

A Probable Meteor Multi-Ring Impact Craters in the North-eastern Morocco: Evidence Petrographic and Morphologic

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ABSTRACT: The north-eastern Morocco, is a peculiar area which is suspected to be a large impact site. It has a conspicuous ring structure with an apparent diameter of about 200 km of which half is in the sea. Jurassic mountains Taourirt-Oujda-Tlemcen showing an arc form correspond to the outer ring. Mesozoic and Palaeozoic bedrock units are locally brecciated and cut by pseudotachylite breccia dykes. Kebdana mounts with its intense and unusual deformation, form probably the central uplift of a complex crater. A wide variety of breccias is located inside and outside of the crater, many of which contain fragments exhibiting shock metamorphic features. The age of the impact is estimated to be toward the late of Messinian.

KEYWORDS: Pseudotachylite, Suevite, Impactite, breccia, Kebdana, Beni Snassen, Messinian.

1 INTRODUCTION

The largest impact structures are multi-ring craters. They are characterized by several structural rings surrounding a topographic crater form. On earth, three large multi-ring basins have been recognized. One of them is the Chicxulub structure in Mexico, of 180-300 km diameter [1], [2].

In the North Eastern Moroccan a circular structure of 200 km of diameter, is visible on the Google Earth image (Fig.1). Half of this circular structure is conspicuous in the Mediterranean Sea. The Shock metamorphic effects present in samples of all sector, [3] suggest that circular region is a meteor impact structure.

In this paper, we announce the existence of a circular structure, and we describe briefly some shocked products from different locality of crater.



Fig. 1 Satellite image large oval structure which half is drawn by the reliefs of mountains ranging from Alhoceima, Taourit, Jerada to Tlemcen. The other half is visible in the Mediterranean Sea.

2 FORM AND GENERAL GEOLOGY

North-Eastern Morocco is a system of plains, plateaus and mountain ranges extending on the eastern parts of the eastern Meseta and Rif domains (Fig. 3). It is represented by the Beni Snassen and Kibdana mounts, the Taourirt-Oujda basin, the Taourirt-Oujda mount named "Pays des Horsts" and a crustal block without notable alpine deformation, which constitutes the High Plateaus. [4]

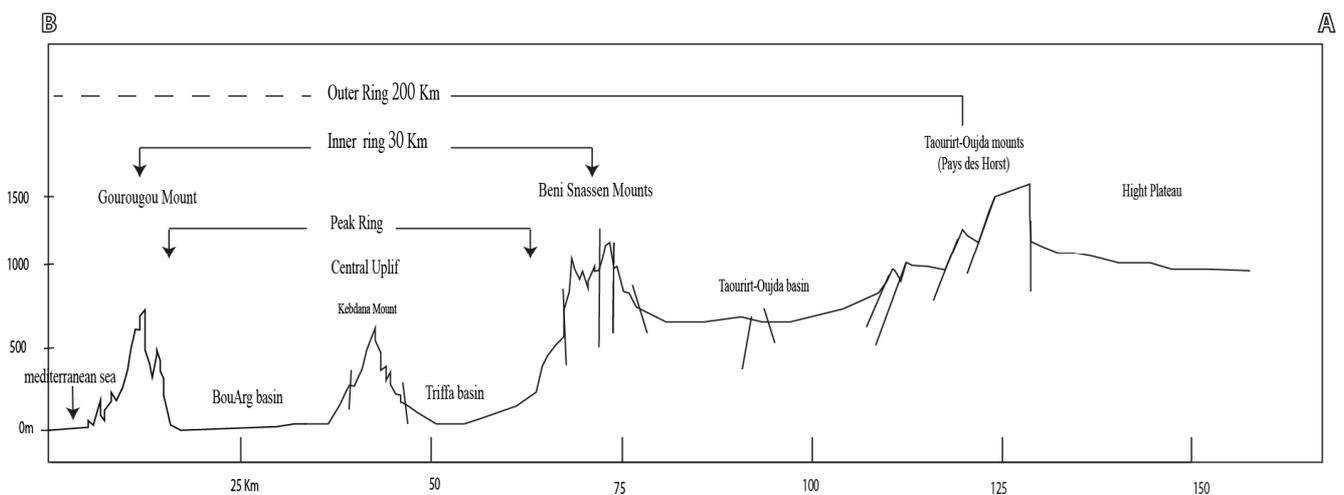


Fig. 2 NW-SE topographic profile of Complex Crater of north-eastern Morocco along the AB transect shown in Fig. 1.

The Kibdana chain located in the center area of the circular structure could be the central uplift of this complex crater. It is ringed by the plains (Triffa Sebra and BouErg) that form a ring of 30 km. Beni Snassen Mountains around the previous plains could be considered as the inner ring (terrestrial part). The Taourirt-Oujda-Tlemcen mounts (Pays des Horst) which show sub-horizontal Jurassic sediments affected by fault systems mounts would correspond to the outer ring. (Fig. 2 and 3)

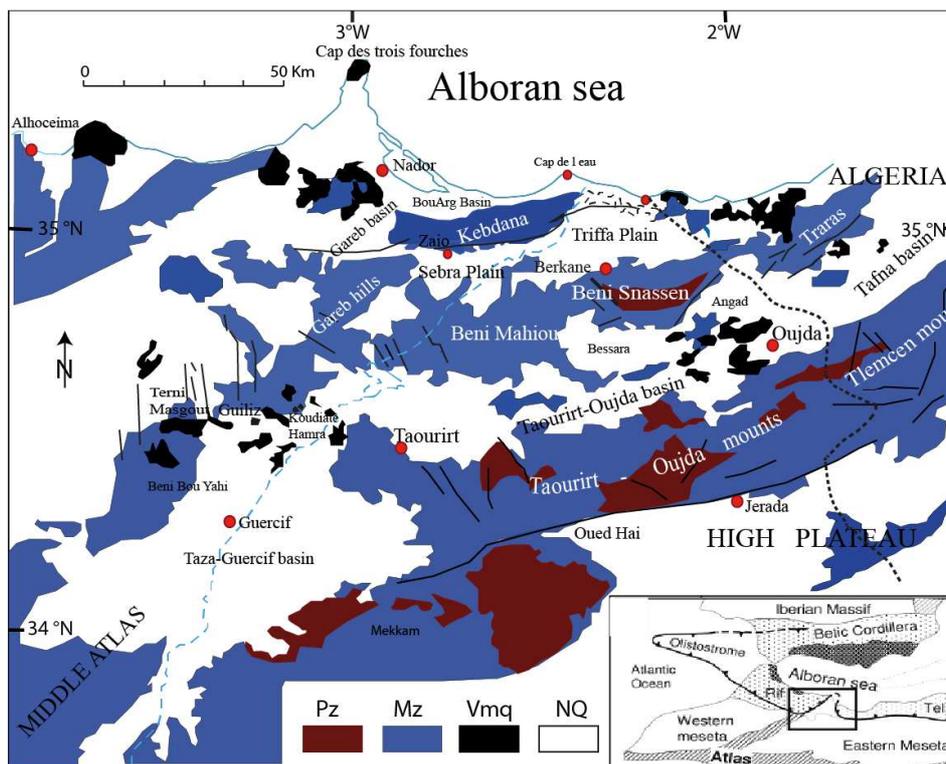


Fig. 3 General location and simplified geologic map of the north-eastern Morocco. [After El Hammichi 4] modified. Pz: Palaeozoic, Mz: Mesozoic, Vmq: Late Miocene to Quaternary volcanics, NQ: Neogene to Quaternary sediments. (Noted that Tertiary magmatism is located inside of the outer ring)

3 KEBDANA DEFORMATION

Several effects of metamorphism choc can be noted in Kebdana mounts. Such as breccia, quartzite with chocked quartz or like the dikes of pseudotachylite.

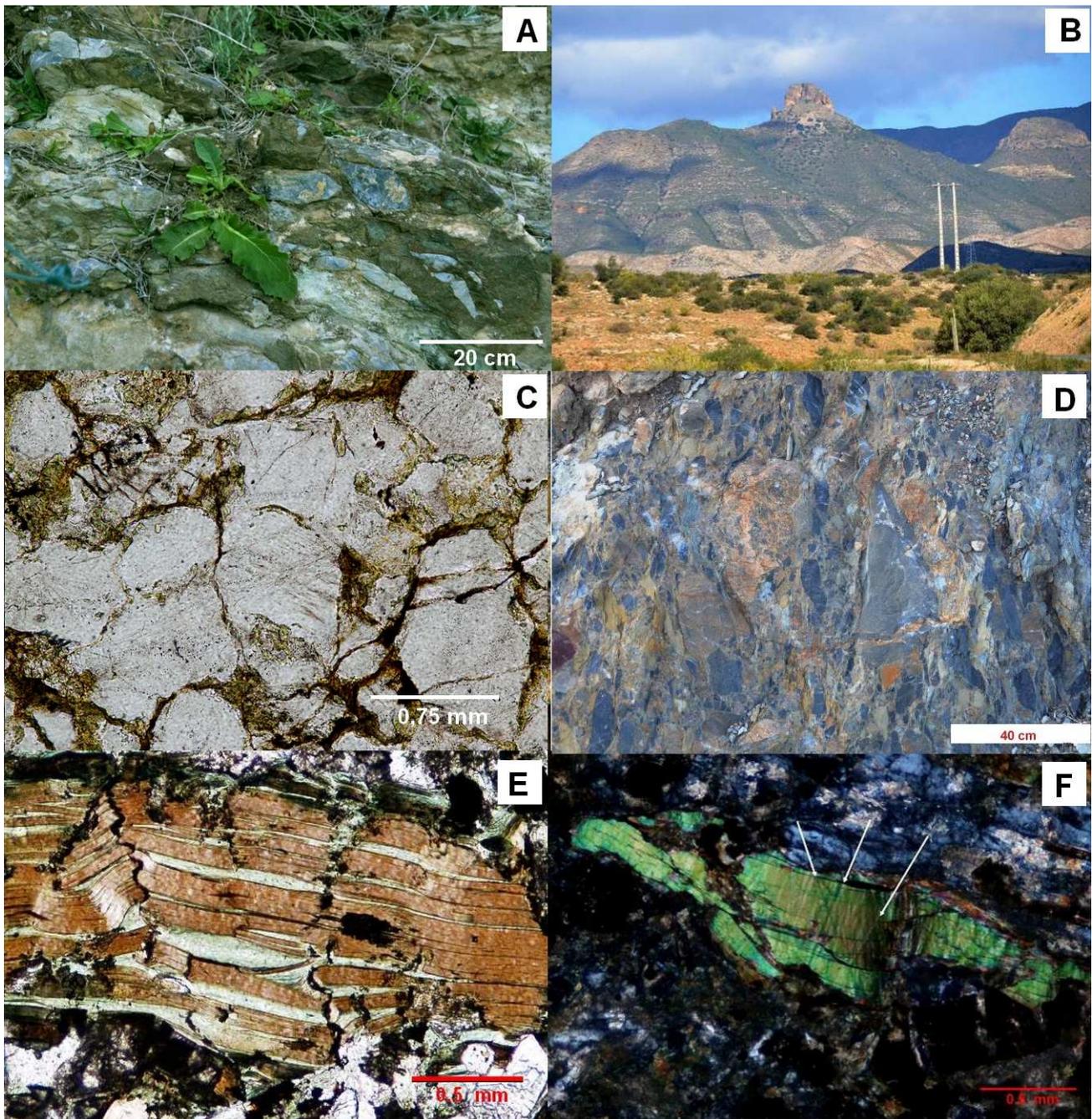


Fig. 4 (A). Dark green pseudotachylite breccia in the Kebdana Mountain. **(B)** A peaks of limestone blocks raised vertically in Kebdana. **(C)** The interstitial altered glass and choked quartz in quartzite from Kebdana. **(D)** Plastically deformed Breccia in Zaio area (Kebdana). **(E)** Complex kink bands and fractured deformation in biotite from Kebdana Pseudotachylite. **(F)** Biotite showing three main sets of PDFs. The arrow indicates the preferential direction of the PDFs in the biotite from Pseudotachylite of Kebdana

3.1 PSEUDOTACHYLITIC IN KEBDANA

Pseudotachylite occurs in the par-autochthonous rocks of large impact structures. It's most developed at two large, ancient impact structures: Vredefort (South Africa) and Sudbury (Canada). They occur like as abundant dikes or bodies that contain numerous large and small rounded inclusions of target rock set in a dense, aphanitic or crystalline matrix that is generally black to green in color [5].

The petrographic study of pseudotachylite (Fig. 4A) from Kibdana, has revealed the presence of the deformed biotite, the brown melanite (titanian garnet), curved apatite and titanite set in a matrix that contain considerable amounts of hydrothermal phases (chlorite, sulfides and carbonates).

The kink-bands are the most frequent micro-deformation in biotite and, more rarely, planar deformation elements (Fig.4E) and the borders are often curved or broken. In contrast to the kink-bands, planar elements display an appearance of very fine lamellae (Fig. 4F), arranged in parallel sets and closely spaced, analogous to those described by Schneider [6]. Along the fine lamellae, the birefringence is intensely reduced.

3.2 QUARTZITE

A wide block of quartzite (10 m) located at east of Kibdana corresponding to an intensely deformed rock, the shock has given the melt in interstices. The majority of quartz grains are shocked (2 to 3 sets planes PDFs) and show rounded shape by resorption (Fig. 4C). The same mineralogical characteristics were noted in the thin section of Miocene cobbles at Aknoul area (Fig. 6D).

3.3 BRECCIA

Several types of breccias have been observed at the Kibdana mount, we note the presence of mega-bloks and the plastically deformed breccia where both clasts and matrix are intensely affected (Fig. 4D). The quartzite clasts show many fracture and the shocked quartz.

The summits of Kibdana are decorated with peaks (Fig. 4B), which correspond to limestone blocks. These blocks are raised vertically, fractured, brecciated and in some times transformed partially to marble

4 BENI SNASSEN DEFORMATION

The deformation is recorded differently depending on the nature of the target rocks. The Jurassic limestone is deformed as monomictic breccias at the Aghbal valley or as conical structures (Fig. 5C and 5D) that are visible on the tops of Foughal and Ain Almou. Some Palaeozoic quartzite have been warmed and partially melted as attests it the presence of resorbed quartz and melt in interstices in thin section. The pseudotachylite occurs as altered magmatic dikes (20 cm to 10 m of thick) cross-cutting the Palaeozoic formations.

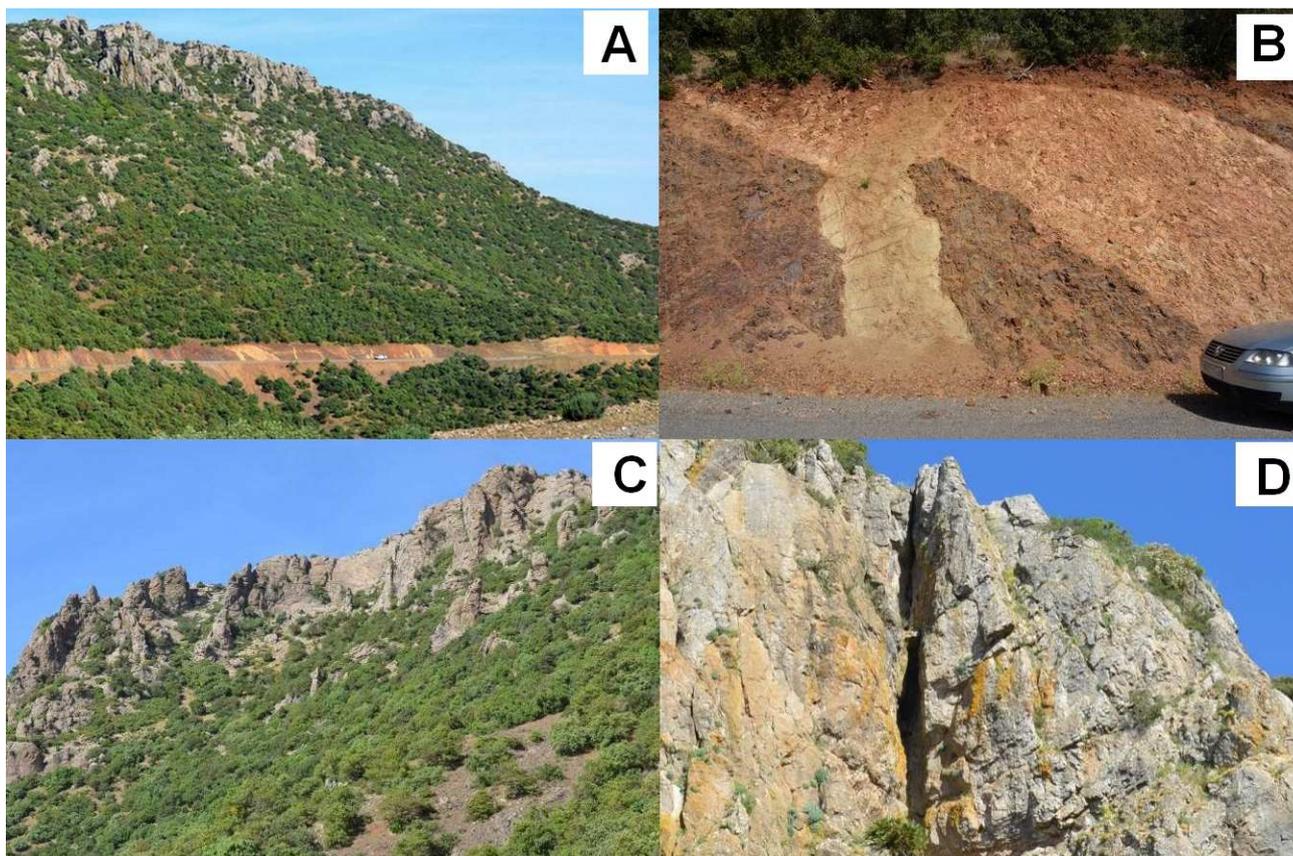


Fig. 5. (A) The pseudotachylite dyke cutting through Palaeozoic formations which are overlain by the Jurassic fractured limestone. (B) A closer view of the pseudotachylite dyke crossed by a later green one. (C) Several blocks showing a conical structure in the Jurassic limestone summit of Foughal. (D) Closer view of the conical structure

4.1 PSEUDOTACHYLITE

Systems of dikes and sill (Fig. 5 A and B), sharply cutting through their host Palaeozoic rock are a prominent structure in the Beni Snassen Mounts. Their aphanitic matrix are much altered into friable rocks, only a few dikes show the intact rounded fragments. All phases appear to be altered. The microlites, indicating devitrification, appear to be chloritized. The rounded Quartz clasts in the pseudotachylite were more resistant to melting than other minerals of the host rock.

("Pseudotachylite" is used here as a descriptive term for tachylite-like, aphanitic inclusion-bearing dike and irregularly shaped bodies that may have glassy, tiny-grained, igneous or clastic matrices.)

5 CARBONATE-RICH SUEVITE

The superficial formations in the north-eastern Morocco occupy vast areas and form deposits and crusts considered Plio-Quaternary (Fig. 6 A, B and C). These are tabular structures formed by a limestone crust, then a conglomerate encrusted and finally a low gravel terrace encrusted [7]. These formations are located in different basins of the region: Oued Hai Basin (Jerada), Taourit-Oujda Basin (Aioune and Taourirt) and Triffa Basin. [8], [9], [10].

The carbonates have often been neglected in studies of impactites. However, carbonates are common at the surface of the earth and, therefore, in target rocks. Several impactites must contain solid and melted carbonate phase. In the Triffa case like Chicxulub [11], where the target rock is Jurassic limestone, the contribution of carbonates to the produced melts was very important. In this case it's difficult to distinguish a carbonate impactite (Fig. 6 A and B) from the sedimentary breccia.

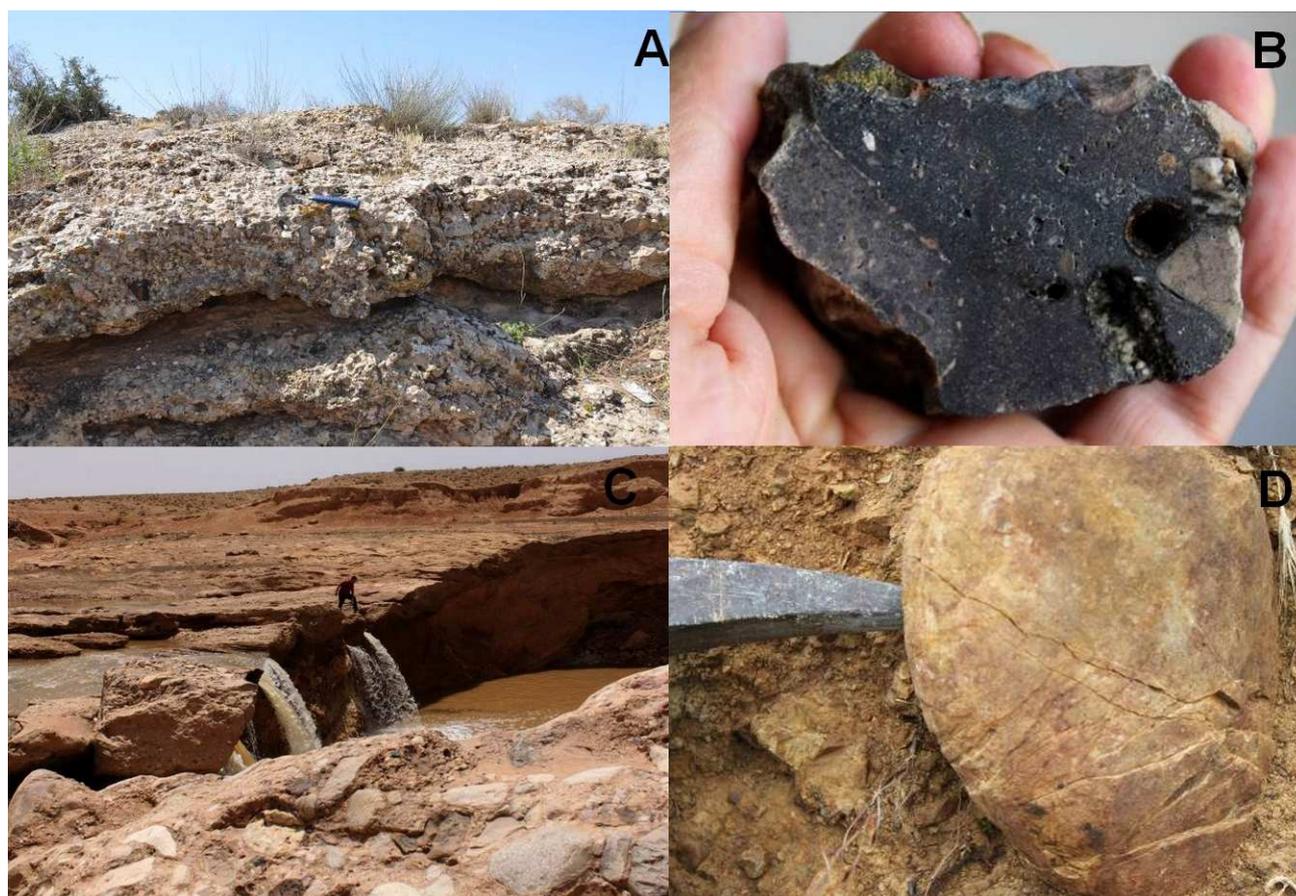


Fig. 6 (A) Suevite corresponding to blanket of encrusted conglomerate in Taourirt area. Fig. (B) Suevite with resorbed clasts in annealed fine-grained matrix from Taourirt. (C) A blanket of the Suevite with rounded clasts in Oued Hai. (D) Strongly deformed cobbles in Miocene outcrop (Aknoul) showing fracturing.

The breccia is mainly composed of carbonate clasts rounded or subangular and a few feldspar and quartz fragments. Clasts composed of clay minerals are also present. Many of the quartz grains are resorbed and rarely where it contains shock-induced planar deformation features (PDFs). The presence of melt and shocked quartz in these rocks allows us to consider, these Quaternary conglomerates present in northeastern Morocco, as the ejecta suevite formed by the fusion of limestone by this impact.

6 AGE

The fractured cobble and the shocked quartz in Miocene conglomerate allow us to suggest that the impact had occurred in the Miocene. However, considering the suevite plio-quaternaire corresponding to extended blanket conglomerate, the age of impact will be different.

The Neogene-Quaternary Taza-Guercif Basin is a neighboring of the crater, this basin position is particularly interesting from the biostratigraphy point of view, such as it records the deposit of the ejecta material in basin sediments. The basin fill of the Guercif Basin, starts with a Tortonian marine marl overlain unconformably by the Messinian marly [12], [13] which is in turn unconformably (Fig. 7A) overlain by the Pliocene continental unit (conglomerate and lacustrine limestone). This unit shows a level formed of carbonate melt (scoria) in the sediment (Fig. 7 B and C) and of conglomerate with shocked quartz. Noted sediment disruptions at the end of Messinian could be induced by the falling of impactite ejecta. So the boundary Messinian-Pliocene would correspond to the age of this impact.

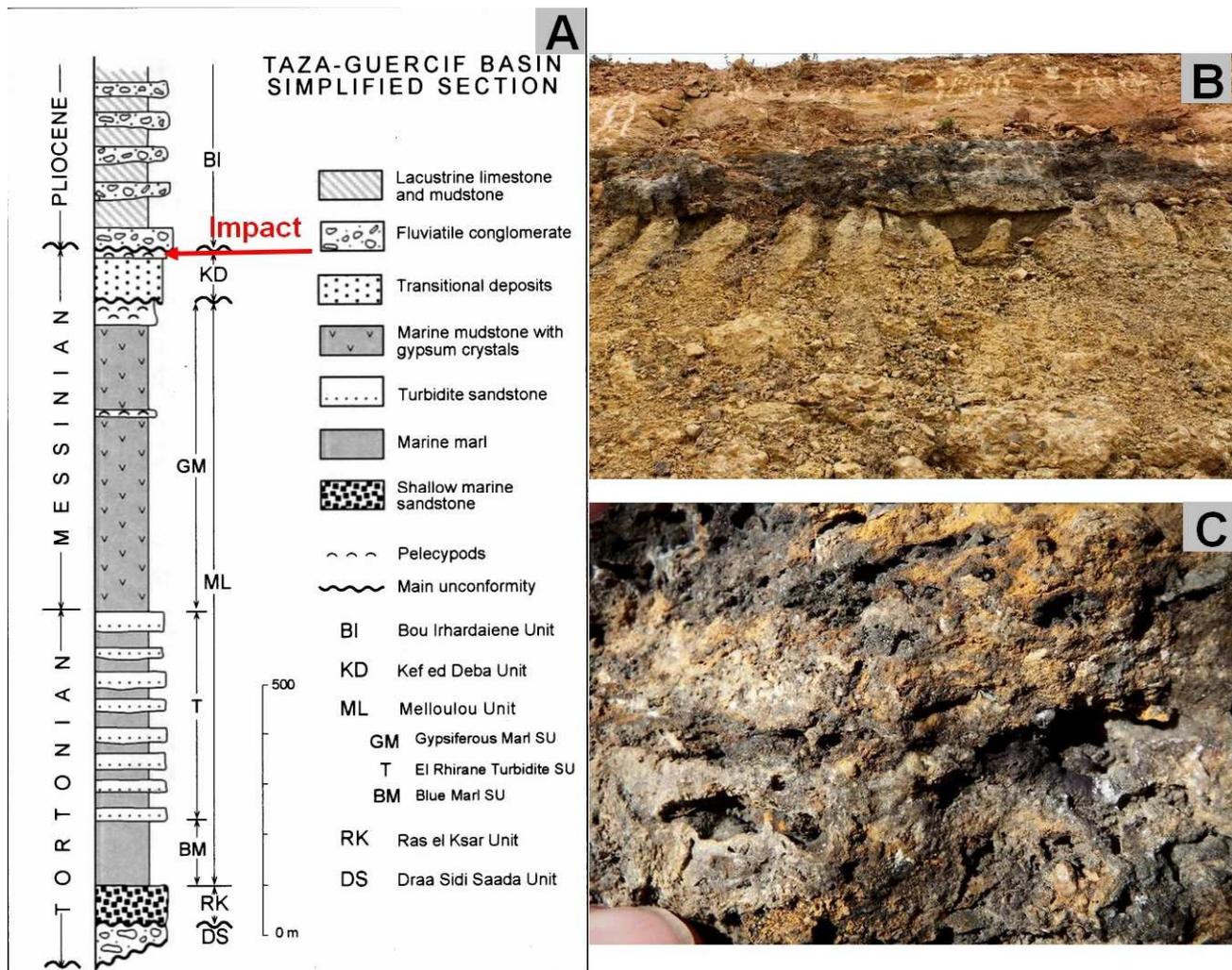


Fig. 7 (A) Schematic stratigraphic column of the Neogene Taza-Guercif basin. The arrow shows a probable impact age at the boundary Messinian-Pliocene. [In Bernini 12]. (B) A black level of carbonate scoria set in the sediment of Taza-Guercif Basin. (C) Close view of Carbonate scoria from black level in 7B.

7 CONCLUSION

Many indices of shock metamorphism are present in the north-eastern of Morocco. Pseudotachylite and monomict breccia are only present in the peak ring (Kebdana and Beni Snassen) but the carbonate suevite is spread from the center to outside ring of the crater.

The blanket conglomerates (Plio-Quaternary) present in the basins in northeastern of Morocco (Triffa, Taourirt, Aioune and Oued Hai (Jerada) would be a suevite with a carbonate matrix. All these suevites contain shocked quartz grains. The target carbonated rock (limestone Jurassic) pulverized and vaporized at impact shock formed a carbonate breccia and suevite.

Based on these criterions we suggest the existence of a wide multi-ring crater in the northeastern morocco. Kebdana Mountains intensely deformed form probably the central uplift of a complex crater. The Beni Snassen mounts could be considered as the inner ring and the Taourirt-Oujda-Tlemcen mounts would correspond to the outer ring.

Further investigations are needed to clarify the structure of this wide crater. New petrographic facies (suevite and pseudotachylite) briefly described in this work deserve more advanced studies.

The presence of the Mio-Pliocene volcanism inside the outer ring of the crater, deserves some new reflection about the origin of this magmatism, taking into account the existence of this wide impact crater.

Also the Messinian age of the impact allows us to ask the following question: Is there a link between this event and the mass extinction known at the end of the Messinian?

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