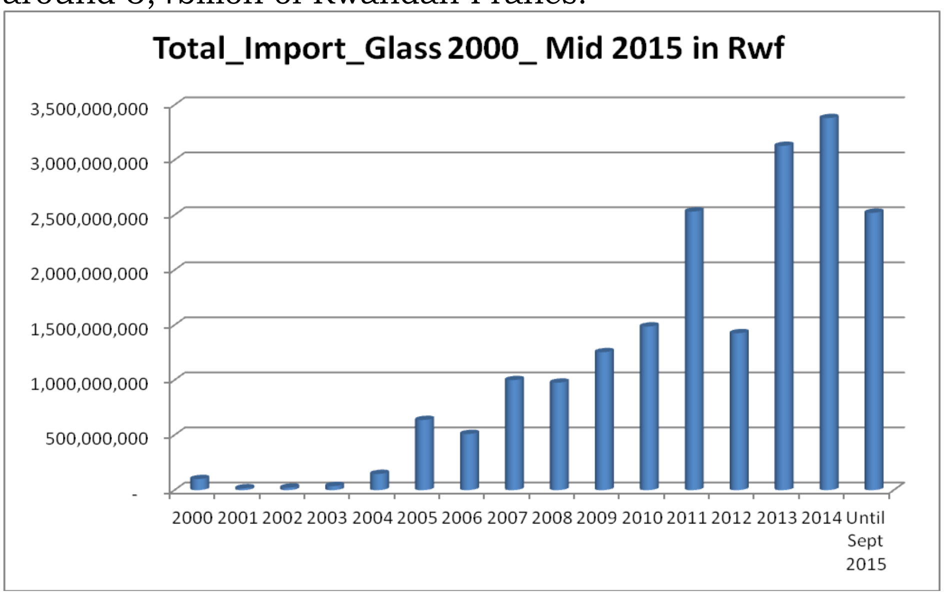

Figure19: Graphic showing annual glass import between 2000 and 2015

By looking on this graphic it is clearly seen that the demand of glass products is going higher which means any glass factory may not be disappointed by the market.

6. WHY TO INVEST IN RWANDA FOR GLASS MANUFACTURING

Apart of the highlighted needs and its internally known law and rules to facilitate investment, Rwanda has many other assets that can uphold a glass industry:

- ✓ ***Geographical well located***: Being located between Easter part of Africa and Central Africa is offering to the glass industry the opportunity of easily accessing at the same time selling on many countries.

- ✓ ***Developing transport network:*** A good road network in Rwanda is facilitating goods from Rwanda to reach directly towns of surrounding Countries like Uganda, Tanzania, Burundi, East Democratic Republic of Congo and also now as the whole region is developing its road connection, goods from Rwanda can now reach other countries that are not directly boarding with Rwanda such Zambia via Burundi, Kenya and South Sudan and Central Africa via Uganda.

  More on this Rwandair with its new planes is connecting Kigali with many towns of six countries of West Africa (Congo Brazzaville, Gabon, Ghana, Nigeria and very soon in Equator Guinea and Cap Verde) and also some town of Southern part of Africa like South Africa, Zambia, Angola and very soon Zimbabwe.

- ✓ ***Good quality of raw material***

For being sure of the quality of the Kirehe Sandtone, a sample from there has been sent to a very well known glass factory in Indonesia (Mulia glass factory) for chemical test and comparison between the two sand silica (one from Kirehe and the second one from Mulia sand deposits.
The tests revealed that Kirehe has a very good quality of sand silica (Table below)

Chemical composition (%)	**Kirehe sand**	**Mulia silica sand**	**Acceptance standards in Mulia factory**
Silica	98.93	99.45	98.5 minimum
Aluminum	0.29	0.02	
Iron	0.0143	0.0357	0.05 max
Calcium	0.00	0.01	
Magnesium	0.00	0.00	
Sodium	0.07	0.07	
Potassium	0.59	0.21	
Titanium	0.02	0.02	

Figure20: Table of comparison between Kirehe sample and Mulia sample

It is clear that Kirehe sand stone is complying perfectly with the standards of the referred factory and has less harmful element such Iron with only 0.0143 while the acceptance standards max is at 0.05 and also the Kirehe sandstone doesn't contain any Magnesium or Calcium elements that can imply additional cost in treatment.

- ✓ **Site availability**

The sandstone location is an area where is not highly populated especially due to the sandstone deposit that is not allowing local people to construct houses or farming on it. This is a good thing to someone who would like to invest in that area while he will be not required to spend much money for expropriation.

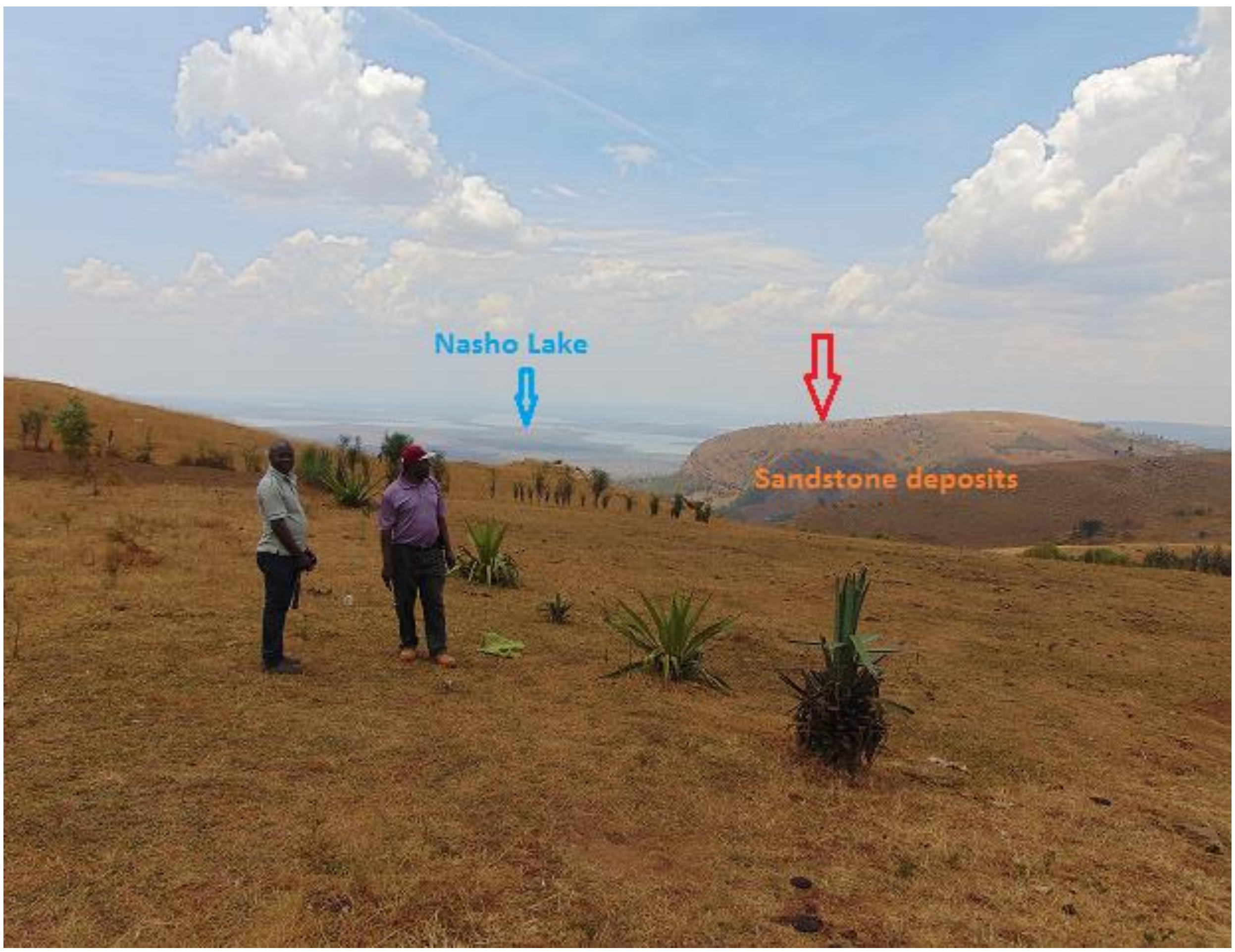

Figure21: Picture the Nyarubuye Landscape

Moreover, the area is very closer to three Lakes Nasho, Cyambwe and Mpanda that can be used to supply water to the factory and also the area is cross passed by an electricity power line.

7. MAJOR NEGATIVE ENVIRONMENTAL IMPACT

The major negative environmental impact of glass production is the gases from melting activities which are emitted into atmosphere:

- The combustion of natural gas/fuel oil and the decomposition of raw materials during melting lead to the emission of CO_2. This is the only greenhouse gas which is emitted during the production of glass;
- Sulphur dioxide (SO_2) from the fuel and /or from the decomposition of sulphate in the batch materials can contribute to the acidification and formation of smog;
- Nitrogen oxides (NOx) due to the high melting temperature and in some cases due to the decomposition of nitrogen compounds in the batch materials also contribute to acidification;
- Evaporation from molten glass and raw materials can release dangerous particles in atmosphere;
- Preparation of raw materials (here, for example, a lot of water is used, to wash the recycled bottles…..);
- Melting (huge amounts of energy are usually in form of burning of natural gas;
-Forming and annealing (where the products assume their final shapes);

Other environmental issues are water pollution which can result from the use of non-renewable natural raw materials such as sand and minerals, production of solid waste and emission of volatile organic compound etc.

8. RECOMMENDATIONS AND CONCLUSION

The present work is clearly demonstrating almost the required raw material is available for setting up a glass factory and at the same time all favorable conditions are met for the same objective such factory. This should incite the government of Rwanda to attract investor in this domain. By this, we here recommend to make further study on this for determining all costs and environment implication. If a suitable investor is found we are sure that the project will get profit and at the same time this will reduce glass products imports and directly reduce the foreign currency that were used to import these materials.
Moreover, this may contribute to develop this rural area of Kirehe but also contribute in Job creation.
It is also important to say that the Kirehe area has many places with a good quality of sand that need to be studied for avoiding any misusing of the resources.