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Colomera (Granada, Spain): More than a century of an IIE iron meteorite journey

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Abstract–Colomera is the Spanish meteorite (IIE) that has aroused the greatest interest among the international scientific community. Until now, the story of the find was only partially known and certain data are incorrect. The amazing journey of this meteorite has been recounted in this work. It reveals unpublished information derived from local archives, and testimonies from the descendants of the family that found the meteorite in 1913, and from the inhabitants of Colomera (Granada, Spain). We also document the story after its discovery, which culminated in a 2015 court ruling demanding the return of the largest part the mass (120.34 kg) to the heirs of the Spanish family that discovered the meteorite. Some of the material initially extracted in Spain (305 g) is currently housed in the Natural History Museum (121.3 g; London, UK). Nine kilograms of fragments remains in the United States after returning the meteorite to Spain in 1969. Of these, we have only located slightly more than 4 kg in several American institutions. Recently, 235 g has been returned to Spain: two fragments in private collections and two fragments in the Museo Geominero, Spanish Geological and Mining Institute (Spanish acronym: IGME).

INTRODUCTION

Colomera was the first metallic meteorite found in Spain at the beginning of the 20th century (Dorronsoro and Moreno Martín 1934). This is a medium octahedrite classified within the rare group IIE (Scott and Wasson 1975), of which only 25 specimens are known worldwide. The silicate-bearing IIE meteorites are arguably the most complex and enigmatic of all iron meteorite groups. Colomera is the fourth largest mass within this restricted group (134 kg), only surpassed by Mont Dieu (a piece of 435 kg, Sedan, France; Van Roosbroek et al. 2015), Miles (254 kg, Queensland, Australia; Wlotzka 1994), and Netschaëvo (250 kg, Kaluzhskaya Oblast, Russia; Scott and Wasson 1975). As is typical within the IIE group, it contains abundant globular inclusions, mainly composed of silicate and glass, some of which have an alkaline composition (Prinz et al. 1983; Takeda et al. 2003). The presence of feldspar phenocrystals on the meteorite surface is one of the most important scientific textural features (sanidine: Or_{89} Ab_{10} $An_{0.1}$; Wasserburg et al. 1968), given the incompatibility of a metal core with planetary crustal k-feldspar (Marvin 2004). However, it has recently been suggested that the parent body of the IIE iron meteorites was an apparently undifferentiated planetesimal containing an iron core, achondritic silicate mantles, and chondritic crust (Maurel et al. 2020).

Currently, there are 31 Spanish meteorites registered by the Meteoritical Society. The most studied are Barea (1842; mesosiderite A-1; Albrecht et al. 2000); Roda (1871; diogenite; Mittlefehldt 2015); and Colomera, which is the Spanish meteorite that has led to the largest amount of scientific production. It was reanalyzed in Spain 20 years after the preliminary study of Dorronsoro and Moreno Martín (1934), and the elementary metal composition was determined (Pérez-Mateos 1954). A few years later, German researchers from the Max Planck Institute dated a set of metallic meteorites, including Colomera, to an age of 4000 Ma using the Re-Os method (Herr et al. 1961). Vilcsek and Wänke (1963) established the age of Colomera's exposure to cosmic rays at 75 Ma, based on measurements of ^{36}Cl, and a year later, Hintenberger and Wänke (1964) published the He and Ne contents. It was an exciting scientific challenge, trying to establish the age of the meteorites using radiometric dating and, thus, determining the age of the solar system and the Earth (Marvin 2004). This work unveiled the Colomera meteorite to the international scientific community and it attracted the interest of US researchers, as the silicate inclusions were suitable for ^{87}Rb-^{86}Sr radiometric method dating. For this reason, the whole meteorite was shipped to CALTECH (California Institute of Technology, Pasadena, USA) in 1966 (Wasserburg 2003). All the research objectives were met in a short time with two works reporting radiometric ages of between 4700 and 4600 Ma (Burnett and Wasserburg 1967; Sanz et al. 1970). Furthermore, Mason (1967) published the first characterization of their silicate inclusions, Bunch (1969) discovered yagiite, a new mineral species, and other rare minerals (Buchwald 1977). Subsequent studies focused again on the silicate inclusions, exploring the possible genetic relationship between chondrites and metallic meteorites through the analysis of rare earth elements (Armstrong et al. 1990; Hsu et al. 1997) and the I-Xe cooling rates (Hohenberg et al. 2004). The ^{39}Ar-^{40}Ar dating of Colomera feldspar (Bogard et al. 2000) fits well with the results obtained by Sanz et al. (1970). Snelling (2015) summarizes all the published dates of Colomera. To date, the most complete mineralogical and chemical characterization of these inclusions has been reported by Takeda et al. (2003), suggesting impact mixing of metal and silicates. Finally, McDermott et al. (2016) analyzed the oxygen isotopes (δ^{17}O-δ^{18}O) from Colomera and other IIE group meteorites, comparing them with those obtained in H chondrites.

The principal objective of this work is the complete reconstruction of the discovery of the meteorite (Dorronsoro and Moreno Martín 1934). This is based on new data obtained from different public and private documents of the time, together with oral testimonies from relatives of the owners as well as from the oldest inhabitants of Colomera. Among other findings, the research shows the exact location of the house where the discovery occurred, and the find date (1913), erroneously reported as 1912 by Dorronsoro and Moreno Martín (1934). Until now, the information related to the current location of the fragments in the United States and Europe was incomplete and out of date (King et al. 1986; Grady 2000; Muñoz-Espadas et al. 2002). The Colomera meteorite was incorporated into the collection of the National Museum of Natural Sciences (Spanish acronym: MNCN, Madrid, Spain) in 1935. After it was moved for study to CALTECH, the specimen was returned to the MNCN in 1969. It weighed somewhat less due to cleaning and the fragments taken by the different American institutions. The second objective of this work is to update the current locations of the fragments of this exceptional meteorite. Many pieces were sent to various institutions for different reasons, in most of cases due to research that was conducted from the 1930s to the 1970s. The final objective is to describe the details of the judicial process that returned the fragments housed for almost 80 years in the MNCN to the heirs of the Spanish family that discovered the meteorite. This information is of special interest in regard to the future international development of patrimonial legislation for meteorites (Gounelle and Gounelle 2019).

THE FIND STORY

The only written source close to the date of the discovery is Dorronsoro and Moreno Martín (1934). It includes the brief information provided by the eldest son of the Pontes Vílchez family (Antonio Pontes Vílchez), the owners of the house where the meteorite was found. These authors pointed out that the available information about the discovery was scarce: "Its current owner, Mr. Ponte, tells us that it was found in 1912 in the village of Colomera (Granada), buried about a metre deep, in the centre of a small patio or yard, attached to the house." Muñoz-Espadas et al. (2002) cited the date of November 5, 1912 as the date of the discovery in the MNCN meteorite catalog, although the authors do not provide any information about the source of this date.

The story of the discovery began with the purchase of the house where the meteorite was found. Miguel Pontes Márquez worked as a pharmacist in the village of Colomera (Granada, Spain; Fig. 1). Given the need for a suitable premises in which to install their pharmacy and their home, Miguel Pontes Márquez and his wife Maria Luisa Vilchez Aimar acquired two adjoining houses (numbers 6 and 8 of "Los arcos del Horno" street; Fig. 2A), currently known as "Arco del Horno" street (Fig. 2B) in the village of Colomera on October 10, 1911. The document was granted before the notary Bruno Rafael Juristo Crespo, residing in Iznalloz, Granada (Fig. 3A).

On September 5, 1913, Saturnino Mota, as representative of the mayor of the municipality of Colomera, required the Pontes Vílchez family to put a stop to the wastewater discharges to the "Barranco de Calero" street (currently "Barranco Calero"; Fig. 2B). This was for health and hygiene reasons under threat of penalty, giving them the short period of 48 h to undertake the necessary works to channel this

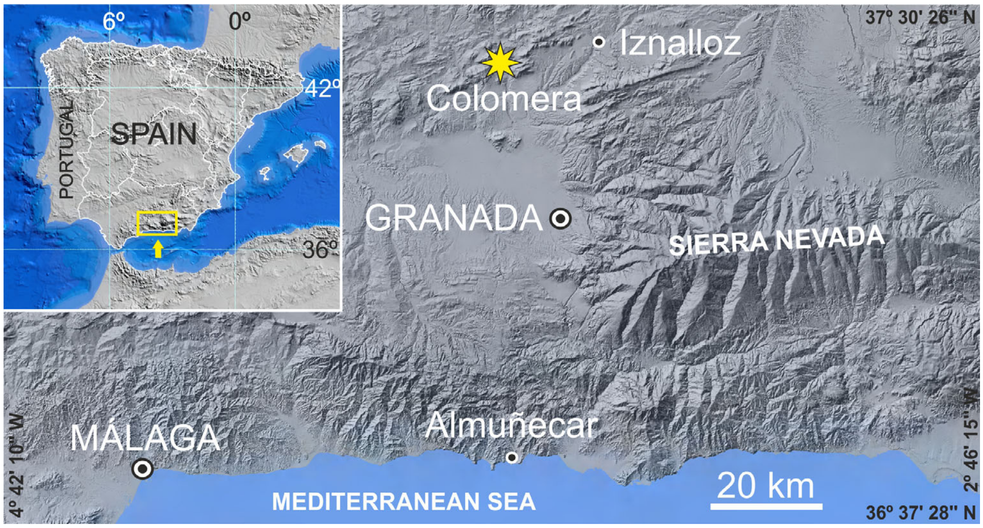


Fig. 1. Location of Colomera in the province of Granada (S Spain), including other localities mentioned in the text.

wastewater into the nearest sewers or septic tanks (Fig. 3B). The Pontes Vílchez family undertook the connection works of the wastewater to the sewer on September 6 or 7, 1913. During the excavation, they encountered a large and very dense metal mass buried a meter and a half below ground, which was removed from the trench to continue the work. These facts have been confirmed by María Paz Clemente Pontes, Miguel Pontes's granddaughter (and Antonio Pontes's mother), who lived with her grandmother in Almuñecar until her death in 1958. María Paz was present at many family gatherings where her grandmother Maria Luisa commented on the details of the discovery with her daughters, Maria Paz and Magdalena Pontes Vilchez.

After locating the house where the discovery took place, and establishing the real reason that led to the excavation, we have recognized and visited the exact place where the meteorite was found. The current number 10 of "Arco del Horno" street (Fig. 3C) corresponds to the numbers 6 and 8 of the former "Los Arcos del Horno" street. Both old houses have been uninhabited for decades and are at risk of collapse. However, both interior patios are preserved as they were in 1913. The patio corresponding to the old number 8 still has an artesian well with the water table at a depth of some 12 m (in September 2018), and a sink for hand-washing clothes, as was customary at the time. The meteorite was found in the other patio, corresponding to the former number 6, and closer to the current "Barranco Calero" street. At a corner of this patio, there is a toilet without a door (Fig. 3D), with a drainage outlet in the floor. Close to this point is the access to the sewer connection where the meteorite was found (37°22′17.60″N, 3°42′51.30″W).

Dorronsoro and Moreno Martín (1934) had doubts about the exact location of the fall because the data provided by Antonio Pontes (Miguel Pontes's son) made them think that "either the mass was found elsewhere and moved there later, or it fell at a time when the site was uninhabited. Otherwise more specific data would be available regarding the date and the phenomena that would have accompanied the fall". Indeed, the absence of news about the fall of a meteorite indicates that it occurred prior to the founding of the village. Colomera has Roman archaeological remains, so its foundation probably dates back to the second century (Sánchez and Pajares 2007) and, therefore, the meteorite would have struck more than 2000 years ago. Although where it was found has been traditionally considered to be the location of the fall (Martín Escorza 1987), it is possible this may not be the case. In 1640, a huge landslide took place, dragging half of the village down the slope to the west (Sánchez and Pajares 2007). The site of the discovery was affected by this landslide, so it is highly likely that the original fall site was topographically higher, to the east of the village. The effects of this landslide are visible today especially in the north-western sector of the village, where the semicircular front of the landslide can be observed (Fig. 2B).

According to testimonies by the family and the inhabitants of Colomera, just over 50 m from the site of the discovery (a place formerly known as "Cruz de Ánimas," Fig. 2A, see current appearance in Fig. 3E), the young people of the village would organize games to test their strength and would try to lift the specimen. In the 1990s, the metallic meteorite of Retuerta del Bullaque (100 kg; Ciudad Real, Spain) was also used in lifting exercises (Lozano et al. 2013).

Fig. 2. A) Map of the Colomera town (Granada) in 1896 (CC-BY 4.0, Instituto Geográfico Nacional) with enlargement of the discovery site. The yellow arrow indicates the place where the young people of the village gathered to measure their strength in a playful way, trying to lift the specimen. B) Current aerial view of the Colomera town with enlargement of the area (images from Google Maps). The yellow dashed line indicates the front of the landslide that took place in 1640 (Sánchez and Pajares 2007). The yellow arrow indicates the location of the find.

THE METEORITE'S JOURNEY

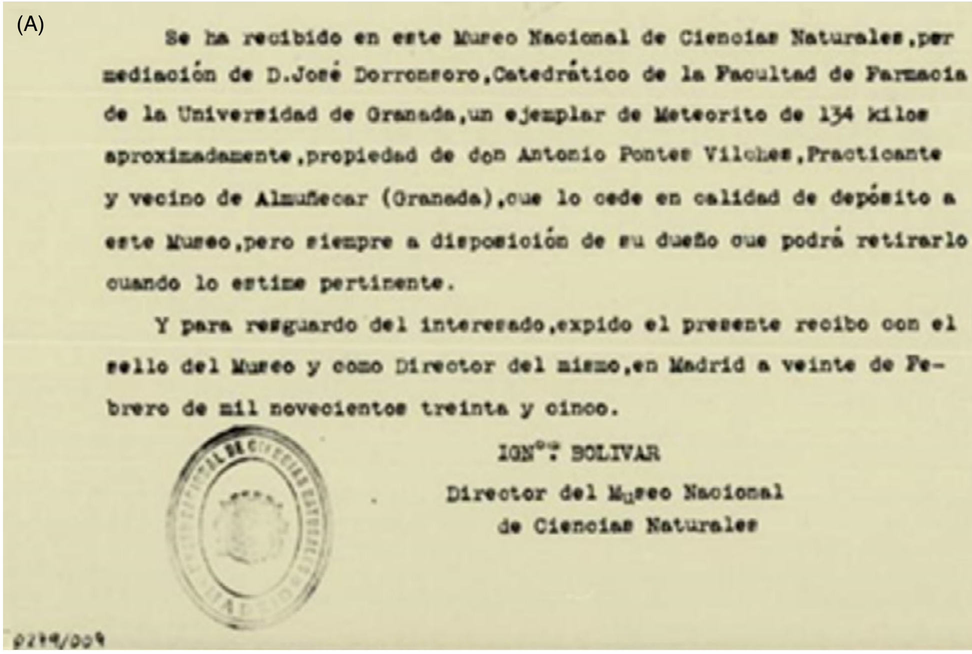
Almuñecar (Granada) and the Entry in the MNCN

In early 1926, the Pontes Vílchez family left the village of Colomera and moved the meteorite to a house in "Bajo el Mar" Street (Almuñecar, Granada; Fig. 1) as stated in the Title of Ownership. Two years later, Miguel Pontes died in Almuñecar, and his son, Antonio Pontes Vílchez, the eldest of the brothers, continued the work of his father in determining the meteoric origin of Colomera (years later, he would deposit it at the MNCN in Madrid, Fig. 4A). Dorronsoro and Moreno Martín (1934) mention carrying out a chemical analysis prior to the transfer of the meteorite to Almuñecar: It was composed of iron with a significant amount of vanadium. Although we have no such information, the sample was most likely analyzed in the only institution of the time close to Colomera, the Department of Inorganic Chemistry of the Faculty of Pharmacy (University of Granada), where they had the necessary instruments.

Between 1926 and 1934, those who would decide on the immediate future of the meteorite met in Almuñecar: Antonio Pontes Vílchez, Julio Mateos García (a pharmacy student at University of Granada),

Fig. 3. A) Purchase deeds of the two adjoining houses acquired by Miguel Pontes Márquez and María Luisa Vílchez Aimar in 1911. These were, more precisely, houses No. 6 and 8 of the Los Arcos del Horno street (current Arco de Horno), where the meteorite was discovered. B) Municipal order to the family Pontes Vílchez requiring them to stop discharging sewage onto the street: "For hygiene and health reasons, this city council has agreed that the sewage pipes be connected to the nearest sewers or septic tanks. It urges you to connect the pipe to the tank in Barranco Calera Street within the precise term of 48 h. Otherwise, the maximum fine will be imposed. Colomera, September 5, 1913." Origin of the two documents: Colomera City Council Registry (Granada). C) Current Arco del Horno, 10-house façade. D) Current view of the patio where the meteorite was found. E) Crossing of Emilio Castro Nievas, Pilar Leonés, and Alonso Rivas streets; the place where the young people of the village played games to measure their strength by trying to lift the specimen (place formerly known as Cruz de las Ánimas).

and the professor of inorganic chemistry José Dorronsoro Velilla, who spent his summers in the town. Antonio communicated with Julio Mateos regarding the existence of the strange object. Julio took some small pieces cut from the main mass to his university. The analysis of the fragments was carried out by Julio



(A)

Se ha recibido en este Museo Nacional de Ciencias Naturales, por mediación de D. José Dorronsoro, Catedrático de la Facultad de Farmacia de la Universidad de Granada, un ejemplar de Meteorito de 134 kilos aproximadamente, propiedad de don Antonio Pontes Vilches, Practicante y vecino de Almuñecar (Granada), que lo cede en calidad de depósito a este Museo, pero siempre a disposición de su dueño que podrá retirarlo cuando lo estime pertinente.

Y para resguardo del interesado, expido el presente recibo con el sello del Museo y como Director del mismo, en Madrid a veinte de Febrero de mil novecientos treinta y cinco.

IGN$^{\circ}$. BOLIVAR
Director del Museo Nacional
de Ciencias Naturales

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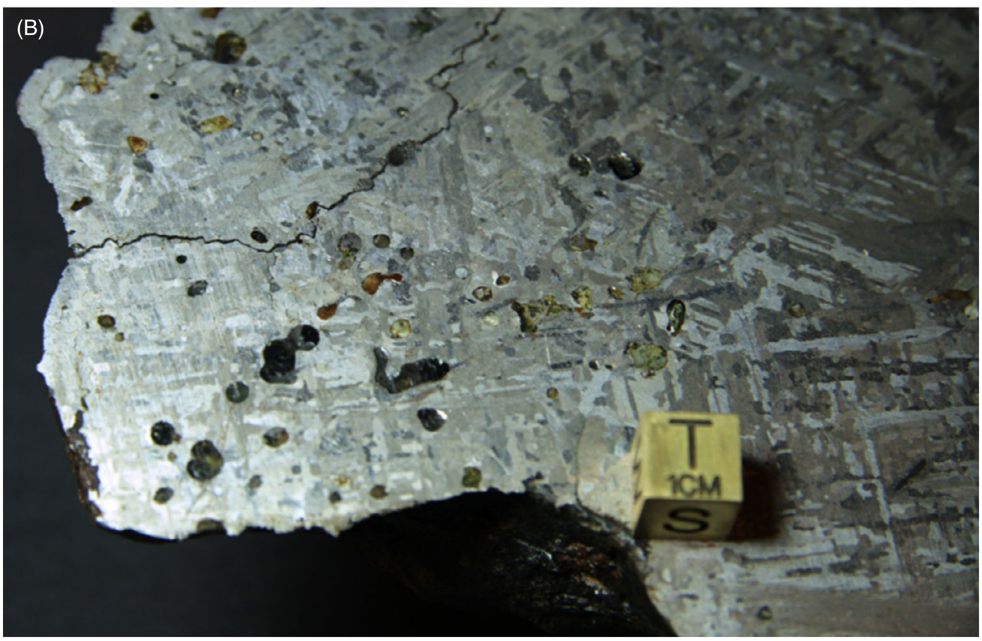

Fig. 4. A) Receipt for the deposit of the Colomera meteorite in the MNCN, signed by Ignacio Bolívar y Urrutia, the director in 1935. It reads: "A specimen of a meteorite weighing approximately 134 kg, owned by Antonio Pontes Vilchez, a practitioner and resident of Almuñecar (Granada), has been received, through Mr. José Dorronsoro, professor at the Faculty of Pharmacy of the University of Granada. He has loaned it to this museum, but it is always at his disposal and he may withdraw it whenever he wishes." B) Polished and nitric acid etched surface of the Colomera meteorite. An anomalous Widmanstätten pattern (polycrystalline texture) and glassy inclusions with droplet silicates are clearly visible. Photography: Emilio Gilabert. Fragment 17517, 12.5 kg, photographed at the Museo Nacional de Ciencias Naturales (MNCN), Madrid.

Mateos himself under the direction of Dorronsoro and Moreno Martín, with the results clearly showing that it was a metallic meteorite with significant Ni-iron and cobalt, but not vanadium (Dorronsoro and Moreno Martín 1934).

To conduct a detailed study of the specimen, Dorronsoro arranged to move the meteorite from Almuñecar to the University of Granada. He cut a 255 g piece by making two perpendicular cuts. A polished section large enough to be tested with 1%

nitric acid solution was obtained. After several hours in contact with the acid, a clear Widmanstätten pattern was not achieved (Fig. 4B). However, convergent straight lines were observed and identified as Neumann bands. In addition to this, Dorronsoro extracted 50 g of filings for a metal chemical analysis (Dorronsoro and Moreno Martín 1934).

After finishing this analysis, the main specimen weighed approximately 133.6 kg due to the extraction of 305 g (the piece + filings) and the material lost to cutting (approximately 100 g). Dorronsoro then sent the meteorite to the MNCN in Madrid. Ignacio Bolívar y Urrutia, director of this museum at that time, signed the receipt dated February 20, 1935, stating that he received the Colomera meteorite from its owner (Fig. 4A).

The Meteorite in the United States

The Colomera meteorite was shipped to the Division of Geological and Planetary Sciences, (CALTECH; Pasadena, USA) along with other Spanish specimens in 1966, with funding from the National Science Foundation and NASA. The MNCN temporarily transferred the specimen within the framework of an agreement signed between the Spanish National Commission for Space Research (Spanish acronym: CONIE, created in 1963), the Nuclear Energy Board (Spanish acronym: JEN, created in 1951), and the MNCN itself. The main goal of the agreement was the study of the meteorites and the training of JEN scientists, within the period between 1966 and 1969. The agreement was signed in an atmosphere of full cordiality between Spain and the United States, since collaborative relationships already existed in the space field, specifically within the US Gemini and Apollo space programs (Urech 2011). The Spanish chemists Hermógenes Guillermo Sanz (JEN) and his wife Maria Luisa Santillana were chosen to train in isotope spectrometry applied to meteorite and lunar sample dating (Wasserburg 2003). However, the testimony of their daughter, Maria Luisa Sanz Santillana, shows that only Sanz received geochemistry training. In fact, only Sanz was a documented member of this American institution from October 1, 1967 to October 30, 1969 (Anonymous 1967). He took part in and signed off on the first dating of lunar material collected in the Apollo XI mission (Albee et al. 1970).

Gerard Joseph Wasserburg, a specialist in isotope geochemistry, was the CALTECH researcher who requested the Colomera meteorite (Fig. 5A), very suitable for $^{87}Rb/^{87}Sr$ dating. Wasserburg clearly described his interest in an article in the American magazine *Mineral Information Service*: "Our method will be to study the isotopes of rubidium and strontium that we find in the very small crystals of silicates embedded in the iron. By this procedure we hope to determine the meteorite's story of heating and collisions in space in the past 4.6 billion years" (Anonymous 1968). Wasserburg (2003) also related the arrival of the specimen:

> This meteorite arrived in a beautifully made wooden crate. We all stood in the hall to open it. After unscrewing the lid, there was a tightly fitting sheet of finished wood inside. When this was gently pried out, there was a drawing of Sanz with his legs in chains attached to a piano where he was playing Colomera's Bolero. The sky overhead had flying cacti, space

Fig. 5. A) Gerald Joseph Wasserburg (left) and Hermógenes Guillermo Sanz (right) with the meteorite at Division of Geological and Planetary Sciences (CALTECH; Pasadena, USA), after the previous cut made in the United States National Museum (USNM, today Smithsonian National Museum of Natural History: NMNH). The second cut was made perpendicularly to the first, on the side where Hermógenes Guillermo Sanz stands. At the background, above the researchers, the Lunatic mass spectrometer (I. Image 9® D GJW57.1-2, Courtesy of the Archives, California Institute of Technology). B) Two views of the Colomera meteorite. The feldspar inclusion and the broken surface discovered by Gerard Joseph Wasserburg after cleaning in the United States in 1966 can be observed.

> ships, and autographs of the Staff of the Junta. I was shown standing over Sanz beating him with a cat-o-nine tails containing micrometeorites. The picture still hangs in the lab. When we got the meteorite out, it was a mass of iron full of little silicate globules. Dick Feynman came to look it over and to talk about it. We had to lie on the floor to study the cut face.

The same day that the meteorite arrived at CALTECH, Wasserburg cleaned the surface of the specimen at the Jet Propulsion Laboratory. It showed evident signs of oxidation and ground contamination, produced while it was underground prior to the discovery. Using the sandblasting technique (titanium spherules), he cleaned the surface and found a huge feldspar crystal (11 cm long; Fig. 5B). This finding was in itself a major scientific advance as a potassium feldspar of this size had never been found within a metallic meteorite (Wasserburg et al. 1968). After cleaning, he also found several areas where the surface was damaged: Remains of the forge attachment, hammer, and chisel marks generated by the 1930s sampling. A very interesting feature that emerged after the cleaning was a 100 cm^2 break in the surface (Fig. 5B), suggesting the removal of a large meteorite fragment. This could be considered a primary fracture that was practically unaffected by atmospheric ablation. If this were the case, it is likely that the other part of the original mass is still buried near the town of Colomera. After cleaning, the meteorite was moved to the United States National Museum (USNM; nowadays the Smithsonian National Museum of Natural History: NMNH) where a first cut was made (Figs. 5A and 6A–B). On returning to CALTECH, a second cut, perpendicular to the one above it, was performed (approximately 35 $\times$ 17 cm; Figs. 5B and 6A–C). When the meteorite reached the United States, it weighed about 133.6 kg. The cleaning and removal of the pieces removed 4.3 kg, and the specimen weighed about 129.3 kg (Wasserburg et al. 1968). Wasserburg (2003) erroneously cites the weight of the mass of Colomera and confuses the total mass (133.6 kg) with the mass remaining after the samples taken at USNM and CALTECH (129.3 kg).

The specimen weighed approximately 120.3 kg when it was returned to Spain in 1969, with nine kilograms of fragments remaining in the United States. These fragments were closely studied by scientists around the world, which improved our knowledge of this peculiar meteorite group (Mason 1967; Bunch and Olsen 1968; Wasserburg et al. 1968; Bunch 1969; Chang and Wänke 1969; Hsu et al. 2000) and was used to date the solar system and create the first hypotheses about metallic meteorites unrelated to planetary cores (Burnett and Wasserburg 1967; Sanz et al. 1970; Wasserburg 2003).

CURRENT LOCATION OF FRAGMENTS

The data obtained as to the current location of the fragments after cutting and sampling show that most of them are in the United States and Europe. One of the interesting chapters of the Colomera story is related to the present location of the main mass, currently in Spain.

The Fragments in the United States

The NMNH (previously USNM) preserved most of the fragments obtained after the first cut made in the 1960s. The museum currently has 15 fragments, which together weigh 3149.96 g, plus 11 thin and polished samples (https://collections.nmnh.si.edu; Table 1). In the 1960s, a fragment of unknown weight was cut from one side. Without accurate information, one can only speculate that this fragment was cut to obtain a thick slice and other fragments, including an end cut (Fig. 6B). In fact, Burnett and Wasserburg (1967) refer to a slice that measures 35 $\times$ 5 $\times$ 2 cm belonging to the USNM, which was used to date the silicate inclusions. Eight years later, Buchwald (1975) mentioned that three slices of 40 $\times$ 10 $\times$ 0.5 cm (No. 3396: 1224 + 1200 + 781 g) were in the NMNH collection, plus a small portion of a slab (no. 1514: 133 g), with a total weight of 3338 g. This seems to indicate that the initial fragment was divided into a 2 cm thick sheet, cited by Burnett and Wasserburg (1967), and one of the ends was cut off. This 2 cm thick slice was later sectioned into 0.5 cm thick slices. However, the width and the length cited by Burnett and Wasserburg (1967) and Buchwald (1975) do not match. In the scaled images provided by Tim McCoy (NMNH), the maximum length and width of the slabs are 38 and 10 cm, respectively (Fig. 7A).

If the weights cited by Buchwald (1975) are accurate, only the smallest slice (3396C, 781.1 g) would remain in the NMNH collection. The 3396A slice currently weighs 1220 g, although Buchwald (1975) cites a slice of 1224 g. It is possible that a small fragment was cut off, as the NMNH has a 3.2 g specimen (3396). The 3396B slice (928 g) must have originally weighed 1200 g (Buchwald 1975). It is likely that this slice was cut and specimen 3396D (107.4 g) is an offcut of the slice obtained. Information about the rest of this fragment is not available.

There are other fragments still in the NMNH collection bearing three different numbers (Table 1):

- 1514: 3 fragments (110.6 g in total) that were taken from the 133 g slice cited by Buchwald (1975).
- 6997: 4 samples (2.26 g in total) from the collection of the former NMNH curator, Brian Harold

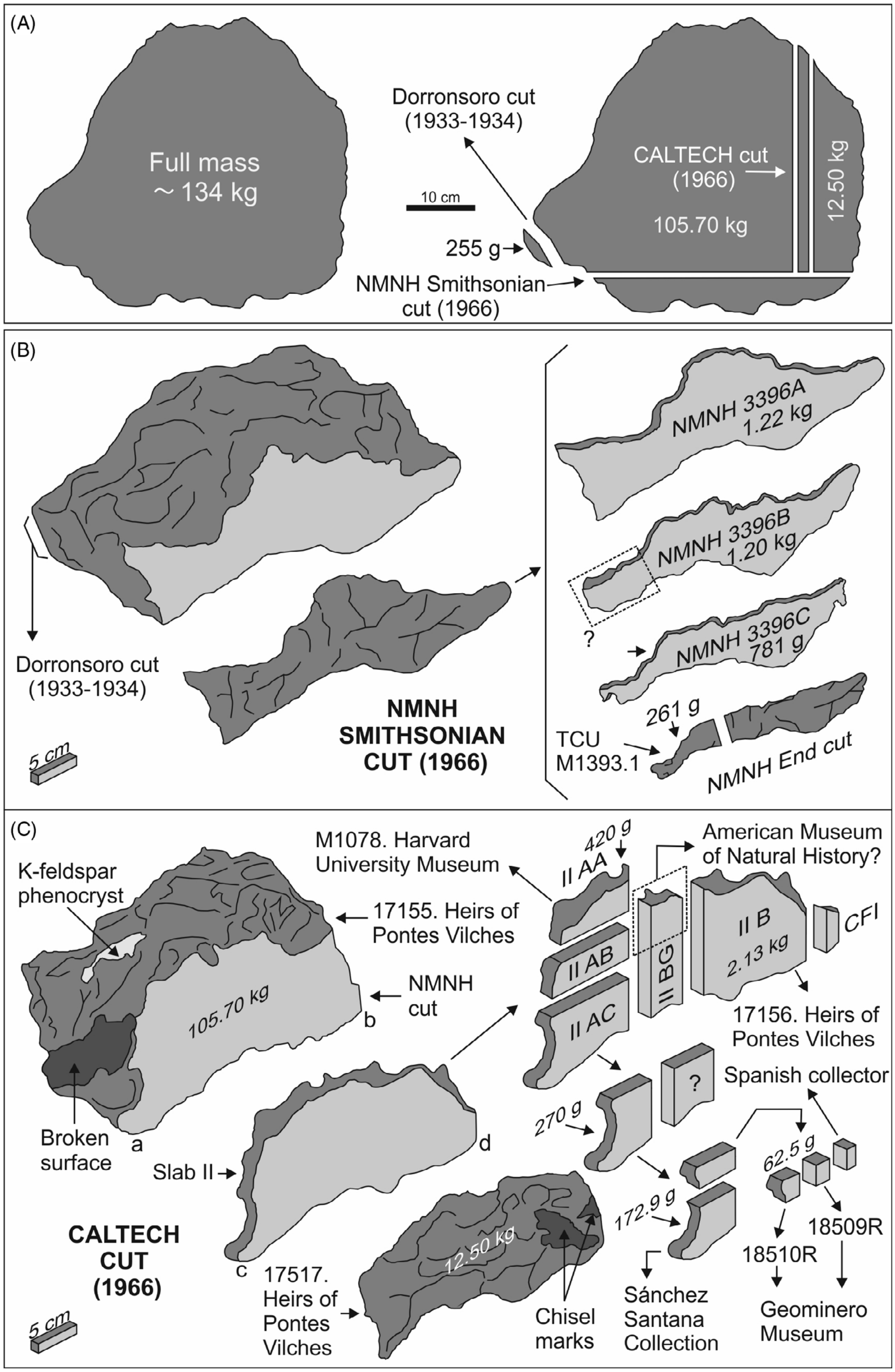

Fig. 6. A) View of the complete mass of the Colomera meteorite. The cut made by Dorronsoro and Moreno Martín in the 1930s and cuts made in the United States in 1966 are displayed. B) Fragments cut at the United States National Museum (USNM; now Smithsonian National Museum of Natural History: NMNH) in 1966 and later. C) Fragments obtained after the cut made at Division of Geological and Planetary Sciences (CALTECH; Pasadena, USA). The current location of each fragment is included.

Table 1. Current location of the Colomera meteorite samples preserved in US collections.

Collection	Total weight (g)	Samples	Sample type	Catalog number	Weight (g)	Approx. size (cm)
National Museum of Natural History Smithsonian, NMNH (Washington)	3149.96	26	Fragment	3396 A	1220.1	38 × 10 × 0.5
				3396 B	928.0	
				3396 C	781.1	34 × 10 × 0.5
				3396 D	107.4	
				3396	3.2	
				1514	23.98	
				1514	23.54	
				1514	19.64	
				7778	20.82	
				7778	20.15	
				7778	2.01	
				6997 145	1.109	
				6997 146	0.047	
				6997 147	0.904	
				6997 148	0.204	
			Thin section	3396		
				3396-1		
				3396-2		
				3396-3		
				3396-4		
				3396-5		
				3396-6		
				3396-7		
			Polished section	7777 a		
				1514 a		
				1514 b		
Mineralogical & Geological Museum, Harvard University, MGMH (Massachusetts)	420	1	Fragment	M1078	420	12 × 4.5 × 3.5
Monnig meteorite collection, Texas Christian University, TCU (Texas)	261.0	1	Fragment	M1393.1	261.0	11 × 5 × 1
American Museum of Natural History, AMNH (New York)	201.9	1	Fragment			
Geological and Planetary Sciences Collection, California Institute of Technology, CALTECH (California)	67.3	5	Fragment	W(179)19	32.0	4.0 × 1.0 × 0.5
				W(179)20	29.2	4.0 × 1.0 × 0.5
				W(179)18	3.8	2.5 × 1.0 × 0.5
				W(179)22	1.9	1.5 × 1.0 × 0.5
				W(179)21	0.4	0.5 × 0.5 × 0.5
Field Museum Meteorites of Natural History (Chicago, Illinois), The Robert A. Pritzker Center for Meteoritics and Polar Studies	61.12	4	Fragment	ME 2763.1	59.12	
			Powder in vial	ME 5867.1	1.0	
				ME 5867.2	1.0	
			Polished section	ME 2763.2		
Arizona State University, ASU's, Center for Meteorite Studies (Phoenix, Arizona), Carleton B. Moore Meteorite Collection		1				

Mason. It is unknown from which part of the meteorite these fragments were obtained since they were not cited by Buchwald (1975).

- 7778: 3 fragments (42.98 g in total), also not cited by Buchwald (1975). Although information was not available, it is possible that these fragments came from the end piece that was generated when the 2 cm thick slice was cut from the original fragment. A specimen of the Colomera meteorite (261 g) is retained in the Texas Christian University collection (TCU, Monnig Meteorite Collection; https://monnigmuseum.tcu.edu/our-collection; Table 1). The presence of a fusion crust indicates that it is a part of the initial fragment end. Furthermore, its morphology is similar to one of

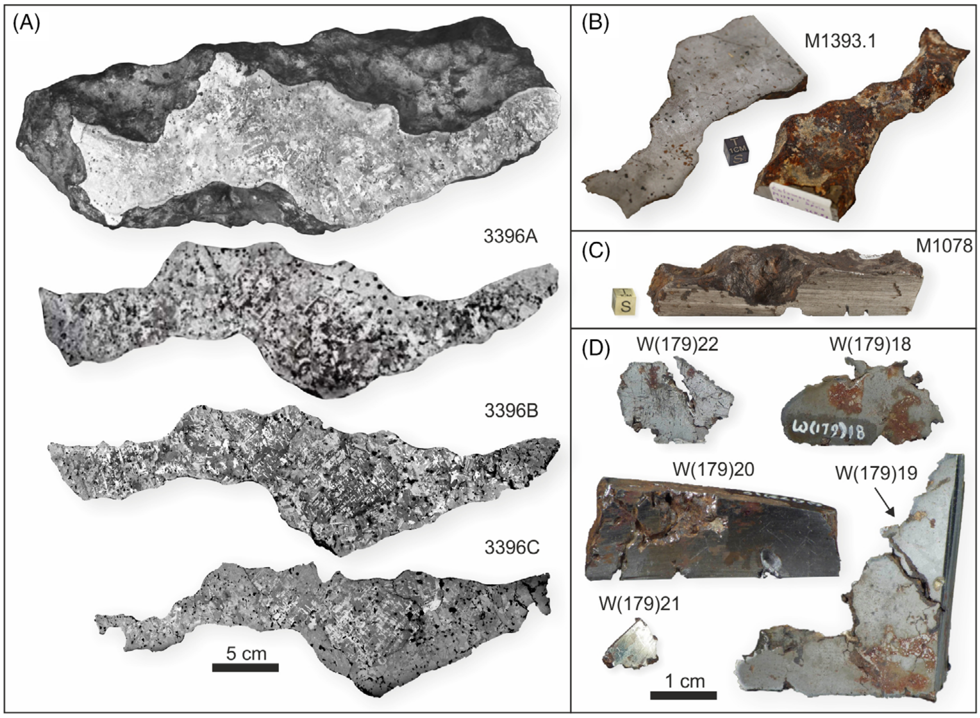

Fig. 7. A) First cut of the Colomera meteorite in the United States National Museum (USNM; now Smithsonian National Museum of Natural History: NMNH) and slabs obtained from the first 2 cm thick cut in the 1960s (Burnett and Wasserburg 1967). These slabs were obtained between 1967 and 1975, since they are cited in Buchwald (1975). Image 3396A was obtained from Buchwald (1975), the other section images are courtesy of Tim McCoy (Smithsonian Institution). B) Fragment M1393.1 preserved at Texas Christian University (TUC, Monnig Meteorite Collection), courtesy of Rhiannon Mayne (TUC). C) Fragment preserved in the Mineralogical & Geological Museum, Harvard University, MGMH (Massachusetts), courtesy of Raquel Alonso Pérez (MGMH). D) Fragments of the Gerald Wasserburg collection kept in the CALTECH GPS Collection, Division of Geological and Planetary Sciences (Pasadena); images taken from http://collections.gps.caltech.edu/fmi/iwp/cgi?-db=collections&-loadframes.

the ends of the final slice cut at NMNH (3396C) (Figs. 6B and 7B).

After the cut made in the USNM, the main mass of the meteorite was returned to CALTECH. There, two more cuts were made, spaced 2 cm apart (a–b and c–d; Fig. 6C). This divided the main body into three parts: the largest one (17155, 105.7 kg), a 12.5 kg fragment (17517), and a central 2 cm thick slice (slab II). This central slab was cut into six more pieces (II AA, II AB, II AC, II BG, II B, and CFI). The CFI fragment was sectioned for the study by Sanz et al. (1970). Currently, five fragments, weighing 67.3 g in total, are kept at the Geological and Planetary Sciences Collection at CALTECH (http://collections.gps.caltech.edu/fmi/iwp/cgi?-db=collections&-loadframes; Table 1; Fig. 7D). These specimens come from the private collection of Gerard Joseph Wasserburg. The II AA fragment is currently in the Mineralogical & Geological Museum at Harvard University (MGMH), in Massachusetts (http://minecat.rc.fas.harvard.edu/search/colomera; Fig. 7C; Table 1). It was donated to this institution in 2011 (cataloged on September 14 of that year). The fragment has been intensely studied, since it has been loaned four times (Alonso-Pérez, personal communication). The main mass returned to Spain in 1969, together with the other larger specimen (17517), one of the fragments of slab II (IIB; 17156), and some metallic powder (17186) (Table 2).

Authors have confirmed that the American Museum of Natural History (AMNH) in New York has a fragment weighing about 201.9 g (Table 1) donated by the MNCN. Although no information about the size and morphology of the piece has been obtained, it could be a part of the II BG fragment (https://www.amnh.org/research/physical-sciences/earth-and-planetary-sciences/collections). If this is the case, this fragment would have been returned to Spain in 1969 together with the main mass and the rest of the fragments.

Currently, four samples of Colomera are preserved in the Field Museum of Natural History of Chicago (Illinois): a fragment of 59.12 g, a thin section and two vials with powder (https://meteorites.fieldmuseum.org/node/12; Table 1). A fragment is also preserved at the Center for Meteorite Studies, Arizona State University

Table 2. Current location of the Colomera meteorite samples preserved in European collections.

Collection	Country	Total weight (g)	Samples	Sample type	Catalog number	Weight (g)	Approx. size (cm)
Miguel Pontes heirs	Spain	120342.3	4	Main mass	17155*	105700	38 × 38 × 15
				Fragment	17517*	12500	28 × 13 × 8
					17156*	2125	15 × 10 × 2
				Metallic powder	17186*	17.3	
Natural History Museum (London)	United Kingdom	121.3	2	Fragment	BM.2005 M88	115.2	5.0 × 2.2 × 1.8
				Bottle with filings	BM.2005 M89	6.1	
Sánchez J.A. private collection	Spain	172.9	1	Fragment		172.9	7.4 × 5 × 1
Museo Geominero, IGME (Madrid)	Spain	62.45	2	Fragment	18410	34.55	2.2 × 2.7 × 1
					18409	27.90	2.2 × 1.7 × 1
Unknown private collection	Spain	≈20	1	Fragment		≈20	≈2 × 1.5 × 1

*MNCN catalog number.

(ASU, Phoenix, Arizona), although data about weight, size, or morphology are not included in the catalog (https://meteorites.asu.edu/collection/specimen-catalog). In the same way, it is likely that samples from Pasadena, Chicago, and Phoenix come from the original fragments of the slab cut at CALTECH in the 1960s, probably the II AB and CFI fragments.

The Fragments in Europe

Table 2 displays the Colomera fragments preserved in European collections, ranked by their total weight. It is highly surprising that only 64.5 g of the initial 134 kg mass is in public institutions.

As mentioned previously, the main mass, together with the other large specimen, one of the slab II fragments, and some metallic powder, was returned to Spain in 1969. The whole set was conserved in the MNCN of Madrid (Spain) until 2015. That year, the Spanish courts ordered that the specimen be returned to private hands, through a judicial process that was both long and complicated (see the next section).

Figure 8A shows the fragment (115.2 g) and a jar with turnings (6.1 g) of the meteorite kept in the Natural History Museum in London (NHM, UK) (https://www.nhm.ac.uk/our-science/data/metcat/search/list.dsml?Country=Spain&sort=Name). The specimen comes from the first cut made by Dorronsoro and Moreno Martín (1934), obtaining a 255 g fragment (Fig. 5). After the analysis of the metal in 1934, Dorronsoro donated the rest of the fragment to Friedrich Adolf Paneth, a pioneer in isotope dating of metal meteorites. He worked intensely from the 1920s on developing precise techniques to measure extremely small amounts of helium. In the 1940s, Paneth moved to the United Kingdom to continue his research, where he was a professor at the University of Durham. From the labeling of the NHM specimens, it can be deduced that Paneth traveled to Granada (Spain) in October 1949. There José Dorronsoro provided him with the 245.15 g left over from his analyses. From these, Paneth gave a 7.27 g fragment to W. Hoffmeister on November 12, 1959. Hoffmeister and other researchers published the dating of Colomera using the Re-Os method (Herr et al. 1961). From the 237.88 g remaining, only 115.2 g are preserved in the NHM (Table 2). It is probable that the missing fragments (122.68 g), or at least part, were used to measure the He and Ne contents (Hintenberger and Wänke 1964). These German researchers were working along the same line of research as Hoffmeister and Paneth, and were undoubtedly in contact at that time.

Recently, four fragments of the Colomera meteorite have been returned to Spain. The fragments are from the central slab cut in CALTECH in the 1960s (slab II), specifically from fragment II AC (Fig. 6C). At the beginning of the 21st century, Gerard Joseph Wasserburg offered Gary R. Huss the opportunity to work with Colomera samples in the CALTECH laboratories. Shortly after, Huss published an amazing work with the chemical and textural features of the different types of silicate inclusions (Takeda et al. 2003). After finishing the work at CALTECH, Wasserburg donated the II AC fragment to Huss. A part of fragment II AB (270 g) was subsequently given to the celebrated American mineralogist Jim Schwade by Huss, and it was then transferred to the American physician and meteorite collector Roger Piatec. The collector cut this part of II AC fragment into four with the intention of selling them. The largest part (172.9 g; Figs. 6C and 8B) was exchanged with Piatec for an ordinary

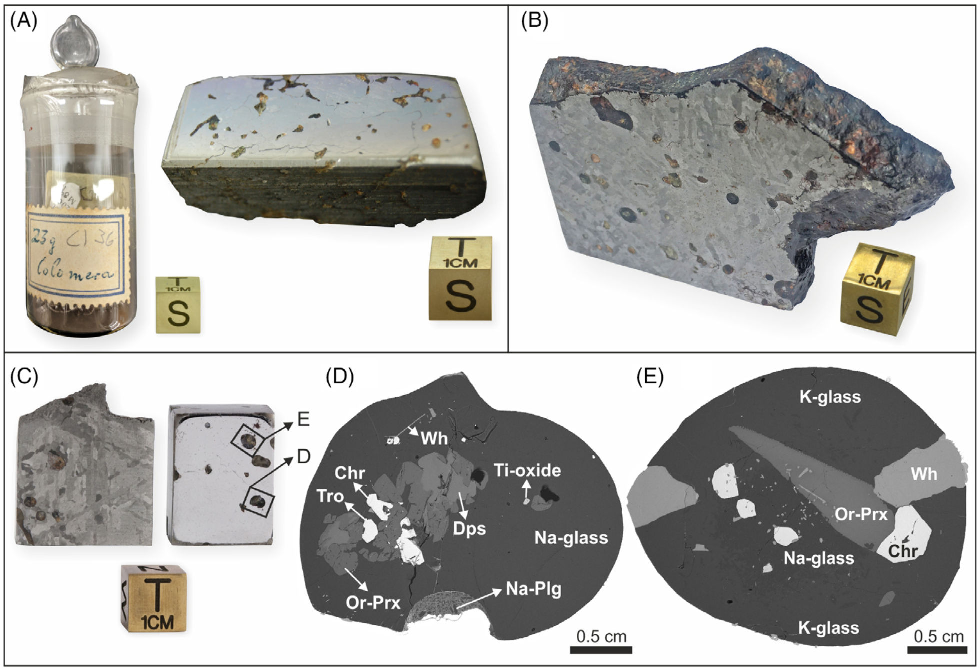

Fig. 8. A) Specimens kept in the Natural History Museum in London (© The Trustees of the Natural History Museum, London). B) Specimen from the Sánchez collection derived from the central slab cut at the Division of Geological and Planetary Sciences (CALTECH; Pasadena, USA) in the 1960s (slab II), specifically from fragment II AC (Fig. 6). C) fragments of the Geominero Museum (IGME) derived from the same slab as before. D–E) Two silicate inclusions, backscattered electron images from one of the Museo Geominero fragments: Chr = chromite, Dps = diopside, Tro = troilite, Wh = whitlockite, Or-Prx = orthopyroxene, Na-Plg = sodic plagioclase.

chondrite by one of the authors of this work (Sánchez), who keeps it in his collection. The Museo Geominero (IGME, Spain) has recently acquired two other fragments of Colomera derived from the cut made at CALTECH in 1966 (62.45 g in total; Figs. 6C and 8C–E). At present, they are the only fragments kept in a Spanish public institution. The remaining fragment (≈15–20 g) was sold by Piatec to an anonymous Spanish collector (Table 2).

The surface of one of the Museo Geominero fragments purchased from Piatec has been analyzed at the IGME facilities in Tres Cantos (Madrid, Spain) to verify its authenticity. A JEOL JSM-218 6010 PLUS scanning electron microscope (SEM) equipped with an energy-dispersive X-ray micro analyzer and a backscattered electron detector (BSE) have been used. The results are shown in Figs. 8D–E. The composition of the two silicate inclusions is characterized by glass with inclusions of minerals (chromite, orthopyroxene, phosphate, diopside, plagioclase, sulfide, and Ti-oxide). The mineralogical and semiquantitative chemical composition obtained is quite similar to that reported by Takeda et al. (2003). One of the inclusions exclusively contains Na-glass (Fig. 7D), but the other also contains K-glass (Fig. 7E). Idiomorphic and skeletal chromite crystals (Chr) grow in glass, adjacent to orthopyroxene (Or-Prx) or phosphate (whitlockite; Wh) crystals. Aciculate whitlockite grows in glass or within orthopyroxene. Diopside (Dps) grows in glass in contact with orthopyroxene. Na-plagioclase (Na-Plg) occurs as small brecciated fragments within a circular subinclusion. Sulfides (troilite: Tro) occur in glass, adjacent to orthopyroxene.

THE JUDICIAL PROCESS IN SPAIN

At the request of the Colomera City Council, the MNCN opened a temporary exhibition in this town in 2008. The inhabitants of Colomera had the opportunity to observe for themselves the meteorite that had been found in their town almost 100 years previously. In addition to the specimen itself, the exhibition also included the original registration document when it was moved to the MNCN collection. The document states that its owner (Antonio Pontes Vílchez) was loaning the meteorite to the museum, and that he could request its return whenever he deemed appropriate (Fig. 4A). After the exhibition, the residents of the town probably told the heir that the document granted him hereditary title and he sued 2 years later.

The MNCN had exhibited the meteorite in different events and the purchase appraisal used for the insurance in each exposition was different, between 5.66 and 2.69 € g^{-1}. After administratively claiming the delivery of the meteorite and being denied in 2010 by the Spanish National Research Council (Spanish acronym: CSIC), in which the MNCN is included, the heir filed a lawsuit. He claiming the return of the complete specimen or 758,440 €, since it was impossible to return the meteorite in the same state in which it had been delivered. The amount was calculated in the highest purchase appraisal of MNCN (5.66 € g^{-1} × 134,000 g = 758,440 €).

Section 13 of the Provincial Court of Madrid considered the claim as a civil action, based on the deposit contract (Fig. 4A), regulated in article 1758 of the Spanish Civil Code.

From this statement, the First Instance Court N° 81 of Madrid by Judgment of 11/29/2013, partially upheld the claim of the heir, condemning the CSIC to pay the amount of 36,328.45 €, without returning the main mass or the rest of the fragments. This amount is obtained by multiplying the lowest appraisal used in the MNCN's exposures insurance (2.69 € g^{-1}) by the meteorite weight lost during the stay in the United States (13,505 g). The arguments used by the judge can be summarized in the following points:

a. In the absence of specific regulation on meteorites, it was considered by analogy that the regulation of the Spanish Civil Code provisions for *hidden treasure* (article 350: "the owner of a land owns its surface and what is below it..." and article 351: "the hidden treasure belongs to the owner of the land on which it is located...").
b. The CSIC argued that the meteorite was a property in the public domain framed in article 44 of Law 16/1985, of June 25, on Spanish Historical Heritage. The court rejected this argument as it is only applicable to archaeological or paleontological elements, but not to geological heritage. Furthermore, in article 3 of Law 42/2007, of December 13, on Natural Heritage and Biodiversity, the word meteorite was only included in a list of geological heritage elements. In any case, these two laws did not exist at the time of the discovery and were not retroactive. The law of July 7, 1911 on archaeological excavations was in force at the time the meteorite was discovered and entered the MNCN collection. It states in the article 5: "the antiquities discovered by chance in the subsoil will be property of the State, after compensating the discoverer with half of its legal appraisal." Ignacio Bolívar y Urrutia, director of the MNCN at that time, did not compensate Antonio Pontes, so he lost the opportunity to obtain state ownership of the meteorite.
c. The court only compensated for the weight lost during the stay in the United States, opting for the lowest appraisal used by the MNCN exposures insurance (2.69 € g^{-1}) in application of the principle *favor debitoris* (in case of doubt in an obligation, it is decided in favor of the debtor). The court considered that cutting and cleaning carried out at CALTECH did not damage the meteorite, but rather increased its value due to the scientific results obtained.
d. The court rejected the return of the main mass and the rest of the fragments in order not to incur the *extra petita* incongruity, which occurs when the judicial authority grants something not requested (the plaintiff requested the complete meteorite and this was impossible after the cuts made in the United States).

Not satisfied with the sentence, the heir filed an appeal with Section 13 of the Madrid Provincial Court. Although this court accepted as valid the arguments used in the previous process, it ordered the return of all the fragments preserved in the MNCN by judgment n° 188/2015 of May 29. Furthermore, the court increased compensation to 50,000 € for the damage caused to the meteorite, in accordance with the provisions of the Spanish Civil Code for the deposit contract (Fig. 4A).

Thus, after almost a century of custody in the MNCN, the main mass of Colomera is now in private hands, which corroborates that meteorites are legally ill-defined objects (Gounelle and Gounelle 2019).

CONCLUSIONS

The meteorite was not discovered in 1912, it was found a year later on September 6 or 7, 1913. The exact coordinates of the discovery are: 37°22′17.7″N–3°42′51.3″W. This might not have been the original location since a landslide affected this sector of the town in 1640.

The meteorite remained in the town of Colomera from 1913 to 1926, when it was moved by the Pontes family to Almuñecar (Granada, Spain). The meteorite arrived at the MNCN in Madrid in 1935 and was moved in 1966 to CALTECH (Pasadena, US) for study, returning 3 years later.

Fragments of the Colomera meteorite are currently housed in at least seven US institutions. A part of the original mass cut by Dorronsoro is preserved in the NHM of London, UK. Recently, several fragments from the United States have entered Spanish private and public collections (Museo Geominero, Madrid).

After spending more than 80 years in the MNCN (Madrid, Spain), Spanish courts ordered in 2015 that all fragments that were returned from the United States (including the main mass) be returned to the heirs of the Pontes Vílchez family, along with financial compensation covering the value of the missing pieces.

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