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Tissint Meteorite: New Mars Meteorite fall in Morocco

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Abstract
The existence of Martian meteorites in the region of Tata had been notified to a group of scientists of the Ibn Zohr University of Agadir, Morocco, at the beginning of January 2012 by a nomad of Tata who had found a small fragment in the region. A soon as a scientific expedition arrived at the place of the meteorite fall, the members of the laboratory of Geo-heritage and Geo-materials science collected the debris of this Martian meteorite and many information's.
The Tissint fireball is the only fireball to have been observed and reported by numerous witnesses across the south-east of Morocco. The event was extremely valuable to the scientific community; show an extraordinary and rare event and were also the brightest and most comprehensively observed fireball in Morocco's known astronomical history. Now we are in a position to draw the distribution ellipse of the fall, which starts on Jbel Al Gallab continues in the east-south-east direction above big rocky plateaus.

Keywords: Mars meteorite, Tissint, fall, Morocco, strewnfield

1. Introduction
A meteoritic body entered the earth's atmosphere in the south-east skies of Tata, Morocco, On Sunday July, 18th, 2011 at 2 o'clock in the morning. Its interaction with the atmosphere led to brilliant light flashes accompanied with detonations. The apparent magnitude of the fireball was brighter than -20. A large number of fragments survived the fireball phenomena. The saharian nomads living in the surrounding region then came together for searching the debris of this extraterrestrial rock. The first fragment had been discovered at the end of December. About a hundred persons came to the region
of Tissint (Tata, Morocco) and about fifty fragments had been collected by the nomads, traders and hunters with some knowledge about extraterrestrial rocks. This extraterrestrial debris became a source of revenue and this explains the trade value of these rocks, which appears to be reached 1000 dollars for one gram, to be paid directly in cash in the desert.
Ahmed Sghiwar, a nomad who found a small block of 5 grams in the region, contacted at the beginning of January 2012 the author, Prof. Ibhi Abderrahmane, scientist and collector of meteorites at the Ibn Zohr University in order to inform him about the findings of freshly fallen meteorites in the region of Tata. Immediately a scientific expedition formed by 2 teaching researchers and two student of the Geo-heritage and Geo-materials Science Laboratory went to the fall area equipped with a modern navigation and detection instruments. The member of this team succeeded in collecting debris of this Martian meteorite and information on the fall. We present in this paper results of systematic search made over a period of one month to collect the data of this meteorite which has been named as Tissint, where a large number of fragments were found within a seven months of the fall.

The Martian meteorite of Morocco
Morocco is an outraging place for the finding of meteorites thanks to the large extensions of the surfaces of the prospection areas of the Sahara, which extend on thousands of square kilometers

without any obstacle. These areas are very dry with a semi-arid climate and very low erosion, so the meteorites can be preserved for a long time [1, 2]. Since the year 2000 the discovering of meteorites in the hot desert of South Morocco increased steadily [3, 4, 5, 6]. Some of the samples have a very high scientific value. One counts actually 20 Moroccan Martian meteorites [7, 8] of 50 Martian meteorites found worldwide until today and one of the Moroccan Martian meteorites is a very rare sample (NWA 2737) because it is the second known Chassignite. These rare meteorites create restless activities around the world, since the NASA announced in August 1996, that the proof of microfossils might be found in a Martian meteorite.

The meteorite of Tata is the first fall of a Martian meteorite observed in Morocco and the 5th worldwide. Historically, watched falls took place only once in 50 years or more (1815 in France, 1865 in India, 1911 in Egypt and 1962 in Nigeria). This is once in the career of a human being. The following table gives the details of the five falls of Martian meteorites.

Date of discovery and classification of Martian meteorite falls

Name	Find Location	Year	Classification	Mass (kg)
Chassigny	Marne, France	1815	Dunite	4
Shergotty	Bihar, India	1865	Basalt	5
Nakhla	Alexandria, Egypt	1911	Clinopyroxenite	10
Zagami	Katsina, Nigeria	1962	Basalt	18
Tissint	Tata, Morocco	2011	Basaltic shergottite	17

2. The Martian meteorite of Tissint

The meteorite of Tissint is the first fall of a Martian meteorite observed in Morocco and the 5th worldwide [9]. It is classified as a depleted permafic olivine-phyric shergottite [10]. This is once in the career of a human being. The nomads of the region of Tissint (a region in the east of Morocco, situated 60 km to the south-east of the town of Tata nearby the Moroccan-Algerian border) became to know that the pieces of rocks collected nearby their camp of the beginning of January 2012 had been in fact Martian meteorites. They started a search for the other pieces of the same fall and indeed other pieces were found in a long drawn-out zone of about 15 km in length. Most fragments have a small size, which is explained by the explosive nature of the bolide. Most fragments were found to have a well developed crust. 16 of the 51 fragments are completely crusted, 11 are partly crusted and 24 fragments have crusts only on a small fraction of the surface area (figure 1). In the sands of Oued El Myit and Oued Bou Ifasouan the men and women of the nomads used sieves in order to find debris if not even dust of this extraterrestrial rock.

The bolide broke into parts, when he entered the earth's atmosphere, throwing numerous fragments into similar tracks ending in an extended zone called the ellipse of the fall. Further the nomads and the military reported that it was at first yellow in color, and then turned green before it appeared to split into two parts. One portion appeared to fall in the valley, while another portion was seen to strike a prominent mountain (El Aglab). It is estimated that the bolide entered the Earth's atmosphere at a highly inclined angle southeast of Tata. The fireball detonated at a height of approximately 10 km above the point location 29° 31' N, 7° 36' W, close to the Oued Drâa in the Tissint Region. An accurate speed has not been obtained; however, on average, meteors and fireball move through the atmosphere at speeds up to and greater than 15 km/s.

The measurement of the magnetic susceptibility performed by the scientific team of the Ibn Zohr University on two fragments of the meteorite of Tata showed that Log X (10^{-9} m^3/kg) is about 3.40. This value corresponds well to the confidence interval of the SNC meteorites (shergottite, nakhlite and chassignite) in the alignment chart given by Folco et al. [11].

The isotopic analysis of oxygen of acid-washed subsamples by laser fluorination done by Tanaka R. of the Institute for Study of the Earth's Interior, Okayama University [12] confirmed that this meteorite is a shergottite of the red planet. The analysis showed respectively $\delta^{17}O$ = 2.849, 2.892; $\delta^{18}O$ = 4.844, 4.943; $\Delta^{17}O$ = 0.299, 0.290 per mil. The geochemical study of this rock done by Chen et Herd at University of Alberta, Canada [13], shows that the chemical composition of the powder analysed by ICPMS has a value of

Sm/Nd = 0.646, indicating that this specimen has affinities with the depleted compositional group of shergottites. One particularity of the beginning scientific work, which is unique in the sense, that the just starting research work about this meteorite, showed that this is a very fresh rock and that the megacrysts of olivine show crystal defects filled generally with fluids. These information will be very interesting for the study of fluids of the red planet.

Fragment is completely crusted.

Fragment is partly crusted.

Crust only on a small fraction.

Debris of Tissint meteorite.

Figure 1 : Samples of Martian meteorites Tissint (Tata, Morocco)

3. The strewnfield of the Martian meteorite of Tissint

The strewnfield of Tissint is situated in about 60 km of linear distance to the south-east of Tata in the area of the rural commune of Tissint. It is covered within the topographic map 1: 100.000th of Tata (Figure 2). The Lambert coordinates are x = 280 800 and y = 280 100 and the GPS coordinates are “29° 31’ 2881N ; 7° 36’ 4472 W”.

In fact this fall took place in the heart of a usual prospection area of the Arabic nomads living in the military zone between Morocco and Algeria, which have some knowledge of meteorites and are looking for meteorites for the whole year on their wandering through the desert (figure 3). In several weeks of a deep search the nomads collected about 17 kg of fragments of the meteorite, some of them not passing 1 gram.

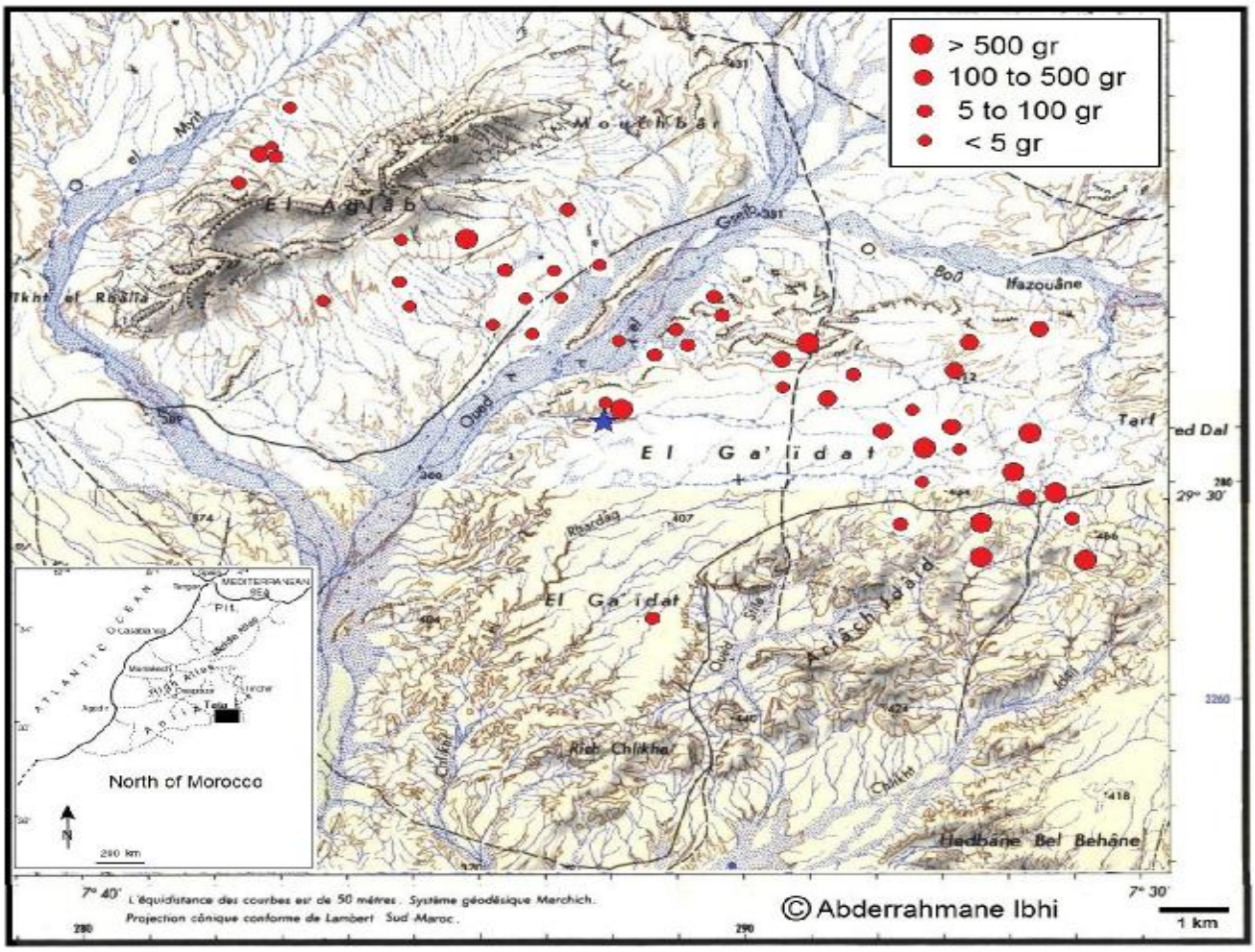

Figure 2 : Dispersion of Tissint fragments in Oued Drâa. Topographic map 1:100.000th of T ata, Morocco.

Figure 3 : Nomads collecting debris of the Martian meteorite of Tissint (Tata Morocco).

We would take months to explore the entire ellipse of the fall due to the rough ground, the difficulties to access and the overall uneasy conditions. Nevertheless reliable coordinates of most of the falling places had to be got in order to determine the strewn field of the meteorite of Tata, so it had been necessary to move with 4WD cars and sometimes for narrow foot paths even with motorbikes. Additionally the nomads had to be paid for leading the scientists to the places of their findings in order to get their coordinates. Each fragment found was coded and documented with respect to its position in the field. The position of the fragments could be ascertained conveniently in the 1 x 1 km grid map with respect to local landmarks (figure 4). To date a total of nominally 50 fragments weighing about 17 kg have been found. The largest fragment weighed 1100 g and was found accidentally, near the eastern tip of the strewnfield. An important reason for the low efficiency is the similar appearance of the crusted Tissint stones and the dark colored sandstone fragments found extensively in the strewnfield. The nomads, however, quickly learnt to distinguish meteorite pieces from native rock fragments.

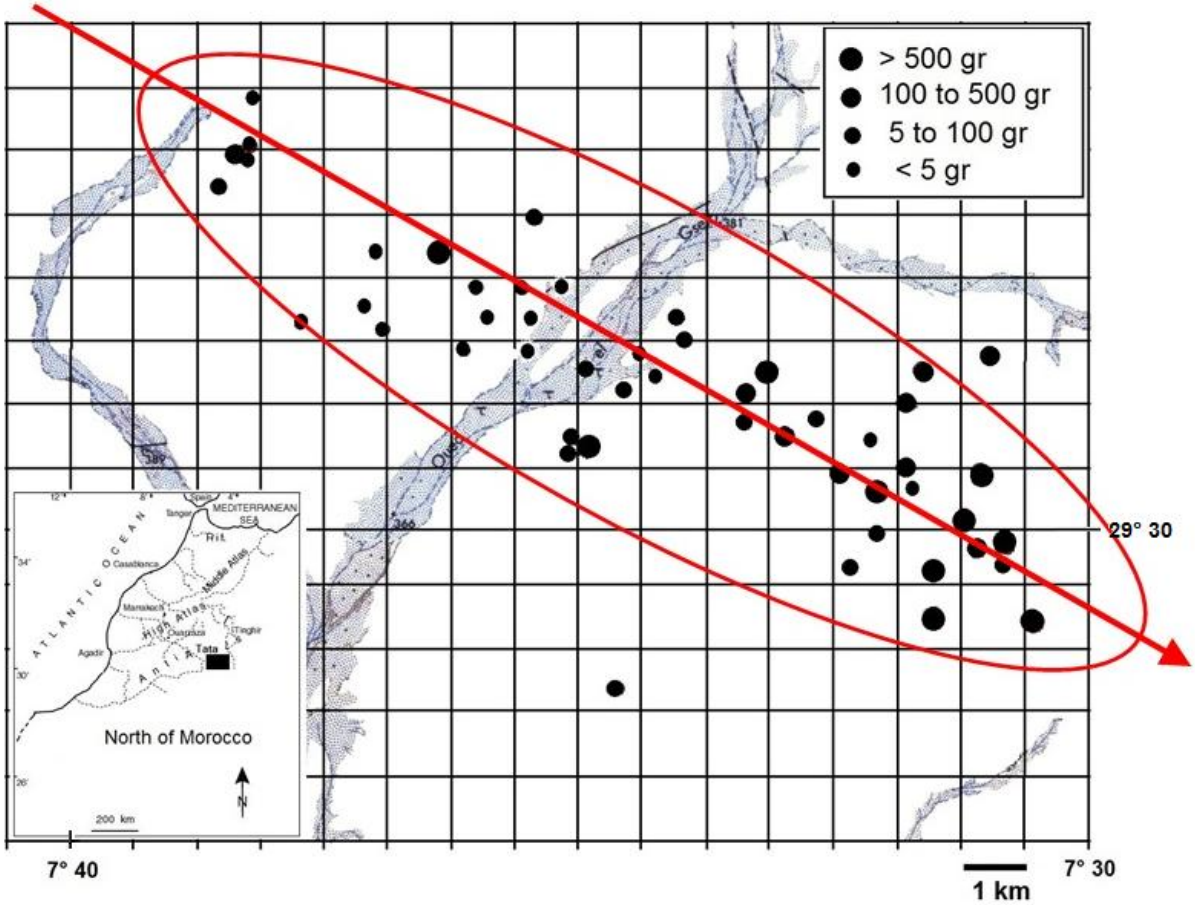

Figure 4 : show the distribution of meteorites in the strewnfield and approximate size of the fragments found at different locations.

4. Discussion and conclusion

Tissint represents the fifth witnessed fall of a Martian meteorite (the last one being Zagami 49 years earlier) and the first such olivine-phyric shergottite example [10]. Represents the freshest sample of this important group of Martian meteorites and thus provides an unprecedented opportunity to study pristine material derived from the depleted Martian mantle.

In the field, we collected the coordinates of the most significant masses and met eyewitnesses. The coordinates are reported on the 1/100,000th map, with the inferred trajectory NW to SE. This information is in accordance with the reported testimonies.

The strewnfield of this meteorite fall extends at least 15 km from the west-north-west to east-south-east, which is also the flight direction of the meteorite after the observations of the nomads. More than 51 fragments of Tissint meteorite weighing about 17 kg have been recovered from the strewnfield of 60 km^2

area. Information about their position in the strewnfield is available in the case of practically all the fragments. Each fragment has been coded and information on the crusting of the surfaces has been documented.
In view of the relatively high efficiency of collection for the Tissint fragments probably higher than for any of the meteorite showers reported earlier, we have made a detailed analysis of the number and mass distribution of meteorite fragments as well as their location in the strewnfield. These data are a true heritage and has to be archived.

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