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Reports

Fuegian Firestone Quarry

Iron Pyrite on Capitán Aracena Island, Magallanes Archipelago, Southern Chile

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Fire was essential for the ancient inhabitants of Tierra del Fuego, at the southernmost end of the Americas. The Fuegians, as these human groups are traditionally known, produced fire primarily by striking a piece of iron pyrite against a flint nodule. Several European chroniclers mention this firestone technology and note its social value, a conclusion based on the fact that it was carefully safeguarded in leather pouches. Anglican missionary Thomas Bridges visited one of these pyrite sources in 1883 with two Yaghan guides and left behind a brief description of its out-of-the-way location. Almost 130 years later, we rediscovered this mine on Capitán Aracena Island in the Strait of Magellan. In this study, we present a brief report focused on the mine's exact location, archaeological materials, and layout, and we offer the first physical-chemical description of the pyrite source. Comparison of these results to similar analyses of archaeological samples from the Santa Isabel Island settlements in the Magellan Strait suggests that the early inhabitants of the area used different pyrite sources, only one of them corresponding to the Capitán Aracena Island mine.

For the inhabitants of Chile's southernmost archipelago, a region with an extremely cold, rainy, and windy climate, fire was synonymous with survival. The most common way to obtain it was to strike a piece of iron pyrite against a flint nodule and allow the sparks to fall onto tinder consisting of bird feathers, moss, or a fungus that the Selk'nam people called *uoo* (Cooper 1917:191–192; Gallardo 1910; Hyades and Deniker 1891; Lothrop 1928; Weddell 1825:167). After being lit, the fire was quickly stoked with twigs, sticks, or handfuls of dried plants. Among the peoples that inhabited Tierra del Fuego's channels and islands, pyrite, flint, and tinder were carefully safeguarded in leather pouches or bladders (see Lothrop 1928, fig. 53).

The geological inventory of the Museo Maggiorino Borgatello in Punta Arenas includes samples of pyrite ore that attest to this mineral's widespread geographic distribution in the rugged Fuegian landscape. But the information available suggests that economically viable sources of pyrite were limited to Solitario Island, in the Gulf of Penas, which was used by the Kawesqar inhabitants of the northern archipelago; an unconfirmed site in northern Tierra del Fuego Island, from which the Selk'nam provisioned themselves; and the southern part of Capitán Aracena Island, which was visited by both the Kawesqar and the Yaghanes (Bridges 1952; Emperaire 1963; Gallardo 1910; Lothrop 1928). The last of these three sites is probably the most well reported in writings about Tierra del Fuego; indeed, Anglican missionary Thomas Bridges, who visited the site in 1883, was clearly amazed by the scale of the deposit. To reach it, he recruited two Yaghanes from the Brecknock Peninsula, one called Acualisnam and the other called Sailapaiyinj, the latter having a Kawesqar mother (Bridges 1952:130–132). Both Bridges and the captain of the ship *Allan Gardiner*, on which he sailed, reported that one had to sail to Park Bay, on the southern coast of "Clarence Island" (now called Capitán Aracena Island, in the Strait of Magellan), where the pyrite deposit rose up from the beach among piles of waste rock that attested to its long-standing use as an extraction site (Bridges 1883:139; Willis 1883:140). Although there are many references to the place, and despite its obvious importance, the mine was never located or described at any later date. In this text, we report on the results of our recent successful expedition, in which we managed to corroborate Bridges' observations and provide additional information about the physical-chemical properties of the deposit and its function as a source of pyrite. Finally, we compare some samples from the site with archaeological pyrite recovered from Santa Isabel Island in the Strait of Magellan—over 200 km away from the mine—to broaden our understanding of the regional distribution of this particular source and the social, economic, and cultural importance of this material to the ancient maritime and terrestrial inhabitants of this remote zone of Tierra del Fuego.

Firestone Quarry

The iron pyrite mine Bridges mentioned is located on the southern coast of Capitán Aracena Island, situated almost 130 km

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south of Punta Arenas, in a channel of Mercurio Sound that connects to the Strait of Magellan (fig. 1). The deposit (universal transverse Mercator coordinates 19F 350447 m N 3980673 m E) is located near the coast, beside a small inland saltwater lagoon that is connected to the sea by a narrow channel. Because the lagoon is on a rise, above sea level, the tidal action creates strong currents and fluctuations in the water level of the channel, making it challenging for vessels with large drafts to access the site.

The lagoon itself is oblong, 1.8 km in length and 900 m wide, and covers an area of approximately 0.8 km^2. It is bordered on the east and west by hills rising to 650 m asl. The coastal side is rugged, with high bluffs alternating with small sandy beaches, whereas dense forest and swamps cover the inland side. Facing the access channel, at the opposite end of the lagoon, is a small isthmus approximately 50 m wide and 10 m high that separates the lagoon from the Cockburn Channel and the Pacific Ocean.

On a short, narrow beach on the western shore of the lagoon there are rocky outcrops rich in pyrite and associated with mining waste scattered over an area of approximately 400 m^2. Alongside one of the outcrops, approximately 10 m inland, is a pit or mine shaft (now flooded by a small watercourse) 2 m in diameter and more than 1 m deep, that could have been a pyrite extraction site (fig. 1). The soil profile exposed by the pit also shows a cultural deposit of crushed shells. Other outcrops appear along the shoreline and are more visible at low tide, when they reveal dense groupings of stoneworking waste and several roundstone hammers.

The waste from mining activity includes primary blocks separated from the rocky outcrops and others that likely were naturally fractured, secondary waste, and pieces of nodules left over from working the pyrite rocks. These remains provide strong evidence of mining, because they resulted from the production of high-quality pyrite nodules that could be transported to other locations. Twelve hammers were also found among the mining waste, near the mine shaft, all made of round cobbles with clear signs of use, such as grinding and flaking on their ends. Unfortunately, moss and surface patinas on the hammers hindered the in situ characterization of specific raw materials, specifically in terms of their mineralogical and petrographic composition. The different sizes and weights of the hammers that were found no doubt reflect their effectiveness at different stages of the process; large, heavy stones would have been used to separate blocks from the pyrite outcrops, and smaller stones would have been used to reduce and shape nodules (fig. 2).

We visited the few beaches on Park Bay in search of indigenous camps, but our observation of soil profiles and exposed surfaces did not yield any findings of archeological interest, although dense vegetation limited visibility and made it difficult to conclusively determine whether any indigenous camps are present. The only actual evidence of human occupation around the deposit was located in the narrow entrance to the bay, where mollusk remains crushed by human transit were found (fig. 1). Certainly, test pits and excavations are required in the area to conclusively determine the function and age of the occupations.

Firestone from Santa Isabel Island in the Strait of Magellan

On August 24, 1578, Sir Francis Drake disembarked on an island in the Strait of Magellan, where he reportedly killed 3,000 penguins in less than a day (Vaux 1854). Such enormously rich resources had been the main reason why the local

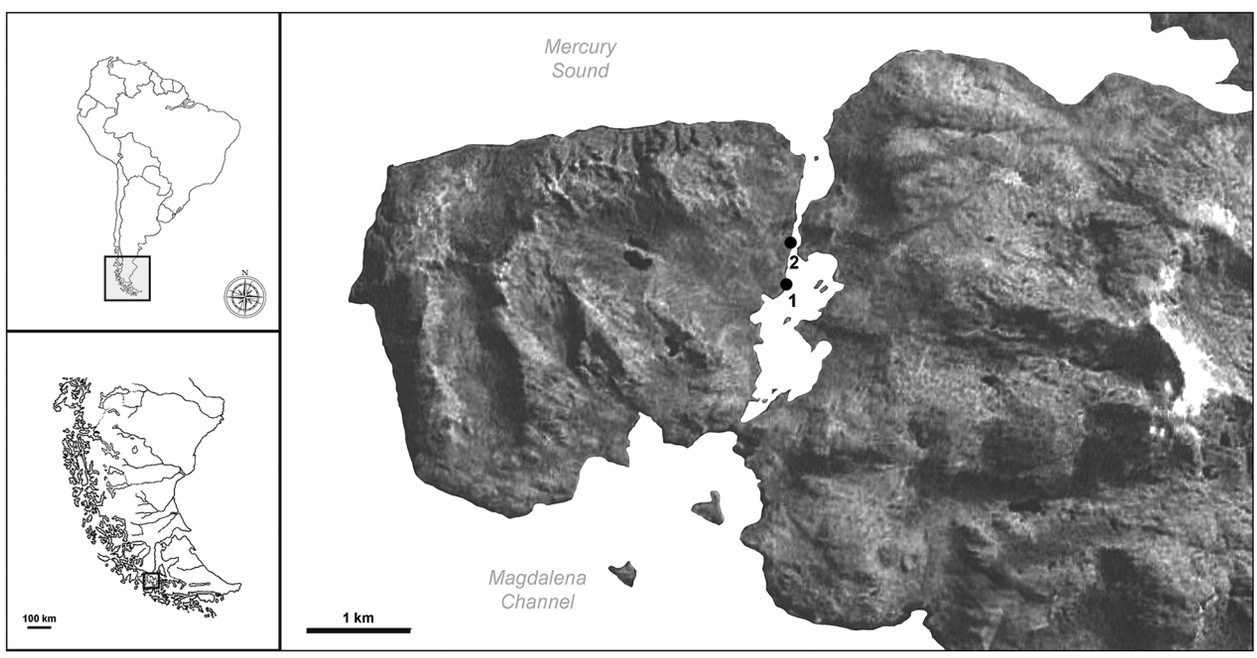

Figure 1. Maps of Capitán Aracena Island showing the pyrite source (1) and the site with occupational evidence (2).

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Figure 2. Hammerstones from the pyrite source on Capitán Aracena Island.

canoe-faring indigenous people visited the island during the nesting season. Sir John Narborough, a Rear Admiral of the British Navy, set foot on the island in October 1670, where he met with a group of 19 indigenous people and engaged in a friendly exchange of goods (Narborough 1711:63–64). In his writings, Narborough expressed his admiration for how easily and skillfully the natives made fire.

That island was later given the name of Santa Isabel (Ortiz-Troncoso 1971). It faces Cabo Negro on the northwestern shore of the Strait of Magellan, just 3 km from the present-day mainland coast. Long and thin, the island measures 12 km in length, is just 3 km across at its widest point, and has a total land area of 35 km^2. It reaches 54 m asl at its highest point. Although the absence of trees, fuelwood, and freshwater in the interior made it quite unattractive for human settlement, in the late nineteenth century the Italian geologist Domínico Lovisato (1884) described with amazement the enormous shell middens left there by former occupants of the island.

In May 1968, Omar Ortiz-Troncoso (1971) prospected on the island to search for archeological sites and identified several shell middens and human graves. Years later, Junius Bird (1980) visited the island and went in search of the middens that Lovisato had described. In all, he recorded 37 archeological sites, most of them around the coast with direct access to the sea, including traces of awnings or pit houses, piles of waste, and smaller sites. The areas with the greatest concentration of sites are Punta Silvestre (7 sites), Punta Alfredo (6 sites), and Cabo Thorax (6 sites; fig. 3). The author identified a notably

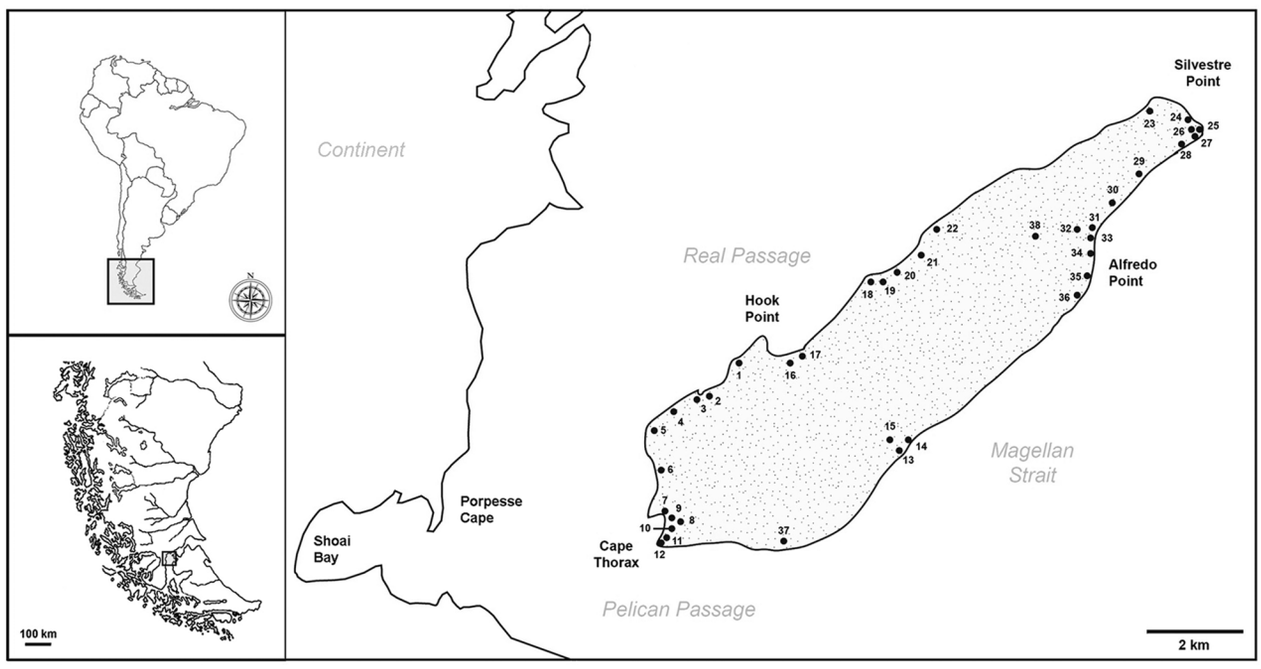

Figure 3. Maps of Santa Isabel Island and the Junius Bird sites.

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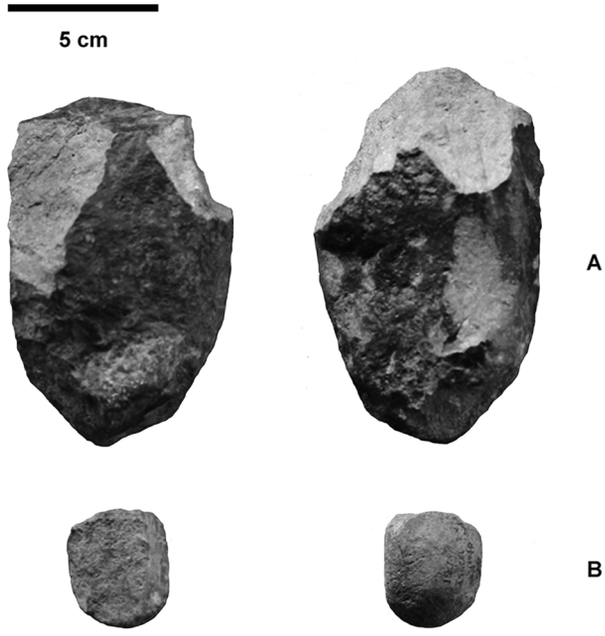

Figure 4. Firestones from Santa Isabel Island. *A*, Sample 3. *B*, Sample 2.

large number of pit houses (range, 259–272), three-quarters of which were circular with a single entrance, whereas the remaining ones were elongated or oval-shaped with two entryways; together they point to significant human occupation of the island.

Surface collection of materials by Junius Bird yielded a considerable quantity of items (219 in total), which according to the author were very similar to those found in a "pit house" settlement identified in the Beagle Channel (Bird 1938, 1946). Notable among the items found were stone artifacts, such as projectile points and knives, bifacial preforms, scrapers, awls, fishing weights, hammers, and *bolas* in addition to wedges, retouchers, burins, and saw-toothed harpoons with bone handles. At what the author named "site 28" (fig. 3)—the same site visited by Lovisato—Junius Bird recovered remains of pyrite along with archaeological material attributed to both the mainland and southern channel Late Period sequences.

During a visit to the island and the adjacent mainland coast to identify the sites mentioned in the literature, two fragments of pyrite were collected on the ground from a site situated on a dune adjacent to the coastline (Prieto 1988). Unfortunately, no excavations have been performed and no dates or stratigraphic information are currently available for the site. We do know, however, that the pyrite had been found among a disperse grouping of stone and bone materials jutting out from some low-lying dunes near the coast and on the nearby slope to the east of a group of pit houses that correspond to the so-called "site 6" of Junius Bird (1980; fig. 3).

This section of the Strait of Magellan is dotted with numerous archaeological sites, at least 37 of them on Santa Isabel Island (Bird 1980) and nine on the mainland near Cabo Negro (Ortiz-Troncoso 1973; Prieto 1988). While the island lies at what was the northeast boundary of Kawesqar territory, Cabo Negro was an old stopping point along the Aonikenk routes to and from the Patagonian steppe (Emperaire 1963; Ortiz-Troncoso 1973). There is little doubt that this was a zone of encounter between terrestrial and maritime hunter-gatherers (Bird 1980; Massone 1979; Ortiz-Troncoso 1971, 1973).

Preliminary Physical-Chemical Characterization of the Pyrites

The account left by Thomas Bridges (1883:139) affirms that the firestone was composed "almost entirely of iron and sulphur," which explains why it gave off sparks when struck against flint. According to the French Scientific Mission of the Cape Horn of 1882–1883, these firestones were composed primarily of iron pyrite (91.3%) and a small proportion of copper pyrite (2.0%), although that expedition unfortunately failed to report on the method(s) employed or the provenance(s) of the samples (Hyades and Deniker 1891:345). Beyond these analyses conducted more than 130 years ago, no physical-chemical characterization of this raw material is available for any archaeological context anywhere in the Southern Cone of the Americas, and thus this work comprises an initial description of this type of mineral obtained from nondestructive, noninvasive techniques. Specifically, three kinds of analyses were performed—one molecular (Raman spectroscopy) and two elemental (scanning electron microscopy coupled with an energy dispersive x-ray spectroscopy [SEM-EDX]; and portable x-ray fluorescence [XRF]).

Three samples were analyzed employing these techniques, one recovered from the mine site on Capitan Aracena Island (sample 1) and two recovered from archaeological objects collected from a site on Santa Isabel Island during the 1980s (samples 2 and 3; Prieto 1988). One of the latter samples corre-

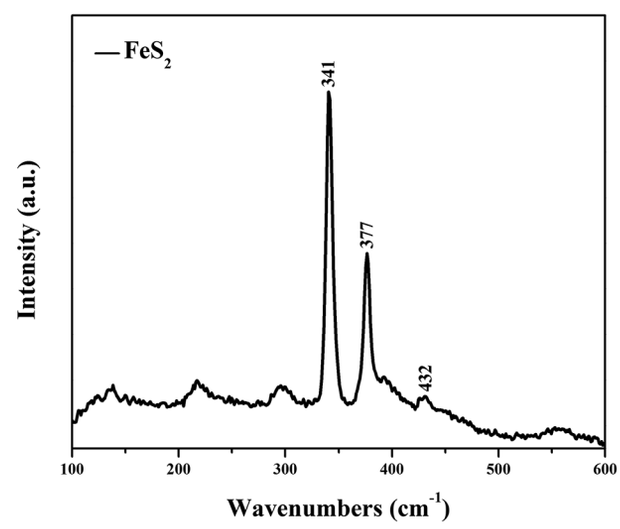

Figure 5. Raman spectrum for sample 1 from the Capitán Aracena Island source. a.u., arbitrary units; Fe, iron; S, sulphur.

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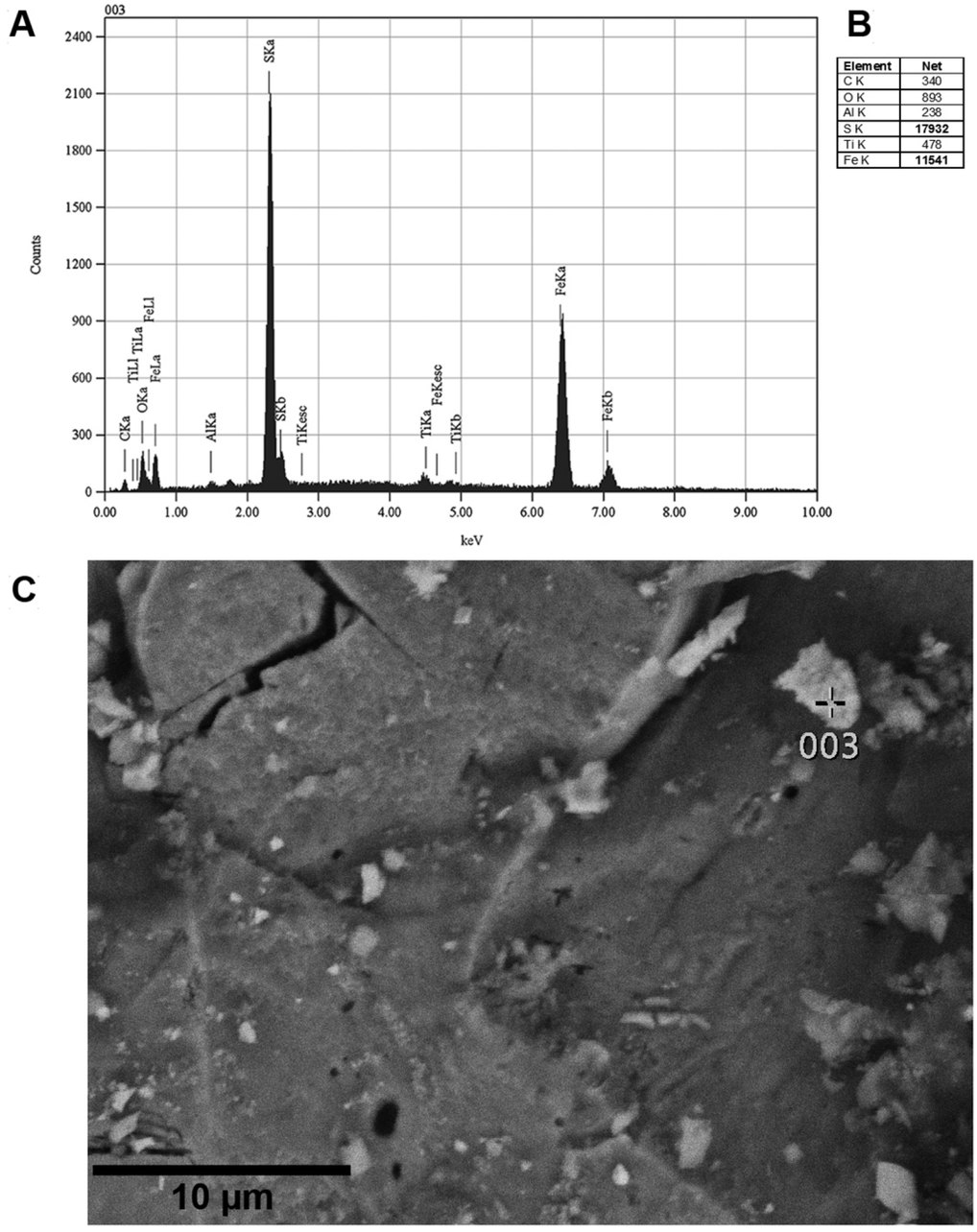

Figure 6. Scanning electron microscopy coupled with an energy dispersive x-ray spectroscopy. *A*, Spectrum. *B*, Quantification. *C*, Image obtained for sample 1. Al, aluminum; C, carbon; Fe, iron; K, potassium; O, oxygen; S, sulphur; Tl, thallium.

sponds to an angular nodule (12 cm × 7 cm) with close to 60% cortex and six negative extractions on one end, showing clear evidence of percussion against a hard surface (sample 3), whereas the other fragment is spherical, with a polished surface, fractured in half (4 cm × 4 cm; sample 2; fig. 4). Both artifacts present different degrees of surface work.

The mineral from the Capitán Aracena source (sample 1) was studied using Raman spectroscopy to obtain a molecular characterization and with SEM-EDX to acquire a quantitative elemental analysis to determine its specific composition. Using the same technique, we obtained a chemical contrast image at high magnification (× 3000 or greater) to determine the condition of the surface. Finally, to assess the variability and provenance of the three samples, a portable XRF was used to obtain a semiquantitative elemental characterization.

The samples analyzed are solid fragments that contain inclusions or grains of different sizes, morphologies, color, and brightness. All of them are crystals of irregular shape, generally

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tending to cubic forms, with different degrees of brightness—some are darker, almost shiny black, whereas others are equally shiny, with a golden hue. Notwithstanding their compact appearance, they display very fine grains that detach easily as dust particles as well as larger inclusions that also can be removed with greater force or pressure. These qualities would have enabled the extraction of the incandescent particles needed to start fires.

The Raman spectra were recorded on a Renishaw InVia Reflex, at excitation sources of 532, 633, and 785 nm, equipped with a Leica microscope and an electrically cooled charge-coupled device camera. Micro-Raman measurements were calibrated using a silica plate and ×50 objective lenses. To obtain the spectra, one to three scans were performed for 10 to 30 seconds each. The 785-nm laser power was adjusted to between 10 and 100 mW. The spectra were recorded in the region of 200 to 1,800 cm^{-1}. The replicable spectra from the pyrite sample were recorded by using the laser to directly scan the samples deposited on a quartz plate. Measuring conditions were adjusted to prevent degradation and photodegradation of the samples. The Wire 3.4 and GRAMS/AI 9 programs were employed to analyze the information obtained from the measurements. The pyrite Raman spectrum obtained from the source is consistent with that published in the RRuFF database for Pyrite (Lafuente et al. 2015), displaying the characteristic bands at 341 cm^{-1} and 375 cm^{-1} (fig. 5).

Scanning electron microscopic analysis was performed using the JCM-6000 JEOL model. The images were obtained at a magnification of ×3400, and measurements were taken at 15KeV for 30 seconds. Complementing the three samples studied, a portable XRF Bruker Tracer III SD series was used at 40 KeV with a current flow of 37.8 uA for 180 seconds of exposure to obtain optimal resolution.

Pyrite is an iron sulfide composed primarily of sulfur and, to a lesser degree, iron, as Bridges indicated previously. This composition coincides with the SEM-EDX spectrum (fig. 6*A*) obtained from sample 1 from the Capitán Aracena source, in which these two elements clearly predominate, with only insignificant amounts of other elements (fig. 6*B*). The complementary image (fig. 6*C*) shows the sample's homogenous, smooth surface, free of inclusions.

The XRF spectra obtained for the three samples measured, using x-rays at a higher energy level (KeV) than those used in the SEM-EDX, allowed the detection of elements present in small trace amounts (fig. 7). Thus, the spectra obtained in this case enabled the differentiation of two elemental combinations in the pyrites analyzed. In those, copper and selenium appear as distinctive elements in sample 2, differentiating it from samples 1 and 3. The other elements visible in the spectrum are part of the inclusions or impurities, also known as trace elements, which could help to identify specific areas or sources where the pyrites were found. The spectra in figure 7 display a higher quantity of iron than those of figure 6, mainly owing to the readings produced by the portable equipment used.

Table 1 displays the quantities of each element, after standardization of the results, providing a semiquantitative idea of the proportions of each. As the results show, iron and sulfur are indeed the most prevalent in all three cases. We also observe a higher proportion of copper and selenium in sample 2. In contrast, samples 1 and 3 display trace quantities of arsenic that, while small, differentiate them from sample 2. The same is true for potassium and phosphate.

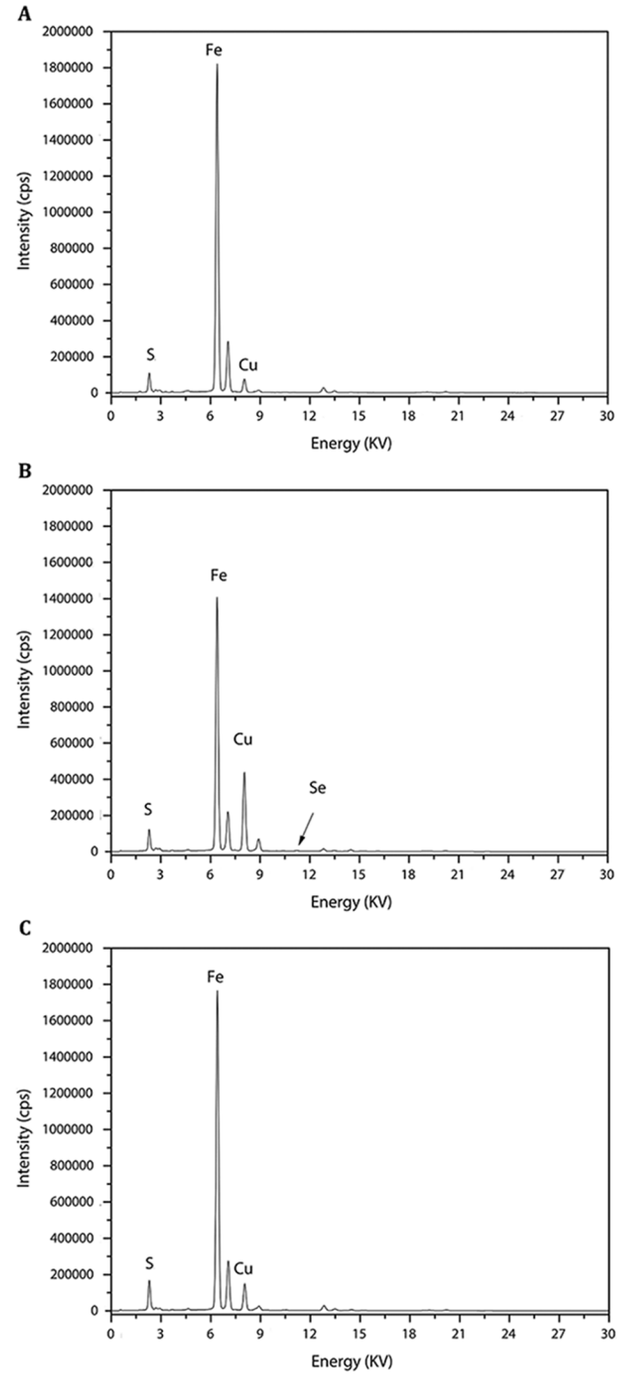

Figure 7. Portable x-ray fluorescence spectra of the three samples analyzed: sample 1, sourced from Capitán Aracena Island (*A*); sample 2 (semispherical fragment; *B*) and sample 3 (angular fragment; *C*), archeological samples from Santa Isabel Island. cps, counts per second; Cu, copper; Fe, iron; S, sulphur; Se, selenium.

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Table 1. Semiquantitative elemental results for the three samples analyzed by x-ray fluorescence

Sample	Al	Si	P	S	K	Ca	Fe	Cu	As	Se
1	.0012845	.0034671	ND	.0439777	.0030458	.0035346	.8937724	.0412508	.0027364	ND
2	ND	.0015857	.0029131	.0499015	ND	.0037292	.6982181	.234772	ND	.0042429
3	ND	ND	ND	.0650471	.0021496	.0033167	.8436408	.0778359	.0029703	ND

Note. Al, aluminum; As, arsenic; Ca, calcium; Cu, copper; Fe, iron; K, potassium; P, phosphate; S, sulphur; Se, selenium; Si, silicon; ND, no data.

In summary, two types of pyrites were identified, differentiated by their trace elements. It is therefore quite likely that sample 3 came from the Capitán Aracena Island source, whereas sample 2, with different elemental characteristics, may be from another source. It is interesting that two elemental forms of pyrite can be found on Santa Isabel Island, which suggests that two different areas were possibly used to source it, and ethnographic information seems to confirm this.

Epilogue

Pyrite was a key raw material for all indigenous peoples of Magallanes region. However, many of their sources of pyrite were inaccessible to pedestrian hunter-gatherers, who must have had other fire-starting methods, as records from the early historic period affirm. Indeed, when asked about their fire-starting techniques, the pedestrian hunter-gatherers captured by Ferdinand Magellan in 1520 mentioned friction using sticks (Pigafetta 2012:34). Narborough (1711) also found fire-starting sticks among the same population, and much later, there is even a curious reference by Martin Gusinde (1951:218–219) describing the Kawesqar technique for making fire with friction.

Our first analyses suggested that the pyrite mine on Capitán Aracena Island served as a provisioning source for the canoe-faring Kaweskar and Yaghan peoples that inhabited the islands of the Strait of Magellan. Nevertheless, given that one of the samples collected on Isabel Island did not come from the reported site, it seems evident that it was not the only source of that mineral, although further study is needed to confirm this. Certainly, the next step will be to investigate the range of distribution of the pyrite from the mine that was discovered to determine whether that pyrite was among the goods that circulated in the exchange networks that operated among the different hunter-gatherer groups that inhabited Fuegian Patagonia.

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