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First African diamonds discovered in Algeria by the ancient Arabo-Berbers: History and insight into the source rocks

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ABSTRACT

It is generally believed that the first diamonds ever found in Africa were discovered in South Africa in 1867. Actually, three diamonds had already been found in 1833 near Constantine (Algeria). One of these, still preserved, shows radiohalos that suggest an old age. It could be a Sahara diamond reworked in more recent sediments, possibly the Oligo-Miocene Numidian Flysch; however, this occurrence remains uncertain. The ancient Arabs or Berbers also knew of diamonds in the Reggane region (Algerian Sahara), at *Bilād al-mās* (بلاد الماس: "country of the diamond"). Since 1975, some 1500 diamonds have been collected from the alluvial deposits of this area. A manuscript written in Arabic in 1851 mentions diamonds in this region and describes their source rock, looked for in vain by modern geologists. The description is unclear, but might refer to Devonian oolitic ironstones. Modern investigations would rather suggest a kimberlitic primary source with intermediate Early Cretaceous palaeoplacers.

1. Introduction

Until the 18th century, India was the only known source of diamond. However, a few antique chronicles recounted that diamond also existed in northern Africa. Pliny, in particular, says in his *Naturalis Historia* (37.55) that the diamond existed in Ethiopia – that is, to the South of Egypt. It has also been reported that the Carthaginians exchanged precious stones, among which were diamonds, with the interior of Africa (*e.g.*, Agricola, 1546; Heeren, 1799).

More recently, in 1834, the "Muséum national d'histoire naturelle", Paris, purchased a diamond reportedly found in the Ghoumel River, near Constantine (Algeria). In addition, the papers of Du Couret's Saharan mission (1849–1852) include an Arabic manuscript that describes diamonds in the Reggane region, which were rediscovered by modern exploration as late as 1975. Although it is frequently asserted that the first diamonds ever found on the African continent were discovered in South Africa in 1867, it seems that the Arabs and/or Berbers knew of diamonds in Algeria well before the colonial era.

A historical investigation of the Algerian diamonds, interesting in itself, also carries some geological interest. It may clarify the still enigmatic origin of the diamonds from Constantine and can provide indications in the quest for the source rock of the Sahara diamonds, for which modern geologists have searched for decades. Here, we relate the history of the diamond discoveries near Constantine and

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then in the Algerian Sahara, and recall forgotten historical information that may be useful for the knowledge and exploration of these deposits.

2. The Constantine diamonds

2.1. History of the finds

Saint Augustine, born in 354 AD in Thagaste (now Souk Ahras) at 125 km from Constantine (Fig. 1a) and bishop of Hippo (now Annaba, 120 km northeast of Constantine), evokes diamonds in his *De Civitate Dei* (21.4), but specifies neither their origin nor where he observed them. The first mention of a diamond from Constantine dates back to the 18th century; Magalotti (1721, pp. 228–230; 1741, pp. 206–215) reports that a merchant from Constantine brought to Livorno in Tuscany a cut and engraved diamond of the "half size of a hazelnut".

Later, in 1833, Paolo Francesco Peloso [1793–1856], consul of Piedmont-Sardinia at Algiers, sold to the French three diamonds reportedly found by a "native" in the auriferous gravels of the Ghoumel River, near Constantine. Two of these diamonds were shown in Algiers in November 1833 at an exhibition of the natural resources of Algeria

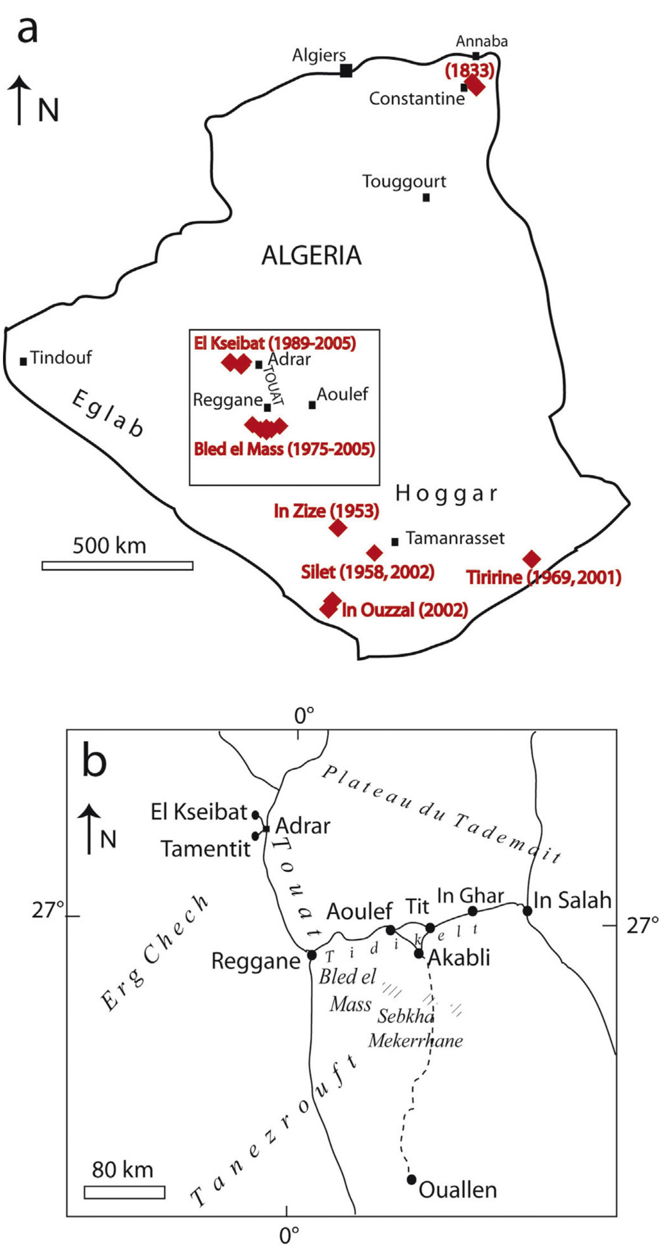

Fig. 1. (Colour online.) Diamond in Algeria: a: diamond finds; b: map of the Reggane region (dashed line: ancient caravan route between Akabli and Ouallen).

Table 1
Location of the Constantine diamonds, according to various authors.

Authors	Muséum National d'Histoire Naturelle (MNHN)	École des mines	De Drée's collection
Anonymous (1835a,b,c)	1 diamond	1 diamond	1 diamond
Élie de Beaumont (1838, p. 152)	2 diamonds		
Héricart de Thury (1840)	1 diamond (1.25 carat = 250 mg)	1 diamond (3 carats)	1 diamond (1 carat)
Lacroix (1893–1913, vol. 2, p. 354)	1 diamond (octahedron of 91 mg)		
This study	1 diamond (rounded octahedron of 91 mg)	Not found	Sold to MNHN in 1844; not found

(Guyon, 1834). In 1834, a French officer named Louis-Charles-Albert Sayde de Bellecôte [1807–1872] negotiated the sale of these diamonds to three mineralogical collections in Paris, namely "École des mines", "Muséum national d'histoire naturelle" [MNHN] and Étienne de Drée's private collection (Anonymous, 1835a). The discovery was presented at the "Société géologique de France" (Dufrénoy, 1834) and the "Académie des sciences" (Élie de Beaumont, 1838; Héricart de Thury, 1840; Table 1). Several American and European periodicals of the time echoed the find (*e.g.*, Anonymous, 1835a,b,c; d'Avezac de Castera-Macaya, 1835–1836; Dureau de La Malle, 1837; see Boutan, 1886), which they presented as the first discovery of diamond ever made in Africa – the South African diamonds were discovered later, in 1867.

The geologists who worked in Algeria during the 19th century were embarrassed about this find, which they considered as a hoax and thus soon forgot. The geology of the Constantine province, which consists mostly of Mesozoic marine sediments hardly favourable to the presence of diamond, as well as the lack of new discoveries, discredited the find. It must also be recalled that, in the middle of the 19th century, diamond was known to occur only in India, Borneo and Brazil. Émilien Renou (1848) thought that the so-called Algerian diamonds may have come from the "pays de Bornou" (*i.e.*, Chad region). In 1849, Henri Fournel, a leader of the Saint-Simonian movement, proposed a strange origin for these diamonds; in his *Richesse minérale de l'Algérie*, he imagines that they could have belonged to one of the adulterous women who, according to an ancient tale, were thrown into the Ghoumel gorge at Constantine during Roman times (Fournel, 1849–1854). As for the geologists who studied the Constantine region after Fournel, they simply ignored the diamonds (*e.g.*, Coquand, 1854; Joleaud, 1912; Ville, 1869). The mineral catalogue of Algeria published in 1873 by Alexandre Papier does not mention them. It looks like an oversight; however, Papier certainly knew Bellecôte, who in 1834 had negotiated the sale of the diamonds in Paris, since they both lived in Bône (now Annaba) and were both members of the *Académie d'Hippone*. It seems that Papier (1873) deliberately ignored the Constantine diamonds.

Fournel's hypothesis is indeed absurd, as the Romans were certainly not stupid enough to throw jewels away with their victims, but a hoax remains nevertheless possible. When the French entered the Kasbah of Algiers on 5 July 1830, they seized the treasury of the Dey of Algiers, Hussein Pasha. Soon afterwards, because of the French revolution of July 1830 and the subsequent abdication of King Charles X, the chiefs of the expedition were forced to leave Algiers and fled into exile. When the new French regime sent its own administrators to Algiers, most of the gold, silver and precious stones of the treasury had disappeared (Péan, 2004). A commission of inquiry noted that a few French had entrusted their spoils to the care of the consuls of England, Denmark and Piedmont-Sardinia, protected by diplomatic immunity (Flandin, 1835, p. 27). Did Bellecôte and the consul Peloso conceive an ingenious stratagem to sell three diamonds that, in reality, had been extracted from the Kasbah treasury? It is possible, but not proven. Bellecôte did not participate to the capture of Algiers in 1830, since he landed with the "4e Régiment de ligne" 2 years later. Moreover, the diamond still preserved at MNHN is less than one carat in weight, uncut and it is obviously not a jewel, so the hoax is not evident.

In the 1970s, Miocene lamproites were discovered in the Constantine province (Kaminsky et al., 1993; Raoult and Velde, 1971; Vila et al., 1974), reviving the interest for the Constantine diamonds meanwhile forgotten. Although new diamonds have not been found since 1833, this discovery provides a possible primary source for the Constantine diamonds.

2.2. Mineralogical observations

The three diamonds reportedly found at Constantine were purchased in 1834 for the "École des mines", De Drée and MNHN mineralogical collections. There is apparently no mention of a diamond from Constantine at the "École des mines"; it could be one of the 23 diamonds of "unknown origin" that exist in the collection. De Drée's collection was sold to the MNHN in 1844 ("Archives nationales" [AN]: AJ/15/545). Only one diamond from Constantine is still preserved at the MNHN (Fig. 2). Labelled "MIN000-5608", it is recorded in the collection catalogue as found in the "Constantine Basin" and sold in 1834 by Bellecôte for 100 Francs. Alfred Lacroix (1893–1913, vol. 2, p. 354) described it as a "greenish octahedron, with curved faces, weighting 91 milligrams", which does not match the weight of "$1^{1/4}$ karat" (*i.e.*, ca 250 mg) mentioned for the same diamond by Héricart de Thury (1840) (Table 1).

Under the optical microscope, the crystal appears as a greenish octahedron ca 4.8 mm in size. The crystal weighs 91 mg, so it is evidently the one observed by Lacroix (1893–1913). Raman spectrometry yielded a single band at 1333.5 cm^{-1}, typical of diamond (ideally, 1332 cm^{-1}).

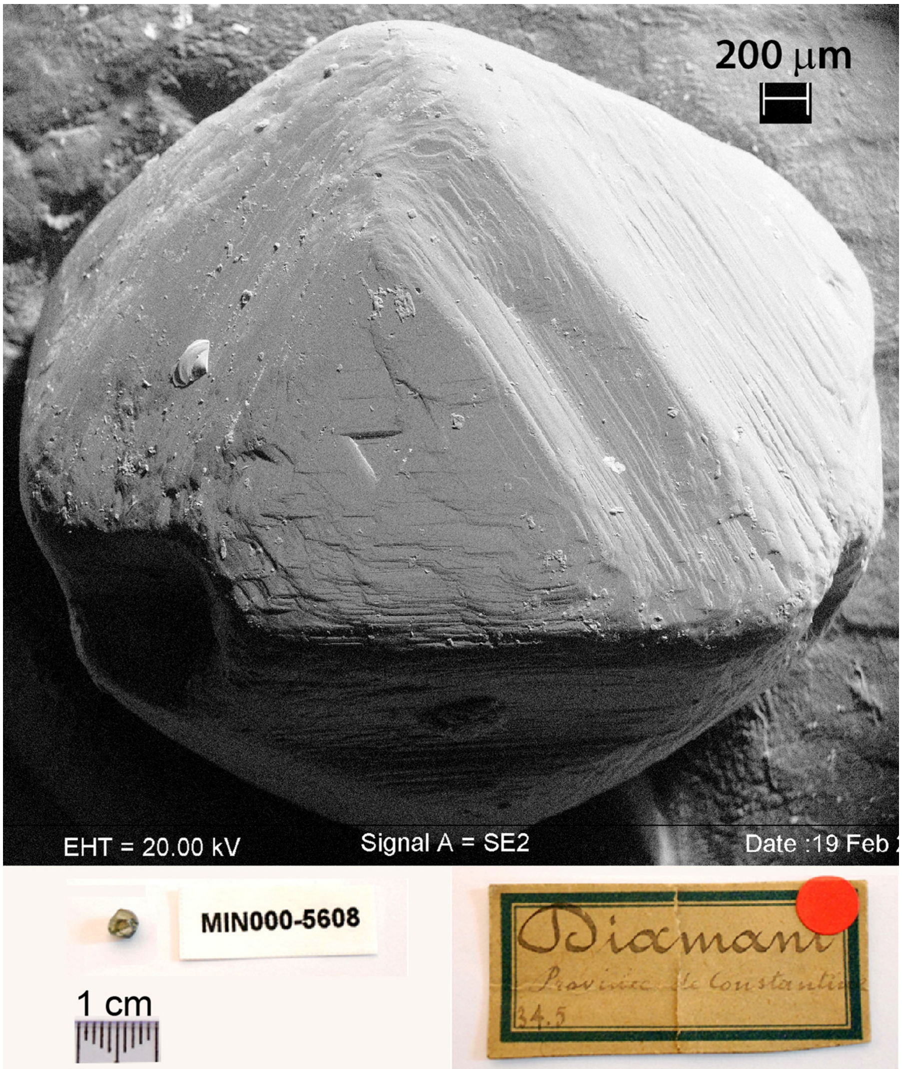

Fig. 2. (Colour online.) The diamond from Constantine preserved at the "*Muséum national d'histoire naturelle*" in Paris. Macroscopic view (below) and secondary electron image (above); note the striations, the rounded edges and the left-bottom broken apex.

Observation under the scanning electron microscope (SEM), without coating, reveals strongly rounded octahedron edges and apexes, and {111} faces with <110> striations parallel to the edges (Figs. 2 and 3a). The diagonals joining two opposite apices of the octahedron (*i.e.*, the 3 A4 axes), ideally equal, are 4.87, 4.65 and 4.77 mm long. Assuming a density of 3.517 for diamond, the mass of 91 mg corresponds to a volume of 25.9 mm^3. Thus, the crystal appears to be a strongly rounded octahedron, since its average diagonal length (4.76 mm) is intermediate between that of an ideal octahedron (5.37 mm) and the diameter of a sphere (3.67 mm) of the same weight and volume.

The cathodoluminescence (CL) spectra obtained on the SEM show a peak at ca 520 nm, corresponding to a green colour. CL was also observed under an optical microscope equipped with a vacuum chamber; it revealed numerous 30 μm-sized circular halos (Fig. 3b), where the CL signal is strongly attenuated. These halos, visible as dark-green spots under normal light (Fig. 3a), are better visible in the SEM with the Variable Pressure Secondary Electron (VPSE) detector; they form circular dark roundels on the surface of the crystal, on the faces as well as on the rounded edges (Fig. 3c). The centres of the roundels are generally arranged along superficial striations or cracks. Since the VPSE signal shows how the surface dissipates charge, these halos correspond to an electrically conductive material, probably *sp*^{2}-bonded carbon, either graphite or amorphous C, present at the surface and contrasting with the resistant *sp*^{3}-bonded carbon of the surrounding diamond. Such green halos are commonly interpreted as being due to alpha radiation emanating from radioactive minerals located in contact, or in close proximity, to the diamond surface (*e.g.*, Nasdala et al., 2013; see Fig. 2d therein and our Fig. 3c).

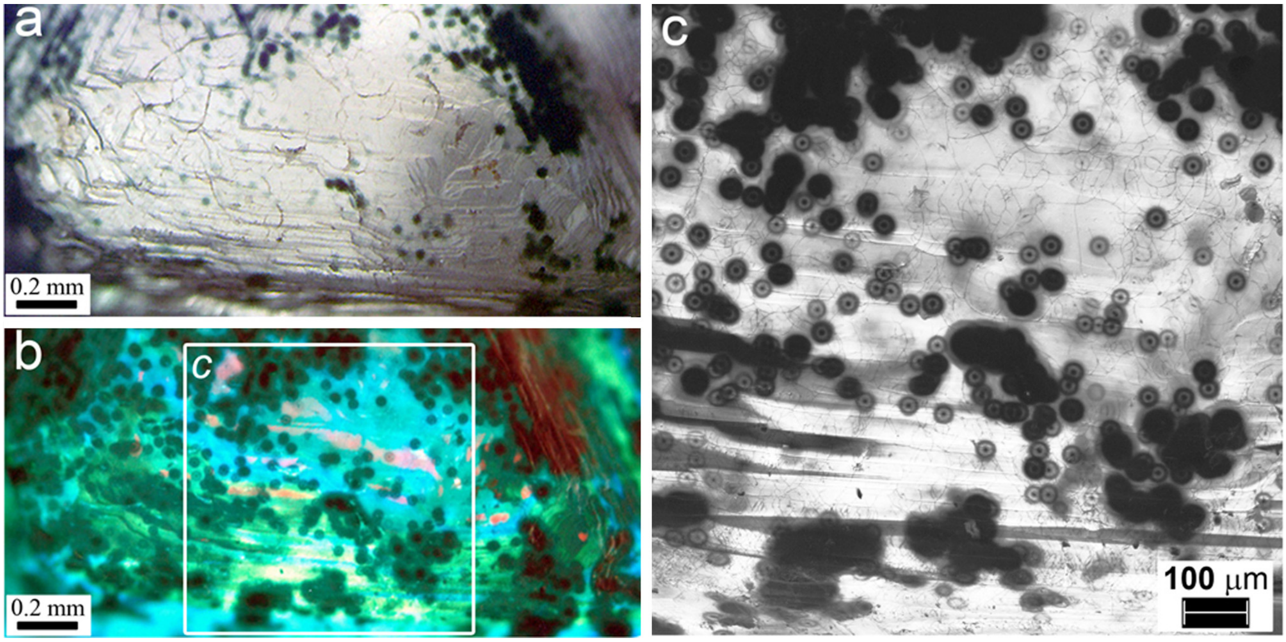

Fig. 3. (Colour online.) Radiohalos at the surface of the Constantine diamond: a: normal light under an optical microscope; b: cathodoluminescence under a microscope equipped with a vacuum chamber and a cold cathode; c: variable pressure secondary electron image (20 kV) at the scanning electron microscope.

No inclusions are visible under the optical microscope. However, superficial very thin fractures are filled with a TiO_2-rich substance (Fig. 4a) and a few μm-sized crystals have been observed under the SEM in superficial microcavities that display the negative crystal shapes of diamond (Fig. 4b). These microcrystals did not yield exploitable Raman spectra, and so could not be identified with certainty, but their X-ray spectra obtained by SEM using energy-dispersion spectrometry allowed qualitative estimates of their chemical composition. Most of them have the composition of muscovite, silica (probably quartz) or biotite, whereas garnet, chromite and olivine have not been observed.

2.3. Insight into the origin

The study of the MNHN diamond yields constraints on its origin. The crystal, strongly rounded, has been transported and reworked in sediments. A pebble of quartz of the same weight and submitted to the same hydrodynamics would have an average diameter of 4.1 mm, so the host sediment should have been a coarse sand (or sandstone) or a microconglomerate. The microcrystals trapped in superficial irregularities mostly consist of muscovite and silica, which do not normally exist in kimberlite or lamproites and thus probably belonged to the host sediment. The radius of the observed radiohalos

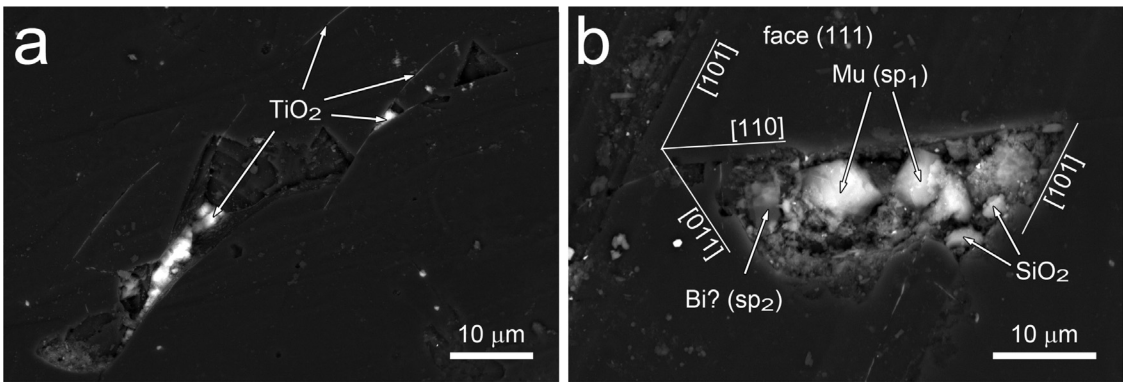

Fig. 4. Irregularities and fractures at the surface of the Constantine diamond. Observations at the scanning electron microscope in backscattered electrons: a: superficial cracks filled with a TiO_2-rich substance; b: microcrystals identified by energy-dispersion spectrometry (Mu: muscovite; Bi: biotite?; silica: quartz?) in a microcavity that displays the negative shapes of diamond.

(13.5–15.6 μm: Fig. 3c) matches those due to alpha decay of ^{238}U (from 12.3 to 16.0 μm, depending on the irradiated material) and the other radionuclides of the same decay chain, ^{226}Ra, ^{230}Th and ^{234}U, which generate slightly larger halos (Gentry, 1974). Since these radionuclides have long half-lives (4.47 Ga for ^{238}U) and because the halos also formed on the rounded edges of the crystal, thus after its transport and sedimentation, the diamond and its host sediment should necessarily be "old".

Keeping in mind these requisites, three main hypotheses can be envisaged for the origin of the Constantine diamonds:

- the primary source could be Miocene ultrapotassic lamproitic rocks that have been recognized in two places within the Constantine region, at Koudiat Anzazza and Kef Hahouner (Raoult and Velde, 1971; Vila et al., 1974) and belong to a belt of lamproites that extends from southeastern Spain to Tunisia (Kaminsky et al., 1993). However, there are several objections to this hypothesis. First of all, the radiohalos most probably exclude an age as recent as Miocene. Moreover, Kaminsky et al. (1993) concluded, on the basis of petrologic and geochemical studies, that the Algerian Miocene lamproites are of too shallow an origin to contain diamond. Finally, the two Algerian occurrences do not belong to the Ghoumel basin and hence cannot be the direct source of the diamonds – at least, if these were really found in the Ghoumel River near Constantine. To sustain this hypothesis, it would be necessary to demonstrate that other lamproites occur in the Ghoumel basin or that Miocene sediments might have acted as an intermediate placer source;
- the MNHN diamond could come from the Saharan deposits situated 1500 km to the southwest (Fig. 1a). This is supported by:
  - the halos that suggest an ancient age similar to that of the Sahara diamonds, some of which also display dark-green and brown radiohalos, present on the rounded surfaces as well (Kaminsky et al., 1990, 1992b; see Section 3),
  - its octahedral habit like 38% of the Bled-el-Mass diamonds (see Section 3.1),
  - its rounded shape suggesting a long transport, also inferred for many Sahara diamonds (Kaminsky et al., 1990, 1992b; see Section 3.1),
  - its rarity, which can be explained by a long distance from the primary source. A direct connection between the Saharan deposits and Constantine during the Quaternary is excluded, because the two regions are separated by the sandy "Grand Erg occidental" that impedes river flows. Sediments like microconglomerates and coarse sandstones that may have acted as intermediate placers are not common upstream of Constantine. The abundant marine Mesozoic sediments, mostly fine-grained limestones and marls (*e.g.*, Joleaud, 1912), are hardly favourable. On the other hand, the Numidian Flysch, dated as Oligocene to Early Miocene, has quite a large extension upstream of Constantine. Thomas et al. (2010) have recently demonstrated, on the basis of detrital zircon ages and palaeocurrent trends, that the Numidian sandstones are derived from the Saharan 'craton' and/or its Early Cretaceous cover; so that they could have served as a secondary source, intermediate between the Saharan diamondiferous formations and the Ghoumel fluvial sediments;
- finally, we cannot rule out the possibility of a hoax (see Section 2.1), and hence of an origin far removed from the Constantine region. It seems strange that the only 3 diamonds ever found near Constantine have been discovered by a single person; as for the diamond sold at Livorno a few years before 1721 (Magalotti, 1721, 1741), the merchant was from Constantine but not necessarily the diamond. Moreover, the diamonds were reportedly found in auriferous sediments, which do not seem to be present in the Ghoumel River at Constantine; some confusion may have arisen with two other rivers of the Constantine province named Oued-Deheb (واد الذهب; *i.e.*, "river of the gold") and known to be auriferous (*e.g.*, Renou, 1848). It should be noted that this pessimistic hypothesis is not incompatible with a Saharan origin, since the only rough diamonds available in Algeria in 1833 were most probably from the Sahara (see below).

3. The Sahara diamonds

3.1. History of the finds

In 1849, the French adventurer Louis Du Couret [1812–1867?], also called Hadji Abd-El-Hamid Bey—he claimed to have converted to Islam—, initiated an expedition across Africa, from Tunis to Cap town (*sic*), for which he received instructions from the "Académie des sciences" (Élie de Beaumont, 1849). The mission actually ended in January 1852 at Touggourt, to the North of the Algerian Sahara, after an order of the French "Ministre de l'Instruction publique" (Anonymous, 1851; Du Couret, 1853). Du Couret brought back from Touggourt countless samples, maps and manuscripts that are still preserved (see Note 1 in Appendix A; Mantran, 1955). Soon afterwards, in 1854, Alexandre Dumas edited a fanciful version of Du Couret's earlier journeys across equatorial Africa, in search of the so-called tailed men of the Niam-Niam tribe (Du Couret, 1854). This hoax discredited Du Couret, so the French "Académie des sciences" did not publish the results of his last mission to Touggourt and the MNHN accepted his samples with much reluctance (AN: AJ/15/545). Du Couret got a bad reputation of amateurishness if not of charlatanism (Emerit, 1956; Hill, 1955) and, after various cases against the French government (AN: 243AP/1) and Alexandre Dumas (BNF: Ms NAF 18918), both accused of not having complied with their commitments, his life ended miserably (AN: F/18/273; Hill, 1955).

Du Couret might have been an *amateur*, but he brought back from the Algerian Sahara various samples, unedited maps and original manuscripts. While he was at Touggourt, he collected information on the geology of Sahara from erudite persons of this region. In particular, Cid-El-Hadj-Abd-El-Kader Ben-Abou-Bekr-Et-Touaty (thereafter named Et-Touaty), born near Aoulef (Fig. 1b), wrote for him in Arabic a manuscript that describes the precious stones of the Sahara, among which are "emeralds" and "diamonds" (see Note 2 in Appendix A; Bargès, 1853). Et-Touaty wrote the following about diamond:

> "As for the diamond, we have found it in our country [*i.e.*, in the Aoulef region, near Akabli?], in the middle of black stones. Since we had no tools to break it, we left it in place. It resembled the grains of pomegranate, in the middle of this darkish mass, reflecting a shiny colour, like Pharaoh's glass, grading from white to yellow. As for the place, we have found the stone between Ouallen and Akabli".

Writing in colloquial Arabic, Et-Touaty uses the Berber name *yamanta* for diamond (يمنتا) instead of the Arabic word *mās* (ماس), but there is no ambiguity, as confirmed by Bargès' translation in French, since *yamanta* or *yamant* is still used in the Algerian dialect. Bargès' translation, which differs slightly from the manuscript (see Note 2 in Appendix A), gives further details: the diamond, "excessively heavy", displays shiny colours, and the diamondiferous black stones are so hard that it is impossible to break them with an iron tool, as they even break iron.

Akabli (26.712°N; 1.370°E) and Ouallen (24.607°N; 1.287°E) are two localities lying ca 250 km apart along the ancient trans-Saharan caravan route from Aïn-Salah (NE) towards Timbuktu (S). Ancient maps and travel records (*e.g.*, Gautier, 1907, 1908; IGN, 1930; Sabatier, 1891) indicate that the route passed between Akabli and Ouallen ca 50 km east of the Bled-el-Mass area (dashed line *in* Fig. 1b), where diamonds have actually been discovered in the 1970s. For the sake of convenience, we will call hereafter the "Reggane region" the diamondiferous area that extends around Bled-el-Mass, between Akabli to the east, the Tidikelt Plateau to the north and the modern town of Reggane to the west (Figs. 1b and 5).

Et-Touaty also provided Du Couret with one "emerald" and two "diamonds" (AS: 14 March 1853; BI: Ms 3817/V/2; see Note 1 in Appendix A). Bargès' version suggests that these specimens have been found on the Tidikelt Plateau, to the NE of Akabli (Fig. 1b), whereas the diamondiferous black stones would have been found to the south: "As for the places where we found the stones that we have brought, [...] you should know that they are between Aïn-Ghar, Tit and Aoulef" (Fig. 1b; see Note 2 in Appendix A). Du Couret was sceptical about these diamonds, since he noted: "two diamond stones?? [question marks by Du Couret]; these two transparent stones that [Et-Touaty] gave to me could be diamond considering their density and transparency" (AS: 14 March 1853). The two crystals were catalogued at the MNHN as "small pebbles of hyaline quartz" of an origin far removed from the Tidikelt region cited by Et-Touaty and Du Couret (MNHN, catalogue Carré 500, n° 28: "may be [...] between Touggourt and Biskra"). It is impossible now to settle the question, since the so-called diamonds are unfortunately missing among what remains of Du Couret's samples (19 out of 66) after 160 years in the "Galerie de minéralogie" at the MNHN. It could be concluded that Et-Touaty's diamonds are doubtful and that Du Couret may have been fooled, but, as we will see, the story is not so simple.

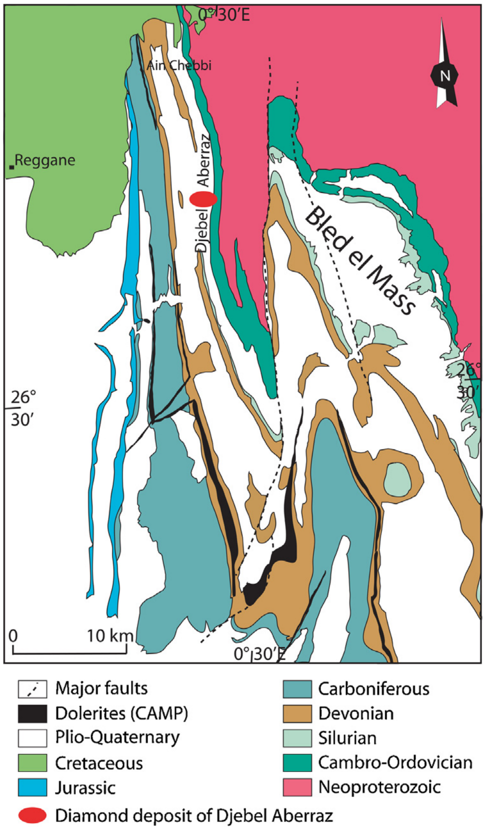

Fig. 5. (Colour online.) Geological map of the Bled-el-Mass area in the Reggane region. Note the Devonian sediments with interbedded oolitic ironstones, the dolerite dykes of the Central Atlantic Magmatic Province (CAMP) and, to the northwest around Reggane Plateau (Tidikelt), the Early Cretaceous that rests unconformably on the other formations.

As for the "emerald" (زمرّد; zumurrud) mentioned by Et-Touaty, the sample that he gave to Du Couret has been catalogued at the MNHN as "fragment of green jasper" (MNHN: catalogue Carré 500, n° 29), but again this so-called emerald is missing from Du Couret's collection at the MNHN. The question of the "emerald" in the Reggane, Touat and Tidikelt regions has been reviewed carefully by Flamand (1897), who considered it plausible that it could be true emerald. On the other hand, while criticizing Et-Touaty's manuscript, he denied the existence of diamond in the same region – wrongly, as we will see. Actually, it is admitted today that the mythic Sahara emeralds, known to the ancient Romans and otherwise called the emerald of the Garamantes after an antique Berber tribe, are not truly emerald in the modern sense but could be any kind of emerald-green semi-precious stone, among which is amazonite (*e.g.*, Monod, 1974).

The first geological survey of the Reggane region was performed around 1900 by Laperrine, Flamand (1897), and mostly by Émile Gautier (1907, 1908) who carried out the geological study and mapping of an area called "Bled-el-Mass" (see supplementary material, SM1). Gautier apparently did not notice that "Bled-el-Mass" means "Country of the diamond" in Arabic (بلاد الماس; *Bilād al-mās* in modern transcription). The topographic maps published since 1930 locate Bled-el-Mass between Reggane and Akabli, at ca 26.61°N–0.62°E (*e.g.*, IGN, 1930).

The first modern discovery of diamond in the Algerian Sahara was made in 1953 by Ranou, at In Zize, in the northern part of the In Ouzzal terrane (western Hoggar: Fig. 1a). The diamond recovered was a rounded crystal of 0.2 carat weight (Kahoui et al., 2008; Kaminsky et al., 1992b; Meindre, 1959; Thébault, 1959; Touahri et al., 1996). In 1958, a carbonado of 0.1 carat was found at Tibeghim near Silet in the central Hoggar, as well as seven fragments of spinel (Meindre, 1959; Touahri et al., 1996). After these first discoveries, an intensive exploration for diamonds was undertaken in the Hoggar in the 1960s–1970s. As a result of these campaigns, one small (0.36 mm) dodecahedral diamond was found in 1969 by V. Izarov in the Tiririne area, in the eastern Hoggar (Kaminsky et al., 1992b).

In light of these poor results, prospecting for diamonds in the Algerian Sahara moved to the north, towards the Reggane and Touat regions where two diamonds had been found in 1975–1976 (Touahri et al., 1996). Between 1978 and 2001, a high concentration of diamonds was discovered in the Reggane region, in the Bled-el-Mass Valley (Fig. 5): 1485 at Djebel Aberraz, 16 to the south of Aïn Chebbi and 26 at Bled-el-Mass (Bouarroudj, 2005; Kahoui et al., 2008, 2012). The diamonds occur in alluvial deposits of Quaternary age that are up to 12–15 m thick. The crystals have rounded shapes with octahedral (38%), dodecahedral (25%) and combined (22%) habits; they range in weight from 1.5 mg to 45 mg (Bouarroudj, 2005), and contain micro-inclusions of sulphides, chromite, chrome diopside and garnet (Kaminsky et al., 1990, 1992b).

In 1989, a diamond was found by M. Wilczynski near El Kseibat (Adrar, Touat region), ca 160 km to the NNW of Reggane (Fig. 1). Since then, more than 19 small detrital diamonds have been recovered in this area (Belghaït, 2003; Kahoui et al., 2012), which makes the El Kseibat placer deposit the second most important concentration of diamonds in the Algerian Sahara.

More recently, new diamond occurrences have been found in the Hoggar (Fig. 1a):

- a diamond was found in 2001 in the Tiririne-Hanane area (ORGM, 2003);
- in 2002, a diamond $1 \times 1 \times 0.35$ mm in size was discovered near Silet (ORGM, 2003);
- three diamonds were found in 2002 in the southern part of the In Ouzzal (western Hoggar; Zerrouki, 2007).

In addition, diamond indicator minerals such as pyrope-rich garnet, chrome spinel and picroilmenite were discovered in an area that stretches on 700 km around Reggane, from the Tanezrouft in the southwest to El Kseibat (Adrar) in the northwest (Fig. 1b; Bouarroudj, 2005; Kahoui et al., 2012). Pyrope, kimberlitic ilmenite, chrome spinel and chrome diopside were also found in the In Ouzzal, Silet and Tiririne areas, in the Hoggar massif (ORGM, 2003; Zerrouki, 2007).

3.2. Insight into the origin

Bled-el-Mass, the "country of the diamond" where diamond has been found in placer deposits in the 1970s, is a few tens of kilometres to the west of Akabli (Figs. 1b and 4). This fact gives credibility to Et-Touaty, who located his diamondiferous "black stone harder than iron" between Akabli and Ouallen, although the two so-called diamonds that he gave to Du Couret are doubtful and might come from another place (see above). Et-Touaty's manuscript insinuates that the ancient Arabs knew the source rock, looked for in vain by modern geologists over the last decades.

What could this rock be? At Bled-el-Mass there are wide dykes and sills of a dark fine-grained volcanic rock (Fig. 5) that could match Et-Touaty's description, and such an origin for the diamond has already been proposed by Thébault (1959). However, these dykes are apparently all tholeiitic dolerites of the Central Atlantic Magmatic Province rather than ultrapotassic lamproitic rocks (Chabou et al., 2007, 2010), so they are not favourable to the presence of diamond.

Other rocks might correspond to Et-Touaty's description. One possibility is the oolitic ironstones interbedded within Devonian sediments that crop out from Bled-el-Mass (Fig. 5) to the region that extends between Akabli and Ouallen (Fig. 1 *in* Guerrak, 1987). These rocks are black, very hard and show oolitic to micro-conglomeratic facies (Guerrak, 1987) that resemble "the grains of pomegranate". This formation, which could have acted as placer, deserves some consideration since it surprisingly matches all the features reported by Et-Touaty.

Modern authors have preferred a kimberlitic origin for the primary source of the diamonds in the Reggane region, without excluding lamproites. They have pointed out that a local occurrence of the primary source in the Bled-el-Mass area is unlikely, as the latter is located outside the craton, in the Pan-African mobile belt, which is not favourable for the emplacement of diamondiferous kimberlites. Lamproite occurrences in the Reggane region cannot be excluded, however, as several diamondiferous lamproite bodies have been discovered within similar mobile belts (*e.g.*, Ellendale lamproitic deposits in western Australia: White et al., 1995). Kahoui et al. (2008) advocated a primary kimberlitic source further west in the Eglab shield of the West African Craton, where Allek and Hamoudi (2008) recognized three target areas favourable for kimberlite emplacement on the basis of geological and geophysical criteria. On the other hand, Semiani and Lardjane (2010) invoked an eastern provenance on geomorphological grounds. Although much older ages have been envisaged (Kechid, 2007), these hypothetical kimberlites could be Jurassic, like the 21 kimberlite bodies recently found in northern Mauritania (Rombouts, 2003); this would be compatible with the presence of indicator minerals reworked in the Early Cretaceous cover.

Northwards of the Reggane region, coarse sediments of the Early Cretaceous, known in northern Africa as "Continental intercalaire" (*e.g.*, Lefranc and Guiraud, 1990), rest unconformably on the Saharan basement and form the Tidikelt Plateau (Fig. 5). Several authors have proposed this formation as an intermediate source, since grains of pyrope with kimberlitic features have been found in it (Kahoui et al., 2012; Kaminsky et al., 1992a,b; Sobolev et al., 1992). Considering that the Bled-el-Mass diamonds are rounded and show typical features of a marine-shore environment, Kaminsky et al. (1992b) suggested that they could originate from the reworking of such Cretaceous sediments cropping out on the Tidikelt Plateau at a few kilometres upstream of the Djebel Aberraz deposit in the Bled-el-Mass area (Fig. 5); a similar origin has been suggested for the El Kseibat occurrence (Kahoui et al., 2012). Besides the two doubtful diamonds that Et-Touaty gave to Du Couret (Bargès, 1853), only one small diamond chip of 0.15 mm has been found on the Tidikelt Plateau (Kaminsky et al., 1992b). Much to the southeast, diamonds are mined from the Continental Intercalaire sandstones of the Central African Republic (*e.g.*, Lefranc and Guiraud, 1990).

The radiohalos described by Kaminsky et al. (1990, p. 79; 1992b) at Bled-el-Mass are of a great importance. They link the Constantine diamond to those of the Sahara, and above all they can provide a key to the recognition of the source rock, which must necessarily be "old" and contain radioactive microcrystals. These spots are observed on the eroded parts of the diamond crystals from Bled-el-Mass (Kaminsky et al., 1990) and from Constantine (Fig. 3), which implies that they formed in a sedimentary rock. In both occurrences, the spots display a regular concentric structure (Kaminsky et al., 1990; Fig. 3c); on the MNHN diamond surface, the halo centres, from which emanated the alpha radiation, are μm-sized and seem arranged along superficial striations or cracks (Fig. 3c). This is hardly compatible with detrital zircon or monazite grains but rather suggests uraniferous microcrystals formed in the sediment at the surface of the diamond crystals.

4. Conclusion

Although the early finds of diamonds at Constantine (1833) and in the Sahara between Akabli and Ouallen by Et-Touaty (ca 1851) are debatable, it can be concluded that the ancient Arabs and/or Berbers knew some of the Algerian diamond occurrences, which were probably the first ever found in Africa in historical times, before the discoveries in South Africa in 1867 (see Boutan, 1886). This is undoubtedly testified to by the Arabic name Bled-el-Mass (*i.e.*, "Country of the diamond"), given in ancient time to a region situated to the west of Akabli in the Reggane region and where diamonds have actually been found. However, like the emerald of the Garamantes, the diamond issue in ancient Algeria is difficult to sort out, since it consists of an inextricable mixture of false and true information, of myth and reality, of imaginary and real diamonds.

The scarce information and samples that are related to these early finds can contribute to unravelling the origin of the diamonds. The Constantine diamonds might have a Saharan origin through an intermediate palaeoplacer, but this occurrence remains uncertain. As for the diamonds of the Reggane region, modern investigations have favoured Jurassic kimberlites that are yet be found in the West African Craton, as a primary source, and the Early Cretaceous cover as a secondary source. Et-Touaty's manuscript insinuates that the ancient Arabs or Berbers knew the source rock, which has been sought in vain for decades by modern geologists, and calls our attention to other possible sources. The diamondiferous "black stone harder than iron" briefly described by Et-Touaty can hardly refer to lamproites, unknown in this region, but it may depict Devonian oolitic ironstones, which deserve some attention, although not considered as a potential diamond placer till now. Finally, the regular concentric radiohalos observed at the surface of the Bled-el-Mass and Constantine diamonds should be considered carefully, as they could lead to the recognition of the intermediate sedimentary source.

There remains some chance to get more information on the diamond occurrences of the Reggane region, by assessing the ancient manuscripts that are preserved in the Touat *khizanat*. The Touat is an archipelago of oases that stretches on ca 150 km to the north of Reggane (Fig. 1b). It has been an important centre of civilization and still preserves numerous Arabic manuscripts (Bouterfa, 2005). Although most of these are devoted to religious or historical matters, a few of them deal with science. Their inventory, which has been initiated a few years ago and is still in progress (Bouterfa, 2005), might provide further information on how and where the diamonds were found by the Berbers and Arabs in the Reggane region.

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Appendix A

Note 1: the original manuscripts of Du Couret's mission are preserved at:

- Archives nationales de France (AN): 243AP/1 (correspondence); F/17/2957/B (reports, maps, correspondence); AJ/15/545 (samples); F/18/273 (demand for a pension);
- Bibliothèque de l'Institut (BI): ms 4483 (letter) and 3817/V/2 (geological samples);
- Archives de l'Académie des sciences (AS): "pochette de la séance du 14 mars 1853" (geological samples, scientific reports);

- Muséum national d'histoire naturelle (MNHN): Carré 467, 500 and 634 (catalogues of geological samples);
- Centre des archives d'Outre-mer, Aix-en-Provence: FR ANOM 50COL1 (correspondence, notes).

Note 2: Et-Touaty's manuscript was written on 14 September 1851, in old Maghribi Arabic script, revised and completed under Et-Touaty's control by Mohammed Abd-El-Djellil, one of Du Couret's companions, and sent from Touggourt on 6 January 1852. Two copies of this manuscript are preserved at the "Archives nationales de France" (AN: F/17/2957/B, pièces 2 & 139); the second is available as supplementary material of this article. Du Couret's report also comprises a French translation of the manuscript by l'abbé Bargès (AN: F/17/2957/B, rapport, pp. 604–607), published later on (Bargès, 1853). This translation differs significantly from the manuscript, so that Bargès had probably another Arabic version at his disposal.

Appendix B. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.crte.2014.03.007.

References

Agricola, G., 1546. De Natura Fossilium. Froben & Episcopius, Basel (lib. VI).

Allek, K., Hamoudi, M., 2008. Regional-scale aeromagnetic survey of the Southwest of Algeria: a tool for area selection for diamond exploration. J. Afr. Earth Sci. 50, 67–78.

Anonymous, 1835a. Diamonds at Algiers. Am. J. Sci. Arts 28, 394.

Anonymous, 1835b. Diamonds in Africa. Rec. Gen. Sci. 1, 475.

Anonymous, 1835c. Die Diamanten Afrikas. Pharm. Ztg. Apoth.-Ver. Noerd. Dtschl. 9, 9–11.

Anonymous, 1851. Nouvelles des missions. Archives des missions scientifiques et littéraires : choix de rapports et instructions publié sous les auspices du ministère de l'Instruction Publique et des Cultes. 2, 407–408.

Bargès, A., 1853. Le Sahara et le Soudan ; documents historiques et géographiques recueillis par le Cid-el-Hadj-Abd'-El-Kader-Ben-Abou-Bekr-Et-Touaty, avec un alphabet touareg inédit. Rev. Orient Alger. Colonies 13, 73–91.

Belghaït, T., 2003. Traitement des échantillons volumineux des dépôts plio-villafranchiens diamantifères de la Hamada Chemmar (El Kseibat-Ougarta). In: 2[e] séminaire national de stratigraphie ; recueil des résumés, Beni Abbes, Algérie, p. 46.

Bouarroudj, M.T., 2005. L'exploration du diamant en Algérie : principaux résultats et perspectives. In: Colloque sur l'état de la Recherche et du Développement du secteur minier dans le monde arabe, Rabat, 13–15 déc. 2005.

Boutan, E., 1886. Le diamant. Dunot, Paris (323 p.).

Bouterfa, S., 2005. Les manuscrits du Touat : le Sud algérien. Éd. Barzakh, Alger, [102 p.]

Chabou, M.C., Bertrand, H., Sebai, A., 2010. Geochemistry of the Central Atlantic Magmatic Province (CAMP) in southwestern Algeria. J. Afr. Earth Sci. 58, 211–213.

Chabou, M.C., Sebai, A., Feraud, G., Bertrand, H., 2007. Datation $^{40}Ar/^{39}Ar$ de la province magmatique de l'Atlantique central dans le Sud-Ouest algérien. C. R. Geoscience 339, 970–978.

Coquand, H., 1854. Description géologique de la province de Constantine. Mem. Soc. geol. France 2[e]s (1) (155 p. + 5 pl).

d'Avezac de Castera-Macaya, P., 1835–1836. Note. In: Ritter, K. (Ed.), Géographie générale comparée [...]. Traduit de l'allemand par E. Buret et E. Desor. Paulin, Paris, pp. 389–417.

Du Couret, L., 1853. Mémoire à Sa Majesté Napoléon III, empereur des Français, par le hadji Abd-el-Hamid Bey [...] sur les résultats de la mission officielle que ce voyageur vient de remplir en Afrique. Pommeret et Moreau, Paris (16 p.).

Du Couret, L., 1854. Voyage au pays des Niam-Niams ou hommes à queues par Hadji Abd-el-Hamid Bey ; avec un portrait d'un Niam-Niam et une notice biographique sur l'auteur par Alexandre Dumas. Martinon, Paris (102 p.).

Dufrénoy, A., 1834. Sur les diamants des environs de Constantine. Bull. Soc. geol. France 4, 164.

Dureau de La Malle, A., 1837. Province de Constantine, recueil de renseignemens pour l'expédition et l'établissement des Français dans cette partie de l'Afrique septentrionale. Gide, Paris (xvi-315 p.).

Élie de Beaumont, L., 1838. Rapport de la Commission chargée, sur l'invitation de M. le ministre de la Guerre, de rédiger des instructions pour une exploration scientifique de l'Algérie. Instructions pour la géologie. C. R. Hebd. Seances Acad. Sci. France 7, 142–182.

Élie de Beaumont, L., 1849. Voyages scientifiques. Instructions demandées par M. le Ministre de l'instruction publique, et destinées à M. le colonel Ducouret. Minéralogie et géologie. C. R. Hebd. Seances Acad. Sci. France 29, 211–212.

Emerit, M., 1956. Un collaborateur d'Alexandre Dumas : Ducouret Abd al-Hamid. Cah. Tunis. 4, 243–249.

Flamand, G.B.M., 1897. Productions du Touat ; productions minérales. Aperçu général sur la géologie du Bassin de l'Oued Saoura et des régions limitrophes. In: Lacroix, N., de La Martinière, H.P. (Eds.), Documents pour servir à l'étude du Nord-Ouest africain. Gouvernement général de l'Algérie, service des affaires indigènes, Alger (III, 241–307, 473–540).

Flandin, J.B., 1835. Prise de possession des trésors d'Alger : requête présentée par M. Flandin, sous-intendant militaire. Jules Didot l'Aîné, Paris (32 p.).

Fournel, H., 1849–1854. Richesse minérale de l'Algérie, 2 vol. Imprimerie nationale, Paris (xvii-476, xi-240 p. + atlas [20 pl.]).

Gautier, E.-F., 1907. Études Sahariennes. Ann. Geogr. 16, 46–69.

Gautier, E.-F., 1908. I. Sahara algérien. In: Gautier, E.-F., Chudeau, R. (Eds.), Missions au Sahara, 2 vol. A. Colin, Paris (+ pl. et cartes).

Gentry, R.V., 1974. Radiohalos in a radiochronological and cosmological perspective. Science 184, 62–66.

Guerrak, S., 1987. Metallogenesis of cratonic oolitic ironstone deposits in the Bled-el-Mass, Azzel Matti, Ahnet and Mouydir basins, Central Sahara, Algeria. Geol. Rundsch. 76, 903–922.

Guyon, 1834. Sur l'ancienne Cirta, aujourd'hui Constantine. Monit. Alger. 105, (also: n[o] 94, 9 nov. 1833).

Heeren, A.H.L., 1799. Handbuch der Geschichte der Staaten des Alterthums, mit besonderer Rücksicht auf ihre Verfassungen, ihren Handel und ihre Colonien, zum Gebrauch öffentlichen Vorlesungen. J.G. Rosenbuch's Wittwe, Göttingen (xii-576 p.).

Héricart de Thury, L.E., 1840. Découverte de diamants en Algérie. Rev. Encyclopedique Connaissances Hum. Part. Sci. 10, 571.

Hill, R., 1955. Louis du Couret. Fr. Stud. 9, 143–153.

IGN, 1930. Carte du Sahara au 200 000[e] ; feuille Reggane, NG-31-XIII ; 1[re] éd. [+2[e] éd., 1967]. Institut Géographique National, Paris.

Joleaud, L., 1912. Étude géologique de la chaîne numidique et des monts de Constantine, Algérie. Montane Sicardi et Valentin, Montpellier (439 p.).

Kahoui, M., Kaminsky, F., Griffin, W.L., Belousova, E., Mahdjoub, Y., Chabane, M., 2012. Detrital pyrope garnets from the El Kseibat area, Algeria; a glimpse into the lithospheric mantle beneath the north-eastern edge of the West African Craton. J. Afr. Earth Sci. 63, 1–11.

Kahoui, M., Mahdjoub, Y., Kaminsky, F., 2008. Possible primary sources of diamond in the North-African diamondiferous province. In: Ennih, N., Liegeois, J.P. (Eds.), The boundaries of the West African Craton. Geological Society Special Publications 297, London, pp. 77–109.

Kaminsky, F., Kolesnikov, S.K., Petelina, N.A., Khamani, M., Khenni, A., Khufani, M., Verzhak, V.V., Azzi, A., 1992a. Minerals associated with diamond in the Algerian Sahara [in Russian]. Mineralogicheskiy Zh. [Kiev] 14, 15–25.

Kaminsky, F., Konyukhov, Y.I., Verzhak, V.V., Khamani, M., Khenni, A., 1990. Diamonds from the Algerian Sahara [in Russian]. Mineralogicheskiy Zh. [Kiev] 12, 76–80.

Kaminsky, F., Romanko, Y., Kolesnikov, S., Salkhi, M., 1993. Lamproites of northern Algeria. Int. Geol. Rev. 35, 235–252 (translated from: Izvestiya Akademii Nauk SSSR. Seriya Geologicheskaya, 1992, issue 10, pp. 56–71).

Kaminsky, F., Verzhak, V.V., Dauev, Y.M., Buima, T., Boukhalfa, L., Kaui, M., Salhi, A., Slugi, M., 1992b. The North-African diamondiferous province. Russ. Geol. Geophys. 33, 91–95.

Kechid, S., 2007. Hypothèse d'une accrétion océanique éburnéenne et ses implications sur l'origine des kimberlites et éclogites sahariennes (Algérie). Bull. Serv. Geol. Nat. 18, 263–275.

Lacroix, A., 1893–1913. Minéralogie de la France et de ses colonies : description physique et chimique des minéraux, étude des conditions géologiques de leurs gisements, 5 vol. Baudry, Paris.

Lefranc, J.P., Guiraud, R., 1990. The Continental Intercalaire of northwestern Sahara and its equivalents in the neighbouring regions. J. Afr. Earth Sci. 10, 27–77.
Magalotti, L., 1721. Sopra un intaglio, in un diamante. A Monsignor Leone Strozzi. Lettera XVII. Lettere scientifiche ed erudite del conte Lorenzo Magalotti. per i Tartini e Franchi, Firenze (xxiv-303 p.).
Magalotti, L., 1741. Lettere familiari del conte Lorenzo Magalotti. G. Bettinelli, Firenze (xvi-271 p.).
Mantran, R., 1955. Une relation inédite d'un voyage en Tunisie au milieu du 19e siècle. Cah. Tunis. 3, 474–480.
Meindre, M., 1959. Principales minéralisations du Hoggar (Sahara algérien). Chron. Mines Outre-Mer 271, 9–22 (+ carte).
Monod, T., 1974. Le mythe de l'émeraude des Garamantes. Antiquites Afr. 8, 51–66.
Nasdala, L., Grambole, D., Wildner, M., Gigler, A.M., Hainschwang, T., Zaitsev, A.M., Harris, J.W., Milledge, J., Schulze, D.J., Hofmeister, W., Balmer, W.A., 2013. Radio-colouration of diamond: a spectroscopic study. Contrib. Mineral. Petrol. 165, 843–861.
ORGM, 2003. Silet. Découverte d'un grain de diamant. Bull. Prospect 20, 1.
Papier, A., 1873. Essai d'un catalogue minéralogique algérien. Bull. Acad. Hippone 11, 5–211 (+ Tables).
Péan, P., 2004. Main basse sur Alger : enquête sur un pillage, juillet 1830. Plon, Paris (271-[12] p.).
Raoult, J.-F., Velde, D., 1971. Découverte de trachytes potassiques à olivine et d'andésites en coulées dans le Miocène continental au Sud du Kef Hahouner (Nord du Constantinois, Algérie). C. R. Acad. Sci. Paris Ser. D 272, 1051–1054.
Renou, E., 1848. Description géologique de l'Algérie. Exploration scientifique de l'Algérie. Imprimerie nationale, Paris (iv-182 p. + 4 pl).
Rombouts, L., 2003. Distribution of diamonds and kimberlites on the Reguibat craton, Mauritania. In: 8th International Kimberlite Conference. Victoria, Canada, 22–27 June 2003, (abstract), p. 14.
Sabatier, C., 1891. Touat, Sahara et Soudan : étude géographique, politique, économique et militaire. Société d'éditions scientifiques, Paris (336 p.).
Semiani, A., Lardjane, T., 2010. Quelle origine pour les diamants de Reggane ? In: 1er Colloque international sur la géologie du Sahara algérien : ressources minérales, hydrocarbures et eau, Ouargla, 5–7 déc. 2010, pp. 205–209.
Sobolev, N.V., Afanas'yev, V.P., Pokhilenko, N.P., Kaminsky, F.V., Tarasyuk, O.N., Henni, A., 1992. Pyropes and diamonds from the Algerian Sahara, Doklady. Earth Sci. Sect. 326, 151–157.
Thébault, J.Y., 1959. Problème de la recherche du diamant en pays saharien et plus précisement au Hoggar. Bull. Sci. Econ. Bur. Rech. Min. Alger. 6, 65–81.
Thomas, M.F.H., Bodin, S., Redfern, J., Irving, D.H.B., 2010. A constrained African craton source for the Cenozoic Numidian Flysch: implications for the palaeogeography of the western Mediterranean basin. Earth Sci. Rev. 101, 1–23.
Touahri, B., Fabre, J., Piboule, M., Kaddour, M., 1996. Les diamants du Bled-el-Mass (Touat) : contexte géologique. Mem. Serv. Geol. Alger. 8, 159–172.
Vila, J.-M., Hernandez, J., Velde, D., 1974. Sur la présence d'un filon de roche lamproïtique (trachyte potassique à olivine) recoupant le flysch de type Guerrouch entre Azzaba (ex-Jemmapes) et Hammam-Meskoutine, dans l'Est du Constantinois (Algérie). C. R. Acad. Sci. Paris, Ser. D 278, 2589–2592.
Ville, L., 1869. Notice sur les gîtes minéraux et les matériaux de construction de l'Algérie. Ann. Mines 16, (70 p.).
White, S.H., de Boorder, H., Smith, C.B., 1995. Structural controls of kimberlite and lamproite emplacement. J. Geochem. Explor. 53, 245–264.
Zerrouki, A., 2007. Principaux résultats et perspectives de l'exploration du diamant en Algérie. In: 6e séminaire de géologie pétrolière, Boumerdès, Algérie, 15–16 avril 2007.