# Francisco Hervé, a pioneer in the study of the Chilean accretionary prism

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## Abstract

This paper presents a brief overview of the evolution of knowledge regarding the accretionary prism of the Chilean Pacific margin, with particular emphasis on the contributions of Francisco Hervé, who has been a leading figure for over fifty years in advancing our understanding of its formation processes. The early contributions of Félix González Bonorino and Luis Aguirre LeBert are highlighted in this story, as they brought about a profound shift in the interpretations of their time and, through their studies, paved the way for subsequent research. These studies were based on solid petrological foundations, complemented by geochemical and isotopic analysis that allowed the reconstruction of metamorphic characteristics along the Pacific margin. Fossil-bearing rocks, found in a few areas, not only established their age, but also the paleogeography and the environment of emplacement. In some cases, such as the fusulinid-bearing limestones of Madre de Dios, these fossils have revealed the complex late Paleozoic circum-Pacific paleogeography. Geochronological and other studies have allowed us to understand the evolution of these rocks over time. Complex trajectories of pressure and temperature conditions of the different sectors that led to their present-day exhumation were established. A key result of this research is the identification of the collision of an allochthonous island arc, the Chaitenia terrane, and the impact of this proposal on some local communities, such as the town of Chaitén in the Los Lagos Region. The local people have proudly embraced the findings of these studies. This community adoption of the geological explanation of the territory is one of the greatest honors a researcher can receive.

**Keywords:** History of knowledge, accretionary prism, metamorphic series, Chaitenia.

## Resumen

**Francisco Hervé, un pionero en el estudio del prisma de acreción de Chile.** Este artículo presenta una breve reseña de la evolución del conocimiento sobre el prisma de acreción del margen del Pacífico chileno, con especial énfasis en las contribuciones de Francisco Hervé, quien ha sido una figura destacada durante más de cincuenta años en el avance de nuestra comprensión de sus procesos de formación. Se destacan las primeras contribuciones de Félix González Bonorino y Luis Aguirre LeBert, quienes propiciaron un profundo cambio en las interpretaciones de su tiempo y, a través de sus estudios, allanaron el camino para investigaciones posteriores. Estos estudios se basaron en sólidos fundamentos petrológicos, complementados con análisis geoquímicos e isotópicos que permitieron la reconstrucción de las características metamórficas a lo largo del margen del Pacífico. Las rocas fosilíferas, halladas en algunas áreas, no solo establecieron su edad, sino también la paleogeografía y el entorno de emplazamiento. En algunos casos, como las calizas fusulínidas de Madre de Dios, estos fósiles han revelado la compleja paleogeografía circunpacífica del Paleozoico tardío. Estudios geocronológicos y de otro tipo nos han permitido comprender la evolución de estas rocas a lo largo del tiempo. Se establecieron trayectorias complejas de las condiciones de presión y temperatura de los diferentes sectores que llevaron a su exhumación actual. Un resultado clave de esta investigación es la identificación de la colisión de un arco de islas alóctono, el terreno de Chaitenia, y el impacto de esta propuesta en algunas comunidades locales, como la ciudad de Chaitén en la Región de Los Lagos. La población local ha acogido con orgullo los hallazgos de estos estudios. Esta adopción comunitaria de la explicación geológica del territorio es uno de los mayores honores que puede recibir un investigador.

**Palabras clave:** Historia del conocimiento, prisma de acreción, series metamórficas, Chaitenia.

## Introduction

This contribution aims to pay a modest tribute to Francisco Hervé, who has investigated the Chilean accretionary prism for over 50 years. His studies on the Pacific continental margin of Chile have made him an international authority on these geological environments. His biographical account is widely known and distinguished by the numerous awards he has received, so I will focus solely on his contributions to this field.

My opinion is based on nearly 60 years of knowing him, first through his scientific contributions, then through his excellent presentations at regional and international congresses and symposia. We both graduated as geologists in 1965, and despite our different geological orientations, our research has continually crossed paths. We have shared diverse evidence, mutually enriching each other with our experiences, discussions, and exchange of ideas. Last but not least, I am grateful for having shared countless hours of exchange, both academic and personal, in Chile, Argentina, and other parts of the world. With Prof. Hervé, I have participated in long days of fieldwork, voyages in the southern seas, and numerous enjoyable meetings. I have attended the Chilean Geological Congresses, just as he has attended the Argentine ones, which has allowed me to witness firsthand the impact and respect his presentations have garnered, both from his colleagues on both sides of the Andes and from the students.

**A bit of history from the protagonists**

The presence of metamorphic rocks along the Pacific continental margin was known from the early 20$^{th}$ century. Horacio Harrington (1910-1973), in his studies of the Antofagasta and Atacama provinces between 22° and 26°S, considered the Limón Verde rocks and other metamorphic complexes in Chile to be Precambrian (Harrington, 1961). In his excellent paleogeographic reconstruction of South America, he extended this Precambrian assignment to the metamorphic complexes of southern Chile, following the prevailing opinion of the time (Harrington, 1962). A similar criterion was adopted in Carlos Ruiz Fuller's (1916-1997) synthesis of the regional geology and deposits of Chile, where, in the chapter on the "Crystalline Basement," Luis Aguirre LeBert (1931-2025) continued to assign these metamorphic rocks to the Precambrian (see Ruiz, 1965).

This undeniable Precambrian age was based, according to the arguments recounted by Francisco Hervé, on *"the fact that in the Lake Lleu Lleu region, there were iron-bearing schists, similar to the itabirites of Brazil, which were undoubtedly of Precambrian age, since at that time oxidizing conditions in the Earth's atmosphere would have been generated for the first time, inducing the precipitation of Fe dissolved in the water of the planet's oceans, generating this type of rock on a global scale. A second argument used at that time… was that in some locations in Chile there were Paleozoic fossiliferous*

*sedimentary rocks whose metamorphic grade was lower than that of the greenschist facies exhibited by the Metamorphic Basement. Lacking other arguments, it was considered that the higher degree of metamorphism was an indicator of a greater age. Using this criterion, Professor Henning Illies, of the Austral University of Valdivia, published, in 1960, a work in which, grouping the basement outcrops under the name of Piedra Laja Formation, he assigned them a higher Algonquian age*" (Hervé in Ramos, 2023).

This concept began to change with the arrival of Félix González Bonorino (1918-1988), who went into exile in Santiago at the end of 1966 after the *"La Noche de los bastones largos"*[1] at the University of Buenos Aires. Dr. Aguirre LeBert recounts the events firsthand: "At the end of July of that year, I received a phone call from Dean Enrique d'Etigny requesting information about Dr. Félix González Bonorino, who had just contacted him from Argentina to inquire about the possibility of being accepted at the University of Chile. I immediately informed the Dean that this was none other than the then-Director of the Department of Geological Sciences at the University of Buenos Aires and possibly **the most talented Latin American geologist of that time**. In my opinion, aside from the ethical obligation involved, it was an opportunity for us to incorporate such a brilliant scientist into our Department. I expressed this to the Dean in that conversation, and he immediately contacted Dr. Bonorino to inform him of the agreement regarding his arrival…. *Bonorino, with his encyclopedic knowledge and extensive experience in mineralogical and structural problems related to the development of metamorphic complexes, was key to the study of our exposed basement in the coastal region of central and southern Chile. This was also my main research topic, and together we were able to make significant progress in understanding this geological unit, resulting in international publications"* (Aguirre LeBert, *pers. comm*., 2022) (Fig. 1).

[1] "Night of the long canes". It refers to the batons used by the police to repress teachers and students.

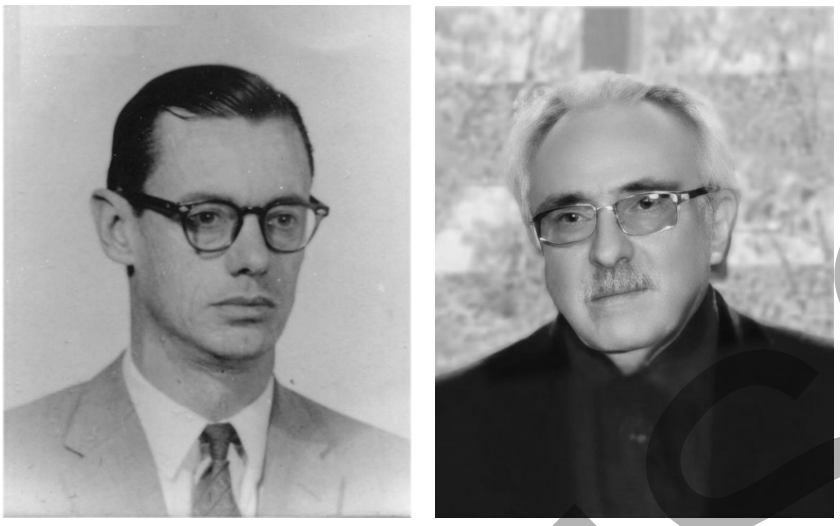

**Fig. 1**. Félix González Bonorino and Luis Aguirre LeBert, two promoters of the study of metamorphic rocks in Chile in the early 1970s.

Francisco Hervé also shared his memories of the new professor: *"Don Félix, as he is remembered in our country, brought about a tremendous shift in geological understanding of the so-called Metamorphic Basement of Central Chile. Knowledge of this unit was astonishingly limited at that time. Drawn to this, Don Félix decided, with the support of Don Luis Aguirre LeBert, to undertake a more systematic study of it. Don Félix probably began his work on the basement of the Coastal Range of Central Chile in 1966, and after published several contributions. I imagine him setting off into the field in some rickety jeep from the Department and that he began with an impressive discovery: in the first outcrop he visited, near Tranque Alcones, on the old road from San Fernando to Pichilemu, he found gneisses with garnet and sillimanite. This last mineral, to my knowledge, had not been identified in the country. And he identified it macroscopically in some exceptional rocks... After exploring the extensive unit from Tanumé (34°S Lat.) to Chiloé (42°S Lat.), he presented his results in his 1970 work. He described three different metamorphic series in the basement: the Curepto Series, the Pichilemu Series, and the Nirivilo Series, a concept that, with minor modifications, has continued to this day. The initial series was created by his iconoclastic disciple, Don Estanislao Godoy, who reorganized them, naming them the Eastern Series and the Western Series, which is how they are known today. Meanwhile, Don Fernando Munizaga had obtained, in the laboratory of the Institute of Geological Research (predecessor of the current SERNAGEOMIN), an Rb-Sr isochron indicating an age of 342 Ma, which Don Félix*

*interpreted as the sedimentation age of the protolith of the Basement schists. With considerable and wise reservations, he interpreted his series as possible equivalents of the paired metamorphic belts that Miyashiro, in 1961, had suggested developed along the Pacific margins during orogenic processes, emphasizing that these were Paleozoic, unlike the better-known ones in Japan, which were Mesozoic. Today there is a certain consensus in interpreting the basement of the Coastal Range of Central Chile as having been generated under these geological conditions, which the genius of Don Félix put at the disposal of the geological community"* (Hervé in Ramos, 2023).

Estanislao Godoy Pirzio-Biroli recounted in first person how the study of the metamorphic basement of the Coastal Range began in late 1966: *"I was fortunate enough to be offered the position of field assistant to "Don Félix" by the director of the Geology Department at the University of Chile, Luis Aguirre. I began with a long hike north of Pichilemu, the area where he started his study of the Metamorphic Basement of Central Chile. The gatekeeper of the Fundo Tanume was adamant about not letting our vehicle through, so we had to walk. On the coast, adorned by an Egyptian-style mansion, we were greeted by spectacular outcrops of metaturbidites bearing staurolite and chiastolite mega-porphyroblasts. A magnificent introduction for someone whose background in metamorphic rocks was based solely on isolated mining surveys. As a teaching assistant, I had the opportunity to use his field notebooks to assemble a collection of transparent sections of the basement rock of Central Chile (now lost). Imagine my astonishment when, at his very first sampling point, he recognized the sillimanite-cordierite-K-feldspar association, the highest grade of his emerging metamorphic facies zoning. Starting almost from scratch, from the very first day in the field, he began constructing the isograds of his Pichilemu Series. The year after the hike to Tanume, I accompanied him to the Cordillera de Nahuelbuta, south of Concepción. There, too, high-grade associations crop out, but now the cordierite crystallizes in the form of white nodules. Once again, the master's eye recognized a metamorphic mineral habit still unknown in the country. Don Félix did not manage to apply the accretionary prism models in his detailed mapping of the basement rock of Central Chile. The rigor of his study, however, allowed for rapid progress towards the current state of knowledge"* (Estanislao Godoy in Ramos, 2023).

During those years, the first metamorphic dates were published by Francisco Munizaga (1945-2020) (Munizaga, 1967; González Bonorino, 1967). These Rb-Sr dates, along with their analytical data and implications, were later presented in Munizaga *et al*. (1973).

Concerning the characterization of metamorphic facies, two works were important during those years: one on the *Metamorphic facies series of the crystalline basement of Chile*, published in *Geologische Rundschau*, and another on the *Metamorphism of the crystalline basement of Central Chile*, which appeared in Journal of Petrology. Both had a strong impact on understanding the metamorphism of the Coastal Range (González Bonorino and Aguirre, 1970; González Bonorino, 1971). These works examine the relationship of these metamorphic series with the paired circum-Pacific arcs of Miyashiro (1961) and the role of this basement during the Andean orogeny.

**The discovery of glaucophane schists**

*"One summer morning in 1970, a young researcher from the Geology Department at the University of Chile, Estanislao Godoy Pirzio-Biroli, received a couple of sections from the transparent section workshop, leftover material from his already printed thesis. In it, he had included an appendix on the surroundings of the Pichilemu Granite, which proposed modifications to González-Bonorino's isograd lines in the Pichilemu Series. One of the samples was a medium-grained, light green metabasite that, instead of confirming a staurolite isograd line, contained nuclei of a violet pleochroic mineral embedded in actinolite.* ***'Could this be the much sought-after blue amphibole, indicative of high-pressure metamorphism?'*** *Pirzio wondered and went to the Director's office (Lucho Aguirre). Aguirre was in a meeting with Félix and Beatriz Levi, but with Beatriz's enthusiastic support, they quickly went to examine the section:* ***Confirmed****, after the suspicious reference in Tierra del Fuego (discarded by M. de Wital when reviewing Kranck's collection) we had the first glaucophane from the southern cone* (Estanislao Godoy, *pers com*., 2025) (Fig. 2).

**Fig. 2**. Estanislao Godoy and Francisco Munizaga, two important participants in the studies of the Chilean accretionary prism.

The presence was briefly reported in a later synthesis paper (Aguirre LeBert *et al*., 1972). The find was made at the now-destroyed site of El Molino. The schists were dated by Francisco Munizaga and studied in detail with Francisco Hervé (Hervé *et al*., 1974). In this work, the authors conclude that this blueschist facies represents high-pressure, low-temperature conditions unique to deformation belts in subduction zones. Based on this, they interpreted the glaucophane schists as the first identified in the late Paleozoic subduction zone along the western margin of South America.

Stimulated by recent descriptions of metamorphic series, Gary Ernst described the presence of blueschists in southern Chile (Ernst, 1973). He decided to visit the region, and Francisco Hervé took him to examine the Coastal Range complexes from the central region to Chiloé. He was pleasantly surprised by the Pichilemu belt, where he agreed with the designation of a Western and an Eastern Series and interpreted the contact between them as a suture (see a complete history of Pichilemu in Hervé *et al*., 2018a). Gary Ernst sent a student, Terence Kato, to pursue his doctorate in Pichilemu; his subsequent contributions, partly in collaboration with Estanislao Godoy, have been significant (Kato, 1985; Kato and Godoy, 1995, 2015; Kato *et al*., 2008).

In turn, years later, Hervé and Godoy extended the presence of blue schists to the accretionary prism of Smith Island in the Antarctic Peninsula (Hervé *et al*., 1982).

**Fossils that dated the accretionary prism**

Independent of absolute dating efforts, fossil evidence contained in the low-grade metamorphic rocks of the accretionary prism complemented the determination of its age. One of the first discoveries was made by Beatriz Levi (1930-2022), who rediscovered Devonian trilobites in the Buill Shales, confirming the earlier finding by Walter Biese (1885-1960). Years later, in 1988, Francisco Hervé and Robert Pankhurst found trilobites again in the same area, which, when studied by Richard Fortey, confirmed an Early to Middle Devonian age (Biese, 1953; Levi *et al*., 1966; Fortey *et al*., 1992).

These findings can be correlated, based on their age, with those reported from the Chonos Archipelago, where Devonian brachiopods were found on Potranca Island (Miller and Sprechman, 1978). However, it should be noted that Arthur J. Boucot (1924-2017), in his study of the Devonian brachiopods of Chile, questioned these assignments (Boucot *et al.*, 1995).

Further south, on Madre de Dios Island, there are abundant carbonate rocks bearing fusulinids. Giovanni Cecioni recounts the discovery made in November 1953 and his attempt to establish the stratigraphy. He described several layers of fusulinids above basaltic rocks in various areas and the presence of varves on Contreras and Ramírez Islands (Cecioni, 1956). This association of warm-water fusulinids with varves and breccias concerned him, although he rejected Heinrich Gerth's proposal, which attempted to explain them through a warm current reaching high latitudes. He analyzed the possibility of rapid climate change but found no reasonable hypothesis to explain this unusual association in a region relatively close to the Gondwanan pole (Cecioni, 1970).

Randall Forsythe and Constantino Mpodozis, through meticulous fieldwork, characterized the association of oceanic basalts, chert layers, and fusulinid limestones with a macro-melange resulting from their accretion to the late Paleozoic subduction complex. In their model, the limestones were deposited on shallow guyots (off-ridge seamounts) in the ancient Pacific Ocean and were subsequently transported and obducted (scraped off) within the accretionary prism. The deformation structure allowed them to infer an origin from the southwest (Forsythe and Mpodozis, 1979, 1983; Mpodozis and Forsythe, 1983).

At the *International Symposium on the Carboniferous and Permian Systems* in South America, held in São Paulo in 1972, Raymond Douglas and Jim Helwig presented two important facts. The first was that the systematic study of the fusulinids from Madre de

Dios (Douglass and Nestell, 1972) indicated a strong correlation with those found in Bolivia's Copacabana Formation, a correlation confirmed by subsequent detailed studies (Douglass and Nestell, 1976). The second was based on research by Jim Helwig, who conducted an exhaustive study of the tropical sedimentation conditions of the Copacabana Formation in Bolivia and its relationship to glacial deposits in the Argentine basins. Furthermore, he proposed the first hypothesis of how these tropical limestones, deposited in surface waters, could have been incorporated into the accretionary prism of southern Chile, dominated by a glacial environment (Helwig, 1972a, b) (Fig. 3).

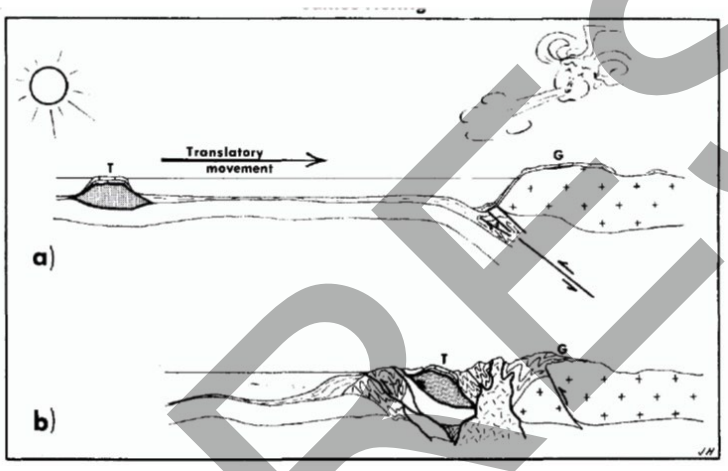


**Fig. 3.** Copacabana Limestones (T) from a tropical environment and deposited on guyots are transported to a subduction zone where a glacial environment predominates (G), culminating in the collision and incorporation into the accretionary prism (from Helwig, 1972a, b).

It is noteworthy that Helwig's hypothesis was formulated without any prior experience in Madre de Dios, solely to explain the interrelationship between sediments from low-latitude tropical environments and glacial deposits at latitudes above 50°S. In his work, he emphasizes that from Bolivia southward, sedimentation is dominated by deposits corresponding to the Gondwana glaciation, with no carbonate sedimentation recorded in the late Paleozoic basins (Helwig, 1972a, b). Confirming these observations, paleomagnetic studies indicated that the fusulinid-bearing limestones originated from the north (Rapalini *et al*., 2001) (Fig. 4).

**Fig. 4**. Augusto Rapalini, Francisco Hervé and the author in the Madre de Dios region during the paleomagnetic studies that we conducted in 1997.

John Bradshaw's studies made it possible to reconstruct the Gondwana forearc region, which showed various places where oceanic crust had accreted with limestones from Chile to New Zealand (Bradshaw *et al*., 1981) (Fig. 5).

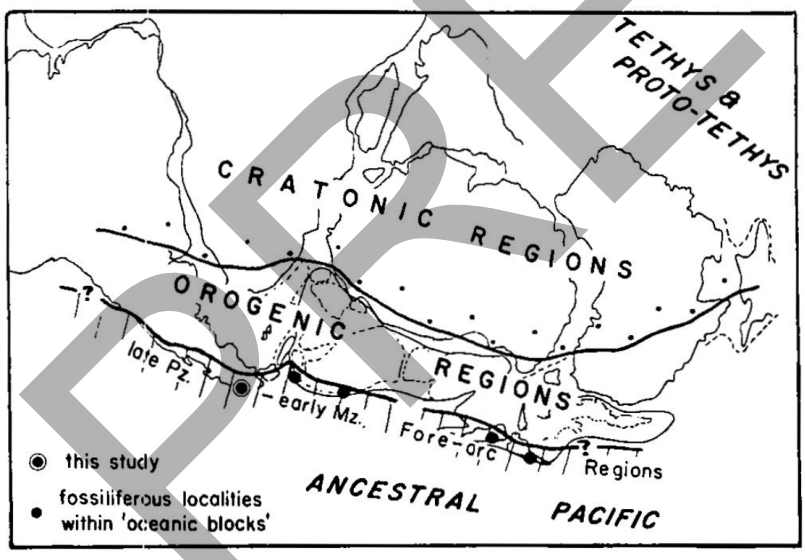


**Fig. 5.** Reconstruction of the ancestral Pacific margin of Gondwana by the end of the Paleozoic, indicating the sectors where the occurrence of fusulinid limestones was found in the accretionary prisms from Chile to New Zealand (from Bradshaw *et al*., 1981).

On the South Island of New Zealand, the Torlesse terrane developed along the late Paleozoic accretionary prism, which was subsequently disrupted by strike-slip along the Southern Alpine Fault, resulting in a complex structure today (see MacKinnon, 1983). In this terrane, as well as in Auckland Bay on North Island, late Paleozoic fusulinid-bearing limestone blocks are known, along with exotic oceanic basalts that have also been interpreted as accreted to the subduction complex (Bradshaw *et al*., 1981).

Furthermore, studies conducted by Ling *et al*. (1985) in Madre de Dios identified late Paleozoic radiolarians with strong affinities to those of the forearc accreted terrane in various areas of Japan. These exotic fusulinid-bearing blocks have allowed the recognition of a complex paleogeography for the forearc and reconstruction of the accretion history in this sector of the circum-Pacific (Ozawa and Kanmera, 1984).

Another interesting experience was the fieldtrip I made in British Columbia, Canada, conducted with James (Jim) Monger. There, in addition to familiarizing myself with the allochthonous terrains identified on the Pacific margin, we examined the fusulinid-bearing limestones of the Cache Creek terrane (see Monger and Price, 2002). It was a surprise to find graffiti on these limestones with the inscription "made in Japan". This sparked a long discussion with Jim Monger, who explained that these fusulinid-bearing limestones were different from those found further east in the rest of North America and that they might have come from Japan (Monger and Ross, 1971). I tried to convince him that a more likely origin was from the south, from a location at the latitude of Bolivia between 10° and 20° S, deposited on oceanic guyots, following Jim Helwig's hypothesis. He finally acknowledged that the paleomagnetic studies of Ted Irving (1927-2014) of the Canadian Geological Survey indicated that the Vancouver terranes came from between one thousand and/or five thousand kilometers to the south, depending on whether they originated in the Northern or Southern Hemisphere (Irving and Yole, 1987) (Fig. 6).

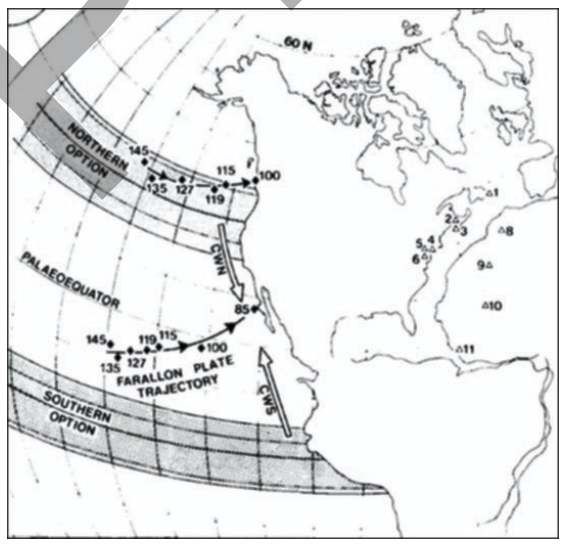


**Fig. 6.** Latitudinal translation obtained for the Vancouver region, where two alternatives are proposed. A nearby origin in the northern hemisphere with a displacement of one thousand kilometers, or from the southern hemisphere opposite Bolivia and Peru, which would indicate more than 5,000 km, consistent with a provenance from the Copacabana Formation (from Irving and Yole, 1987).

Although Irving's paleomagnetic study was not conducted on rocks from the Cache Creek terrane, it provided insight into the mobility of the westernmost allochthonous terranes of British Columbia. Advances in knowledge in recent years have shown that within the circum-Pacific region, there may have been a dispersal centre in the ancestral Pacific Ocean at paleolatitudes similar to those of Bolivia. This could have been an aseismic mid-ocean ridge originating from a hotspot and formed by guyots. This scattering centre could be the source of the numerous blocks that were accreted in Chile and New Zealand, as well as in Japan and Canada. Their fusulinids would have affinities with those of the Copacabana Formation of Bolivia and would be distinct from those from the Tethys.

Francisco Hervé, based on the fossil evidence associated with the Pacific accretionary prism from Potranca Island to Madre de Dios, proposed that it grew southwards (Hervé, 1988).

**Other alternative interpretations**

With the arrival of Hubert Miller (1936-2020) in Chile, there began a series of studies on the microtectonics of the metamorphic rocks of the Chilean margin (Miller, 1970). His detailed studies, in addition to the discovery of Devonian brachiopods of Isla Potranca, allowed him to postulate the existence of at least three orogenic cycles superimposed on the accretionary prism (Miller, 1976, 1979a, b). He analyzed the structural characteristics of the different units, recognizing different orientations and assuming an older unit possibly deposited during the Cambro-Ordovician with pre-Devonian deformation. Despite the superimposition of Variscan deformation, he was able to recognize this older deformation, based on the orientation of the structural elements (Miller, 1973). The brachiopod-bearing unit would have been deformed by the Variscan orogeny of Carboniferous age, and the dominant complex structure would have been finally produced at the end of the Paleozoic (Miller, 1976).

This criterion was widely discussed at the *Colloquium on Age Problems and Structural Relationships in Pre-Andean Orogens of Argentina and Chile*, organized by Hubert Miller and sponsored by the University of Buenos Aires and the Goethe Institute in Buenos Aires in 1979. At that meeting, the use of structural orientation to define the age of a deformation cycle was questioned, but no consensus was reached (Ramos, 1980).

In one of his last syntheses on the Paleozoic of South America, Hubert Miller reiterated this point, and proposed again that the orogenic cycles of Argentina and Chile developed successively from the Brazilian Shield. Thus, they began in the Cambrian and extended southwestwards, with each deformation superimposed on the previous one, the most intense being those of the Gondwanides in southern Chile. While acknowledging the lack of fossils and dates for the oldest orogenies, his analysis was based on the different structural trends he could identify with specific orientations for each cycle (see figure 4 in Miller, 1984).

These superimposed orogenies have fallen into disuse due to a lack of evidence, given that new studies have shown their development to be accretionary.

**Towards current knowledge**

It is important to highlight that from the beginning, Francisco Hervé focused his efforts on the study of metamorphic rocks. He first investigated the metamorphic rocks of the Massif Central in France for his doctoral thesis. Upon his return to Chile, the focus was the metamorphism of the rocks cropping out in the Coastal Range and its Pacific margin, which in turn was the subject of his second thesis in Japan. During those years, there was hardly any study of these metamorphic rocks that he did not lead, participate in, or promote.

During the following decades, the metamorphic rocks of the Coastal Range basement were interpreted as having been generated at a subduction margin. The metamorphic associations were simplified into two series with their own characteristics, partly following the original proposal of Félix González Bonorino (Aguirre LeBert *et al*., 1972). A Western Series that is now interpreted as the basal accretion part in an accretionary prism, and the Eastern Series as the frontal accretion part.

Francisco Hervé participated in the first petrographic studies of the blueschists discovered by Estanislao Godoy (Aguirre LeBert *et al*., 1972) and in the first geochronological dating of these rocks with Francisco Munizaga (Munizaga *et al*., 1973; Hervé *et al*., 1974). Through numerous research projects and the supervision of undergraduate and doctoral theses, he advanced the understanding of the metamorphic processes. The frequent occurrence of metabasites and their geochemical characteristics led

him to interpret them as remnants of oceanic crust (Hervé, 1977; Godoy, 1979, 1980, 1986; Godoy *et al*., 1984), with characteristics similar to the current ocean floor.

Among his contributions, his first synthesis of these metamorphic rocks stands out, published in Episodes in 1988, the official journal of the International Union of Geological Sciences (IUGS). This work on *Late Paleozoic Subduction and Accretion in Southern Chile*, in addition to having a high impact, promoted his international recognition as a leading authority in these geological environments (Fig. 7).

**Fig. 7**. Francisco Hervé in 1988.

During those years, numerous investigations reinforced the late Paleozoic age of these rocks through various geochronological analyses, beginning with Rb-Sr and K-Ar determinations, and continuing to the present U-Pb and Lu-Hf zircon studies. These studies have allowed the differentiation of the age of the two metamorphic series and the latitudinal variations from Santiago to Tierra del Fuego.

Petrological studies identified the protoliths of these metamorphic rocks, revealing a predominance of oceanic rocks. They ranged from turbidites with chert layers and remnants of oceanic crust in the Western Series, to terrigenous sequences associated with volcanic rocks and plutonic clasts derived from the magmatic arc and surrounding massifs in the Eastern Series (Hervé, 2000). These investigations were combined with studies of pressure and temperature conditions, which permitted the establishment of the typical P-T-t paths that characterized the different metamorphic complexes. These studies, in which Arne

Willner and other leading specialists participated, established the trajectories and characteristics of the metamorphic sequences of southern Chile (Willner *et al*., 2000, 2004) (Fig. 8).

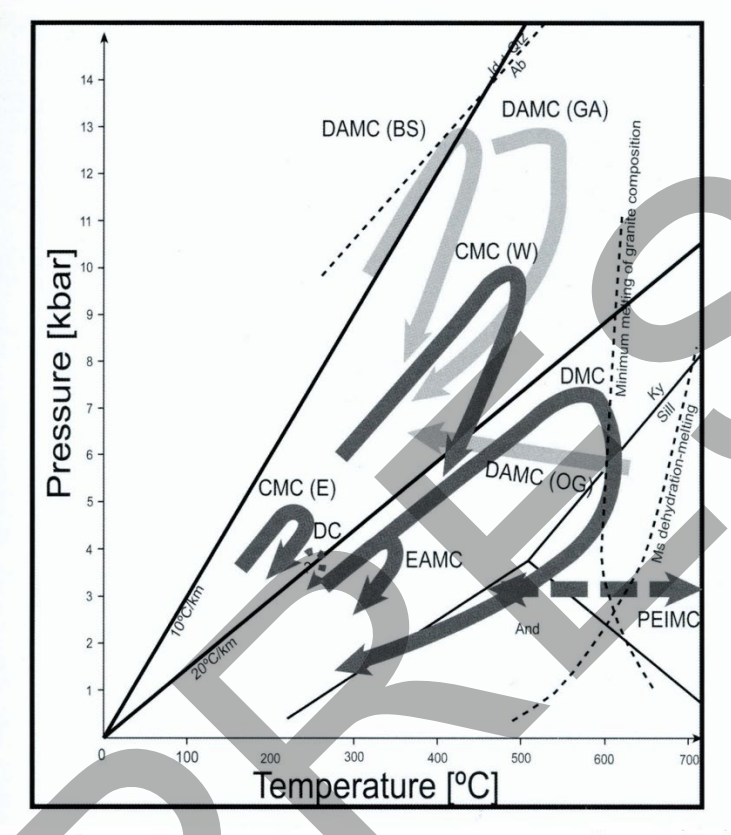


**Fig. 8.** Synthesis of the different P-T pathways of the metamorphic rocks of southern Chile based on different authors (see Hervé *et al*., 2007). The different metamorphic complexes are identified as Diego de Almagro: DAMC; Chonos: CMC; Denaro: DC; Darwin Range: DMC; Eastern Andes: EAMC; and Puerto Eden Igneous: PEIMC.

These studies also encompassed the evolution and exhumation history of the late Paleozoic metamorphic pairs in the central belt of Chile, further north (Hervé, 2005; Hervé *et al*., 2007). Although we have focused on the metamorphic belts of southern Chile, his studies have been broader, covering the plutonic rocks of this sector and contributions from the rest of the country, including important areas of Argentina and Antarctica.

**Chaitenia, an allochthonous terrane in southern Chile**

The research conducted to identify the Chaitenia terrane deserves special mention, not only for its scientific implications but also for its impact on the local community. A

series of petrological and geochronological studies carried out with colleagues such as Carlos Rapela, Robert Pankhurst, Mark Fanning, and Mauricio Calderón, among others, on the accretionary prism and associated granitoids in the Chaitén region, led to the proposal of an allochthonous terrane, formed by an oceanic island arc that was incorporated into the Pacific margin after the Devonian (Hervé *et al*., 2018b).

Their previous work had demonstrated that Devonian magmatism in the Southern Andes occurred in two contemporaneous belts: one emplaced in the continental crust of Patagonia and the other, to the west, in an oceanic island arc that later accreted to the Pacific margin of Gondwana. The country rocks of these arc granitoids consist of metasedimentary complexes and metabasalts where marked pillow structures are preserved. U-Pb ages of detrital zircons in these rocks mainly fall in the range 370 to 900 Ma and ca. 1200 Ma, suggesting typical Gondwana sources and Devonian sedimentation similar to that of the fossiliferous shales at Buill. The deeper crust is not exposed, but outcrops of ultramafic rocks are known (Fig. 9).

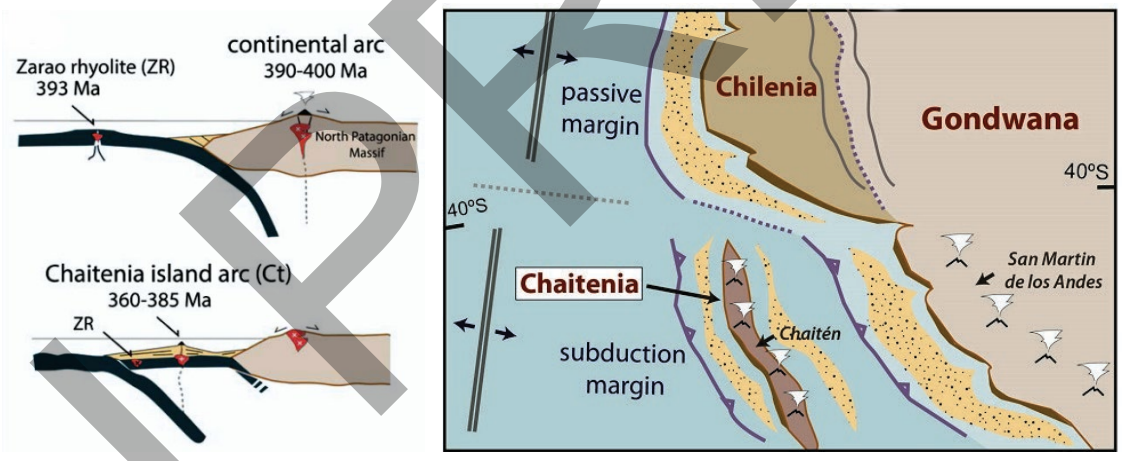


**Fig. 9**. Scheme of evolution and accretion of the Chaitenia terrane (Hervé, 2018b), and its paleogeography for the Devonian (Hervé, 2022).

The news of the discovery was presented at international and regional conferences, generating significant impact and strong acceptance within the geological community. However, it is worth noting that the greatest impact has been felt in the town of Chaitén, a community of ~4,000 inhabitants in Los Lagos Region of southern Chile. The first news its residents received, through national newspapers, digital platforms, and academic bulletins, was that an international team led by Francisco Hervé had discovered that the town was

part of an allochthonous microcontinent. This block, formed by a chain of volcanic islands, collided with Gondwana approximately 380 million years ago. The townspeople quickly sprang into action, mobilized by the school teacher Luis Soto. They erected a monument at the town's entrance commemorating the discovery and published the book "Chaitenia" by Hervé and Soto, which explains the geological evolution of the region in language accessible to children and young people (Fig. 10).



**Fig. 10.** The 'fathers of Chaitenia', Carlos Rapela, Francisco Hervé, Robert Pankhurst, and Mauricio Calderón, in front of the monument commemorating the collision. Cover of the book "Chaitenia" by Francisco Hervé and Luis Soto, which was published locally to explain the geology of the territory.

**Some awards received**

Over the years, Francisco Hervé has received numerous awards and recognitions, among which I would like to highlight those bestowed by my country (Argentina). In 1992, the Argentine Geological Association appointed him a Corresponding Member for his significant contributions to the understanding of the Pacific accretionary prism, the age of its metamorphic rocks on both sides of the Andes, and their Antarctic correlations. In 2012, the National Academy of Sciences in Córdoba appointed him a Corresponding Academician based on the results of his studies of the Paleozoic metamorphic and igneous complexes of Chile and his comparison of the tectonic evolution of Patagonia with the Antarctic Peninsula. Just a few years ago, in 2022, the National Academy of Exact, Physical, and Natural Sciences, based in Buenos Aires, also appointed him a Corresponding Member for his extensive career and contributions to the geology of southern South America, particularly the Patagonian Andes and their relationship with West Antarctica.

This is just a small example of the recognition received from his colleagues across the Andes for the impact and contributions made by Francisco Hervé, both in Chile and in various sectors of Argentina.

To these recognitions, I would like to add him being one of the first South American geologists to be recognized as an *Honorary Member* of the *Geological Society of America* and the *Geological Society of London* and having received the highest award from the *Deutsche Geologische Gesellschaft*, the *Leopold von Buch Plakette*, of Germany, among many other regional and local awards. He has recently been appointed Professor Emeritus by the University of Chile.

**Final considerations**

Looking back on Francisco Hervé's career, one can only admire his perseverance and diligence, both in his fieldwork on the frigid islands of the Patagonian Archipelago, in the Lake District, in the Fuegian channels, and in the icy Antarctic mountains, where he dedicated his efforts, knowledge, and wisdom to unraveling their mysteries.

In this brief overview, we cannot do justice to his more than 500 scientific publications disseminated in the best journals in his field, in books, and in conference proceedings, which are widely known. Suffice it to say that his scientific contributions have made him one of Chile's most prominent geologists. He is currently a global authority on the metamorphic processes of the accretionary prisms, a position that has grown over the years with his continuous contributions on the age and Paleozoic metamorphism of Chile's extensive Pacific margin.

As he himself points out, when recalling one of his mentors, Dr. Félix González Bonorino, saying, *"such a great influence for a relatively short presence in the country* (Chile) *is quite special. One of his last comments before leaving was – referring to the metamorphic basement – "…there is still much to be done here…". I have dedicated my academic life trying to do it"* (Francisco Hervé, pers. comm., 2022).

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