CHEMICAL CHARACTERIZATION OF GOLD FROM MIARINAVARATRA-FANDRIANA, SOUTH-CENTRAL MADAGASCAR BY SCANNING ELECTRON MICROSCOPE (SEM)

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Summary

The characterization of gold is an international project like the case of gold from Guyana, in June 2013, launched by the WWF and carried out by the BRGM whose purpose was a *"service of sampling and physico-chemical characterization and mineralogy of gold"* (Auge, T et al. 2015). Inspired by this project, this article aims to characterize the specific signature of Miarinavaratra-Fandriana gold. The methodology applied is the use of scanning electron microscope (SEM) for the analysis of micro-inclusions in gold grains. The gold particles in this deposit are accompanied by the following micro inclusions, including oxygen (O) with an average content of 42.61%; aluminum (Al) 5.44%; silicon (Si) 4.84%; titanium (Ti) 11.93%; vanadium (V) 0.23%; iron (Fe) 1.97%; magnesium (Mg) 0.43%; phosphorus; (P) 0.10%; and chromium (Cr) 0.06%.

Keywords: *Gold, Miarinavaratra, Micro inclusion, Scanning Electron Microscope (SEM), Fandriana*

I. INTRODUCTION

The subsoil of Madagascar contains different natural resources, particularly mining resources. Our island has mining potential and a great diversity of mineral substances such as precious stones and also precious metals such as Platinum, gold, silver.

Among these different mineral resources, the commune of Miarinavaratra -Fandriana commune located in the Amoron'i Mania Region, is renowned for its gold potential (Randrianaivo N., 2018). Although some end-of-study dissertations have been completed in this municipality, no research has been carried out on the studies of micro inclusions in gold grains.

This is why we opted for the theme: "Chemical characterization of gold from Miarinavaratra-Fandriana, south-central Madagascar by scanning electron microscope (SEM)". This article aims to determine the chemical characteristics of gold in this site.

II.   METHODS AND MATERIALS

In order for the objective to be achieved, the research methodology represented by Figure 1 is divided into three very different large parts including field work and chemical analysis within the Geology laboratory of Lhomond, Paris V-France and the data processing using XLSTAT 2019 software followed by final writing.

II.1.Field work

II.1.1. Location [3]

The Miarinavaratra Rural Commune is geographically located between 503,517m and 533,798m east longitude, and 646,542m and 674,500m south latitude by the Laborde projection. Its total surface area is approximately 466 km2.

The Vondrona gold panning site is a primary deposit (Rasamimanana V., 2014). It is located at the geographical coordinates:

• X: 527,767 m

• Y: 652,560 m

Figure 2 presents the map showing the different administrative hierarchies of the study area of the Region up to Fokontany (locality) where this deposit is located.
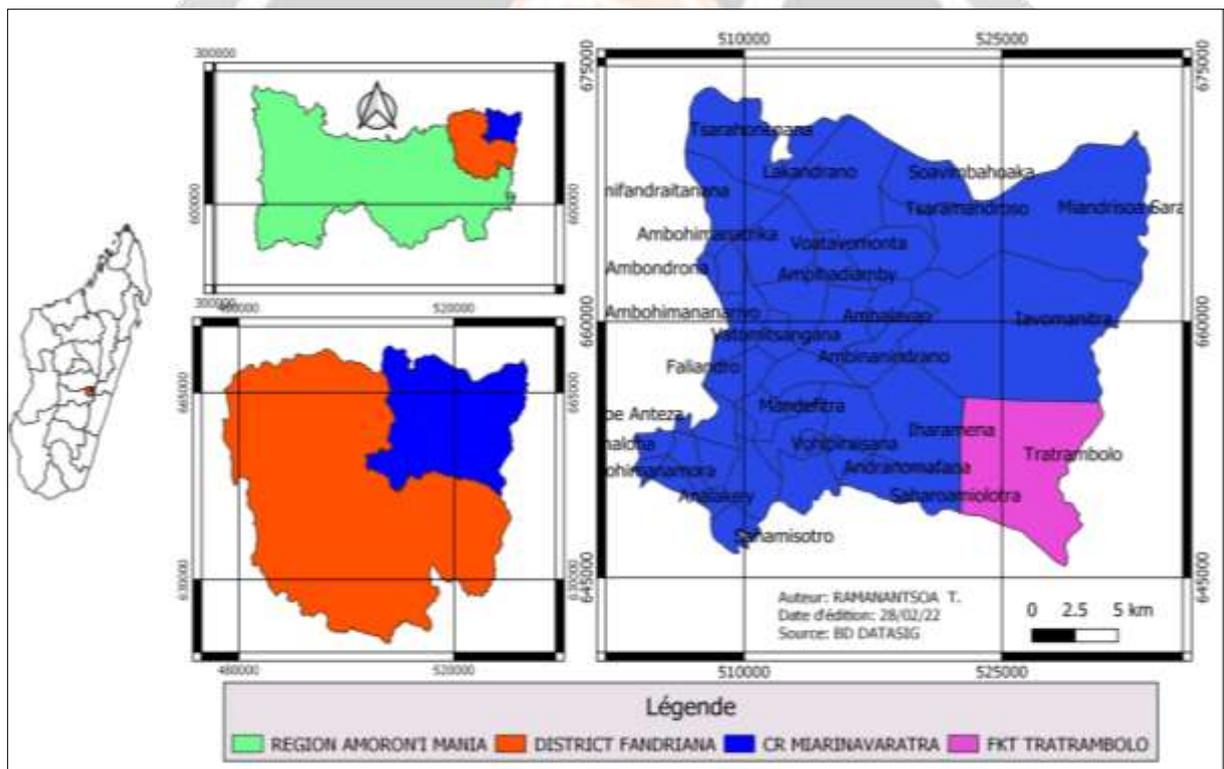
Fig. 1: Miarinavaratra location map (Ramanantsoa T.2024)

II.1.2.Geology of the Fandriana district

Figure 3 illustrates the geological formation in the Fandriana District. It is made up of gneisses, mica schists and migmatites which cover the central part of the area. The eastern sector is dominated by the migmatite and magnetite quartzite formation. There is also an intercalation of migmatitic granites, granitoid migmatites which cut the gneisses (Randrianaivo, N.2018).
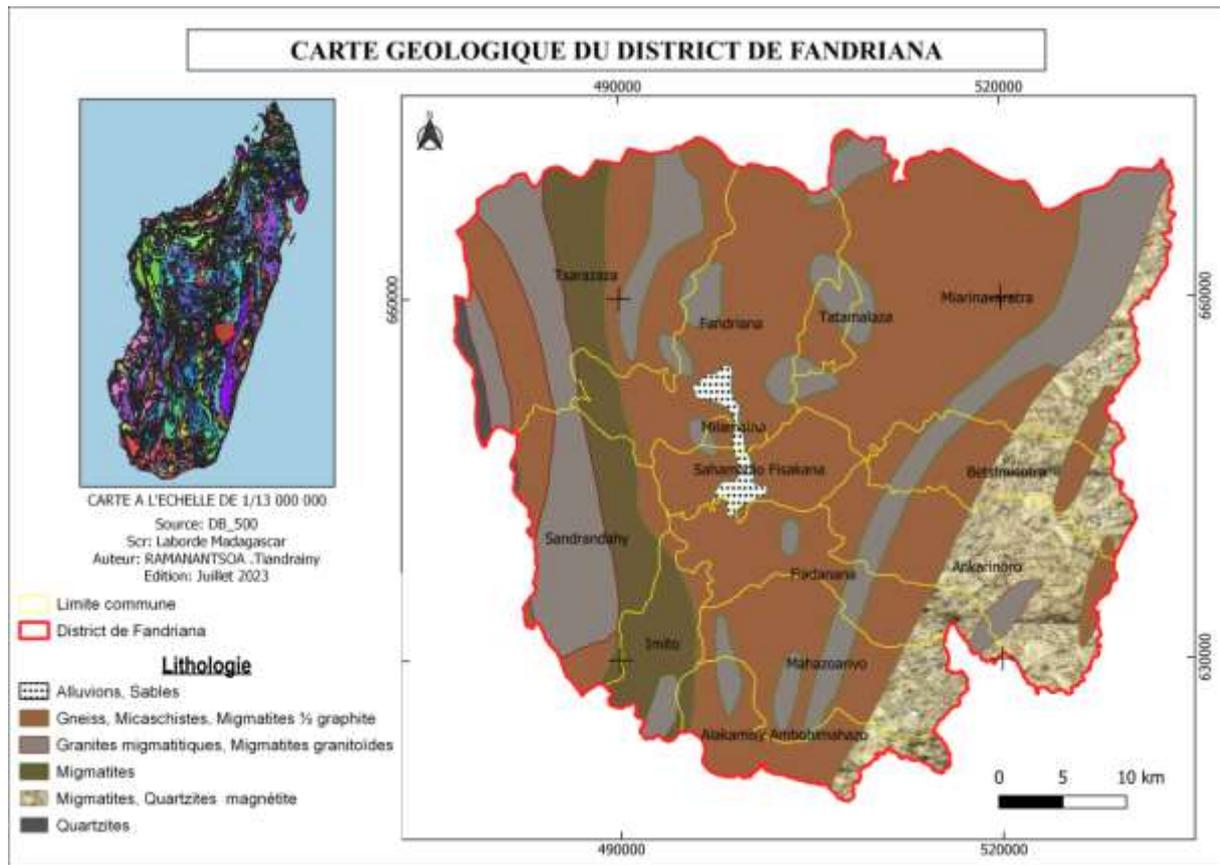
Fig. 2: Geological map of the Fandriana District

II.2.Laboratory work

II.2.1.Introduction

SEM characterizations made it possible to locate the elementary micro-inclusions present in the gold grains and to obtain their qualitative chemical composition (Augé T., Bailly L., Bourbon P., Guerrot C., Viprey L. 2015) . The elemental analysis of gold by SEM was carried out in the geology laboratory of the École Normale Supérieure (ENS) of Lhomond, Paris V-France.

II.2.2.Preparation and analysis by the M.E. B.

For chemical analysis, three (3) gold grains among the 6 samples contain inclusions. Microscopic observation of the gold grains was carried out at the level of the impurity zones. The analyzes determine the point composition at the observation points.

The first concentrate is observed by six (6) analysis points, represented by spectra (2 to 7). Sample E2 is examined by five (5) analysis points and sample E3 is also observed by five (5) analysis points.

II.2.3.Study materials

♣ Scanning Electron Microscope (SEM)

The SEM equipment consists of the central unit (gun, scanning lens) and three computers, each screen of which provides the following function: machine control, sample scanning and spectra display. Figures 4 and 5 show the devices and the device for placing the samples.

Fig.3: Scanning Electron Microscope (SEM) equipment - (ENS Geology Laboratory. Lhomond. Paris V) Source: Ramanantsoa Tiandrainy. 2023

Fig. 4: Placement of the sample in the chamber (MEB) - (Laboratoire de Géologie ENS. Lhomond .Paris V). Source: Ramanantsoa Tiandrainy. 2023
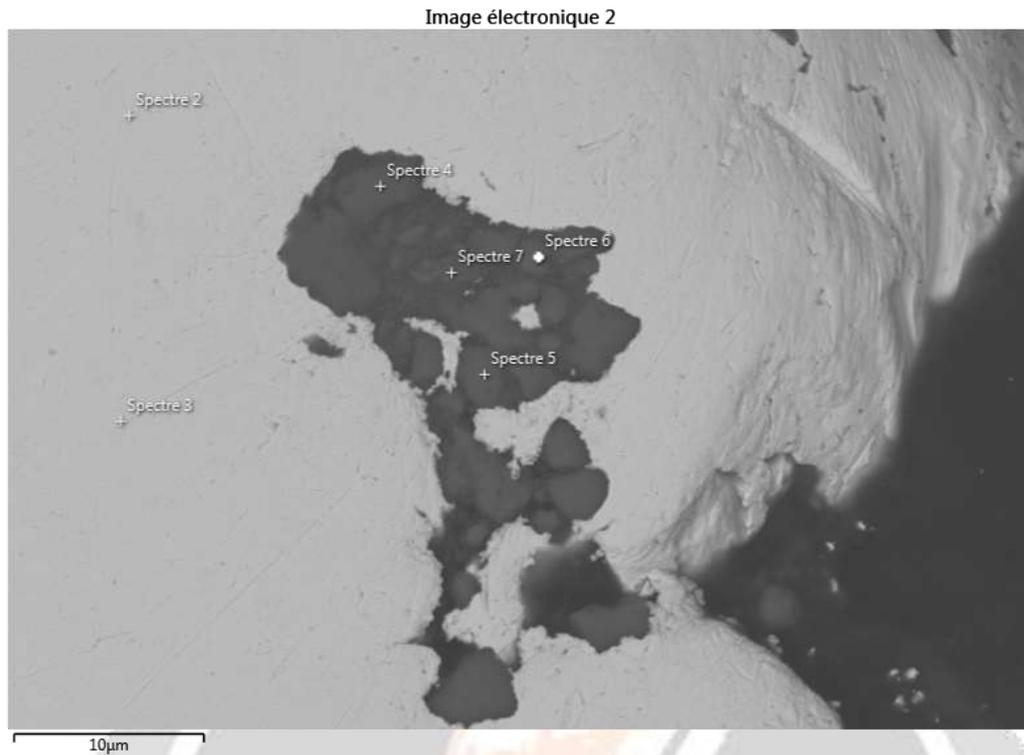
III. ANALYSIS RESULTS

III.1.Result of chemical analysis of the grains

The results obtained are presented in the form of spectra, descriptive tables and representative figures. They consist of three (3) electronic images where traces of impurities and analysis points are located on the samples, three (3) descriptive tables and three (3) micro-inclusion distribution diagrams.

Sample E1

Sample E1 is analyzed by six (6) analysis points (spectrum 2 to spectrum 7) represented by Figure 11 and Figures 12 to 17 for the spectra.

**Fig. 5: Grain photograph of sample E1 with inclusions**
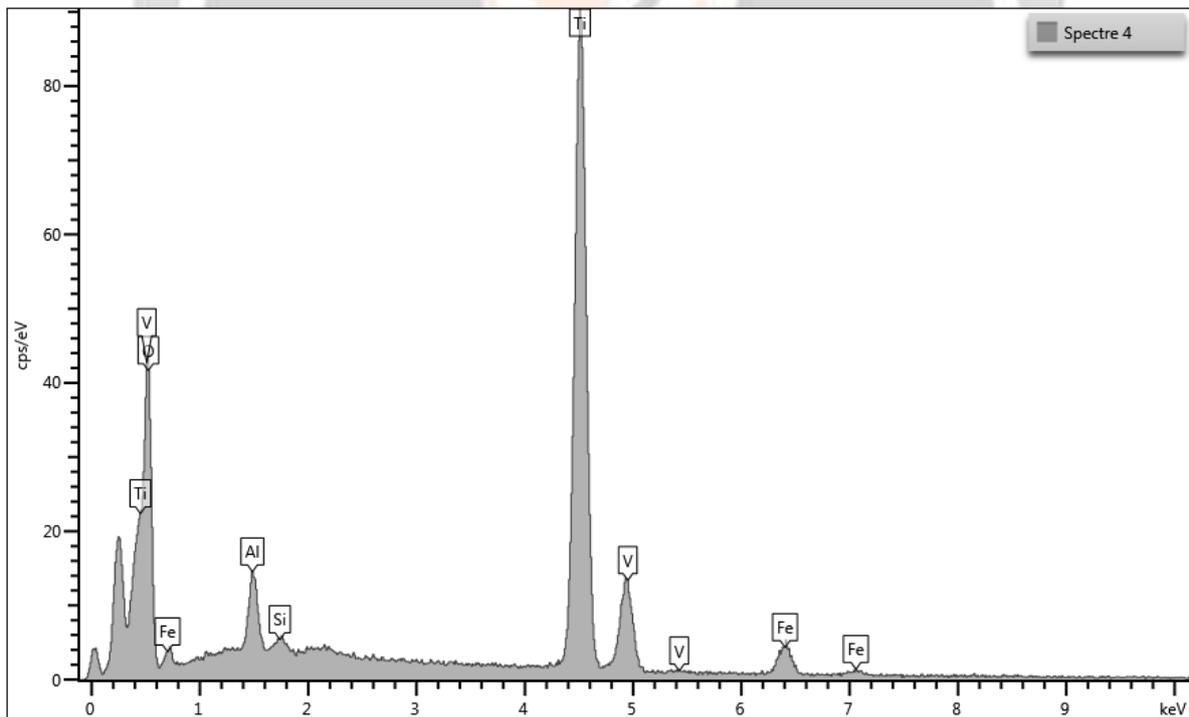
Fig. 6: Example of spectrum 4 of sample E1

The analysis results are summarized in Table 1 below. It presents the chemical elements found and the description of spectra 2 to 6. The results obtained are oxygen (O); aluminum (Al); silicon (Si); titanium (Ti); vanadium (V); sulfur (S) and iron (Fe).

Table 1: Analysis results of sample E1 in atomic %

Descriptif de spectre	Spectre 7	Spectre 2	Spectre 3	Spectre 4	Spectre 5	Spectre 6	TOTAL	en %
O	62.31			61.23	60.86	56.59	240.99	40.165
Al	2.22			2.28	2.31	2.58	9.39	1.565
Si	2.1			0.35	0.64	1.45	4.54	0.757
S						0.34	0.34	0.057
Ti	30.29			32.35	32.78	36.08	131.5	21.917
V	0.78			0.68	0.93	0.66	3.05	0.508
Fe	2.3			3.11	2.48	2.31	10.2	1.700
Au		100	100				200	33.333
Total	100	100	100	100	100	100	600	100.000
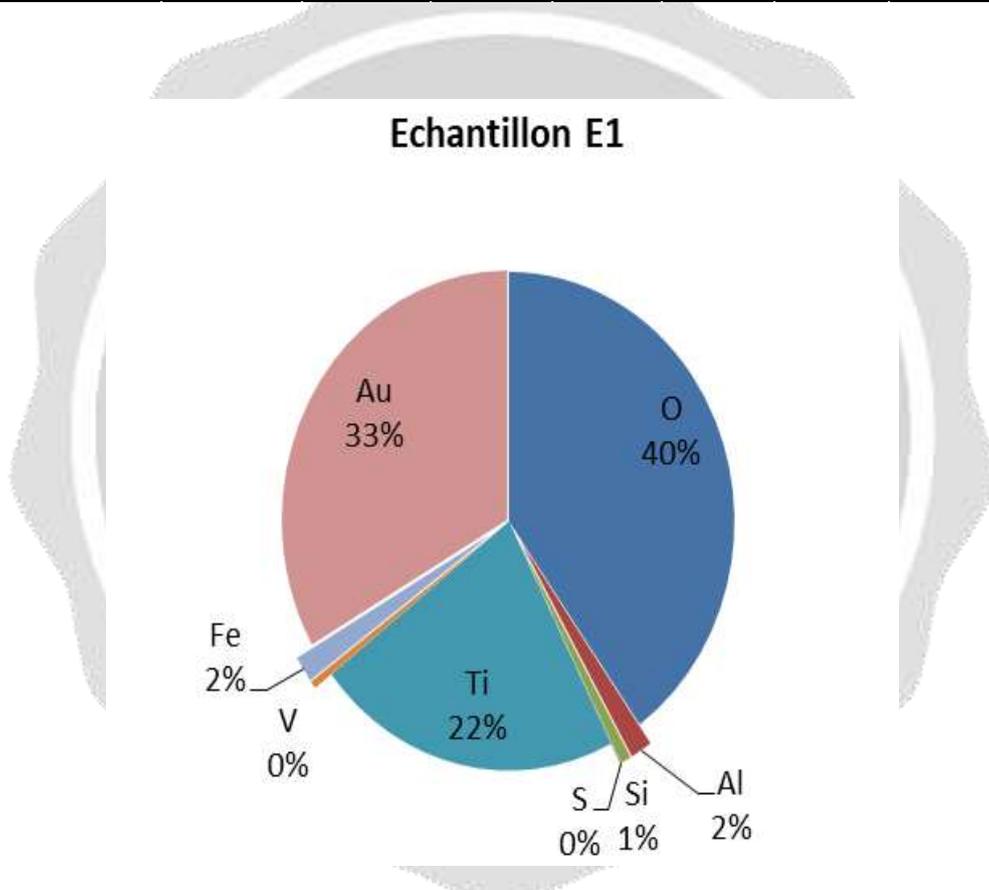
Fig.7: Distribution diagram of micro-inclusions contained in the grains of sample E1 (Ramanantsoa T.2023)

♣ Sample E2

Sample E2 in the Vondrona site is observed by five (5) points according to the shade of gray color (figure 5). The elements detected are presented in the form of spectra including oxygen (O); aluminum (Al); silicon (Si); titanium (Ti); vanadium (V) and iron (Fe).
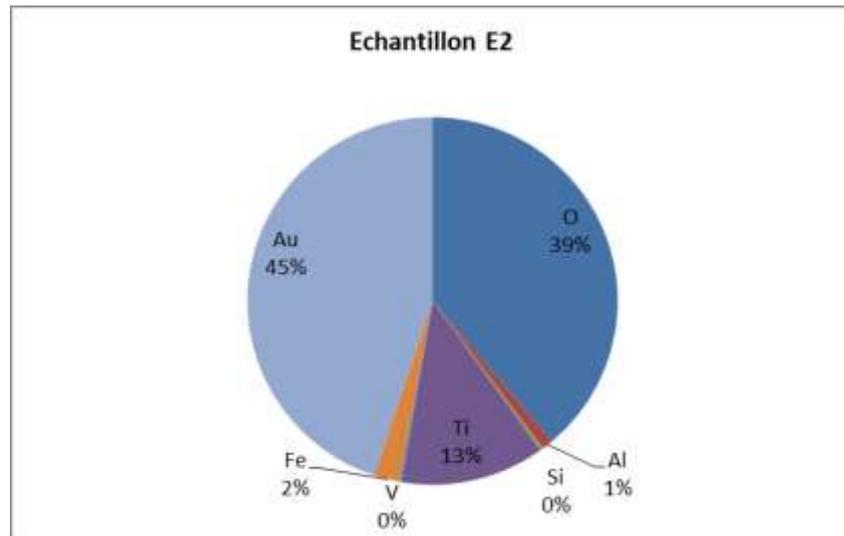
Fig.8: Distribution diagram of micro-inclusions contained in the grains of sample E1 (Ramanantsoa T.2023)

♣ Sample E2

       Sample E2 in the Vondrona site is observed by five (5) points according to the shade of gray color (figure 5). The elements detected are presented in the form of spectra including oxygen (O); aluminum (Al); silicon (Si); titanium (Ti); vanadium (V) and iron (Fe).

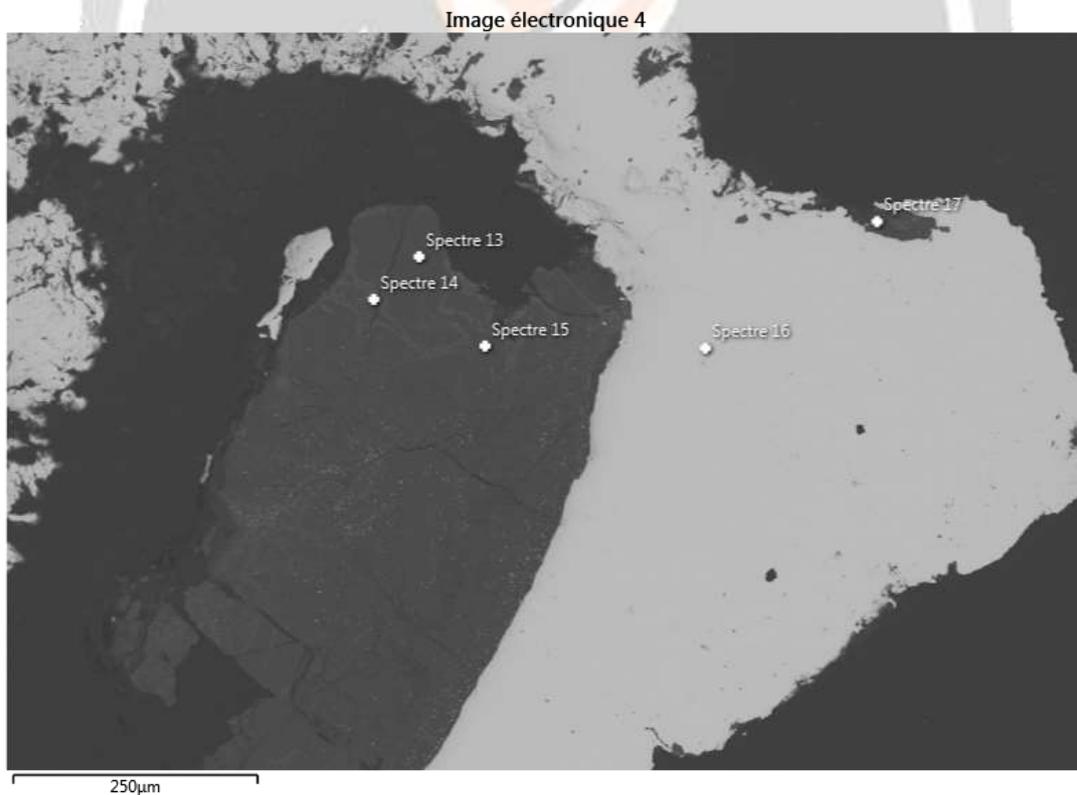**Table 2 : Analysis results of sample E2 in atomic %**

Descriptif de spectre	Spectre 12	Spectre 8	Spectre 9	Spectre 10	Spectre 11	TOTAL	%
O	63.09	67.09	64.16			194.34	**38.868**
Al	1.35	2.18	1.19			4.72	**0.944**
Si		0.66	0.69			1.35	**0.27**
Ti	12.42	27.67	22.93			63.02	**12.604**
V		0.53	0.39			0.92	**0.184**
Fe	1.23	1.42	8.58			11.23	**2.246**
Au	21.91	0.45	2.04	100	100	224.4	**44.88**
Total	100	100	100	100	100	500	**100**

Fig. 9: Distribution diagram of micro-inclusions contained in the grains of sample E2 (Ramanantsoa T.2023)
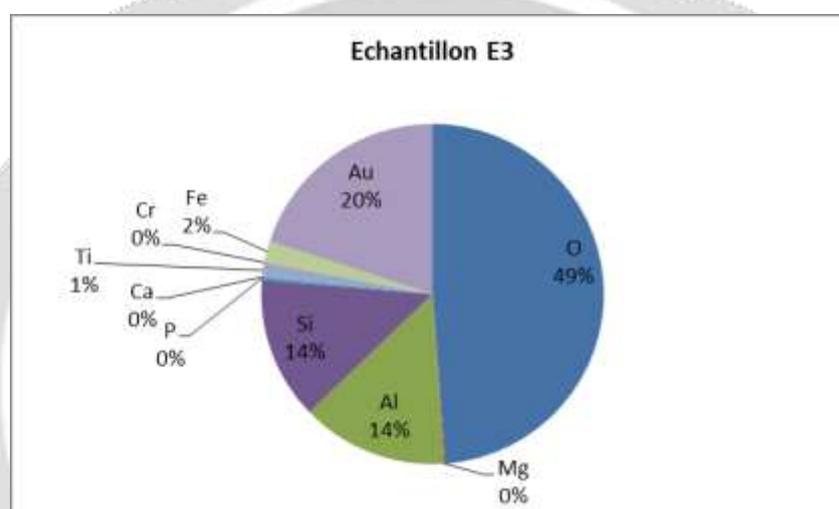
♣ Sample E3

This concentrate was analyzed by five (5) spectra numbered from 13 to 17. The 9 chemical elements accompanying gold represented by the spectra in Figures 27 to 31; including oxygen (O); magnesium (Mg); aluminum (Al); silicon (Si); potassium (P); calcium (Ca); titanium (Ti); chromium (Cr) and iron (Fe).

Fig.10: Grain photograph of sample E3 with inclusions

Table 3: Analysis results of sample E3 in atomic %

Descriptif de spectre	Spectre 17	Spectre 13	Spectre 14	Spectre 15	Spectre 16	TOTAL	%
O	62.43	61.33	60.62	59.65		244.03	**48.806**
Mg	0.66					0.66	**0.132**
Al	16.89	17.3	16	19		69.19	**13.838**
Si	18.28	17.3	13.23	18.76		67.57	**13.514**
P		0.31	0.88	0.31		1.5	**0.3**
Ca			0.19			0.19	**0.038**
Ti	0.47	1.36	3.32	0.94		6.09	**1.218**
Cr		0.31	0.63			0.94	**0.188**
Fe	1.27	2.09	5.13	1.34		9.83	**1.966**
Au					100	100	**20**
Total	100	100	100	100	100	500	**100**

Fig. 11: Distribution diagram of micro-inclusions contained in the grains of sample E3 (Ramanantsoa T.2023)

IV. DISCUSSIONS

IV.2. Chemical analysis of micro-inclusions

The gold grains in the Vondrona site are accompanied by nine (09) chemical elements including:

- Oxygen (O) with an average content of 42.61 atomic%;
- Aluminum (Al) with an average content of 5.44 atomic%;
- Silicon (Si) with an average content of 4.84 atomic%;
- Titanium (Ti) with an average content of 11.93 atomic%;
- Vanadium (V) with an average content of 0.23 atomic%;
- Iron (Fe) with an average content of 1.97 atomic%;
- Magnesium (Mg) with an average content of 0.43 atomic%;
- Phosphorus (P) with an average content of 0.10 atomic%;
- Chromium (Cr) with an average content of 0.06 atomic%.

Figure 33 below presents the summary of the signature elements of gold by sample in the Vondrona deposit.

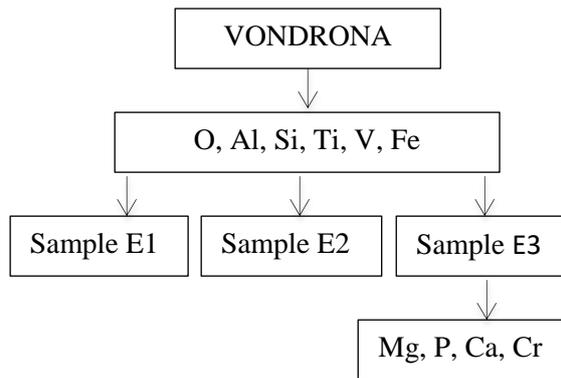Table 4 provides a description of the average element content per sample.

Fig. 12 : Éléments signatures de l'or de Vondrona

Tableau 4 : Récapitulation des résultats d'analyse chimiques de l'or

échantillons	O	Al	Si	S	Ti	Va	Mg	Cr	P	Fe	Au
E1	40.16	1.56	0.75	0.057	21.91	0.5	0	0	0	1.7	33.33
E2	38.86	0.94	0.27	0	12.6	0.18	0	0	0	2.24	44.88
E3	48.8	13.8	13.51	0	1.28	0	0.13	0.18	0.3	1.96	20
MOY	42.61	5.44	4.84	0.019	11.93	0.23	0.043	0.06	0.1	1.97	32.74

Figure 13 shows the diagram of gold impurities in this gold panning site. The major elements in gold particles are oxygen O (42.61 at%), titanium Ti (11.93 at%), aluminum Al (5.44 at%) and silicon Si (4.84 at%).
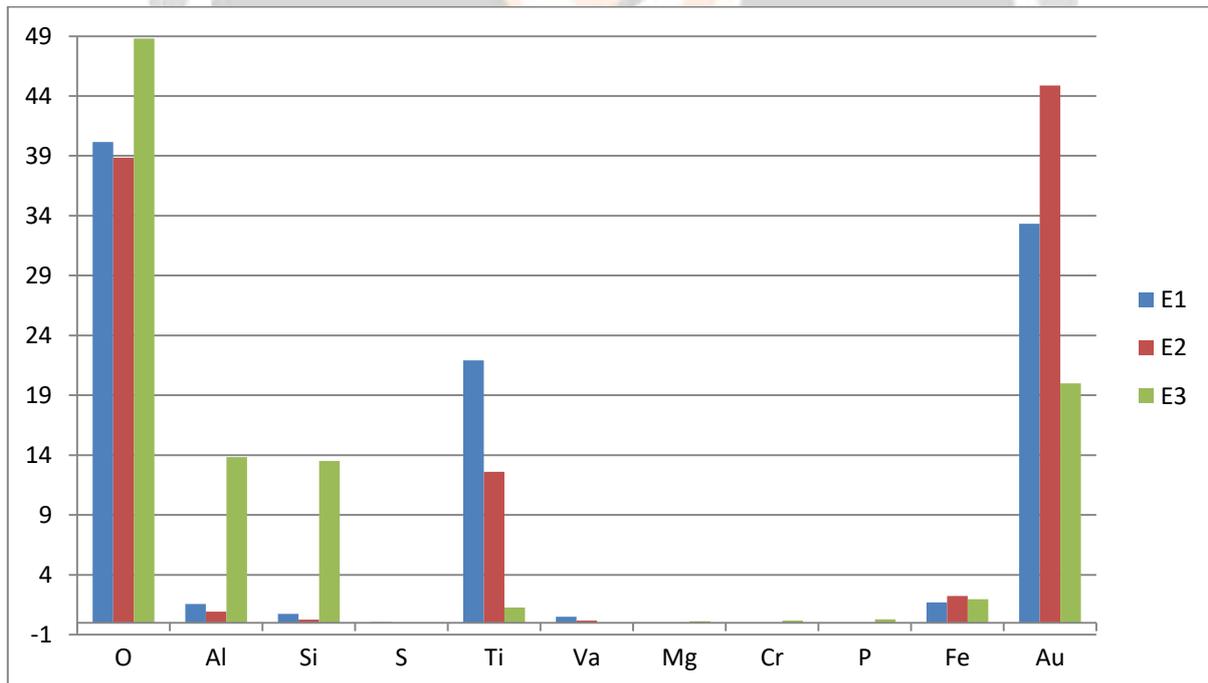

Fig. 13: Diagram of gold impurities from Vondrona (Madagascar)

CONCLUSION AND PERSPECTIVE

The Vondrona gold deposit is located in the Fokontany of Tratrambolo, Rural Commune of Miarinavaratra, and District of Fandriana in the Amoron'i Mania Region. The problem of this study is the ignorance of the chemical and morphoscopic characteristics of gold in this place, which are like the DNA (desoxybonucleic acid) of gold.

The theme entitled "Chemical characterization of gold from Miarinavaratra-Fandriana, south-central Madagascar, by the Scanning Electron Microscope (SEM)" is a modest contribution to the traceability of Madagascar's gold. The use of SEM microscope is a scientific opportunity for this research and which is not accessible at the laboratory level in Madagascar.

The gold particles in this deposit are accompanied by oxygen (O) with an average content of 42.61%; aluminum (Al) 5.44%; silicon (Si) 4.84%; titanium (Ti) 11.93%; vanadium (V) 0.23%; iron (Fe) 1.97%; magnesium (Mg) 0.43%; phosphorus; (P) 0.10%; and chromium (Cr) 0.06%.

This study is limited to the Miarinavaratra deposit. This subject is explored in depth for a doctoral thesis entitled "Analytical traceability of gold in the Fandriana District, south-central Madagascar" which deals with the physico-analytical characteristics of gold in nine (9) communes with fifty-four (54) gold particles studied.

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