

Meteorite and bright fireball records from Cuba

YASMANI CEBALLOS IZQUIERDO^{1*}, JOHANSET ORIHUELA², GABRIEL GONÇALVES SILVA^{3,4},
MARCELO ZURITA^{4,5}, DANIELA CARDOZO MOURÃO⁶ and HENRY DELGADO MANZOR⁷

¹ Biblioteca Digital Cubana de Geociencias, Cuba; yasmaniceballos@gmail.com

² Department of Earth and Environment (Geosciences), Florida International University,
Miami, Florida 33199, USA

³ Instituto de Química, Universidade de São Paulo, São Paulo, Brazil

⁴ Brazilian Meteor Observation Network, Nhandeara, São Paulo, Brazil

⁵ Associação Paraibana de Astronomia (APA), Brazil

⁶ Grupo de Dinâmica Orbital e Planetologia, UNESP – São Paulo State University, Brazil

⁷ Sociedad Espeleológica de Cuba, Cuba

Abstract: This paper provides a comprehensive catalog of meteorite landfalls from existing records for the Cuban archipelago. We register a total of two official meteorites, and eight unofficial, empirically unconfirmed, or questionable. The oldest record extends back to 1833, whereas the oldest recovered meteorite pertains to an event in 1844 for which fragments were hitherto unpublished. Although several specimens likely constitute new records, they have not been formally analysed, and thus their classification as meteorites is dubious or pending. Our records draw attention to the frequency of meteorite landfall as a field that still requires development in Cuba. Furthermore, this study highlights the importance of amateur and professional observers and collectors to improve the record, and creates a historic review to preserve the memory of fireball and meteorite related events in Cuba. Moreover, it provides a basis for future analyses that may help to confirm or reject some of these records.

Key words: meteorite catalog, fireball, meteor, Viñales, Cuba

Graphical abstract



Highlights

- The meteoritic record documented from the island of Cuba from 1833 to 2021 is reviewed.
- Las Canas, Lajas and Ramón de las Yaguas, should be officially classified in order to be recognized as a true meteorite record.
- Mango Jobo, Boyeros, La Lisa, and Güira de Melena, are meteorite fragments and not true meteorites.
- A trajectory for the Viñales bolide is estimated, as an alternative very similar to the trajectory estimated by Zuluaga et al. (2019).

1. Introduction

Hundreds of tons of cosmic debris make landfall every year on Earth. Meteorites represent natural solid objects that survived the meteor phase in a gaseous atmosphere without being completely vaporized and reach the Earth's surface (Commission F1 of the International Astronomical Union, 2017). Any meteor brighter than magnitude -4 is called a fireball or bolide, whereas a meteor brighter than magnitude -17 is often called a super bolide (l.c.). Although meteorites and fireball events are a commonly studied phenomenon throughout the planet, from Cuba they have been insufficiently studied and scantily reported.

Meteorite falls have been registered in Cuba at least since 1833, while the first recovered meteorite dates to 1844

(Greg, 1854; Harris, 1859; Lores, 1977; Meunier, 1867). Two records were provided by Rodríguez-Ferrer (1876), unfortunately, each without date or available specimens: one was referred to an iron-type from a poorly identified locality mentioned as “dos leguas de Cienfuegos, cerca de la confluencia del arroyo Saladito y río Salado” (“two leagues from Cienfuegos, near the Saladito stream and Salado River”), and the other was a meteorite shower that would have caused great destruction in Baracoa, eastern Cuba. The latter one seems to have occurred on August 14, 1833, and partially destroyed the local church of Baracoa (Lores, 1977).

One of the oldest reports in Cuba is of an iron-meteorite known as Cuba, found much before 1871, whose main

mass is stored in the collection of the National Museum of Natural Sciences of Madrid (Solano y Eulate, 1872; see also Farrington, 1909). The most spectacular recorded landfall occurred on February 1, 2019, in the Viñales Valley (Pinar del Río province, western Cuba) with a shower of fragments that attracted interest of the local and international scientific community, giving rise to several scientific publications (Ceballos-Izquierdo, 2019; Garcia, 2019a, b, c; Iturralde-Vinent et al., 2019; Vázquez-Torres and Pino-Torga, 2019; Zuluaga et al., 2019; Yin and Dai, 2021).

However, only a few detailed descriptions of Cuban meteoritic material along with pertinent information on both landfall and fireball sightings have been published or divulged, and several require revision. Here we provide an actualized summary of all known registered meteorites or supposed meteorites available from the island. Our synopsis is based on published accounts, mostly available on the Cuban Digital Library of Geosciences (Ceballos-Izquierdo and Iturralde-Vinent, 2011), but also include unpublished or unreported specimens. The latter collection contains multiple articles on bright fireballs and meteorites that occurred on the Cuban archipelago, which overall seem to suggest that meteorite sighting or landfalls are relatively frequent, but whose evidence still lacks further attention and research (Ceballos-Izquierdo, 2016, 2019).

The goal of this contribution is to provide a comprehensive record of meteorites for the island of Cuba. However, it do not intend to classify the known specimens based on their petrological or mineralogical qualities or verify their current identification. In most cases, present records are known only from small samples recovered or witness accounts and lack high-quality photographs or modern mineralogical analyses that could aid in the reaffirmation of their classification or their dismissal as a true meteorite. Our aim has been solely to provide a record that can help towards that future endeavour, as a contribution to the meteorite record of Cuba.

2. Materials and methods

The Cuban record of meteorites is sparse, with only two confirmed and eight unclassified, and many times poorly studied, specimens known from the island. Most of the samples are small, ranging in size between a few centimeters to about 20 cm (e.g., one of the fragments from the Viñales event, Viñales No. 1 Ancón, in Vázquez-Torres and Pino-Torga, 2019). Only five of the records have available specimens for study being stored at institutions, museum or private collections, the others have been lost. The lost specimens are listed on here for future reference.

Many of the meteorite-fireball records are based on forgotten documentation, short papers of limited circulation, newspaper articles, and museum records. Some of the

published papers, are available on the Cuban Digital Library of Geosciences (<http://www.redciencia.cu/geobiblio/inicioEN.html>) (Ceballos-Izquierdo and Iturralde-Vinent, 2011).

Acronyms of collections and institutions mentioned throughout the text in which reside Cuban specimens or material are as follow: Center for Meteorite Studies, Arizona State University, Arizona, United States (ASU), European Centre for Research and Teaching in Environmental Geosciences, France (CEREGE), Field Museum of Natural History, Chicago, United States (FMNH), Institute of Geophysics and Astronomy of Cuba (IGA), Institute of Geophysics and Planetary Physics, University of California, Los Angeles, United States (UCLA), Institute of Meteoritics, University of New Mexico Albuquerque, United States (UNM), Institute of Geology of Ore Deposits, Petrography, Mineralogy, and Geochemistry, Russian Academy of Sciences, Moscow, Russia (IGEM), Canarian Museum of Meteorites (MCM), Museum of Natural Sciences in Madrid, Spain (MNCN), National Museum of Natural History of Cuba (MNHNCu), Natural History Museum of Vienna, Austria (NHMV), Smithsonian National Museum of Natural History, Washington (USNM), Vernadsky Institute of Geochemistry and Analytical Chemistry, Russia (VERNAD).

3. Results and discussion

3.1. Record of Cuban meteorites

Available data on each specimen is summarized in the accompanying Table 1 and a location map is provided in Fig. 1. Several records lack high quality photographs or other direct evidence that could ascertain their identification as an official meteorite. Further, it is acknowledged that some specimens discussed here are of questionable identification, and some may not represent actual meteorites but are included in this work because they are part of the published record – for the sake of completeness. Anyway, here is provided a record of the verified and unverified meteorites, and fireball incidents for the island of Cuba.

Las Canas, 1844

A 0.3 g crusted fragment of stone, with an old handwritten label that reads “Las Canas, St. Andras, Cuba, 2. Oct 1844” is hosted at the ASU’s Carleton B. Moore Meteorite Collection under the catalog number 2 051 (Fig. 2). According to the cataloguer Laurence Garvie (pers. comm., 2019), the institution acquired this piece from the Amherst/Shepard collection. There is no information on how it arrived at Amherst College in Massachusetts. The catalog and museum archive provides only a number (164) but no further data, and thus the manner of the acquisition remains unknown.

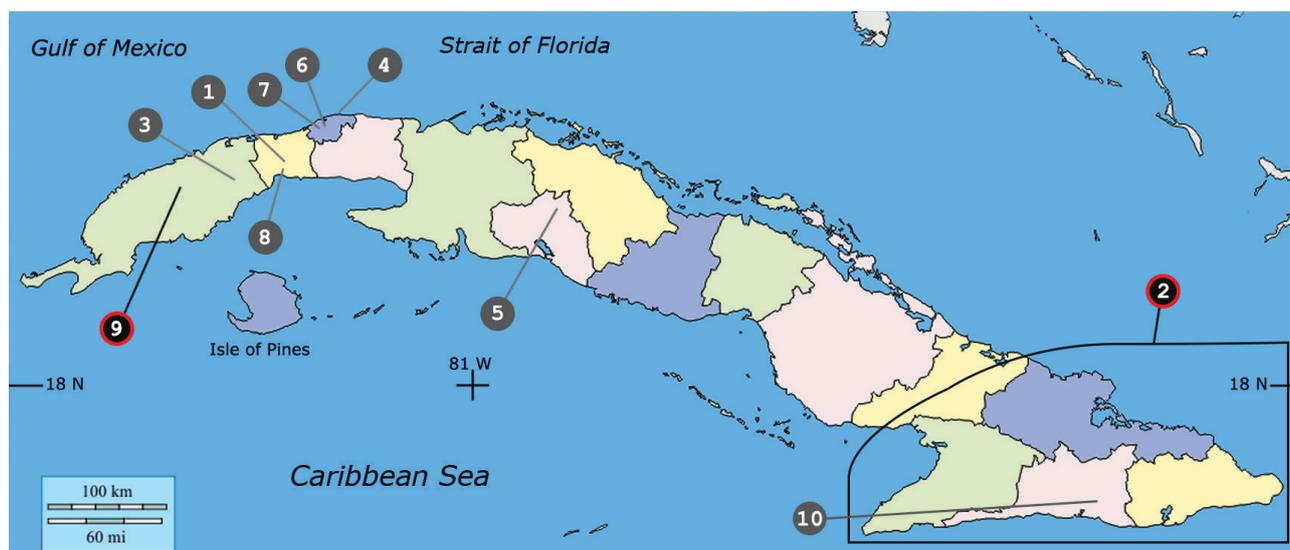


Fig. 1. Map of Cuba with the location of the two Cuban official meteorites (in black with red rim) and the unofficial, pending or very doubtful specimens (in grey) (the numbers correspond to those in Table 1). The locality of the Cuba meteorite (2) is reported as the “Eastern Department” that includes the current provinces of Las Tunas, Holguín, Guantánamo, Granma, and Santiago de Cuba. Scale bar = 100 km.

Tab. 1

List of Cuban specimens investigated in this paper. EUC? – HOW? = Eucrite? or Howardite? OC = ordinary chondrite. A (*) refers to material available in institutions, museums, or private collections or (**) included in the Meteoritical Society online database, (X) refers to a doubtful record. A “fall” designates a meteorite specimen found after a fireball has been observed; a “find” is a meteorite recovered not associated with a witnessed event.

Specimens	Date	How	Classification	A	Mass (g)	Reference
1 Las Canas	1844	Fall	EUC? – HOW?	*	0.3	Harris (1859), Greg (1860)
2 Cuba	1871	Find	IAB	**	1 327	Solano y Eulate (1872)
3 Mango Jobo	1938	Find	Doubtful (Iron)	X	1 099, 344, 162	Pérez-Doval (1996)
4 Bacuranao	1974	Find	Doubtful (Iron)	X	(?)	Segura-Soto (1983)
5 Lajas	1994	Fall	OC	*	405	Moreira-Martínez (1994)
6 Boyeros	1996	Find	Doubtful (Stony-iron)	X	117.5, 14.9	Jaimez-Salgado et al. (2001)
7 Balcón de La Lisa	2001	Find	Doubtful (Stony-iron)	X	4.44	Jaimez-Salgado et al. (2007)
8 Güira de Melena	2001	Find	Doubtful (Stony-iron)	X	194.9	Jaimez-Salgado et al. (2007)
9 Viñales	2019	Fall	L6	**	50 000–100 000	Gattacceca et al. (2020)
10 Ramón de las Yaguas	2021	Fall	OC	*	2 760	This paper

“Las Canas, St. Andras” [*sic*] or “St. Andrews” [*sic*] is an ambiguous locality, but it may probably refer to Las Cañas in the present Artemisa province, which in the past included a site with the name San Andrés.

Little information concerning the circumstances of its recovery has been published, including a line from Greg (1854) who first listed the fireball (under St. Andrews, Cuba) as an “explosive meteor; aerolitic?”, Harris (1859) who mentioned “a stone is reported to have fallen at St. Andrews, Cuba, but it is not beyond doubt” and Meunier (1867) who cited “Pierre à Saint-Andrews, Cuba”. The preserved sample is small and pyramidal. It seems to have a remnant of the darker fusion crust with a fine-grained and lighter core. Besides the record in the ASU’s online cata-

log (<https://meteorites.asu.edu/collection/specimen-catalogue>), the only modern mention of this strange-looking specimen appears in the Meteorite mailing list (<https://www.mail-archive.com/meteorite-list@meteoritecentral.com/msg88156.html>). However, recent oxygen isotope and mineralogy analysis confirm it as an achondritic stony meteorite within the range of a eucrite or howardite (Laurence Garvie, unpublished data). This specimen constitutes a new, hitherto unknown, first historic meteorite recovery report in Cuba. The presence of the thin, black layer clearly resembles a fusion crust, while the isotopic analysis is consistent with the meteoritic range. Based on this, it is recommended further study so this specimen can be officially (i.e., empirically) classified.

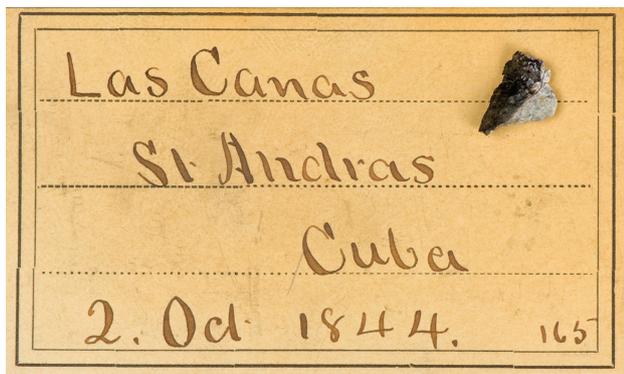


Fig. 2. Las Canas meteorite, according to the old label this stone fell in “Las Canas, St. Andras, Cuba, 2. Oct 1844” (ASU number 2 051). Scale ~ 1–2 cm for the specimen.

Cuba, 1871

The first well-documented meteorite from Cuba was found in the eastern part of the island much before 1871, as was reported by Solano y Eulate (1872) (Fig. 3). The main mass is now part of the meteorite collection of the MNCN in Spain (Fernández-Navarro, 1923; King et al., 1986; Muñoz-Espadas et al., 2002; Nieto-Codina, pers. comm., 2018; Soto, 2018). According to the inventory of Muñoz-Espadas et al. (2002), the Cuban specimen is catalogued as No. 17294 and is classified as a medium octahedrite (subtype IAB).

Muñoz-Espadas et al. (2002) used the name Cuba written in the catalog of the Natural History Museum of London (Grady, 2000), although the name came from

previous research (Buchwald, 1975; Prior, 1923). Before the Viñales event of February 1, 2019 (Iturralde-Vinent et al., 2019), it was the only Cuban meteorite included in the Meteoritical Society online database with an official name. There, it was inscribed as Cuba (see <https://www.lpi.usra.edu/meteor/metbull.php?code=5479>) and georeferenced with very doubtful coordinates 22° N, 80° W, since the original publication of Solano y Eulate (1872) did not provide a date or place of landfall. Instead, it was referred to as the “Eastern Department”, which at that time included the current provinces of Las Tunas, Holguín, Guantánamo, Granma, and Santiago de Cuba. Buchwald (1975) reported a different location (approximately 20° N, 76° W) and Farrington (1909) provided a map and a location (approximately 21° N, 77° W) more in agreement with the original publication.

Several weights have been reported for the meteorite since Solano y Eulate (1872). The original publication provided a weight of 1 327 g (at least 0.49 g was removed for chemical analysis), whereas subsequent works, however, have conflictingly indicated a weight variation of 1 297 g, 1 195 g, and 1 200.6 g (Fernández-Navarro, 1923; King et al., 1986; Muñoz-Espadas et al., 2002). The different weights may represent alteration and extraction of material for analysis. Furthermore, it is possible that the meteorite originally had several fragments, or was fragmented to be given to different collections. For instance, Ward (1904) reported 3 g in his collection, where as Horback and

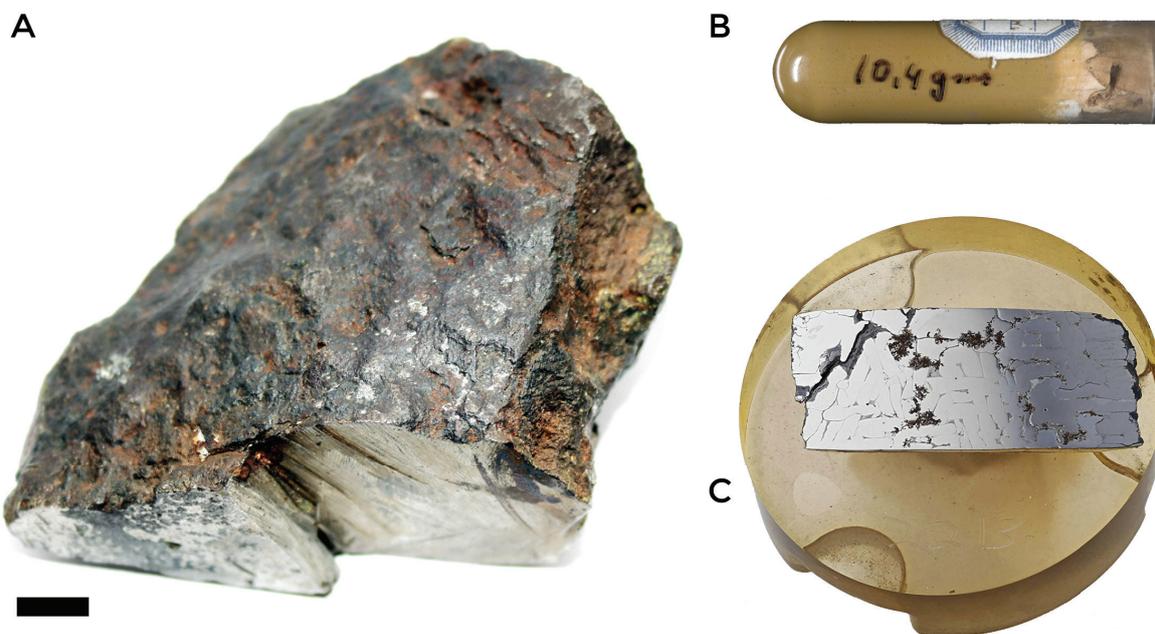


Fig. 3. Cuba iron meteorite was found in 1871 in eastern Cuba. **A** – Main mass (MNCN No. 17294). **B** – Meteorite dust (MNCN No. 17294). **C** – Etched slice showing a weak Widmannstätten structure (USNM No. 2213). Scale = ~1 cm.

Olsen-Edward (1965) mentioned the existence of oxidized fragments of about 2.6 g in the MFHN collection. There is also a fragment of 23 g acquired in 1963 by the USNM, seemingly from the original material. Buchwald (1975) suspected that the meteorite is, in fact, a piece of a larger mass and suggest a more detailed investigation in order to confirm the Cuban origin of the USNM specimen and not a part of the Toluca meteorite (Mexico), a hypothesis that has never been corroborated nor completely ruled out.

According to available descriptions, the main mass (MNCN No. 17294) is an incomplete semi-trapezoidal-shaped fragment, irregular in the narrowest part, rounded, and attenuated in the widest (Fig. 3A). The surface of its upper and lower faces is undulating, and recalls, although roughly, the impressions which the fingers leave upon a pasty substance (regmaglypts). The structure is granular, due perhaps to the fusion of the troilite. It has an unusual hardness of near 6.9 in Mohs, high magnetism, poor malleability, and a density of 6.44 g/cm^3 . The mineralogical composition includes schreibersite and probably some troilite inclusions. Cut and polished, the lustrous metallic matrix featured a classic Widmannstätten pattern (Solano y Eulate, 1872). Its peculiar hardness, very little below that of quartz, suggested to Solano y Eulate (1872) some comparisons with other scientifically significant iron meteorites known from Arizona, Kentucky, and Pennsylvania.

Buchwald (1975) characterized the 23 g part slice in the USNM (No. 2213, $3 \times 1.2 \times 0.5 \text{ cm}$) as a medium to coarse octahedrite (kamacite lamellae have an average width of $1.30 \pm 0.30 \text{ mm}$) with well-developed Widmannstätten pattern with oriented shine, common Neumann bands, no recrystallization, somewhat brecciated schreibersite but monocrystalline, and the total amount of phosphorus from 0.2 to 0.3 %. The hardness, 210 ± 15 , suggest some slight cold-deformation. Taenite and plessite occupy about 15 % by area. The plessite has either comb-like, or martensitic, or pearlitic or acicular interior, which is a constellation frequently met with in Group I irons. The pearlitic decomposition of the austenite to about $0.5 \mu\text{m}$ subparallel, vermicular lamellae is seen ex-

ceptionally well in this specimen. A few of the pearlitic fields have small ($100 \mu\text{m}$) and imperfect carbide roses, i.e., complex intergrowths of haxonite, taenite and kamacite. Schreibersite occurs as $1 \times 0.2 \text{ mm}$ subangular grains centrally in the α -lamellae, as $25\text{--}50 \mu\text{m}$ grain boundary precipitates and as $5\text{--}20 \mu\text{m}$ irregular bodies in the plessite fields. Rhabdites occur everywhere as $1\text{--}10 \mu\text{m}$ tetragonal prisms. According to this author, the 1 872 analysis that indicates an anomalous low nickel content (3.24 %) is wrong but provides no further explanation. A modern photograph shows the highly polished metallic matrix now with a weak Widmannstätten pattern, filled with a scattered distribution of brown iron oxides, probably the result of weathering (Fig. 3C). The specimen was embedded in epoxy many years ago for preservation.

The fragments in the MFHN collection (Me 1087) have not yet been properly described and resembles an aggregate of iron-like oxides (Fig. 4). The material includes seven fragments, which probably came off naturally due the fragment weathering or were man-worked. What seems to be a thin reaction surface or fusion crust is visible on some of the specimens and some regmaglypts-like structures are visible as well. At least one of the fragments shows a pattern consistent with a Widmannstätten structure. The oxidation is evident in some of the fragments. Some of the



Fig. 4. Oxidized fragments of the Cuba iron meteorite (Me 1087). Scale = 1 cm.

edges are very sharp, which is unusual for a meteorite, but still, it seems to be part of the original material. Chemical analysis or mineralogical studies are not available for these specimens.

Mango Jobo, 1938

The specimen is recorded as fallen in 1938 in the town of Mango Jobo, San Cristóbal, Artemisa province, western Cuba. It originally belonged to the collection of the prominent Cuban naturalist Dr. René Herrera Fritot (Pérez-Doval, 1996). The material was originally treasured in the Department of Archaeology of the former Academy of Sciences (Academia de Ciencias de Cuba; ACC) but later was relocated in the IGA collection since June of 1987. It has been exhibited in the former National Museum of Natural History of Havana (La Habana), and the largest piece was temporarily on display in the Planetarium of Havana.

Apparently, the original material included three rusty fragments weighing 1099, 344, and 162 g, respectively, with a density of 5.4 g/cm³ (Pérez-Doval, 1996). According to this author, concentrated nitric acid was applied to the larger fragment to reveal the Widmannstätten pattern, but no figures were ever published. Jaimez-Salgado et al. (2007) investigated the smaller fragment with X-ray diffractometry, although these data were not presented.

Unpublished diffractograms of the sample show strong cristobalite peaks, suggesting that this fragment is not a meteorite.

The known evidence shows a stone (supposedly the larger fragment) with an extremely irregular surface with bulges (and not regmaglypts) (Fig. 5D). Along with the sparse information available, the density reading is too low for an octahedrite, which would suggest that the density measurement is incorrect or the specimen is not a meteorite. Another possibility is that the authentic meteoritic material has been changed, but either way this is a very doubtful meteorite record or a meteor-wrong.

Bacuranao, 1974

Segura-Soto (1983) reported the mineralogical and chemical analysis of a rock found on the beach of Bacuranao and inferred their extraterrestrial origin. The specimen was discovered by Ing. Arnaldo Correa during an underwater exploration conducted in August 1974, in a sandy bed between 6 and 8 feet deep and about 40 m from the coast. Later, it was handed by Correa to Dr. Manuel Iturralde-Vinent, who transferred the specimen to Dr. Rafael Segura-Soto for study.

According to Segura-Soto (1983), it is an ellipsoidal regmaglypted metallic object that in cross-section tends to be quadrangular, with dimensions of 8.4 cm in length and 7.0 cm in diameter. A polished section and a thin section,

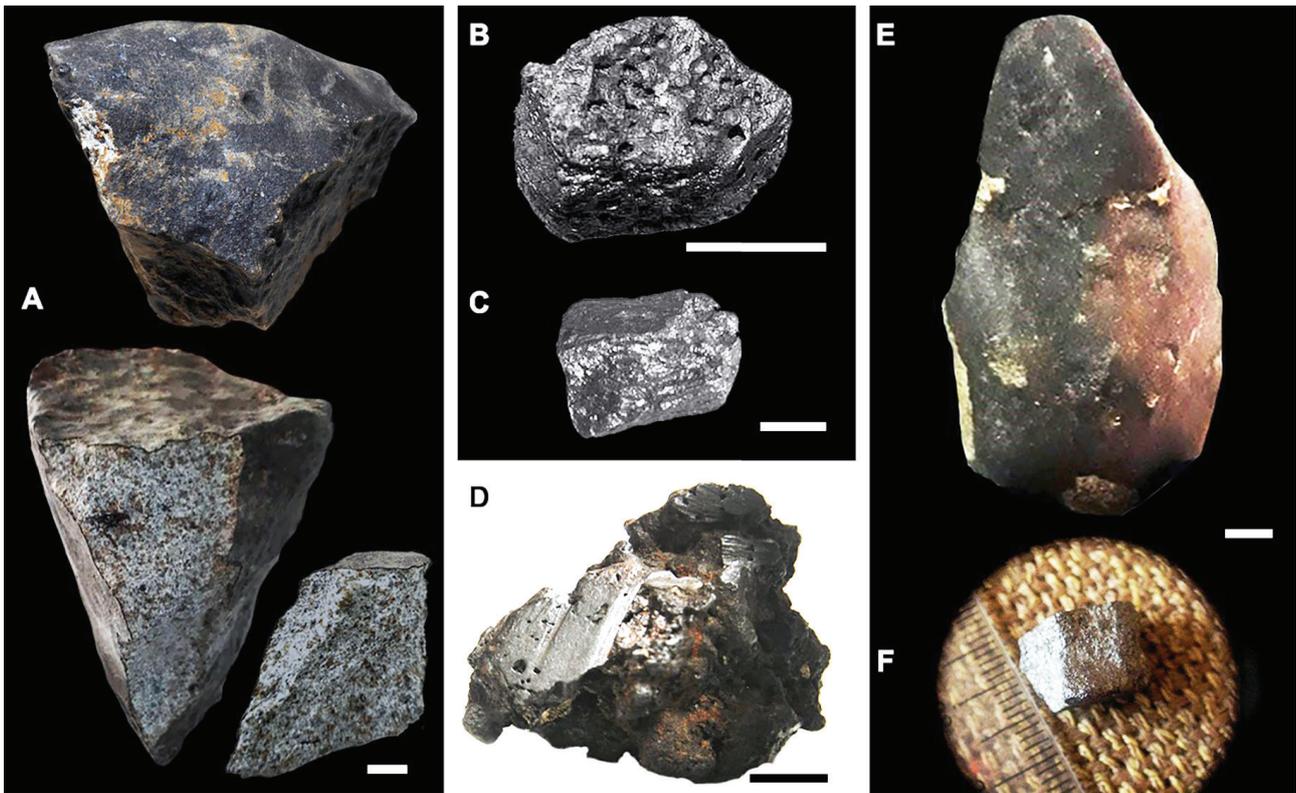


Fig. 5. Cuban specimens investigated in this paper. **A** – Ramón de las Yaguas (two views of the same specimen and a small fragment), **B** – Boyeros, **C** – Güira de Melena, **D** – Mango Jobo, **E** – Lajas, **F** – Balcón de La Lisa. Scale = ~ 1 cm.

showed the presence of metallic minerals (kamacite), lamellar bands and figures of Widmannstätten, typical of an octahedrite. In addition, Segura-Soto (1983) reported few lithic chondrules in which well-defined quartz and ferromagnesian minerals (breunnerite) are identified, however, these structures and minerals are not common on iron meteorites. This specimen was on display at the MNHNCu, where it was stolen, so it cannot currently be verified. In a recent newspaper article on Cuban meteorites, Peláez (2018) erroneously used a photograph of a meteorite on display at the USNM collection (found in California, United States) to illustrate the Bacuranao specimen.

Lajas, 1994

According to Moreira-Martínez (1994), this fall was sighted around 10:00 am on Friday, June 10, 1994, in Finca Palmarito, 2 km away from the town of Santa Isabel de las Lajas, Cienfuegos province, in central Cuba. The object quickly crossed the sky, giving off sparks and leaving behind a trail of weak light and smoke. The light went out as suddenly as it appeared and after a few seconds, explosions and blows were felt, like shots of heavy artillery pieces, which caused panic in many people.

The meteorite split into several fragments that dispersed throughout the Palmarito area. Two farmers who were working the land saw as one of the fragments (12 x 5 cm) impacted a few meters from them, producing a small crater about 15 cm in diameter and 55 cm deep (Moreira-Martínez, 1994).

The fragment that was recovered is in a good state of preservation with a mass of 405g and a shape like the head of a projectile (indicating possible flight orientation) (Fig. 5E). A very thin (tenths of millimeters), black, and well-formed fusion crust contrast with a light, almost white interior as seen in a fractured surface. There are regmaglypts at one of its surfaces (Moreira-Martínez, 1994).

According to Moreira-Martínez (pers. comm., 2019), the preliminary study in thin and polished sections revealed a nodular porphyry texture, composed of up to 80 % of non-metallic or rocky phase minerals, while the opaque and metallic phase minerals represent only 20 %. Minerals from the olivine group were identified (50 %), described as with a relict nodular form, strong cracking, and evidence of deformations due to high stresses. The size of this mineral ranges between 0.2 and 4.5 mm. There are also present the orthopyroxene (enstatite) (20 %), with tabular to prismatic forms, and size between 0.3 and 1.5 mm, as well as clinopyroxene of the clinoenstatite type (5 %), with short prismatic to irregular shapes and a diameter of 0.1 to 0.6 mm. Inclusions of metallic ore (sulphide) were recognized, and impregnations of iron oxides and hydroxides bordering on these mineral and filling veins.

Due to their optical characteristics, iron sulphides were referred to the troilite-pyrrhotite group, and they appear intercropped in xenomorphic grains with sizes that reach 14 μm . They form a granular texture and are strongly magnetic. The native iron present has a high and isotropic reflection capacity, with grains of xenomorphic form and sub-rounded edges sometimes in the form of drops that can reach 86 μm and its texture is granular (Moreira-Martínez, pers. comm., 2019).

Pérez-Doval (1996) indicated that this seemed like a stony-iron meteorite, but Moreira-Martínez (pers. comm., 2019) referred it to an achondrite with few spherical inclusions or chondrules. However, the latter statement is contradictory, if the specimen includes chondrules it is more likely an ordinary chondrite. The specimen is in possession of Moreira-Martínez (pers. comm., 2019).

Although the petrography has not prioritized the description of the main elements necessary for the classification of a meteorite and geochemistry analyses were not performed in this sample, the description seems consistent with what is expected for an ordinary chondrite. A more speculative analysis of the available information may allow a preliminary classification of the rock. The large range of what is deduced to be the chondrules diameter is compatible to the L or LL groups. The ratio of clinopyroxene to total of pyroxene (20 %) could indicate a more equilibrated (4 or 5) petrologic type (Krot et al., 2014). The presence of so-called strong cracking and deformations in the olivine grains and melt veins agree with a moderate to severe shock degree (Stöffler et al., 1991). Finally, although the meteorite fall was observed, the presence of some oxidation of the metallic phase puts its weathering degree as, at least, W1 (Wlotzka, 1993). A complete study, including a more detailed petrography and geochemistry is strongly recommended for this rock so it can be officially recognised as a meteorite.

Boyer, 1996

In February 1996, members of the “Pedro A. Borrás” group of the Speleological Society of Cuba found two fragments with a strong metallic shine and weight of 117.5 g and 14.9 g respectively (Jaimez-Salgado, 2001; Jaimez-Salgado et al., 2001, 2007) (Fig. 5B). As it was reported, the object fragmented into two parts when it landed on the pavement, and opened three narrow, but deep holes on the road, cutting the asphalt and reaching even the underlying filling material. However, it is intriguing that a such small fragment could generate such a large damage. The locality is reported as “roadside of the Calabazar road, Boyeros, Havana”.

This specimen was originally classified as an iron meteorite and it was reported a global chemical composition as follow: Fe (53.7 %), Ni (7.03 %), Co (0.19 %) and Si (39.08 %) (Jaimez-Salgado, 2001). However, a later in-

vestigation of the smaller fragment through X-ray diffraction revealed a mineralogical composition with the presence of fersilicite (FeSi – also known as the mineral Naquite) and ferdisilicite (FeSi₂ – also known as the mineral Linzhiite), and the object was classified as a stony-iron meteorite (Jaimez-Salgado et al., 2007).

This specimen is not housed at the IGA collection as Ceballos-Izquierdo (2019) incorrectly reported. What is left of this material (due to the different tests performed), is a very small fragment preserved in the private collection of the group Pedro A. Borrás (Jaimez-Salgado, pers. comm., 2019).

Both chemical composition and the X-ray diffraction are inconsistent with what is expected of meteorites. High concentration of metallic silicon is not found in iron meteorites and, although both minerals identified in the sample were already found in meteorites, they represent accessory phases present only as small grains (Rubin and Ma, 2017). Other meteorite types can be ruled out by its visual appearance and lack of other typical minerals in the X-ray diffraction. Metallic silicon alloys are industrially produced in large scale as it has many applications, and its shine, colour and resistance to weathering makes it a usually mistaken for meteorites. The extraterrestrial origin of this specimen is highly unlikely and it is suggested that the material to be regarded as terrestrial.

Balcón de La Lisa, 2001

Jaimez-Salgado et al. (2007) reported a small object of 4.44 g of weight and dimensions of 0.8 x 1.5 x 2.2 cm found on the pavement at the locality Balcón de La Lisa, town La Lisa, Havana City, in 2001, by a member of the astronomy fan group Cosmos (Fig. 5F). It was suggested to be classified as stony-iron, as it resembles the Güira de Melena specimen (see below) and both are very similar in mineralogical composition to the Boyeros specimen. It has also been suggested that these specimens are from the same falling event (Jaimez-Salgado et al., 2007), a doubtful statement considering the lack of a complete mineralogical study of the three rocks or any visual report of the fall. The current whereabouts of this specimen is unknown (Ceballos-Izquierdo, 2019).

Güira de Melena, 2001

This specimen was found in 2001, with a metal detector, buried about 20 cm below the ground level, in a plowed field composed of red soils near the town of Güira de Melena (Artemisa province, western Cuba) (Fig. 5C). A mass of 194.9 g was recovered and was informally named “Gámez” in honour of a young astronomer (Rafael Gámez) who, suspecting it was a meteorite, brought it from Güira de Melena to the IGA. However, if eventually it is probed to be a meteorite, the name must be referred to as Güira de Melena following the Guidelines for Meteorite

Nomenclature from the Meteoritical Bulletin (<https://www.lpi.usra.edu/meteor/docs/nc-guidelines.pdf>).

Jaimez-Salgado et al. (2007) mentioned that the mineralogy resembles the Balcón de La Lisa and Boyeros specimen and suggested that these objects are highly related to each other (as probably three pieces that could be fragments of the same meteorite). They stated that the fragments may have originated as part of a single original object of larger dimensions, probably fragmenting into many pieces just before the impact when it disintegrated over at different locations. The whereabouts of the specimen is unknown (Ceballos-Izquierdo, 2019).

The visual resemblance among Boyeros, Balcón de La Lisa and Güira de Melena samples and the suggestion given by Jaimez-Salgado et al. (2007) that they could be from the same event corroborate the idea that the three rocks have a similar composition and origin. As mentioned in the Boyeros section, the characteristics of the material points to a terrestrial origin as a metallic silicon alloy and it is highly unlikely to be meteoritic.

Viñales, 2019

Event, trajectory and orbit

The astronomical event took place at 1:17 pm local time (18:17:10 UTC) on February 1, 2019, when a daytime bolide was observed by many inhabitants of the Viñales Valle, east of Viñales, in the province of Pinar del Río in western Cuba (Iturralde-Vinent et al., 2019). The fireball was also seen by occasional observers in Havana and Matanzas provinces, and outside Cuba, including Florida (USA) and Quintana Roo (Mexico), with about 20 submitted reports to the American Meteor Society ([**Tab. 2**
Estimates of the orbit and trajectory parameters
for the Viñales bolide.](https://fire-</p>
</div>
<div data-bbox=)

	Zuluaga et al., 2019	This work
Lon.imp [°]	-83.8037	-83.7238
Lat.imp [°]	22.8820	22.8692
A [°]	178.9	171.8
h [°]	31.8	39.5
v.imp [km/s]	16.9	16.6
a [au]	1.217	1.038
e [-]	0.391	0.371
q [au]	0.74	0.653
i [°]	11.47	10.589
Ω [°]	132.28	132.343
ω [°]	276.97	255.740
P [yr]	1.34	1.058

ball.amsmeteors.org/). Loud sonic booms from the fireball were also reported and a long smoke trail was observed (Iturralde-Vinent et al., 2019; Zuluaga et al., 2019).

U.S. Government sensors recorded the event at 18:17:10 UTC and estimated total impact energy of 1.4 kt of TNT (<https://cneos.jpl.nasa.gov/fireballs/>) at 22.5° N, 83.8° W and 23.7 km of altitude. The reported bolide velocity was 16.3 km/s (velocity components: $v_x = -2.4$ km/s; $v_y = 13.6$ km/s; $v_z = 8.7$ km/s). The event was also detected with high confidence by Geostationary Lightning Mapper (GLM) aboard of both GOES (16 and 17) satellites, as known as a stereo detection. GOES 16 satellite detected the event between 18:17:09.375 and 18:17:11.679

UTC while GOES 17 recorded it between 18:17:09.347 and 18:17:12.345 UTC. The position was estimated at 22.6° N and 83.5° W with a variation of 1° in both latitude and longitude. However, the location accuracy in both systems is considered low for a good trajectory and orbit estimation.

Zuluaga et al. (2019) studied three different vantages points and implemented a trajectory fitting in order to find the best-fit value of the trajectory parameters, namely the Havana Harbor (Cuba), the Gull Wing Beach Resort (Florida, USA), and the Alameda Pinar del Rio (Cuba). Corrections were applied in the Florida and Havana videos to correct the effect of atmospheric refraction. From the trajectory, they were also able to obtain the parameters of the asymptotic orbit of the meteoroid, both summarized at the Table 2.

In our analysis, we also used three different vantages, the same cameras in the Havana Harbor (Cuba), and the Gull Wing Beach Resort (Florida, USA). It was also used the images obtained by Cruz María Ruiz, that was aboard of the Spirit flight 923 travelling from Orlando, Florida, to San Jose, Costa Rica. It was used local references to pinpoint the correct camera position and estimate their pointing direction and field of view (FOV). The flight position at the moment of the meteor was obtained in the Flight Radar website. No corrections of the atmospheric refraction were applied in this analysis. With these images, it was possible to estimate the azimuth and elevation of the bolide in each, in addition to the event duration. From the triangulation of these images, the initial and final points of the meteor were estimated: initial point at 21.85672° N 83.86851° W, 72.240 km of altitude; final point at 22.54245° N 83.77053° W, 23.313 km of altitude. These values were then used to calculate the orbit of the meteoroid using a modelling routine that takes in account the

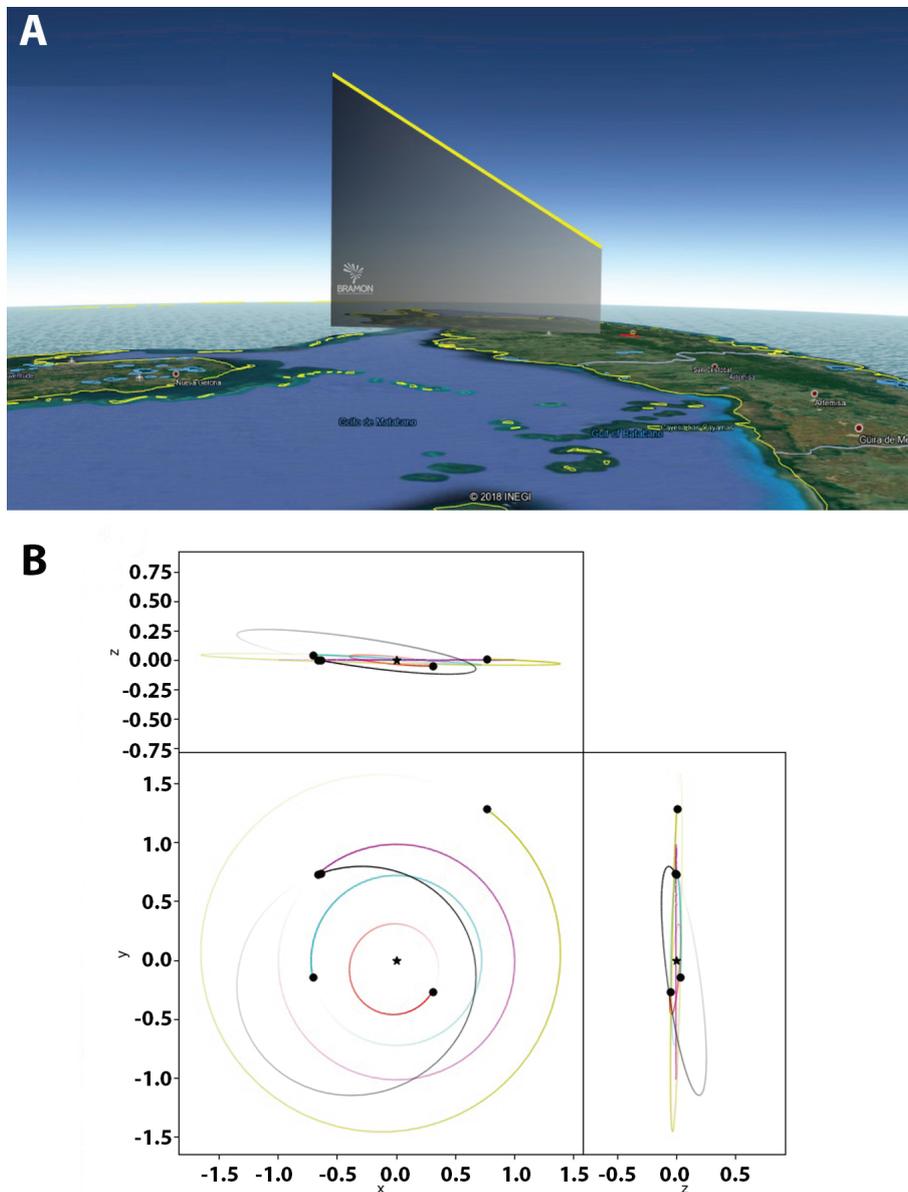


Fig. 6. A – Trajectory estimated for the Viñales bolide as seen from the Spirit flight 923 (different FOV). B – Three different views of the orbit obtained for the Viñales meteoroid.

atmospheric drag in the Earth proximity and gravitational influences of the Earth-Moon system. The orbit and trajectory (Fig. 6) parameters obtained are summarized in the Table 2 and are in good agreement with those from Zuluaga et al. (2019). The main deviation is found in the semi-major axis values of the orbits, so the aphelion obtained by Zuluaga et al. (2019) is beyond the orbit of Mars, while our calculation shows an orbit internal to Mars. In both cases, the meteoroids are classified as a member of the Apollo group.

Fragments

According to the NASA (as cited in Karmaka Meteorites, 2021), “The first appearance of the falling meteorites on radar occurs at 18:18:14 UTC and 10,600 m above sea level (ASL) in the 1816 UTC data set for the KBYX radar in the 0.88 degree elevation radar sweep. Signatures consistent with falling meteorites appear in a total of three radar sweeps from the KBYX radar, with a final signature appearing at 18:22:02 UTC”.

The meteorite shower fell on Viñales Valley, a national park area, and a UNESCO world heritage site. Some of the meteorite fragments penetrated the soil, producing impact pits as large as 45 cm. One of them broke through an asphalt road, and some holes were produced when fragments hit the rooftops; about 35 such impacts have been catalogued (Vázquez-Torres and Pino-Torga, 2019). The fall was officially registered in the Meteoritical Society online database on March 27, 2019, with official status as

confirmed fall, type Ordinary Chondrite L6, shock stage S3 or S4 with an estimated recovered weight of about 50 kg (Gattacceca et al., 2020).

So far, more than one hundred fragments have been recovered and a strewn field map was obtained, however it is probable that many more specimens lie undiscovered in farm fields and karstic hills named mogotes (Vázquez-Torres and Pino-Torga, 2019). Since then, many samples have found their way into foreign institutions, museums, meteorite dealers, and collectors, but most are poorly documented. Thus, tracing many of the original specimens is a daunting task (see Table 1 in Vázquez-Torres and Pino-Torga, 2019).

The Meteoritical Society official entry for Viñales: (<https://www.lpi.usra.edu/meteor/metbull.php?code=69213>) listed an individual (type) specimen of 148 g and one transparent-polished section deposited in VERNAD; 22 g in UCLA; 18 g in CEREGE; and cited eight individual samples of total mass 2.31 kg which were deposited in the IGA in Cuba. Currently, only one fragment was left in the later institution, as all others were sent to other laboratories in Cuba and Russia, while another sample was donated to the scientific meteorite collection of the NHMV. Samples of the specimen Viñales No 36 Jazmines 1 have also been deposited in the NHMV (Iturralde-Vinent et al., 2019). The Jazmines’ material was split into two parts (NHMV-01191 and NHMV-13514) and a thin section (NHMV-13514) was made from the last. The ASU’s online catalog has an entry for Viñales under the number 2118, without information of

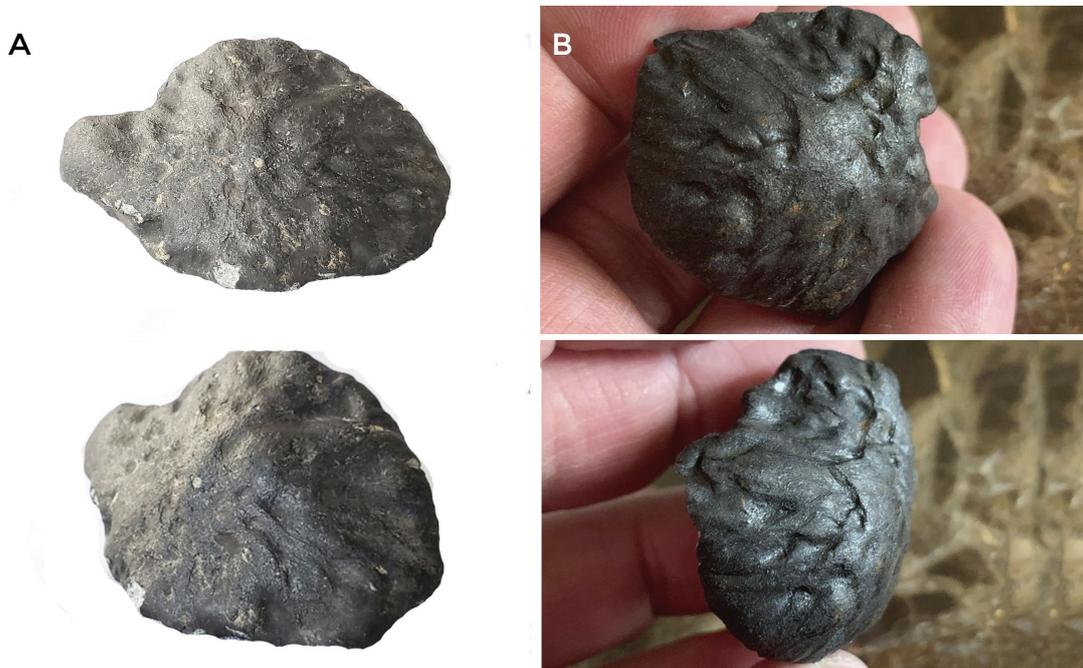


Fig. 7. Highly oriented Viñales individuals from the Viñales strewn field. **A** – Oriented piece of 39.05 g (C. Zliven collection, unnumbered). **B** – Almost fully crusted specimen with quite elongated regmaglypts, exhibiting strong orientation (M. Farmer collection, unnumbered). Not to scale.

its weight. García (2019b) investigated a single specimen (ID190503 #2) at the MCM, and two more (ID190503 #1, #3), now in the private collection of Dra. Inés T. (Girona, España). Additional masses are also available in the following private collections in USA: Darryl Pitt, New York (DPitt), Michael Farmer, Tucson (MFarmer), Craig Zliment, Minnesota (CZliment) and John Higgins, New Jersey (JHiggins), but they are unnumbered.

Macroscopically, the fragments show dark marron-ochre colour, seemingly black in some parts, with a thin external and rugose (regmaglypts) fusion crust. Internally, they display a breccia-like texture, with predominant light silicates and shiny opaque minerals (likely metallic in composition). There are specimens with elongated regmaglypts and radial flow lines, exhibiting orientation (Fig. 7).

We examined original polished and thin sections photographs from the MCM ID190503 #2 specimen, which resembles a porphyric igneous rock. Chondrules are equant, fine to medium heterogranoblastic, composed of porphyritic olivine and pyroxene, few barred olivine making up ~30 % of the overall observed composition. The olivine is dominant in anhedral and subhedral forms. Some of the olivine crystals seemed deformed and slightly reacted or shocked. The composition is over 70 % of irregular crystals, microcrystals, and chondrules. Matrix is made of < 20 % opaque material. These, in turn, seem to be metal-rich microcrystals; some identified as kamacite and troilite, while the observation of chromite and taenite lacks a higher degree of certainty. Opaque minerals make up to about 10 % of the sample, whereas other, plagioclase-like material, also make up < 10 %, both occurring mainly in veins. Larger aluminium-rich grains are also visible (> 0.1 mm).

Further information on the Viñales meteorite is found in the following references: García (2019a, b, c), Gattacceca et al. (2020), Iturralde-Vinent et al. (2019), Vázquez-Torres and Pino-Torga (2019), Yin and Dai (2021) and Zuluaga et al. (2019).

Ramón de las Yaguas, 2021

The most recently recovered landfall is a single stone that fell on July 10, 2021 near the village Ramón de las Yaguas, Santiago de Cuba province, eastern Cuba (coordinates Lat. 20.04766°, Long. -75.52891°). The object with dimensions of 13 x 12 x 11 cm and weight of 2.76 kg, was associated with a daytime bolide observed by witnesses. According to the finder, three explosions were heard, and a burning object was observed to fall. Other sounds were described as thunder-like noise or as airplane booms. Sonic booms produced by the fireball were recorded by four seismic stations located opportunely not so far of the impact locality. The fireball likely crossed the middle of this area in the second half of its trajectory.

The meteorite landed just a dozen meters from a house, but the crater was disturbed by the locals. It was found by a local family, reportedly being slightly warm. Inspection of the fall area was conducted by Dr. Enrique Arango Arias (from the National Seismological Service), who interviewed many local people and collected the rock. The event was reported on July 16 by the Ministerio de Ciencia Tecnología y Medio Ambiente (CITMA) and the specimen was kindly donated for scientific research and transferred to the IGA. Preliminary examination shows the presence of chondrules confirming it as an ordinary chondrite. More in-depth studies are on the way.

Macroscopically, the specimen is ~90 % covered by a black fusion crust up to ~1 mm thick. Well-preserved regmaglypts are common and a chondritic texture is visible within the broken surface (Fig. 5A). A small piece (about 45 g) was removed from one end for a closer look to the matrix. This event must likely triggered multiple meteorites falls in the area however only one fragment was recovered until now. Unfortunately, there was no registry of the event in the Geostationary Lightning Mapper (GLM) detector that has been placed on the GOES 16 and 17 satellites, nor it was detected by the infrasound sensors of the US Government.

3.2. Bright fireballs

Sightings of the crossing of bright fireballs have been reported in the Cuban sky, but there are no recovered material or scientific studies of them. For example, between 2012 and 2019 several reports are logged at the online fireball event database (Event number 2206-2014, 414-2016, 1559-2016, 1497-2017, 4759-2018, 5025-2018, 5233-2018, 5955-2018) of the American Meteor Society. The fireballs 1497-2017 and 4759-2018 are over Florida (USA), not Cuba. All the others Cuban events are from single observers only. If they were very bright fireballs, they would have been seen by more people. Since the beginning of the use of the Geostationary Lightning Mapper (GLM) aboard the GOES 16 and GOES 17 satellites for detection of meteors in July 23, 2017 until the last update (August 8, 2021), there are 8 meteors reported over Cuba: 3 events of low confidence (2 from GLM-16 and 1 stereo), 3 events of medium confidence (1 from GLM-16 and 2 stereo), 2 events of high confidence (both stereo: the Viñales meteorite fall and the Holguín event).

An alleged fireball was seen by casual eyewitnesses on July 29, 2013, from Cayo Coco (Cuba), Jamaica, Cayman Islands, Honduras, and Mexico as mentioned by various websites and bots on the internet, claiming a possible space trash fall event.

Many observers were engaged by a dramatic sight of a brilliant light streak on 25 April 2019 and referred to it as the landing of an unusual object or a meteorite. No sounds or fragmentation were reported, however. A recent analysis

of the video record and the low-resolution photographs from two different locations leads to the conclusion that it was neither a fireball nor a reentry. The smoke trail from a meteoric bolide or a re-entry takes time to be blown by the wind until it twists. In Moa's video, the speed is low even for reentry, and the irregular path of the object itself is observed, leaving a weak twisted smoke trail.

We focus here on historical bright fireballs reports and some recent but not listed in the American Meteor Society database. Most of them are either not published at all or only partially. The available information on such cases is summarized below.

Morón, 1867

Naranjo and Aguilar (1941) mentioned the occurrence of a probable meteorite that fell near the town of Morón (Ciego de Ávila province), on the night of November 24, 1867. These authors recount the tale of a suspected meteorite landfall based on the narration of Caridad Recino, who was an eyewitness: "she was with her family at the door of the house, when everything was illuminated, seeing how the sky was divided by a wide strip of fire, throwing sparks and stars, the bolide followed the north direction and fell with a fantastic crash, which produced a big alarm in Morón". The fireball supposedly crossed over the northbound town and crashed causing an earthquake.

Havana, 1886

Viñes (1886) described what appears to be possibly a meteorite of great brightness and size that fell into the sea front of Havana city, causing panic in the neighbors. He pointed out that on Monday, May 10, 1886, approximately at 7:30 pm, the inhabitants of Havana city witnessed a luminous object that was moving slowly in the sky, coming from the north. It produced such a commotion, that the Spanish authorities asked Viñes, director of the Observatory of the city, to publish a note explaining the phenomenon and in the next two days the main newspapers wrote about the event to calm the inhabitants.

Based on the Viñes' narration, Ramos-Guadalupe (2004) suggested a tentative magnitude around -10 for this fireball and estimated the meteor entered the atmosphere through a point located on the Gulf of Mexico, almost north of Havana, with part of its trajectory over the bay area.

Consolación del Sur, 2010

On June 7, 2010, 10:40 pm, a striking fireball was observed from Consolación del Sur (Pinar del Río province), but no meteorite was located. Peláez (2010) reported this rare event in the press and cited Efrén Jaimez-Salgado as a witness, saying that a huge and bright bolide crossed from north to south the sky of Pueblo Nuevo, near

Consolación del Sur and could have fallen somewhere south of the town of Alonso de Rojas, or at sea, in waters of the Gulf of Batabanó. He also indicated that the object, apparently quite large, was leaving behind a huge bright greenish-white trail and a detonation a few seconds later.

Calimete, 2013

An unidentified light phenomenon crossed the sky of Calimete (Matanzas province) at 8:30 pm on February 5, 2013, and was sighted by dozens of residents of the town (Solís-Díaz, 2013). Eyewitnesses described the event as a reddish light source descended at high speed, crossed over the town from the northeast, and then in a descent in which disappeared, caused a sound like an explosion. The locality of the alleged crashing could be a site near the contiguous town of Los Arabos; an area with unfavorable terrain conditions for recovery due to sugar cane plantations. Meteorites were not located.

Rodas, 2013

On February 14, 2013, a fireball was reported from several communities in Rodas (Cienfuegos province, central Cuba), on a smaller scale, almost simultaneously with the Chelyabinsk superbolide in Russia (Peláez, 2014). Local researcher Marcos Rodríguez-Matamoros described the event as a small bolide, without being able to verify a meteorite landfall with the collection of any fragment. The bolide explosion occurred at a height of 18 – 21 km (Lobanovsky, 2014). Testimonies agreed that there was a very intense light that reached, at a glance, the size of a bus and exploded, and windows and walls shook following the explosion. No damages or injuries were reported. We gathered limited photographic data of this event and, thus only poor visual information is available.

Holguín, 2021

Recently, a rare event aroused attention when the National Seismological Service of Cuba reported in a note that, on the night of March 19, 2021, at 10:06 pm (02:06 UTC), their stations in Oriente had registered vibrations that did not correspond with an earthquake (Arango-Arias, 2021). Coinciding with the time of the anomaly, a natural phenomenon was observed in the eastern provinces of the island. The following day, the online fireball event database of the American Meteor Society recorded the event as 1755-2021, for a fireball sighted by various observers who reported it to this international platform, including witnesses from Jamaica and the west coast of the United States. This bolide (including the trajectory) was investigated in a separate paper by the senior author and colleagues (Ceballos-Izquierdo et al., 2021). Based on a video recorded in Kingston (Jamaica) and the GLM / GOES-16 data, the space rock reached the Earth's

atmosphere at an angle of 42.7° relative to the ground and a speed of $\sim 50\,000$ km/h. The meteor appeared at an altitude of approximately 65.5 km between the town of La Maya and Los Reynaldos and continued for 3.7 seconds in a northerly direction until it disappeared at an altitude of 30.4 km, northeast of La Deseada. No meteorites from this bolide have been found thus far.

4. Conclusions

The paper provides a record of meteorites and probable meteorites documented from the island of Cuba. These constitute noteworthy events, documented as early as 1833 for a meteorite landfall, and 1844 for a recovered meteorite specimen. A total of ten important records exists from the 19th century and span up to the year 2021. A rise in recorded observations since the 1990s may reflect increased attention or interest of amateur and professional observers alike. Hitherto, there were only two official meteorite records recognized by the Meteoritical Society for the island of Cuba. Our investigation included also three unpublished unofficial records (Las Canas, Lajas, and las Yaguas), recovered on the island, as well as several fireball sightings reports. No meteorites have been recovered from bright fireballs probably because they included fragile objects that have not survived atmospheric descent, but no systematic searches of possible remains have been conducted as well. More data are needed, as, due to their scarcity, statistics on these events are yet very poor.

The Viñales event of 2019 is one of the latest of the meteorites recovered, and its landfall was attractive to many researchers worldwide. Unfortunately, many valuable specimens from this event have been extracted from the country by private collectors, which limits access to some specimens, but a few ended in museum collections. Some specimens are oriented, showing flow lines, roll-over lipping, and elongated regmaglypts; being the second example of an oriented meteorite recorded from the island (the first one is the Lajas' meteorite).

The Mango Jobo, Boyeros, La Lisa, and Güira de Melena specimens are traditionally reported as meteorites. However, they were poorly described and illustrated, and our current understanding of these objects is limited by the scarcity of data presented in their original publications, plus their unavailability for modern analyses. Upon examination, they seem to represent meteorite fragments and not true meteorites.

Although some older meteoritic samples are not available for laboratory studies, their information and their properties are important for our understanding of the relative abundance of meteorite types on the island and their importance, although minor, as a geo-natural hazard. Increased awareness of these phenomena by all – specialists, amateur, and civilian observers can provide an

important, and sometimes noteworthy source of records in order to improve our knowledge of their occurrence in the region.

Acknowledgments

We gratefully acknowledge Efrén Jaimez-Salgado (IGA) for providing literature and whereabouts for some of the Cuban specimens. We thank Tim McCoy (USNM), Laurence Garvie (ASU), and Philipp Heck (FMNH), who kindly provided photographs and information of the Cuban specimens deposited in their institutions. We also thank Jose García (MCM), John Higgins, Michael Farmer, and Craig Zlimen, who provided photographs of specimens from Viñales in their collections. Hayley Singleton shared information about Las Canas' meteorite. Historical information about the Lajas' meteorite was provided by geologist Jesus Moreira-Martínez. The authors would like to thank Othon Cabo Winter and Rafael Sfair de Oliveira, who helped the development of the software used to calculate the Viñales orbit. Enrique Arango Arias kindly provided data and photographs of las Yaguas meteorite. We are also grateful to anonymous reviewers, and especially to the editor Zoltán Németh, for all their useful comments that have improved this work. Y. C-I. thanks Manuel Iturralde-Vinent for his encouragement to study the Cuban meteorite record and Carlos Augusto di Pietro for fruitful discussions on Cuban bolides and meteorites.

References

- ARANGO-ARIAS, E. D., 2021: Información sobre el fenómeno registrado en la noche del 19 de marzo por el Servicio Sismológico Nacional para el Instituto de Geofísica y Astronomía. *Ministerio de Ciencia Tecnología y Medio Ambiente*, 2 p.
- BUCHWALD, V. F., 1975: Handbook of Iron Meteorites. *Univ. of California Press*, 1418 p.
- CEBALLOS-IZQUIERDO, Y., 2016: Energía desde el espacio. Impacto de meteoritos en Cuba: *Energía y Tú*, 76, 29–33.
- CEBALLOS-IZQUIERDO, Y., 2019: Recuento de los meteoritos reportados en Cuba y bibliografía sobre el tema. *An. Acad. Cienc. Cuba*, 9, 1, 1–18.
- CEBALLOS-IZQUIERDO, Y., DI PIETRO, C. A. & ZURITA, M., 2021: El bólido meteórico de marzo 19, 2021 en el oriente de Cuba. *Meteoritos*, 27, 54–62.
- CEBALLOS-IZQUIERDO, Y. & ITURRALDE-VINENT, M., 2011: Biblioteca Digital Cubana de Geociencias. *Red Cubana de las Ciencias*, available at: <http://www.redciencia.cu/geobiblio/inicio.html>, last accessed 21 October 2019.
- Commission F1 of the International Astronomical Union, 2017: Definitions of terms in meteor astronomy: IAU, Available at: https://www.iau.org/static/science/scientific_bodies/commissions/f1/meteordefinitions_approved.pdf, last accessed 13 June 2020.

- Cubadebate, 2015: La imagen captada por los lectores: ¿Un meteorito en Cuba? Cubadebate, available at: <http://www.cubadebate.cu/noticias/2015/09/05/la-imagen-de-los-lectores-un-meteorito-en-alquizar/>, last accessed 15 October 2019.
- FARRINGTON, O. C., 1909: Catalogue of the Meteorites of North America to January 1, 1909. *Mem. Nati. Acad. Sci.*, 13, 1–560.
- FERNÁNDEZ-NAVARRO, L., 1923: Los Meteoritos del Museo de Madrid. *Bol. Real Soc. Española Hist. Natur.*, 23, 224–233.
- GARCÍA, J., 2019a: Viñales clasificado. *Meteoritos*, 15, 30–31.
- GARCÍA, J., 2019b: Caracterización petrográfica de muestra ID190503 Meteorito de Viñales (Cuba). *Labor. petrogr. Mus. Canario de Meteoritos (España)*, 3 p.
- GARCÍA, J., 2019c: Viñales en el MCM. *Meteoritos*, 16, 24–28.
- GATTACCECA, J., MCCUBBIN, F. M., BOUVIER, A. & GROSSMAN, J. N., 2020: The Meteoritical Bulletin, 108. *Meteor. Planet. Sci.*, doi: <https://doi.org/10.1111/maps.13493>.
- GRADY, M. M., 2000: Catalogue of Meteorites: With Special Reference to Those Represented in the Collection of the Natural History Museum, London. 5th ed. *Cambridge Univ. Press, U. K.*, 689 p.
- GREG, R. P., 1854: Observations on Meteorolites or Aerolites, considered Geographically, Statistically, and Cosmically, accompanied by a complete Catalogue. *London, Edinburgh and Dublin Philosoph. Mag. J. Sci.*, 8, 4, 329–341, 449–462.
- HARRIS, E. P., 1859: The Chemical Constitution and Chronological Arrangement of Meteorites. PhD dissertation. *Georgia, Augusta University*.
- HORBACK, H. & OLSEN-EDWARD, J., 1965: Catalog of the Collection of Meteorites in Chicago Natural History Museum. *Fieldiana, Geology*, 15, 3, <https://doi.org/10.5962/bhl.title.5157>.
- ITURRALDE-VINENT, M., LLANES-CASTRO, A. I., SANTA CRUZ-PACHECO, M., TOLEDO-SÁNCHEZ, C. A. & CABRERA-DÍAZ, I., 2019: Estudio espectroscópico, composicional y mineralógico de un fragmento del meteorito Viñales, caído en Los Jazmines, Cuba occidental. *An. Acad. Cienc. Cuba*, 9, 1, 29–58.
- JAIMEZ-SALGADO, E., 2001: Notas sobre el hallazgo de un meteorito férrico (siderito) en Ciudad de la Habana. *Carta Informativa*, 2, Grupo “Pedro A. Borrás”, *Sociedad Espeleológica de Cuba*.
- JAIMEZ-SALGADO, E., ALONSO, J. A. & FLEITA, R., 2001: Notas sobre el hallazgo de un meteorito férrico (siderito) en Ciudad de la Habana. *Datos Astronóm. Cuba*, 74–75.
- JAIMEZ-SALGADO, E., ALONSO, J. A. & FLEITA, R., 2007: Nuevos reportes de meteoritos en las provincias de la Habana y Ciudad de la Habana, Cuba. *Datos Astronóm. Cuba*, 94–95.
- Karmaka Meteorites, 2021: Viñales Meteorite fall (L6, >21,752.38 g) on 1 February 2019 near Viñales, Pinar del Río, Cuba at ~1:17:10 p.m. local time (~18:17:10 UTC). Available at: http://karmaka.de/?page_id=17353.
- KING, E. A., SAN MIGUEL, A., CASANOVA, I. & KEIL, K., 1986. Inventory of the meteorite collection of the Museo Nacional de Ciencias Naturales, C.S.I.C., Madrid, Spain. *Meteoritics*, 21, 193–197.
- KROT, A. N., KEIL, K., SCOTT, E. R. D., GOODRICH, C. A. & WEISBERG, M. K., 2014: Classification of Meteorites and their genetic relationships. In: Meteorites and Cosmochemical Processes, Volume 1 of Treatise on Geochemistry, Sec. Ed. (Davis, A. M., ed.). *Elsevier Sci.*, 1–63.
- LOBANOVSKY, Y. I., 2014: Comet and Meteor Threat: Historical Aspects. Synerjetics Group, available at: <http://www.synerjetics.ru/article/history.htm> (in Russian).
- LORES, J. I., 1977: Baracoa, Apuntes para su historia. *Edit. Arte Lit., La Habana*.
- MEUNIER, S., 1867: Géologie comparée. Étude descriptive théorique et expérimentale sur les météorites. *Paris*, 187 p.
- MOREIRA MARTÍNEZ, J., 1994: Impacto meteorítico en Santa Isabel de las Lajas (resumen). In: Libro de Resúmenes del II Congreso cubano de Geología, *Santiago de Cuba*, 170 p.
- MUÑOZ-ESPADAS, M. J., MARTÍNEZ-FRÍAS, J., LUNAR, R., SÁNCHEZ, B. & SÁNCHEZ, J., 2002: The meteorite collection of the National Museum of Natural Sciences, Madrid, Spain: An updated catalog. *Meteor. Planet. Sci.*, 37, B1–B6.
- NARANJO, F. & AGUILAR, R., 1941: Notas sobre Morón. *Rev. Sint.*
- PELÁEZ, O., 2010: ¿Bólide sobre el cielo pinareño? *Granma*: available at: <http://www.granma.cu/granmad/2010/06/12/nacional/artic07.html/>, last accessed 30 September 2019.
- PELÁEZ, O., 2014: Meteoritos. *Granma*: available at: <http://www.granma.cu/ciencia/2014-03-01/meteoritos/>, last accessed 30 September 2019.
- PELÁEZ, O., 2018: ¿Han caído meteoritos en Cuba? *Granma*: available at: www.granma.cu/file/pdf/2018/08/11/G_2018081108.pdf, last accessed 30 September 2019.
- PÉREZ-DOVAL, J., 1996: Meteoritos Cubanos. *Datos Astronóm. Cuba*, 101.
- PRIOR, G. T., 1923: Catalogue of Meteorites: With Special Reference to Those Represented in the Collection of the British Museum (Natural History). *London, British Mus. Natur. Hist.*
- RAMOS-GUADALUPE, L. E., 2004: Sobre un notable bólide observado en La Habana en mayo de 1886. *Datos Astronóm. Cuba*, 89–91.
- RODRÍGUEZ-FERRER, M., 1876: Naturaleza y civilización de la grandiosa Isla de Cuba. *Madrid, Imprenta de J. Noguera*.
- ROJAS-AGUILERA, A., 2013: La roca parece vino del cielo. *Ahora*, 478 p.
- RUBIN, A. E. & MA, CH., 2017: Meteoritic minerals and their origins. *Geochemistry*, 77, 3, 325–385, <http://dx.doi.org/10.1016/j.chemer.2017.01.005>.
- SEGURA-SOTO, R., 1983: Hallazgo de un meteorito en la Playa de Bacuranao, Cuba. *Bol. Soc. Cubana Geol.*, 1, 1, 76–82.
- SOLANO Y EULATE, J. M., 1872: Noticia sobre un hierro meteórico hallado en el departamento oriental de la isla de Cuba. *An. Soc. Esp. Hist. Natur., Madrid*, 1, 183–186.
- SOLÍS-DÍAZ, J. M., 2013: Avistado en Calimete fenómeno celeste luminoso. Radio Rebelde, available at: <http://www.radiorebelde.cu/noticia/avistado-calimete-fenomeno-celeste-luminoso-20130211/>, last accessed 30 September 2019.

- SOTO, G. J., 2018: La meteorítica en América Latina en el siglo XIX. In: 125 años de las meteoritas en el Palacio de Minería Lucero Morelos Rodríguez y Omar Escamilla González (coordinadores), *Universidad Nacional Autónoma de México*, 79–89.
- STÖFFLER, D., KEIL, K. & SCOTT, E. R. D., 1991: Shock metamorphism of ordinary chondrites. *Geochim. Cosmochim. Acta*, 55, 3845–3867.
- VÁZQUEZ-TORRES, M. & PINO TORGA, R. M., 2019: El meteorito de Viñales: campo de dispersión y daños ocasionados. *An. Acad. Cienc. Cuba*, 9, 1, 19–28.
- VIÑES, R., 1886: El aerolito de la noche del 10 de mayo de 1886. *Enciclopedia*, 2, 5, 238–239.
- WARD, H. A., 1904: Catalogue of the Ward-Coonley Collection of Meteorites. Chicago. Available at: http://www.woreczko.pl/meteorites/references/ref_Catalogs/Ward-Coonley-1904.pdf.
- WLOTZKA, F., 1993: A weathering scale for ordinary chondrites. *Meteoritics*, 28, 460.
- YIN, F. & DAI, D., 2021: Petrology and mineralogy of the Viñales meteorite, the latest fall in Cuba. *Sci. Progress*, 104, 2, 1–12.
- ZULUAGA, J. I., CUARTAS-RESTREPO, P. A., OSPINA, J. & SUCERQUIA, M., 2019: Can we predict the impact conditions of meter-sized meteoroids? *Monthly Notices of the Royal Astronomical Society. Letters*, 486, L69–L73. <https://doi.org/10.1093/mnrasl/slz060>.

Meteority a pozorovania meteorov a bolidov na Kube

Úvodný článok o problematike meteoritov na Kube poskytuje dostupné informácie od roku 1833, rovnako aj o vzorkách s neistou príslušnosťou (obr. 1). Prehodnotené sú aj dostupné záznamy o pozorovaniach letiacich žiarivých objektov – meteorov či bolidov.

Prvá vzorka meteoritu bola objavená v roku 1844 na kubánskej lokalite Las Canas, St. Andras (obr. 2). Celkovo bolo na Kube zaznamenaných 10 zistení meteoritov. Zvýšený záujem o danú problematiku zo strany amatérskych aj profesionálnych bádateľov sa datuje do obdobia po roku 1990.

Článok hodnotí záznamy z roku 1871 a neskoršie nálezy Mango Jobo (1938), Bacuranao (1974), Lajas (1994), Boyeros (1996), Balcón de LaLisa (2001) a Güira de Melena (2001). V prípade podrobne prezentovanej udalosti v doline Viñales autori uvádzajú aj trajektóriu viñaleského bolidu (obr. 6 a 7), ktorá je veľmi podobná trajektórii určenej autormi Zuluaga et al. (2019).

Pri hodnotení žiarivých objektov (meteorov, bolidov) autori článku prezentujú archívne záznamy z nasledujúcich zistení: Morón (1867), Havana (1886), Consolación del Sur (2010), Calimete (2013), Rodas (2013) a Hoguín (2021).

Nálezy Mango Jobo, Boyeros, La Lisa a Güira de Melena sa tradične označujú ako meteority. Tieto nedostatočne popísané a slabo zdokumentované nálezy a nedostupnosť vzoriek na moderné analýzy však indikujú, že išlo skôr o meteory než pravé meteority.

Za potvrdené pozorovania meteoritov možno považovať výskyty Las Canas, Lajas a Ramón de las Yaguas. Spomedzi nájdených úlomkov článok poskytuje dostupné informácie o náleze Ramón de las Yaguas z roku 2021.

Pád meteoritu v doline Viñales v roku 2019 vzbudil záujem bádateľov z celého sveta. Mnoho hodnotných vzoriek bolo z Kuby odvezených do súkromných zbierok s obmedzeným prístupom pre bádateľov, len malé množstvo vzoriek sa dostalo do muzeálnych zbierok. Na niektorých vzorkách sa zistili orientované štruktúry a predĺžené regmaglypty. Meteorit z doliny Viñales bol už druhým prípadom s takýmito orientovanými štruktúrami po tom, ako sa zistili v prípade meteoritu Lajas.

Doručené / Received: 29. 6. 2021
Prijaté na publikovanie / Accepted: 15. 12. 2021