MINERAL EXPLORATION AND ASSESSMENT OF GEOLOGICAL MATERIALS AND GEOTOURISM SITES IN ALRMP PROJECT AREA, BARI NGO AND EAST POKOT DISTRICTS

APRIL 2009
(Fieldwork conducted between 1st and 15th December 2008)

BY
Judith J. Kotut - Geologist I, Mines & Geological Dept.
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ACCRONYMS

A.L.R.M.P. Arid Lands Resource Management Programme
S.L.D.O. Support to Local Development Officer
WHO World Health Organization
D.M.O. Drought Management Officer
HSC Head of State's Commendation
CDF Constituency Development Fund
Supt. Superintending
Dept. Department
a.s.l. above sea level
NNE North-north-east
ppm parts per million
mg/kg milligrams per kilogram
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INTRODUCTION

Problem Statement
The lower regions of Baringo and East Pokot are classified in the Semi-Arid areas. The areas have a low agricultural productivity save for irrigated areas. The areas are believed to be rich in minerals and geological materials as they are readily exposed due to the rocky nature of the areas. There have been reports of mineral occurrences by some locals, a suggestion that the area has some minerals.

Exploration for minerals and geological materials has not been done in the areas by Mines and Geological Department due to limited funding.

The creation of the new East Pokot District has brought about many challenges. These include:

- Poverty eradication and employment creation in the area
- How the Local Authority in the area will be able to support itself financially
- Alternative source of income for the community apart from livestock. This can contribute in the reduction of insecurity which is mainly due to cattle rustling
- The need for construction materials for the improvement of infrastructure in the region e.g. roads, buildings, schools etc
- Etc

This exploration aims at the discovery of minerals and geological materials in the areas. These include minerals, building stone, sand, archeological (fossil) sites, caves, mapping of rocks for ballast crushing, tourist attraction sites e.g. view points, etc.
Area

Baringo and East Pokot Districts are new districts that have resulted from the division of Baringo into two Districts. The division was implemented early this year. The two districts are among the twenty six districts that form Rift Valley Province.

Baringo District borders East Pokot district to the north, Keiyo and Marakwet districts to the West, Koibatek district to the South and Laikipia district to the East. East Pokot borders Baringo to the south, Turkana to the North, Marakwet to the west, Samburu to the north-east, and West Pokot to the North-West.

The mandate of Arid Lands Resource Management Programme (ALRMP) within the two Districts cover the whole of East Pokot District and the arid lowlands of Baringo District. These areas are Salawa, Barwessa, Bartabwa and Marigat Divisions, Lower Kabartonjo, Lower Kipsaraman, Lower Tenges and Chebinyiny Location of Mochongoi Division. These areas of Baringo District have a total area of 3191 km². The total population in the areas is estimated at 114,693 (year 2007 using projections from 1999 census) with an average population density of 40 persons per km².

East Pokot has an area of 4524.8 km² and comprises three divisions namely Kolowa, Nginyang and Tangulbei. The livelihood in the district is categorized as pastoral. The total district population is estimated at 76,328 (2006 figures prorated from 1999 census) people with an average population density of 15 people per km².
Topography

Baringo District

Baringo district has the highest elevation at about 2,466-m a.s.l in the Tugen hills falling to about 762 m a.s.l in Kapendo. The Tugen hills runs north to south, dividing the district into two distinct valleys. The Kerio Valley to the west of the hills and the Lakes Baringo-Bogoria basin lies to the east. The eastern parts of the district are the Laikipia ranges which cover parts of Mochongoi Division.

Prominent physical features are the Tugen hills, Lakes Baringo, Bogoria and Kamnarok. Lake Baringo has one big island, Kokwo, which is inhabited and several small ones.
The dominant features that control drainage are the Tugen hills and the Laikipia ranges. The Tugen hills act as the divide of the streams and river systems where the western side streams drain to the Kerio River that flows northwards. Those in the east drain into Perkerra River, which flows into Lake Baringo and the Suguta in East Pokot. Streams emanating from the Laikipia ranges flow westwards draining to Lakes Baringo, Bogoria. There is also the southern system coming from Molo forming the Molo River and the Lorwai of the hills west of Lake Bogoria. The rivers draining from Laikipia escarpment are Mukutani, Arabal and Waseges. The former two drain into Lake Baringo while the later drain into Lake Bogoria.

**East Pokot District**

The highest point in East Pokot district is Tiati hills with a height of 2352m above sea level. The hills are an extension of the Tugen hills in the south and extend northwards into Turkana district. To the eastern plains of the district are the Korossi, Paka, and Silale hills. These hills are volcanic and have craters at their tops. The eastern part of the district rises to the Laikipia ranges at Churo and Amaya. The lowest part of the district is at Kapedo plains with an elevation of 762m above sea level.

Drainage in the district is mainly northwards. Rivers to the west of Tiati hills drain into Kerio River which drains northwards to Lake Turkana. To the east of the hills, rivers from the hills drain in an easterly direction towards Kapedo. Rivers from Tugen Hills drain northwards and converge with those from the Laikipia escarpment at Kapedo, forming Suguta River which drains into Suguta swamps. A few rivers from Tangulbei and Kokwototo areas drain into Lake Tilam in Nginyang division.

**Climate**

Generally, the rainfall pattern follows the relief features. It is highest in the Tugen hills and Mochongoi with a mean annual rainfall of about 1200 mm and low in the Lowlands averaging about 750 mm. Rainfall is unevenly distributed in the district.
In the highlands, the annual rainfall received computed as monthly totals was 1573.8 mm (measured in Kabarnet), which was slightly above the mean annual rainfall of 1500 mm. The lowlands received monthly totals of 377.4 mm (measured in Marigat) as compared with expected mean annual rainfall of 600 mm.

The driest months in the district covers the period January to February while the wettest is April to May. There are two rainy seasons in the district, one normally expected between March and May and the other between July and September. A non-reliable short rain of November/December is not regular.

East Pokot district receives less rainfall than Baringo district and therefore it is much drier.
MINERALS

Ruby
Ruby deposits are found in two areas of the project area. These are Kapleng’noi, and Kwirintoi in Mochongoi Division of Baringo District and Barsemoi, Koitilion, Kipcherere and Bartum areas of Marigat and Kabartonjo Divisions of Baringo and Baringo North Districts respectively.

Some local communities have formed cooperative societies and have applied for prospecting licenses. They are yet to complete the prospecting work. Many complain of inadequate funds to conduct the work which will lead to them determining if the quantities and quality of the deposits and hence the economic viability. Some are looking for external investors who can team up together and provide the needed funding.

Plate 1: Ruby from Baringo District
Fluorite
Fluorite is found in two areas in the project area. These areas are Kolowa and Kipcherere. Kolowa has three clustered deposits in the form of one large vein of approximately 4m that extends from Barbello to Lobokoi area in Ngoron whereas Kipcherere has a small deposit within a small area.

Kolowa deposit
The first cluster is situated around Barbello market. 430m south of the market, a deposit is observed, covering an area 20m wide. The rocks are mineralized with colourless fluorite. Another deposit was also encountered in an excavation next to Barbello cattle dip. It is not exposed on the surface at this point.

Plate 2: A fluorite vein measuring 4m at Kokwo Pkokoch
890m to the southwest of Barbello centre, an area measuring over 40m wide is mineralized with fluorite. Large purple, white and transparent crystals of fluorite were observed. Some parts of the area have deep pits, a sign of mining activity by previous prospectors and locals since the 1960s.

A second cluster is observed 2.8km to the south west of Kapunyany market. The exposures are at Kokwo Pkokoch and Koiba Siran areas. This exposure is about 30m wide and has purple, white and transparent fluorite crystals in a quartzite rock. At Kokwo Pkokoch, the deposit is along a vein measuring about 4m wide and trending at a bearing of about 320°. Purple and translucent crystals are found in pits dug on alluvial deposits of an old river channel 140m to the northeast of the vein. Locals say that some mining of the fluorite was done in the 1960s by white prospectors.

The third cluster is found 3.4km to the west of Ngoron market at Lobokoi area. It is mineralized in a large vein, 2 to 3 meters wide trending at a bearing of 331°. There are smaller mineralized veins in the area. The area has pits and trenches dug by prospectors and local miners since 1960s.

**Kipcherere deposit**

The deposit is situated 300m south of Kipcherere market. It is 4m wide and trends westwards. Green, purple and colourless translucent crystals are found in the deposit within clay soils. The clays are also rich in fine crystals of fluorite. The deposit is about 20m long and thins out into the surrounding rock.

**Diatomite**

Diatomite is found as a stretch running across the boundary of Baringo North and East Pokot Districts between Kaptur and Kositei areas. The stretch has an N-S direction and a non uniform width of about 150m.
At a hill 8km west of Kositei market, the thickness of the deposit is over 50m. The diatomite is composed of layers of varying sizes intercalated with soil sediments. The beds are almost horizontal with most of it being thin and friable. The thicker layers are purer than the thinner ones. At the hill, the purity of the mineral is good and more analysis needs to be done to ascertain it.

Plate 3: A hill covered by diatomite and capped by a basalt flow between Chepkesin and Kapturo markets

At another point 4.7km to the north east of Chepkesin market, the diatomite is also observed and covers a hill with similar purity.
Garnet
Garnets are found 400m to the north west of Ngoron market in Kolowa Division. The area is covered by fragmented quartzite rock with the garnets being found in the soils in numerous small particles of up to 0.5cm width. The soils are reddish due to the amounts of garnets.

Trenching will need to be done to find the source of the garnets, which is close due to its concentrations.

Plate 4: Small red crystals of garnets in sandy soil at Ngoron
More garnets were found at Makany area, 1.5km south east of Makany market (11.6km east of Akwichatis market). They are found in small veins with calcite. They are pink in colour and are seen as small crystals of up to 2mm in width.

**Amethyst Quartz**

Amethyst is found at Rapaa area near Murgomul hill, 14.5km to the northeast of Churo market. The area with the amethyst crystals spans a distance of 2km in a direction of NW – SE and a width of about 150m.

The crystals are within colluviums from the hills and commonly found in purple to colorless colour. The crystals have sizes of up to 5cm length. Many have perfect crystal shapes. Their colours are however not uniform, ranging from colourless to purple. Many pits dot the area, having been dug by local prospectors.
Trona

Trona is found at Lorusio, a swampy area 10.2km NNE of Kapedo town. The area surrounds a warm water spring and is generally damp.

The trona is deposited by evaporation of water that contains the mineral as it reaches the surface, leaving the mineral on the surface. It forms a layer of white trona (about a centimeter thick) over the whole area. The deposits keep growing even after the layer is removed. The area measures approximately 1km by 1km. Recharge of the trona is from the saturated spring water.
Salt Lick
Salt licks are found in many places in the two districts. The areas are popular with pastoralists as a source of mineral salt for their livestock, mainly goats and cattle.

A large salt lick is found 900m to the north west of Nginyang market. It covers an area of almost 100m by 100m in a dry area and bare area. The area is beside the main Nginyang - Chemolingot road, hence it is very accessible. Some livestock farmers collect and carry the salt lick for their livestock at home.

Other salt licks, though smaller are found in Kolowa and Chepkesin areas.
CONSTRUCTION MATERIALS
The area is endowed with many construction materials. These materials include building stone, sand and rocks that can be fragmented into ballast. The geology of the Project area shows that different types of rocks are well distributed within the area such that construction materials are also well distributed except for sand.

Map 3: Areas with construction materials

Building Stone
Building stone is common and well distributed all over the districts. Building stone in the area has its source rocks as tuff, welded tuff, vesicular basalts, sediments of volcanic origin, mudstone and light diatomaceous rock. Tuff is found in Kolowa, Tangulbei, Marigat and Tenges areas. Sediments of volcanic origin are found north of Kolowa while...
diatomaceous stone is found in a stretch between Lower Kipsaraman and Chemolingot. Vesicular basalts are well distributed throughout the area.

Diatomaceous stone is light and easily disintegrate when exposed to water and stress. Mudstone and other rocks of sedimentary origin are also fragile and also disintegrate when exposed to the above conditions.

Some quarries are close to main roads and construction centres and therefore have ready markets. Some are isolated in areas with poor roads, and inaccessible.

Plate 8: Building stone at Kopeyen quarry
Map 4: Geology of the project area
In Kolowa Division, building stone is mainly from sedimentary origin, being mudstones and siltstone. The active quarries in the Division are found at Kopeyen quarry, Cheptangarmet and Cherengetet areas. These are busy and the stone is used in nearby markets, schools and homes.

In Nginyang Division, stone quarries are found at Chemolingot, Kositei, Chesanja, Kadakotume and Koryo areas. The busy ones are Chemolingot and Kositei due to their proximity to main towns and ready market. The stone from Chemolingot quarry is soft and friable, being a result of sedimentary origin and contains some percentage of diatomite. It is not strong enough and constructors prefer the tougher tuff from Kositei. The Kositei quarry is tuff layer around one of the surrounding hills.

In Tangulbei Division, the only place with building stone is Lochukia, 8km south of Tangulbei market. Accessibility is however an inhibiting factor for its exploitation.

In Baringo District, the main source of building stone in the highlands at Tulwongoi, 3.7km south of Tenges. Other areas are Kapkelelwa and Cheplambus in Sacho Division, Sabor in Marigat Division, and Kapindasum in Mochongoi Division.

The following table summarizes the occurrence of building stone in the project area:

<table>
<thead>
<tr>
<th>Area name</th>
<th>Region</th>
<th>Quantity</th>
<th>Problems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tulwongoi</td>
<td>Tenges</td>
<td>Large</td>
<td>Far from major markets</td>
</tr>
<tr>
<td>Kositei</td>
<td>Nginyang</td>
<td>Large</td>
<td>Medium local markets. Far from major markets.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Bad roads to other areas</td>
</tr>
<tr>
<td>Chesanja</td>
<td>Nginyang</td>
<td>Medium</td>
<td>Small local market. Far from major markets</td>
</tr>
<tr>
<td>Chemolingot</td>
<td>Chemolingot</td>
<td>Medium</td>
<td>Poor quality, small local market</td>
</tr>
</tbody>
</table>
Table 1: Building stone quarries within the project area

The main reasons for low exploitation of the building stones are:

- Competition from quarries near to the urban centers. This leads to lower demand for stones from the quarries except where the stones are unique

- Crude methods of excavation in the quarries

- Poor roads to the quarries. This leads to high transportation costs.

- Poverty, which makes construction of stone houses unaffordable to many locals
**Sand**

Sand is a construction material that is found almost all over the lowlands of the district. It is found in almost all rivers in the regions.

To the west of the Tugen hills, the source of sand is River Kerio. Other rivers with good quality sand in the area are Chepkererat which flows from the hills near Barpello through Kolowa area and into Kerio.

Chemolingot, Nginyang, Kapedo, Tangulbei and Churo areas get sand from river Cheptopokwo (Chemolingot) which flows from Ngoron hills and joins river Nginyang. River Nginyang has very good quality sand. Users from as far as Nakuru travel to the site to collect sand.

Marigat and the surrounding areas get their sand from river Katiorin near Kampi-Ya-Samaki. Small streams around Logumugum flowing from the hills to the east also have good sand.
Ballast

Ballast in the area is normally produced by individuals who break the rock manually with small hand tools. These individuals are found in market centres or have their homes (base) adjacent to roads for easy access to markets. The main markets for the ballast are in urban areas, market centres, and schools.

Ballast was found in Salawa, Barwessa, Barbello, Tangulbei, Marigat and Churo areas. Ballast production in small scale is also done in other main market centres all over the two districts.

Good quality ballast can be made from several rock types of volcanic origin. These are phonolite, trachy-phonolite and basalt. Trachyte produces medium grade ballast. The rocks are normally fine to medium grained and dark coloured. These rocks are found in Bartum – Yatya – Nginyang – Natan areas, Maron area and Chebinyiny – Mukutani – Churo areas (refer to Map 4). Mozambiquan and sedimentary rocks yield poor quality ballast as in Barpello (plate below).
Plate 10: Poor quality ballast made from quartzite rock near Barpello market

Plate 11: Good quality ballast from phonolite rock
GEO-TOURISM SITES

Lake Baringo and Lake Bogoria

Lake Bogoria
The saline-alkaline Lake Bogoria forms part of a spectacular section of the Baringo-Bogoria ‘half-graben’. In this area faults trending NW-SE in alignment form the eastern wall of the Kenya Rift Valley.

The soda lake occupies a spectacular trough 18km long and up to 5km wide. It is bounded to the east by the cliffs of the Siracho escarpment rising to over 700m above the lake surface, which is at about 1000m above sea level.

The lake has no surface outlet although some seepage may occur to the north through Loboi Silts.

Numerous hot springs, geysers and steam jets occur on the western and south eastern shores of the lake, though there is indication of submerged hot springs. These geothermal manifestations and the spectacular scenery are the main attraction to visitors.

Plate 12: Geysers in Lake Bogoria
Lake Baringo
Lake Baringo is the second most north lake in Kenya's Great Rift Valley, after Lake Turkana. The lake covers an area of 130km² at an elevation of 970m above the sea level. The lake is part of the spectacular section of the Baringo-Bogoria ‘half-graben’, and lies between the Tugen hills, an uplifted fault block of volcanic, sedimentary and metamorphic rocks in the west, and the Laikipia Escarpment in the east. The lake has fresh water although it has no obvious outlets. However water is assumed to seep through lake sediments into volcanic bedrock. The lake has seven small islands. The largest the Ol Kokwe Island is an extinct volcano composed of basalts and trachytes. The island has several hot springs and steam jets at the north eastern shores some of which have precipitated sulfur deposits. The Ol Kokwe Island has three villages, one primary school and about 500 inhabitants. The locals rely on canoes and boats for transportation to the mainland. Fishing and tourism are important economic activities to the local community. Fresh water fish, birds, hippopotamus, crocodiles, the islands, hot springs and steam jets are some of the tourist attractions in lake Baringo.
View Points and Hills

The district is rich in sites of good scenery. This is owed to the position of the District in relation to the Great Rift Valley. These view points are not well developed due to poor infrastructure e.g. roads and electricity. The eastern flank of the rift valley passes through the two districts along Laikipia escarpment. The flank provides very good view points that give spectacular views of the rift valley. Some of these points are Mochongoi, Ngelecha, and Churo.

The Tugen Hills and the hills in other parts of the district also provide view points that give similar spectacular views of the lowlands including Lake Baringo. Some notable points are Kipsaraman, Ngoron, Barpello and Tangulbei. Hills (some with craters) also dot the lowlands of East Pokot and include Paka, Silale, Korossi and others.
Plate 15: Silale crater as seen from the satellite image (Google Earth). Note the Kapedo hot springs between the crater and Kapedo Market (white patches)

Plate 16: Magnificent view of the hills to the northwest of Kapedo market showing lava flows

Hot Springs and Steam Jets

Hot springs and steam jets are found in Kapedo, Loiyamarok (north of Korossi hill) area, Kasiela, Ol Kokwe Island in Lake Baringo and around Lake Bogoria (described earlier). The hot water from Kapedo area display spectacular view at its waterfall as it enters Kapedo River within Kapedo market. The waterfall has a height of about 15m, with the
water almost at boiling point. It was once developed to generate electricity for the market by missionaries who had camped at the market.

Plate 17: The team members and guides at Kapedo waterfalls

**Historical Sites**

Fossil sites are common in the sedimentary terrain called the Ngorora Formation that runs from Rondinin in Lower Kipsaraman to Kapturo area. In these sediments, fossils of various kinds of animals including the famous human fossil “Orrorin Tugenensis”, fish, tortoise, and rhino/elephant fossils have been found in the area. Fossils of plants have also been found in the sediments. *Orrorin Tugenensis* is considered to be the second-oldest known hominin ancestor that is possibly related to modern humans and is the only species classified in genus *Orrorin*. The name was given by the discoverers who found *Orrorin* fossils. By using radiometric dating techniques, the volcanic tuffs and lavas, faunal correlation and magneto-stratigraphy, the strata in which the fossils were found were estimated to date between 6.1 and 5.8 million years ago, during the Miocene. This find is important because it is possibly an early bipedal hominin.

This led to the opening of Kipsaraman Museum in Kipsaraman market which was meant to attract tourists. There are two museums in the district. These are in Kabarnet and
Kipsaraman. The Museum is owned by both Community Museums of Kenya (an NGO) and the County Council of Baringo.

Another site with fossils is Kamoi area in Akoroyan Sub-Location, 7km west of Kampi Ya Samaki market. It is found in younger sediments of Chemeron Formation. At this site, fossils of fish, pigs, and other animals are found.

Plate 18: A fossil of animal tooth found at Kamoi area of Akoroyan

Caves
Two large caves are situated 5km NNE of Natan market. They are 460m apart and aligned in a northwest - southeast direction.

The cave to the northwest is smaller with the collapsed basaltic layer measuring about 25m in wide and about 8m deep. The cave itself is covered by boulders of the basalt, leaving small holes between them that are used by bats as their entry points into the cave.
The second cave has an elongated collapsed basalt surface measuring about 25m wide and 50m long. Both ends of its length have caves whose end could not be seen. The trend of the caves is $282^\circ$. The cave in the north-western side is larger, measuring about 15m wide and 10m high. Its width and height has little change as it gets deeper. The cave in the eastern side measures about 15m wide and 7m high. Its width and height decrease as it gets deeper.

The caves are a result of collapse of the overlying vesicular basaltic flow which forms a cap in the area. The collapse exposed the underlying sediments in which the caves run through. This cave could have been an ancient underground river channel running below the basalt layer.

The locals say that the caves acted as a hiding place when they were attacked by their enemies.
Plate 20: A view of the mouth of the cave from the inside

Plate 21: The entrance of the caves (bottom right and top left) of the plate as seen in Google Earth image

By Enoch K. Kipseba, Judith J. Kotut and Julius Kasitet
GEO CHEMICAL ANALYSIS OF STREAM SEDIMENTS

As part of the mineral exploration, stream sediment samples and a few ant-hill soil samples were collected and analyzed for base metals. A total of 34 stream sediment samples were collected on the main rivers and streams and 4 ant hill samples in areas without rivers in East Pokot District during the exploration exercise.

The samples were however sparsely distributed due to inaccessibility in many parts of the district. The locations of the samples are shown in the map below.

Map 5: Map showing the locations of sample points

Ten metals were analyzed for their concentration in the stream sediments and ant hills. These are Silver, gold, cobalt, chromium, copper, fluorite, iron, manganese, nickel and...
lead. A sample of water from a hot spring north of Kapedo was also collected (Sample EP/TR) and analyzed.

Map 6: Drainage map in relation to the sample points

The analysis results are shown in the table below in parts per million (ppm).

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Fluorite</th>
<th>Zinc</th>
<th>Copper</th>
<th>Nickel</th>
<th>Cobalt</th>
<th>Chromium</th>
<th>Silver</th>
<th>Lead</th>
<th>Iron</th>
<th>Manganese</th>
<th>Gold</th>
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<tr>
<td>01AH</td>
<td>0.529</td>
<td>0.217</td>
<td>0.49</td>
<td>0.73</td>
<td>0.14</td>
<td>Nil</td>
<td>0.39</td>
<td>0.32</td>
<td>343.75</td>
<td>17.75</td>
<td>Nil</td>
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<tr>
<td>01LS</td>
<td>0.457</td>
<td>8.50</td>
<td>0.35</td>
<td>1.21</td>
<td>0.35</td>
<td>10.4</td>
<td>0.16</td>
<td>0.67</td>
<td>1562.50</td>
<td>50.00</td>
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<tr>
<td>02AH</td>
<td>0.383</td>
<td>2.56</td>
<td>0.16</td>
<td>1.25</td>
<td>0.05</td>
<td>0.21</td>
<td>0.14</td>
<td>0.20</td>
<td>2193.75</td>
<td>16.75</td>
<td>Nil</td>
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<tr>
<td>02LS</td>
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<td>1.54</td>
<td>0.40</td>
<td>1.19</td>
<td>0.17</td>
<td>1.43</td>
<td>0.10</td>
<td>0.35</td>
<td>2143.75</td>
<td>16.75</td>
<td>0.11</td>
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<tr>
<td>03LS</td>
<td>0.211</td>
<td>3.57</td>
<td>0.21</td>
<td>0.95</td>
<td>0.15</td>
<td>Nil</td>
<td>0.7</td>
<td>0.42</td>
<td>437.50</td>
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<td>4.50</td>
<td>0.11</td>
<td>0.30</td>
<td>0.24</td>
<td>Nil</td>
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<td>0.21</td>
<td>6556.25</td>
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<tr>
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<td>8.80</td>
<td>0.22</td>
<td>1.04</td>
<td>0.31</td>
<td>Nil</td>
<td>0.03</td>
<td>0.93</td>
<td>287.50</td>
<td>73.75</td>
<td>0.07</td>
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<tr>
<td></td>
<td>04AH</td>
<td>05</td>
<td>06</td>
<td>07A</td>
<td>07B</td>
<td>08</td>
<td>09</td>
<td>10</td>
<td>11</td>
<td>12</td>
<td>13</td>
</tr>
<tr>
<td>--------</td>
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<td>------</td>
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<td>------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>Min.</td>
<td>0.235</td>
<td>0.235</td>
<td>0.236</td>
<td>0.148</td>
<td>0.205</td>
<td>0.137</td>
<td>0.130</td>
<td>0.164</td>
<td>0.140</td>
<td>0.202</td>
<td>0.146</td>
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<tr>
<td>Max.</td>
<td>0.338</td>
<td>0.803</td>
<td>0.707</td>
<td>0.355</td>
<td>0.562</td>
<td>0.778</td>
<td>0.355</td>
<td>0.334</td>
<td>0.324</td>
<td>0.462</td>
<td>0.505</td>
</tr>
<tr>
<td>Mean</td>
<td>0.291</td>
<td>0.475</td>
<td>0.292</td>
<td>0.320</td>
<td>0.375</td>
<td>0.331</td>
<td>0.320</td>
<td>0.311</td>
<td>0.320</td>
<td>0.331</td>
<td>0.311</td>
</tr>
<tr>
<td>Value</td>
<td>7.22</td>
<td>8.03</td>
<td>2.97</td>
<td>1.43</td>
<td>2.43</td>
<td>1.57</td>
<td>4.67</td>
<td>2.68</td>
<td>4.20</td>
<td>2.95</td>
<td>1.33</td>
</tr>
<tr>
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<td>Nil</td>
<td>Nil</td>
<td>Nil</td>
<td>Nil</td>
<td>0.39</td>
<td>Nil</td>
<td>0.82</td>
<td>2.21</td>
<td>0.66</td>
<td>0.96</td>
</tr>
</tbody>
</table>
Table 2: Table of the mineral analysis results

The concentrations of the results may be low but it is a pointer of areas that need more detailed exploration. The source areas are upstream from the sample points since the flowing rivers/streams carry dissolved minerals downstream from their sources, leaving traces of the minerals in sediments deposited along its course. More work is therefore required to be done in these source areas to determine the actual source of the minerals and their amounts.
Fluorite

Fluorite is the only mineral for which significant quantities of the important element fluorine can be obtained. Fluorite is also used as a flux in the manufacture of steel and other metals to eliminate impurities. There is a great demand for Fluorite in the optics field, and to meet it synthetic crystals are grown to produce special lenses. It is used in the production of certain glass and enamel. Ornamental objects have been found carved from Fluorite. Fluorite very often occurs in unflawed crystals in beautiful colors, but its softness prevents it from being a gemstone and it is only faceted for collectors.

Fluorite levels are high soils of areas with fluorite mineralization. It is also high in water from hot springs. A water sample collected from Lorusio hot springs (north of Kapedo market) had a concentration of 94 ppm.

Map 7: Map showing fluorite concentration distribution in the area
Concentrations of fluorite of up to 0.99 ppm are found around Akwichatis, Nginyang and Barpello areas. To the south of the area, it has been found to be high around Kampi Ya Samaki area. The level of fluorite contained in borehole water in this area is higher than the acceptable WHO limits of 1.5 ppm. This has caused health problems in the area.

**Zinc**

Zinc is a metallic chemical element with the symbol Zn and atomic number 30. Zinc is the 24th most abundant element in the Earth's crust and has five stable isotopes. The most exploited zinc ore is sphalerite, or zinc sulfide.

Corrosion-resistant zinc plating of steel is the major application for zinc. Other applications are in batteries and alloys, such as brass. A variety of zinc compounds are commonly used, such as zinc chloride (in deodorants), zinc pyrithione (anti-dandruff shampoos), zinc sulfide (in luminescent paints), and zinc methyl or zinc diethyl in the organic laboratory. Zinc is an essential mineral of "exceptional biologic and public health importance". Zinc deficiency affects about 2 billion people in the developing world and is associated with many diseases. In children it causes growth retardation, delayed sexual maturation, infection susceptibility, and diarrhea, contributing to the death of about 800,000 children worldwide per year.

Concentrations found in the area are up to 8.8 ppm near Kapunyany, Barpello, and Kapedo. High concentrations are also found at Chemolingot and Kositei. This suggests that the zinc concentrations are high in the highlands around Maron and Tiati area.
Copper

Copper is a chemical element with the symbol Cu (Latin: cuprum). It is a ductile metal with very high thermal and electrical conductivity. Pure copper is rather soft and malleable and a freshly-exposed surface has a pinkish or peachy color. Gold, caesium and copper are the only metallic elements with a natural color other than gray or white. It is used as a thermal conductor, an electrical conductor, a building material, and a constituent of various metal alloys. Evidence has been preserved from several early civilizations of the use of copper.

In the area, high copper concentrations of up to 1.77 ppm are ofund in Makany, Murgomul and Kositei areas. This points to the source of the copper to be the hills to the east and of Makany and Murgomul and the Tugen Hills west of Kositei.
Nickel
Nickel is a silvery-white metal with a slight golden tinge that takes a high polish. It is one of only four elements that are magnetic at or near room temperature. The metal is corrosion-resistant, finding many uses in alloys, as a plating, in the manufacture of coins, magnets and common household utensils, as a catalyst for hydrogenation, and in a variety of other applications. Enzymes of certain life-forms contain nickel as an active center making the metal essential for them. Nickel is also used in rechargeable batteries and as a green tint in glass.

Concentrations of up to 85 ppm are found southeast of Nginyang. This is a pointer that its source towards Chesirimion area.
Map 10: Map showing nickel concentration distribution in the area
Cobalt
Cobalt is a ferromagnetic metal. Pure cobalt is not found in nature, but compounds of cobalt are common. Small amounts of it are found in most rocks, soil, plants, and animals.

Cobalt is used in the preparation of magnetic, wear-resistant, and high-strength alloys. Cobalt blue (cobalt (II) aluminate, CoAl₂O₄) gives a distinctive deep blue color to glass, ceramics, inks, paints, and varnishes. Cobalt-60 is a commercially important radioisotope, used as a tracer and in the production of gamma rays for industrial use. Soils should contain 0.13 to 0.30 ppm of cobalt for proper animal nutrition.

Concentrations of cobalt of up to 0.96 ppm were found near Murgomul and Makany areas. The source of the metal is southeast of the area.
**Chromium**

Chromium is the 21st most abundant element in Earth's crust with an average concentration of 100 ppm. Chromium compounds are found in the environment, due to erosion of chromium containing rocks and can be distributed by volcanic eruptions. The concentrations range in soil is between 1 and 3000 mg/kg.

The concentrations in the area range from no trace to 10.4 ppm near Barpello. This shows that the source of the metal is within the hills east of Barpello area.

*Map 12: Map showing chromium concentration distribution in the area*
Silver

Silver has been known since ancient times and has long been valued as a precious metal, used to make ornaments, jewelry, high-value tableware, utensils (hence the term *silverware*), and currency coins. Today, silver metal is used in electrical contacts and conductors, in mirrors and in catalysis of chemical reactions. Its compounds are used in photographic film and dilute solutions of silver nitrate and other silver compounds are used as disinfectants.

The concentrations found in the area range from Nil to 0.7 parts per million. The highest concentration was found near Kolowa. The results suggest the source areas of the high concentrations to the area east of Kolowa, area west of Kapedo and Natan area.

Map 13: Map showing silver concentration distribution in the area
Lead
Lead is a soft, malleable metal, also considered to be one of the heavy metals. It has a bluish-white color when freshly cut, but tarnishes to a dull grayish color when exposed to air. It has a shiny chrome-silver luster when melted into a liquid.

Lead is used in building construction, lead-acid batteries, bullets and shot, weights, and is part of solder, pewter, fusible alloys and radiation shields.

In the area, concentrations of up to 1.02 ppm were found at Kapunyany, Chepkesin and Plesian areas. This indicates that its sources are east of Kapunyany and Barpello, west of Kositei and east of Plesian areas.

Map 14: Map showing lead concentration distribution in the area
Iron

Iron and iron alloys (steels) are by far the most common metals and the most common ferromagnetic materials in everyday use. Fresh iron surfaces are lustrous and silvery-grey in color, but oxidize in air to form a red or brown coating of ferrous oxide or rust. Iron is the sixth most abundant element in the Universe. While it makes up about 5% of the Earth's crust, the Earth's core is believed to consist largely of an iron-nickel alloy constituting 35% of the mass of the Earth as a whole. Iron is consequently the most abundant element on Earth, but only the fourth most abundant element in the Earth's crust. Most of the iron in the crust is found combined with oxygen as iron oxide minerals such as hematite and magnetite.

Map 15: Map showing iron concentration distribution in the area
Iron is the most widely used of all the metals, accounting for 95% of worldwide metal production. Its low cost and high strength make it indispensable in engineering applications such as the construction of machinery and machine tools, automobiles, the hulls of large ships, and structural components for buildings. Since pure iron is quite soft, it is most commonly used in the form of steel.

Concentrations of iron in the area are generally low. Iron concentrations need to be over 65% for exploitation.
**Manganese**

Manganese is a gray-white metal, resembling iron. It is a hard metal and is very brittle, fusible with difficulty, but easily oxidized. Manganese metal and its common ions are paramagnetic. While manganese metal does not form a permanent magnet, it does exhibit strong magnetic properties in the presence of an external magnetic field.

Manganese is essential to iron and steel production. The metal is very occasionally used in coins.

In the area, manganese concentrations are high around Kapedo, Nginyang and Kositei with levels of up to 135 ppm. This points the sources to be Tirioko and Chepanda Hills areas.

Map 16: Map showing manganese concentration distribution in the area
Gold
Gold is dense, soft, shiny and the most malleable and ductile pure metal known. Pure gold has a bright yellow color and luster traditionally considered attractive, which it maintains without rusting in air or water.

The highest concentrations in the area measure 0.75 ppm near Natan and Akwichatis. This points the source of the concentrations to the areas south east of Akwichatis and Natan area.

Map 17: Map showing gold concentration distribution in the area
CONCLUSION AND RECOMMENDATIONS

Conclusion

1. The exploration done has shown that there are minerals in the Project area. These include fluorite, gemstones, and trona. Traces of other minerals were also found in laboratory analysis of the stream sediment samples collected.

2. Rock sources for construction materials (building stone, ballast and sand) are abundant in the area. Their exploitation is however restricted by inability of the locals to exploit and poor road network in the area.

3. There are many geo-tourism sites in the area. These include Lakes, hot springs and gas vents, caves, scenery, and historical sites. These can be used to promote tourism in the area and indirectly improves business opportunities and infrastructure.

4. The poorly developed roads and communication networks, hilly terrain and harsh climatic conditions, low awareness of the locals on mineral exploration and exploitation, and insecurity are among the problems experienced during the exploration.

5. The development of the mineral and geotourism sectors will generate sources of income for the locals, government and local authorities through employment, infrastructure development and business opportunities. It will also offer an alternative activity other than dependence on livestock.

6. With the development of the sectors, construction materials will be available from within, therefore reducing unnecessary transport expenses.
Recommendations

1. Detailed exploration for minerals that have been found is required to determine the quantities of the minerals.

2. A more representative stream sediment and anthill sampling is required so as to increase the accuracy of the results. Follow up to determine the source of the high concentrations may lead to deposits of the minerals.

3. Local groups need the support of the government through ALRMP, CDF and Local Authorities to develop their activities in building material quarries. These include building stone, sand and ballast quarries. The issues of concern should be development of the quarries, employment creation and environmental issues.

4. The locals need awareness creation on development and exploitation of minerals, construction materials and development and conservation of geotourism and historical sites in the area.

5. Good roads should be constructed to the construction materials sites and Geotourism sites in order to facilitate their development. The roads should also benefit other sectors both directly and indirectly.
REFERENCES


2. Robert Webster, 1983, Gems – Their sources, descriptions and identification


7. Google Earth satellite imagery