Libyan Journal of Science & Technology 9:1 (2019) 98–101
The 2nd International Conference on Geosciences of Libya-GeoLibya 2 (2017), 14-16 October 2017, Benghazi-Libya

Faculty of Science - University of Benghazi
Libyan Journal of Science & Technology
journal home page: www.sc.uob.edu.ly/pages/page/77

Description and characteristics of chert nodules in Appollonia Formation, Al Hmmeda road-cut, Al Jabal Al Akhdar, NE Libya

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Highlights

- **The characteristics of physical, petrographic and bulk elements of the Appollonia chert nodules in Al Hmmeda area is documenting its origin by replacement.**
- **Low crystallized silica of possible organic origin composed mainly the Appollonia Formation chert nodules.**
- **Partial to total dissolution of low crystallized silica is under the influence of increasing temperature and pH.**
- **Local porosity and permeability variations in the examined Appollonia chert, mostly produced mixing of the diffused digenetic fluids resulted in the formation of nodular form of this chert.**

ARTICLE INFO

Article history:
Received 01 February 2018
Revised 19 February 2018
Accepted 22 September 2018
Available online 31 March 2019

Keywords:
Chert nodules, Appollonia Formation, Al Hmmeda road-cut, physical properties.

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ABSTRACT

Physical, petrographic and bulk elements analysis of Chert Nodules in Appollonia Formation, Al Hmmeda road-cut were conducted and showed that the origin of these chert by replacement. The suspected siliceous organic matters are of low crystallized silica and were dissolved under the influence of increasing temperature and pH. Most of the chert was localized in the limestone and dolomitic limestone of Appollonia Formation (nodular zone) by percolation of silica-rich solution along microfractures and porous/permeability zones. This local porosity and permeability variations, mostly produced mixing of the diffused digenetic fluids. This process produces the nodular form of the cherts in the Appollonia mudstone facies in the nodular zone, while less marked permeability variations could have produced more regular tabular bodies of chert, which were not observed at least in the studied section. The absence of chert nodules in some adjacent rocks and even at higher elevation in the Appollonia stratigraphic section (non-nodular zone), might reflect effective exhaustion of the silica supply, fewer microfractures condition and perhaps dilution by the marine water of highly reduced silica-rich solution.

1. Introduction

There were superb outcrops of tertiary carbonate rocks along Al Hmmeda road – cut, among them, some yellowish cream limestone with chert nodules. These chert nodules in Appollonia Formation have been reported by some references (Pietersz, 1968; Benerjee, 1980; Muftah *et al*., 2015), but their physical properties, occurrences and origin are largely unknown. The examined outcrop section in the study area (Fig. 1) is characterized by selected limited dimensions of about 300m width and of 280m height at the first escarpment of Al Hmmeda road-cut. The objective of this paper is to describe, characterize and graphically document natural chert occurrence in the Appollonia Formation exposed in Al Hmmeda road-cut, east of Tansulukh Village.

2. Methodology

a) Fieldwork

The present study includes the analysis of chert nodules samples, which are brought from the Appollonia carbonate sites of Al Hmmeda road-cut, Al Jabal Al Akhdar. First, completed the field observation and macroscopic examination of seven samples, took into account the visible physical properties of the chert nodules such as color, shape, size, compactness, spacing and their orientation relative to bedding planes (Table 1). Also paid close attention to other properties like, texture, fragility and sample weight that were determined through simple observation. Field photographs were taken with SONY 12.1 Megapixels camera in which we controlled the coloration of the photographs with auto-reference color scale.

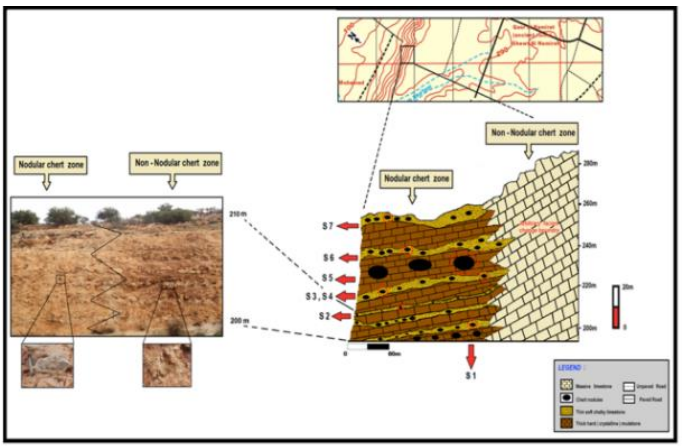

Fig. 1. Location Map and General Outcrop Section of the Study Area, Al Hmmeda Road-Cut, Al Jabal AL Akhdar, NE Libya.

b) Laboratory work

A selection of seven samples was analyzed using a polarized microscope for petrographic examination. Other selected samples (S1, S3, S6) were also examined using XRD techniques for elemental analysis.

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3. Chert nodules description in hand specimens

A composite columnar section (Fig. 2) was constructed and composed of thin soft chalky limestone with dense chert nodules at the base to alternating thick, hard crystalline mudstone with scattered chert nodules, and topped by thick, hard, fossiliferous mudstone with no chert nodules. Several forms of crystalline silica occur locally in Appollonia Formation. Elliptical chert nodules is volumetrically significant (>10%) but relatively sparse in the dolomitic limestone and chalky limestone of the lower section of Appollonia Formation (nodular chert zone), while it could be volumetrically insignificant (<2%) in the mudstone–wackestone facies of the upper part of Appollonia Formation (non–nodular chert zone). These nodules are medium–brown to light black, micro–cryptocrystals texture and generally between (5–30 cm). Upon closer examination of hand specimen, the matrix or (groundmass) is seen to have numerous small (0.2–0.5 mm) dark colored spots (dolomite) crystals and light colored foraminifera fragments.

Chert nodules distribution can be seen in (Fig. 3) in which chert density is concentrated in the lower part of the nodular zone where it decreases and may be absent in some adjacent rocks at higher elevation (non-nodular zone) in the Appollonia stratigraphic section.

Table 1

Field Observation and physical properties of Chert Nodules in Appollonia Formation, Al Hmmeda Road- cut

Sample No.	Elevation (m)	Color	Shape	Size (cm)	Spacing (cm)	Orientation to bedding plane	Texture	Facies	Fragility	Weight	Photo
S7	255	Gray	Sub-elliptical	13	20-25	Parallel	Irregular	Chalky limestone	unfragile	Light	
S6	240	Gray	Sub-elliptical	5	20-25	Parallel	Spotty	Chalky limestone	unfragile	Light	
S5	230	Bluish gray	Elliptical	27-30	90-120	Parallel	Spotty	Mudstone (dense)	unfragile	Light	
S4	225	Gray	Lens	18	25-28	Parallel	Spotty	Chalky limestone	unfragile	Light	
S3	220	Bluish gray	Elliptical	7	25-28	Parallel	Irregular	Chalky limestone	unfragile	Light	
S2	210	Gray	Spherical	3-5	25-30	Parallel	Irregular	Chalky limestone	unfragile	Light	
S1	200	Gray	Semi-spherical	5-7	20-25	Parallel	With cavity	Chalky limestone	unfragile	Light	

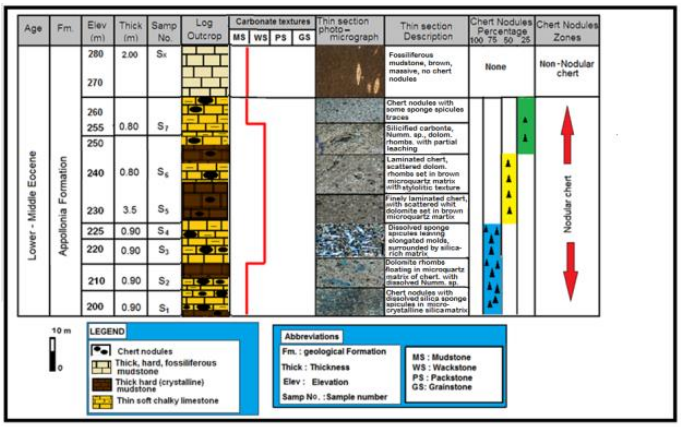

Fig. 2. Composite columnar section of the studied Appollonia Formation, Al Hmmeda Road- cut, AlJabal Al Akhdar, NE Libya

4. Thin section study

Selected thin sections were studied petrographically, in these thin sections, the Appollonian Formation chert nodules at Al Hmmeda road-cut are of light to medium brown translucent, finely laminated chert (Fig. 4), consisting of very fine grained equidimensional micro quartz and chalcedonic quartz with scattered white dolomite rhombs set in brown micro-quartz matrix, fine branched dissolved sponge spicules are also present. Occasionally with minor amounts of carbonate minerals (dolomite rhombs and other undetermined opaque granules or pellets), with some stylolite structures, (Fig. 5).

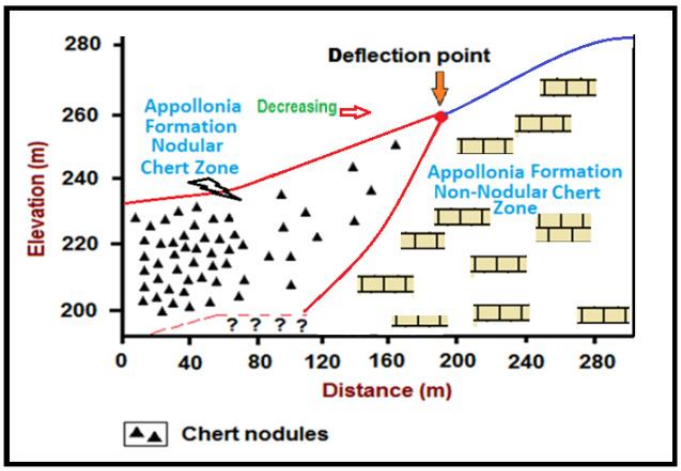

Fig. 3. Chert nodules density graph showing their general distribution in the studied area.

Abundant foraminiferal pseudomorphs are scattered (Fig. 6) where the foraminiferal shells consist occasionally of cryptocrystalline and microcrystalline quartz, which are indistinguishable from the surrounding cement material forming a structure-like ghost. Although the foraminiferal tests are partially or totally replaced and their cavities are filled with silica (Fig. 7). The forms of these microfossils seem to be well preserved in the microquartz matrix of chert. The material filling the foraminiferal pore spaces is mostly fine to medium grained, colorless chalcedonic quartz. Dissolved siliceous sponge spicules are also present in the chert as aggregates or branched forms of blue elongated areas occur as traces of sponge spicule particles showing scattered moldic porosity (Fig. 8).

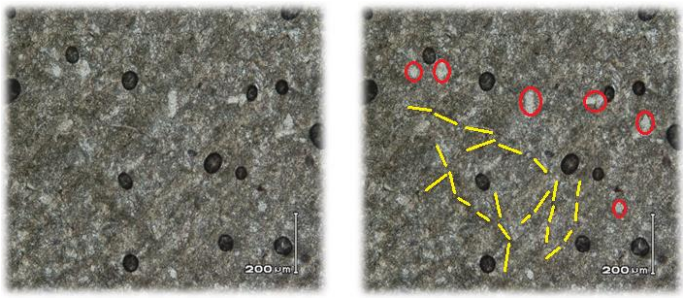

Fig. 4. Thin section photomicrograph of finely laminated chert showing scattered white dolomite rhombs (circles) set in brown micro-quartz matrix, fine branched dissolved sponge spicules (dashed) can be seen.

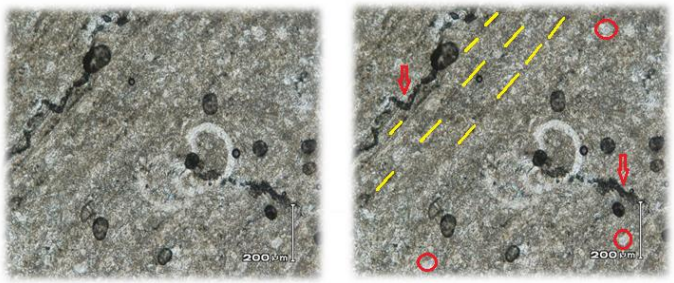

Fig. 5. Thin section photomicrograph of laminated chert (dashed) showing scattered dark –grey dolomite rhombs (circles) set in brown micro-quartz-matrix with stylolitic structures (arrows), dark colored stylolite's boundaries are probably organic origin.

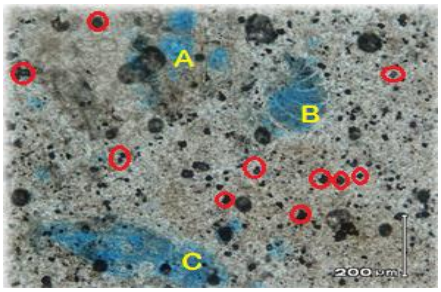

Fig. 6. Thin section photomicrograph of crystalline matrix of chert, showing dolomite rhombs floating in micro-quartz (circles) and dissolved nummulite structures (A, B and C).

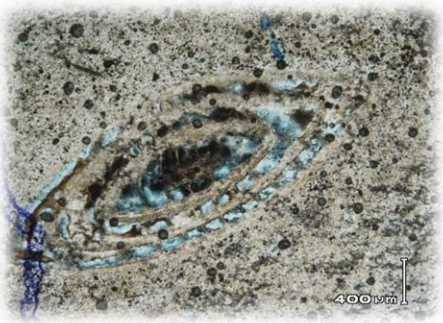

Fig. 7. Thin section photomicrograph showing partially silicified Nummulites *sp.*, with partial leaching intragranular porosity.

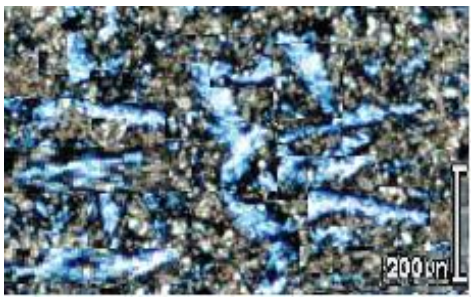

Fig. 8. Thin section photomicrograph showing sponge spicules have been dissolved leaving molds (blue elongated areas) and the surrounding matrix has been mostly replaced by silica (dark grey areas).

5. Interpretation of thin sections

The Appollonia Formation is limestone to dolomitic limestone, the matrix is a calcitic microspar in which the chert nodules which formed by replacement micro-quartz are consistently equicrystalline, suggesting that nucleation sites for replacement (calcite–silica) were evenly distributed under high-level silica supersaturated digenetic fluid (Gregg and Sibley, 1987). The recovered dolomite rhombs are best explained as left- behind phase pre-existing the silicified matrix around. The floating dolomite rhombs and other carbonate pellets may suggest that the replacement of the carbonate matrix was on a micro-volume basis.

The good preservation of carbonate microfossils in micro-quartz matrix may be suggested that foraminiferal test did not dissolve until silica precipitated in their cavities and in cementing groundmass and that the replacement of carbonate by silica prograded gradually in favorable acidic condition. Horizontal stylolites with amplitudes up to 10 cm occur in laminated chert sample (Fig. 5) suggesting that stylolization in a given lithology was progressive during intermediate and deep burial (Duggan, 2004). The dark-colored stylolite's boundaries are probably organic origin. The very early dissolution of sponge –silica spicules may suggest their local moldic preservation as microfractures and permeability increased which effect chert nodules formation . However, the presence of bluish-gray chert nodules in some horizons and are commonly associated with imprints of dissolved sponge spicules may suggest a local biogenic source for much of the silica.

6. X-Ray powder diffraction

Two selected rock samples were crushed to powder and examined under X-Ray diffractometer, type (PW 3050/60) for bulk rock (minerals) examination, where the examined chert samples consisted almost entirely of quartz (98%), with minor amount (2%) of carbonate minerals (calcite/dolomite) (Table 2). These results are not contradictory to those of the petrographic study. In Fig. 9, prominent quartz peak (@ 2Theta 26.60°), other minor quartz peaks (@ 2Theta 21°& 50°) can be seen with some minor calcite peak (@ 2Theta 29.46°). Possible minor dolomite peaks (@ 2Theta 40°& 46°) can also be seen. The absence of distinct patterns of dolomite mineral in X-Ray diffraction analyses in the case of quartz–rich chert samples may be due to the interface between quartz peak and calcite peak, which can cause a serious underestimation of dolomite proportion in the examined samples.

Table 2

Minerals detected in chert nodules of Appollonia formation, using XRD method.

Item No.	Mineral name	Chemical formula	Index name	Quantity (%)	Rel. intensity (%)	d-spacing	2° Theta
1	Quartz	SiO_2	Silicon	98	100.00	3.353	26.60°, 50°
2	Calcite	CaCO3	oxide	2	1.25	3.031	29.46°

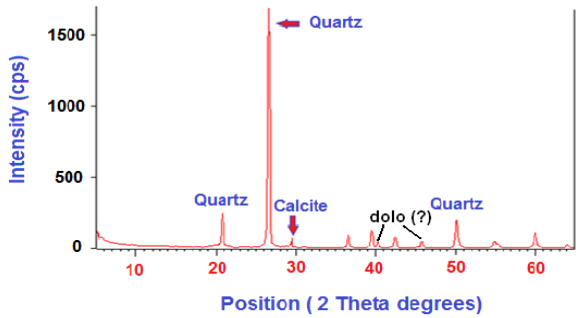

Fig. 9. XRD chart of chert nodules in Appollonia Formation.

7. Conclusions

The study of the characteristics of physical, petrographic and bulk elements of the Appollonia chert nodules in Al Hmmeda area is documenting its origin by replacement; the source of the silica, however, remains speculative. There are, however, minute dissolved sponge spicules in this chert. The suspected siliceous sponge spicules composed of low crystallized silica were buried and dissolved with increasing temperature and pH in the solution trapped in the sediments. Most of the chert was localized in the limestone and dolomitic limestone of Appollonia Formation (nodular zone) by percolation of silica-rich solution along microfractures and porous/permeability zones. This local porosity and permeability variations, mostly produced mixing of the diffused digenetic fluids (Mcbride *et al.*, 1999). This process produces the nodular form of the cherts in the Appollonia mudstone facies in the nodular zone, while less marked permeability variations could have produced more regular tabular bodies of chert, which were not observed at least in the studied section. The absence of chert nodules in some adjacent rocks and even at higher elevation in the Appollonia stratigraphic section (non-nodular zone), might reflect effective exhaustion of the silica supply, fewer microfractures condition and perhaps dilution by the marine water of highly reduced silica-rich solution.

8. Recommendation

Because of the fact that the origin of the chert nodules of Appollonia Formation is still debatable; SEM study for these chert nodules is very needed to ensure the presence of sponge spicules and to define their fragmental morphology and texture. Also suggested

oxygen isotope analysis and signature for the chert nodules and their comparison in the studied sections (nodular and non-nodular zones) is highly recommended.

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