بِسۡمِ ٱللَّهِ ٱلرَّحۡمَٰنِ ٱلرَّحِيمِ

Sudan University of Science and Technology
College of Graduate Studies

Evaluation of rare earth and some rare elements and their environmental impact in their mining area in northern Sudan

تقييم العناصر الارضية النادرة وبعض العناصر النادرة ومدى تاثيرها البيئى فى منطقة تعدينها فى شمال السودان

A thesis submitted in fulfillment of the requirements for the degree of Doctor of Philosophy in chemistry

By

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بسم الله الرحمن الرحيم

قال تعالى :

{ وَتَرَى اْلْجِبَالَ تَحْسَبُهَا جَامِدَةً وَهِى تَمُرُّ مَرُّ اْلسَّحَابِ صُنْعَ اْللهِ
اْلَّذى أتْقَنَ كُل شَىءٍ إِنَّةُ خَبِيرٌ بِمَا تَفْعَلُونَ }

صدق الله العظيم

سورة النمل ـ الآية ٨٨

Dedication

To the Soul of my father

To my mother,

Husband,

\ ***Sons, daughter ,***

brothers and

sisters

Publications

Daffalla, E.A. (2020). The strategy of rare earth elements and their role in industrial development. Volume 4, Issue2, February 2020 Edition. International Journal of Advanced Research and Publication. Page 38-51

Dafalla, E.A. and Hussin, M. (2021). The future of the lithium Mining Industry in Sudan. 21th edition June 2021. Dongola : University of Dongola Journal for scientific Research. Page 159-166

Abstract

The aim of the study is to evaluate the amount of rare earth and rare elements in Albir mining area , which located about 84 km southWadi Halfa on Northern Sudan.

Because of the great geological diversity of elements in Sudan, many rare elements were detected. The present work is the first study to evaluate rare earth elements and lithium in Sudan using a number of instrumental techniques, including a flame photometry, X-rays fluorometry (XRF), X-ray powder diffraction (XRD), inductively coupled plasma mass spectrometry (ICP-MS) and gamma spectrumetry.

Results show that The concentration range (ppm) for Sc (0.5 – 64.135), Y (1,23- 159.139), for La(0.8 – 243,651) , Ce (5.99 – 590.139), Nd (0.3 – 387.395) , Sm(N.D - 75.848) , Yb (N.D – 4.126), Ta (N.D – 95) , W (1.18 -377.869) , Nb(0.06 – 24.129) , Sn (N.D – 7.6), Li (20 -770).

The estimated ore reserves for each of the rare-earth elements, rare elements and lithium were found to be of economic value, and estimated to be 5.000 tons, 3.800 tons and15.000 tons, respectively . It's considered to be of economic value. Two samples of water as well as soil samples were collected and analysed to ensure that underground water in the mining area and adjacent area was not polluted. It was found that the underground water was suitable for human consumption. Thorium and uranium samples were also analysed to determine their radioactivity which was found to lie with in the normal range ; thus radioactive environmental impact were absent.

المستخلص

هدفت الدراسة الى تقييم كمية العناصر الارضية النادرة المكتشفة في منطقة البئر علي بعد حوالي ٨٤ كلم جنوب وادي حلفا شمال السودان.

ونسبه للتنوع الجيولوجى الذى يحظى به السودان بالتالى تنوعه الكبير فى العناصر مما ادى الى تواجد كثير من العناصر النادره . العمل الحالى هو اول دراسة لتقييم عناصر كاليثيوم والعناصر الارضيه النادرة فى السودان باستخدم عدد من التقنيات الالية ، مثل مضوائية اللهب لضوء بالهب ، مفلورية الاشعة السينية ، حيود الاشعة السيتيه ، مطيافية كتلة البلازما المقترنة الحثية ومطيافي غاما.

كان نطاق التركيز الموجود كجزء من المليون كالاتـى:-

(Sc (0.5 – 64.135), Y (1,23- 159.139), for La (0.8 – 243,651) , Ce (5.99 – 590.139), Nd (0.3 – 387.395) , Sm (N.D - 75.848) , Yb (N.D – 4.126), Ta (N.D – 95) , W (1.18 -377.869) , Nb (0.06 – 24.129) , Sn (N.D – 7.6), Li (20 -770).

تقديراحتياطيات الخام لكل من العناصر الارضية النادرة والعناصر النادرة والليثيوم هى:- ٥ الف طن، ٣,٨ الف طن و ١٥ الف طن على التوالى. تعتبر هذه الاحتياطيات ذات قيمة اقتصادية. تم جمع عينتين من الماء وعينتين من التربه وتحليلها للتاكد من عدم تلوث المياه الجوفية فى منطقة التعدين و المنطقة المجاورة. وجد ان المياه الجوفية مناسبه للاستهلاك الادمى . تم تحليل العينات لعنصر الثوريوم واليورانيوم وتعيين النشاط الاشعاعى فى منطقة التعدين ووجد انه يقع فى المجال العادى وبالتالى تبين عدم وجود تاثيرات اشعاعية.

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List of abbreviation

Abbreviation	Terminology
REE	Arare - earth element
REM	Arare - earth metal
IUPAC	International Union of Pure and Applied Chemistry.
OSHA	Occupational Safety and Health Administration.
WHS	Work place Health and Safety
IAEA	International Atomic Energy Agency
EIA	Environmental impacts assessment
SSMO	Sudanese Authority for Standardization and Metrology
LIBs	lithium ion Batteries
a.s.l	Above sea level
HREE	Heavy rare earth elements
LREE	Light rare earth elements

Chapter one

Introduction and literature review

Chapter one

Introduction and Literature Review

1.1 Introduction

1.1.1 Location and Accessibility of the Study Area

The study areais located about 84km south of Wadi-Halfa border town with Egypt, between latitudes 20^{o} 57$^{'}$ 34.7 and 21^{o} 17$^{'}$ 49.5 N$^{''}$; and longitudes 30^{o} 40$^{'}$ 23.45$^{''}$ and 31^{o} 00$^{'}$ 52.28$^{''}$ E (Fig. 1.1). It represents part of the basement complex forming a relatively inverse V-shaped boundary delineating the sedimentary formations around Wadi-Halfa to the north.

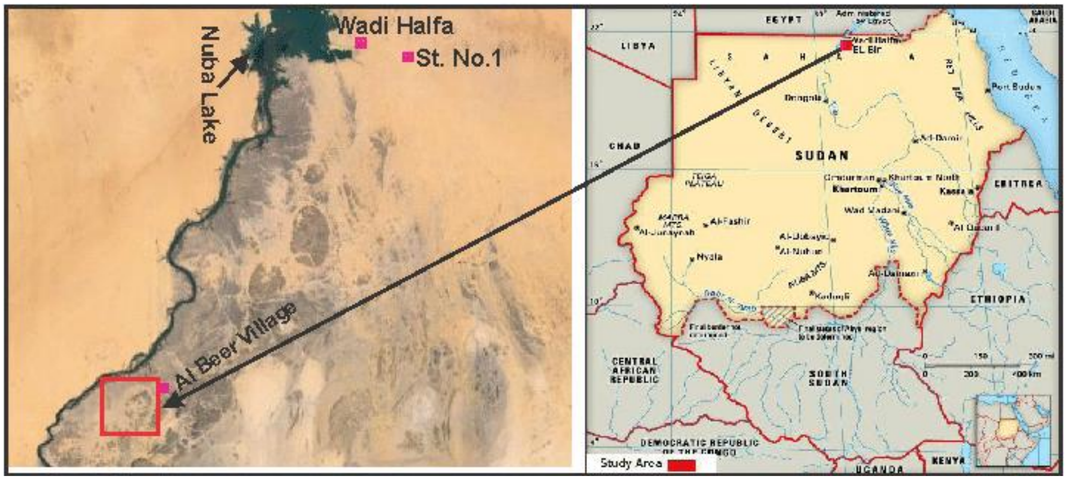


Fig 1.1: Location map of the study area.

The area is very easy to access through the paved highway road from the capital of the Sudan, Khartoum, to Wadi-Halfa via Dongola and Elselem,the total length of the road from Khartoum to El Bir, which lies in the study area, is about 800 km, or form Port Sudan via Atbara and Merowe to Elselem- Wadi-Halfa. Also it can be reached by airplane, in 2 hours from

Khartoum. Moreover, the area is accessible through railways Port Sudan- Atbara- Wadi-Halfa, or through Khartoum-Atbara-Wadi-Halfa; and also with boat from Aswan (Egypt) to Wadi-Halfa (Sudan).

1.1.2 Physiographic Features

1.1.2.1 Topography of the Study Area

Most area of Sudan is covered by plateaus (300-1000 m high), which is crossed, from the south to the north by the valley of the Nile River. In the north, stretch the Libyan Desert and Nubian Desert with almost no vegetation. In the south part, there are savannahs and tropical swamps. The eastern and western parts of the country are covered by mountains. Mount Kineti (3,187 m) is the highest point of the Sudan, in the far west of Sudan lies the Darfur Plateau, with heights from 1,500 to 3,000 m (the highest point is Mount Marra, 3,088 m). A number of separate ranges, from 750 to 1000 m high, are scattered between the Kordofan Plateau and the Darfur Plateau. Mount Oda (2,259 m) is the highest summit of the plateau in the Nubian Desert, situated east of the Nile Valley. Other important mountain ranges in Sudan are the Kordofan Plateau with heights from 300 to 600 m, the Gebel Marra mountain ridge, Mount Pemading(1,460m), Mountain Haraza (1,127m).The study area is a rough physiographically complex area with elevations ranging between (700 and 1200 m A.S.L.). In this area the Precambrian basement complex forms hill chains reaching heights of about 1,079 m a.s.l.

1.1.3 Climate of the Study Area

Sudan is a vast country with an area stretching over 1,865,813 km^2 and with a climate varying from hyper-arid conditions in the north to humid conditions in the south. The study area lies in hyper-arid conditions where temperatures are highest at the end of the dry season. The warmest months are April to July, when average temperature 41 % year-round and temperatures can reach 48% . The hot day time temperatures during the dry season fall rapidly after sunset. Low in the area average 9% in January and drops to as low as 6% after the passing of a cool front in winter. The study area is one of the lowest average annual precipitation extremes where the rain fall does not exceed 0.1 mm .

1.1.4 Hydrology

The study area is one of the most arid areas in the Sudan at some thousands years ago, and now the whole region is an extreme desert. The Nile River is the only permanent surface water sourse through which the whole of the study area finally drained, and without doubt, the Nubia Lake forms one of the important hydrologic features in the study area.

1.1.5 Vegetation

The study area lies in the desert climate region which is characterized by very high-temperatures in the afternoons and low-temperatures in the mid-nights. The vegetation cover is sparse and presents only along the Nile basin. A small number of foxes and other desert animals survive in the increasing aridity of the region.

1.1.6 Previous work

The Nubia area is known since old civilizations by its mineral potentialities, particularly the precious metals like gold, which was mined by the ancient Egyptians, the Nubians, the Turkish as well as the British.

Previously, the basement complex of northern Sudan was poorly mapped and only little information had been collected over the years. No systematic regional or detailed geological mapping had been previously carried out in the regionally mapped area.

Higazy(1991) mapped Abu Sari area southwest of the study area. Stern et al. (1994) reported among others, from geochemical and isotopic data on the Precambrian basement around Wadi-Halfa, the presence of a Pre-Pan-African crust west of the Nile whose components are preserved in the Duweishat gneisses north of the study area.

Abdelsalam et al. (2002) introduced the term “The Saharan Metacraton” for central Africa and the Saharan area, since it was modified in the NeoProterozoic times through deformation, metamorphism and igneous activity.The magnetite ore mineralization at the study area was firstly described by El Nadi et al. (2010) who reported also on the geology and economic potential of Elbir Area, about 100 km south of Wadi-Halfa, and El Nadi et al., (2011) presented an unpublished reconnaissance report on the gold mineralization east of Wadi Gabgaba.

1.1.7 Regional geology

The study area is situated between the Pre-pan African high-grade gneissic terrane of the Bayuda Desert that belongs to the Saharan Metacraton in the west and southwest and the Neoproterozoic juvenile, accreted arc terranes of the Nubian Shield in the east and southeast. Schandelmeier et al. (1988) discussed the possibility of pre-Pan African crust in NE Africa west of the Nile.

According to the previous studies, most of the region of N and NE Sudan is exposed crystalline metamorphic rocks (oldest rocks) belonging to what is generally referred to as the precambrian basement Complex rocks Figure (1.2).

Based on the distribution of the lithological units, the deformation style, the degree of metamorphism and the types of lithostratigraphic successions, the region comprises the following characteristic rock associations (Table 1.1):

1. High- grade Gneisses and Migmatites (oldest)
2. High-grade supracrust almeta seidments
3. Ophiolitic melange rocks (Ophiolitic Mafic Ultramafic Rocks)
4. Low-grade volcano-sedimentary sequences
5. Pre, syn, late-tectonic and Anorogenic granitoid rocks.
6. Post-orogenic younger intrusion
7. Late Paleozoic-Mesozoic Sediments (Previously known as Nubian Sandstone Group).
8. Tertiary volcanic.
9. Superficial Recent sediments (youngest)

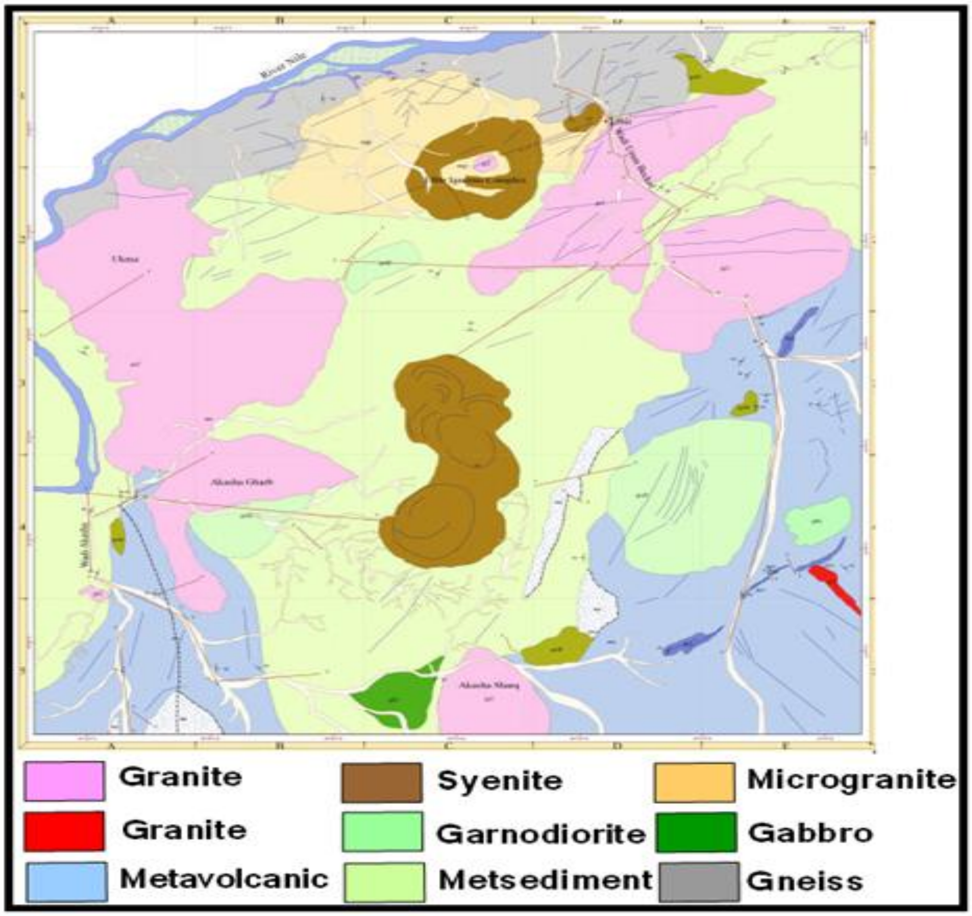


Fig1.2: Regional geological map of Wadi-Akasha- Albir area, northern Sudan (Elnadi and El Sayed 2015).

Table 1.1: The geological column of N and NE Sudan

<table>
<tr><th colspan="2">Formation</th><th>Units</th><th>Age</th></tr>
<tr><td colspan="2">Unconsolidated Cover</td><td>Superficial deposits (Nile Silts, Alluvial Fans, Aeolian Sands, Lag Gravels, and Wash Sands).</td><td>Pleistocene/ Holocene</td></tr>
<tr><td colspan="4">……………………………………….Unconformity…………………..……..……………</td></tr>
<tr><td colspan="2">Volcanic Extrusives</td><td>basaltic volcanoes
basaltic shields ,basaltic /phonolitic plugs</td><td>Cainozoic</td></tr>
<tr><td colspan="2">Paleozoic-Mesozoic-Cenozoic Sediments (Previously known as Nubian Sandstone Group)</td><td>Siltstones ,shale, oolitic ironstone, mudstone, conglomeratic sandstone, Sandstones, limestone, Conglomerates</td><td>Paleozoic- Mesozoic-Cenozoic</td></tr>
<tr><td colspan="4">……………………………………….Unconformity…………………..……..……………</td></tr>
<tr><td colspan="2">Younger Intrusives</td><td>Quartz veins, Acidic and Basic Dykes Pegmatites</td><td>Paleozoic/ Early Mesozoic</td></tr>
<tr><td colspan="4">……………………………………….Unconformity…………………..……..……………</td></tr>
<tr><td rowspan="9">Basement Complex</td><td>Anorogenic Younger Granites</td><td>True Granites, Microgranites and Syenites</td><td>Paleozoic/ Early Mesozoic</td></tr>
<tr><td colspan="3">………………………………Disconformity……………………………..……..…</td></tr>
<tr><td>Older Granitoids</td><td></td><td>Neoproterozoic</td></tr>
<tr><td colspan="3">………………………………Disconformity……………………………..……..…</td></tr>
<tr><td>Low- grade Metavolcanincs</td><td></td><td>Neoproterozoic</td></tr>
<tr><td>Low-grade Metasediments</td><td></td><td>Neoproterozoic</td></tr>
<tr><td colspan="3">……………………………Structural Contact……………………………..…..…</td></tr>
<tr><td>Ophiolitic Mafic Ultramafic Rocks</td><td></td><td>Neoproterozoic</td></tr>
<tr><td colspan="3">……………………………Structural Contact……………………………..…..…</td></tr>
</table>

	High- grade gneisses and Migamaties		Neoproterozoic

1.2 Literature Review

1.2.1 Preliminaries

A rare-earth element (REE) or A rare-earth metal (REM) , as defined by IUPAC, is one of a set of seventeen chemical elements in the periodic table, specifically the fifteen lanthanides, as well as scandium and yttrium (Connelly et al. 2005). Scandium and yttrium are considered rare –earth elements because they tend to occur in the same ore deposited as lanthanides and exhibit similar chemical properties.Rare-earth elements are cerium (Ce) , Dysprosium(Dy),erbium(Er)europium (Eu), gadolinium (Gd), holmium (Ho) , lanthanum (La) , Lutetium (Lu) , neodymium (Nd) , praseodymium (Pr) , promethium (Pm) ,samarium (Sm) , scandium (Sc) , terbium (Tb), thulium (Tm) , ytterbium (Yb) , and yttrium(Y).

Despite their name , rare-earth elements are – with the exception of the radioactive promethium- relatively plentiful in Earth's crust, with cerium being the 25th most abundant element at 68 parts per million , or as abundant as copper . They are not especially rare, but they tend to occur together in nature and are difficult to separate from one another. However, because of their geochemical properties, rare-earth elements are typically dispersed and not often found concentrated as rare-earth minerals in economically exploitable ore deposits (Haxel et al.2006*)*.The first such mineral discovered was gadolinite, a mineral composed of cerium, yttrium, iron, silicon and other elements. This mineral was extracted from a mine in the village of Ytterby in Sweden; four of the rare-earth elements bear names derived from this single location. The estimated average concentration of the rare earth elements in the Earth's crust ranges from around 150 to 220 parts per million , and many other metals that are mined on an industrial scale, such as copper (55 parts per million) and zinc (70 parts per million). Unlike most commercially mined base and precious metals, however, rare earth elements are rarely concentrated into mineable ore deposits (Keith et al.2010).

1.2.2 Source of rare earth elements

The principal source of rare-earth elements (REE) are the minerals bastnasite, monazite, and Loparite and the lateritic ion-adsorptionclay. Despite their high relative abundance, rare-earth minerals are more difficult to mine and extract than equivalent sources of transition metals (owing partially to their similar chemical properties), making the rare-earth elements relatively expensive. Their industrial use was very limited until efficient separation techniques were developed, such as ion exchange , fractional crystallization and liquid- liquid extraction during the late 1950s and early 1960s (Koribanics et al.2015*)*.

Significant quantities of rare-earth oxides are found in tailing accumulate from 50 years of uranium ore, shale and lopraite mining at sillamae, Estonia (Roferet al.2000). Owing to the rising prices of rare earth, extraction of these oxides has become economically viable. China currently export around 3.000 tons per year, representing around 2% of world production (Anneli Reigas 2010). Similar resources are suspected in the western United States, where gold rush –era mines are believed to have discarded large amounts of rare earths, because they had no value at the time(Cone and Tracie 2013) these rare-earth oxides are used as tracers to determine which parts of drainage basin are eroding.

1.2.3The Rare Earth Elements Chemistry

The lanthanides have the valence shell electron configuration $6S^{2}5d^{1}4f^{n-1}$ or $6S^{2}4f^{n}$. In the ground state, the electrons of the 4*f* and 5*d* orbitals have similar energies. The lanthanides are electropositive metals which commonly exist in the trivalent oxidation state (Ln^{3+}).Other oxidation states are attained when the ion contains an empty (f^{0}), half-full (f^{7}) orfilled (f^{14}) *f* subshell. The *f* electrons are tightly held by the nucleus, once the *s* and *d* electrons are removed. Thus Ln^{3+} ions have no frontier orbitals with directional preference, and bonding is due to the electrostatic attraction of ions (Pin and Joannon2002).

The radii of the lanthanides decrease with increasing atomic number, from 103 pm for $La^{3+}$to 86 pm for Lu^{3+} (Pin and Joannon, 2002).This effect is known as the 'lanthanide contraction'. Asthe 4*f* orbitals have poor shielding properties, the valence electrons are more susceptible to attraction by the nuclear charge (Pin and Joannon 2002). Repulsion between electrons as the number of valence electrons increases across the periodic table does not compensate for the increasing nuclear charge.

Consequently, the effective nuclear charge is increased across the Periodic table, resulting in the drawing effect on electrons. Subtle relative effects are also believed to contribute to the lanthanide contraction (Yang *et al.* 2011).

Other ionic compounds of the REE, including hydroxide, perchlorate, carbonate, oxalate,phosphate, sulfate, borate, cyanide and thiocyanate species, are also known (Casacuberta et al.2012). Rare earth hydroxides (such as $Lu(OH)_3$, Fig (1.3) are generally precipitated from a high pHsolution as a gel and may be converted to oxides at temperatures greater than 200% .(Fujiwara et al. 2007**).**

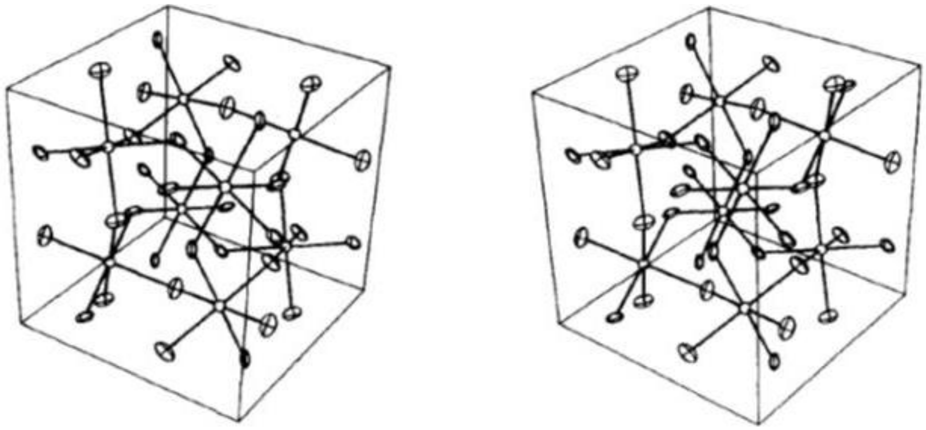


Fig 1.3:Crystal structures of Lu $(OH)_3$

Rare earth chloride hydrates form triclinic(lanthanum, cerium and praseodymium); and monoclinic (neodymium–lutetium, yttrium) crystal systems. Cerium forms a nine-coordinate dimer with formula, $[(H_2O)_7Ce(\mu_2\text{-}Cl_2)Ce(H_2O)_7]^{+4}$ which has a destroyed mono-capped squarenaturism configuration Fi g(1.4). *(*Casacuberta *et al.*2012**)**

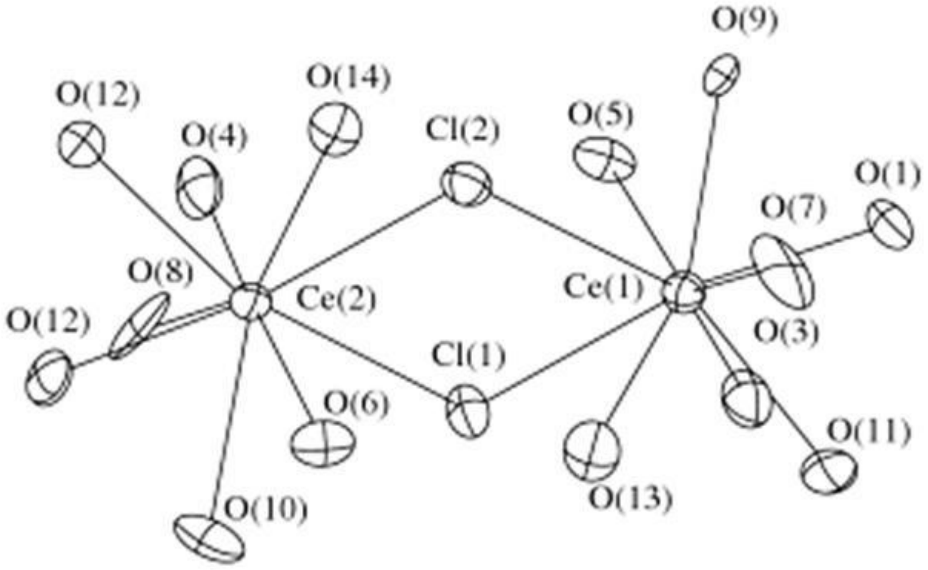


Fig 1.4:Structure of the [(H2O)$_7$Ce (μ2-Cl2) Ce(H2O)7]$^{4+}$dimer in hydrated Cerium chloride

1.2.4 Major use and application of rare-earth elements

The uses, applications, and demand for rare-earth elements have expanded over the years. Globally, most REEs are used as catalysts and magnets. (Zhou et al.2017) Other important uses of rare-earth elements are applicable to the production of high-performance magnets, alloys, glasses, and electronics. Ce and La are important as catalysts, and are used for petroleum refining and as diesel additives. Nd is important in magnet production in traditional and low-carbon technologies. Rare-earth elements in this category are used in the electric motors of hybrid and electric vehicles, generators in wind turbines, hard disc drives, portable electronics, microphones, speakers. Ce, La and Nd are important in alloy making, and in the production of fuel cells and Nickel-metal hydride batteries. Ce, Ga and Nd are important in electronics and are used in the production of plasma screens, fiber optics, lasers (Duarteed

1995), as well as in medical imaging. Additional uses for earth elements are as tracers in medical applications, fertilizers, and in water treatment. (Working Group 2011).

REEs have been used in agriculture to increase plant growth, productivity, and stress resistance seemingly without negative effects for human and animal consumption. REEs are used in agriculture through REE-enriched fertilizers which is a widely used practice in China (*Panget al.2002*). In addition, REEs are feed additives for livestock which has resulted in increased production such as larger animals and a higher production of eggs and dairy products. However, this practice has resulted in REE bio-accumulation within livestock and has impacted vegetation and algae growth in these agricultural areas (Rim and Kyung 2016). Additionally while no ill effects have been observed at current low concentrations the effects over the long term and with accumulation over time are unknown prompting some calls for more research into their possible effects (Pang set al.2002).

1.2.5 Ore minerals and deposits of the rare earth

This an overview of the major and minor ore minerals of the rare earths, and related major ore deposits. As most of the rare earths are mined in China, the impression may arise that ore deposits of these metals occur in few other places on Earth. However, deposits occur in many countries, and that the apparent dominance of China is economically (and politically) powered.

1.2.6 Major ore minerals

The principal ore minerals for the REEs are monazite, bastnaesite,(Evans 2006) and xenotime. The first REE mineral to be used was gadolinite, and from this mineral, several REE were first isolated, but it was not applied on an industrial scale.The first REE ore mineral from which REE were extracted for industrial use was monazite.

1.2.6.1 Monazite

Monazite (Figure1.5) has a generalized chemical formula CePO4. The name is derived from the Greek monazeis, meaning “to be alone” because of the isolated crystals of monazite, and the fact that it was quite rare when first found. Besides Ce, also other REEs occur in monazite. These are mostly the LREEs (light rare earth elements: La, Ce, Pr, Nd, and Sm). Invariably, a mix of rare earths is present.

Fig 1.5: Monazite

Monazite is most frequently occurring REE. It usually contains Th and/or U, but the amounts in monazite are generally too low to be extracted as a valuable by-product. Monazite occurs generally as a minor mineral in granites and granodiorites and associated pegmatites, and also occurs in many metamorphic rocks.

1.2.6.2 Bastnaesite

Bastnaesite (Fig. 1.6) was first described by the Swedish chemist Wilhelm Hisingeras “basis-fluor-cerium”. The general formula of bastnaesite is Ce(CO)F.Bastnaesite is another major REEs ore mineral containing mostly the LREEs cerium, lanthanum, praseodymium, and neodymium. Of the HREEs, only Y is regularly found. Bastnaesite, generally contains, besides Y, appreciable amounts of the HREEs (Heavy Rare Earth Elements: Y, Tb, Dy, Ho, Er, Tm, Yb, and Lu). Most often occurring are dysprosium, ytterbium, erbium, and gadolinium.

Fig. 1.6: Bastnaeite

1.2.6.3 Xenotime

The generalized chemical formula of xenotime is (YPO_4). xenotime, in contrast to monazite and xenotime contains lesser quantities of terbium, holmium, thulium, and lutetium.Xenotime is the major source for HREE but like monazite also containsTh and/or U, which, depends on the location of the deposit. Xenotime tends to concentrate the HREEs (Gd, Tb, Dy, Ho, Er, Yb, Lu), whereas monazite tends to concentrate the LREEs (La, Ce, Pr, Nd, Sm). Xenotime is an accessory mineral in pegmatites and other (non-basic) igneous rocks, but also is common in metamorphic rocks, and concentrates in placers and heavy mineral sands.

Fig. 1.7:Xenotime

With respect to the actinides, monazite tends to concentrate Thorium, whereas xenotime tends to concentrate Uranium, but can take up also appreciable amounts of thorium, whereas uranium occurs in minor amounts.

1.2.6.4 Eudialyte

Eudialyte is acyclosilicate with the general formula Na_4 $(Ca, Ce)_2(Fe^{2+}, Mn^{2+})ZrSi_8O_{22}(OH, Cl)_2$. The name is from the Greek, meaning readily decomposable. Igneous eudialyte occurs in under saturated alkaline intrusions

1.2.7 The rare metals (Ta, Nb, W, Sn,Li)

Despite their name, rare metals are relatively plentiful in Earth's crust, their geochemical properties are the same .The principal concentrations of rare metals are associated with uncommon varieties of igneous rocks, namely alkaline rocks and carbonatites. Potentially useful concentrations are also found in placer deposits, residual deposits formed from deep weathering of igneous rocks, pegmatite, iron-oxide copper-gold deposits, and marine phosphates. (Agulyansky and Anatoly 2004)

1.2.7.1 Tantalum

Is a chemical element with symbol **Ta** and atomic number 73. Previously known as *tantalium.* Tantalum is estimated to make up about*)*2 ppm (Agulyansky and Anatoly 2004) of the Earth's crust by weight. There are many species of tantalum minerals, only some of which are so far being used by industry as raw materials. Tantalite (Fe, Mn)Ta_2O_6 is the most important mineral for tantalum extraction. Tantalite has the same mineral structure as columbite (Fe, Mn) $(Ta, Nb)_2O_6$ when there is more tantalum than niobium it is called tantalite and when there is more niobium than tantalumit is called columbite (or niobite). The high density of tantalite and other tantalum containing minerals makes the use of gravitational separation the best method. Other minerals include samarskite and fergusonite. .Tantalumphysical properties is a rare, hard, blue-gray,(Colakis et al. 2007) dense, ductile, very hard, easily fabricated, and highly conductive of heat and electricity.Its high melting point of 3017 % (boiling point 5458 %) is exceeded among the elements only by tungsten, rhenium and osmium for metals, and carbon .Lustrous transition metal that is highly corrosion-resistant. The chemical inertness of tantalum makes it a valuable substance for laboratory equipment and a substitute for platinum. Its main use today is in tantalum capacitors in electronic equipment such as mobile phones, video game systems and computers. Tantalum, always together with the chemically similar niobium, occurs in the mineral stantalite, columbite and coltan.

The metal is renowned for its resistance to corrosion by acids; in fact, at temperatures below 150 % tantalum is almost completely immune to attack by the normally aggressive, aqua regia. It can be dissolved in hydrofluoric acid or acidic solutions containing the fluoride ion and sulfur trioxide, as well as with a solution of potassium hydroxide.

Tantalum forms compounds in oxidation states -3 to +5. Most commonly encountered are oxides of Ta (5), which includes all minerals. The chemical properties of Ta and Nb are very similar. In aqueous media, Ta only exhibit the +5 oxidation state. Like niobium, tantalum is barely soluble in dilute solutions of hydrochloric, sulphuric, nitric and phosphoric acids due to the precipitation of hydrous Ta(5) oxide (Agulyansky, Anatoly 2004). In basic media, Ta can be solubilized due to the formation of polyoxotantalate species (Deblonde et al. 2015) . Oxides of tantalum in lower oxidation states are numerous, including many defect structures, are lightly studied or poorly characterized (Greenwood et al.1997). Tantalite's, compounds containing $[TaO_4]^{3-}$ or $[TaO_3]^-$ are numerous. Lithium tantalite ($LiTaO_3$) adopts a perovskite structure.

It is part of the refractory metals group, the members of which are widely used as minor components in alloys.As in the cases of other refractory metals, the hardest known compounds of tantalum are nitrides and carbides. Tantalum carbide, TaC, like the more commonly used tungsten carbide, is a hard ceramic that is used in cutting tools.

The best studied chalcogenide is TaS_2, a layered semiconductor, as seen for other transition metal dichalcogenides (Holleman et al.2007).

Natural tantalum consists of two isotopes: ^{180m}Ta (0.012%) and ^{181}Ta (99.988%). ^{181}Ta is a stable isotope. ^{180m}Ta (*m* denotes a metastable state) is predicted to decay in three ways: isomeric transition to the ground state of ^{180}Ta, beta decay to ^{180}W, or electron capture to ^{180}Hf. However, radioactivity of this nuclear isomer has never been observed, and only a lower limit on its half-life of 2.0×10^{16} years has been set (Deblonde et al. *2015)*. The ground state of ^{180}Ta has a half-life of only 8 hours. ^{180m}Ta is the only naturally occurring nuclear isomer (excluding radiogenic and cosmogenic short-living nuclides). It is also the rarest isotope in the Universe, taking into account the elemental abundance of tantalum and isotopic abundance of ^{180m}Ta in the natural mixture of isotopes.

Tantalum has been theoretically examined as a "salting" material used to intensify the power of nuclear weapons (cobalt is the better-known hypothetical salting material). An external shell of ^{181}Ta would be irradiated by the intensive high-energy neutron flux from a hypothetical exploding nuclear weapon. This would transmute the tantalum into the radioactive isotope ^{182}Ta, which has a half-life of 114.4 days and produces gamma rays with approximately 1.12 million electron-volts (MeV) of energy apiece, which would significantly increase the radioactivity of the nuclear fallout from the explosion for several months.

Such "salted" weapons have never been built or tested, as far as is publicly known, and certainly never used as weapons (Holleman et al.2007).

1.2.7 .2 Niobium

Niobium is a transition metal in Group (5B) of the Periodic Table. It is a shiny gray metal with a melting point of 2,468°C and a boiling point of 4,927%. Its density is 8.57 grams per cubic centimeter.

Nioubium is used in many alloys. An alloy is made by mixing and melting two or more metals. The mixture has properties different from those of the individual metals. Niobium alloys are used in jewelry items , such as rings for pierced ears, nose,. because it does not cause allergies or skin problems.

Niobium metal is resistant to attack by most common chemicals. It does not combine with oxygen or most other active elements except at high temperatures. It does not react with most strong acids unless they are hot and concentrated (Lide, 2005). Niobium-93 is the only isotope . Isotopes are two or more forms of an element, that differ from each by their mass number. The mass number represents the number of protons plus neutrons in the nucleus of an atom of the element. The number of protons determines the element, but the number of neutrons in the atom of any one element can vary. Each variant is an isotope. At least a dozen radioactive isotopes of niobium are known also. A radioactive isotope is one that breaks apart and gives off some form of radiation. Radioactive isotopes are produced when very small particles are fired at atoms.

One use of niobium steel is in the construction of nuclear reactors. The demand for niobium steel has increased. One reason is its increased use in airplanes and space vehicles. Some skateboards also include niobium steel components. Niobium alloys are lightweight and hypoallergenic. The term hypoallergenic means that they do not cause skin reactions. People who wear pierced earrings or similar forms of jewelry will not develop skin problems from niobium alloy jewelry. Niobium diselenide ($NbSe_{2)}$ is sometimes used as a lubricant at high temperatures. It does not break down at temperatures up to 1300%. Niobium silicide ($NbSi_{2)}$ is used as a refractory material.

1.2.7 .3 Tungsten

Also known as wolfram, is a chemical element with symbol **W** and atomic number 74. The name "tungsten" comes from the Swedish words "tungsten", which directly translates to "heavy stone (Oxford University 2005*)*. Its name in Swedish is wolfram, in order to distinguish it from tungstate minerals cheelite, which is alternatively named in Swedish tungsten,it's found in wolframite Figure (1.8) (iron–manganese tungstate $(Fe,Mn)WO_4$ being a solid solution of the minerals ferberite $FeWO_4$ and hübnerite $MnWO_4$) and scheelite (calcium tungstate ($CaWO_4$).

Tungsten is a hard, rare metal (under standard conditions, when uncombined), and is found naturally on Earth almost exclusively in chemical compounds. It was identified as a new element in 1781, and first isolated as a metal in 1783. Its important ores include wolframite and scheelite. The free element is remarkable for its robustness, especially the fact that it has the highest melting point of all the elements discovered, melting at 3422 %.It also has the second highest boiling point, at 5930 % .Its high density is 19.3 times that of water, comparable to that of uranium and gold, and much higher (about 1.7 times) than that of lead (Daintith,and John 2005).Tungsten's many alloys have numerous applications, including incandescent light bulb filaments, X-ray tubes (as both Elemental tungsten resists attack by oxygen, acids, and alkalis (Emsley and John 1991).The most common formal oxidation state of tungsten is +6, but it exhibits all oxidation states from −2 to +6 (Emsley and John 1991, Morse et al.2008).Naturally occurring tungsten consists of five isotopes whose half-lives are so long that they can be considered stable. Theoretically, all five can decay into isotopes of element 72 (hafnium) by alpha emission, but only ^{180}W has been observed (Danevich et al. 2003, Cozzini et al. 2004).To do so with a half-life of $(1.8 \pm 0.2)\times 10^{18}$ years; on average, this yields about two alpha decays of ^{180}W in one gram of natural tungsten per year. The other naturally occurring isotopes have not been observed to decay, constraining their half-lives to be at least 4×10^{21} years.About 61,300 tonnes of tungsten concentrates were produced in the year 2009(Shedd and Kim 2009) and in (2010), world production of tungsten was about 68,000 tones .

Fig 1.8:Wolframite,

1.2.7.4 Tin

Tin is a soft, malleable, ductile and highly crystalline silvery-white metal. Is a chemical element with the symbol **Sn** (from Latin: *stannum*) and atomic number 50. It is a post-transition metal in group 14 of the periodic table of elements. It is obtained chiefly from the mineral cassiterite Figure (1.9), which contains stannic oxide, SnO_2. Tin shows a chemical similarity to it neighbors in group 14, germanium and lead, and has two main oxidation states, +2 and the slightly more stable +4**.** The first tin alloy used on a large scale was bronze, made of (1:8) tin and (7:8) copper . In modern times, tin is used in many alloys, most notably tin/lead soft solders, which are typically 60% or more tin, and in the manufacture of transparent, electrically, conducting films of indium tin oxide in optoelectronic applications. Another large application for tin is corrosion-resistant tin plating of steel. Because of the low toxicity of inorganic tin, tin-plated steel is widely used for food packaging as tin cans. Tin has ten stable isotopes, with atomic masses of 112, 114 through 120, 122 and 124 . Of these, the most abundant are ^{120}Sn (almost a third of all tin), ^{118}Sn, and ^{116}Sn, while the least abundant is ^{115}Sn. The isotopes with even mass numbers have no nuclear spin, while those with odd have a spin of +1/2. Tin, with its three common isotopes ^{116}Sn, ^{118}Sn and ^{120}Sn, is among the easiest elements to detect and analyzed (NMR Frequency Map2011)

Fig 1.9: Cassiterite with muscovite

1.2.7.5 Lithium

Is a chemical element with symbol **Li** and atomic number 3. It is a soft, silvery-white alkali metal.When cut, it exhibits a metallic luster, but moist air corrodes it quickly to a dull silvery gray, then black tarnish,has a very low density (0.534 g/cm^3. Under standard conditions, it is the lightest metal and the lightest solid element. Like all alkali metals, lithium is highly reactive and flammable, and is stored in mineral oil. It never occurs freely in nature, but only in compounds, such as pegmatitic minerals, which were once the main source of lithium. Due to its solubility as an ion, it is present in ocean water and is, commonly obtained from brines. Lithium metal is isolated electrolytically from a mixture of lithium chloride and potassium chloride. Lithium can float on the lightest hydrocarbon oils and is one of only three metals that can float on water, the other two being sodium and potassium Fig (1.10).The nucleus of the lithium atom verges on instability, since the two stable lithium isotopes found in nature^{6}Li and ^{7}Li, the latter being the more

abundant (92.5% natural abundance)(Greenwood et al.1984; Emsley and John ,2001; Krebs and Robert 2006).

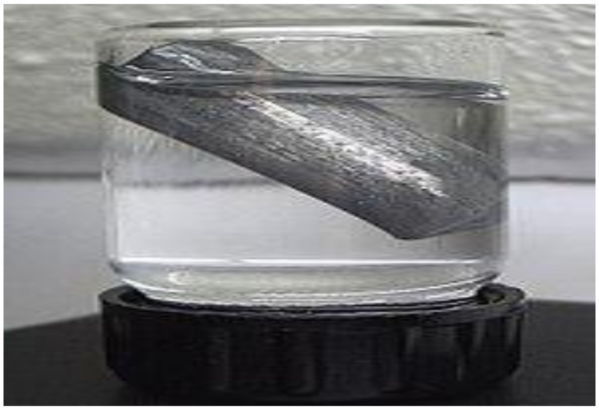


Fig 1.10:Lithium metal

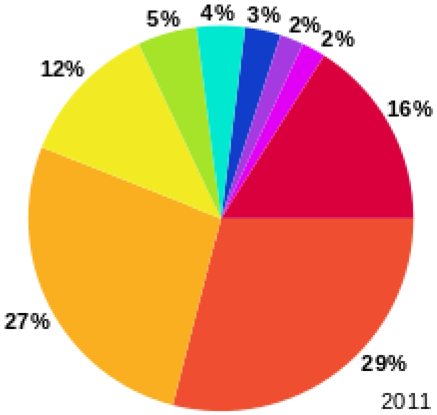
For lithium source, there over 40 lithium minerals have been named and described. Silicates and phosphates, the most common minerals, generally classified as pegmatites .although the theoretical lithium content of these minerals 2 to 5 % (Table 1.3). Relatively high concentration of lithium also occurs in sediment such as clays. Other source was, recycling waste lithium ion batteries (LIBs) and eliminate environmental risks **(**Page et al.2010**)**

Table 1.2 Lithium content of commercial minerals

Mineral source material	Chemical composition	Theoretical lithium content %.	Approximate rang of Li in commercial minerals %.
Ambygonite	**$LiAl(PO_4)_{(F.\ OH)}$**	**4.73**	**3.7- 4.2**
Lepdoite	**$K_2Li_3Al_3(AlSi_3O_{10})_2$ (O,OH,F)4**	**variable**	**1.4- 1.9**
Petalite	**$Li_2OAL_2O_38SiO_2$**	**2.26**	**1.4 – 2.2**
Spodumene	**$Li_2OAL_2O_34SiO_2$**	**3.73**	**2.6 -3.0**

Lithium and its compounds have several industrial applications, including heat-resistant glass and ceramics, lithium grease lubricants, flux additives for iron, steel and aluminium production, lithium batteries, and lithium-ion batteries. These uses consume more than three quarters of lithium production.

🟥 Ceramics and glass (32%)
🟧 Batteries (35%)



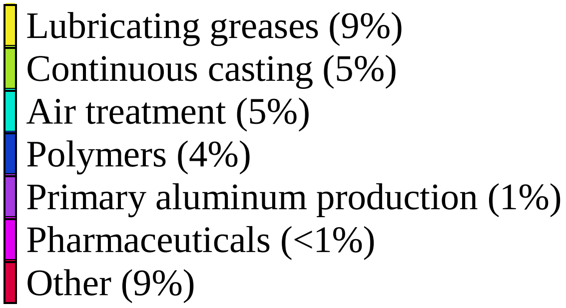


Fig. 1.11:Estimates of global lithium (Wald, 2011)

1.2.8 Instrumental analysis of Element

1.2.8.1X-rays fluorometer (XRF)

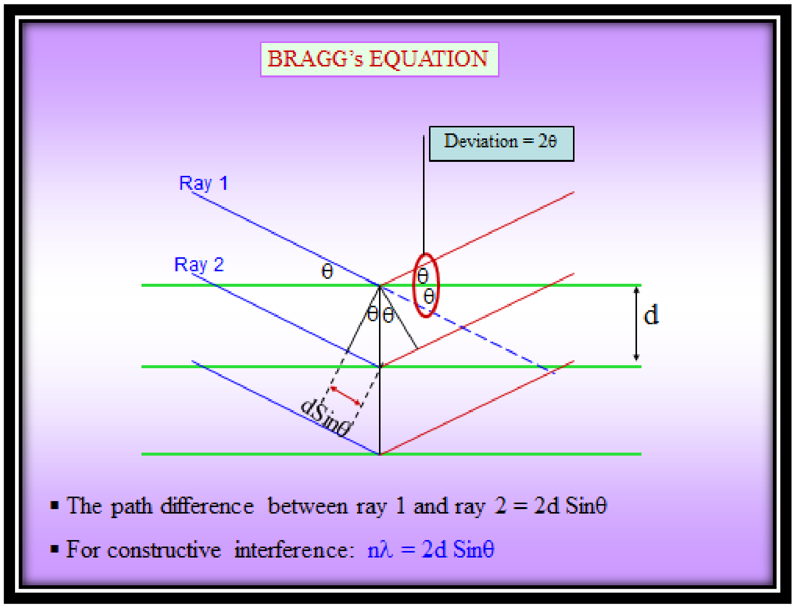
XRF is one of the most powerful and flexible techniques available for the analysis and characterization of materials today.

Many samples can be examined with little or no pre- treatment.
This technique is used for the analysis of materials (heavy metals, sulfur, chlorine) in the environment (soil, water, air particulate (Panalytical company 2010).

1.2.8.2 X-ray diffraction (XRD)

X-ray diffraction is based on constructive interference of monochromatic X-rays and a crystalline sample. The interaction of the incident rays with *($n\lambda=2d \sin \theta$)* Figure (2.3).All diffraction methods are based on generation of X-rays between the incident and diffracted rays. A key component of all diffraction is the angle.

Is the most widely used for the identification of unknown crystalline materials (e.g. minerals, inorganic compounds). Max von Laue, in 1912, discovered that crystalline substances act as three-dimensional diffraction gratings for X-ray wavelengths similar to the spacing of planes in a crystal lattice, and X-ray diffraction now a common technique for the study of crystal structures and atomic spacing. Determination of unknown solids is critical to studies in geology, environmental science, material science, engineering and biology(panalytical.User guide 2008).



BRAGG's EQUATION

- The path difference between ray 1 and ray 2 = 2d Sinθ
- For constructive interference: $n\lambda = 2d \sin\theta$

Fig 2.3: Bragg's Equation

1.2.8.3 Inductively coupled plasma mass spectrometer (ICP-MS)

Inductively coupled plasma mass spectrometry (ICP-MS), is a type of mass spectrometry which is capable of detecting metals and several non-metals at concentrations as low as one part in 10^{15} (part per quadrillion, ppq) on non-interfered low-background isotopes. ICP-MS is widely used in the geochemistry field for radiometric dating, in which it is used to analyze relative abundance of different isotopes, in particular uranium and lead. It is more suitable for this application than the previously used thermal ionization mass spectrometry, as species with high ionization energy such as osmium and tungsten can be easily ionized. For high precision ratio work, multiple

collector instruments are normally used to reduce the effect noise on the calculated ratios. **(** Mas et al. 2012**)**.

1.2.8.4 Flame photometer

In principle, it is a controlled flame test with the intensity of the flame color quantified by photoelectric circuitry. The intensity of the color will depend on the energy that had been absorbed by the atoms that was sufficient to vaporize them. The sample is introduced to the flame at a constant rate. Filters select which colors the photometer detects and exclude the influence of other atoms. Before use, the device requires calibration with a series of standard solutions of the atom to be tested.

Flame photometry is crude but cheap compared to flame emission spectroscopy or ICP-AES, where the emitted light is analyzed with a monochromator. Its status is similar to that of the colorimeter (which uses filters) compared to the spectrophotometer (which uses a monochromator). It also has the range of metals that could be analyzed and the limit of detection is considered.

The basis of low temperature flame photometry is the same as that of the simple quantitative analytical flame test. This exploits the fact that compounds of the alkali and alkaline earth metals are thermally dissociated into atoms at the temperature of a Bunsen burner flame and that some of the atoms produced are further excited to a higher energy level. When these 'excited' atoms return to the ground state, they emit radiation, which for the elements of these two groups lies mainly in the visible region of the electromagnetic spectrum.

Is a device used in inorganic chemicalanalysis to determine the concentration of certain metal ions, among them sodium, potassium, lithium, and calcium. Group 1 and Group 2 metals are quite sensitive to flame photometry due to their low excitation energies(Russell Mainstream Supply Ltd.2009).

1.2.8.5 Gamma spectroscopy

Gamma-ray spectroscopy is the quantitative study of the energy spectra of gamma-ray sources , such as in the nuclear industry, geochemical investigation, environmental controlThe boundary between gamma rays and X rays is somewhat blurred, as X rays typically refer to the high energy electronic emission of atoms, which may extend to over 100 keV, whereas the lowest energy emissions of nuclei are typically termed gamma rays, even though their energies may be below 20 keV.(**BSI 1994**).

1.3 Objectives

1.3.1Questions and hypothesis

The relevant hypothesis addressed and the related questions asked are:

(1) What are the geology and geological structure of the study area?

(2) How to evaluate the rare – earth elements in Albir area?

(3) What is the hypothesis of existence of lithium in the rare- earth elements?

(4) What is the environmental challenge from radioactive thorium and uranium associated with rare-earth elements in mining area?

1.3.2 The main objectives

In line with the strategies plan of the country to encourage mining of minerals and ores of industrial importance the main objectives of the present work are:

- To determine and evaluate the rare-earth elements in mining area of the Northern State, Sudan.
- To assess the environmental hazards of mining in this area.

1.3.3The specific objectives

The specific objectives are:

- To determine the contents of Li,W, Sn, Ta and Nb in alkaline and acidic rocks of Elbir area in Northern State.
- To determine the levels stable isotopes of rare-earth elements.
- To determine actually of radioactive minerals associated with alkaline rare earth mineral rocks.
- To analyse drinking water in the mining area.

Chapter two
Materials and Methods

2.1Materials

2.1.1Chemicals

The chemical used were hydrofluoric acid (HF 40%) MRS Scientific Ltd, Nitric acid (HNO_3 69%) extra pure Loba PVT. Ltd, Hydrocloric acid (HCL 36.34) Extra pure grad Duk San pure Chemicals , Percloric acid ($HCLO_4$70%) gentral drug house (p) Ltd New Dalhi (India),sulfuric acid($HSO_4$96%) carlo Erba Reagents (ASP) **,** Eriochrome black T indicator – Scientific Ltd, **(** Sodium hydroxide, EDTA, silver nitratepotassium chromate as indicator- Trust chemical labroteries - India), (Cadmium metal, Nesler reagent, barium chloride**,** zirconium –dye solutionand– Hach USA) and Phenanthroline– lopa chemie –India.

2.1.2Apparatus

An oven, four decimal placesdigital balance, quartz mortaring unit, pressing machine, sandpath.

2.1.3 Equipment

Teflon beackers (50 ml),Glass beackers (600 ml Class A), Glassrod, Volumetric flask (50 ml Class A), Magnetic stirrer, Burritt (50 ml Class A).

2.1.4 Instrument

- Sequential X-ray fluorescence spectrometer
- Axios max 4.0kw and super Q application software
- X-ray powder diffraction (*XRDPw3040/60xperit*).
- inductively coupled plasma mass spectrometer (ICP-MS) a Perkin Elmer Elan 9000.

2.2Methods

2.2.1 Sample collection

1-Twenty nine chip, trench and BH rock samples from Albir area were collected as follows:

i. The microgranite pluton NW and west of El Bir igneous complex.
ii. The pegmatitic facies of quartz syenite of the ring dyke and
iii. The small pluton of quartz syenite immediately NE of the igneous complex.

2-The chip samples collected from around Elbir area had the same rock types mentioned above

3-Two samples were taken from surface for determination the grain size.

4- Two samples were taken from underground water

2.2.2 Sample preparation

The crushing and grinding of the chip and bulk samples were made at the Geological Research Authority of the Sudan (GRAS) laboratories. Each bulk sample was first crushed by jaw crusher to obtain a reasonable grain size for grinding, Figure (2.1). The crushed material was repeatedly quartered down to about 400 g , which was there ground to a finer fraction for 4 ~ 5 minutes. The 400 g of each sample was then subdivided into two equal portions, each of which was about 200 g.

2.2.1.2Geochemical Sampling

The study area was subjected to an intensive sampling for alkaline and acidic rock samples to determine their rare- earth elements content. Twenty nine samples were analyzed to determine their rare - earth elements content by XRF and XRD and their lithium content by flame photometer. Seventeen samplesof rare- earth elements were selected to determine their radioactivity content by Gama ray spectrometer and twelve samples were sent to Managim laboratory in Morocco to determine their Isotopes by inductively coupled plasma - mass (ICPMs).Two soil samples were collected to determine their grain size by sieves analysis and two water samples to determine their physical properties (pH, Hardness, TDS, ect) and chemical analysis.

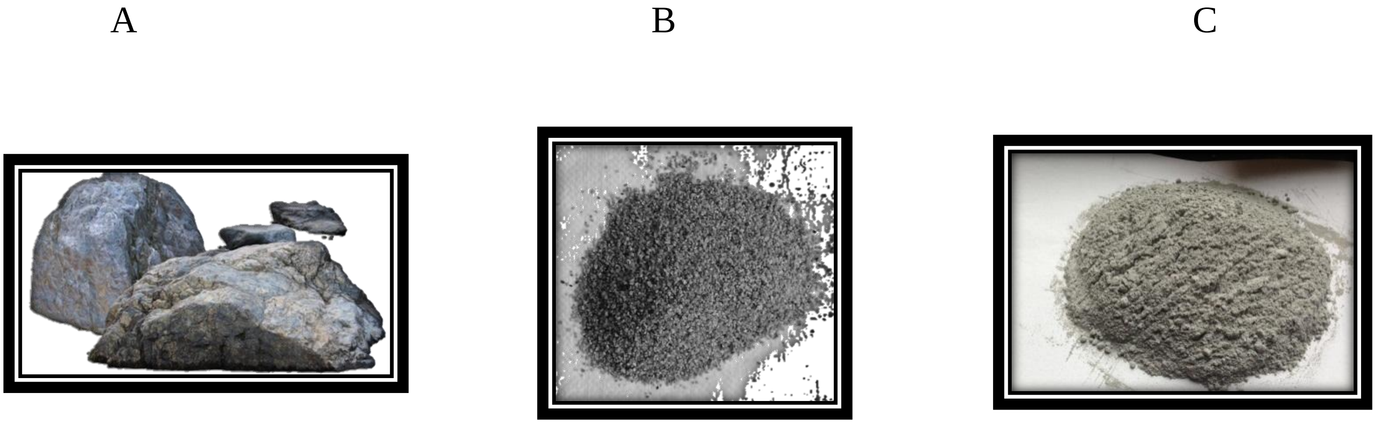


Fig. 2.1: Samples preparation

2.2.2Methods of investigation

The commercial minerals exploration during the past two decades had increased manifold owing to the relaxed mining policies and the growing economies of the third world countries. Since mineral prospecting and mining activities have increased, prospectors are constantly on the search for new technologies that can help them identify minerals chemical composition at reduced rapidly costs. Today, there are variety of instrumentsavailable (X-ray diffraction, X – ray flourcence, Atomic flame photometer, .etc.) to determine elements content in the rock sample and has been integrated together to evaluate the deposition of minerals and economic value.Evaluation were carried out using, geochemical analysis for the collected samples. Figure (2.2) shows the scheme of the methods of investigation of minerals exploration.

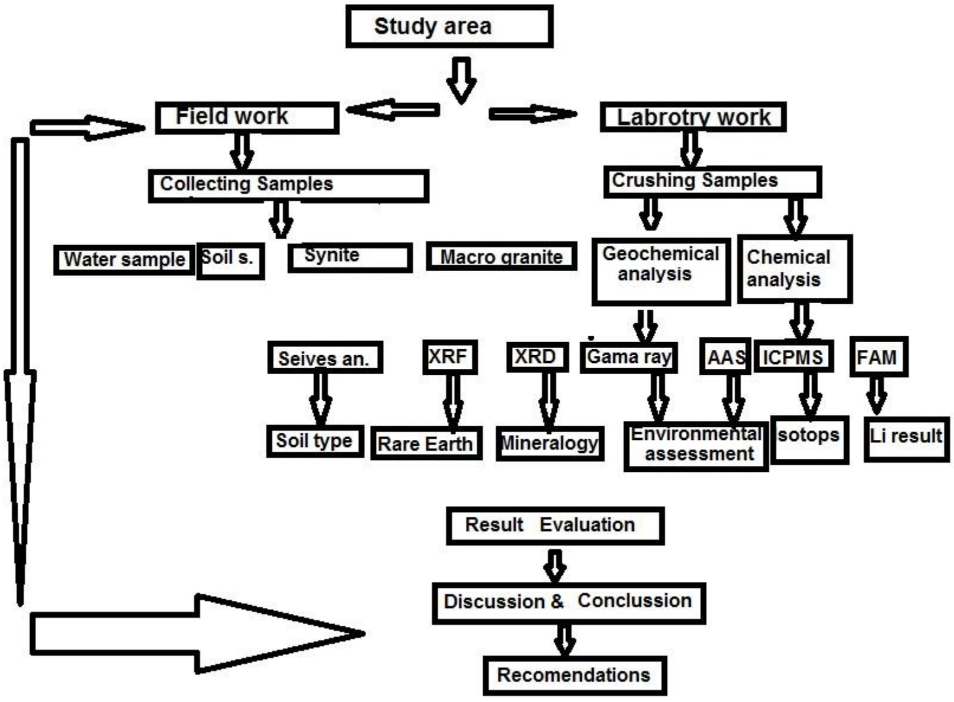


Fig. 2.2: Scheme of the methods of investigation of sample

2.2.2.1Determination of rare-earth elements by X-ray fluorescence (XRF)

The samples ought to be dry. Specified samples were heated in an oven at105% for an hour, ground, transferred into cassettes, marked and weighed.

Twelve grams (protrace application) of fine sample (0.075mm) were weighed accurately in an analytical digital balance, 3g of binder (sugar binder) were added, then ground in mortar until it were homogenous , transferred into aluminum cup, then pressed by pressing machine and then analyzed by X-ray fluoresce (XRF).

2.2.2.1.1 Standard preparation

XRF was calibrated using a series of standards for several elements. Series of rock standards were prepared in the same way as that of standard elements from Be to U. The calibration carve for each element was automatically s plotted, and the concentration for each element, in the sample was directly determined. The slope was monitored after each subsequent reading.

2.2.2.1.2 Measurement

- When a primary x-ray excitation source from an X-ray tube or a radioactive source strikes a sample, the X-ray can either be absorbed by the atom or scattered through the material.
- An X-ray is absorbed by the atom by transferring all of its energy to an innermost electron to give what is called the "photoelectric effect. “
- Each element present in the object produces X-rays with different energies.
- An electron can be ejected from its atomic orbital by the absorption of a light wave (photon) of sufficient energy.
- The energy of the photon (hv) must be greater than the energy with which the electron is bound to the nucleus of the atom.

- If the primary x-ray has sufficient energy, electrons when ejected from the inner shells, creating vacancies.
- These vacancies present an unstable condition for the atom.
- As the atom returns to its stable condition, an electron from a higher energy level orbital will be transferred to the lower energy level orbital.
- During this transition a photon maybe emitted from the atom. This fluorescent light is called the characteristic X-ray of the element.

2.2.2.2 Determination of rare-earth elements by X-ray Powder Diffraction (XRD)

The sample ought to be dry. Specified samples were heatedin an oven at 105^{0}Cfor an hour, transferred into specific XRD sample dish andmarked; the surface was smoothed by glass slide. Their diffraction patterns were recorded by *XRD*.

2.2.2.2.1 Measurement

- X-rays are generated by a cathode ray tube, filtered to produce monochromatic radiation, collimated to concentrate, and directed toward the sample.
- The sample produces constructive interference *(and a diffracted ray)* when conditions satisfy Bragg's Law

- This law relates the wavelength of electromagnetic radiation to the diffraction angle and the lattice spacing in a crystalline sample.

- By scanning the sample through a range of 2θangles, all possible diffraction directions of the lattice should be attained owing to the random orientation of the powdered material.
- These diffracted X-rays are then detected, processed and counted.
- Conversion of the diffraction peaks to d-spacing allows identification of the mineral because each mineral has a set of unique d-spacing.
- Typically, this is achieved by comparison of d-spacing with standard reference patterns.

2.2.2.3 Determination of rare earth elements and their isotopes by ICPMs

0.5 gram of sample powder were weighed accurately in a teflon beaker, 10ml hydrofluoric acid (HF), 2ml Nitric acid (HNO_3) and 5ml perchloric acid, were added. The contents were dried by placing the beakers on hot plate, to which 10ml of 50% hydrochloric acid were added and completely dissolved. The solution was transferred to 50 ml volumetric flask and completed to the volume with deionized water.

The main component of the sample was an internal standard, which also served as the diluent. This internal standard consisted primarily of deionized water, nitric or hydrochloric acid, and indium or gallium or both depending on the sample type;5 mL of the internal standard were added to a test tube along with 10–500 microdecimeater cube of sample. The mixture was then vortexed for several seconds or until mixed well and then loaded onto the auto sampler tray. Then quantifid by (ICPMs).

2.2.2.4 Determination of lithium by flame photometry

0.5 gram were weighed accurately in a teflon beacker, 10ml hydrofluoric acid (HF), 2ml Nitric acid (HNO_3) and 5ml perochloric acid, were added. The contents were dried by placing the beaker on hot plate, to which 10ml of 50% hydrochloric acid were added and completely dissolved. The solution was transferred to 50 ml volumetric flask and completed to volume with deionized water, and the emission of the atomic sample were determined by BWB .xp Flame photometer.

2.2.2.5 Sample treatment for environmental issues

2.2.2.5.1 Sample treatment for determination of radioactivity

200 grams of a combined sample, collected from the study area for the determination of rare-earth elements, were placed in a closed plastic container, left for 30 days and its radioactivity was determined by gamma spectrometry.

Most radioactive sources produce gamma rays, which are of various energies and intensities. When these emissions are detected and analyzed with a spectroscopy system, a gamma-ray energy spectrum can be produced.

A detailed analysis of this spectrum is typically used to determine the identity and quantity of gamma emitters present in a gamma source, and is a vital tool in radiometric assay. The gamma spectrum is characteristic of the gamma-emitting nuclides contained in the source, just as in optical spectroscopy, the optical spectrum is characteristic of the material contained in a sample.

2.2.2.6Sample treatment for determination of grain size by sieves

Two soil samples collected from the study area to determination of grain size distribution, its widely used to classify sedimentary environment; its affected by other factors such as topography. The various techniques employed in grain size determination include direct measurement. All techniques involve the division of the soil sample into a number of size fraction. Firs the samples collected were dried, thena set of 200 mm diameter sieves were often adequately used for the determination of sample size. Computation of the cumulative percentages passing through different size sieves was achieved. The results were presented in the form of grain size distribution curve.

2.2.2.6.1Sample treatment for determination of grain size by hydrometer

The relative proportions of the different grain sizes present in a fine grained soil was determined using hydrometer test.The grain size distribution of the fine fraction passing through 0.075 - mm sieves was studied using hydrometer analysis. The data from hydrometer analysis was combined with the sieve analysis data in completing the grain size distribution plot.

2.2.2.7 Sample treatment for determination of physical and chemical properties of water samples (Baird, 2017)

2.2.2.7.1 Physical properties of water

The physical properties of water samples were determined according to Sudanese Standards (SSMO, 2007).

A/ Appearance, odour and colour (estimation)

B/ PH direct reading using 3510 Jenway pH meter

C/ Suspended solids

Direct measurement at810nm wavelength using Hatch 6000DR spectrophotometer (Standard method for the examination of water and wastewater).

D/ Electrical conductivity

Direct reading using conductivity meter.

E/ Temperature using thermometer

F/ Turbidity direct reading using 2100 Hatch Turbidity meter. This method depends on a comparison of the intensity of light scattered by the sample under defined conditions with the intensity of light scattered by standard reference suspension under the same conditions.

2.2.2.8 Chemical analyses

1/ Total hardness

Dissolved minerals cause hardness in primarily divalent cations, calcium and magnesium ions which are usually the only present in significant amounts, therefore hardness is generally considered to be a measure of the calcium and magnesium content of water.

The pH of the sample was adjusted to 10 with ammonium chloride /hydroxide solution, Eriochrome black T indicator was added and titrated against EDTA disodium salt. The total hardness of the samples of water was calculated as mg dm^{-3} calcium carbonate.

2/ Calcium hardness

Calcium hardness of water samples was determined after removing magnesium interference by adjusting the pH of the sample to 12 with sodium hydroxide, then the solution was titrated againstEDTA using HH S NNA indictor mixture and the amount of calcium was calculated as mg dm^{-3}.

3/Magnesium

Magnesium content was determined by subtracting the calcium hardness from total hardness and reported in mgdm^{-3}.

4/ Total alkalinity

Alkalinity of water is the capacity of water to neutralize acids. It is expressed as phenolphthalein and total, both types were determined with direct titration against standard sulphuric acid solution.

5/ Chloride content

The samples were titrated against standard silver nitrate solution in presence of potassium chromate as indicator.

6/ Nitrate content

Cadmium metal reduces nitrate present in the sample to nitrite which in acidic medium reacts with sulfanilic acid to form an intermediate diazonium salt ; this salt couples with gentistic acid to form an ambercolored product and the intensity of the color is directly proportional to the amount of nitrate. The absorbance of the solution was measured at 500 nm using Hach 6000DRSPECTRO photometer.

7/ Nitrite content

In the sample react with sulphuric acid to form nitrate, intermediatediazonium salt couples with chromo tropic acid to form pink colored the intensity of color in proportional to the amount of nitrate in the sample. The absorbance of the solution was measured at 507 nm using Hach2000DR Spectrophotometer.

8/ Ammoniacontent

Nesler methods:

Nesler reagent reacts under strong alkaline condition with ammonia present in the sample to produce yellow colored species. The intensity of color is proportional to the amount of ammonia in the sample. The absorbance of the solution was measured at 425 nm using Hach6000DRspectropotometer.

9/ Hydrogensulphide andsulphides content

Hydrogen sulphides and acid soluble sulphides react with NN- dimethyle p-phenylenediamine sulphate to form methylene blue the intensity of color is proportional to the amount of sulfatein the sample.The absorbance of the solution was measured at 665 nm using Hach6000DRspectropotometer.

10/ Sulphate content

In sample react with barium chloride to form a precipitate of barium sulphate the amount of turbidity formed is directly in proportion to the amount of sulphate.The solution was measured at450nm using Hach6000DRspectropotometer

11/ Fluoride content

This method involves the reaction of fluoride with redzirconium –dye solution. The fluoride reacts with part of the zirconium to form colorless complex thus bleaching the red color in amount proportionally to the

concentration of fluoride in the sample.The absorbance of the solution was measured at 580nm using Hach6000DRspectropotometer.

12/ Total dissolved solids (TDS)

The total dissolved solution were read directly by using the conductivity (TDS) meter.

13/ Ion ferrous

1,10Phenanthroline method

1, 10 Phenanthroline reacts with ferrous ion to form orange color the intensity of color is proportional to the amount of ferrous ions in the sample. The absorbance of the solution was measured at 580nm using Hach6000DRspectropotometer.

14/ Ion total content

All ion species in the area reduced to soluble ferrous ions which reacted with 1,10Phenanthroline in the reagent to form an orange color the intensity of color in proportional to the amount of ferrous in the sample. The absorbance of the solution was measured at 580nm using Hach6000DRspectropotometer

Chapter three
Results and discussion

3.1 Results

3.1.1 Introduction

Thirty three samples were collected from Elbir area, of which 29 samples were treated to determine the amount of rare earth elements and rare metals (Ta, Nb, W and Sn) using XRF.Twelve samples were selected to determine the rare-earth elements isotopes using ICP-Ms and to determine the minerals source by XRD. Lithium, however, was determined by flame photometry.

For environmental assessment seventeen samples from them were selected to determine radioactive elements (K,Ra and Th)associated to the rare –earth minerals by gamma– ray spectrometry; however,29 samples were treated to determine the amount of (Th and U) elements using XRF,two sample for water and two for soil.

3.1.2 X-Determination of minerals and minerals major oxide by X-ray diffraction (XRD) andX-ray flourmetric (XRF)

The study area has a diversity of geology including all types of igneous, metamorphic and sedimentary rocks. The ages of these rocks range from late pan African to the Cenozoic. The basement rocks are considered as part of the Arabian Shield which had diversity in the rocks.

Arabian - Nubian Shield extends from the west of the Nile east wards to the western Arabian Peninsula. The basement Complex occupies about 50% of Sudan area.

The information available from previous projects, research work and mineral exploration expedition indicated the presence of mineralization of

gold, copper, silver, iron, titanium, chromium minerals. Previous studies showedthat the geological conditions and other factors in the Northern State correspond to some extent with the ideal models recorded regionally and globally.Table 3.1, and Figures 3.1 to 3.12, show that the minerals of major oxides and minerals content of REE in their structures will generally indicate a preference for either light or heavy REE depending on (HCl the nature of the tectonic positions available for substitution.

Table 3.1 Concentration of mineral of major oxides determined byX-ray fluorescence (XRF)

Majoroxides Sample No	K_2O	Na_2O	Cl	CaO	MgO	Fe_2O_3	Al_2O_3	SiO_2	BaO	P_2O_3
CH.S.1	0.618	2.101	0.033	12.59	3.648	8.312	17.557	46.843	0.049	1.151
CH.S.2	0.488	1.59	0.037	13.48	3.58	13.123	15.593	38.106	0.04	0.835

CH.S.1	1.88	2.048	0.040	10.840	2.64	7.38	17.557	46.84	0.005	1.458
CH.S.2	0.55	1.700	0.033	11.40	4.148	11.42	15.38	40.74	0.046	1.065

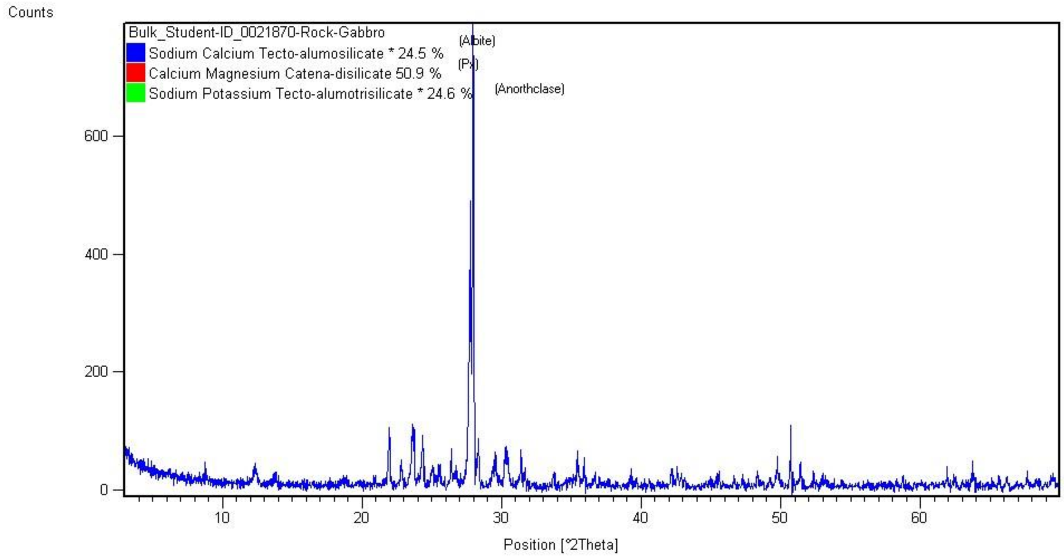


Fig 3.1:XRD spectrum of gabro

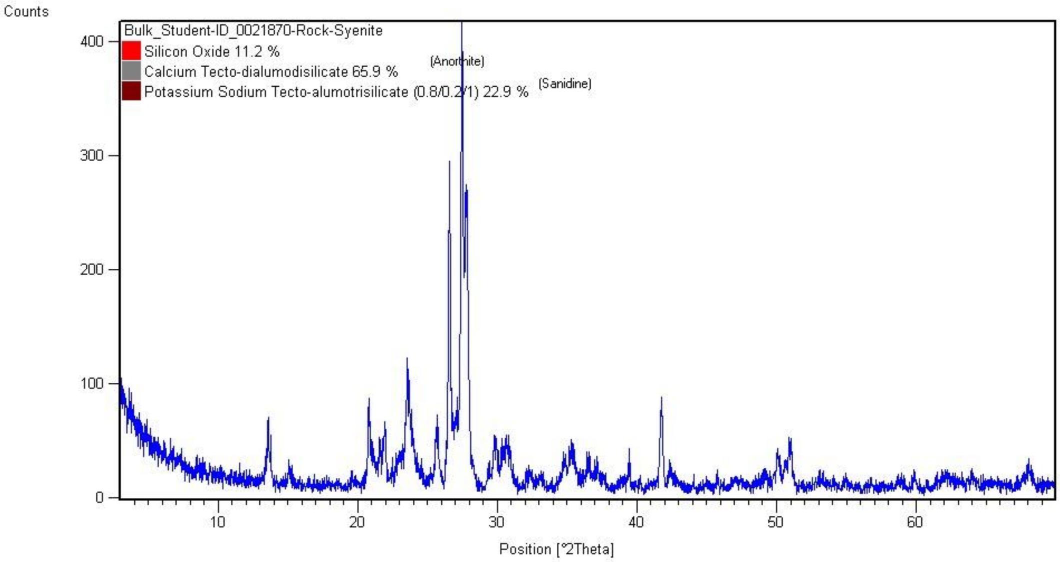


Fig 3.2:XRD spectrum of syenite

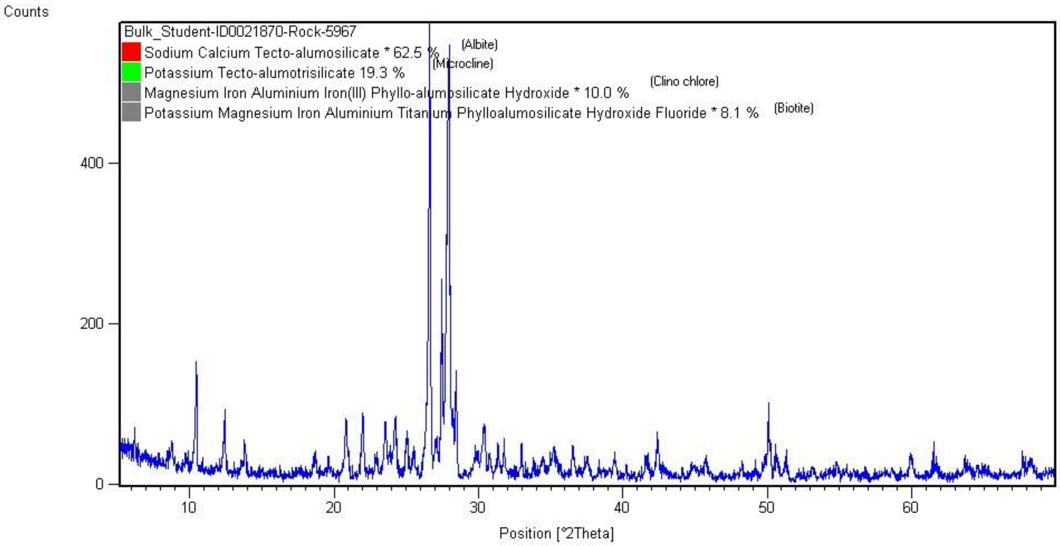


Fig 3.3:XRD spectrum ofalbite

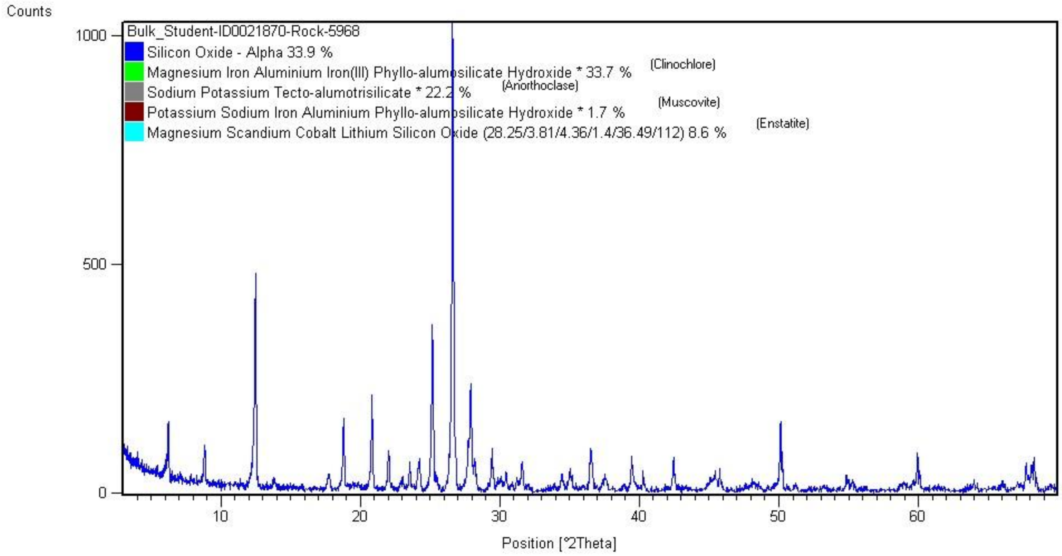


Fig3.4: XRD spectrum ofcilanochlore

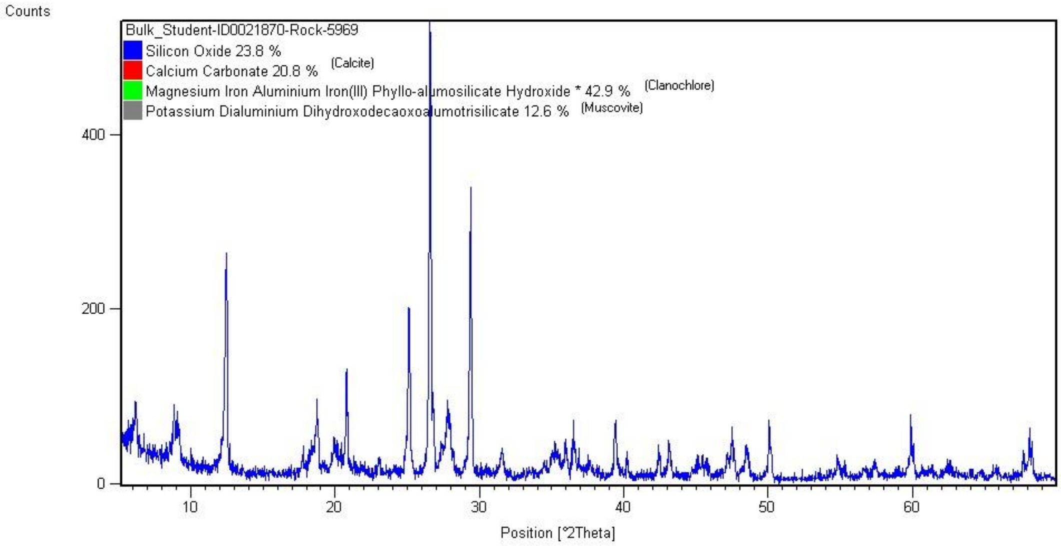


Fig 3.5 XRD spectrum of calcite and mica

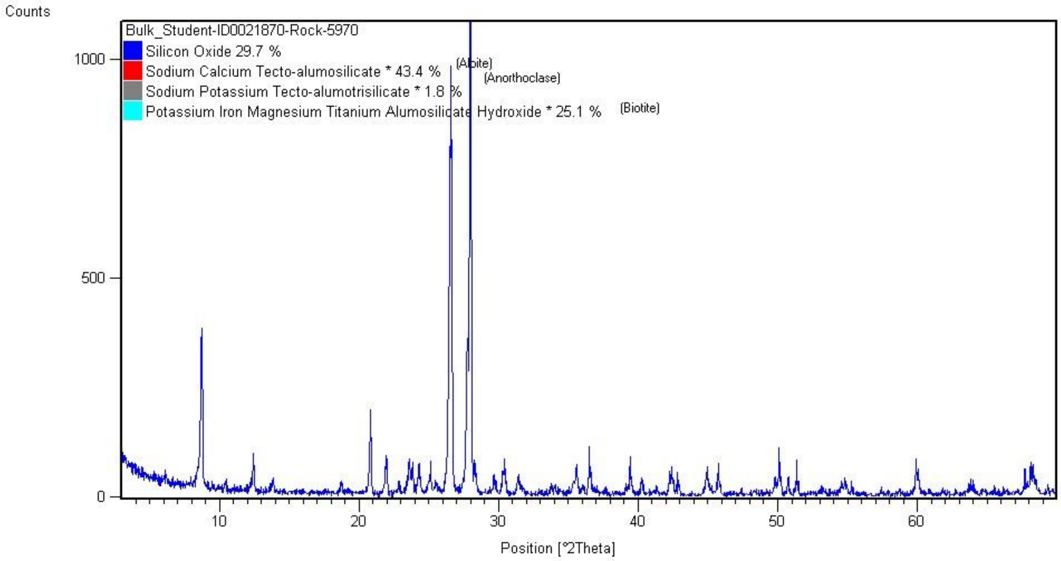


Fig 3.6: XRD spectrum of albite and biotite

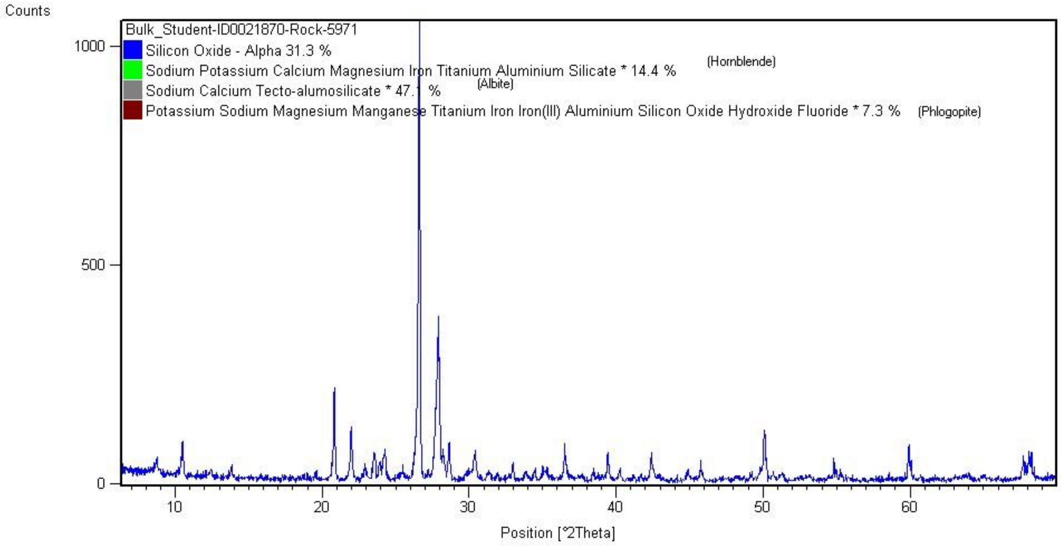


Fig 3.7:XRD spectrum of hornblende

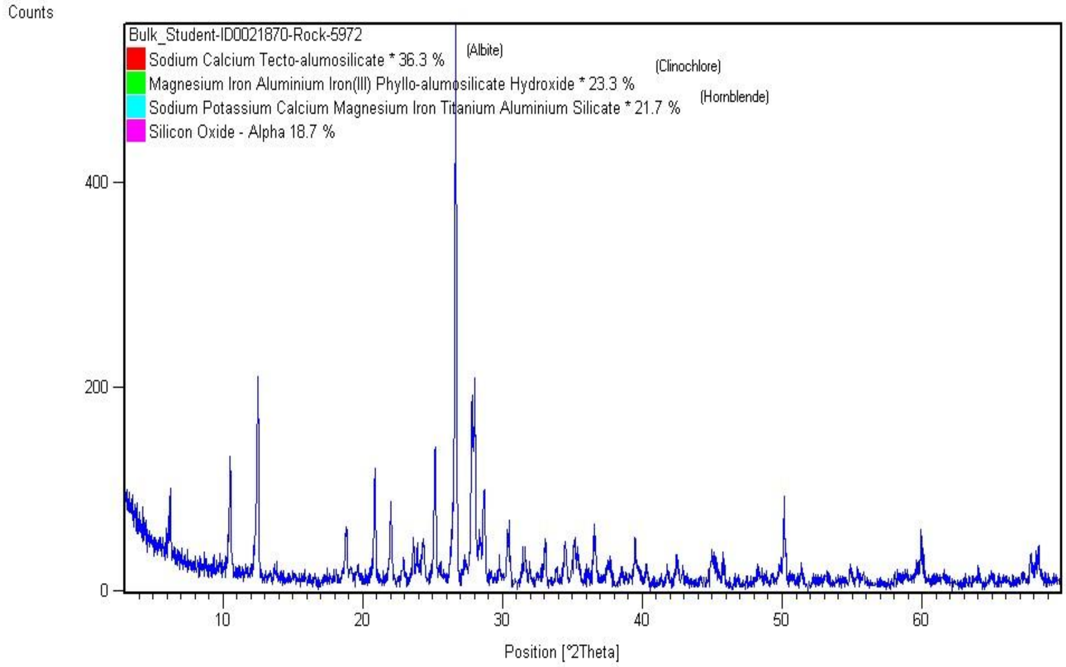


Fig.3.8: XRD spectrum of albite and hornblend

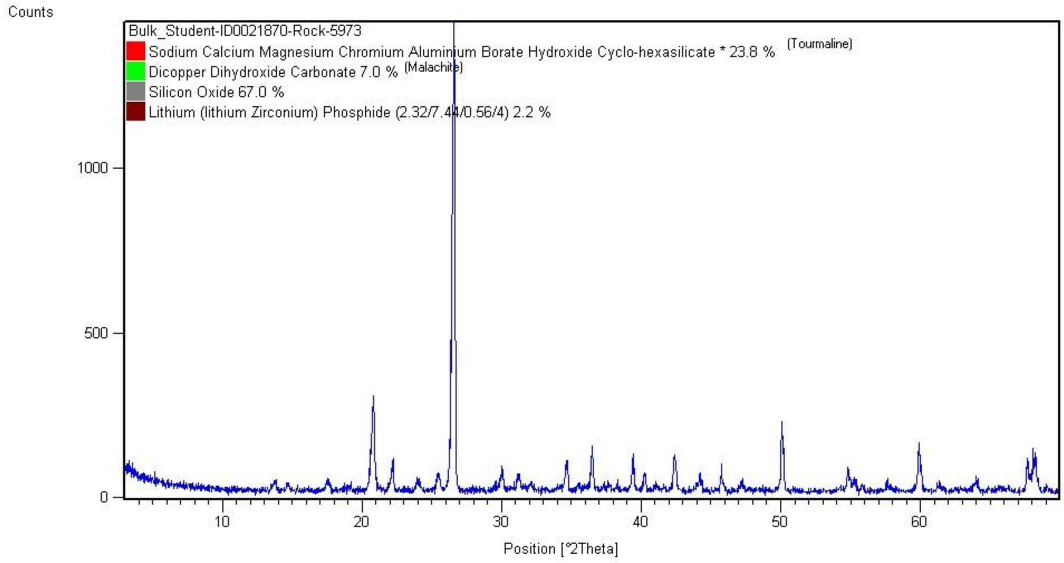


Fig 3.9:XRD spectrum of tourmaline and lithium zirconium phosphide

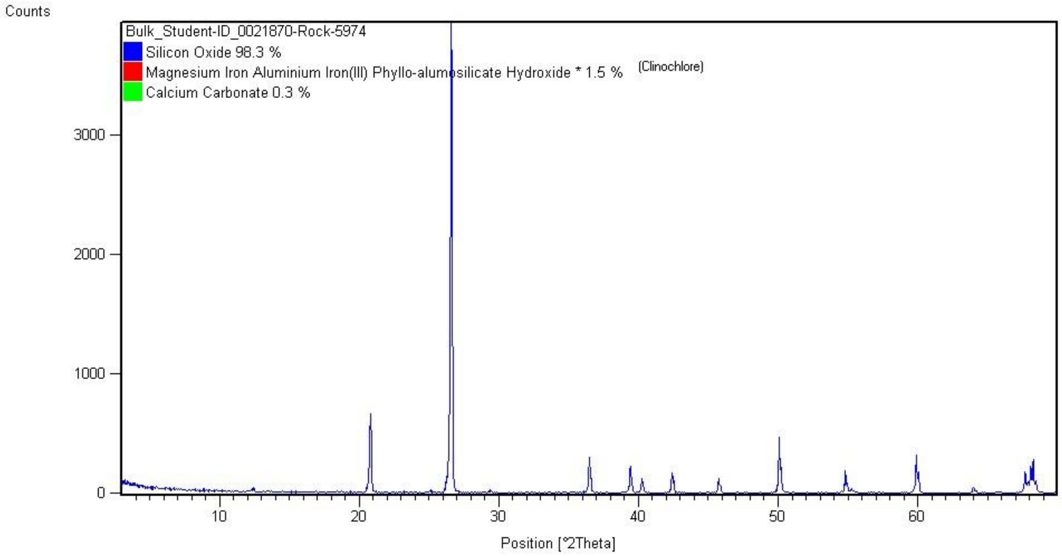


Fig3.10:XRD spectrum of quartz

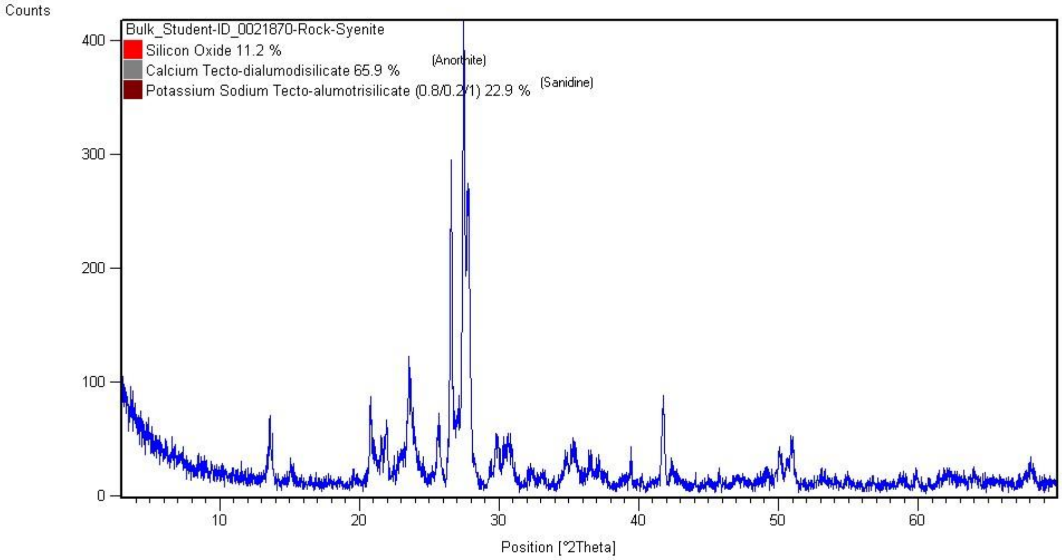


Fig 3.11:XRD spectrum of anorthide

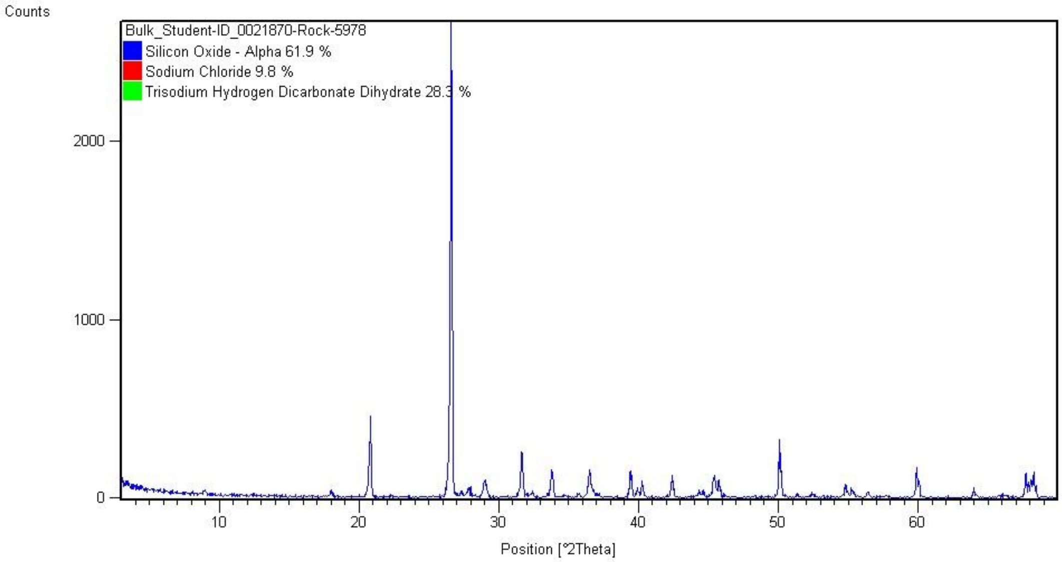


Fig 3.12:XRD spectrum of hyalite

3.1.3Determination of rare earth elements (REE) by X-ray fluorescence (XRF)

The concentration of rare earth elements was determined by X-ray fluorometric(XRF) method. Table 3.2and Figures 3.13 to 3.15 show the concentration of rare elements in chip, trench and BH samples. The concentration in ppm ranges for Sc, Y, La, Ce, Nd, Sm, and Yb, 0.5 – 64.135 ,1.23 – 159.139 , 0.8 -243.651 , 5.99– 590.15, 0.3- 387.395, N.D-75.848 andND-4.146,respectively

Table 3.2 Concentration of rare earth elements (REE) in trench,chip and BH samples determined by X-ray fluorescence (XRF)

REE	Sc	Y	La	Ce	Nd	Sm	Yb
Sample Location	Ppm	ppm	Ppm	ppm	ppm	Ppm	ppm

TA3-528-1	3.185	5.403	48.555	18.222	7.671	4.337	ND
TA2- 512-1	64.135	65. 330	25.397	128.211	77.975	9.43	ND
TA4- 540-3	9.07	23.457	144.634	56.055	38.706	3.765	ND
TA4 -540-4	29.998	50.881	243.651	215.478	138.458	11.443	ND
TA4- 520-3	ND	159.139	154.799	590.343	387.395	75.848	ND
TA439-3	28.116	2.966	49.947	36.824	9.359	ND	ND
CH.S.1	7.76	12	26.099	57.539	28	3.736	ND
CH.S.2	31.55	11.303	5.789	12.9	6.3	2.3	ND
CH.S.3	12.9	13.945	6.23	5.99	3.744	1.83	2.94
CH.S.4	6.02	6.4	22.247	45.88	15.49	2.08	4.126
CH.S.5	10.9	29.69	10.88	13.755	11.08	ND	ND
CH.S.6	20.57	26.2	8.1	10.141	6.237	ND	ND
CH.S.7	1.88	3	43.32	79.03	33.58	9.2	ND
CH.S.8	0.959	1.23	ND	ND	ND	ND	ND
CH.S.9	1.89	16.72	0.8	11.83	4.42	1.97	ND
CH.S.10	5.629	3.88	3.056	7.87	2.7	0.55	ND
CH.S.11	18.2	4.22	6.24	10.78	5.366	2.75	ND
CH.S.12	18,8	3.83	7.2	14.4	2.79	1.36	ND
CH.S.13	52.8	20.646	34.107	ND	0.3	0.3	2.7
GABRO	18.2	13.016	57.5	31.8	15.64	1.55	ND
CYNIDE-1	18.8	14.2	90.4	39	15.64	4.68	ND
CYNIDE-2	52.8	10.375	239.79	53.5	15.64	ND	ND
BH3-8	16.35	11.5	54	19.6	15.64	2.79	nd
BH3-19	28.208	6.615	157	31.4	15.64	Nd	nd
BH3-21	5.96	54.42	84.05	156.89	15.64	14.588	nd
BH3-20	ND	16.891	8.79	10.98	15.64	2.95	5.51
BH3-10	2.02	88.076	130.47	248.76	15.64	21.16	2.22

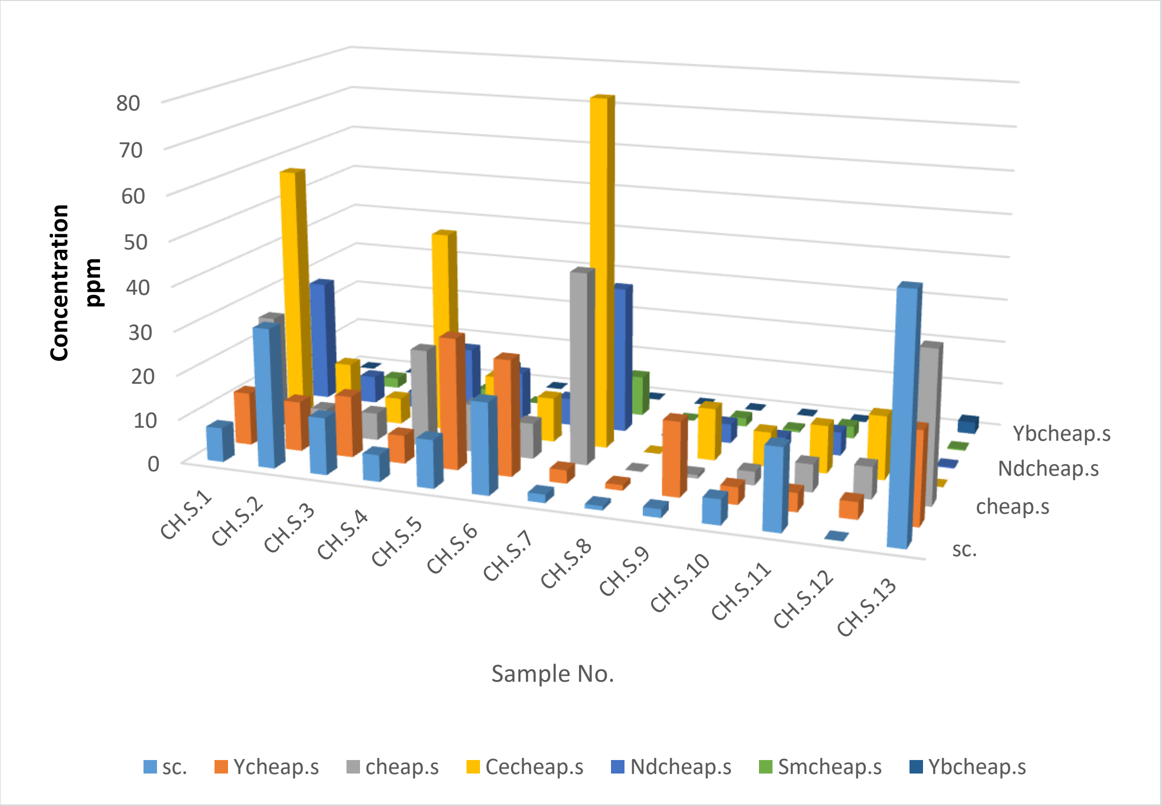


Fig 3.13:Concentration of rare earth elements in chip samples

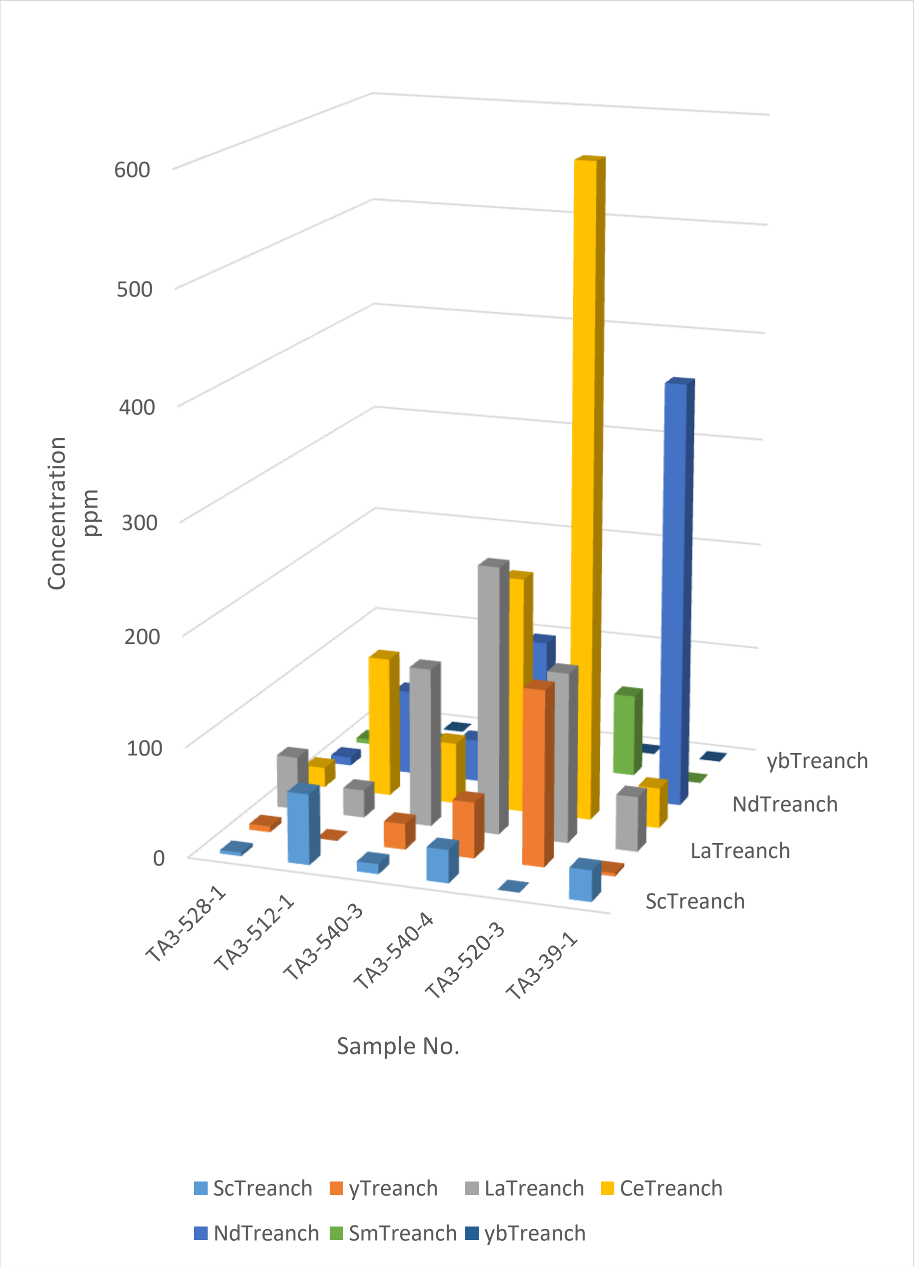


Fig 3.14:Concentration of rare earth elements in trench samples

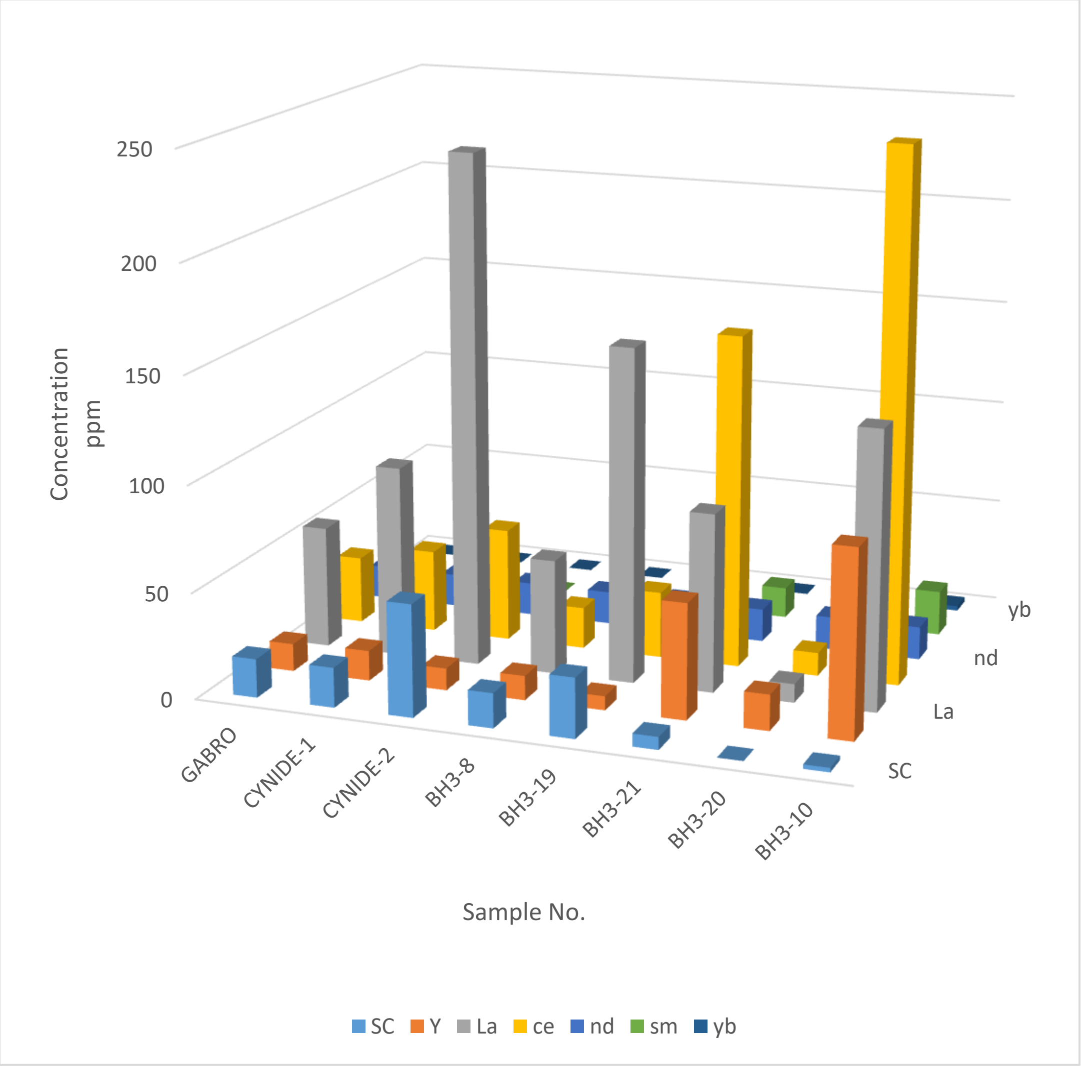


Fig 3.15: **Concentration of rare earth elements in BH samples**

3.1.4 Determination stable isotopes of rare earth elements by inductively coupled plasma mass spectrometry (ICP Ms)

Table 3.3, and Figures from 3.16 and 3.17 show that the level of stable isotopes of Ce and La determinated by (ICP Ms) were high enough to be exploited in industrially. There was also good abundance of (Y, Sm, Yb, Sc, Nd).

Table 3.3 Concentration of rare earth element isotops determined by ICP-MS

REE isotope Sample location	^{89}Y ppm	^{139}La ppm	^{140}Ce ppm	^{146}Nd Ppm	^{147}Sm ppm	^{172}Yb ppm	^{93}Nb ppm	^{118}Sn ppm	^{181}Ta ppm	^{182}W ppm
TA4-39-2	1.954	2.153	5.262	3.449	0.76	0.30	21.45	3.17	2.00	0.25
TA4-540-3	19.11	20.06	55.52	36.28	7.66	1.21	4.41	1.61	0.31	0.97
BH3-8	8.714	8.153	20.77	13.29	2.85	0.84	16.91	1.92	0.53	0.35
2Cynide	71.23	99.69	225.8	92.18	16.81	6.88	143.70	9.20	6.09	3.23
Cynide	66.78	96.66	217.5	89.42	16.22	6.42	147.30	9.20	1.64	3.42
BH3-19	9.079	8.707	22.61	14.63	3.16	0.83	17.96	1.86	1.78	0.09
Ta3-520-3	119.7	113.8	319.5	207.5	41.82	6.53	6.88	3.07	0.56	0.42
TA3-528-1	4.752	11.13	25.36	11.32	2.03	0.46	3.99	1.55	0.25	0.64
TA3-528-2	10.62	11.97	29.2	18.2	3.80	0.89	4.09	1.17	0.09	0.40
TA4-540-1	36.79	34.12	105.9	67.67	14.29	1.95	3.21	1.40	0.32	0.16
TA2-512-3	50.84	54.03	147.5	88.44	19.08	3.80	11.12	1.17	0.93	0.18

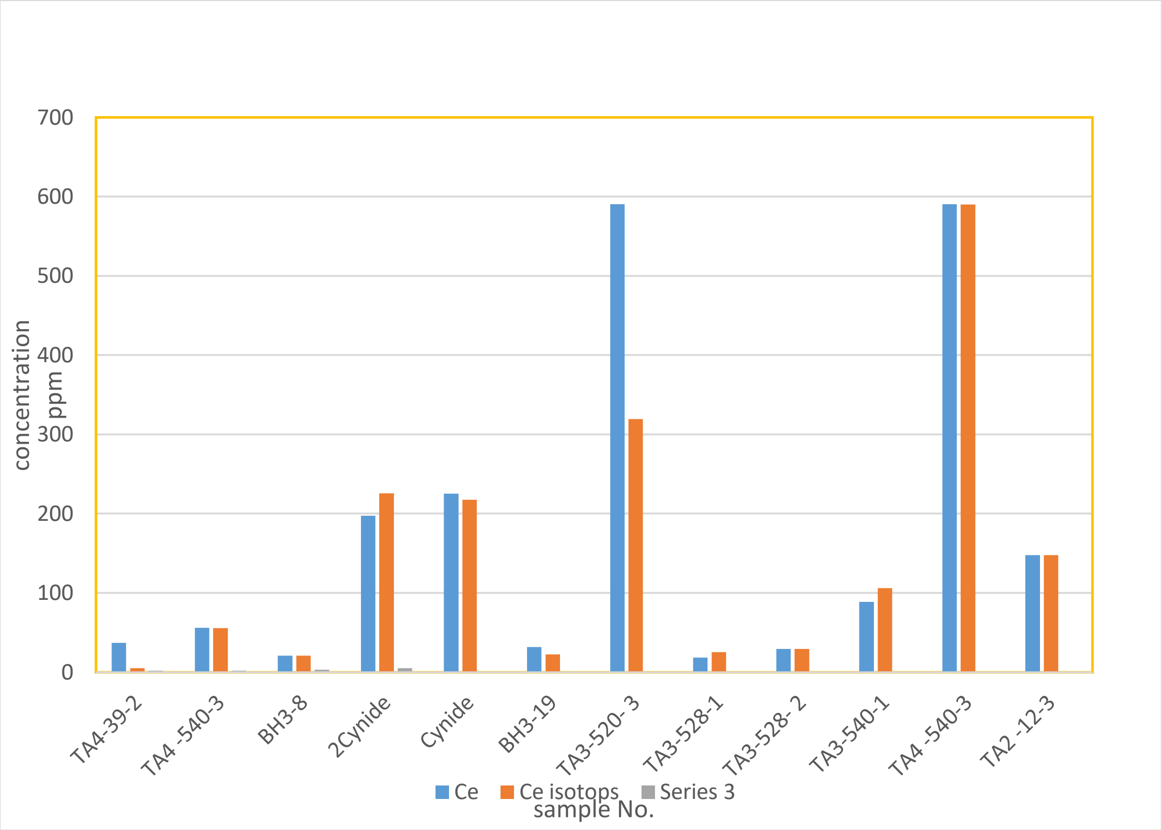


Fig 3.16: The Concentration of Ce and Ce isotops

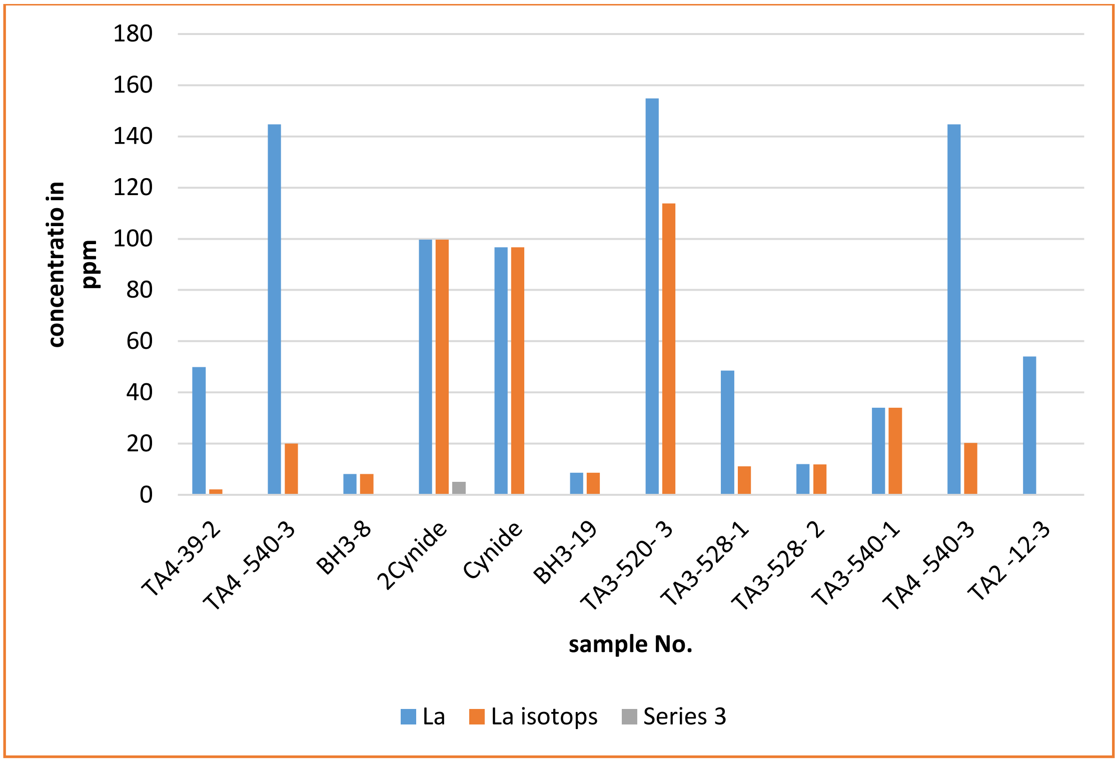


Fig 3.17: Concentration La and La isotopes

Since the rare earth elements have the same geochemical analysis methods, it was difficult to separate each element from each other; hence the elements ore reserves were presented as bulk and were estimated as 5 tons.

3.1.5 Determination of rare elements (Ta, Nb,W and Sn) by X-ray fluoresces (XRF)

The results of the rare earth elements Table 3.2 indicate the variance of presence of its ore deposit in Elbir area.The concentration of rare elements (Ta,Nb,W and Sn) was determined by X-ray fluorescence(XRF) method. Table 3.4,and Figures from 3.18 to 3.20 compare the concentration of rare elements in chip, trench and BH samples. The concentration ranges for Ta ,Nb,Wand Sn were (N.D – 95) ppm,(0.06 – 24.129) ppm , (1.18 -377.869) ppm and(N.D – 7.6) ppm, respectively .

Table 3.4 Concentration of rare elements determine by (XRF) methods

Rare element	Nb ppm	Ta Ppm	Sn ppm	W ppm
Sample Location				
TA_3-528-1	1.609	ND	4.087	5.471
$TA_2$512-1	11.989	ND	ND	35.399
$TA_4$540-3	2.463	ND	1.477	16.451
$TA_4$540-4	15.941	ND	ND	89.030
$TA_4$520-3	21.196	ND	ND	64.601
$TA_4$39-3	24.129	ND	ND	109.448
$TA_4$540-2	5.466	ND	ND	26.112
$TA_4$528-2	2.43	ND	1.526	5.988
CH.S.1	3.8	1.261	7.033	4.696
CH.S.2	1.991	0.633	7.5	9.25
CH.S.3	0.54	1.02	3.7	6.9
CH.S.4	2.9	0.8	7.38	5.47
CH.S.5	1.32	1.01	6.72	7.69
CH.S.6	1.65	0.89	6.399	11.2
CH.S.7	0.129	0.95	7.6	37.869
CH.S.8	0.06	0.8	6.4	2.3
CH.S.9	1.26	ND	3.112	10.4
CH.S.10	1.527	1.5	6.672	1.456
CH.S.11	2.109	0.8	6.499	2.9
CH.S.12	1.529	1.94	6.473	1.18
CH.S.13	8.23	ND	0.979	74.08

GABRO	12.88	ND	ND	25.2
CYNIDE-1	22.64	2.6	0.65	23.11
CYNIDE-2	62.8	8.4	ND	63
BH3-8	14.87	2.094	3.267	17.6
BH3-19	40.8	0.012	ND	62.29
BH3-21	67.24	3.78	10.667	6.68
BH3-20	1.207	ND	6.498	0.176
BH3-10	147.88	9.16	14.193	7.67

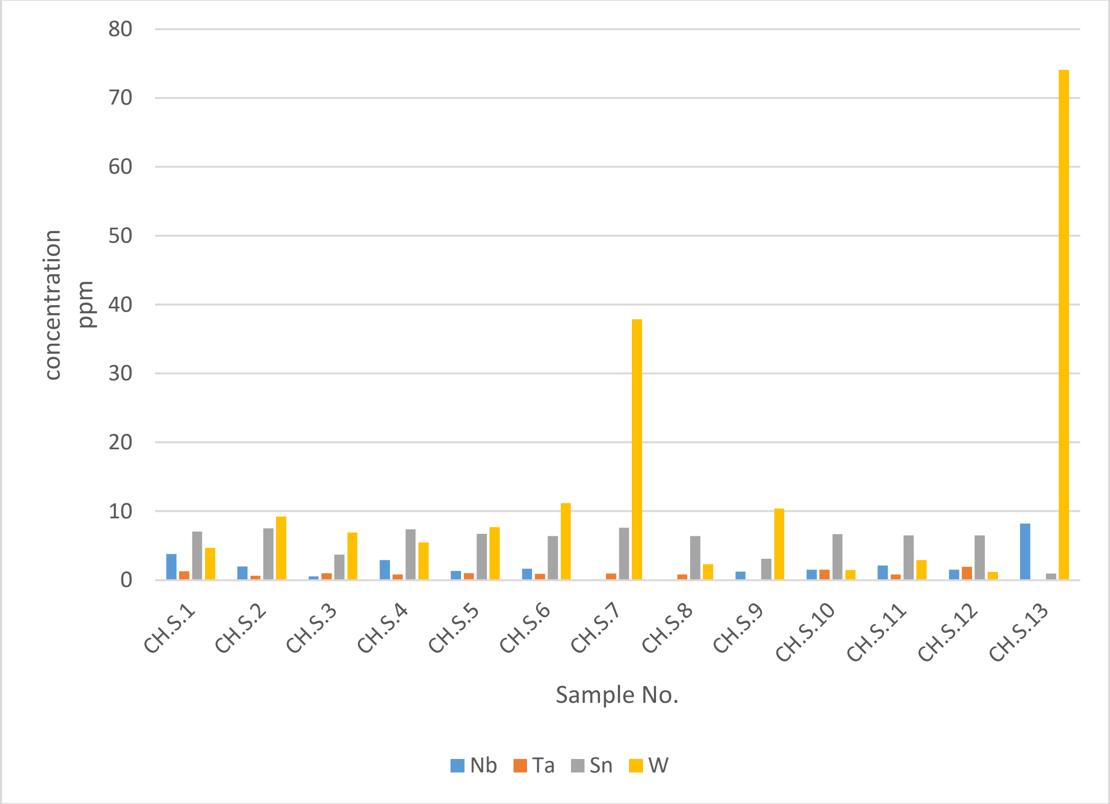
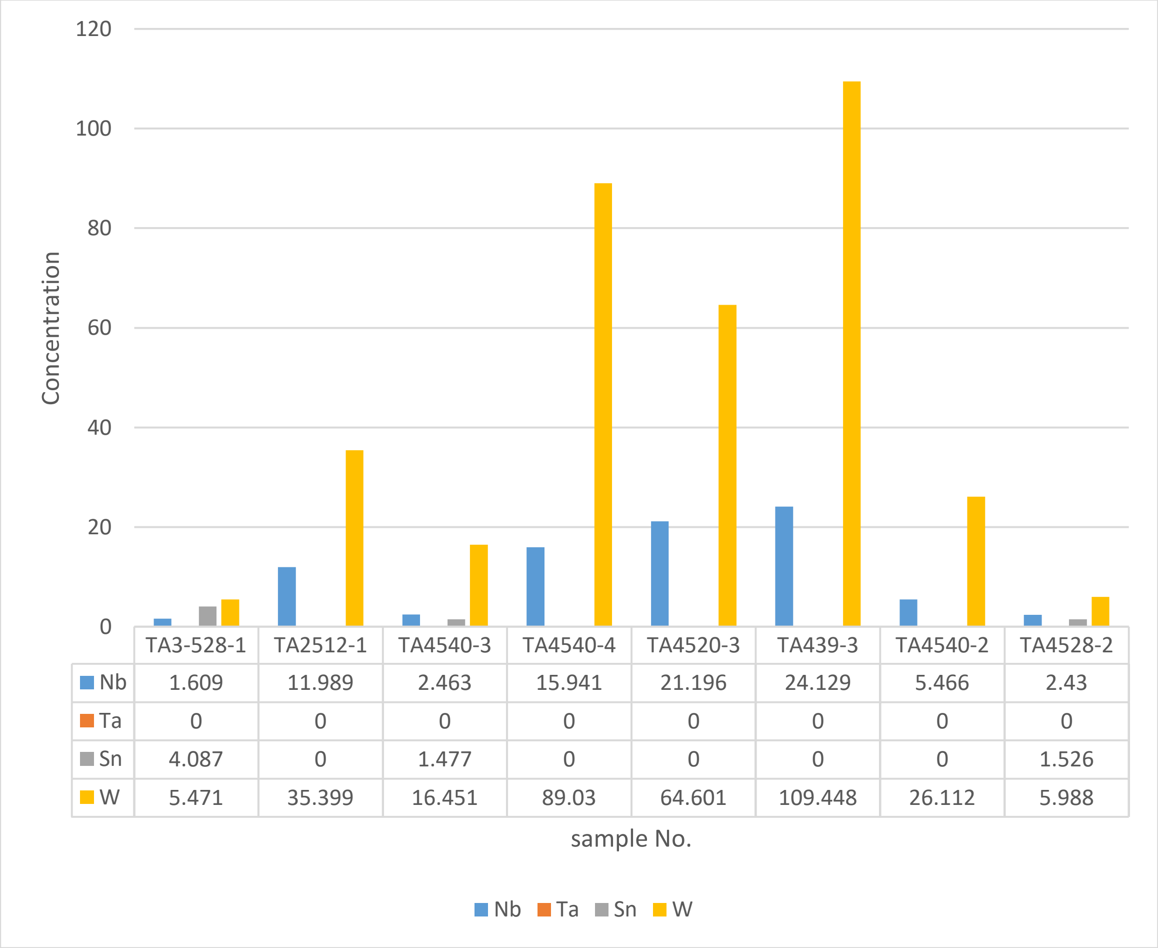


Fig 3.18: Concentration of rare elements in chip samples



	TA3-528-1	TA2512-1	TA4540-3	TA4540-4	TA4520-3	TA439-3	TA4540-2	TA4528-2
Nb	1.609	11.989	2.463	15.941	21.196	24.129	5.466	2.43
Ta	0	0	0	0	0	0	0	0
Sn	4.087	0	1.477	0	0	0	0	1.526
W	5.471	35.399	16.451	89.03	64.601	109.448	26.112	5.988

Fig 3.19: Concentration of rare elements(Ta, Nb, Sn and w) in trench sample

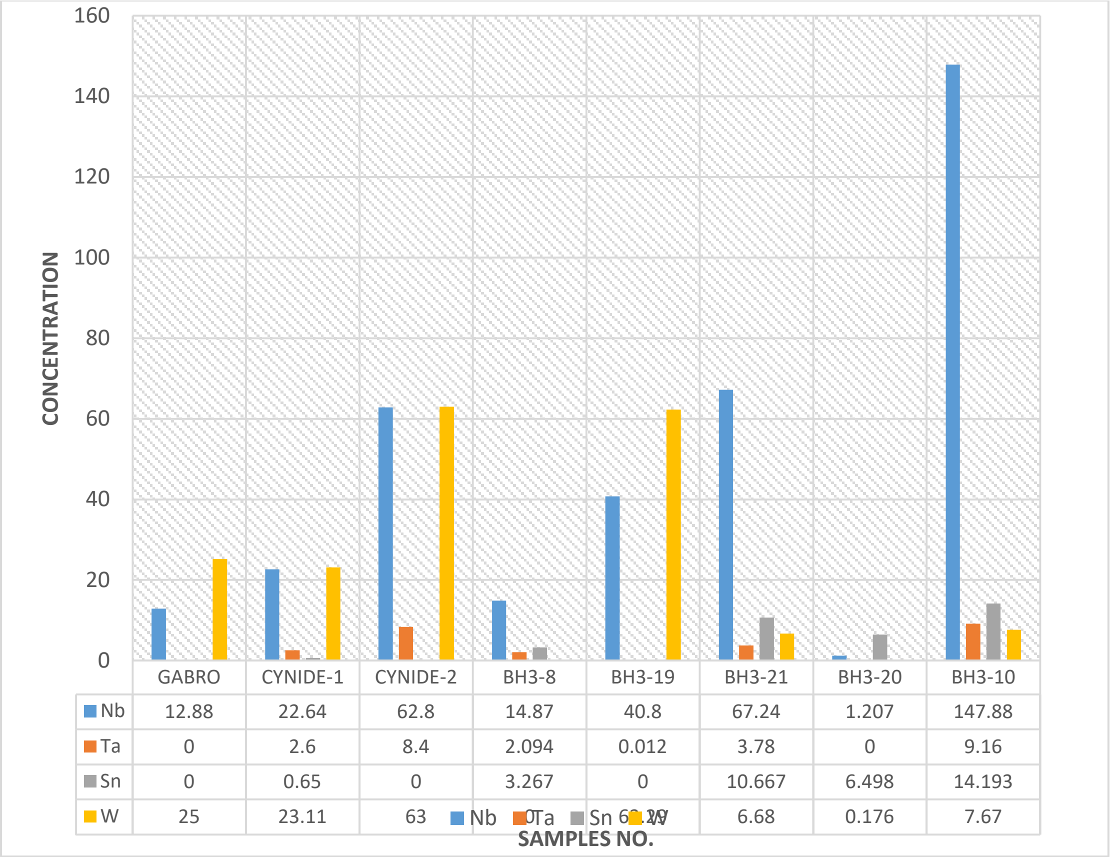


Fig 3.20:Concentration of rare elements in BH sample

3.1.6 Determination of Lithium by flame photometry

Table 3.5 and Figure 3.21 shwo the concentration of Li in chip, trench and BH samples the Figure 3.21 indicates that the high concentration was found in BH sample.

The evaluation value of li in Table(3.5) is **12** tons. This is the first estimate of lithium reserve in Sudan.

Table 3.5 Concentration Lithiumin chip, trench and B.H sample determined by flame photometry

Sample Location	**Lithium concentration in ppm**	Sample Location	**Lithium concentration in ppm**
CH.S.1	70.00	TA4540-3	170.0
CH.S.2	70.00	TA4540-4	670.0
CH.S.2L	60.00	TA4540-4	540.0
CH.S.3	100.0	TA439-3	770.0
CH.S.4	50.0	TA4540-2	410.0
CH.S.5	50.0	TA4528-2	90.00
CH.S.6	70.0	BH3-8	290.0
CH.S.7	40.0	BH3-19L	190.0
CH.S.8	90.0	BH3-19	200.0
CH.S.9	80.0	BH3-20	140.0
CH.S.9L	110.0	BH3-10	600
CH.S.10	40.0	UM17 (L)	20.0
CH.S.11	20.0	UM17	20.0
TA3-528-1	40.00	UM 30-(0.5-50)	20.0
TA2512-1	300.0	UM21-(0.5-50)	20.0

A considerable number of chip samples were collected from the trenching ore bodies the adjacent country rocks in Elbir area. The samples were collected as representative chips along the strike of the mineralized bodies.

The weight of each sample was greater than 2 kg, and all samples were analyzed by flame photometry. The average result of lithium was 200g/ton. The ore body in the study area extended approximately 2 km in length and 200min width while the density of ore body was 3 g/cm^3.

Volume = Ore length × Average Thickness × Estimation ore depth

= 2000 × 200× 50

Quantity = Volume × ore density

(2000x200x50) x3= 60mlion tons

So the li estimate reserve was 60 x200 g/tons = 12 tons

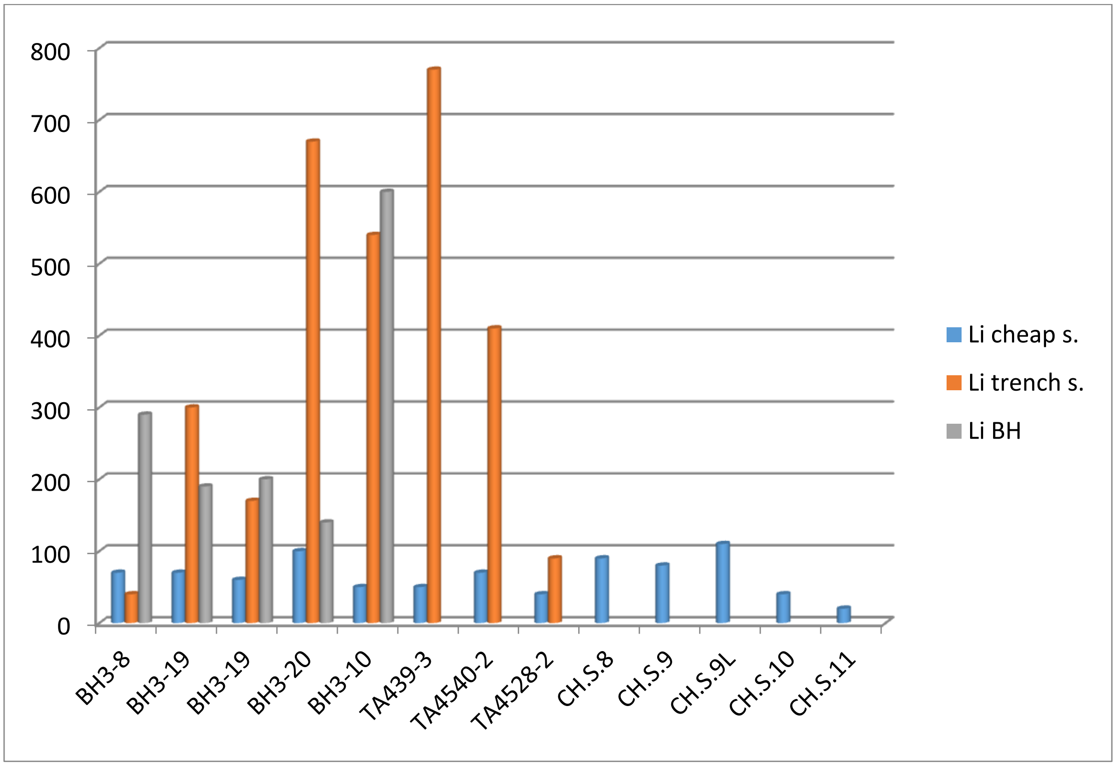


Fig 3.21:Concentration comparison of lithium in chip, trench and B.H sample

3.1.7 Determination of radioactivity of samples in mining area by gamma- ray spectrometry and (XRF)

Radioactive minerals, such as uranium and thorium(Table 3.7), are associated with the samples of rare earth and rare element. The alkaline rocks contain accessory minerals such as Zircon, Sphene, also monazite and appetite which readily accumulate limited and amount of uranium and thorium. The study considers great the environmental impact of mining in the North State of Sudan. Table 3.6 and 3.7 show that the determination of radioactivity of the samples in the mining area by gamma rays and XRF, respectively. The results were with the range of the international atomic energy agent.

Table 3.6 Concentration of radioactivity of mining samples determined by gamma-ray spectrometry

Radioactive con. Sample no.	K40 (Bq/kg)	Ra226 (Bq/kg)	Th232 (Bq/kg)
2Cyinte	21±0.02	5±0.05	4.1±0.04
CH.S.6	40±0.09	2.5±0.15	ND
BH3-19	43.5±0.4	1.32±0.07	ND
BH3-8	32.5±0.03	1.48±0.07	1.64±011
Gabro 02	207±0.02	0.77±0.09	0.71±0.18
MM01	41.6±0.04	2.13±0.06	2.06±0.08
MM02	ND	15.9±0.07	9.5±0.06
MM04	245±0.03	12.8±0.06	28.9±0.06
CH.S.9	153±0.05	ND	ND
CH.S.1	290±0.03	15.8±0.06	11.4±0.07
CH.S.2	154±0.02	2.56±0.06	4.67±0.06

CH.S.3	52±0.06	1.28±0.12	ND
CH.S.4	338±0.04	4.5±0.1	10.5±0.1
CH.S.5	84±0.05	2.19±0.1	1.82±0.09
CH.S.9	1.87±0.1	7.1±0.05	1.87±0.04
TA4-540-3	214±0.05	4.3±011	4.8±0.09
Um-3	632±٠,02	13.3±٠,05	15.5±٠,05

Table 3.7Concentration of Thorium and Uranium intrench, chip and BH samplesin mining areabyX-ray fluorescence (XRF)

Sample Location	Th	U
TA3-528-1	1.27	2.732
TA2512-1	4.061	ND
TA4540-3	ND	2.32
TA4540-4	2.67	ND
TA4520-3	2.066	ND
TA439-3	ND	ND
TA4540-2	0.979	ND
TA4528-2	0.482	1.47
CH.S.1	1.32	0.862
CH.S.2	1.512	6.71
CH.S.3	0.374	0.992
CH.S.4	ND	0.51
CH.S.5	1.087	2.62
Sample Location	Th	U
CH.S.6	ND	3.84

CH.S.7	0.55	0.78
CH.S.8	0.16	ND
CH.S.9	0.21	0.05
CH.S.10	0.398	2.94
CH.S.11	1.4	2.97
CH.S.12	1.2	0.459
CH.S.13	1.112	3.097
GABRO	4.594	0.354
CYNIDE-1	ND	1.879
CYNIDE-2	ND	1.593
BH3-8	2.19	ND
BH3-19	ND	2.77

3.1.8Analysis of water samples around mining area

Water in the whole world contains a percentage of elements, but this ratio varies from place to place according to the properties of water in each region.

Drinking water represents about 20% of the human body, so the lack of elements in the water for a long time leads to a deficiency of these elements in the human body, and this may lead to an increased chance of disease or death.

Elements also enter the human body through several sources including eating meat of animals that drink water containing elements and also food using for its preparation.Tables 3.8 and 3.9 show the result of analysis two water samples taken from the drinking water at the mining area. The range of the results obtained confirmed with the Standards set bySudanese Standards(SSMO)for human consumption Table 3.10.

Table 3.8 Analysis of water sample (1)

Parameter	Content in mg/cm^3	Parameter	Content in mg/cm^3
Appearance	Clear	Chloride	4
Turbidity	3.6	Fluoride	0.46
Colour	-	Sulfate	12
Odor	Nil	Ammonia	Nil
pH	7.7	Nitrite	0.031
Temperature	23.8	Nitrate	10.1
E.conductivity	288	Iron	0.13
T.D.S	173	Calcium	26.4
T.S.S	-	Magnesium	9.12
T. Alkalinity	118	Sodium	15.6
PH.PH alkalinity	Nil	Potassium	4.6
T. Hardness	104	manganese	0.003
Phosphate	0.22		

Table 3.9 Analysis of water sample (2)

Parameter	Content in mg/dm^3
Colour : colourless	-
Odour : unobjectionable	-
pH : 7.3	-
Conuctivity :765	-
Turbidity	3.5
Total dissolved solid	460
Total hardness as CaCO3	320
Total alkalinity as CaCO3	350
Excess alkalinity as CaCO3	32
Calcium as Ca	90

Magnesium as Mg	22
Chloride as Cl	16
Sulphate as SO4	12
Nitrate as NO3	52
Nitrate as NO2	0.03
Fluorite as F	0.9
Ammonia as N	ND; DL=0.01
Zinc as Zn	ND
Arsenic as As	ND
Lead as pb	ND
Sodium as Na	52
Potassium as K	3
Total iron as Fe	0.4

Table 3.10 The maximum permissible dose of toxic inorganic chemicals

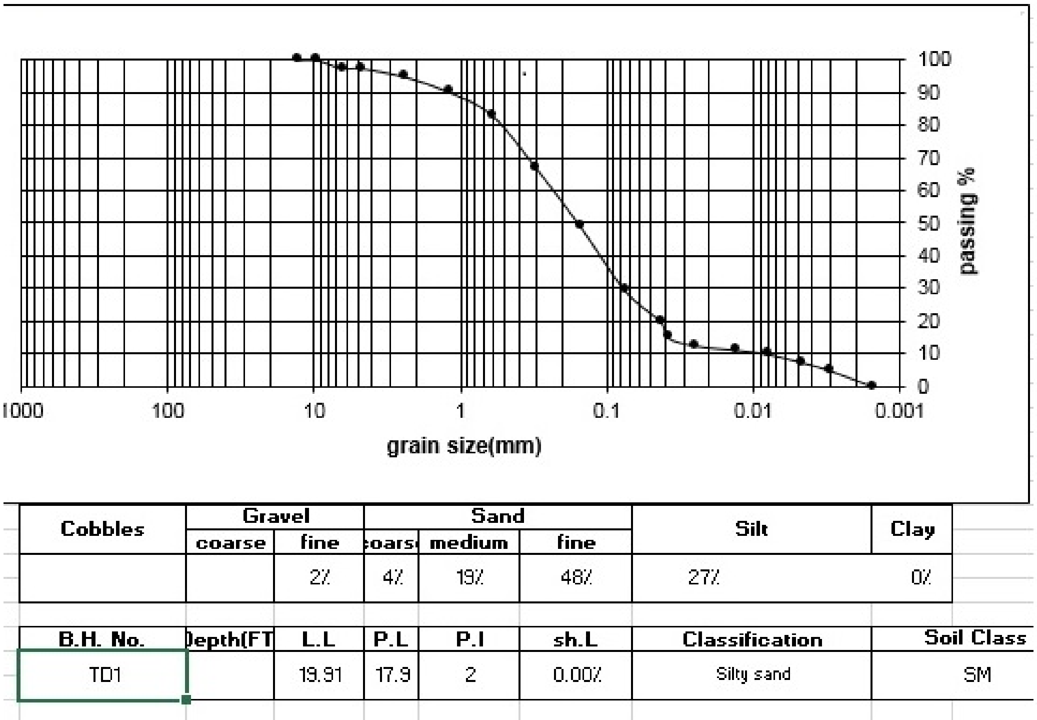
Parameter	level likely to give rise to consumer complaint	Parameter	level likely to give rise to consumer complaint in mg/dm^3
Physical parameter		Lead	0.007
Color	15 TCU	Calcium	500
taste and Odor	Acceptable	Magnesium	
Temperature	Acceptable		
Turbidity	5NTU	potassium	
PH	6.5 – 8.5	phosphate	
Inorganic constituents Parameter	level likely to give rise to consumer complaint in mg/dm^3	T. hardness	
Nitrate as NO_3	33	Arsenic	0.007
Chloride	250	Zinc	

Hydrogen sulfide	0.05		
Ion (Total)	0.3		
Sodium	25		
Sulfate	250		
Total dissolved solid(TDs)	1000		
Nitrite as NO_2	2		
Manganese	0.27		
Fluoride	1.5		
Ammonia	1.5		

3.1.9 Analysis of Grain size of the samples around mining area by sieves and hydrometer

The weight percent for each sieve was processed by computer program. Figures 3.22 and 3.23 show grain size of two soil by of two soil samples determination of the grain size by sieves and hydrometery.

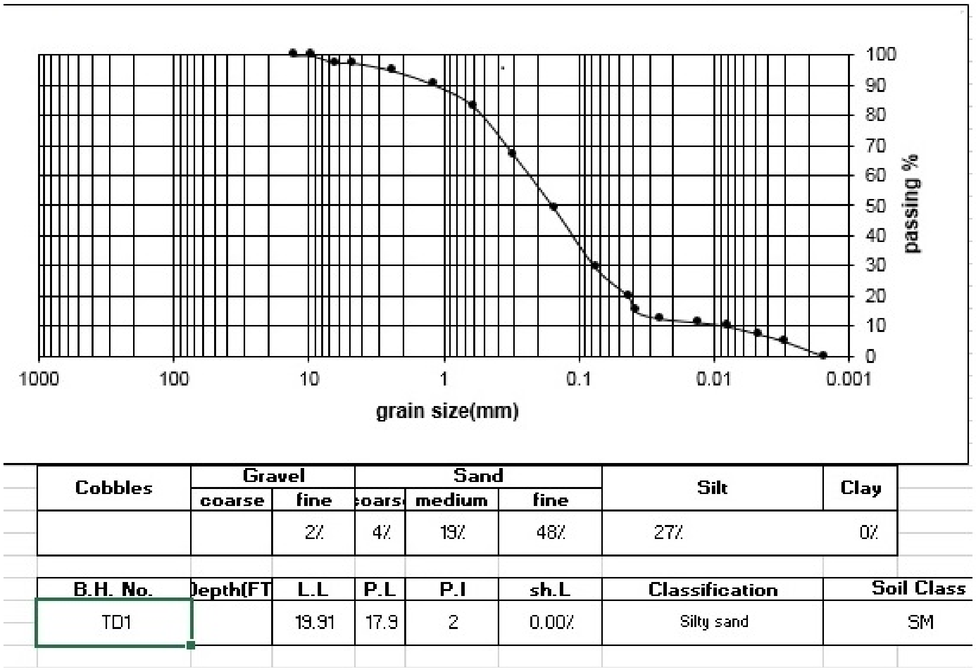
The following point where observed from the table which contains the graphic measure statistic.



Cobbles	Gravel		Sand			Silt	Clay
	coarse	fine	oars	medium	fine		
		2%	4%	19%	48%	27%	0%

B.H. No.	epth(FT	L.L	P.L	P.I	sh.L	Classification	Soil Class
TD1		19.91	17.9	2	0.00%	Silty sand	SM

Fig 3.22: Grain sizeresult of soil sample by sieves and hydrometer analysis



Cobbles	Gravel		Sand			Silt	Clay
	coarse	fine	oars	medium	fine		
		2%	4%	19%	48%	27%	0%

B.H. No.	epth(FT	L.L	P.L	P.I	sh.L	Classification	Soil Class
TD1		19.91	17.9	2	0.00%	Silty sand	SM

Fig 3.23:Grain size result of soil sample by sieves and hydrometer analysis

3.2Discussion

3.2.1 REE- bearing minerals

Several geological aspects of the natural occurrence of rare earth elements strongly influence the supply of rare-earth-elements (REE) raw. The principal concentrations of rare earth elements are associated with uncommon varieties of igneous rocks, namely alkaline rocks and carbonates. Potentially useful concentrations of REE-bearing minerals are also found in placer deposits, residual deposits formed from deep weathering of igneous rocks, pegmatite, iron-oxide copper-gold deposits, and marine phosphates. This is a consequence of the regular decrease in ionic radii for the trivalent REE from La to Lu (the so-called lanthanide contraction. atomic number).

The REE are important metals which form a range of compounds/complexes that have broad and diverse applications in technology. Over the last 50 years, bastnasite had eclipsed monazite as the main rare earth resource.

3.2.2Rare - earth elements (REE)

The results obtained indicated the viability of using the XRF for the determination of the rare earth elements La, Ce, Nd, Sm,Y, Yb.Sc and rare elements Ta, Nb, Sn, W . The results showed that the concentration of REE in alkaline rock were determined for only seven rare earth elements from seventeen in study area. The XRF technique could be effectively used on routine basis for the analysis of a large number of samples in ore prospect and geochemical studies, the REE, could be determined sequentially without any chemical separations that will encourage to make detailed exploration

Preliminary studies were made to determine optimum conditions to obtain interference free photo-peaks of the desired elements.

Their optimization depended on the wave length of elements analyzed and the application protrace (analysis procedure), in order to improve the ratio between the relative activity of each element and the bulk activity of the matrix and this improved the accuracy and increased the sensitively of detection of trace elements.

From the seventeen analyzed rare earth elements only seven elements (Sc, Y,La,Ce,Yb, Sm and Nd) were detected in the study area (Elbir area).

The measuring time of the analysis was 58 hours. Since lanthanum and cerium, are light rare earths elements, they were detected in abundant amount in the study area, (Table3.2and figures from 3 .13 to 3.15).

3.2.3 Rare elements (Ta,Nb,W and Sn)

Tantalum is considered a conflict resource. Coltan, the industrial name for a columbite–tantalite mineral from which columbium (i.e. niobium) and tantalum are extracted. The major consumer of tantalum is the capacitor production industry. Tantalum capacitors have high volumetric efficiency and reliability.

Tantalum production has increased steadily and strongly since 1993. An optimistic forecast regarding the strongly increasing demand for tantalum capacitors caused excessive demand for tantalum powder in 2000, when the overproduction of capacitors led to a sharp shortage in tantalum powder. It is still difficult to predict when the electronics industry will return to balanced condition.

Niobium is used in many alloys; niobium metal is resistant to attack by most common chemicals. It does not combine with oxygenand most other active elements except at high temperatures. Niobium silicide ($NbSi_2$) is used as a refractory material. A refractory material is one that can withstand very high temperatures. Niobium diselenide ($NbSe_{2)}$ is sometimes used as a lubricant at high temperatures. It does not break down at temperatures up to about 1300°C. Nuclear reactors are devices in which the energy of nuclear reactions is converted to electricity. Niobium steel is used because it keeps its strength at the very high temperatures produced there. Niobium alloys are also used in the construction of superconducting magnets. A superconducting material is one that has no resistance to an electric current. Once an electric current begins to flow in such a material, it continues to flow practically forever. Most The powerful magnets in the world are those made with superconducting materials. The refining of tantalum from its ores is one of the more demanding separation processes in industrial metallurgy. The chief problem is that tantalum ores contain significant amounts of niobium, which has chemical properties almost identical to those of Ta. In modern times, the separation is achieved by hydrometallurgy . Extraction begins withleaching the ore with hydrofluoric acid together with sulfuric acid or hydrochloric acid. This step allows the tantalum and niobium to be separated from the various non-metallic (phosphates and calcium carbonate) impurities in the rock.

Tungsten's many alloys have numerous applications, including incandescent light bulb filaments, X-ray tubes (as both the filament and target) and radiation shielding. Tungsten's hardness and high density give it military applications in penetrating projectiles. Tungsten compounds are also often used as industrial catalysts.

Tungsten's desirable properties such as resistance to high temperatures, its hardness and density, and its strengthening of alloys made it an important raw material for the arms industry, both as a constituent of weapons and equipment and employed in production itself, e.g., in tungsten carbide cutting tools for machining steel.

Tin forms several inter-metallic phases with lithium metal, making it a potentially attractive material for battery applications. Large volumetric expansion of tin upon alloying with lithium and instability of the tin-organic electrolyte interface at low electrochemical potentials are the greatest challenges to employment in commercial cells. The problem was partially solved by Sony. Tin inter-metallic compound with cobalt and carbon has been implemented by Sony in its Nexelion cells released in the late 2000s. The composition of the active material is approximately $Sn_{0.3}Co_{0.4}C_{0.3}$. Recent research showed that only some crystalline facets of tetragonal (beta) Sn are responsible for undesirable electrochemical activity. Ourcalculated values presented in Table 3.4 show that, the mean values of all elements in the alkaline rocks in BH samples are higher than the same elements in the trench and cheap sample. The concentrations of rare elements were analyzed by XRF methods.

Figures 3.18 – 3.20 indicate that high concentration of W and Nb but low concentration of Ta. The reserve amount of Nb, Sn and W are estimated as 3.8 tons

3.2.4Lithium

Lithiumhas been assumed to be present in alkaline rocks according to the x-ray diffraction analysis, which confirmed the rock forming minerals, Anorthite, Alabite, and pyroxene. Testing the hypothetical presence of this element in these constituent minerals the samples were analyzed by flame photometry and proved its presence. Lithium element was also estimated in the study area to be about fifteen thousand tons. The importance of lithium element lie in:

- The nucleus of the lithium atom verges on instability, since the two stable lithium isotopes found in nature are among the lowest binding energies per nucleon of all stable nuclides. For related reasons, lithium has important uses in nuclear physics.
- Like the other alkali metals, lithium has a single valence electron that is easily given up to form a cation . Because of this, lithium is a good

conductor of heat and electricity as well as a highly reactive element, though it is the least reactive of the alkali metals.

- With chemical separations in a wide variety of rocks and minerals, flame photometry became a standard technique for light element analysis.

3.2.5Environmental assessment

The purpose of environmental impact assessment is to ensure that the environmental effects of a proposed development are fully considered, together with the economic or social benefits of the development, before determining the application. The process of identifying the main issues that need to be covered in an EIA. Environmental impacts assessment focuses the assessment on the most important issues, while making sure that indirect, secondary and cumulative effects are not overlooked. It should delineate both the geographical study area and the precise topics to be studied. It is important to distinguish between objective reporting of the nature, extent and magnitude of the physical changes which are predicted to occur, and the significance of the consequent effect on natural systems, man-made artifacts, or human interests and concerns. The predicted effects of a development may be international or local, adverse or beneficial, temporary or permanent, intermittent or continuous. The assess of environmental impact Table 3.6 and 3.7showthe radioactivity of Th, Ra and K and the concentration of Th and U in the study area.Radioactivity converts the radioactive element. The nuclearoccur spontaneously and therefor it isdifficult to control. However, the efforts of scientists have tended to produce industrial nuclear transformation.

Currently, there is very little information on radionuclide behavior during the various rare earth processing routes available in the literature. The present work included consideringinformation regarding rare earth elements and rare elements. Theradioactivity determined during the mining practice was found to be with in the normal range. The shape of histogram of the represented samples of study area Figures3.22and3.23indicate that the result gave goodconfirmation that there was no pollution in underground water although, the grain size arranged from course to fine.

3.3 Conclusion

The study of REE concentrations in rocks has long been appreciated as an important source of scientific information, which helps in predicting the source and evolutionary history of the rocks in the study area.XRF was used to determine the concentration of REE, La,Ce,Nd,Sm,Y,Yb,Se,Ta,Nb,W and Sn.The results obtained indicated the viability of using the XRF for the determination of rare- earth elements in alkaline and acidic rocks. The XRF technique can be effectively used on routine basis for the analysis of a large number of samples in ore prospect and geochemical studies.

As noted, exploration and development of Sudan rare-earth deposits requires significant capital expenditure, in order to perform the necessary tests on REE deposits; hundreds of kilograms of material need to be mined in order to get sufficient quantity of rare earths concentrate. As a result, the development costs might be much larger, in magnitude, than those would be for conventional base metal or precious metal mining; however, the price of rare earth elements is higher than that of precious metal price. Generally potential REE producers are operating in an environment where they have capital constraints and fairly significant cash flow restrictions. Considering about capital markets, there are several causes to prevent more investment activity or interest to develop REE resources than those expected. In addition to a slowdown in the whole commodity market, capital markets have realized that it is complex to extract some of these elements and that need much higher capital costs than those originally anticipated.

In the present work the high concentration of Lithium determined,the relatively low cost of its extraction and the great international demandlure decision makers to invest on its mining. The environmental studies is very important for anticipating and monitoring radioactive impact, water pollution and practical means to mitigate these impacts in mining area.

3.4 Recommendations

- The Sudan should look at their geological environments for rare earth elements which may bring more wealth. These elements are very important elements in the modern technological industries that are indispensable to any industrial country.
- Financial resources should be allocated for scientific research and development in the fields of energy research, recycling and green chemistry, and increasing the efficiency of environmental performance and creativity through the use of minerals located in the Sudan region.
- The ministries of industry, trade and energy and mining should discuss the issues of rare earth elements investment.
- The ministry of energy and mining should start a detailed exploration, evaluation and development of lithium mining industry.

- Tailings and water quality management systems should be established to prevent significant environmental impacts on water.
- Different seasonal weather conditions should be considered to study visual impact and air pollution.
- Presence of radioactive isotopes and their environmental hazards should be determined during exploration and exploitation of rare earth elements minerals.
- Researcher must regulation their laboratory work and the instrument available.

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Minerals,**7** (11).pp 203. doi:10.3390/min7110203. production in Figure 1 on page 2**.**

Appendixes

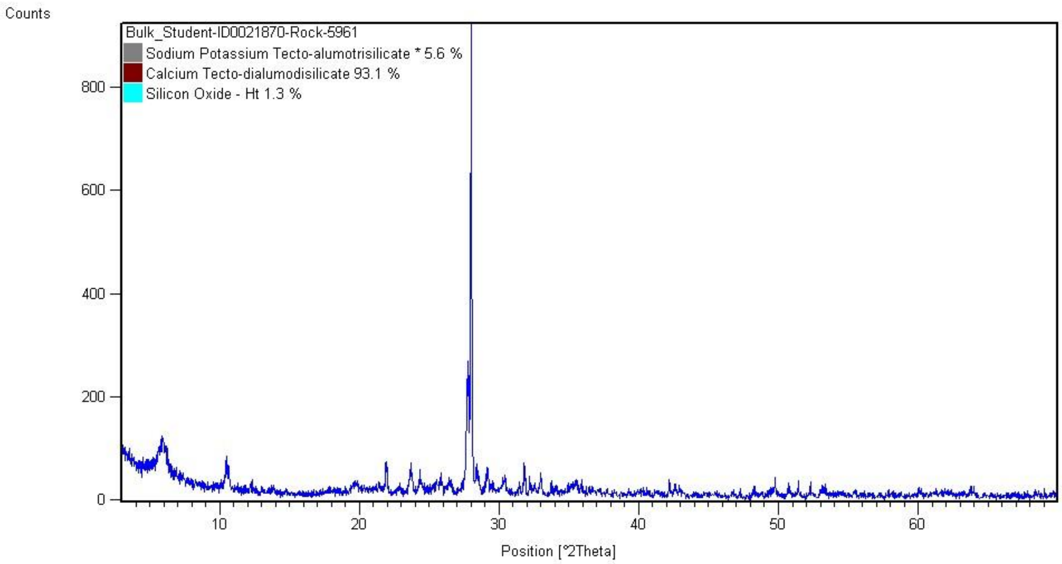
Appendix 1 : Maximum allowed material that may affect the acceptance of consumer

parameter	Levels likely to give rise to consumer complain
Physical parameter	
-color	15 TCU
-taste and odor	Acceptable
-temperature	Acceptable
-Turbidity	5 NTU
-pH	6.5 - 8.5
Inorganic constituents	
Nitrate as NO3	33 mg\dm^{3}
Chloride	250 mg\dm^{3}
Hydrogen sulfide	0.05 mg\dm^{3}
Iron[total]	0.3 mg\dm^{3}
Sodium	250 mg\dm^{3}
Sulfide	250 mg\dm^{3}
Total dissolved solid [TDS]	1000 mg\dm^{3}
Nitrate as NO2	
Manganese	2 mg\dm^{3}
Fluoride	0.27 mg\dm^{3}
Ammonia	1.5 mg\dm^{3}
	1.5 mg\dm^{3}

Appendix 2 :The maximum permissible dose of toxic inorganic chemicals

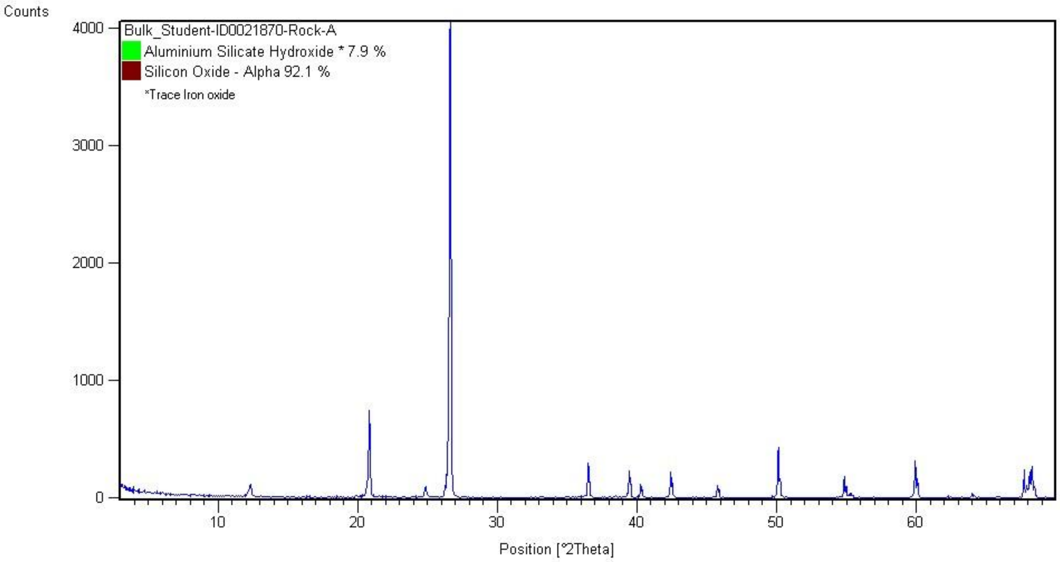
parameter	Max permissible limit in mg\l
Antimony	0.004
Arsenic	0.007
Barium	0.5
Boron	0.2
Cadmium	0.003
Chromium	0.04
Copper	1.5
Cyanide	0.05
Fluoride	1.5
Lead	0.007
Manganese	0.27
Mercury [total]	0.0007
Molybdenum	0.05
Nickel	0.014
Nitrate as NO_3	33
Nitrate as NO_2	2
selenium	0.007

Appendix 3:



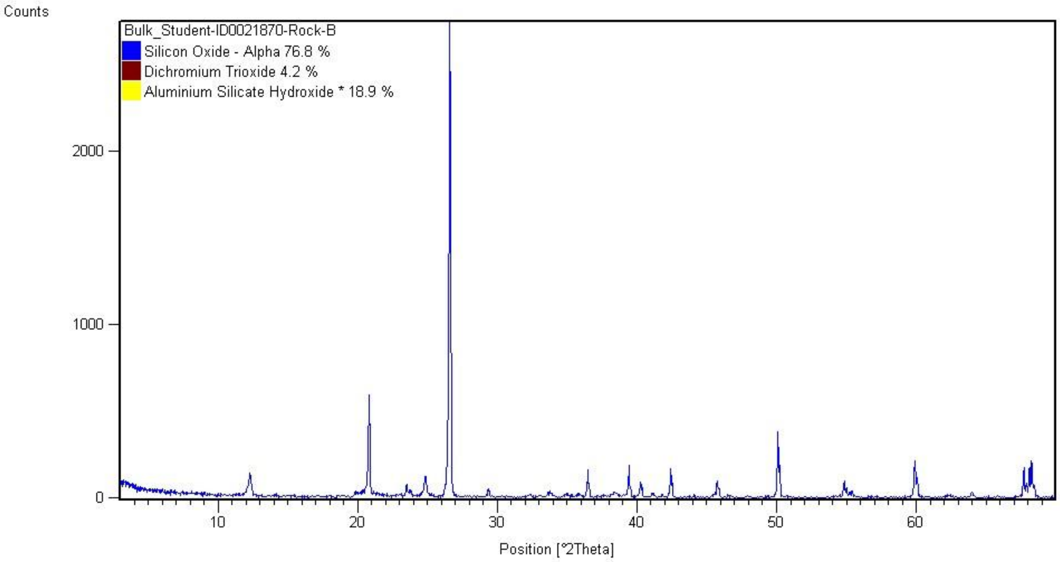
XRD spectrum of anorthite and anorthoclase

Appendix 4:



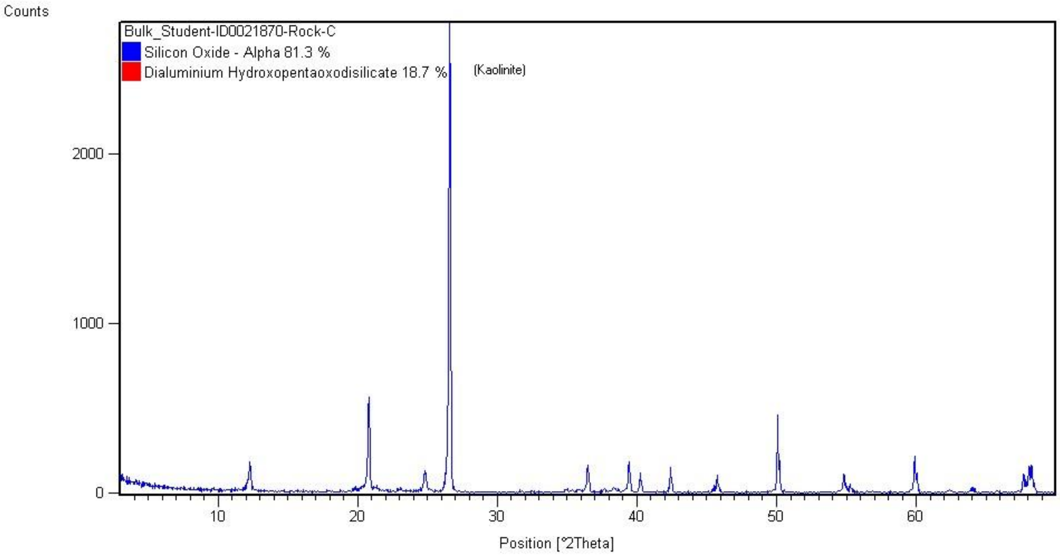
XRD spectrum ofquartz

Appendix 5:



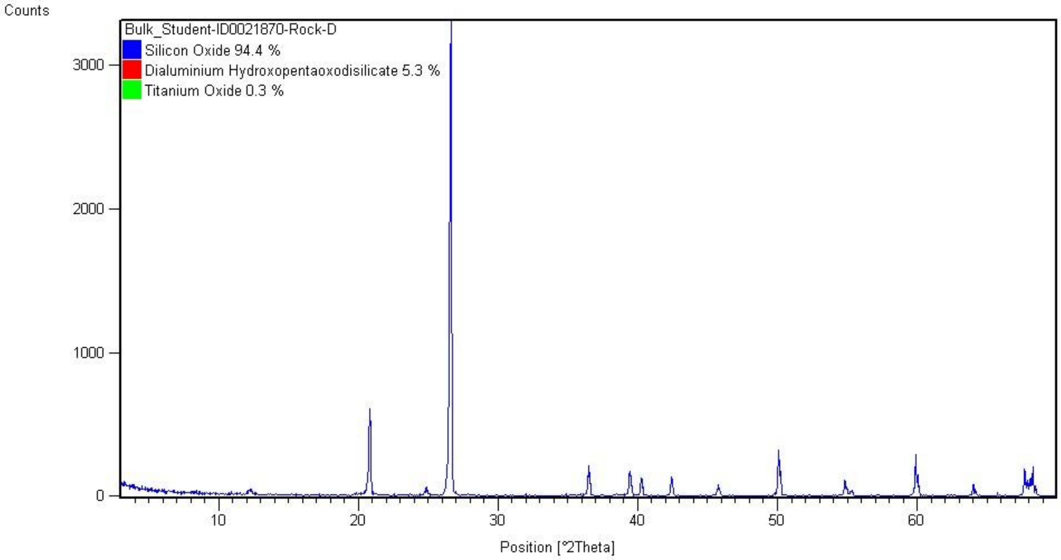
XRD spectrum of chromium oxide

Appendix 6:



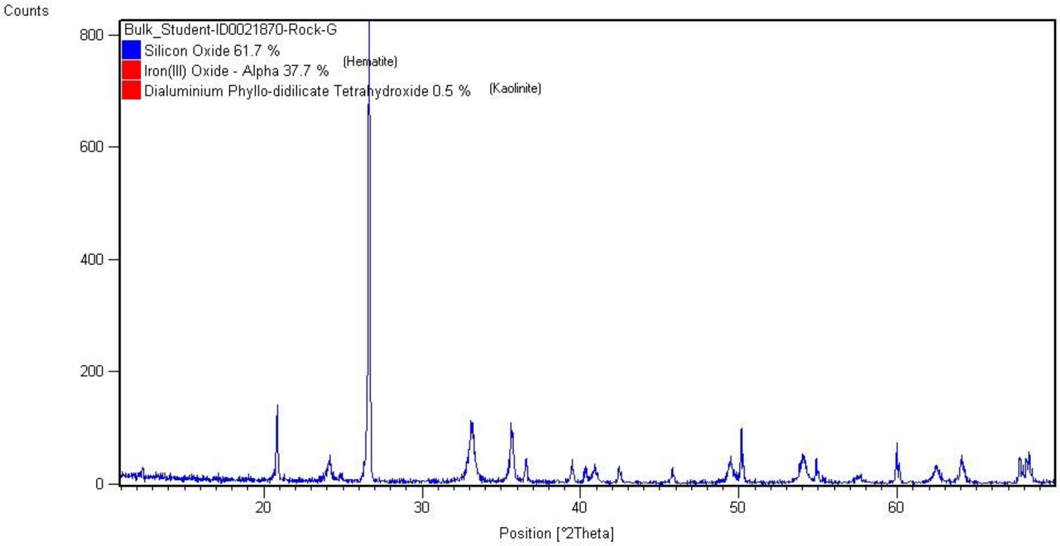
XRD spectrum of kaolinite

Appendix 7:



XRD spectrum of synthetic rutile

Appendix 8:



XRD spectrum of Hematite