Geology and Geochemistry of the Area around Lilida Thermal Spring, DRC


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ABSTRACT

The Democratic Republic of the Congo (DRC) has a lot of geothermal surface manifestations located in its Eastern part within the western branch of the African Rift valley. Lilida is one of them situated in Ituri province. This paper contributes to the geological and geochemical knowledge of rocks around the Lilida thermal spring located in Djugu, Ituri Province. Geochemical investigations were carried out on rock samples, collected from the field around the hot spring, using X-Ray fluorescence at the Kenyan Ministry of Mining and Petroleum. Data from this study indicated that the mineral composition of rocks around the thermal spring of Lilida is characteristic of high SiO₂ content, with moderate to low Al₂O₃, CaO, P₂O₅, MgO and K₂O. A description of samples combined with their geochemical composition revealed that the Lilida hot spring rises from magmatic rocks and mainly granite. Some other surrounding rocks include sedimentary quartzite as well as some loose blocks of diorite. The spring has a temperature of 36 Celsius degrees at the surface and is structurally controlled. This is explained by the fact that water from beneath the earth arrives at the surface through vents which are present in the host magmatic rock. It is recommended that further studies should focus on the structural investigations of the area.

1. Introduction

The DRC is still considered to be one of the potentially richest countries in the world in terms of natural resources. These resources which include minerals, water, forests, soils and energy are immense although still poorly known over the extent of the national territory, due to the lack of support by the state of scientific research sector (Ongendangenda, 2007). Among
energy resources, hydropower, oil and gas are the most prominent. However, due to the size of the country, some other sources of renewable energy are developing, such as solar and to a small extent wind energy. Besides, geothermal energy is one of the sources which has to get some attention as surface manifestations have shown some interesting perspectives.

The significant geothermal potential is found in the eastern part of the DRC within the western branch of the rift valley (Essequat, 2012). Therefore, it is important to get around and identify opportunities related to known geothermal sources. The geological, geochemical and environmental aspects of these sources should be deeply understood to evaluate their respective value in terms of their direct and indirect benefits. To achieve this, investigations have been carried out on geothermal potentials of the DRC (Luse and Makonga, 2018, Mambo and Mahinda, 2012, Mambo et al., 2008, Mukandala et al., 2018).

This work contributes to the geology and geochemistry of Lilida with an aim determining the lithology or likely the host rocks from which the sources arise. Lilida (in local Lendu dialect means hot water) is geographically located in the east of the DRC, Ituri province, Djugu territory (or district), in the Mbongi at between latitude of 1 ° 23'44 " N and longitude of 30 ° 31 ' 23 " E (Figure 1). This thermal spring presents itself in a bog of mud; as a stagnant body of water gushing with a low flow from a central point.

The lithology of the Djugu locality are concomitant with the Kibalian rocks and in close relationship with the East African rift. The three major rocks that are outcropping are a bedrock of granitoid rocks, amphibolite cover and metamorphic rocks (Woodtli, 1956).

2. Literature review

The earth is characterized by tectonic movements and magmatic processes. The rise of magmas is essentially the result of plate tectonics whose movements determine three major types of boundaries and geothermal deposits (Varet, 2012). Philipe et al. (2017) established a classification to properly situate the concept of deep geothermal energy. They distinguished not only a classification based on the recoverable energy potential: very low energy (<30°C), low energy (between 30°C and 90°C), average energy (between 90°C and 150°C) or high energy (>150°C) but also a classification according to the types of valorization of the geothermal heat: production of heat-assisted by heat pump, production of heat by direct use of the geothermal heat, production of electricity.

The best geothermal examples are usually located around active volcanic areas, often near the boundaries of tectonic plates. Nearly 40 countries in the world are considered to have sufficient geothermal potential that would allow, from a more technical than an economic point of view, to satisfy their entire demand of electricity by geothermal energy (Gehringer and Loksha, 2012).
Geothermal energy is independent of the climate and can be exploited for both heat production (house, greenhouses, fish farms and others) and electricity production (Ahmed, 2009). Omenda (2014) points out that in 1952, DRC was the first African country that built a geothermal micro-powerplant in Kiabukwa (Katanga Province, DRC). The latter gushed at a temperature of 91 °C and produced 0.2 MW. Unfortunately, this geothermal powerplant was abandoned a few years later.

Luse and Makonga (2018) reported that the Lilida Spring water is characterized by a bicarbonated calcosodic shallow fresh groundwater with this following geochemical facies for the cations Na > Ca > Mg and this one for the anions: HCO₃ > SO₄ > Cl. The classification diagrams of the water analyses reveal that it had circulated in a shallow argillaceous field certainly containing dolomitic limestone and flysch derivate.

3. Methods

3.1. Fieldwork

Six samples were collected and chosen based on lithological characteristics near the Lilida hot spring. They were described using a magnifier, labelled and packed in plastic bags then sent to the testing laboratory. The outcrops localization and mapping were done thanks to a GPS and QGIS software.
3.2. Laboratory work
Geochemical analyses of eight rock samples were conducted at the Kenyan Ministry of Mining and Petroleum using a S1 TITAN Bruker X-ray fluorescence spectrometer after preparation. The preparation consisted of grounding the sample in a jaw crusher to a 100 microns diameter.

3.3. Geochemical cartographic and lithographic data processing
The field data (cartographic) were imported in Excel and then used in the QGIS software for specific treatments finally mapping of the study area. The geochemical data were processed using Excel, Past and R software following the procedures contained in the related tutorials (Moreau, 2013).

4. Results

4.1. Macroscopic description of the samples
The rock samples described represent a major rock groups: magmatic and to a small extent sedimentary and metamorphic constituting the lithology of Djugu around the Lilida thermal spring. These rock samples were named based on their mineralogic modal composition of essential elements described with a magnifying glass.

Sample NK 01 and 03 is a coarse-grained rock mainly composed of quartz, biotite and K-feldspar. It is a granite (Figure 2).

Sample NK_02 it is a coarse-grained rock characterized by crystals of quartz, muscovite and feldspar. The presence of traces of black tourmaline is noticed. It is a pegmatite (Figure 3).

Sample NK_05 fine-grained rock consisting of a little quartz, biotite and feldspar. It is a diorite (Figure 4).
Sample NK 04 and 06 is a coarse-grained rock consisting of quartz, feldspar and muscovite. These essential minerals follow a preferential orientation. It is a gneiss (Figure 5).

Figure 5: Photograph of a gneiss sample in the Lilida area.

4.2 Geochemical results

4.2.1 Raw results of geochemical analyzes

The results of the chemical composition of rocks surrounding the Lilida thermal spring are given in Table 1.

<table>
<thead>
<tr>
<th></th>
<th>MgO</th>
<th>Al₂O₃</th>
<th>SiO₂</th>
<th>P₂O₅</th>
<th>K₂O</th>
<th>CaO</th>
<th>TiO₂</th>
<th>FeO</th>
<th>MnO</th>
</tr>
</thead>
<tbody>
<tr>
<td>NK_01</td>
<td>0.000</td>
<td>13,370</td>
<td>68,508</td>
<td>1,712</td>
<td>4,049</td>
<td>3,932</td>
<td>0.368</td>
<td>0.117</td>
<td>7,530</td>
</tr>
<tr>
<td>NK_02</td>
<td>6.102</td>
<td>8,210</td>
<td>76,770</td>
<td>2,347</td>
<td>4,086</td>
<td>1,018</td>
<td>0.229</td>
<td>0.000</td>
<td>1,090</td>
</tr>
<tr>
<td>NK_03</td>
<td>0.000</td>
<td>13,365</td>
<td>73,435</td>
<td>3,174</td>
<td>1,742</td>
<td>3,886</td>
<td>0.345</td>
<td>0.229</td>
<td>3,583</td>
</tr>
<tr>
<td>NK_04</td>
<td>9.743</td>
<td>11,432</td>
<td>64,468</td>
<td>2,156</td>
<td>4,835</td>
<td>2,962</td>
<td>0.607</td>
<td>0.283</td>
<td>2,675</td>
</tr>
<tr>
<td>NK_05</td>
<td>0.000</td>
<td>16,660</td>
<td>44,816</td>
<td>0,837</td>
<td>0,947</td>
<td>23,660</td>
<td>0,229</td>
<td>0,116</td>
<td>11,923</td>
</tr>
<tr>
<td>NK_06</td>
<td>0.000</td>
<td>13,554</td>
<td>74,818</td>
<td>1,027</td>
<td>3,182</td>
<td>4,074</td>
<td>0,769</td>
<td>0,049</td>
<td>3,968</td>
</tr>
</tbody>
</table>

4.2.2 Statistical analysis of geochemical data

The distribution of the contents of major elements in the rock samples is irregular; this is indicated by the graph of variation in Figure 6. From the data in Table 1 and Figure 6, SiO₂ is abundant in all the samples at levels between 44-76 wt.-% followed by Al₂O₃ at levels between 8-17 wt.-%. CaO and MnO are in profusion in samples at the concentration lower than 20 except the sample 6 in which CaO is 23,66 wt.-%. MgO, P₂O₅, K₂O, TiO₂, FeO, are present in samples at low contents.

Figure 6: Distribution of the contents of trace metals in Lilida rock samples.
4.2.3. Grouping rock samples according to their compositional resemblance

The grouping of rock samples is presented in Figure 7 based on geochemical analyzes. It reveals that there is a reconciliation of the samples which contain almost equal proportions of elements. This dendrogram presents the samples into two groups. From left to right; the group of sample NK_5 is characterized by high contents of CaO (23.66 wt.-%), FeO (11,923 wt.-%) and the low concentration of SiO₂. The second group consists of Samples NK (1, 2, 3, 4 and 6) which contain more 60 wt.-% of SiO₂ and moderate to low concentrations of Al₂O₃, MgO, P₂O₅, K₂O, TiO₂, FeO, MnO and CaO. This assembly is motivated by the strong concentration SiO₂.

![Figure 7: Grouping the samples according to their compositional resemblance](image)

4.2.4. Principal Component Analysis (PCA) and correlation circle

This analysis consists of defining the distribution of the elements in the samples according to their influence on the construction of the axes. The examination of the factorial plots makes it possible to visualize the correlations between elements and to identify groups of samples with almost identical chemical compositions (Figure 8).

![Figure 8: Principal Component Analysis (PCA) and correlation circle](image)
The principal component analysis graph (Figure 8) shows that the concentrations of MgO, Al₂O₃, SiO₂, P₂O₅, K₂O, TiO₂ and FeO contribute more to the formation of the factorial axis 1 which explains 87.585% of the distribution of these elements concentrations in the samples, whereas CaO and MnO are more related to axis 2 which explains 9.91% of this distribution of elements in the samples. As for the samples, those that come closer and contribute more to the construction of the axis 1 are the samples NK (02 and 05) whereas the sample NK (01, 03, 04 and 06) contributes more to the construction of axis 2. These two axes explain in total 97.495% of the distribution of the elements in the samples analyzed; the remainder of inertia is 2.505% which is influenced by other geological and geochemical factors.

The principal components analysis makes it possible to apprehend the real values of the coexistence of the elements through the correlations observed during axis construction and the relationship existing between these variables and the individuals in the explanation of the phenomenon. This is to say that it summarizes the initial behaviour of the elements for certain membership links. The contribution of the correlation between the geochemical parameters in the samples helps to understand certain phenomena released inter-elements and inter-samples. It gives an approach to the common origin of certain elements.

In general, rock samples that surround the Lilida thermal spring are magmatic with some small part of sedimentary rocks; and the spring waters that spread on the surface are driven through fractures. It is a structurally controlled spring.

### 4.3. Geological map

The geological formations of Djugu are constituted of by complex of gneisses, granites, Kibalian, Pleistocene and Pliocene rocks (Figure 9).
5. Discussion and Conclusion

In the locality of Djugu, around the Lilida hot spring, six samples were collected from rock and were used for geochemical analyzes. These analyzes covered major elements and revealed that rocks in the surroundings of the Lilida thermal spring are characterized by high \( \text{SiO}_2 \) content and a moderate to low \( \text{Al}_2\text{O}_3, \text{CaO}, \text{P}_2\text{O}_5, \text{MgO} \) and \( \text{K}_2\text{O} \) content. The characteristic lithology consists of granite, loose blocks of diorite and sedimentary quartzite. This Lilida flows in the Pleistocene and Pliocene formations. At macroscopic view, the source gushed into the clayey mud mixed with pebbles. It is likely to be structurally controlled by veins as the host rocks are in large part magmatic.

Some similar examples around the world include the thermal waters of Moulay Yacoub which flow from the Miocene formations of the Sillon Sud Rifain. These waters, with therapeutic virtues, are characterized by strong mineralization concerning their storage and circulation in reservoirs of various lithological nature. They have two chemical facies: slightly diluted Cl-Na facies and another Cl-Ca-Mg facies, dominated by immature waters. The discovery of extrusion formed by blocks of liassic limestone, Paleozoic sedimentary and large Triassic dolerite masses, suggests the existence of permeable formations under the Miocene marl cover (Akhdar et al., 2006). Sources in the Rwenzori territory are also structurally controlled (Mukandala et al., 2018).

The Lilida thermal spring has a temperature of 36 Celsius degrees and gushes out in a clayey mud which rests on a base of granitoid. Lilida geochemical facies is characterized by the cations \( \text{Na} > \text{Ca} > \text{Mg} \) and this one for the anions: \( \text{HCO}_3 > \text{SO}_4 > \text{Cl} \) (Luse and Makonga 2018). The geochemical study done of the geological formations around Lilida thermal spring reveals that a large part of the Lilida area geology is hosted in granite, diorite and sedimentary quartzite.
Assessments from Na-K-Ca geothermometer and its correction on Lilida thermal water suggest the existence of a peripheral geothermal reservoir of low enthalpy (45.7 °C). Thus, in this state, this thermal water can only be used for geothermal low energy exploitation and direct utilizations such as heating and cooling of buildings, heating of greenhouses, heating of aquaculture ponds.

REFERENCES


