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WHEN LOCALITIES ARE LOST: SCIENTISTS, COLLECTIONS AND THE CHILEAN FOSSIL WOOD HISTORY AT VALPARAISO

Cuando las localidades se pierden: Científicos, Colecciones y la historia de la madera fósil chilena en Valparaíso

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Abstract. Historical fossil localities are frequently lost because, among other factors, the outcrops have been actively mined or erased by urban development. It would be what happened with historical fossil localities from the old Valparaiso province, in which naturalists, such as C. Darwin, J. Dana, R. Philippi and J. Brüggen collected fossil specimens. Based on the historical evolution of underreported fossil wood localities and local historical collection records, we report on the fossil localities of Valparaíso, Placilla-Curauma and Algarrobo. Historically, most of the early collections were sent overseas and their final destination is mostly unknown. In addition, most historical collections deposited in local museums have lost their labels, limiting the information of the specimens. Nevertheless, morphology, lithology, and color mineralization allow to compare the old specimens with a few ones with labels, allowing to discuss what would be the origin of these collections, as well as assessing what happened with the demise of the localities from where these fossils were collected long ago.

Keywords. Fossil wood, fossil localities, Valparaíso, Placilla-Curauma, Algarrobo.

Resumen. Localidades fósiles históricas suelen perderse debido a que los afloramientos conocidos han sido minados o eliminados por urbanización. Esto último, cuando la ciudad se expande y la urbanización cubre los sitios, sería lo ocurrido con localidades fósiles históricas de la antigua provincia de Valparaíso reportadas por colectores como C. Darwin, J. Dana, R. Philippi y J. Brüggen. Un ejemplo con lo ocurrido con la desaparición de localidades históricas con madera fósiles y las colecciones históricas de Valparaíso, Placilla-Curauma y Algarrobo es informado aquí. La mayoría de las primeras colecciones históricas fueron exportadas del país y su depósito final es en su mayor parte desconocido. La mayoría de las colecciones históricas encontradas en los museos locales no están etiquetadas con información que permita descifrar las localidades de donde fueron colectados. Sin embargo, litología, mineralización y color permitiría comparar de cierta forma con los pocos especímenes que, si tienen información ligada, sobre cuál se podría definir el origen de estas colecciones evaluando también que pasó con la pérdida de las localidades de donde estos fósiles fueron colectados hace largo tiempo.

Palabras claves. Madera fósil, Localidades paleontológicas, Valparaíso, Placilla-Curauma, Algarrobo.

INTRODUCTION

Fossil wood or petrified wood comes from the Greek root *Petro*, meaning "rock" or "stone" that literally means wood turned into stone. It defines a special type of fossilized remains of terrestrial vegetation. Literally, it is what is left of a tree having turned completely into stone by the process of permineralization. In such a case, all the organic materials have been replaced with minerals (most often a silicate, such as quartz), while retaining the original structure of the wood. Unlike other types of fossils which are typically impressions or compressions, petrified wood is one of the few that keeps a three dimensional representation of the original organic material, where the invasion of minerals into cavities between and within cells of natural wood, usually by silica (silicon dioxide, SiO_2) or calcite (calcium carbonate, $CaCO_3$) preserve them as fossil structure.

The earlier definition used to consider fossil wood or petrified wood mixed with folk tales or misconceptions, such as those ideas proposed in the XVII century by Fabio Colonna who considered "*fossil wood and ammonites were mere clay, altered into such forms by sulphureous waters and subterranean heat*" (Lyell, 1830).

Fossil wood was already properly defined around the middle of the XIX century by mineralogists as "*Silicified wood. Petrified wood often consists of quartz. Some specimens, petrified with chalcedony or agate, are remarkably beautiful when sawn across and polished, retaining all the texture or grain as perfect as the original wood*" (Dana, 1865: 138). Nowadays, fossil wood is understood as a fossil where the original organic material has been replaced, usually by chalcedony or agate (cryptocrystalline quartz), but sometimes by opal, coal, pyrite, calcite, apatite and others, and where the colors, usually red and green, are caused by iron, but a few of the more brightly colored green woods may be colored by chromium or vanadium (Mustoe, 2023).

The earlier technical stepping stones

The discovery of fossil wood started to be recorded at least since classical antiquity, when in the West, Pliny described them around 77 AD in his book XXXVI on minerals of his *Naturalis Historiae*. In this book, he described many minerals including a couple that can be interpreted as fossil wood within two categories, as carbonized wood associated with coal (Plinius, XXXVI: 73), or as a silicified rock (Plinius XXXVI: 53.10). In the East, Chinese scholars as early as the IX century AD had described petrified wood and around 1080 AD Shen Kua described a fossil bamboo citing it as evidence of change of climate (Abritton and Winley, 1989: 572).

Fossil wood began to be studied as a subject of study by itself when Robert Hooke started to observe fossil wood structures using a primitive microscope for the first time in 1665, comparing it with cork cells (tracheids), noticing striking similarities between petrified and living wood (Figure 1).

According to Hooke, other substances besides wood were altered by petrification, and that these objects were, as wood, once living things. The numbers and variety of these other petrifications were many and included representatives from both the animal and vegetable kingdoms (Hooke, 1665). Over one hundred sixty years later, in 1831, is when H. Witham made the first anatomical study of petrified plants (Fleet, 1911: 324). The same year, William Nicol of Edimburgh published the first formal account of this technique, "*whereby sections of fossil wood could be cut, mounted on glass, and reduced to such a degree of transparency as to be easily examined under a microscope*" (Geikie, 1911: 647). That was the earlier beginning

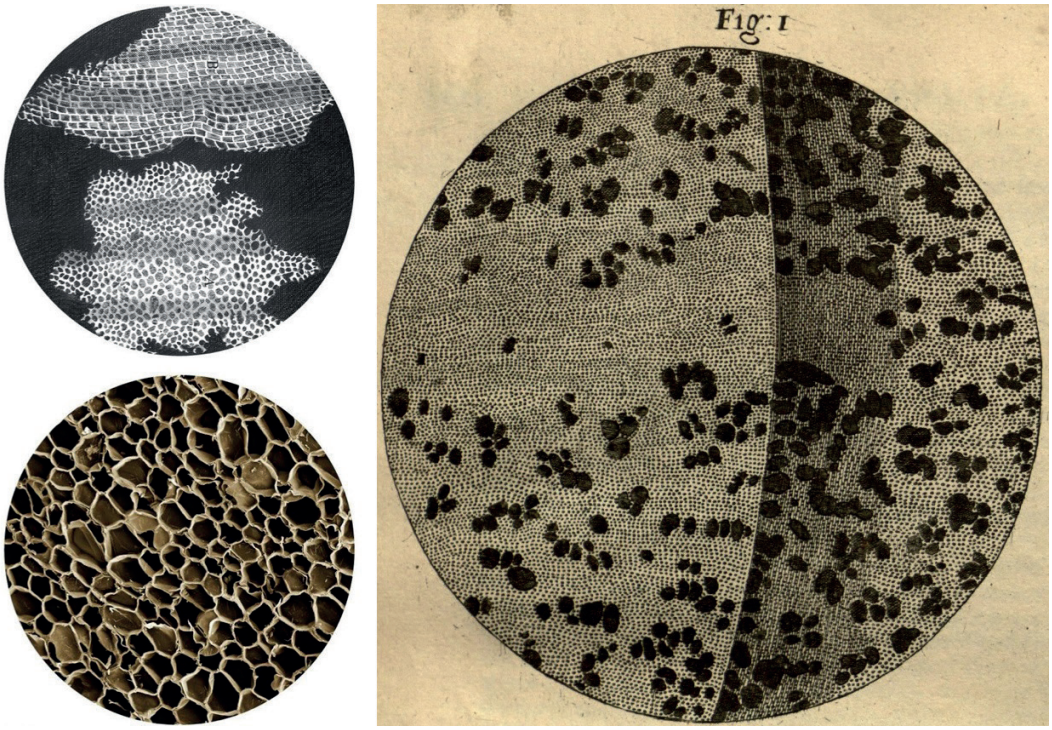


Figure 1 - View of cork cells (left) with fossil wood (right) in a microscope (modified from Hooke, 1665).

of the petrological technique, so basic for any mineralogical analysis. This technique requires some technical equipment, time and effort to define minerals and silicified fossil woods, making thin sections glued with Canada balsam as H. Nicol described cutting standard transverse and longitudinal cuts (Nicol, 1834). A standard procedure that still make harder to work petrological cuts to be able the study anatomical features of fossil wood. Despite the technical difficulties, this methodology started to be widely used to learn about fossil wood anatomy and determining characters to define fossil tree taxonomy. In this earlier endeavour, Robert Brown, keeper of the Botany Department at the British Museum (Natural History), started sectioning fossil plants samples just arrived from the Beagle expedition collection between 1836 to 1837 (Falcon-Lang, 2015). Some of these surviving slides, such as a dark conifer wood sample, came from Tertiary beds the island of Chiloé (Figure 2). It would be the earliest petrographic thin section ever made on a Chilean specimen. These slides are found in the collections of the British Geological Survey, Keyworth, with some more slides from this collection and the specimens themselves found in the Department of Paleontology, Natural History Museum, London (Van Wyhe, 2011).

Historically, most petrified wood collections found at museums and the general use of fossil wood as an ornamental stone started in the XIX century, when large quantities of Triassic petrified wood from the Arizona fossil forest discovered in 1850 started to be sold in the market from 1870 onwards (Price, 2008). Around 1870, important taxonomic works were underway exemplified by studies such as the description of 136 fossil plants found in fossil for-

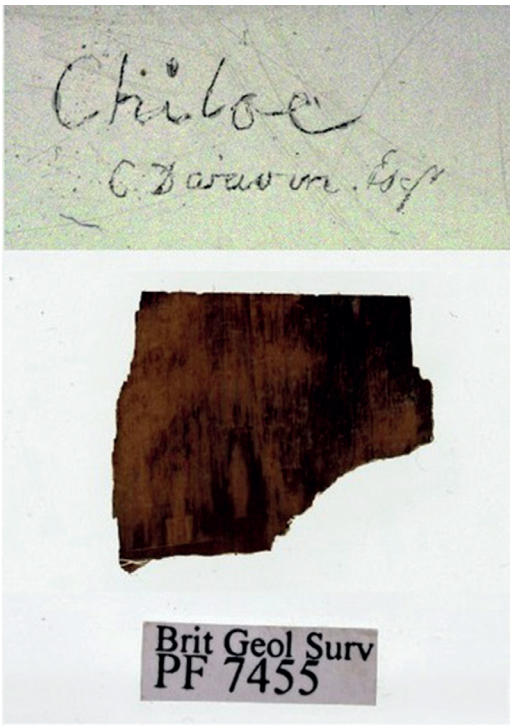


Figure 2 - Beagle´s expedition Tertiary conifer wood thin section (PF7455) from Chiloé obtained by R. Brown (Falcon-Lang, 2015).

ests from Spitzbergen described in a series of seven monographs on these paleofloras (Heer, 1868; Chaney and Arnold, 1970), and the discovery of large fossil forests at 82º lat. North (Geikie, 1879).

As it was already understood in middle XIX century, in order to work identifying fossil woods it was required to make thin sections. At the time, the collection of these specimens was more focused on its lapidary and ornamental value than setting a scientific goal in mind. When scientific work was the main goal, thin sections were obtained by cutting the fossil in two, grinding the cut surface smooth and examining it, or fastening it firmly to a glass slide, and making a second cut close to the slide, thus getting a thin section which was then ground as thin as possible. Then, the preparation of fossil thin sections was not only a tedious process, but also one that was much wasteful of the material. Around 1930s, a far more efficient method was developed where etching the flat surface with acid to get a regrounded peeled surface, resulting in a process where little material was wasted (Field and Whelden, 1937). Therefore, with the older method, it was very difficult to do such work in countries like Chile as it was commented by Philippi (1887), who based on his experience studying Vesubian volcanic rocks in 1840s, he knew already how to make petrographic thin sections he figured in some of his later work in Chile (Philippi, 1877: 325).

Therefore, the petrographic thin section techniques were widely known around the middle of the XIX century, but recently independent countries such as Chile, where science and engineering were doing their first footsteps, this advancement lagged behind. It was only years after the foundation of the National Museum (1830), the first mineralogy cathedra and mine school (1838), normal teaching schools (1842) and the University of Chile (1842), that petrographic thin sections would be made locally with petrified wood samples. At the time, very few people were learned enough and had the time, suitable microscopes as well as were able to cover the expense that meant the work with thin sections. Most likely, several attempts were made before 1893, when Roberto Pohlmann, a German professional petrographer, who besides petrographic works, he had published also some botany papers, started to work petrographic studies making his own petrographic thin sections (Pohlmann, 1893; Fuenzalida, 1961; Pohlmann and Reiche, 1900). Then, we could deduce that most of XIX century petrified wood collections found in Chile did not have local thin sections to determine taxonomy. Therefore, these collections would not have been stud-

ied further until just forty years ago, when Teresa Torres started to review and study them with new thin sections from localities from continental Chile and the Antarctic Peninsula (Torres, 1983).

METHODOLOGY

In order to study historical collections containing petrified wood samples from the old Valparaíso province, it has been proposed to review the available collections. It requires an historiographic approach tracking down all kind of information that could be linked to the specimens such as records, labels, cartography, collector´s journals, letters, etc. that were reported as coming from Valparaiso over a century ago. Another intended pathway to follow is to compare the features of the specimens themselves with those of specimens we could study that count with attached geographical data that may be checked visiting the localities cited.

RESULTS

The earlier explorations

The earlier scientist explorers in Chile were naturalist collectors who gathered all kinds of natural history items, especially those that were most attractive to be sent or sold to European museums. This fact made that fossil wood was not counted or described like other items in the earlier published reviews, and only a few expeditions like those sponsored by the state such as the "Wilkes US Exploring Expedition", the British "Beagle`s expedition" or "Heuland´s Spanish" mineralogical expedition to Chile and Perú had a wider scope allowing them to collect more items, including fossil wood. Almost the same could apply to two French naturalists, Alcides D´Orbigny (1802-1857) and Claudio Gay (1800-1873). Alcides D´Orbigny, one of the founders of the micropaleontology, was exploring South America following a Humboldtian voyaging model, so he was briefly in Chile, and during his stay he collected in the Quiriquina Formation outcrops around Concepción, and while in Valparaíso in 1833, he reported to have gotten a large piece of fossil wood from a French whaler in the bay, who had collected it on the shore off Mocha island (most likely Tirúa) in the southern part of the Arauco peninsula (D´Orbigny, 1842: 90). D´Orbigny met Claudio Gay in Chile, who since 1830 was collecting specimens in the country and will continue collecting during twelve years thanks to a contract with the Chilean government. This also required to prepare collections for natural history cabinets/museums, as well as write a report summarizing the natural history of Chile, and editing an encyclopedic report that it would be turned out to be published in 28 volumes and 2 atlas dealing with the natural history, physical and political history of Chile from 1846 to 1871. Two of the most famous French naturalists of this epoch, Louis Hippolyte Hupé and Paul Gervais described the fossil species collected by Claudio Gay (Mollusca and vertebrates, respectively), and even though Claudio Gay himself was a respected botanist, there was no citation to fossil plants or petrified woods in that earlier work (Gay, 1854). Most of the Chilean collected specimens (minerals, fossils, and seeds) taken by Gay to France, were studied by specialist scientists such as Hupé, and were later given to the Natural History Museum at Paris (Sagredo, 2007).

People and petrified woods in Chilean history

The story of how fossil wood began to be recognized and collected in the country started with some scientific expeditions,

where a few researchers reported their occurrence without geolocating the localities where these fossils were collected. Then, there were resident scientists such as Ignacio Domeyko and Rudolf A. Philippi who collected specimens during their fieldtrips in the country, leaving these samples in university collections and the National Museum at Santiago.

In this summarized review dealing with historical collections of fossil woods found in central Chile and shipped from Valparaiso, we should consider expeditions such as the Spanish mineralogical expedition by the Heuland brothers, who visited Chile around 1795-96, the Beagle expedition between 1833-35, and the U.S. scientific expedition in 1838-1839. In addition, a few remarks are needed on the people who collected and wrote the earlier reports from these expeditions on these fossils: Conrad and Christian Heuland, Charles Darwin, and James Dana.

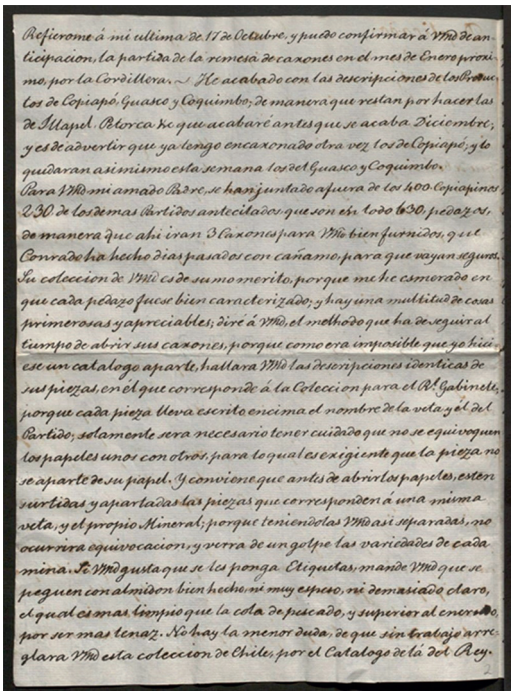


Figure 3 - Letter from Christian Heuland to J. Clavijo with labeling remarks (Archivo CSIC).

Heuland. The first Chilean collection currently found in a museum was made by the Royal mineralogical expedition to Chile and Perú lead by the brothers, Conrad and Christian Heuland, German mineralogists, who had studied at the famous Freiberg School of Mines. They were commissioned by the Spanish crown, "*to collect mineralogical samples and marine shells, crystallizations and fossils, plus to write the physical-mineralogical history of the visited kingdoms*" (Arias, 1978). The brothers travelled collecting minerals through Chile from North to South from July of 1795 to June of 1796 (Cubas and Oyarzún, 1987). This expedition stayed some additional months in the country labeling, packing and preparing the shipping to Spain of these labeled samples that included some fossils. Since, no field catalogue was made to go along the shipped boxes, careful labeling instructions were detailed in a letter written in Santiago on December 26th 1796 sent to the director of the Museum at Madrid, Joseph de Clavijo (Figure 3).

The Heuland brothers collected the first fossils ever recorded in Chile including some samples of fossil wood without locality plus some other specimen from Nacimiento, Bío Bío region, that are found currently in the collections at the National Museum of Natural Sciences at Madrid (Montero and Diéguez, 1998).

Darwin. Three decades later, during the South American Beagle´s Surveying expedition in Chile (1834-35), the naturalist on board, Charles Darwin was a young English naturalist scientist in the making (Figure 4), who stayed based at Valparaiso for eight months, lodged with his friend and former classmate Richard Corfield, who was a merchant in town. Here, he organized fieldtrips, collecting and interacting with the local English merchant commu-

nity. Darwin wrote that he had "*been struck by the great superiority in the English residents over other towns in S. America. Already I have met who have read works on geology & other branches of science*" (Darwin, 1988). He was quite surprised and pleasant to be asked his thoughts of the just recently published Lyell´s Geology. A very important first textbook of Geology in three volumes, where Darwin learn much about Geology and whose third volume fresh off from the press was received by Darwin when he arrived to Valparaiso.

Darwin had some local collaboration from some of these English speaking merchants like R. Alison who used to do some nature fieldtrips around and provided Darwin with samples and outcrops descriptions (in Van Wyhe, 2011), that were complementary to those written by Darwin in his journal describing outcrops like those at Playa Ancha: "*A few days ago I went along the Coast from Playa-ancha towards Laguna, and in a ravine nearly parallel with that of Quebrada Verde and about 300 yards from the sea, I observed that it had intersected several strata of shells leaving them exposed to the right and left on both sides of the ravine, on one side they continued up a series of steps or beaches forming a little hill about 80 feet high from the brink of the ravine, and about 350 feet above the level of the sea—The face of the hill was much covered with brush-wood, so that it was only by pulling it up and removing the earth that the shells could be found, and the steps were not well defined— The bottom of the ravine and the loose stones in it were gneiss of a very compact character with veins of feltspar; on digging a hole into one of the sides of the ravine about 3 feet from the edge I found the pelvis of some quadruped in a state of great decay. it was too small for a horse. I br[t] it in to show you the state of the bone but I do not think it worth sending you— The shells were the large concholepus, patella of various sizes some too small for the purposes of food, some turbos, and the metillus in a broken state, but I was not able to find some of the small concholepus.— I have sent you some for your inspection—*"

Figure 4 - Don Carlos as he was called in Chile and South America in 1840 (watercolor by George Simmond).

At the same time, Allison described in one of his two known letters to Darwin about the local geology around Valparaíso. In one of these letters explained that: "*The piece of fossil wood you allude to, and which I send was found in a ravine beyond Playa-ancha towards Quebrada Verde, but I did not find it in situ, but in the water amongst the rocks. The sides of the ravine were a sandy conglomerate with rounded pieces of indurated clay similar to those in the road of the Alto del Puerto. The bottom of the ravine appeared a sort of grünsteinic rock*".

Records for this kind of fossils were kept by Darwin within a summary petrified wood entry in his locality notebook, where he identified the following localities: near Iquique (1), Copiapó (2), costa de Valparaiso (3), Cordillera de Aconcagua (4), Concepción (5) and north of Chiloé (6). Localities where he collected fossil wood in 1834-35 (Figure 5).

Dana. James Dana was perhaps the foremost American mineralogist from the XIX century, who before 1868, had published the description of 28 new minerals, and he was also even a more famous professor and since 1848 writer of his *Manual of Mineralogy* as well as his treatise, that through many

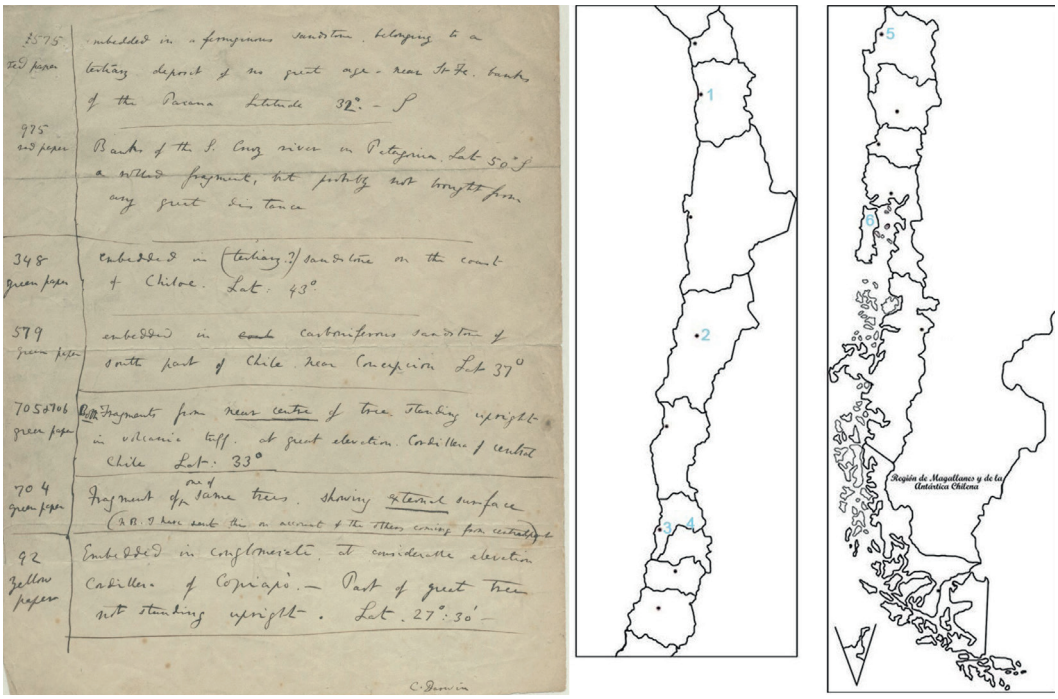
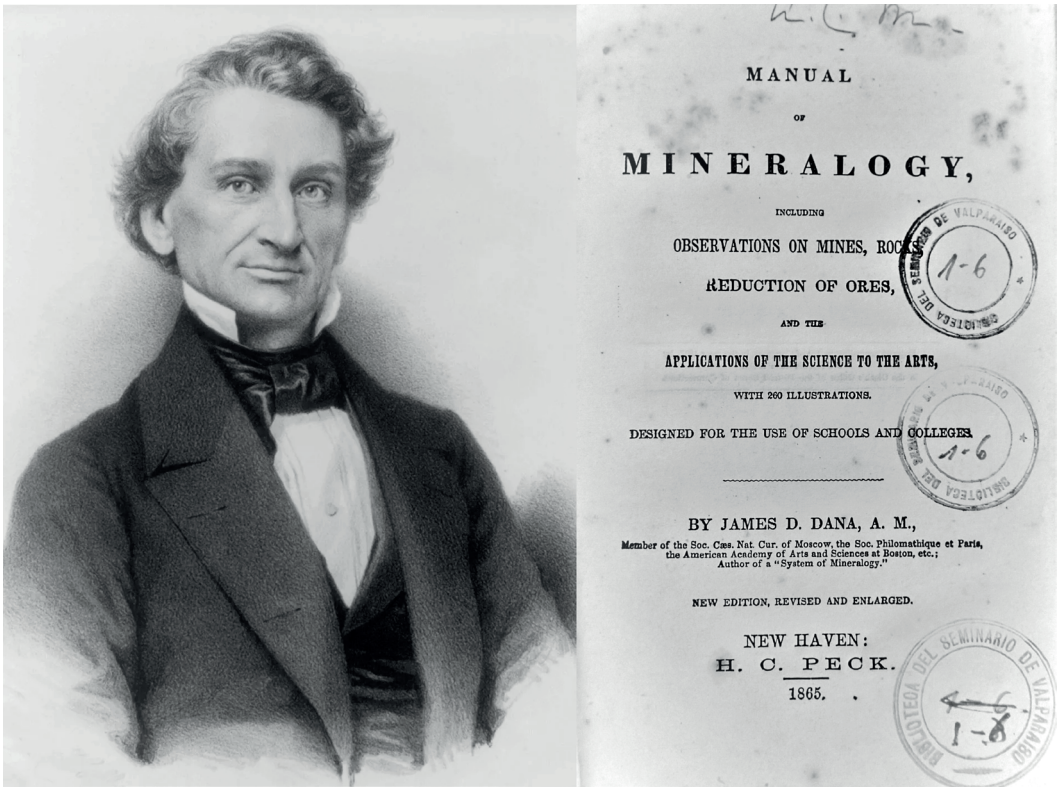


Figure 5 - Darwin´s fossil wood localities notebook page naming Chilean localities (from Darwin Online).

editions made his name as synonymous to Mineralogy, an later on his legacy that has been preserved with new revised editions (24th) to our day. Therefore, his Manual was used by whoever wanted to study minerals in the second part of the XIX century (Figure 6). Ten years before, he was a young naturalist eagerly collecting minerals and invertebrates in the surroundings of Valparaíso, including a few fossils such as fossil wood samples.

James Dana, as a naturalist, was member of the Gillis U.S. scientific expedition, who described invertebrates and rocks collected by him at Valparaiso in 1838. Among the samples collected, he tells the story about the finding of some fossil wood around Valparaiso.

"*The silicified wood of the Andes is said to occur in a similar conglomerate; but whether it belongs to a single epoch, or as is more probable, to different periods, has not been satisfactorily determined. It occurs in the form of agate, jasper and hornstone, and generally retains well the texture of the original wood*". '*The external surface is often bleached by exposure, and sometimes in this way is made to resemble bark. One specimen obtained had been bored by some insect or worm before it was petrified. About two miles from the Post House, eight miles east of Valparaiso, there are numerous fragments of silicified wood, and among them part of a trunk of a tree, two feet in diameter and fifteen inches long. From their position, it was evident that they had been transported to their present place since they were silicified. A single specimen of similar fossil wood was met with on the hills just south of the Concon, twenty-five miles north of Valparaiso*" (Dana, 1849: 584). This description could be correlated with historical and recent fossil wood found around Placilla; a suburb town located 12 km to the SE of the location mentioned by Dana for Valparaíso. Even though, this distance would match the distance calculated


MANUAL

OF

MINERALOGY,

INCLUDING

OBSERVATIONS ON MINES, ROCKS,

REDUCTION OF ORES,

AND THE

APPLICATIONS OF THE SCIENCE TO THE ARTS,

WITH 260 ILLUSTRATIONS.

DESIGNED FOR THE USE OF SCHOOLS AND COLLEGES.

BY JAMES D. DANA, A. M.,

Member of the Soc. Ces. Nat. Cur. of Moscow, the Soc. Philomathique et Paris, the American Academy of Arts and Sciences at Boston, etc.; Author of a "System of Mineralogy."

NEW EDITION, REVISED AND ENLARGED.

NEW HAVEN:
H. C. PECK.
1865.

Figure 6 - James Dana and his Manual as it is found at the MSV (Dana, 1865).

in miles by Dana, his orientation is to the SE. If we take as eastern strike, the historical location of this fossil wood should be located in the higher ground of Reñaca Alto and Quilpué, a current suburb location around Viña del Mar.

Chilean Historical Collections by Domeyko, Philippi, and Brüggen

Ignacio Domeyko, Rodulfo (Rudolf) Philippi and Juan (Johannes) Brüggen, were well known European scientists who settled in Chile, a country where they taught science (mineralogy, geology and natural history) to many student generations at the Instituto Nacional and/or University of Chile leaving many records and publications on collecting fossils that include petrified wood that haven´t been reviewed until now. Their combined input is very important in the history and evolution of Chilean geology, so it requires some paragraphs historically arranged to tell who they were and what happened to their accounts and fossil collections.

The first to settle in Chile was Ignacio Domeyko (1802-1889), who was a Polish/Lithuanian *emigré* who became the first professor who taught mineralogy in Chile, and also the most important researcher describing the geology and mineralogy of the country. Of the many minerals he characterized, there are three names for valid minerals he described, and two valid minerals dedicated to him by other mineralogists (Cuadra, 2022). He collected min-

erals and fossils in field trips through the country since 1838. These minerals were described in his Mineralogy treatise and manuals, including there also, the occurrence of fossil wood (Figure 7).

Some of these fossil wood samples were mineralogically described by Domeyko as lignites, coppery galena, chalcedony, and as fossil cork, whose features are listed below:

Galena in fossil wood found in a copper mine in Catemu: "504……*Galena cobriza… galena intercalada entre las fibras de madera en parte silicífera, en parte carbonizada penetrada de minerales de cobre en la mina llamada Manto de Lilen en Catemo (Aconcagua)"* (Domeyko, 1879: 324).

Chalcedony in the Atacama desert is characterized in Spanish as found in "*En masas pequeñas irregulares, globosa, arriñonada, estalactítica: veces forma la masa de algunos restos animales de madera petrificada*".

Soft Hydroscopic fossil cork found in many localities is described in Spanish as "*Corcho fósil.—Mui blando, dócil casi como el corcho. Estructura fibrosa entretejida: apénas se pega la lengua; mui liviano. Ps. 0,68 0,99; pero absorbe agua. Tanto el asbesto como el corcho se han hallado en muchas localidades en Chile como en el Perú*." (Domeyko, 1879: 594).

Some lignites, if the surface is fibrous it could be considered as fossil wood described in the original Spanish as "*fibrosa, puede pasar insensiblemente madera fósil, cuando por su color, cierta dureza la dureza la conservación completa de su contextura fibrosa aun de la forma de troncos, se parece más bien la madera que al carbón*" (Domeyko, 1879: 670).

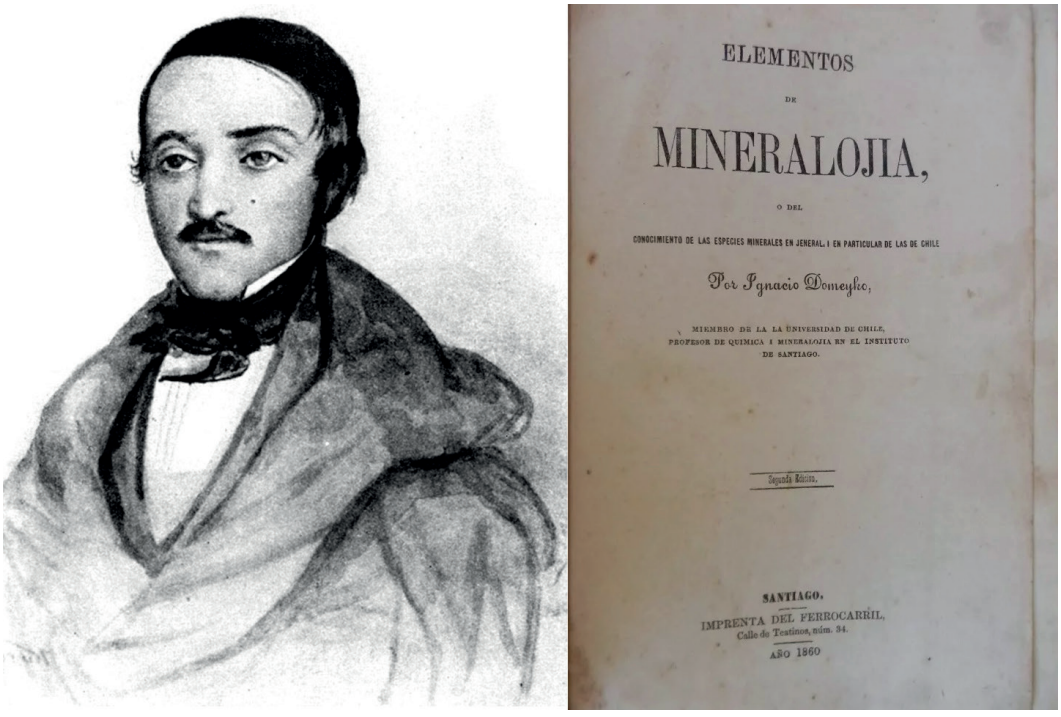


Figure 7 - Ignacio Domeyko and his Mineralojia (Domeyko, 1879).

Even though Domeyko was describing minerals, he characterized some fossil wood samples he found in the Atacama Desert, around Copiapó (Atacama), Catemu (Valparaíso), and partially carbonized, and partially petrified woods found from Cartagena and Topocalma, to the Magallanes Straits (Domeyko, 1879: 672).

Rudolf Amandus Philippi (1808-1904) was a Prussian naturalist, who arrived to Chile in 1851 escaping from the European 1848 revolutions. He was the director of the National Museum from 1853 onwards, and also he was professor at the Instituto Nacional and University of Chile (Figure 8A). Through many years he was in charge of the National Museum, he collected of kinds of Natural history specimens minerals (Verdejo et al., 2018), and more than eight hundred new fossil species (Pérez-Barria et al., 2018). These fossils were mainly described in his two monographs (Philippi, 1887, 1899), where he summarized the occurrence of fossil woods at different locations in the country.

Johannes Brüggen (1887-1953) was a German geologist who arrived to Chile in 1911 to work as Engineer at the Public Work Ministry (Figure 8B). From 1917 onwards, he was professor of mineralogy, geology and later, founder of the Geological Institute at the University of Chile. He is considered to be the father of the Chilean geology (Charrier *et al.*, 2016). He collected many fossils through his 40 years long geological experience in Chile, summarizing their stratigraphic occurrence in his book "*Fundamentals of the Geology of Chile*" (1950),

Figure 8 - The Chilean German collectors R. A. Philippi. **A**,(Fundación R.A. Philippi) and J. Brüggen. **B**, (Charrier *et al.*, 2016) when both were young age.

where he updated his view at the time on many localities including the Algarrobo fossiliferous locality.

Paleontological historical background in Valparaíso province

Valparaiso used to be the port of entry for geoscientists to Chile, so naturally, the first descriptions of the surrounding geology were made by them in this area. Therefore, the first sketches of a formal description of one local sedimentary fossiliferous formation was done by Charles Darwin in 1835, when he characterized the Navidad Formation, an important fossiliferous marine Neogene sequence where he found 31 species of marine invertebrates with a "*sandstone contain*(ing) *fragments of wood, either in the state of lignite or partially silicified*" (Darwin, 1846).

Closer to town, Valparaiso started to be named as a fossil locality around the time of Beagle`s Expedition visit, when Darwin tells about doing some geology around this city port in 1835. Among the fossils reported so early on, there were fossil wood specimens (Darwin, 1835; Dana, 1849), also found in the surrounding area in Placilla/Curauma, and Algarrobo (Philippi, 1887). Not much of this area was mapped showing its geology until the XX century, so all these areas where fossils were found had been mostly considered in the literature for a while as undifferentiated sedimentary tertiary beds with fossiliferous outcrops recognized at Algarrobo and Lo Abarca (Figure 9).

Later on, when the local stratigraphy was mapped, most of these outcrops were recognized as part of the Navidad Formation, considered to be the main source for marine fossils as well as fossil wood (Darwin, 1846), spreading its beds from south of Valparaíso to Topocalma (Pissis, 1854).

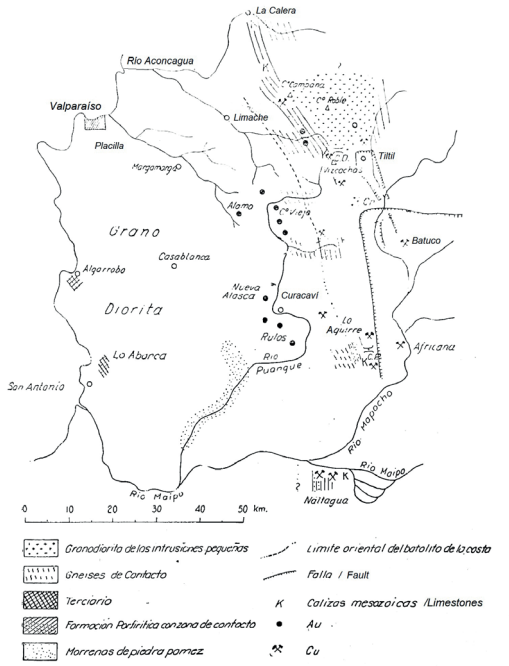


Figure 9 - Geologic sketch for Valparaiso area showing tertiary fossiliferous beds (modified from Brüggen, 1950).

The lost fossil Localities around Valparaiso

The fossil localities from where these recorded fossils were found are not precisely plotted in a map. Most of them were only named as Valparaíso, and that could mean sometimes the hamlets of Placilla/Curau-

COORDENADAS JEOGRAFICAS DE LOS PUNTOS MAS NOTABLES DE LA PROVINCIA DE VALPARAISO.

POBLACIONES.	LATITUD.	LONJITUD.	ALTURA.
Valparaiso (el faro) (1).	33° 1' 3" S	1° 0' 44" O	41 met.
Quillota (el cerro).	32 51 59	0 37 17	124 ciudad
Casa-Blanca (la plaza).	33 18 40	0 47 14	232
Limache (la plaza).	32 59 50	0 38 24	67
Olmué (la capilla).	32 58 28	0 33 19	94
Alvarado.	33 2 35	0 28 30	240
Dormida (la capilla).	33 2 35	0 27 0	513
Concheli (la capilla).	32 47 30	0 29 40	204
Purutun (la capilla).	32 46 27	0 32 50	219
Ocoa (primeras casas).	32 50 48	0 28 30	289
Puebuncavi (la plaza).	32 44 32	0 43 50	116
La Placilla (posada).	33 6 0	0 57 45	363
Las Dichas (plaza).	33 17 8	0 52 56	138
Quintero (puerto).			

Figure 10 - Geographical coordinates for main Valparaiso Localities (Pissis, 1854).

ma and Algarrobo as well, whose inhabited hamlets where part of some large hacienda. Therefore, in order to find the old locations with geographic coordinates, it should be located using surveying records from the XIX century (Figure 10) like those mapped and plotted by Pissis (1854).

Checking, official sources like the Census made every 10 years plus the available cartography, we could assess the growing urban development that occurred in Valparaiso in the XIX century, where neighboring localities such as Placilla and Algarrobo at the time where just little hamlets (see Table 1).

Valparaíso. After the independence in 1818, this city port grew demographically fast during most of the XIX century covering with buildings any available flatland (El Plan) around 1838 (Figure 11) and starting to build

Table 1 - Urban demographic evolution between 1831-1895 (Source: Bodini, 1985; Espinoza, 1903).

	1831	1854	1865	1875	1885	1895
Valparaíso	24000	52600	70438	97737	104952	121600
Placilla	**posada**					320
Algarrobo		**Puerto menor**				101

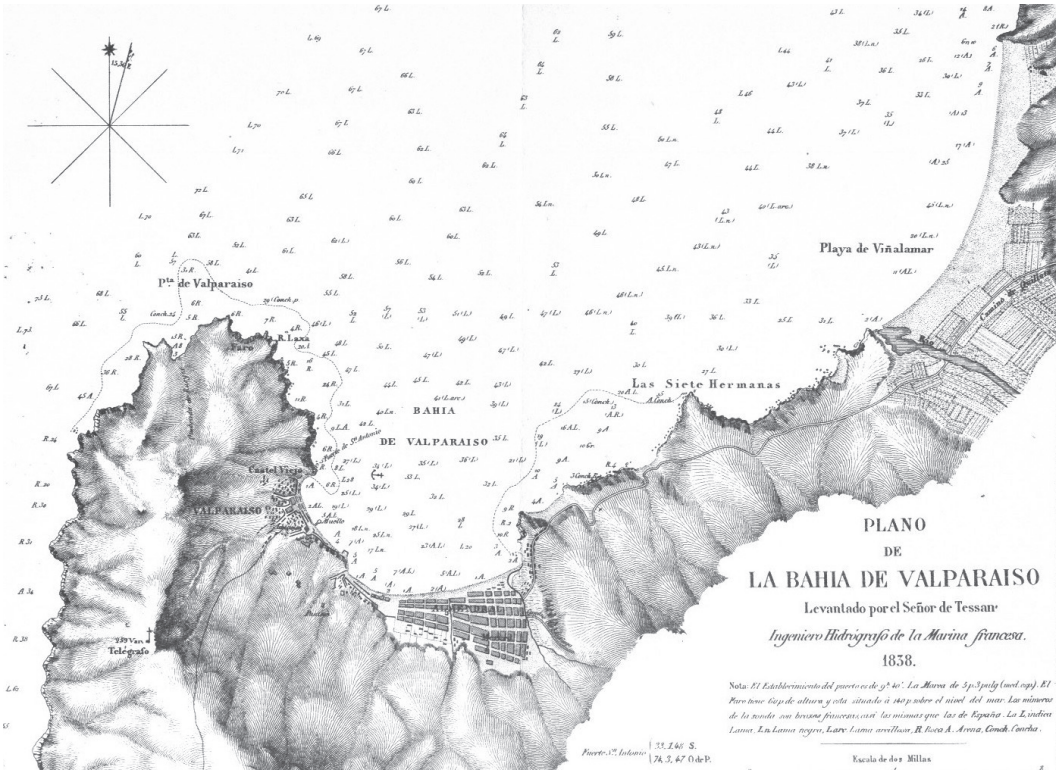


Figure 11 - Valparaiso, a little town when was visited by Darwin and Dana (Tessan, 1838).

Figure 12 - Valparaíso´s panoramic view evolution looking above sedimentary outcrops cuts 1860 and 2023 (Charton de Treville, 1860).

houses on the hills a few years later reaching a built surface area of 800 Ha around 1900s (Risopatrón, 1924). A more recent assessment of the built urban area of the city adds over 3000 Ha (CONAF-CONAMA, 1999).

Therefore, the historical urban development of Valparaiso has obliterated any suitable sedimentary outcrops recorded by Darwin (1834-5), Alison (in Darwin, 1835) and Dana (1838) in the higher ground around Playa Ancha covering any outcrops in the area (Gana *et al.*, 1996). Most that it was left today is found on the slopes cuts around the old road to Santiago on La Virgen Hill (Campos, 2017) and Ramaditas Hill (Grimme and Alvarez, 1964), where cuts still are visible on some slopes on the hill (Figure 12).

Placilla/Curauma. Placilla de Peñuelas was a small hamlet during the XIX century, getting some importance as a water reservoir

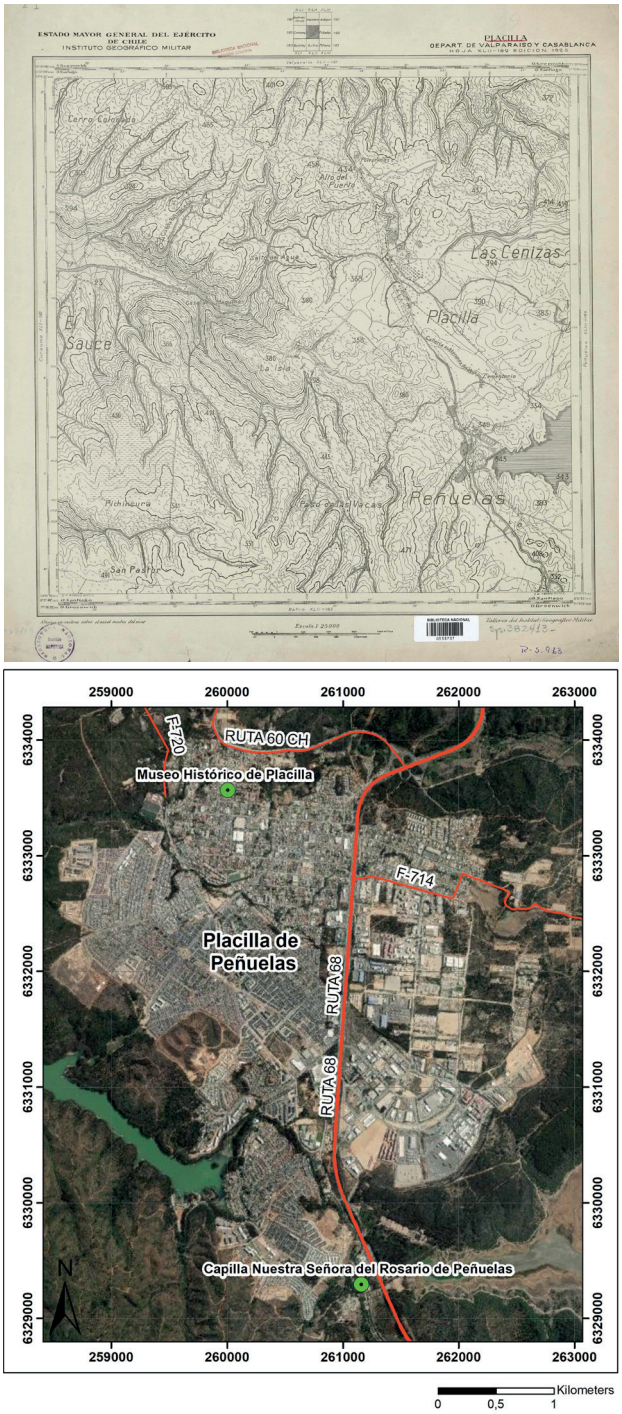


Figure 13 - Placilla/Curauma urban evolution (IGM, 1908-Google Earth, 2023).

for the growing population of the city of Valparaíso. The first steps on that regard begin in 1869, when "Las Cenizas" reservoir is built in the old 60 Ha "Fundo Las Cenizas", and later when between 1895 and 1900, the larger Peñuelas reservoir was built. Later, this reservoir would become the "Lago Peñuelas" reserve (in 1952). In addition to Las Cenizas and Peñuelas reservoirs, Laguna Curauma, known also as Tranque La Luz is a third reservoir. All of them adds up 1309 Ha (CONAF-CONAMA, 1999) of former land with outcrops along with additional 11000 Ha of more recent pines, and eucalyptus plantations (CONAF-CONAMA, 1999) plus the recent surrounding industrial development that have covered most or all of the older outcrops from where Darwin and Philippi reported fossil wood.

At the beginning of the XX century, Placilla was still a small hamlet with 320 inhabitants dispersed on 2 km on both sides of the Valparaiso road (Espinoza, 1903), that only in the last 30 years has been growing fast to reach 39344 inhabitants (INE, 2017) in an area of 1377 Ha obliterating any historical outcrops by urban development (Figure 13).

Placilla de Peñuelas was until 1864 a large farm ("*hacienda*") and stage coach station ("*posada*") visited by Darwin on his way to Santiago in March of 1835, and not much had changed when it was visited by Philippi around 1870. The place where both naturalists, collected and reported petrified wood. Darwin collected in Placilla "*petrified wood in a conglomerate*" (sample Beagle 2155 at Sedgwick Museum) during a stagecoach stopover at the Placilla´s "*posada*", located along the old royal road to Santiago. According to old maps and coordinates, the original location where these fossils were collected should be found on the northern side of the town alongside the "*camino viejo*", when only the "*posada*" and a few isolated houses were on the place. Conversely, Placilla de Peñuelas today, is a large suburban area of Valparaíso with nearly 40000 inhabitants, spreading over 1727 Ha of the old farmland, that also includes an area southwards known as Curauma located 8 km south of Valparaíso, that was another large farm ("*Fundo*") centered on the Curauma Creek, where there was a "*lagoon*" draining a creek coming from Placilla with tertiary outcrops (Philippi, 1887:10).

Algarrobo. This locality started to be officially recorded as "*puerto menor*" in 1854, and as a subdelegation (village) attached to Lagunillas (Casablanca) in 1891. In 1920s still was considered as one street hamlet (Caserío) (Risopatrón, 1924). Algarrobo was also known because of the finding of marine reptile remains plus many invertebrates since 1860s. Philippi described some of these fossils in 1887 in his monography on Tertiary fossils commenting on finding outcrops bordering the sea shore on 4 to 5 km and 40 feet wide (Philippi, 1887: 10). Later in 1915, Brüggen mapped the area distinguishing two beds (Figure 14), an underlying Cretaceous bed and another Eocene bed on top divided by an unconformity seen on the coastal outcrops above a beach area.

Brüggen found Cretaceous fossil beds off a small creek that descends 500 m east from the now nonexistent main outcrop found at the larger *Municipalidad* creek, where he found marine invertebrates noticing as most frequent fossils *Cardium acuticostaum* D´Orbigny, *Trigonia hanetiana* D´Orbigny and *Mactra colossea* Philippi associated with "*pieces of carbonized wood that are not rare*" (Brüggen, 1915).

Therefore, those inland outcrops disappeared with the XX century urbanization of Algarrobo. Since the creation of a subdelegation (village) dependent from Lagunillas in 1891 when the population was around 100 (Espinoza, 1903), becoming a municipality after 1945 with a steady demographic

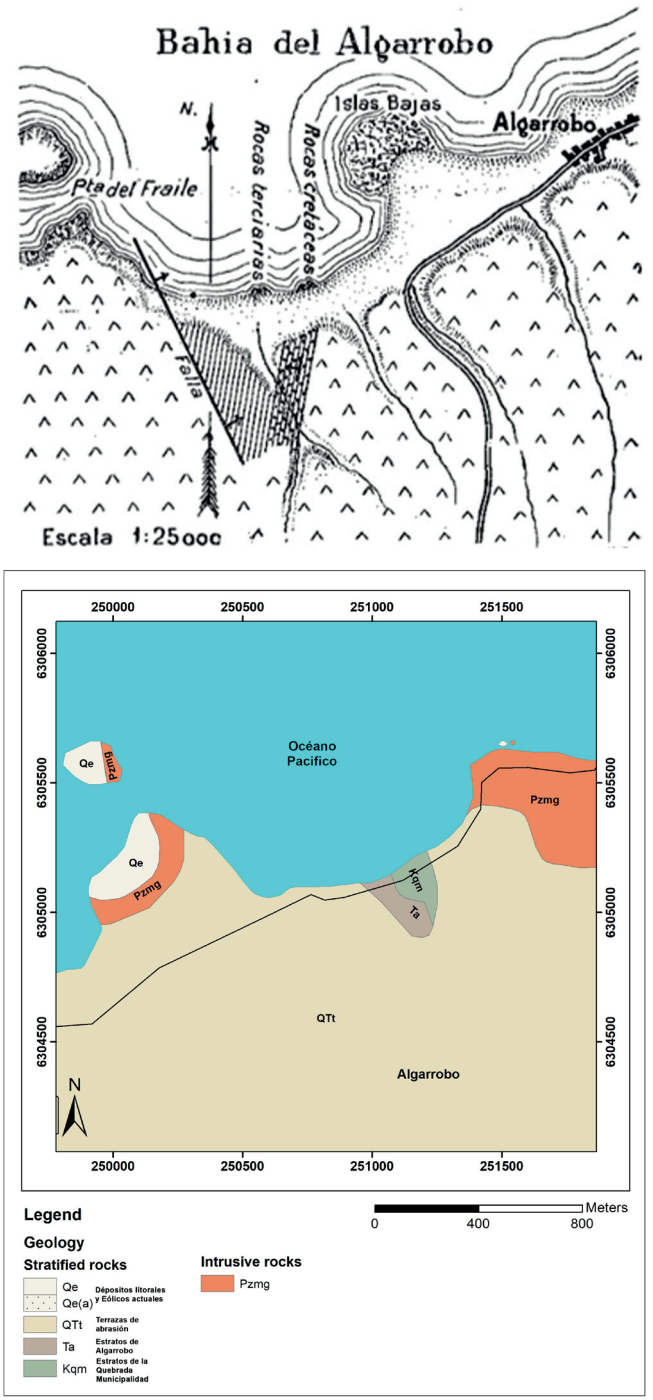


Figure 14 - Algarrobo geological map evolution (modified from Brûggen, 1915; Wall *et al.*, 1996).

growth that had reached an official figure of 13817 (INE, 2017).

On the other hand, recent changes have occurred because the coast around Algarrobo have been affected by more extreme stormy events since 2015 (Figure 15), with recurrent swells that have increased between 10% and 25% compared to previous years, causing the interruption of the annual dynamic process of the beaches accentuated by anthropic interventions that promote coastal degradation (Briceño *et al.*, 2021). This dynamics has been characterized assessing 6 local sedimentological profiles on a 4 km beach shore on the northern part of this bay (<1.5 km from outcropping fossils) measuring which part of the beaches and at what time of year there is a higher risk of severe erosion in the immediate areas (Briceño *et al.*, 2021; Briceño, 2022). Therefore, with the erosion increase, new outcrops belonging to the same beds are reappearing on the seashore.

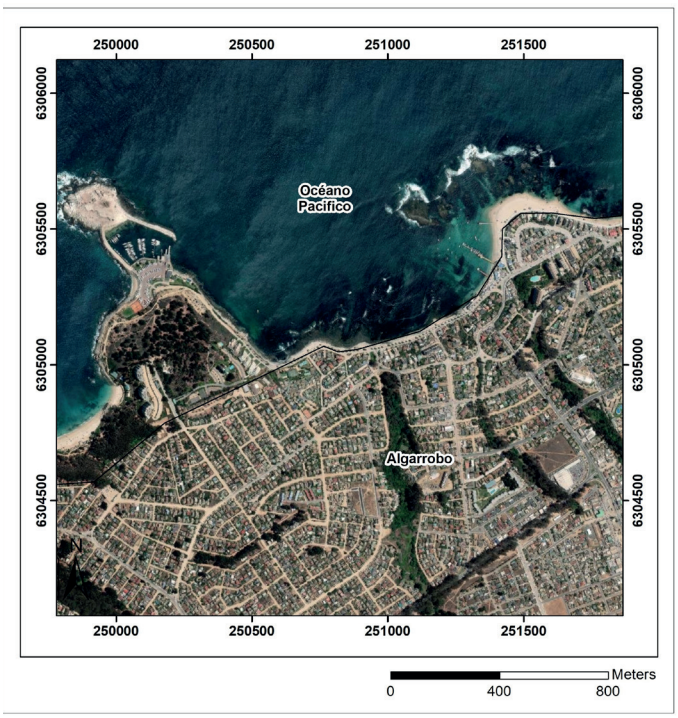


Figure 15 - Current outcrops with fossil wood at the shore and former outcrops covered by urbanization at Algarrobo (Google Earth).

In addition, we have to count the uplift associated with several large earthquakes such as those in 1730, 1822, 1906, and 1985 yielding an apparently regular return period of 82 +/- 6 years, which is highly unusual for large subduction zone earthquakes. The rupture zones for the 1822, 1906, and 1985 earthquakes overlap in the vicinity of Valparaíso, where the Nazca plate slips beneath the continental crust of South America by as much as 2 meters along a rupture measuring hundreds of square kilometers (Thorson, 1999). Abrupt coseismic uplifts also occurred during these large earthquakes. The 1822 earthquake, considered historically the strongest, produced nearly a meter of coseismic uplift at Valparaíso and surrounding region. This was witnessed at the time by Mary Graham and published as a report in the *Transactions of the Geological Society* (1824), noting the large uplift of the seashore around Valparaíso (Kölbl-Ebert, 1999). Evidently, every time this uplift has occurred the coastal outcrops are exposed and eroded. For the Algarrobo area, a geological study calculated a local uplift rate of approximately 0.4 m/ky (Encinas *et al.*, 2006). Therefore, new outcrops not seen historically before are being exposed and eroding now at the edge of the sea, where increasing beach erosion is also locally recorded (Briceño *et al.*, 2021, 2022). Then, even though the original locality is already gone because of urban development, the local uplift allows that the same beds could be found today again under an eroding 450 m beach front at the edge of the sea in playa Los Tubos (Algarrobo). For example, it has been proved that uplifting associated to the 1985 Algarrobo earthquake was 20 cm (Comte *et al*., 1986). Then, calculating average local uplifting minus sea level rise balance around the coast of Valparaíso. It shows that the coast is presently rising relative to the sea by at a rate less than 0.5 mm per year (Thorson, 1999) also attested by a local geological study estimate of 0.4 m/ky (Encinas *et al.*, 2006). Therefore, this uplift increases the erosion rate on the coastal fossiliferous outcrops at Algarrobo.

Museum collections

The original records associated with most of the earlier expeditions and the collected specimens do not recall later detailed whereabouts of the specimens either in Britain or the US. The US Wilkes expedition specimens collected in 1838-39 were somewhere misplaced within the collections through transfer to the Smithsonian Institution (founded in 1852), where according to the Smithsonian Institution archives should be located in boxes belonging the Janes Dana or in the Chilean collection boxes sent by ambassador Pollard to the US. The Beagle Expedition specimens collected by Charles Darwin in 1834-35 should be at the Sedgwick Museum of University of Cambridge. On the other hand, it is a well known fact that local resident collectors such as Domeyko, Philippi and Brüggen sent specimens not only to local museums but through gifts, exchanges or sale to many of the main European museums.

Besides the National Museum (Museo Nacional de Historia Natural) at Santiago, we have four local museums where fossil wood specimens are in deposit: the Museo de Historia Natural de Valparaiso (MHNV) whose published catalogue counts fossil plants but not petrified wood (Fuentes, 2019; Campos, 2017), 57 fragments from Museo Fonck (MF), 10 fragments from the Museo Histórico de Placilla (MHPL), and 18 from the Museo del Seminario de Valparaíso (MSV) who have some fossil wood collections (Figure 16) that have been taken into account to discover their origin using an historiographical approach.

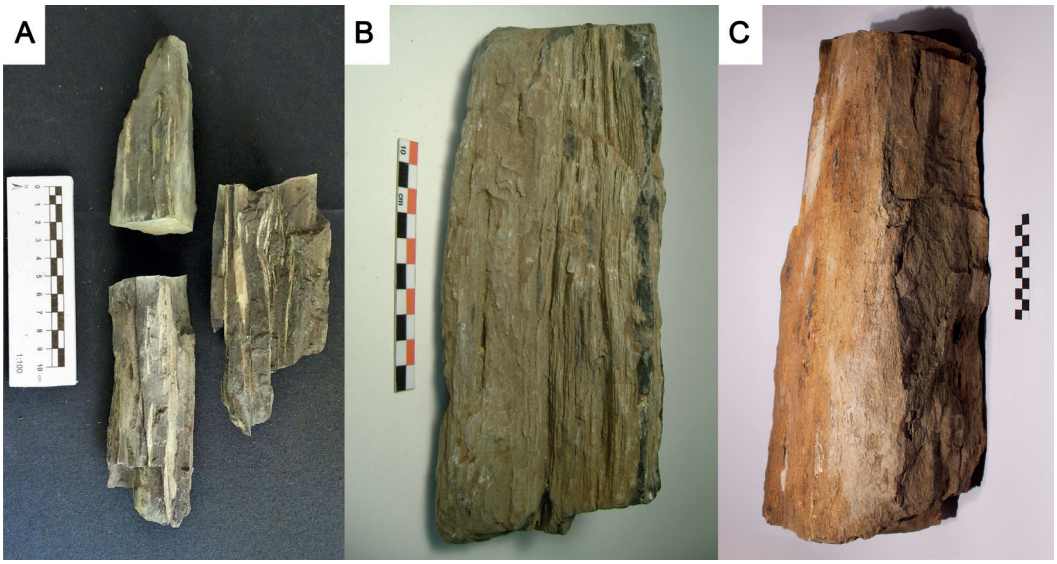


Figure 16 - Local Fossil Wood fragments from Museo del Seminario de Valparaíso (**A**), Museo Fonck (**B**) and Museo Placilla (**C**).

Proposing how to find locations with the fossil woods collected

As already stated, fossil wood collections are often mislabeled or simply do not have a locality label attached, since often the specimens are collected *ex situ* without reference to the outcrops from where the specimens came from. Therefore, studying old collections is a challenge because no relevant information is associated with the specimen. The original organic material of the fossil wood has been replaced, usually by chalcedony or agate (cryptocrystalline quartz), but sometimes by opal, coal, pyrite, calcite, apatite and others that may be stained by traces with colors red and green usually caused by iron, as it had been recorded historically first as a metallic cation (Bahr, 1852; Leet, 1853), and as oxides whose specific color may be associated with different metallic cations, usually from hydrothermal ores, where for example, in countries such as Chile, it is known that traditional artisanal miners crushed in their mills greenish fossil wood to get copper ore in areas such as around Pichasca Natural Monument (Coquimbo Region). Therefore, from the more typical reddish brown hematite tone colors to a few of the more brightly colored green woods that may be colored by chromium or vanadium (Mustoe and Acosta, 2016), there is a correlation between color, the kind of oxide trace staining the fossil and the outcrop from where it comes. Then, these mineralogical characteristics may be associated with the surrounded rocks in order to differentiate outcrops on the ground to find what is the most likely source of the fossils.

Therefore, as in this case study, there are not so many localities to study. Then, fossil wood fragments on the suspected sites could be useful to compare them using traces with suspected fossils from that area in storage in museum collections, studying the staining traces of minerals that might be useful indicators to reduce the number of possible localities or even iden-

tify the most likely locality that should be associated with the specimens.

DISCUSSION

In the XIX century, fossil wood used to be confused or being called for as such for some kinds of fibrous lignite (Lyell, 1830; DEHA, 1888: 916). As the petrified wood collecting used to be done mainly with a lapidary or ornamental goal in mind, the locality and stratigraphy was not important in older collections. Then, there is a gap with scientific data available in those collections that might be helped to be resolved with further studies using classic and more recent methodologies such as SEM microscopy and X-ray diffraction that have been developed and applied to studies on fossil wood since 1970s (Buurman, 1972).

There are many world examples where land development and urban expansion can have large impacts on geodiversity as it has been observed by the danger of destruction of fossiliferous outcrops such as examples given as by industrial and road development in the Gingko Petrified Forest State Park at Washington State (Gray, 2004), or by the urbanization pressure at Maadi petrified forest that covered an large area of thousands Ha, now being partially decimated (40%) and accelerated its destruction by urbanization by New Cairo (AbdelMaksoud and El Metwaly, 2020), with a remaining 70 Ha being preserved as a park surrounded by the growing Cairo megalopolis in Egypt (Figure 17).

Another example that should be cited is what happened to the fossil forest at "Agua de la Zorra", near Uspallata. A site discovered by Darwin on his Andean crossing back from Mendoza to Valparaiso in 1835. This place was the first in situ fossil forest discovered in South America (Brea *et al*., 2009). According to Morton, the fossilized trees would have been removed to museums, but some fossil tree stumps were still visible along with a marker at the site commemorating Darwin´s work (Morton, 1995).

Perhaps the famous Arizona petrified

Figure 17 - Maadi Petrified forest in danger in Cairo (2019).

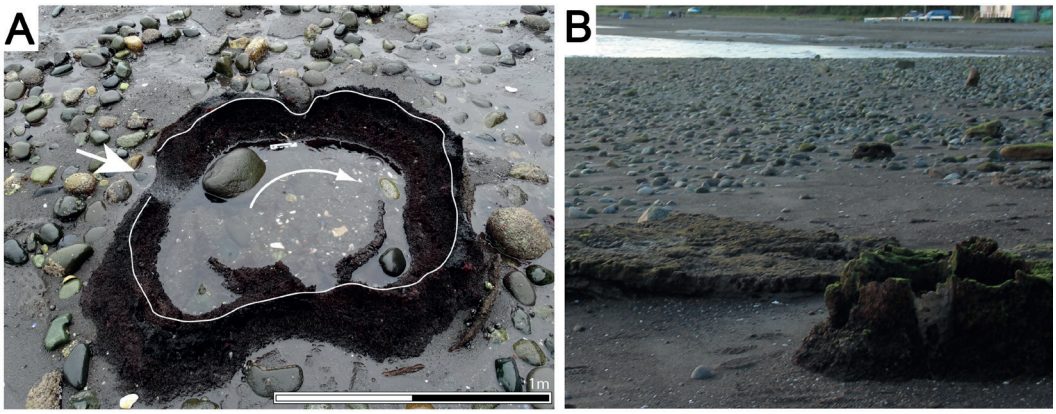


Figure 18 - Stump of ancient coniferous in the Natural Sanctuary "Fossil Forest of Punta Pelluco". **A**, Erosive action on the stump made by waves and stones. Arrows indicate the movement and flow of water. **B**, Intertidal area where the stumps are outcropping.

forest discovered around 1850s, is the best example on what happen when an area is preserved as a national park (founded in 1962), and what have happened with outlying bordering areas where tons of fossil wood are mined annually. This park is visited by nearly nine hundred thousand visitors every year, where some of these visitors steal fossil wood fragments as souvenirs reaching up to 12 tons a year (McKinnon, 2015).

On the other hand, the Chilean showcase is not so well known or studied. Up to 1980s, only twenty historical fossil wood localities had been recorded and studied in the continental Chilean territory (Torres, 1983). The first Chilean Natural Sanctuary (protected natural site according to law 17288) was missing from that earlier list. It was declared in 1978 as "Punta Pelluco Fossil Forest" located a few kilometers east of Puerto Montt (41.58º S, 72.98º W) covering 4 Ha. There, the beach exposes tree stumps in life position originally buried by a lahar (Klohn, 1976) exposed after the world´s largest magnitude earthquake ever registered uplifted the area (Valdivia-Concepción in 1960). The site is severely degraded by unregulated tourists visiting the site, plus erosion associated with the impact of waves and stones moving inside the stumps (Figure 18), besides the intensive bioactivity of a high diversity of algae and invertebrate epibionts eroding the surface (personal observation, LPB). The number of stumps and lost information is difficult to precise due to tides in the inundated area. This forest has been dated in the mid-late Pleistocene age (Roig et al., 2001).

Another missing locality from that earlier list were some fossiliferous outcrops known from the historical paleontological site at Algarrobo beach (Philippi, 1887), a place where abundant carbonaceous wood fragments are found in Eocene beds and a little bit less underlying the Cretaceous beds where they have been recorded (Tavera, 1980), as well as in other minor localities such as Topocalma, Idalgo and Quilpué, places where some fossil woods such as *Jubaea chilensis* were recorded long ago (Pissis, 1873; Reiche, 1934). Also missing from that list are the older cited localities, most likely because land development and urban expansion has already obliterated them as outcrops long ago.

None of the recorded localities by Torres (1983) come from Valparaíso area. Recent

paleo/archaeological findings along the estero Quilpué (near Viña del Mar) recorded some fossil wood that has been dated around 15000 years old (Rafael Labarca, com. pers.). Therefore, that finding is too recent to be correlated with earlier historical discoveries we report here.

On a smaller scale, the Chilean Pichasca Natural Monument is a 120 Ha protected site administered by CONAF (Chilean Forest Service) since 1985 with near 100 araucaria stump fragments where an additional three more species have been anatomically recognized (Torres and Rallo, 1981) and found outcropping alongside 1 km visitor pathway. As Pichasca is a classical tourist and geological fieldtrip stopover, through the years it has been observed that these stumps are getting smaller and some of them even disappearing.

The rediscovery of a historical petrified forest in "El Rosado" (Ortega Village in the Chilean Patagonia), where three fossil stands are outcropping in 13 Ha, reaching an area of 102 Ha surveyed within 4275 Ha (source MMA Gob. Chile) in a locality known by local colonists from the seventies (only a few kilometers from where Nishida's Japanese expedition found Cretaceous *Araucarioxylon*; Nishida *et al.*, 1992). This is another example of loss of critical geological information caused by the illegal subtraction of pieces (Pérez-Barría, 2021). Only some of it ended up in the local museum of Villa Ortega and the historical collection of the Regional Museum of Aysén (see Ortiz, 2022). Even though, accessibility is limited, in recent years, "El Rosado" (Figure 19) growing popularity with visitors has increased the risk of disappearing before minimal research is done (Avendaño, 2022; Guajardo, 2022; Pérez-Barría *et al*., 2022).

Examples from Chile and across the world are a reminder about what has occurred with fossiliferous outcrops even when fossils are officially protected by law like in Chile (Law 17288), as equally may have additional preservation issues because they are very fragile to anthropic pressure. For comparison, in this study around Valparaiso´s localities, only Algarrobo still have some fossils found bordering the tide on the sea shore line with 1.03 Ha of coastal outcrops covered partially by sand with two main fossiliferous components from

Figure 19 - The Rosado site, Aysén Region. Camp of petrified wood in natural condition (left), and relocated and decontextualized trunks of the historical locality most affected by illegal extraction. Both are different localities (modified from Pérez-Barría, 2021).

Figure 20 - Recent seashore evolution of fossiliferous outcrops at Algarrobo from 1960 to 2019 (modified from Pablo Salinas, Algarrobo al Día).

Cretaceous and Eocene age where fossil plants, invertebrates, birds, fishes and reptiles are recorded (Otero *et al*., 2023, 2012; Otero and Suárez, 2022; Schweitzer *et al*., 2009; Yuri *et al*., 2012). When considering the paleodiversity found there and its high scientific value of the fossils found, along with raised erosion at the shore, which increases degradation risk. Hence, this locality should be considered as a priority site to be protected.(Figure 20).

All of these elements count when assessing that Algarrobo fossiliferous site should be considered to be an excellent location for a site Museum (National Monument according to Chilean law) as it has been proposed already (Tapia *et al*., 2022).

CONCLUSIONS

This assessment studies the neglected historical records associated with fossil wood collections gathered during the XIX century and beginning of the XX century in outcrops from the old Valparaiso province. Only a partial record of these collections is currently known and the whereabouts of many of these specimens is still a partial enigma. Nevertheless, these fossil localities records named by well-known naturalists such as C. Darwin, J. Dana, I. Domeyko, R. A. Philippi and later by the geologist J. Brüggen allow finding that the places from where they were collected are in Valparaíso, Placilla/Curauma and Algarrobo. Since then, large demographic and urban growth in Valparaiso´s area would have obliterated the older cited localities with one exception on the Algarrobo sea shore where, despite the urban growth also covered the historical inland outcrops, the episodic local tectonic uplift associated to earthquakes minus sea level rise is positive for the area, leaving then, an increased erosion on the beach, currently exposing 1.03 Ha outcrop in a 450 m long beach front above tide sea level, where would be likely to find new specimens in the foreseeable future.

Finally, these fossil wood specimens from the Museo del Seminario de Valparaíso, Museo Fonck and Museo Histórico de Placilla require further studies working with thin sections in order to define the fossil wood taxonomy, which should be associated with paleoecological assessments of any new specimens associated with localities *in situ* in the area.

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REFERENCES

Abritton, C. C. and Wimley, W. F. (1989). The Earth Sciences (part). In: Encyclopedia Britannica, 15th Edition. Vol. 17, 571-582.

AbdelMaksoud, K. M. and El Metwaly, W. (2020). Maadi petrified Forest in Cairo, Egypt, as a geologic heritage under urbanization Pressure. *Geoheritage*, 12(44), 11 pp.

Avendaño, C. (2022). Geoconservación del sector de los petrificados de Cerro Rosado, Villa Ortega, Región de Aysén, Chile: puesta en valor y zonificación. Tesina para optar al título de Geólogo, Universidad Católica del Norte, Antofagasta. 112 pp.

Arias, J. (1978). *Expedición científica de los hermanos Heuland. 1795-1800*. Ediciones Cultura Hispánica del Centro Iberoamericano de Cooperación. Madrid. 154p.

Bahr, M. (1852). Sobre la existencia de hierro metálico en la madera fósil. *El Restaurador Farmacéutico*, 8(13),70.

Bodini, H. (1985). *Geografía urbana*. Tomo X, serie Geografía de Chile. Instituto Geográfico Militar, 233 pp.

Brea, M., Artabe, A., Emilia, E. and Spalletti, L. A. (2009). Darwin forest at Agua de la Zorra: the first

in situ forest discovered in South America by Darwin in 1835. *Revista de la Asociación Geológica Argentina*, 64(1), 21-31.

Briceño, I (2022). Determinación de erosión costera con imágenes satelitales Sentinel-2 entre 2015 – 2022. Caso de estudio Bahía de Algarrobo, Chile Central. Ciclo de Seminarios quincenales de la Alianza Copernicus-Chile. (https://www.cmm.uchile.cl/?p=44963).

Briceño-de-Urbaneja, I., Sánchez-García, E., Pardo-Pascual, J., Palomar-Vázquez, J., Ugalde Peralta, R., Aguirre Galaz, M.C., Pérez-Martínez, W. and Vidal-Páez, P. (2021). Cambios espacio temporales costeros con imágenes Landsat 8 y Sentinel 2 (2015-2019) en Chile Central; Playa Reñaca, Bahía de Concón y Bahía de Algarrobo. Tercer Congreso en Ingeniería Geomática Valencia, 7 – 8 de Julio de 2021, Editorial Universitat Politècnica de València. https://dx.doi.org/10.4995/CiGeo2021.2021.12766

Brüggen, J. (1915). El cretáceo del Algarrobo i las supuestas relaciones entre las formaciones cretácea i terciaria de Chile. *Anales de la Universidad de Chile*, 73(136), 429-441.

Brüggen, J. (1950). Fundamentos de la Geología de Chile. Instituto Geográfico Militar, 374 pp.

Buurman, P. (1972). Mineralization of fossil wood. *Scripta Geologica*, 12, 1-43.

Campos, D. (2017). Restos fósiles de hojas en Valparaíso. *Anales del Museo de Historia Natural de Valparaíso*, 30, 83-85.

Charrier, R., Hervé, F. and Aceituno, P. (2016). Contribución del Profesor Johannes Brüggen a la geología en Chile. *Revista del Museo de La Plata (Especial – La Historia de la Geología en el Bicentenario de la Argentina*), pp. 61-85.

Chaney, R. W. and Arnold, C. A. (1970). Paleobotany. *In*: Encyclopedia Britannica, 14th Edition, Vol. 17, 97-116.

Charton de Treville, E. (1860). Vista general de Valparaíso (colección privada).

Comte, D., Eisenberg, A., Lorca, E., Pardo, M., Ponce, L., Saragoni, R., Singh, S.K. and Suárez, G. (1986). The 1985 Central Chile Earthquake: A Repeat of Previous Great Earthquakes in the Region? *Science*, 233(4762), 449-453.

CONAF-CONAMA (1999). Catastro y Evaluación de Recursos Nativos de Chile, Informe Regional Quinta Región.

Cuadra, P. (2022). Especies minerales chilenas. Un aporte al conocimiento del geopatrimonio de Chile. Serie Profesional de Publicaciones, SGCh. 55 pp.

Cubas, P. and Oyarzún R.. (1987). Entorno geográfico de la Expedición Heuland. Introducción. *In*: La Expedición mineralógica de los hermanos Heuland a Chile y Perú. Museo Nacional de Ciencias Naturales, pp. 39-50. CSIC, Madrid, 93 pp.

Dana, J. (1849). Exploring Expedition, during the years 1838, 1839, 1840, 1841, 1842. under the command of CHARLES WILKES, U.S.N. United States Exploring Expedition v.10 (1849) [Geology Text], G. Putnam, Ed., United States Exploring Expedition.

Dana, J. (1865). *Manual of Mineralogy*. New Haven. H.C. Peck, 456 pp.

Darwin, C. R. (1835). Geological diary: Examined with Mr Alison shells on Hills [Valparaiso]. [2.1835] CUL-DAR36.424 Transcribed by Kees Rookmaaker, edited by John van Wyhe (Darwin Online, http://darwin-online.org.uk/).

Darwin, C. (1988). *Charles Darwin´s Beagle Diary*. Edited by Richard Darwin Keynes. [Diary of the voyage of the H.M.S. Beagle]. Cambridge University Press. 464 pp.

Darwin, C. (1846). South America: Geological observations on South America. Being the third part of the geology of the voyage of the Beagle, under the command of Capt. FitzRoy RN, during the years 1832 to 1836. London: Smith, Elder & Co.

DEHA (1888). Lignito *In*: Diccionario Enciclopédico Hispano Americano. Tomo XII. J-LLU.

Domeyko, I. (1879). *Mineralojia*. Tercera edición. Santiago, 760 pp.

D´Orbigny, A. (1842). Voyage dans l'Amérique Méridionale. Tom. 3, pt. 3-4

Encinas, A., Hervé, F., Villa-Martínez, R., Nielsen, S., Finger, K., and Peterson, D. (2006). Finding of a Holocene marine layer in Algarrobo (33°22'S), central Chile: Implications for coastal uplift. *Revista geológica de Chile*, 33(2), 339-345.

Espinoza, E. (1903). Geografía descriptiva de la República de Chile (Edición facsímil Rafael Sagredo Baeza). Original, Imprenta Gutenberg, 493 pp.

Falcon-Lang, H. (2015). Palaeobotany under the microscope: history of the invention and widespread adoption of the petrographic thin section technique. *Microscopy: The Journal of the Quekett Microscopical Club*, 42 253-280.

Field, R. M. & Whelden, R. M. (1938). Paleobotany. *In* Van Nostrand`s Scientific Encyclopedia, Pp. 806-808, Van Nostrand Company, New York, 1234 pp.

Fleet, J. W. (1911). Petrology. *In* Encyclopedia Britannica. Eleventh edition. Vol. XXI, Pp. 323-333, Payn to Polka. Cambridge, England: New York.

Fuenzalida, H. (1961). La Geología en el Museo Nacional de Historia Natural. *Noticiario mensual Museo Nacional de Historia Natural*, 59(v), 1-8

Fuentes, F. (2019). *Colección Fósiles*. Museo Historia Natural de Valparaíso, Chile 2019. 84 pp.

Gana, P., Wall, R. and Gutiérrez, A. (1996). Geología del área Valparaíso -- Puchuncaví, Región de Val-

paraíso y Región Metropolitana. Servicio Nacional de Geología y Minería, Chile.

Gay, C. (1846-71). Historia Física y política de Chile. 28 volúmenes. Paris. En casa del autor.

Geikie, A. (1879). Geology. *In* Encyclopedia Britannica. Nine edition. Vol X, Pp. 212-375, Edimburgh. Charles and Adam Black.

Geikie, A. (1911). Geology. *In* Encyclopedia Britannica. Eleventh edition. Vol. XI, Pp. 638-674, Franciscans to Gibson. Cambridge, England: New York.

Grimme, K. and Alvarez Sch., L. (1964). El suelo de fundación de Valparaíso y Viña del Mar. Provincia de Valparaíso. Geología del área Valparaíso-Viña del Mar. *Instituto de Investigaciones Geológicas, Santiago de Chile, Boletín* 16, 58 pp.

Gray, M. (2004). Geodiversity; valuing and conserving abiotic nature. Wiley. 434 pp.

Guajardo, F. (2022). Geología y patrimonio del sector Río Correntoso – Cerro el Rosado, entre las coordenadas 45°20'-45°23' S y 72°10'-72°5' W. Memoria para optar al título de Geólogo, Universidad Andrés Bello, Viña del Mar. 113 pp.

Heer, O. (1868). *Flora fossilis arctica*. Zürich.

Hooke, R. (1665). Micrography: or, Some Physiological Descriptions of Minute Bodies Made by Magnifying Glasses. With Observations and Inquiries Thereupon / By R. Hooke. London: Printed by Jo. Martyn and Ja. Allestry, printers to the Royal Society, and are to be sold at their shop at the Bell in St. Paul's Churchyard, 1665. Print.

IGM (Instituto Geográfico Militar). (1908/25). Placilla Departamento de Valparaíso y Casablanca. Hoja XLII- 18° Edición. (Autor: Luis A. Vega). Estado Mayor general del Ejército de Chile. [Santiago de Chile], Talleres del instituto Geográfico Militar.

INE (Instituto Nacional de Estadísticas). (2017). Censo de Población y Vivienda 2017 (Censo2017.cl).

Klohn, C. (1975-1976). Beobachtungen über die Reste eines späteiszeitlichen Alerceswaldes. *Z. Naturfreunde Wanderer*, 75-78.

Kölbl-Ebert, M. (1999). Observing orogeny — Maria Graham's account of the earthquake in Chile in 1822. *EPISODES*, 1999, 36-40.

Leet, W.G. (1853). On the occurrence of metallic iron in fossil wood. *Journal of the Franklin Institute-Engineering and Applied Mathematics*, 1853, 62-64.

Lyell, C. (1830-33). Principles of Geology or, The Modern Changes of the Earth and its Inhabitants Considered as Illustrative of Geology. Three volumes. London. John Murray.

McKinnon, S. (2015). Rewriting the story of Arizona petrified forest. *The Republic* (May 30.2015).

Montero, A. and Diéguez, C. (1998). Datos para la paleontología chilena. La Paleontología en la Expedición Heuland a Chile y Perú (1795-1800). *Asclepio*, 50(1), 69-78.

Morton, N. (1995). In the footsteps of Darwin in South America. *Geology Today*, 11, 190-195.

Mustoe, G. (2023). Silicification of Wood: An Overview. *Minerals*, 13(2), 206.

Mustoe, G. and Acosta, M. (2016). Origin of Petrified Wood Color. *Geosciences*, 6(2), 25.

Nicol, W. (1834). Observations on the structure of recent and fossil Coniferae. *Edinburgh New Philosophical Journal*, 14, 137-158.

Nishida, M., Ohsawa, T., Nishida, H. and Rancussi, M. (1992). Permineralized coniferous woods from the XI Region of Chile, Central Patagonia. *Research Institute of Evolutionary Biology*, *Sci. Rep.*, 7, 47-59.

Otero, R.A., Pérez-Barría, L. y Rubilar-Rogers, D. (2023). Validación de *Ischyrhiza chilensis* Wetzel, 1930 (Rajiformes, Sclerorhynchoidei), un histórico pez cartilaginoso endémico del Cretácico Superior austral. *Boletín del Museo Nacional de Historia Natural*, *Chile,* 72(1), 35-53.

Ortiz, H. (2022). La colección Histórica de Paleontología del Museo Regional de Aysén y su vínculo con la identidad local. Bajo la Lupa, Subdirección de Investigación del Ministerio de las Culturas las Artes y el Patrimonio. 38 pp.

Otero, R. and Suárez, M. (2022). Ray-finned fishes (Actinopterygii) from the lower Maastrichtian of Algarrobo, central Chile. *Cretaceous Research*, 130, 105027.

Otero, R., Parham, S., Soto-Acuña, S., Jiménez-Huidobro, P. and Rubilar-Rogers, D. (2012). Marine reptiles from Late Cretaceous (early Maastrichtian) deposits in Algarrobo, central Chile. *Cretaceous Research*, 35, 124-132.

Pérez Barria, L., Ortiz, F, Vadés, C., and Araya, I. (2018). El material tipo de invertebradsos fósiles dado por R.A. Philippi: Museología, avances y desafíos en el Museo Nacional de Historia Natural (MNHN), Santiago. 1er Congreso de Paleontología en Chile, Punta Arenas. Actas, pp. 21-22.

Pérez-Barría, L. (2021). Evaluación de dos sitios con maderas fósiles en el área del Cerro Rosado, Región de Aysén. Informe para el Consejo de Monumentos Nacionales, AC. MURAY.01.2021: 13 pp.

Pérez-Barría, L., Cea, P., Avendaño, C., Soto, I., Guajardo, F., Saldivia, P. and Varela, J.P. (2022). Redescubriendo el "Bosque Fósil de Cerro Rosado" (Región de Aysén, Chile). 2do Congreso Chileno de Paleontología, San Vicente de Tagua-Tagua, p. 127.

Philippi, R. A. (1899). *Los fósiles secundarios de Chile.* Brockhaus, Leipzig, 104 pp.

Philippi, R. A. (1887). *Fósiles terciarios i cuartarios de Chile.* Brockhaus. Leipzig, 256 pp.

Philippi, R. A. (1877). *Elementos de Historia Natural*. Santiago. 398 pp.

Pissis, A. (1854). *Descripción de la Provincia de Valparaíso*. Anales de la Universidad de Chile.

Pissis, A. (1873). *Geografía Física de la República de Chile*. Instituto Geográfico de París. 536 pp.

Plinius. Book XXXVI. The Natural History, Ancient and Modern, of Precious Stones and gems, and of Precious Metals. *In:* Historia Naturalis. 37 vols.

Pohlmann, R. (1893). Noticias Petrográficas de Llanquihue. In: Viaje de estudio a la Región Andina. *Anales de la Universidad*, 84, 1247-1258.

Pöhlmann, R. and Reiche, K. (1900). Beiträge zur Kenntnis der Flora der Flussthäler Camarones und Vitor und ihres Zwischenlandes (19º s. Br.), in Verhandlungen der Deutschen Wissenschaftlichen Vereins zu Santiago de Chile, vol. IV, Valparaíso, 1900 pp. 263-305.

Price, M. (2008). *Rocas Ornamentales.* Blume. 283 pp.

Reiche, K. (1934). *Geografía botánica de Chile*. Imprenta Universitaria. 609 pp.

Risopatrón, L. (1924). *Diccionario Geográfico de Chile*. Imprenta Universitaria. 975 pp.

Roig, F.A., Le-Quesne, C., Boninsegna, J.A., Briffa, K.R., Lara, A., Grudd, H., Jones, P.D. and Villagrán. C. 2001. Climate variability 50,000 years ago in mid-latitude Chile as reconstructed from tree rings. *Nature*, 410(6828), 567-570.

Sagredo, R. (2007). De la historia natural a la historia nacional. La historia física y política de Claudio Gay y la nación chilena.*In* Historia física y política de Chile Claudio Gay Historia, Vol. VIII, Pp. IX-LVII.

Schweitzer, C. E., Feldmann, R. M., Encinas, A. and Suárez, M. (2009). New Cretaceous and Eocene Callianassoidea (Thalassinidea, Decapoda) from Algarrobo, Chile. *Journal of Crustacean Biology*, 26, 73-81.

Tapia, T., Moreno, K. and Brito, J. L. (2022). Playa Fósil de Algarrobo: Potencial Santuario de la Naturaleza. Libro Resúmenes II Congreso Paleontología Tagua Tagua, p. 126.

Tavera, J. (1980). *Cretáceo y Terciario de la localidad de Algarrobo*. Imprentas gráficas, 45 pp. Conchalí, Santiago.

Tessan, S. (1838). *Plano de la Bahía de Valparaíso levantado por el señor de Tessan, ingeniero hidrógrafo de la Marina francesa; gravé par Erhard*. Paris, Imprenta Chez Kaeppelin.

Thorson, R. (1999). *La Falla Geológica Marga Marga, Viña del Mar, Chile*. Universidad Técnica Federico Santa María.

Torres, T. (1983). Maderas fósiles, testigos del pasado. *Revista Creces*, 16-22.

Torres, T. and Rallo, M. (1981). Anatomía de Troncos fósiles del Cretácico superior de Pichasca en el Norte de Chile. *Anais II Congreso Latinoamericano de Paleontología, Porto Alegre, Brasil*, Tomo 2, 385-398.

Van Wyhe, J. (2011). The complete Work of Charles Darwin Online (http://darwin-online.org.uk/)

Verdejo, N. Ardiles, C., Pérez, L. and Araya, I. (2018). La colección de minerales R.A. Philippi (Siglo XIX) depositada en el Museo Nacional de Historia Natural, Santiago. XV Congreso Geológico Chileno, Concepción, Actas , p. 169.

Wall, R., Gana, P. and Gutiérrez, A. (1996). Mapa geológico del área de San Antonio-Melipilla. *Servicio Nacional de Geología y Minería, Mapas Geológicos*, 2, 19 p. Santiago.

Yury-Yáñez, R.E, Otero, R.A., Soto-Acuña, S., Suárez, M.E., Rubilar-Rogers, D. and Sallaberry, M. (2012). First bird remains from the Eocene of Algarrobo, central Chile. *Andean Geology*, 39, 548-557.

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