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CHARACTERISATION OF SEPTARIAS IN THE TATAO-AMBONDROMAMY REGION OF MADAGASCAR

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SUMMARY

Tatao area, localised at the northwest of Madagascar near by Ambondromamy is known for it's richness in septarian concretion deposits. Those septarian nodules are much admired by lithotherapy enthusiasts and collectors while geological concept about genesis of this sedimentary rocks is musenderstood. Analysing deposits in Tatao area helps to improve geodynamical knowledge of Mahajanga basin and can be used as a model of global warming effect and intense evaporation inside of lagoon.

Field observation, thin sections were therefore carried out to try understanding the origin mechanisms likely to play a role in the phenomena that lead to the diversity of coloration, size, and types of septaria.

The origin of the color diversification of calcites (yellow, brown, milky white, grey, black) can be interpreted as a different episode of crystallizations as well as different liquids origin. As for the size and shape of septaria, they are generally conditioned by the lithological nature, the conditions of sedimentary deposit and above all, by tectonics.

KEY WORDS: color, evaporation, genesis, lithotherapy, mechanism, septaria, shape,size

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1- INTRODUCTION

Septaria are classed as an industrial and collector's stones. Used mainly in decoration and lithotherapy, even the grammatical gender of the name "septaria" is undefined and supposed to be neuter. The origin of septaria is still misunderstood; the most common explanation is that the septarian concretions formed near by the sediment-water interface [1] and the cracks in septaria are the result of traction during rapid burial [2] [3].

The best-known deposits in the world are in England, Morocco, Utah in the United States and Madagascar; those in Madagascar are very popular and come from the town of Ambondromamy. Despite the work of Henri Besairie [4] on the geology of the Mahajanga basin, and the reports of the SPM (Société Pétrolière de Madagascar) in 1950, no mention is made in those works about the origin of septaria nodules or of the joint presence of marl and septaria in this Tatao zone. Although the septarias of this region are highly prized for their beautiful colors and patterns, their origins and chemical compositions are still unclear.

The objectives of this project are therefore to identify the mechanisms likely to play a role in the phenomena that have led to the diversity of coloration, size and types of septaria, and to attempt to quantify the importance of these mechanisms. The results will contribute to a better understanding of the geodynamics and sedimentology of this part of the Mahajanga basin and will help to enhance the value of septaria mining. Preliminary results from field and laboratory work are discussed in this article to shed some light on the subject.

2- METHODS

The Tatao area is located around ten kilometers north-west of the town of Ambondromamy *(Figure 1)*, It has been long and used to collect gypsum for various companies, as well as Septaria for craftsmen and collectors. Small-scale farmers working with traditional equipment have been digging wells in this area for a long time.

It is an extension of the Ankara Basin, with NW direction almost, bordered by the Ambondromamy fault to the east and the Ankarafantsika Horst to the west.

In this area, the Upper Jurassic [4] is predominantly marine, with a few lagoonal episodes, whereas a few kilometers further south, the Jurassic is clearly continental. The facies recognized in the Tatao area are varied, but the presence of marl-clay levels often interspersed with fibrous or spearhead gypsum and septarias clearly marks the end of the Jurassic. This area is essentially covered by jujube forest *(Figure 3).*

The methods adopted combine those used by field geologists, sedimentologists, and paleontologists.

2.1. Field observations and data acquisition:

Field work was focused on observing the shapes and sizes of septaria, the different types of lithological layers and the relation of the position of septaria with the various adjacent layers. It was about exploring wells, make lithological cross-sections and make sampling. Samples were taken for each variation of color, lithology and texture along the wells.

Samples of septaria nodules, were selected based on differences in color, geometric shape and, above all, the variety of fissure shapes.

The presence or absence of fossils was carefully noted.

2.2. Thin section:

The choice of section is focused on the difference of color, and so as to have blades showing the progressive passage of the marl/limestone assembly. A glue bath with an epoxy resin mixed with a hardener for 48 hours was necessary before any cutting and polishing operations. As for observation, two polarising microscopes (Axioscop ZEISS and WETZLAR V300) were used to obtain two different fields of vision. Folk's 1950[5] classification of crystal size based on the length/width ratio was used [6].

3- RESULTS

3.1. Lithology and cross-section:

Generally rectangular in shape, sometimes circular; the depth of the well varies from three to around ten meters. Observation and analysis of samples revealed alternating layers of marly clay and argillaceous marl with intercalation of thin, fibrous gypsum *(Figure 4)*. Septaria were found at depths of 3 to 4, 7 and more than 12 meters, with nodules grouped or isolated in the marl layers. But to the south-west of Tsaramandroso, nearby Amboazango village, septaria outcrop directly on the surface along the entire side of a hill *(Figure 5)*.

On the north-eastern side of Tatao (X :480251 et Y :10772392), near by the National Road No. 6, a layer of very fossiliferous limestone was revealed, then the facies changed completely to terrigenous detrital sediments composed mainly of quartz.

Determination of the faunal association revealed that ammonite fossils (varying in size from around 0.5 to 40 cm), belemnites and lamellibranches are very common. These fossils were found in the sediments and sometimes preserved in septaria nodules.

3.2. Septaria nodules

A wide variety of colors, generally a greyish mass with black, yellow, milky white, bluish grey or brown calcite crystals inside, the septaria of the Tatao region are fascinating. A variety of geometric shapes have been recorded: spherical *(figure 6A)*; sub-spherical or oval *(figure6B)*; and the most common are irregular, slightly elongated,mamillated or flattened *(figure 7A,7B, 7C)*. Their size varies from 4 to 40 cm in diameter, and the elongated irregulars can reach around 60 cm in length. Septaria nodules look like geodes with small, well-crystallized crystals; some looks like poudingues, most often with large crystals *(figure 8)* and others appear as a concretion around a core *(figure 9)*.

The presence of cracks filled with calcite crystals is also a specific feature of the Tatao septarias. Three very distinct types are observed: rectilinear cracks pointing in the same direction *(figure 17)*, hexagonal cracks *(figure 18)* and irregular cracks that do not have a specific direction *(figure 19)*.

3.3. Microscopic analysis:

Polarizing microscope observation (under analyzed and unanalyzed polarized light) revealed several characteristics:

The marl is observed as a brown mass under polarized light *(figure 10)*, with no crystals except for a few opaque crystals. Calcite, is characterized by a grey hue and low relief [7].

The textures and patterns of the various calcite crystals in contact with the marl towards the interior of the fractures are well defined, aligned and regular, forming very distinct colored bands *(figure 11)*. Fibrous, then bladed and sometimes blocky *(figure 12 et 13)*, according to Folk's 1950 chart. Some calcite crystals represented thin twins (type I: linear and parallel) *(figure14)*.

The cracks can take different shapes and orientations: some have a rectilinear and very fine appearance; others are wider with curvatures. Ramifications and intersections *(figure 15 et 16)* of cracks have created patterns and structures within the septaria.

Microfossils were also observed, notably foraminifera and ammonites, but species identification is difficult on thin sections. Only the foraminiferal genus Astacolus sp. could be determined *(Figure 10)*.

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4- DISCUSSION

The assemblage of marly clay, fibrous gypsum and marine fossils is typical of lagoon environments. The conditions of deposition are often related to climate, temperature, depth and particle size.

Marls are made up of fine particles, particularly clay and limestone, while gypsum is generally formed in arid or semi-arid climates, by the evaporation of salt water in lagoons or salt lakes. The succession of clayey marl, marly clay and laminated gypsum can provide information about temperature variation, above all, an idea of the variation in sea level at the time of deposition.

Septaria nodules, isolated or grouped in layers of clayey marl, mean that the calcareous mud that formed the septaria was deposited at the same time as the layers of clayey marl. The geometric shape of the septaria can be interpreted as the result of rolling or due to mudflows deposition which then evolved: either flattened because of the sedimentary overload.

This is followed by an early stage of diagenesis, involving the compaction of mud and the expulsion of interstitial water, which causes cracks to form within the nodules, giving rise to irregular fissures. The formation of cracks or cracking allows the circulation and precipitation of fluids along these fractures. Rectilinear and parallel cracks and thin twins deformation in calcites are of tectonic origin, more precisely resulting from an extensional event, while hexagonal cracks are similar to desiccation cracks. The cracks inside septaria nodules also create a space, which calcite crystals crystallize and form septaria geodes.

The distribution of septaria nodules is conditioned by the depth of the water at the time of deposit, but also by tectonic activity, which can expose them at the surface.

Seen in a thin section, intersection of cracks means different cracking phases and also different crystallization phases of calcite *(figure 16)*.

The fibrous, bladed, and blocky appearance of calcite crystals in thin sections is the result of different crystallization phases, from the outside to the inside of the cracks, the sense of mineral growth is shown by the yellow pointer on figure 11. Fibrous crystals crystallize first, then bladed crystals and finally blocky crystals *(figure 12 et 13)*. Previous studies have shown that the shape of calcite crystals can provide information about the origin of liquids; but at this preliminary stage of research, making any statements about the origin and nature of liquids would be speculative. However, the fact that the calcite crystals are of different colors suggests that the liquids have different chemical compositions and origins.

The chemical and isotopic analyses of septaria from the Tatao region are therefore new avenues of research that could shed light on the origin of the color variation in these septaria.

5- CONCLUSION

An alternation of clayey marl and marly clay with intercalation of fibrous gypsum and septaria nodules defines the lithology in the Tatao region.

The work focused on observing the different types of septaria nodules both visually and microscopically. Details of the geometric shape of septaria, the shape and structures of cracks, the color of calcite, arrangement and crystals shape in thin sections were examined.

The results helped to confirm that:

- Gypsium presence is the result of global warming effect and intense evaporation during pendant late Jurassic an early Cretaceous period ;
- Deposition conditions and post-depositional deformation conditioned the geometric shapes of the septaria;
- Cracks are the result of compaction and sometimes tectonics.
- The filling of cracks by calcite is the result of fluid circulation during and after diagenesis.
- The crystallization of calcite crystals along the fissures took place in different stages.

Chemical and origin of the liquids responsible for the color differentiation of the calcites could not be discussed and could be the subject of a future study.

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- Professeur Aurélien Jacques Mandimbiharison, « génie géologique » department, Polytechnical University of Antananarivo.
- Local authority and guides of tatao area.

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7- FIGURES

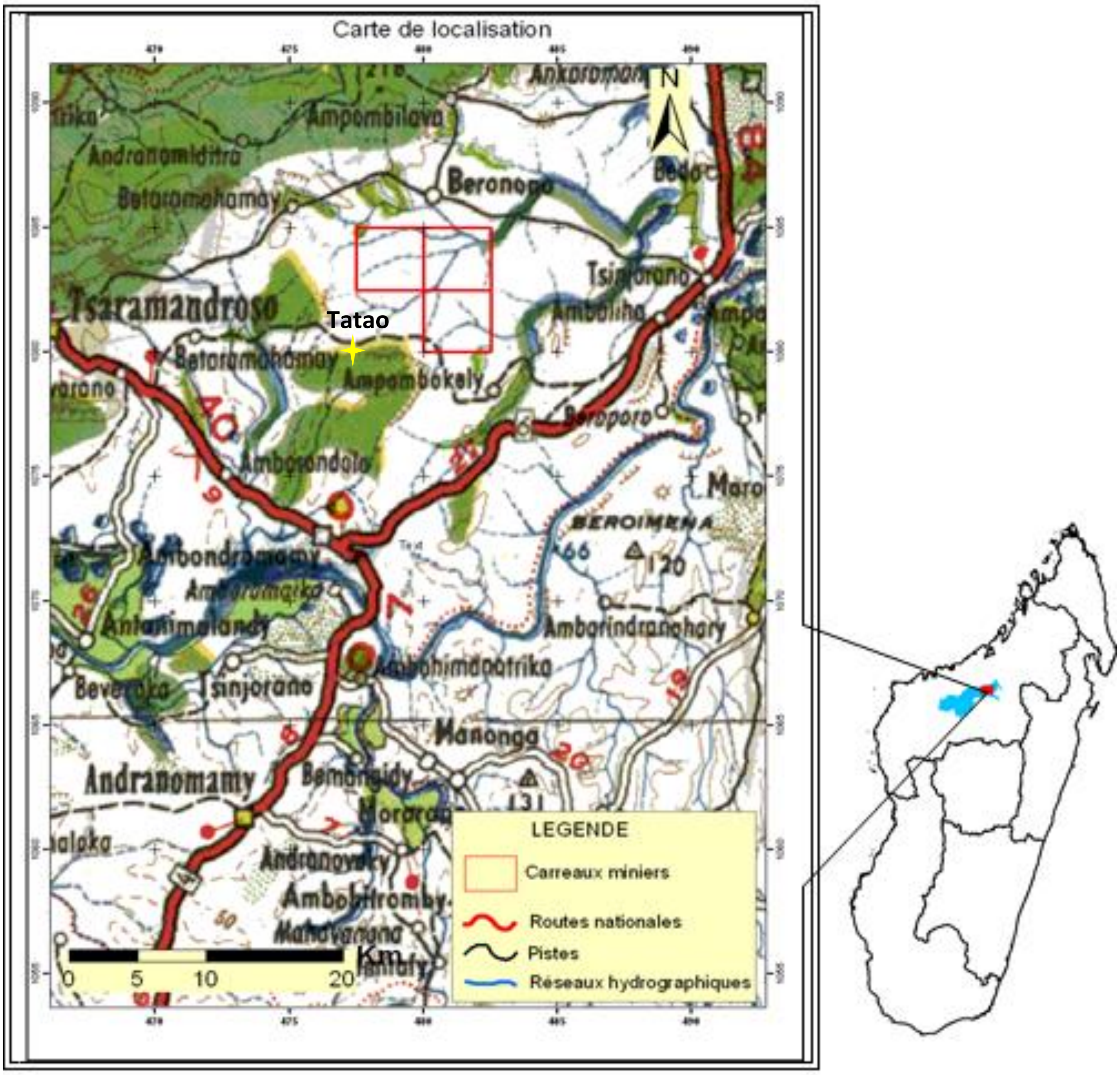

Figure 1: Modified Topography map of Ambondromamy Area

(Source : MANDIMBIHARISON, 2011)

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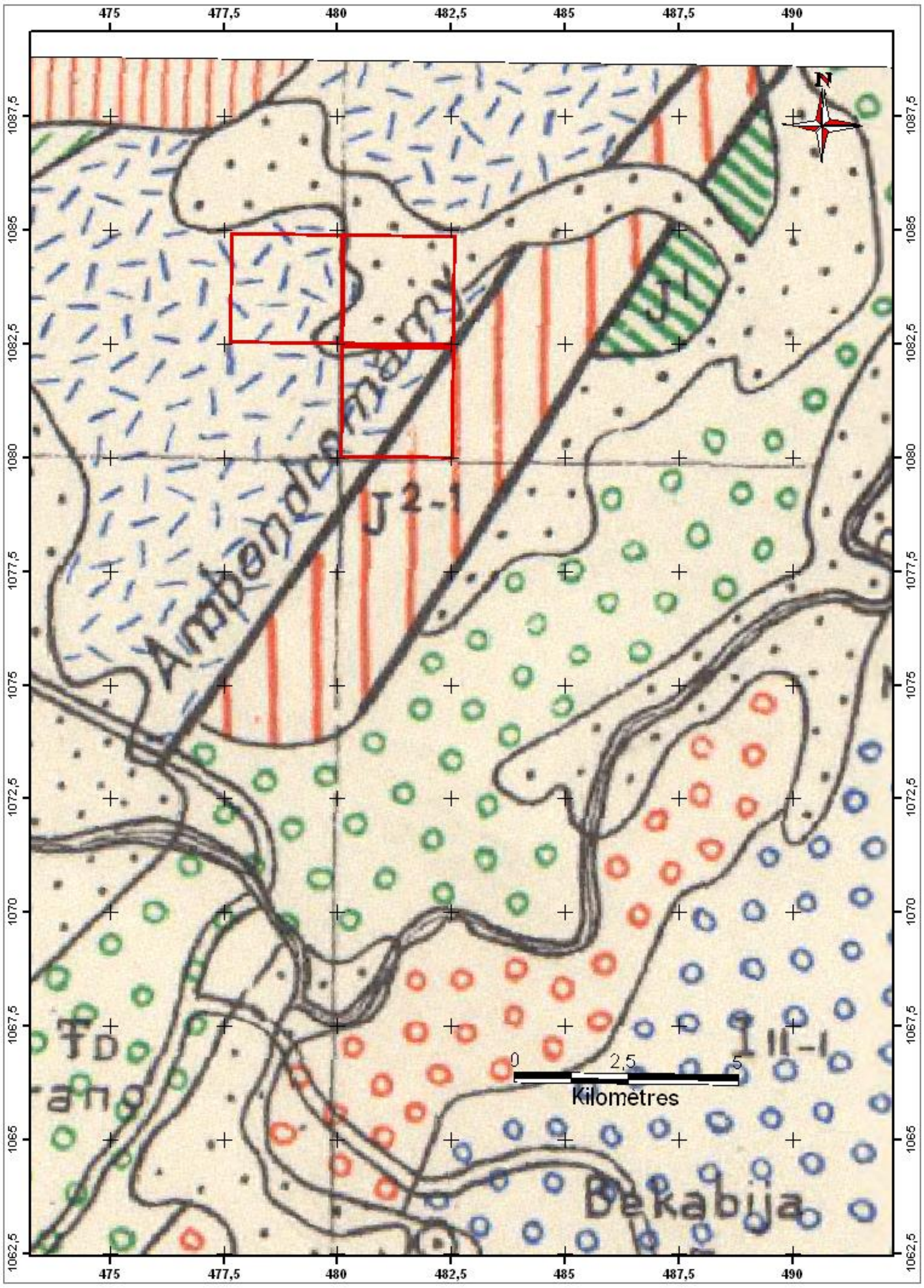

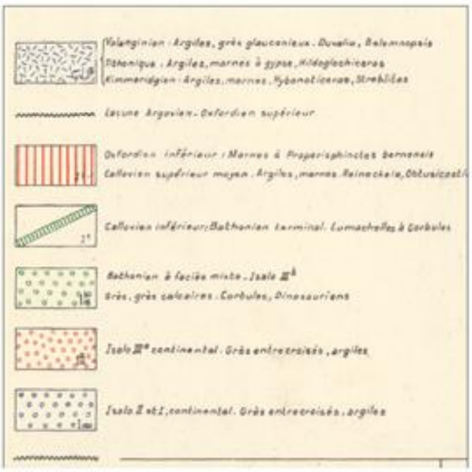

Figure 2 : Modified Geologycal map of Ambondromamy Area

(source : MANDIMBIHARISON, 2011)

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Figure 3 : Global view of the Ankara depression

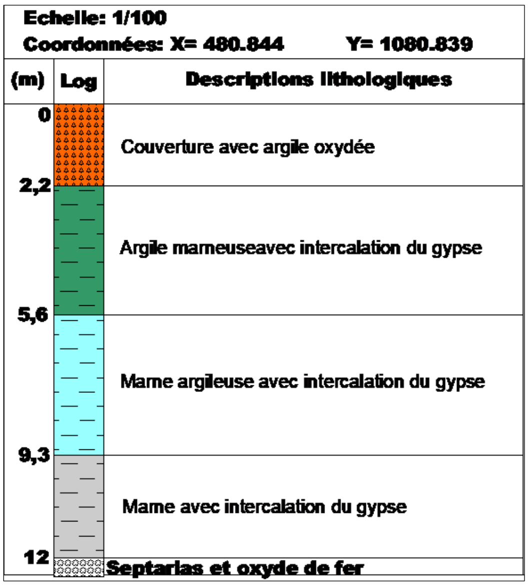

Figure 4 : log lithology types (P1)

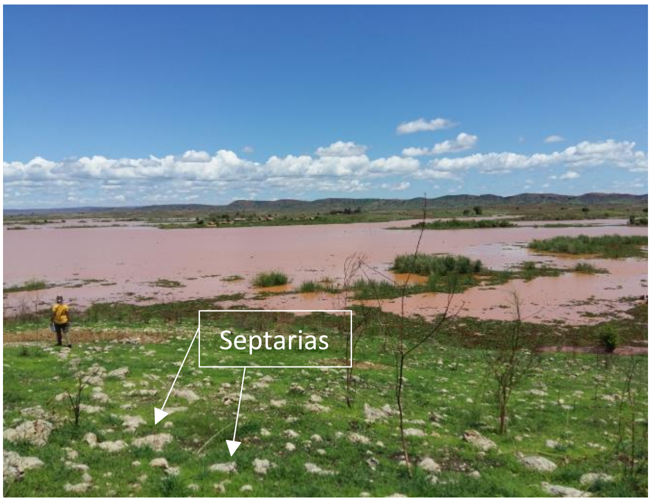

Figure 5: Septaria exposed by erosion

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Figure 6 A : spherical septaria

Figure 6B : oval septaria

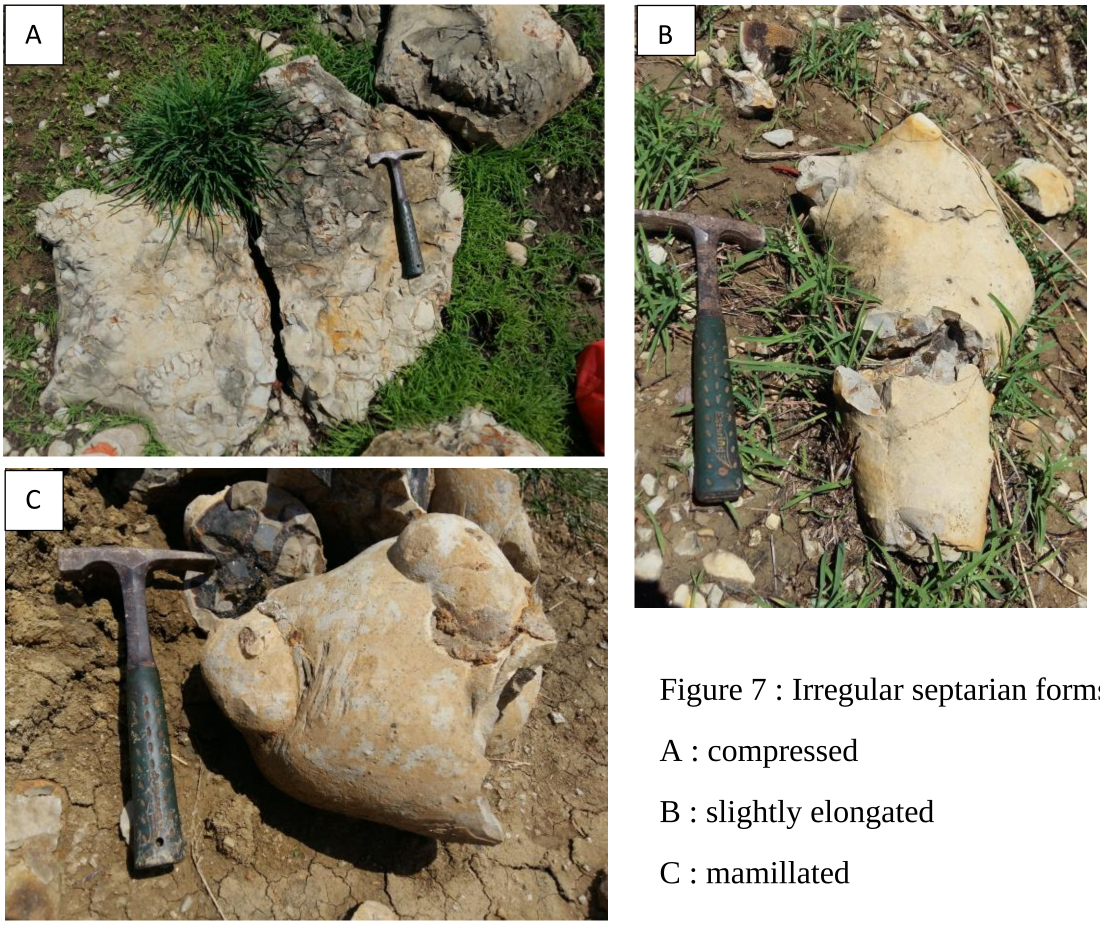

Figure 7 : Irregular septarian forms

A : compressed

B : slightly elongated

C : mamillated

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Figure 8 : Septaria poudingue

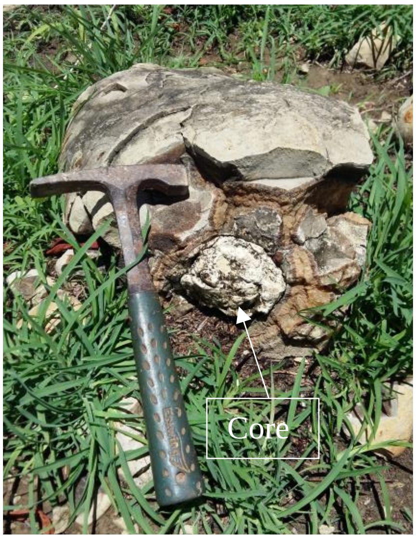

Figure 9 : Concretion around a core or nucleus

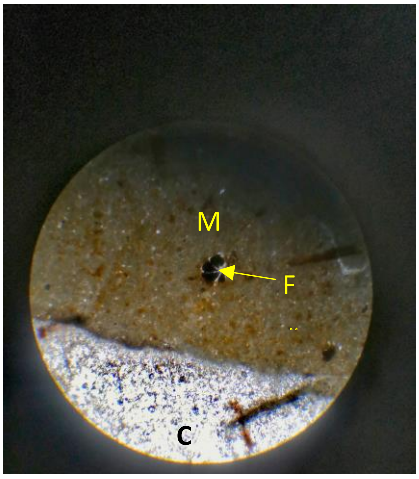

Figure 10 : Polarised microsop view (LPA) magnification 4 : M (marl brown) F (Fossil, *Astracolus sp) C : Calcite*

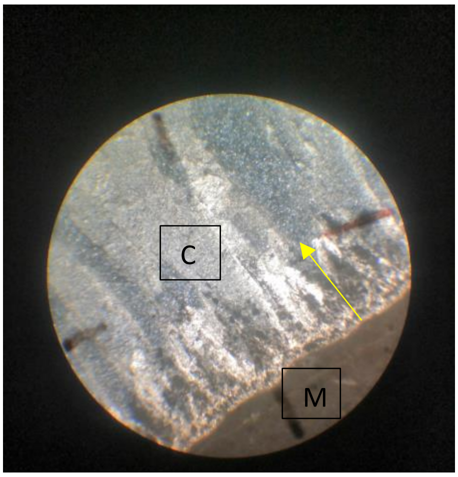

Figure 11 : calcite crystal as linear regular bands C : Calcite, M : Marl (LPA,*4).Figure showing mineral growth sense (yellow arrow)

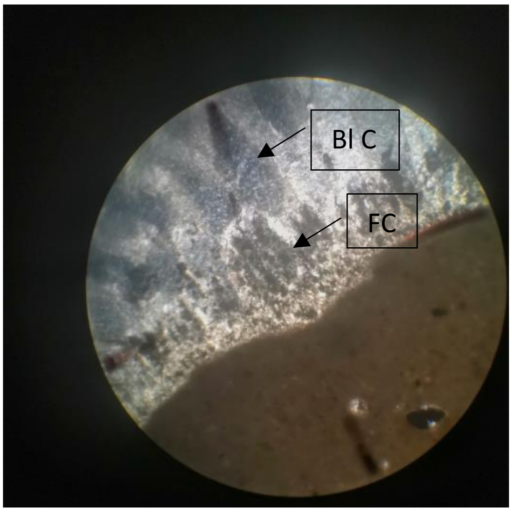

Figure 12 :Different types of crystals Calcite : Bl C Bladed calcite, CF Fibrous Calcite

(LPA,*4)

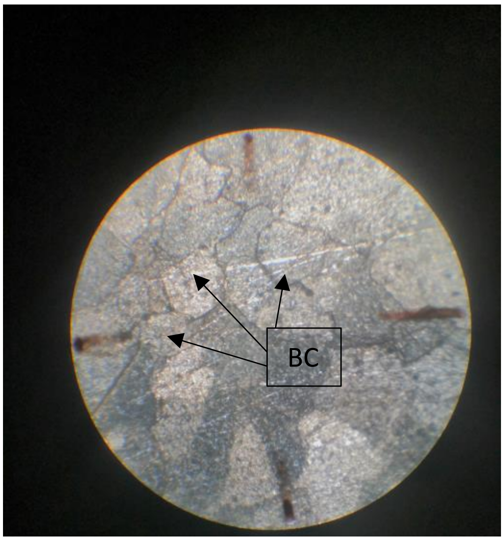

Figure 13 : blocky calcite (BC)

(LPA,*4)

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Figure 14 : thin twins type I

(LPA,*4)

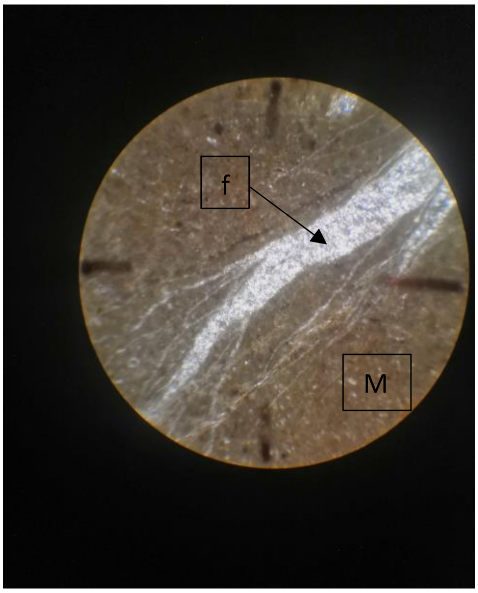

Figure 15 : Ramification of ckracks (f) ,marl (M)

(LPA,*4)

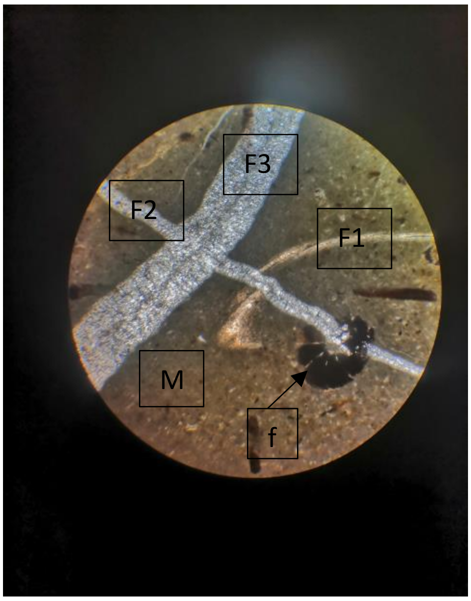

Figure 16 : Figure showing three generation of Crack : F1, F2 et F3 intersection of those cracks is an indice of timing ; F2 cut F1 means that F2 is younger than F1; Same for F2 and F3

f :fossil seems affected by F2

(Sous LPA, *4)

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Figure 17 : Linear crack filling by black crystal calcite

Figure 18 : hexagonal cracks filling by brown and white crystal calcite

Figure 19 : Irregular Crack filling by brown and white calcite