Geological Situation of Tratramarina area : Mahanoro district

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ABSTRACT

Historically, the geological hypotheses advanced by H.Baiserie since 1970 and the cartographic renewal carried out by the Mineral Resources Governance Project (PGRM) in 2008 and in 2012since 1970 and the new cartographic survey made by the Mineral Resources Governance Project (PGRM) in 2008 and 2012 show that the Tratramarina area is covered with basalt flows. This basalt consists of a magmatic rock from a rapidly cooled lava, characterized by 50% plagioclases, 25-40% pyroxene, 10-25% olivine and 2-3% magnetite. On land it has a volcanic origin and consists of the main contents of the crust ocean. As for mining exploration in 2011 and the modern technologies used by SINBAD and UEM, the region has a strong iron mineralization due to the presence of magnetite quartzite.

Keywords*: iron, basalt, Magnetite quartzite, Tratramarina*

1-Introduction

Around 1970, Madagascar already had very accurate lithological maps, but without a structural approach. These maps were developed from various research works over several years.From 2003, various works were undertaken to update the geological infrastructure of Madagascar. The means implemented for this renewal of the infrastructure were cartographic and structural revision, remote sensing, airborne geophysics, geochronology, geochemistry, petrography and gitology. The major results obtained from this work:The new classification of the Malagasy crystalline basement, the new map at 1,000,000, 50 years after that of Besairie, the new architecture and geological history of the Precambrian basement and the new perspective in metallogeny and mining potential of Madagascar. To integrate in this geological context of Madagascar, the region of Tratramarina is located in a completely crystalline country of Precambrian formation separated into two series: Manampotsy and Nosivolo. To better understand the theme, we will first look at the geology of Madagascar since 1961 then we develop the geological situation in 2003 and 2012. Finally, we start the new UEM infrastructure in 2011.

2-Geology General

Like the neighboring islands of Mauritius, Reunion, Rodrigues and the Comoros, Madagascar is not the product of volcanic activity although volcanism is at the origin of certain attractions and curiosities such as the Amber Mountain, , the Ankaratra Massif and Lake Itasy.

From a geological point of view, Madagascar is considered a continental island which owes its formation to the

process of plate tectonics and continental drift. The theory of continental drift was developed by the German meteorologist Wegener at the beginning of the 20th century. Wegener had noted that the contours of the coasts of the South American continent marry those of the coasts of the African continent. from this observation was concluded the belonging of these two continents to a wider continent, the Gondwanaland, which detached itself from an original super continent pangea. The African continent, the island of Madagascar, the South American, Australian, Antarctic and Indian sub-continent as we know them today were all part of the same continent of Gondwanaland there are more than 200 millions of years ago (my) before our era. The African continent, the island of Madagascar, the South American continent, Australia, the Antarctic and the Indian subcontinent began to detach from gondwana land about 165 million years ago. Madagascar became definitely insular about 65 million years ago.

The 2/3 of Madagascar, mainly the eastern part of the island extending from north to south through the highlands of the center of the island, are formed by crystalline basement formations consisting mainly of metamorphic rocks, the The remaining 1/3 consists of sedimentary formations and occupies the west coast of the island from north to south: volcanic and basaltic intrusive formations complete the geological formations and appeared as well at sea to form the island of Nosy be, in central regions as in the north and south of Madagascar. Each of these geological formations are at the origin of the mineralogical, fossiliferous and certainly oil richness of the subsoil of Madagascar.Among the mineral resources of Madagascar, we can classify as follows:

-the precious metals: gold, platinum, silver, ...;

- precious stones and ornamental stones: quartz, beryl, sapphire, emerald, tourmaline, garnet, Sapphire,ruby,...;

-Metals:copper,Lead,Zinc,Iron, Mercury,Chromium,….;

-Radioactive minerals: Uranium, thorium,Cerium,….;

-mica:muscovite,phlogopite

-industrial minerals: graphite, corundum,...;

-Salt and various products: salt, phosphate of lime, potash,sulfur,...;

-the building materials and various: clay, kaolin, gypsum,slate,...

-hydrocarbons: oil, sandstone, bitumen, heavy oil; coal and fossil fuels: coal, lignite, peat.

Madagascar is constituted for the eastern two-thirds of its surface by Precambrian crystalline schists with various eruptive rocks constituting the crystalline basement, and for the western thirds remaining, by sedimentary rocks, which hang slightly to the west and which have deposited almost continuously since the end of theCarboniferous to the present. Its geology consists of Archaean rocks. These justify the pre-Gondwana affiliation of Madagascar with Africa and India. Thus, according to the study made, it is the result of rifting supercontinent Gondwana that occurred during the Jurassic and Cretaceous. The Tratramarina-Mahanoro iron indices are on the crystalline base which is interpreted and commented by many authors.

3-Besairie Henri Hypothesis

For Bésairie (1961), the crystalline basement is like a sedimentary pile taken up by metamorphism, of Precambrian age. Generally, the main rocks encountered are metamorphic rocks, granitic and sometimes volcanic intrusions. He classified it in series, group and system according to the characteristics of the rocks encountered. Thus, he was able to distinguish four major systems, the two oldest of which are the Androyen and Antongilian system, then the graphite system and finally the Vohibory system [**01].**

4-Collins and Windlley

According to the Collins and Windley hypothesis (2003), the Malagasy crystalline basement is like a set shaped by successive tectono-metamorphic events composed of nine units (Fig 1). These are also classified into two groups according to their age of formation:

Archean Age: Antongil unit,Antananarivo unit, Betsimisaraka unit and Tsaratanana unit.

Proterozoic Age: Itremo unit, Ikalamavony unit, Taolagnaro-Ampanihy unit, Vohibory unit and Bemarivo Unit.

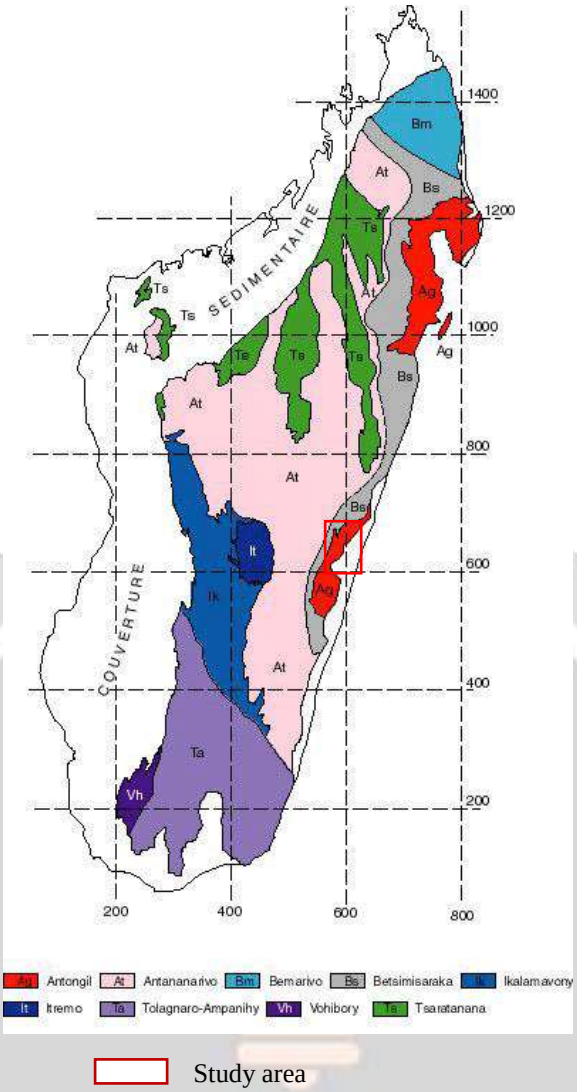

Fig 1: Geological map by Windley and al (2003)

5-Foucault A. and Raoult F.

At the local level, the iron ore zones of Tratramarina-Mahanoro are found in the Nosivolo series, according to the Bésairie nomenclature.
But referring to the Collins and Windley hypothesis, the mineralized zone is in the Betsimisaraka unit.
According to the hypothesis of Foucaul.A in 1975, the Nosivolo series is characterized by micaschists with muscovite, with intercalations of schools of micaceous quartzites and amphibolites. The micaschists are very flaky and wrinkled, often mineralized in pale pink garnet and distenes. They are traversed by numerous pegmatitic veins injected with quartzo-feldspath beds and quartz lenses.
At the extreme south-west of the studied field, they pass to green chloritoschists. Quartzites, which can be followed continuously for tens of kilometers, are white rocks. They are coarse grained and characterized by muscovite beds. This formation may be associated with green mica quartzites, which seem to border the Manampotsy migmatites in the East, parallel to the coast. Amphibolites, Finally, form very powerful benches intercalated in micaschists. They are feldspathic amphibolites with hornblende, sometimes with garnet.

6-Gouvernment Project PGRM in 2008

The study area is located in an entirely crystalline country of Precambrian formation, mainly Archaean in age above 2600 ma. It is very deformed and metamorphosed as a result of a complex geological history that ended with the Panafrican event, from 600 to 500 ma. This old Precambrian base can be divided into two series: Manampotsy and Nosivolo.

The Manampotsy series is essentially characterized by the presence of graphite; the host rock is an amphibole migmatite, with numerous magnetite quartzite beds, pyroxenites, tremolite, peridotites, a cipolin bank. The series Nosivolo, which extends south and east of the previous, is formed mainly mica schists in the first. The Manampotsy series is further affected by migmatization and granitization, which has, among other things, produced granitoid garnetites with garnet and amphibole of the Brickaville type. Like most of the coastal zone, the area is made up of recent sedimentary formation.A thicker lateritic cover extends over the crystalline terrain, masking the outcrops.

6.1 Lithology

The lithology deals with the genesis of the rock, its mineralogical composition, its texture (arrangement of the minerals determined by their size and by their shape), its chemical physic properties and its internal structure (overall architecture, cohesion, mineral cementation, ...). The combination of these various elements makes it possible to distinguish a wide range of geological structures (massive structures, crystalline, sedimentary, shale, carnation, bedded, porous, coherent, furniture, ...). In this part, various geological formations have been studied, in reverse chronological order, from the most recent to the oldest: recent formation; eruptive rock and crystalline schists.

6.2 Recent Formation

6.2.1 Sedimentary Formation

They are located parallel to and near the coast, most often in a swampy area from which they emerge as rounded mounds. They are variegated clays, with sandstone benches and siliceous concretions, subhorizontal dips. In at least two places, these clays contain calcareous lenses (Mahanoro, Betsizaraina) rather thick, but of weak extension, whose exploitation would be interesting for the lime. These limestones and their clays provided a bivalve fauna, and are dated to the Late Cretaceous, by analogy with the formation studied further south.

6.2.2 Eruptive rocks

They are marked by vein intrusions or massive, rocks with different facies. We must distinguish on the one hand the gabbros and dolerites, on the one hand the recent acidic and basic volcanic rocks, numerous especially on the coast.

6.2.3 Gabbros and dolerites

The gabbros encountered are of two petrographic types, which correspond to two types of deposits. We have, in this respect, been led to modify the previous surveys of J. GUIGUES, the vein origin of most of these rocks having been recognized in several places in the field. The first type is a gabbro franc, with a granular structure, labrador violet, olivine and hypersthene, already metamorphosed, which presents itself in small intrusive massifs crossing the migmatites of the Manampotsy in the South-West of Manjakandriana, the second type corresponds to dolerites and gabbros doleritic, called dolerites, with a constantly doleritic structure. Whatever the size of the grain, there are very fine grain varieties, other porphyroids.
These rocks have a vein deposit and are distributed throughout the study area, from the coast to an approximate line Saivaza-Ambinanidilana-Nosivolo.
They meet everywhere in the form of rounded blocks in the laterite and chaos in the bed of torrents.

6.3 Volcanic Rocks

Volcanic rocks, basalt rhyolites, occur as veins in the hinterland and in the Lower Mangoro region. In the hinterland (migmatites of the Manampotsy, micaschists of the Nosivolo), the basaltic veins are very abundant, the rhyolitic and trachytic veins less frequent; they cross indifferently all the crystalline schists
Basalts are black or bluish, with very fine grain, usually without olivine; the rhyolites are most often decomposed into white clays with a conserved structure.
The region of Lower Mangoro has a very varied facies of volcanic series, from rhyolites to basalts, through trachytes, rocks with pearlitic structure; the presence in the laterite of tufa-like puffy rocks suggests that there was a phase of volcanic effusions. The study of alluvial rocks in the region, however, allowed us to find elements of the crystalline basement (quartz, green hornblende, garnet), which is nowhere visible in outcrops.

The veins of the region are of low power which vary up to 10 meters' maximum like the rhyolite on the road of Marolambo.
Their two sheaths are often visible in the laterite. The average orientation of these veins is N30 ° East, their abundance and variety are much greater south of lower Mangoro than north, where a large lateritic zone, then marshy, masks the contours of this area and its relationships with the base. It is in these basaltic veins of the coast that samples were taken for the study of paleomagnetism. They can be dated to the Upper Cretaceous.

6.4 Crystalline schists

The crystalline schists form the major part of the studied lands, and consist mainly of more or less migmatitic gneisses. Their mineralogical composition and structure result not only from regional metamorphism, but also from contact metamorphism due to magmatic intrusions. They include metamorphic formations with mica, garnet, amphibole, sillimanite, cordierite, kyanite, chromium, platinum, nickel, graphite and corundum.
The observed geological successions show migmatites at the base, followed by metamorphic series which are generally the graphite series of Manampotsy and the micaschist and chloritoschist series of Nosivolo.

6.5 Magmatic Series

The schistose migmatites constitute a well individualized group. These are bed-by-bed injection gneisses in which the essentially feldspathic supply is clearly visible macroscopically in the form of massive micro-clinical beds or large pegmatitic or aplitic veinlets. Migmatitic formations locally contain metamorphic schools and septa that have escaped migmatization. the migmatites associated with quartzo-feldspathic gneiss with more or less hornblende biotite constitute the central eastern part of the studied leaf Amphibole migmatites are well presented throughout the Manampotsy group.
Sometimes schistose, sometimes gneissic, they form large horizontal stretches at the edge and in the bed of many rivers: the Vatana, the vintanona and the Manandra west of Befoza especially. To the west of Ambalavato, they have a much more homogeneous and regular appearance (West of Antanandehibe).

6.6 Metamorphic Series

The complete series can be divided into two groups: micaschists and gneiss groups
This group includes the following rocks: micaschists, quartzites,amphibolites.
The micaschists, generally biotite or dominant and accompanied by muscovite, are particularly well exposed in the north of the series, on the north shore of Mangoro; they also made it possible to draw here the limit with the Manampotsy. They contain locally garnet, graphite, sillimanite and corundum. Often poor in quartz, these micashists contain biotites and sillimanites; they are often feldspathic(oligoclase).Quarzites are very numerous, but usually low-power lenses. All these quartzites are metamorphosed sandstones of metamorphic intensity, usually mesozone. The different types are: fine-grained quartzite, often with migmatite; graphite quartzite; calcium and magnesium mineral quartzites (garnets and pyroxenes). Quartzites are formed in Andrajery and many anticlinal or synclinal accidents occur between Saivaza and Ambalavato; magnetite quartzites are also common in Andovolalina. Amphibolites are generally feldspathic and foliated. They do not form large banks in the Manampotsy group. They occur either as feldspathic amphibolites or as amphibolites consisting solely of green hornblende and a little quartz, in the region of Ampasimazava on Vintanona, Famoa, Ambatofotsy, Antanandehibe and Ampitabe.

6.6.1 Gneiss Group

The rocks grouped under the name of gneiss consist essentially of quartz, acidic plagioclase of the albite-oligoclase type, biotite and incidentally hornblende, garnet, sillimanite, magnetite and alteration minerals. The vast majority of these gneisses have undergone very intense deformations as evidenced by a constant cataclastic structure, more or less pronounced. These gneisses usually have a clear stratification due to alternating micaceous beds and mica-free beds. What brings them morphologically closer, on the one hand feldspathic micashists, on the other hand schistose migmatites finely injected bed by bed.
Among the gneisses found in the region, two types were distinguished:Sillimanite gneiss and graphite gneiss.

6.6.2 stratigraphy

The study area is marked by the graphite series of Manampotsy and the micaschist series and chloritoshists ofNosivolo.

Graphite series of Manampotsy

This series is characterized by the presence of many graphitic levels that have been mapped; the dominant rock is a migmatitic gneiss with biotite and amphibole. In some places there are true feldspathic hornblende amphibolites, which can be individualized by sillimanite and garnet levels. Some migmatite beds are more granitized than others, and they often occur in foliated migmatitic granite with amphibole. In these migmatites, there are numerous dark quartzite beds, rich in magnetite. Only one outcrop of cipolin, known for a long time, has been recognized as forming the picturesque natural bridge of Antetezantany, east of Sahasomana (Saivaza region); it is a blue cipolin, largely crystallized, partly cleared by erosion, and forming a vault on the Manandra, supported in its middle by a basaltic pile. Other petrographic facies encountered in this series include pyroxenite, peridotite, tremolite and some soapstones.

Series micaschists and chloritoshists Nosivolo

South of Mangoro and its tributary Nosivolo, extends a thick series of different facies and structures such as muscovite micashists, interspersed with beds of micaceous quartzites and amphibolites. The micaschists are very flaky and pleated, often mineralized in pale pink garnet and disthenes. They are traversed by numerous pegmatitic veins and injected with quartzo-feldspathic beds and quartz lenses of exudation.At the extreme west of the studied field, they pass to green chloritoshists. Quartzites are white, coarse-grained rocks with muscovite beds and may be in the form of continuous shoals for about ten kilometers. It could be related to this formation the green mica quartzites which seem to border the migmatites of Manampotsy in the East, parallel to the coast.

Amphibolites, finally, form very powerful benches intercalated in micaschists. They are feldspathic amphibolites with hornblende, sometimes with garnet. This series of Nosivolo is in contact with that of Manampotsy, along the Mangoro, by layers of direction East-West 50 ° to 60 ° North; if the set was in normal superposition, it would imply for the Nosivolo series an age older than the Manampotsy. But there seems to be an inverted contact there because, in the northern boundary of the Mahanoro leaf, the Nosivolo comes into contact with a group reported by G.NOIZET to the Superior Manampotsy. There is no doubt, however, that the Nosivolo series connects directly to the Southwest with the Maha series of the Vohibory system.

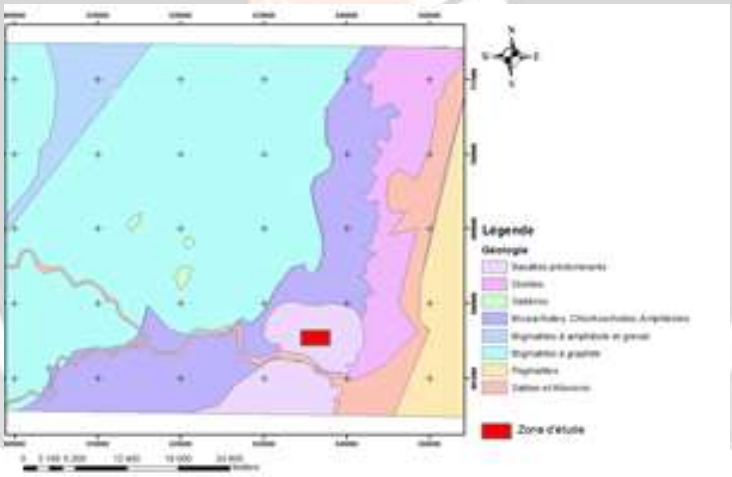

Fig. 2: ST49 Antanandehibe-Mahanoro geological map

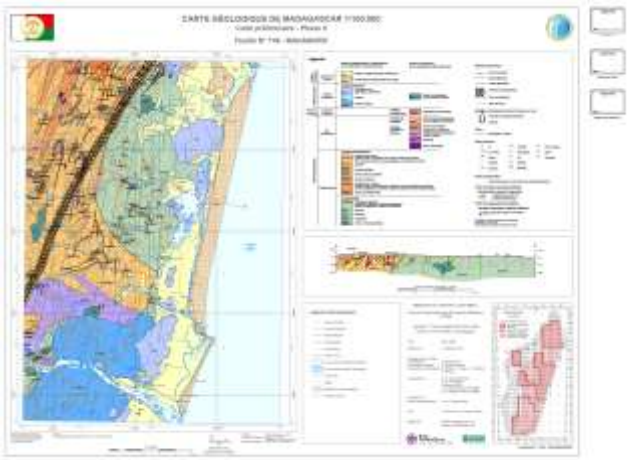

Fig.3: Geological map revised by World Bank (PGRM)

7- SINBAD and UEM, 2011 to the present

According to UEM studies, the iron mineralization is formed by layers of magnetite quartzite. The study is based on the analysis of a thin plate at the quartzite and magnetite laboratory. Due to the more advanced alteration of magnetite, hematite is abundant. Sometimes the hematite is in the form of secularity. Depending on the structure of the rock and the size of the grains, three types of mineralized rock can be distinguished:

• Fine-grained rock where the magnetite appears in grains arranged according to the schistosity plane, without forming continuous stratifications.

• Fine-grained rock where the magnetite alternates with a thin layer of quartz and forms a continuous stratification. this second type is called banded iron formation (BIF). This rock is of Archean age meta sedimentary origin.

• Coarse-grained rock where millimetric millimetric-sized magnetite crystals are arranged in the schistosity plane without forming a continuous overlay

On the surface, magnetite quartzites are often weathered and friable. However, they become hard and compact in depth (15 to 20 meters).

The layers carrying the iron mineralization are classified in three categories according to the characteristics of the quartzites encountered: the first class of black color formed of Quartzite with magnetite and little shale band; the second is a dark gray color consisting of a moderately magnetite-quartzite band and the last class is lightly gray in color with magnetite-quartzite bands. Other non-mineralized rocks found in the area are gabbros, dolerites (part southeast), granites, gneissic granite, dacites and quartzites.

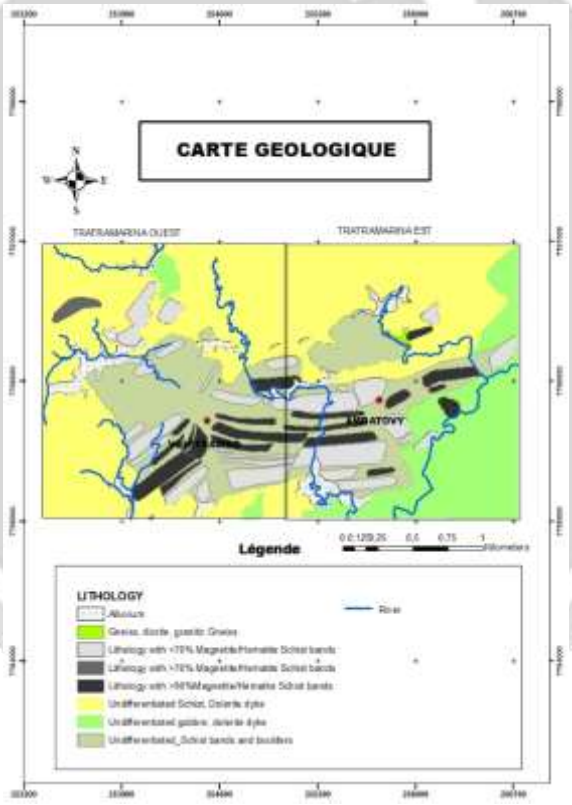

Fig 4: Geological map revised by UEM,2011

8- Conclusion

Geology is a science that is evolving, but since Bésairie until the recent work done by the PGRM, the iron mineralization is located in a basaltic formation in the T49 Mahanoro zone

Apparently, the iron mineralization is not indicated in the maps.From 1959, many geological maps on Mahanoro have been published by the Geological Service of Madagascar. Unfortunately, none show the existence of iron ore in the region. As for the arrival of the EMU in 2011, this iron mineralization has been reported in

mineralized layers more precisely of magnetite quartzite thanks to petrographic, mineralogical, geochemical and structural studies and also rocks in outcrop.

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