Latin American Journal of Sedimentology and Basin Analysis

ISSN 1851-4979
Published by the Asociación Argentina de Sedimentología

An overview of the Late Triassic–Pleistocene magmatism in the Golfo San Jorge Basin

César Rodrigo Navarrete

Received date: 15-10-2024
Accepted date: 09-12-2024
Available online: 27-03-2025

Handling Editor: José M. Paredes

Please cite this article as

Navarrete C. R. (in press). An overview of the Late Triassic–Pleistocene magmatism in the Golfo San Jorge Basin. Latin American Journal of Sedimentology and Basin Analysis.

Navarrete, in press. Latin American Journal of Sedimentology and Basin Analysis

An overview of the Late Triassic–Pleistocene magmatism in the Golfo San Jorge Basin

Navarrete C. R. [1, 2*]

1 – Laboratorio Patagónico de Petro-Tectónica. Universidad Nacional de la Patagonia San Juan Bosco. Comodoro Rivadavia, Chubut, Argentina.

2 – Instituto Multidisciplinario para la Investigación y el Desarrollo Productivo y Social de la Cuenca Golfo San Jorge (IIDEPyS; Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET)–Universidad Nacional de la Patagonia San Juan Bosco). Comodoro Rivadavia, Chubut, Argentina.

**Corresponding author*: cesarnavarrete@live.com.ar

ABSTRACT

The Patagonian Late Triassic–Pleistocene magmatic history encompasses multiple intraplate and subduction–related events associated with diverse geodynamic settings. Key episodes include the Late Triassic and Late Cretaceous–Paleocene flat slabs, the Cenozoic subduction of two mid-ocean ridges, slab break-off and tearing events during the Jurassic, Cretaceous–Paleocene, and Late Miocene–Pleistocene, as well as the influence of the mantle transition zone from the latest Eocene to the Middle Miocene. These processes collectively triggered significant magmatic episodes across the region. This overview highlights the main features of these magmatic events, their associated geodynamic contexts, and the proposed petrogenetic models, focusing on the central Patagonian region, including the Golfo San Jorge Basin and its surrounding areas.

Keywords: Central Patagonia, Golfo San Jorge Basin, magmatism

INTRODUCTION

The central Patagonian region, including the hydrocarbon-rich Golfo San Jorge Basin, has experienced numerous magmatic events from the Paleozoic to the Pleistocene. Abrupt changes in geodynamic conditions and large-scale tectonic processes have triggered magmatism in this region, directly or indirectly related to subduction dynamics. Notably, this region has been affected by two flat subduction events, slab break-offs and tearing, the subduction of two mid-ocean ridges, the interaction between the subducted slab and the mantle transition zone, and possible collisional events. These processes have rendered the region a natural laboratory for studying arc-related and intraplate magmatism.

Nevertheless, none of these Paleozoic to Pleistocene events were confined exclusively to central Patagonia. Much of the magmatic activity recorded in this area has affected most of Patagonia and, at times, much of southwestern Gondwana, as illustrated in Figure 1. This overview outlines the general characteristics of each magmatic event recorded in central Patagonia and their respective geodynamic contexts from the Late Triassic to the Pleistocene. Several of these episodes coincide with the development of the Golfo San Jorge Basin, which includes the Río Mayo sub-basin in its western sector, while others occurred at different geological times.

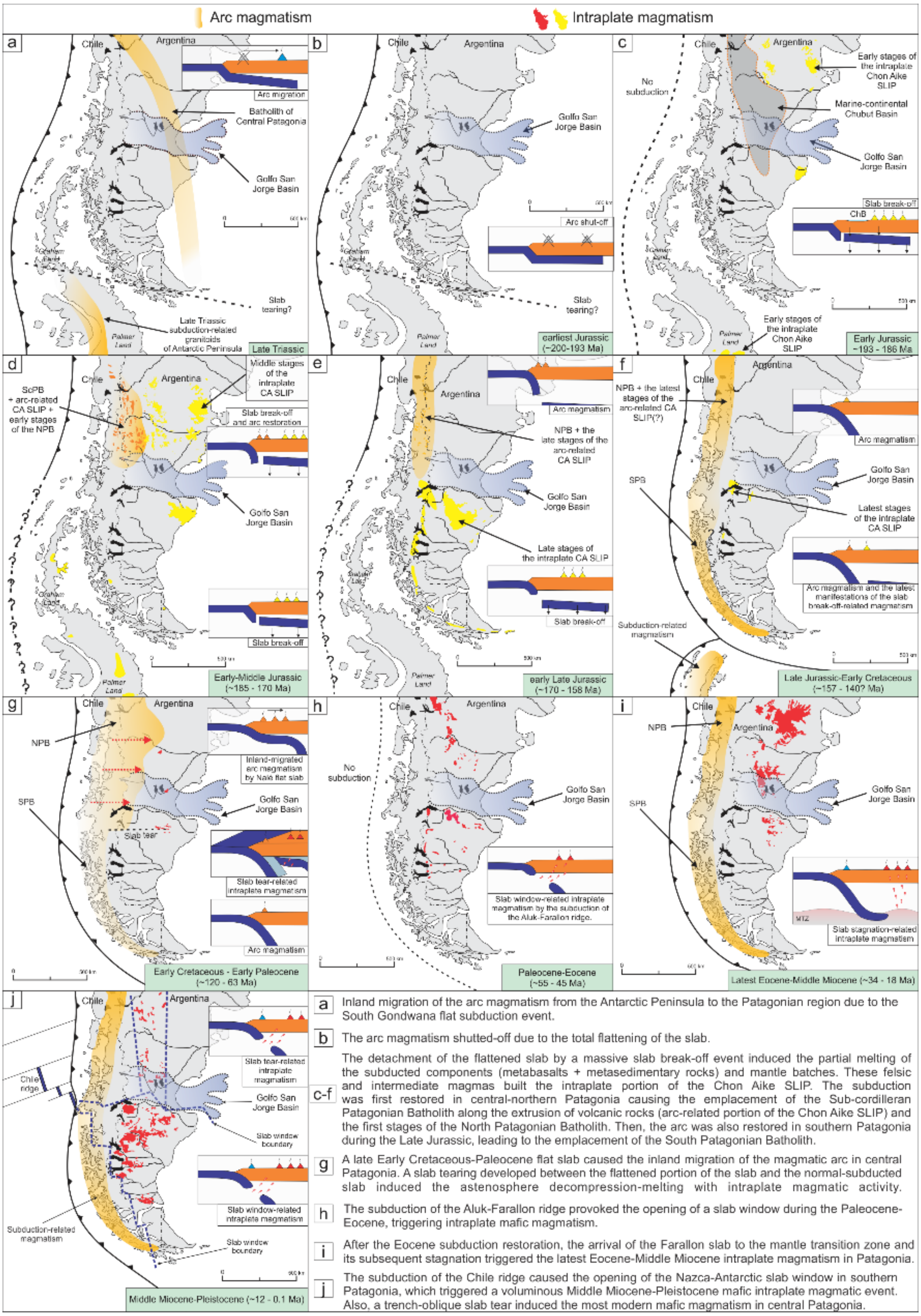
OVERVIEW

Late Triassic–Jurassic

Following the Permian–Triassic magmatic event that led to the formation of the Choiyoi magmatic province in southern South America, which has been ascribed both a magmatic arc and a slab break-off event (see Gianni and Navarrete, 2022 for a review), a Late Triassic magmatic event manifested in central–southern Patagonia. This magmatism developed a NW-oriented composite granitic batholith known as the Batholith of Central Patagonia (e.g., Rapela *et al.*, 1991), whose age range spans the late Upper Triassic (Norian to Rhaetian; ~220–202 Ma). It is composed of calc-alkaline and adakitic granitic, granodioritic, and dioritic bodies (Fig. 2a) referred to as the Gastre and Lipetrén Superunits in its northern portion (Rapela *et al.*, 1991), and the La Leona Unit at the south (Arrondo, 1972; Fig. 2b). These Triassic rocks were ascribed to an intraplate setting related to an extensional and transtensional regime (e.g., Rapela and Pankhurst, 1992). However, subsequent studies suggested a magmatic arc signature linked to a transpressive and contractional tectonic regime affecting southwestern Gondwana (see Navarrete *et al.*, 2019 for a review). Thus, this magmatism has subsequently been linked to a large-scale flat subduction event (the South Gondwana flat slab), which caused inland migration of arc magmatism about 1000 km from the Antarctic Peninsula towards Patagonian latitudes (Navarrete *et al.*, 2019; Fig. 1a).

After this arc-related magmatism, the available geochronological data indicates that there was a magmatic quiescence period from ~200 to ~193 Ma in southwestern Gondwana (Fig. 1b), compatible with the latest stages of a flat subduction event in which the total flattening of the slab inhibits the magmatism.

The flat subduction setting would have destabilized during the Early Jurassic due to the partial or total slab eclogitization, causing the flattened slab detachment and sinking towards the mantle, which triggered large-scale silicic magmatism in southwestern Gondwana. This event gave rise to the Chon Aike silicic large igneous province (Chon Aike SLIP, Pankhurst *et al.* 1998 and references therein) spanned most of the Jurassic, from ~193 to ~150 Ma (see Navarrete *et al.*, 2024a for a review; Fig. 1c–f) and primarily affecting Patagonia, the Antarctic Peninsula, and the Ellsworth-Whitmore Block.



a Inland migration of the arc magmatism from the Antarctic Peninsula to the Patagonian region due to the South Gondwana flat subduction event.

b The arc magmatism shutted-off due to the total flattening of the slab.

c-f The detachment of the flattened slab by a massive slab break-off event induced the partial melting of the subducted components (metabasalts + metasedimentary rocks) and mantle batches. These felsic and intermediate magmas built the intraplate portion of the Chon Aike SLIP. The subduction was first restored in central-northern Patagonia causing the emplacement of the Sub-cordilleran Patagonian Batholith along the extrusion of volcanic rocks (arc-related portion of the Chon Aike SLIP) and the first stages of the North Patagonian Batholith. Then, the arc was also restored in southern Patagonia during the Late Jurassic, leading to the emplacement of the South Patagonian Batholith.

g A late Early Cretaceous-Paleocene flat slab caused the inland migration of the magmatic arc in central Patagonia. A slab tearing developed between the flattened portion of the slab and the normal-subducted slab induced the astenosphere decompression-melting with intraplate magmatic activity.

h The subduction of the Aluk-Farallon ridge provoked the opening of a slab window during the Paleocene-Eocene, triggering intraplate mafic magmatism.

i After the Eocene subduction restoration, the arrival of the Farallon slab to the mantle transition zone and its subsequent stagnation triggered the latest Eocene-Middle Miocene intraplate magmatism in Patagonia.

j The subduction of the Chile ridge caused the opening of the Nazca-Antarctic slab window in southern Patagonia, which triggered a voluminous Middle Miocene-Pleistocene mafic intraplate magmatic event. Also, a trench-oblique slab tear induced the most modern mafic magmatism in central Patagonia.

Figure 1. Late Triassic–Pleistocene Patagonian magmatic events. The Golfo San Jorge Basin appears in all the diagrams, even though the magmatism depicted does not always coincide temporally with its development. Abbreviations: ChB: Chubut Basin; SPB: South Patagonian Batholith; NPB: North Patagonian Batholith; ScPB: Sub-cordilleran Patagonian Batholith; CA SLIP: Chon Aike SLIP.

This Jurassic magmatism was mostly composed of rhyolitic, dacitic, and basaltic andesitic lavas and pyroclastic rocks of calc-alkaline, high-K calc-alkaline, and shoshonitic affinities (Fig. 2c), with dominant magmatic arc and crustal signature. These rocks have been grouped into several lithostratigraphic units throughout Patagonia and the Antarctic Peninsula, among which the more recognized in central Patagonia are the Lonco Trapial Formation (Fig. 2d), the Marifil Volcanic Complex (Fig. 2e), the Cañadón Asfalto Formation, the Bahía Laura Volcanic Complex (Fig. 2f), and the Lago la Plata Formation (see Navarrete *et al.*, 2024a for a review).

In most of the Golfo San Jorge Basin, the buried Jurassic rocks have been referred to as the Lonco Trapial Group, Marifil Formation, Bahía Laura Group (Fig. 2g), or Bahía Laura Volcanic Complex. In its western region (Río Mayo sub-basin), the Lago La Plata Formation grouped the exposed and buried Jurassic volcanic rocks.

The origin of this magmatic province was classically attributed to large-scale continental crustal anatexis (Pankhurst and Rapela, 1995), which may have been triggered by an intense Jurassic extensional event or by the influence of a mantle plume. However, a recent study focusing on its petrogenesis has shown that an origin linked to the melting of the continental crust in a strongly extensional tectonic context needs to be more consistent with the vast majority of the available data (Navarrete *et al.*, 2024a). It is widely known that the Jurassic period in southwestern Gondwana was characterized by continental plate spreading that eventually led to the opening of the Atlantic Ocean and the supercontinent fragmentation during the Early Cretaceous. However, the geochemical data of most of Chon Aike SLIP indicate the partial melting of a thickening crust, which, along with isotopic data, seismic tomography, and thermo-mechanical numerical modeling, allowed reinterpreted the origin of this magmatism. As mentioned, the Late Triassic–earliest Jurassic flat slab was destabilized during the Early Jurassic by a partial or total slab eclogitization, causing a massive slab break-off event. According to Navarrete *et al.* (2024a), the slab break-off and its subsequent sinking would have promoted the fast increase in temperature of partially eclogitized subducted components (metabasalts + metasedimentary rocks) and mantle batches, inducing their partial melting. These slab break-off-related felsic and intermediate magmas would have ascended through the continental lithosphere, being variably affected by crustal assimilation and fractional crystallization processes and giving rise to the Chon Aike SLIP.

Also, the initial stages of the slab sinking could have been responsible for the paleo-Pacific marine flooding that covered a large portion of central Patagonia in an extensional-related NW-directed marine–continental basin known as the Chubut Basin. According to Navarrete *et al.* (2024a) and based on geodynamic studies, the continental lithosphere of southwestern Gondwana would have been downward dragged during the initial stages of the flattened slab foundering, promoting the development of the mentioned marine-dominated basin (Fig. 1c). Once the flattened slab was completely detached, the mantle upwelling induced dynamic uplift of the upper plate, causing the total continentalization of the basin during the Early–Middle Jurassic despite the intense extensional tectonic regime and the Middle Jurassic global-scale sea level rise. The development of this marine–continental basin simultaneously occurred with the initial stages of the Chon Aike SLIP magmatism, which was focused on north–central and eastern Patagonia, as well as on the southern Antarctic Peninsula (Palmer Land; Fig. 1c). Thus, the sedimentary rocks are below or interbedded with the volcanic rocks in some extensional-related depocenters of central–southern Patagonia. In the Golfo San Jorge Basin, multiple Jurassic depocenters, both those that belong to the Chubut Basin and those linked exclusively to the magmatism, were covered by thick, primarily Cretaceous rocks deposited during this basin's most intense subsidence stage.

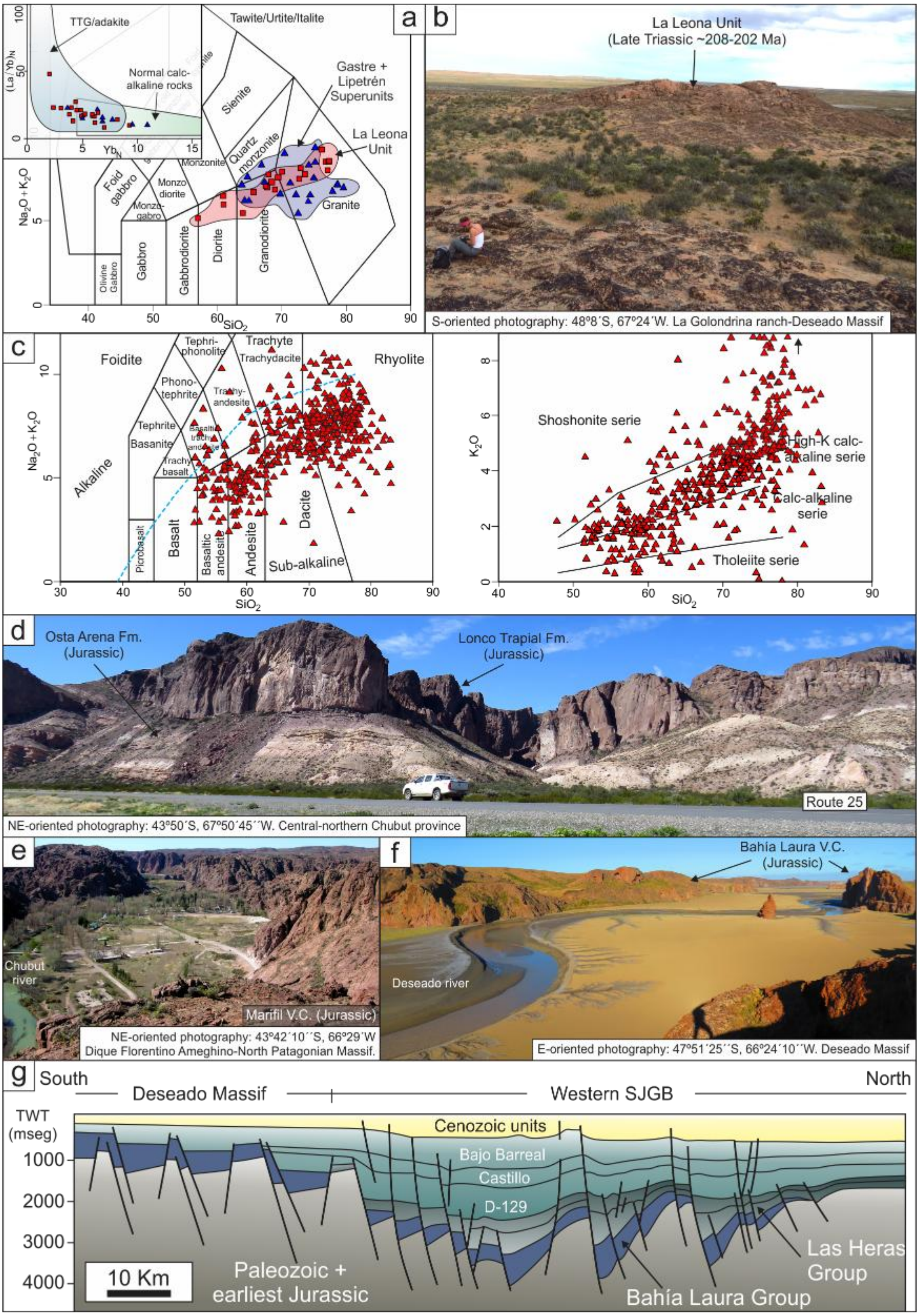

a
TTG/adakite
Normal calc-alkaline rocks
$(La/Yb)_N$
Yb_N
Tawite/Urtite/Italite
Gastre + Lipetrén Superunits
La Leona Unit
Sienite
Quartz monzonite
Monzonite
Foid gabbro
Monzo diorite
Monzo-gabro
Olivine Gabbro
Gabbro
Gabbrodiorite
Diorite
Granodiorite
Granite
Na_2O+K_2O
SiO_2
b
La Leona Unit
(Late Triassic ~208-202 Ma)
S-oriented photography: 48°8´S, 67°24´W. La Golondrina ranch-Deseado Massif
c
Foidite
Tephri-phonolite
Trachyte
Trachydacite
Rhyolite
Phono-tephrite
Trachy-andesite
Tephrite
Basanite
Basaltic trachy andesite
Trachy basalt
Alkaline
Picrobasalt
Basalt
Basaltic andesite
Andesite
Dacite
Sub-alkaline
Na_2O+K_2O
SiO_2
Shoshonite serie
High-K calc-alkaline serie
Calc-alkaline serie
Tholeiite serie
K_2O
SiO_2
d
Osta Arena Fm. (Jurassic)
Lonco Trapial Fm. (Jurassic)
Route 25
NE-oriented photography: 43°50´S, 67°50´45´´W. Central-northern Chubut province
e
Chubut river
Marifil V.C. (Jurassic)
NE-oriented photography: 43°42´10´´S, 66°29´W
Dique Florentino Ameghino-North Patagonian Massif.
f
Bahía Laura V.C. (Jurassic)
Deseado river
E-oriented photography: 47°51´25´´S, 66°24´10´´W. Deseado Massif
g
South
North
Deseado Massif
Western SJGB
TWT (mseg)
1000
2000
3000
4000
Cenozoic units
Bajo Barreal
Castillo
D-129
10 Km
Paleozoic + earliest Jurassic
Las Heras Group
Bahía Laura Group

Figure 2. a) Geochemical classifications [TAS and La/Yb(N) diagrams] of the Late Triassic granitoids of the Batholith of Central Patagonia (modified from Navarrete et al., 2019). **b)** Field photography of the La Leona Unit at eastern Deseado Massif. **c)** Geochemical classifications (TAS and K_2O vs SiO_2 diagrams) of the Jurassic Chon Aike SLIP (modified from Navarrete et al., 2024a). **d)** Jurassic lava flow of the Lonco Trapial Formation overlying Jurassic sedimentary of the Osta Arena Formation in central–northern Chubut province. **e, f)** Jurassic volcanic rocks of the Marifil Volcanic Complex **(e)** and the Bahía Laura Volcanic Complex **(f)**. **g)** Regional N–S seismic section of the central–western Golfo San Jorge Basin and the Deseado Massif (modified from Paredes *et al.*, 2024). Abbreviations: V.C.: Volcanic complex; Fm.: Formation.

Finally, it is worth mentioning that the Jurassic slab break-off event caused the temporary cessation of subduction in the southwestern Gondwana margin for the latitudes of the Chon Aike SLIP. Subduction was re-established in the north–central latitudes of Patagonia around 190–185 Ma, causing the emplacement of subduction-related mafic and felsic intrusive bodies known as the Subcordilleran Patagonian Batholith (ScPB), and multiple volcanic events in surrounding areas (Fig. 1d). This batholith and the surrounding volcanic rocks (e.g., the Lago La Plata Formation) could be considered as the arc-related portion of the Chon Aike SLIP.

This early period of subduction at these latitudes was characterized by a progressive slab steepening and rollback, which triggered a westward migration of arc magmatism and intensified the continental extension. Around 170 Ma, the arc magmatism was emplaced in the Andean region with the initial stages of the North Patagonian Batholith (NPB) and the surrounding volcanism.

Subduction was not restored in central and southern Patagonia until the Late Jurassic–Early Cretaceous, with the emplacement of the first subduction-related plutonic bodies of the South Patagonian Batholith (SPB) in southwestern Chile (see Navarrete *et al.*, 2024a for a review). Arc magmatism was also restored in the Antarctic Peninsula during this period, simultaneously with its southward drift.

Cretaceous–Early Paleocene

This lapse was magmatically characterized in central Patagonia by the inland migration and widening of the arc magmatism and minor intraplate mafic manifestations in the Chubut and Santa Cruz provinces (Figs. 1g and 3a). This eastward displacement of the magmatic arc would have been related to a progressive shallowing of the subducted oceanic slab until it reached a total flattening during the latest Cretaceous–Paleocene (Gianni *et al*., 2018 and references therein). This event, known as the Nalé flat slab, caused the emplacement and extrusion of multiple subduction-related igneous products in the eastern Andean region of Patagonia, central–western Chubut province, and northwestern Santa Cruz province (Fig. 3a). This arc migration occurred throughout much of the Cretaceous, from the Aptian to Campanian (~120–72 Ma). The youngest (~80–72 Ma) arc-related rocks are exposed in the northern and central Chubut province around 500 km from the trench, near the Gastre and José de San Martín towns, respectively (Fig. 3a). The former are adakitic dacites and rhyodacites (Navarrete *et al*., 2021 and references therein), while the second are mostly calc-alkaline andesites and basaltic andesites known as the Tres Picos Prieto Formation.

Regarding the Golfo San Jorge Basin, its western sector (Río Mayo sub-basin) was directly affected by the eastward migration and widening of the magmatic arc. Multiple calc-alkaline plutonic and subvolcanic bodies were intruded in the Early Cretaceous marine–continental sedimentary rocks of the Coyhaique Group (e.g., Gianni *et al*., 2020 and references therein; Fig. 3a, b), along with the extrusion of lava and pyroclastic products (Escosteguy *et al*., 2024). Most of these plutonic bodies are included in several lithostratigraphic units, such as the Cerro Victoria and Muzzio formations and the La Plata Chico granitoid (Escosteguy *et al*., 2024), some of which are part of the North Patagonian Batholith. The subvolcanic and volcanic rocks are mostly referred to as the Divisadero Formation. This unit includes lavas, porphyritic sub-volcanic bodies, and pyroclastic rocks of rhyolitic, trachydacitic, dacitic, and andesitic geochemical compositions (Fig. 3c), with typical magmatic arc geochemical features such as enrichments in Th, U, Pb and depletions in Nb, Ta and Ti (Fig. 3d).

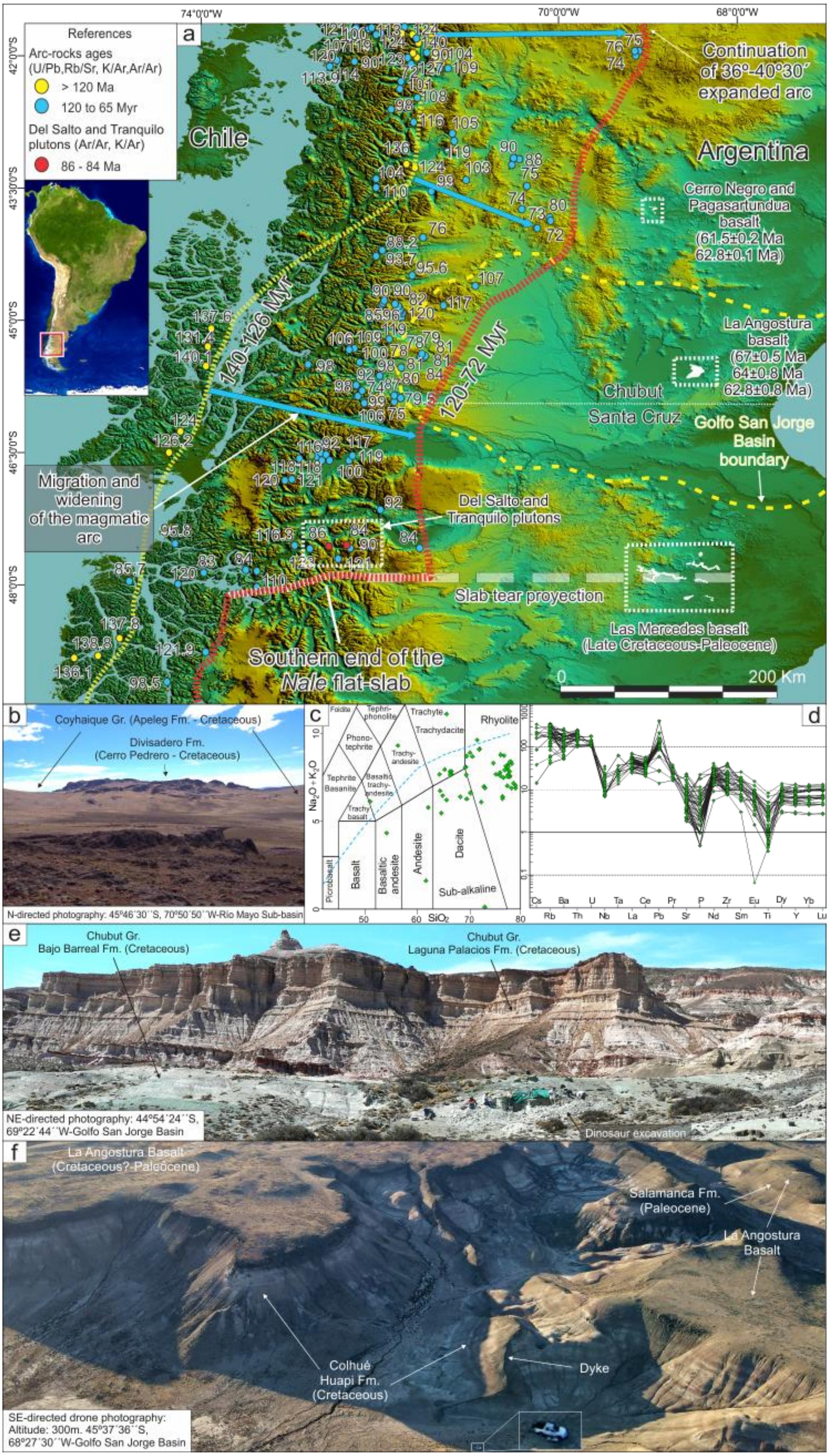

a
74°0'0"W
70°0'0"W
68°0'0"W
42°0'0"S
43°30'0"S
45°0'0"S
46°30'0"S
48°0'0"S
References
Arc-rocks ages (U/Pb,Rb/Sr, K/Ar,Ar/Ar)
> 120 Ma
120 to 65 Myr
Del Salto and Tranquilo plutons (Ar/Ar, K/Ar)
86 - 84 Ma
Chile
Argentina
Continuation of 36°-40°30´ expanded arc
Cerro Negro and Pagasartundua basalt (61.5±0.2 Ma 62.8±0.1 Ma)
140-126 Myr
120-72 Myr
La Angostura basalt (67±0.5 Ma 64±0.8 Ma 62.8±0.8 Ma)
Chubut
Santa Cruz
Golfo San Jorge Basin boundary
Migration and widening of the magmatic arc
Del Salto and Tranquilo plutons
Slab tear proyection
Las Mercedes basalt (Late Cretaceous-Paleocene)
Southern end of the *Nale* flat-slab
0
200 Km
b
Coyhaique Gr. (Apeleg Fm. - Cretaceous)
Divisadero Fm. (Cerro Pedrero - Cretaceous)
N-directed photography: 45º46´30´´S, 70º50´50´´W-Rio Mayo Sub-basin
c
Foidite
Tephri-phonolite
Trachyte
Trachydacite
Rhyolite
Phono-tephrite
Trachy-andesite
Tephrite Basanite
Basaltic trachy-andesite
Trachy basalt
Picrobasalt
Basalt
Basaltic andesite
Andesite
Dacite
Sub-alkaline
Na_2O+K_2O
0
5
10
50
60
SiO_2
70
80
d
1000
100
10
1
0.1
Cs
Rb
Ba
Th
U
Nb
Ta
La
Ce
Pb
Pr
Sr
P
Nd
Zr
Sm
Eu
Ti
Dy
Y
Yb
Lu
e
Chubut Gr. Bajo Barreal Fm. (Cretaceous)
Chubut Gr. Laguna Palacios Fm. (Cretaceous)
NE-directed photography: 44º54´24´´S, 69º22´44´´W-Golfo San Jorge Basin
Dinosaur excavation
f
La Angostura Basalt (Cretaceous? Paleocene)
Salamanca Fm. (Paleocene)
La Angostura Basalt
Colhué Huapi Fm. (Cretaceous)
Dyke
SE-directed drone photography: Altitude: 300m. 45º37´36´´S, 68º27´30´´W-Golfo San Jorge Basin

Figure 3. a) The Late Cretaceous–Paleocene igneous activity of the magmatic arc and the intraplate magmatism of central Patagonia (modified from Navarrete *et al.*, 2021. See the text for the geochronological data of the intraplate magmatism). **b)** A sub-volcanic arc-related rhyolitic body of the Divisadero Formation intruded into the sedimentary rocks of the Coyhaique Group. **c, d)** TAS diagram **(c)** and primitive mantle-normalized trace-elements spider diagram **(d)** of the Divisadero Formation (modified from Gianni *et al.*, 2020). **e)** Field photography of the Cretaceous Chubut Group (Bajo Barreal and Laguna Palacios formations) during a dinosaur excavation (provided by Marcelo Luna). **f)** Drone photography of the Cretaceous–Paleocene intraplate La Angostura Basalt.

Another remarkable consequence of this magmatic activity for the Golfo San Jorge Basin was the substantial contribution of pyroclastic material distally deposited and variably resedimented and reworked by multiple sedimentary environments (e.g., Paredes *et al.*, 2021). Thus, much of the Cretaceous fossil-rich Chubut Group (Fig. 3e) comprises primary (ash-fall deposits) and secondary resedimented volcaniclastic deposits.

For the latest Cretaceous, the progressive slab shallowing and its subsequent total flattening would have induced a progressive volumetric decrease of pyroclastic material supplied to the basin by the magmatic arc, until reaching its total interruption. This typical event sequence of a flat slab could explain the scarcity of pyroclastic components in the sedimentary rocks of the latest Cretaceous Colhué Huapi Formation in the Golfo San Jorge Basin (Casal *et al.*, 2015).

This flat subduction event also caused intraplate magmatic events. In the southern edge of the flattened slab, a trench-perpendicular slab tear would have been generated by the slab bending due to the change of its dip from the flattened portion (north of 48° S) to a zone with a steeper subduction angle (south of 48° S; Navarrete *et al.*, 2021).

In addition to the arc retraction south of 48° S (Fig. 3a), this slab gap would have induced the sub-slab asthenosphere decompression melting and triggering intraplate mafic volcanism in central Deseado Massif (Las Mercedes Basalt) and the emplacement of alkaline intrusive bodies (Del Salto and

Tranquilo plutons) in the southern end of the widened magmatic arc (Navarrete *et al.*, 2021; Fig. 3a).

Also, two outcrops of the latest Cretaceous–Paleocene intraplate mafic volcanic rocks appear in the Chubut province. The former is in the central region of the Golfo San Jorge Basin, known as the La Angostura Basalt (Fig. 3e) and dated both as Late Cretaceous (67.3 Ma; Clyde *et al.*, 2014) and Paleocene (64–62.8 Ma; Marshall *et al.*, 1981). These lava flows overlie the Late Cretaceous Colhué Huapi Formation (Fig. 3e) and underlie the marine Salamanca Formation, the reason why they are informally known as the "pre-Salamaquean" basalts. However, new geological mapping works indicated that they are stratigraphically interbedded in the basal rocks of the Salamanca Formation, covering an irregular paleorelief (Fig. 3e).

The other outcrops are located north of the Golfo San Jorge Basin, near the Paso de Indios town. It is referred to as Pagasartundua plateau and Cerro Negro (Fig. 3a), which was dated by Alric (1996) obtaining Paleocene ages (61.5–62.8 Ma). According to Navarrete *et al.* (2024b), the origin of these intraplate basalts could have been related to frontal tears of the flattened slab, which promoted the sub-slab asthenosphere decompression melting.

Paleocene–Pleistocene

The intraplate magmatic activity in Patagonia of the last ~55 Myrs could be divided into three stages: i) the Paleocene–Eocene (~55–45 Ma; Fig. 4a); ii) the latest Eocene–Middle Miocene (~37–15 Ma; Fig. 4b); and iii) the Middle Miocene–Pleistocene (~12–0.1 Ma; Fig. 4c). During these stages, large areas of Patagonia were covered by huge basaltic plateaus and intruded by multiple plutons, laccoliths, lopoliths, and dykes. For specific details and reviews of the intraplate mafic magmatism of Patagonia, readers are referred to Kay *et al.* (2007), Haller *et al.* (2020), Cordenons *et al.* (2020), and Navarrete *et al.* (2020).

Paleocene–Eocene. The Paleocene–Eocene lapse was magmatically influenced by the subduction of the Aluk–Farallon ridge, which caused the opening of a slab window and the temporary cessation of the subduction in southwestern South America (e.g., Iannelli *et al*., 2020; Fig. 1h). The mantle decompression caused by this slab gap induced the partial melting of the sub-slab asthenosphere, leading to the rise of primitive mafic magmas through the continental crust. This event led to the intrusion of multiple mafic intrusive bodies and the extrusion of mafic lava flows in the intraplate region of Patagonia (Fig. 4a). Compositionally, it was dominated by alkaline basalts and basanites, with general Oceanic Island Basalts (OIB) signature (Fig. 4d).

In the Golfo San Jorge Basin, this intraplate magmatic event was mostly covered by younger sedimentary rocks and has been identified by geophysical data (e.g., Plazibat *et al*., 2019). To the north of this basin, this mafic magmatism is primarily represented by lopoliths, plutons (e.g., El Sombrero pluton and La Vaca lopolith; Fig. 4a, e), and dikes, while the lava flows are more frequent to the south (e.g., the Posadas Basalt).

Although this slab window-related magmatism was predominantly mafic in the extra-Andean central–southern Patagonia, in northwestern Chubut province a mostly felsic magmatic event occurred between 56 and 51.5 Ma (early Eocene; Aragón *et al*., 2018 and references therein). This event was characterized by the collapse of a trap door caldera of 25 km diameter, known as the Piedra Parada Caldera (Fig. 4f). This caldera is included in the intraplate portion of the Paleocene–Eocene Pilcaniyeu Volcanic Belt, which continues to the northwestern sector of Patagonia with intraplate and arc-related rocks (e.g., Iannelli *et al*., 2020 and references therein). The caldera collapse caused the eruption of hundreds of cubic kilometers of felsic pyroclastic material and the intrusion of felsic and intermediate dikes and lava domes along the ring fault during the late stages of its evolution (e.g., Aragón *et al*., 2018).

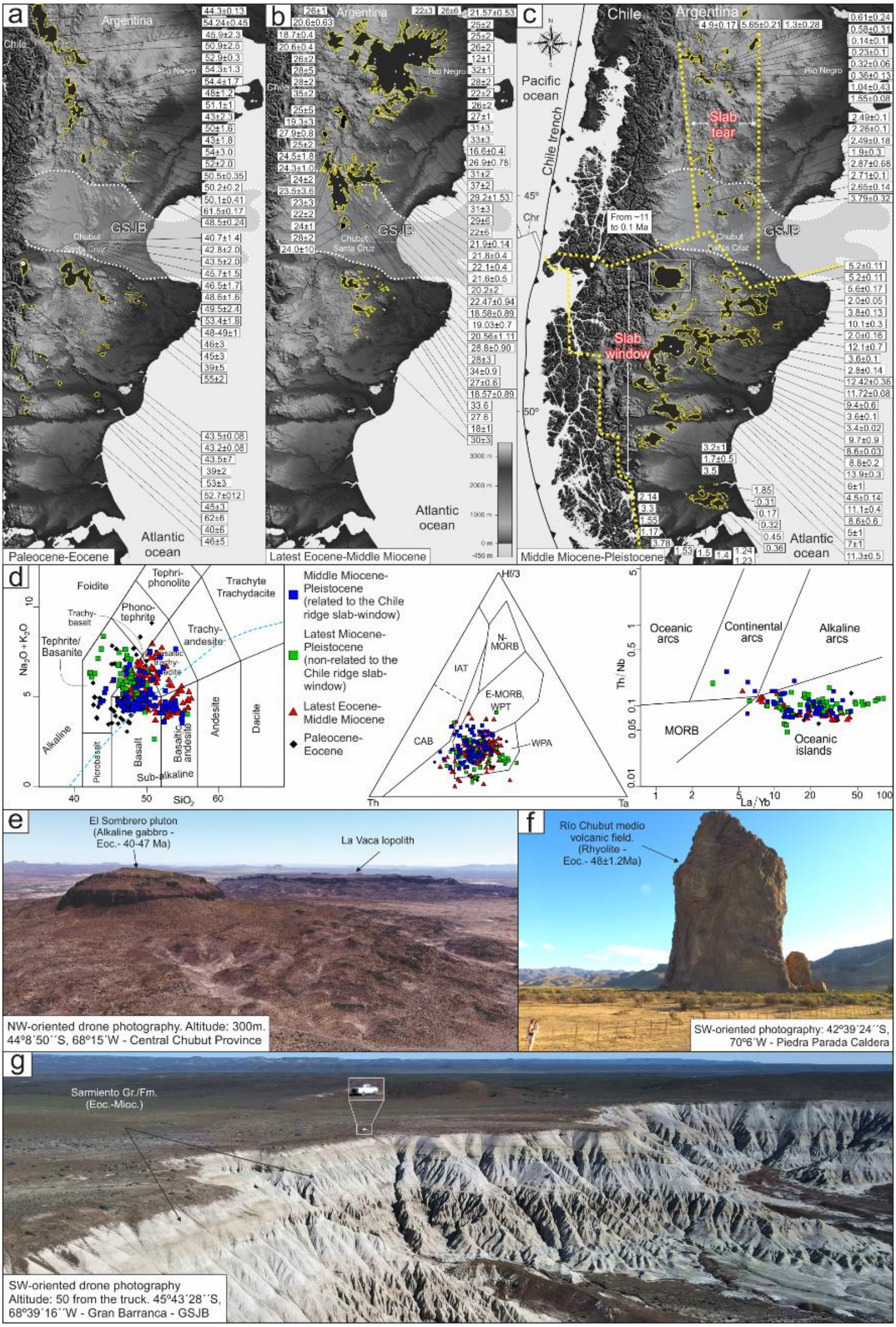

a
Argentina
Chile
Río Negro
GSJB
Chubut
Santa Cruz
Atlantic ocean
Paleocene-Eocene
44.3±0.13
54.24±0.45
45.9±2.3
50.9±2.5
52.9±0.3
54.3±1.3
54.4±1.7
48±1.2
51.1±1
43±2.3
50±1.6
43±1.8
54±3.0
52±2.0
50.5±0.35
50.2±0.2
50.1±0.41
61.5±0.17
48.5±0.24
40.7±1.4
42.8±2.0
43.5±2.0
45.7±1.5
46.5±1.7
48.6±1.6
49.5±2.4
53.4±1.8
48-49±1
46±3
45±3
39±5
55±2
43.5±0.08
43.2±0.08
43.5±7
39±2
53±3
52.7±012
45±3
62±6
40±6
46±5
b
Argentina
Chile
Río Negro
GSJB
Chubut
Santa Cruz
Atlantic ocean
Latest Eocene-Middle Miocene
26±1
20.6±0.63
18.7±0.4
20.6±0.4
26±2
28±5
28±2
35±2
25±5
19.3±3
27.9±0.8
25±2
24.5±1.8
24.3±1.0
24±2
23.5±3.5
23±3
22±2
24±1
28±2
24.0±10
22±3
26±6
21.57±0.53
25±2
25±2
26±2
12±1
32±1
28±2
22±2
26±2
27±1
31±3
33±3
16.6±0.4
26.9±0.78
31±2
37±2
29.2±1.53
31±3
29±6
22±6
21.9±0.14
21.8±0.4
22.1±0.4
21.6±0.5
20.2±2
22.47±0.94
18.58±0.89
19.03±0.7
20.56±1.11
28.8±0.90
28±3
34±0.9
27±0.6
18.57±0.89
33.6
27.6
18±1
30±3
3000 m
2000 m
1000 m
0 m
-456 m
c
N
S
W
E
Chile
Argentina
Pacific ocean
Chile trench
45°
50°
Chr
From ~11 to 0.1 Ma
Slab tear
Slab window
Río Negro
GSJB
Chubut
Santa Cruz
Atlantic ocean
Middle Miocene-Pleistocene
4.9±0.17
5.65±0.21
1.3±0.28
0.61±0.24
0.58±0.31
0.14±0.1
0.23±0.1
0.32±0.06
0.36±0.13
1.04±0.43
1.55±0.08
2.49±0.1
2.26±0.1
2.49±0.18
1.9±0.3
2.87±0.68
2.71±0.1
2.65±0.14
3.79±0.32
5.2±0.11
5.2±0.11
5.6±0.17
2.0±0.05
3.8±0.13
10.1±0.3
2.0±0.16
12.1±0.7
3.6±0.1
2.8±0.14
12.42±0.36
11.72±0.08
9.4±0.6
3.6±0.1
3.4±0.02
9.7±0.9
8.6±0.03
8.8±0.2
13.9±0.3
6±1
4.5±0.14
11.1±0.4
8.6±0.6
5±1
7±1
11.3±0.5
3.2±1
1.7±0.5
3.5
1.85
0.31
0.17
0.32
0.45
0.36
2.14
3.3
1.55
1.17
3.78
1.53
1.5
1.4
1.24
1.23
d
Foidite
Tephri-phonolite
Trachyte Trachydacite
Phono-tephrite
Trachy-basalt
Tephrite/Basanite
Basaltic trachy-andesite
Trachy-andesite
Alkaline
Picrobasalt
Basalt
Basaltic andesite
Andesite
Dacite
Sub-alkaline
$Na_2O + K_2O$
SiO_2
0
5
10
40
50
60
🟦 Middle Miocene-Pleistocene (related to the Chile ridge slab-window)
🟩 Latest Miocene-Pleistocene (non-related to the Chile ridge slab-window)
▲ Latest Eocene-Middle Miocene
◆ Paleocene-Eocene
Hf/3
N-MORB
IAT
E-MORB, WPT
CAB
WPA
Th
Ta
Oceanic arcs
Continental arcs
Alkaline arcs
MORB
Oceanic islands
Th/Nb
La/Yb
0.01
0.05
0.1
0.5
1
5
1
2
5
10
20
50
100
e
El Sombrero pluton (Alkaline gabbro - Eoc.- 40-47 Ma)
La Vaca lopolith
NW-oriented drone photography. Altitude: 300m. 44º8´50´´S, 68º15´W - Central Chubut Province
f
Río Chubut medio volcanic field. (Rhyolite - Eoc.- 48±1.2Ma)
SW-oriented photography: 42º39´24´´S, 70º6´W - Piedra Parada Caldera
g
Sarmiento Gr./Fm. (Eoc.-Mioc.)
SW-oriented drone photography Altitude: 50 from the truck. 45º43´28´´S, 68º39´16´´W - Gran Barranca - GSJB

Figure 4. a–c) Representative radiometric ages for the Cenozoic intraplate magmatism in Patagonia. **d)** Geochemical classification (TAS diagram) and geotectonic environment discrimination diagrams of the Paleocene–Pleistocene intraplate magmatism (modified from Navarrete *et al*., 2020). **e)** Eocene mafic intrusive bodies of the Chubut province. **f)** Part of an Eocene rhyolitic lava dome at central–northern Chubut province. **g)** The Sarmiento Group/Formation in the Golfo San Jorge Basin. Abbreviations: Gr: Group; GSJB: Golfo San Jorge Basin; CAB: continental arc basalts; IAT: island arc tholeiites; WPA: within plate alkaline basalts; E-MORB: enriched middle ocean ridge basalts; WPT: within-plate tholeiites; N-MORB: normal middle ocean ridge basalts.

According to Aragón *et al*. (2018), most of the magmas linked to the Piedra Parada caldera were related to the partial melting of subducted mélanges during the opening of the Aluk–Farallon slab window. Thus, felsic and intermediate magmas would have been generated at mantle depths, much of which would have ascended rapidly through the crust favored by a slightly extensional local tectonic regime, inhibiting the substantial crustal contamination.

Latest Eocene–Middle Miocene. As mentioned, the opening of the Aluk–Farallon slab window caused the temporary interruption of subduction at Patagonian latitudes during the late Paleocene–middle Eocene (see Eagles and Scott, 2014), whose reestablishment would have occurred in the middle to late Eocene. The arc resumption by the Farallon plate subduction gave rise to tholeiitic and calc-alkaline arc-related volcanic units in the western Chubut province known as the El Maitén Belt, including the Ventana and Auca Pan formations (e.g., Fernández Paz *et al*., 2020 and references therein). This magmatism is thought to have been one of the main sources of the pyroclastic material deposited and variably reworked in the Golfo San Jorge Basin (Fig. 4g) and other areas of Patagonia during the middle Eocene–Early Miocene. These deposits are widely known as the Sarmiento Group or Formation (e.g., Simpson, 1941), which contain exceptional and complete Cenozoic paleontological records.

During the middle–late Eocene, the convergence rate at Patagonian latitudes increased to about 50–75 km/Myr in the Early Oligocene (e.g., Eagles and Scott, 2014). The subsequent late Oligocene (~25–23 Ma) breakup of the

Farallon plate into the Nazca and Cocos plates induced a new notable increase in the convergence rate and the subduction obliquity, becoming practically perpendicular to the South American trench (e.g., Eagles and Scott, 2014). While these events occurred, one of the most voluminous Cenozoic intraplate mafic magmatism events affected Patagonia during the latest Eocene–Middle Miocene (~34–18 Ma). This intraplate magmatism created enormous basaltic plateaus (Fig. 4b) in the Río Negro, Chubut (Fig. 5a), and Santa Cruz (Fig. 5b) provinces, and multiple mafic intrusive bodies mostly located in the Chubut province, either in the Golfo San Jorge Basin (Fig. 5c) or in surrounding areas. The largest plateaus are the Meseta de Somuncura and Meseta de Canquel in the Río Negro and Chubut provinces, which were grouped in the Somuncura large igneous province by Kay *et al*. (2007). The composition of this event was predominantly characterized by alkaline and sub-alkaline basalts, trachybasalts, and basaltic andesites, displaying a general OIB signature (Fig. 4d). However, some differentiated products are locally observed (see Cordenons *et al*., 2020 for a review).

The origin of the latest Eocene–Middle Miocene magmatic event has been controversial because multiple hypotheses have been proposed. The absence of a widespread extensional tectonic event for this period to promote mantle decompression melting and other regional geodynamic processes forced researchers to propose diverse mechanisms to explain this large-scale event. Strikingly, this mafic magmatism shows geochemical features suggesting subduction-related fluids' influence at the mantle source (e.g., Kay *et al*., 2007). For this reason, the proposed petrogenetic models have also attempted to explain the participation of subduction fluids, among which the following stand out: i) the interaction of a mantle plume with the Aluk oceanic plate; ii) the ascent of the hydrous mantle transition zone due to a decrease in the subduction angle and/or the convergence rate; iii) the hypothetical Farallon–Nazca slab break-off and a subsequent strong steepening of the Nazca slab; and iv) lithospheric delamination and interaction with slab-derived fluids from the sinking Aluk plate.

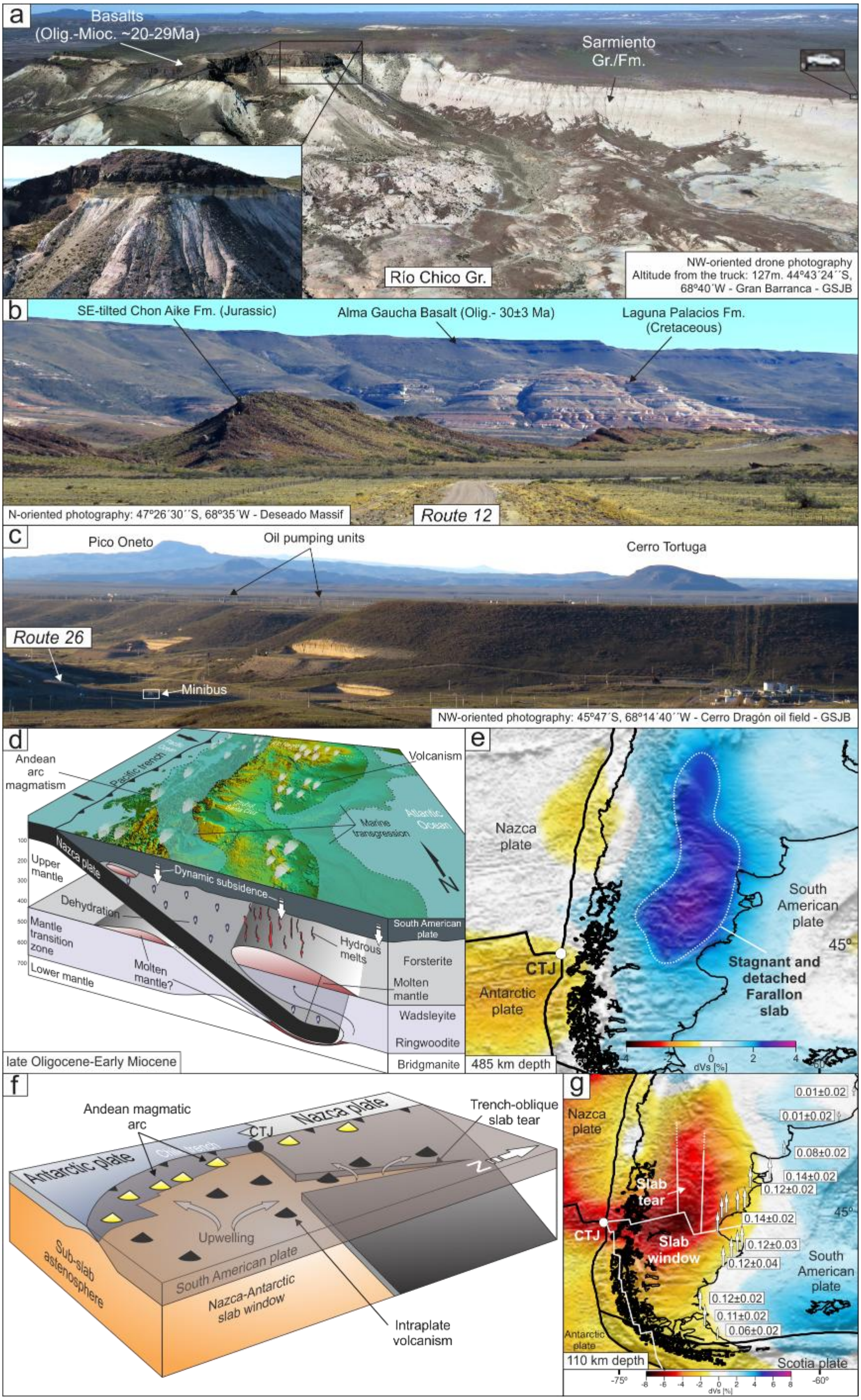

a
Basalts (Olig.-Mioc. ~20-29Ma)
Sarmiento Gr./Fm.
Río Chico Gr.
NW-oriented drone photography Altitude from the truck: 127m. 44°43´24´´S, 68°40´W - Gran Barranca - GSJB
b
SE-tilted Chon Aike Fm. (Jurassic)
Alma Gaucha Basalt (Olig.- 30±3 Ma)
Laguna Palacios Fm. (Cretaceous)
N-oriented photography: 47°26´30´´S, 68°35´W - Deseado Massif
Route 12
c
Pico Oneto
Oil pumping units
Cerro Tortuga
Route 26
Minibus
NW-oriented photography: 45°47´S, 68°14´40´´W - Cerro Dragón oil field - GSJB
d
Andean arc magmatism
Pacific trench
Volcanism
Marine transgression
Atlantic Ocean
N
100
200
300
400
500
600
700
Upper mantle
Nazca plate
Dynamic subsidence
Dehydration
Mantle transition zone
Lower mantle
Molten mantle?
Hydrous melts
South American plate
Forsterite
Molten mantle
Wadsleyite
Ringwoodite
Bridgmanite
late Oligocene-Early Miocene
e
Nazca plate
CTJ
Antarctic plate
South American plate
45°
Stagnant and detached Farallon slab
-4
-2
0
2
4
dVs [%]
485 km depth
f
Andean magmatic arc
CTJ
Nazca plate
Antarctic plate
Chile trench
Trench-oblique slab tear
N
Upwelling
South American plate
Nazca-Antarctic slab window
Sub-slab astenosphere
Intraplate volcanism
g
Nazca plate
Slab tear
CTJ
Slab window
Antarctic plate
South American plate
Scotia plate
45°
0.01±0.02
0.01±0.02
0.08±0.02
0.14±0.02
0.12±0.02
0.14±0.02
0.12±0.03
0.12±0.04
0.12±0.02
0.11±0.02
0.06±0.02
110 km depth
-75°
-60°
-8
-6
-4
-2
0
2
4
6
8
dVs [%]

Figure 5. a, b) Oligocene–Miocene mafic lava flows in central **(a)** and southern **(b)** Patagonia. **c)** Oligocene–Miocene mafic intrusive bodies at the Golfo San Jorge Basin. **d)** Petrogenetic model for the latest Eocene–Middle Miocene intraplate magmatism and oceanic floodings (Navarrete *et al.*, 2020). **e)** A seismic tomography slice of the SA2019 model at 485 km depth (taken from Navarrete *et al.*, 2020 and references therein). **f)** Three-dimensional cartoon showing the current Nazca–Antarctic slab window beneath southern Patagonia and the trench-oblique slab tear below central Patagonia (modified from Navarrete *et al.*, 2020). **g)** A seismic tomography slice of the SA2019 model at 110 km depth (taken from Navarrete *et al.*, 2020 and references therein) and the uplift rates of Pedoja *et al.* (2011) expressed in mm/year.

Recently, Navarrete et al. (2020) have further developed the idea of the influence of the mantle transition zone on the petrogenesis of the latest Eocene–Middle Miocene basalts, which could also have favored the late Eocene–Early Miocene large-scale marine floodings in Patagonia (e.g., Paredes *et al.*, 2015; Encinas *et al.*, 2018 and references therein). According to this petrogenetic model, the subduction of the Farallon oceanic plate began during the middle Eocene (~46 Ma), and it would have reached the mantle transition zone during the latest Eocene–early Oligocene (~36–32 Ma.). Then, the slab reached the base of the mantle transition zone (~660 km depth) during the Oligocene (~29–25 Ma) and would have begun to stagnate by not penetrating the lower mantle (Fig. 5d), remaining still stagnant as evidenced by the high-velocity seismic anomaly (Fig. 5e). This sequence of events remarkably coincides spatially and temporally with the latest Eocene–Middle Miocene intraplate magmatism influenced by subduction-related fluids and with the late Eocene–Early Miocene marine transgressions.

Based on studies about the mantle transition zone and how its interaction with oceanic slabs can induce intraplate magmatism (e.g., Yang and Faccenda, 2020), it has been indicated that the interaction between the Farallon plate and the mantle transition zone would have induced the deformation of this mantle layer causing the decompression of the hydrous high-pressure polymorphs of olivine (i.e., wadsleyite and ringwoodite; Navarrete *et al.*, 2020; Fig. 5d). Such decompression caused the transformation of wadsleyite into forsterite, releasing subduction-related fluids stored in the mantle transition zone by the protracted subduction history. The fluids would have induced a low partial melting degree of the mantle above the Farallon stagnated slab, giving rise to the latest Eocene–Middle Miocene intraplate fluids-influenced magmatism.

Furthermore, the Atlantic and Pacific marine flooding that affected southern Argentina and Chile respectively, could have been promoted by dynamic subsidence caused by the stagnation of the Farallon oceanic plate in the mantle transition zone. The interaction of this slab with the mantle transition zone would have caused a sudden tilt of the southern South American plate towards the trench and its subsidence due to the enhanced subduction-induced mantle flow cell triggered by the displacement of higher-viscosity material in the lower mantle (Navarrete *et al.*, 2020 and references therein). Thus, the latest Eocene–Middle Miocene Patagonian intraplate magmatism was accompanied by marine transgressions possibly caused by the same large-scale geodynamic process.

Middle Miocene–Pleistocene. The most modern intraplate magmatic episode in central and southern Patagonia caused the extrusion of an enormous volume of mafic lava flows (Figs. 4c). Compositionally, this event was characterized by alkaline and sub-alkaline basalts, basanites, and basaltic andesites, with a general OIB signature (Fig. 4d).

In southern Patagonia, the outcrops are widely distributed throughout the Santa Cruz province, from the Andean region to areas close to the Atlantic Ocean (Fig. 4c), whose origin has been widely ascribed to a large slab window produced by the Chile ridge (Nazca–Antarctic) subduction. The subduction of this mid-ocean ridge beneath southern South America began during the middle Miocene, which induced the opening of the slab window beneath southern Patagonia (e.g., Breitsprecher and Thorkelson, 2009). As the ridge subduction progressed, the slab anisotropy expanded northwards until it reached its current size, covering most of the southern end of South America (Fig. 4c). Its opening triggered an intense decompression of the sub-slab asthenosphere, causing the Middle Miocene–late Pleistocene (~12–0.1 Ma; Fig. 4c) mafic intraplate magmatism of southern Patagonia.

In central Patagonia, modern magmatic activity developed from the latest Miocene to the Late Pleistocene (~5–1.14 Ma), where the outcrops are strikingly restricted to a thin NNW belt of 150–200 km wide, from the Golfo San Jorge Basin to the north (Fig. 4c). Although the southernmost portions of this magmatism were linked to a northward lateral flow from the Nazca–Antarctic slab window (Guillaume *et al*., 2010) and small-scale slab tears (e.g., Georgieva *et al*., 2019), most of this magmatism has been ascribed to an extensional tectonic regime (e.g., Folguera and Ramos, 2011). However, tectonic studies have shown evidence that a contractional regime affected this region (e.g., Gianni *et al*., 2017).

Recently, this modern intraplate magmatism of central Patagonia was related to the opening of a NNW-directed trench-parallel slab tear propagated from the northern boundary of the slab window to the north (Navarrete *et al*., 2020; Fig. 5f). This NNW slab gap was already identified by Aragón *et al*. (2011) at depths around ~350–500 km, who attributed it to the Aluk–Farallon slab window. However, when considering Cenozoic convergence rates (e.g., Eagles and Scott, 2014), it is unlikely that the slab gap currently observed at such depths can be identified as the Aluk–Farallon slab window, as this slab window should be located at deeper mantle depths. Confirming this assumption, Iannelli *et al*. (2020) identified the Aluk plate in the lower mantle (~850 km depth) at Patagonian latitudes through a tomotectonic analysis. Therefore, the NNW slab gap beneath central Patagonia, which cannot be older than 7–6 Ma, could be responsible for the most modern intraplate magmatic event in central Patagonia (~5.6–0.14 Ma; see Navarrete *et al*., 2020; Figs. 4c and 5f). Supporting this idea, a large NNW-oriented low-velocity seismic anomaly has been widely recognized at around 100–150 km depth (Fig. 5g), above the high-velocity seismic anomaly interpreted as the stagnated Farallon slab in the mantle transition zone.

Finally, both the slab window affecting southern Patagonia and the slab tear located beneath central Patagonia have been indicated as potential causes of the Quaternary uplift affecting Patagonia (e.g., Guillaume *et al*., 2010;

Navarrete *et al.*, 2020), whose uplift rates of eastern Patagonia are around 0.11–0.20 mm/year (Pedoja *et al.*, 2011; Fig. 5g).

Acknowledgments. The author thanks Dr. José Paredes for the invitation to participate in this special issue and Victor Ramos for his encouraging comments.

REFERENCES

Alric, V. I. (1996). *Los basaltos portadores de xenolitos aflorantes en las localidades Paso de Indios y Cerro Cóndor, departamento de Paso de Indios, provincia del Chubut* [Tesis de doctorado inédita]. Universidad Nacional de la Patagonia San Juan Bosco, Argentina.

Aragón, E., D'Eramo, F., Castro, A., Pinotti, L., Brunelli, D., Rabbia, O., Rivalenti, G., Varela, R., Spackman, W., Demartis, M. L., Cavarozzi, C. E., Aguilera, Y., Mazzucchelli, M. and Ribot, A. (2011). Tectono-magmatic response to major convergence changes in the north Patagonian suprasubduction system: the Paleogene subduction-transcurrent plate margin transition. *Tectonophysics, 509*, 218–237. https://doi.org/10.1016/j.tecto.2011.06.012

Aragón, E., Castro, A., Díaz-Alvarado, J., Pinotti, L., D´Eramo, F., Demartis, M., Coniglio, J., Hernando, I. and Rodríguez, C. (2018). Mantle derived crystal-poor rhyolitic ignimbrites: Eruptive mechanism from geochemical and geochronological data of the Piedra Parada caldera, Southern Argentina. *Geoscience Frontiers, 9*, 1529–1553. https://doi.org/10.1016/j.gsf.2017.09.004

Arrondo, O. (1972). Estudio geológico y paleontológico en la zona de la estancia La Juanita y alrededores, provincia de Santa Cruz, Argentina. *Revista del Museo de La Plata, 8*(43), 1–143. https://publicaciones.fcnym.unlp.edu.ar/rmlp/issue/view/587

Breitsprecher, K. and Thorkelson, D. J. (2009). Neogene kinematic history of Nazca-Antarctic-Phoenix slab windows beneath Patagonia and the Antarctic Peninsula. *Tectonophysics, 464*(1-4), 10–20. https://doi.org/10.1016/j.tecto.2008.02.013

Casal, G. A., Allard, J. O. and Foix, N. (2015). Análisis estratigráfico y paleontológico del Cretácico superior en la cuenca del Golfo San Jorge: nueva unidad litoestratigráfica para el Grupo Chubut. *Revista de la Asociación Geológica Argentina, 72*, 81–99.

Clyde, W., Wilf, P., Iglesias, A., Slingerland, R.L., Barnum, T., Bijl, P. K., Bralower, T. J., Brinkhuis, H., Comer, E. M., Huber, B. T., Ibañez-Mejia, M., Jicha, B. R., Krause, J. M., Schueth, J. D., Singer, B. S., Raigemborn, M. S., Schmitz, M. D., Sluijs, A. and Zamaloa, M. C. (2014). New age constraints for the Salamanca Formation and lower Río Chico Group in the western San Jorge Basin, Patagonia, Argentina: Implications for Cretaceous-Paleogene extinction recovery and land mammal age correlations. *Geological Society of America Bulletin, 126*(3-4), 289–306. https://doi.org/10.1130/B30915.1

Cordenons, P. D., Remesal, M. B., Salani, F. M. and Cerredo, M. E. (2020). Temporal and spatial evolution of the Somún Curá Magmatic Province, Northern Extra-Andean Patagonia, Argentina. *Journal of South American Earth Sciences, 104*, 102881. https://doi.org/10.1016/j.jsames.2020.102881

Eagles, G. and Scott, B. G. (2014). Plate convergence west of Patagonia and the Antarctic Peninsula since 61 Ma. *Global and Planetary Change, 123*, 189–198. https://doi.org/10.1016/j.gloplacha.2014.08.002

Encinas, A., Folguera, A., Bechis, F., Finger, K. L., Zambrano, P., Pérez, F., Bernabé, P., Tapia, F., Riffo, R., Buatois, L., Orts, D., Nielsen, S. N., Valencia, V. V., Cuitiño, J., Oliveros, V., De Girolamo, L. and Ramos, V. (2018). The Late Oligocene-Early Miocene Marine Transgression of Patagonia. In A. Folguera, E. Contreras-Reyes, N. Heredia, A. Encinas, S. Ianelli, V. Oliveros, F. M. Dávila, G. Collo, L. Giambiagi, A. Maksymowicz, M. P. Iglesias Llanos, M. Turienzo, M. Naipauer, D. Orts, V. Litvak, O. Álvarez and C. Arriagada (Eds.), *The Evolution of the Chilean-Argentinean Andes*. Springer, 443–474. https://doi.org/10.1007/978-3-319-67774-3_18

Escosteguy, L., Geuna, S., Dal Molin, C., Tedesco, A., Márquez, M. and Del Mármol, G. (2024). Hoja Geológica *4572-I/II Gobernador Costa, Provincia del Chubut, escala 1:250.000.* 105 pp. (Boletín 277). Instituto de Geología y Recursos Minerales, Servicio Geológico Minero Argentino (SEGEMAR). ISSN 0328-2333.

Fernández Paz, L., Iannelli, S., Echaurren, A., Ramos, M., Bechis, F., Litvak, V., Encinas, A., Kasemann, S., Lucassen, F. and Folguera, A. (2020). The late Eocene–early Miocene El Maitén Belt evolution: Magmatic response to the changing subduction zone geodynamics. *Journal of South American Earth Sciences, 103*, 102713. https://doi.org/10.1016/j.jsames.2020.102713

Folguera, A. and Ramos, V. A. (2011). Repeated eastward shifts of arc magmatism in the Southern Andes: a revision to the long-term pattern of Andean uplift and magmatism. *Journal of South American Earth Sciences, 32*, 531–546. https://doi.org/10.1016/j.jsames.2011.04.003

Georgieva, V., Gallagher, K., Sobczyk, A., Sobel, E. R., Schildgen, T. F., Ehlers, T. A. and Strecker, M. R. (2019). Effect of slab-window, alkaline volcanism, and glaciation on thermochronometer cooling histories, Patagonian Andes. *Earth and Planetary Science Letters, 511*, 164–176. https://doi.org/10.1016/j.epsl.2019.01.030

Gianni, G. and Navarrete, C. (2022). Catastrophic slab loss in southwestern Pangea preserved in the mantle and igneous record. *Nature Communications, 13*, 698. https://doi.org/10.1038/s41467-022-28290-z

Gianni, G., Navarrete, C., Echaurren, A., Díaz, M., Butler, K., Horton, B., Encinas, A. and Folguera, A. (2020). Northward propagation of Andean genesis: Insights from Early Cretaceous synorogenic deposits in the Aysén-Río Mayo basin. *Gondwana Research, 77*, 238–259. https://doi.org/10.1016/j.gr.2019.07.014

Gianni, G., Dávila, F., Echaurren, A., Fennell, L., Tobal, J., Navarrete, C., Quezada, P., Folguera, A. and Giménez, M. (2018). A geodynamic model linking Cretaceous orogeny, arc migration, foreland dynamic subsidence and marine ingression in southern South America. *Earth-Science Reviews*, *185*, 437–462. https://doi.org/10.1016/j.earscirev.2018.06.016

Gianni, G. M., Echaurren, A., Folguera, A., Likerman, J., Encinas, A., García, H. P. A., Dalmolin, C. and Valencia, V. A. (2017). Cenozoic intraplate tectonics in Central Patagonia: record of main Andean phases in a weak upper plate. *Tectonophysics, 721*, 151–166. https://doi.org/10.1016/j.tecto.2017.10.005

Guillaume, B., Moroni, M., Funiciello, F., Martinod, J. and Faccena, C. (2010). Mantle Flow and dynamic topography associated with slab window opening: Insights from laboratory models. *Tectonophysics, 496*, 83–98. https://doi.org/10.1016/j.tecto.2010.10.014

Haller, M. J., Massaferro, G. I., Alric, V. I. and Navarrete, C. R. (2020). Cenozoic intraplate magmatism of central Patagonia, Argentina. *Journal of South American Earth Sciences, 102*, 102650. https://doi.org/10.1016/j.jsames.2020.102650

Iannelli, S., Fernández Paz, L., Litvak, V., Gianni, G., Fennell, L., González, J., Lucassen, F., Kasemann, S., Oliveros, V. and Folguera, A. (2020). Southward-directed subduction of the Farallon-Aluk spreading ridge and its impact on subduction mechanics and Andean arc magmatism: insights from geochemical and seismic tomographic data. *Frontiers in Earth Science, 8*, 121. https://doi.org/10.3389/feart.2020.00121

Kay, S. M., Ardolino, A. A., Gorring, M. L. and Ramos, V. A. (2007). The Somuncura large Igneous Province in Patagonia: interaction of a transient mantle thermal anomaly with a subducting slab. *Journal of Petrology, 48*, 43–77. https://doi.org/10.1093/petrology/egl053

Marshall, L. G., Butler, R. F., Drake, R. E. and Curtis, G. H. (1981). Calibration of the beginning of the age of mammals in Patagonia. *Science*, *212*, 43–45. https://doi.org/10.1126/science.212.4490.43

Navarrete, C., Gianni, G., Tassara, S., Zaffarana, C., Likerman, J., Márquez, M., Wostbrock, J., Planavsky, N., Tardani, D. and Perez Frasette. (2024a). Massive Jurassic slab break-off revealed by a multidisciplinary reappraisal of the Chon Aike silicic large igneous province. *Earth-Science Reviews, 249*, 104651. https://doi.org/10.1016/j.earscirev.2023.104651

Navarrete, C., Gianni, G., Massaferro, G. and Lastra, M. B. (2024b). *Tectonic significance of Late Cretaceous-Paleocene intraplate magmatism in central Patagonia* [Abstract]. XXII Congreso Geológico Argentino, San Luis, Argentina.

Navarrete, C., Massaferro, G., Gianni, G. and Lastra, M. B. (2021). The slab gap-related Late Cretaceous-Paleocene magmatism of southern Patagonia. *Journal of Geodynamics, 147*, 101869. https://doi.org/10.1016/j.jog.2021.101869

Navarrete, C., Gianni, G., Massaferro, G. and Butler, K. (2020). The fate of the Farallon slab beneath Patagonia and its links to Cenozoic intraplate magmatism, marine transgressions and topographic uplift. *Earth-Science Reviews, 210*, 103379. https://doi.org/10.1016/j.earscirev.2020.103379

Navarrete, C., Gianni, G., Encinas, A., Márquez, M., Kamerbeek, Y., Valle, N. and Folguera, A. (2019). Upper Triassic to Middle Jurassic geodynamic evolution of southwestern Gondwana: from a large flat-slab to a mantle plume suction in a rollback subduction setting. *Earth-Science Reviews, 194*, 125–159. https://doi.org/10.1016/j.earscirev.2019.05.002

Pankhurst, R. and Rapela, C. W. (1995). Production of Jurassic rhyolite by anatexis of the lower crust of Patagonia. *Earth and Planetary Science Letters, 134*, 23–36. https://doi.org/10.1016/0012-821X(95)00103-J

Pankhurst, R., Leat, P., Sruoga, P., Rapela, C., Marquez, M., Storey, B. and Riley, T. (1998). The Chon Aike province of Patagonia and related rocks in West Antarctica: a silicic large igneous province. *Journal of Volcanology and Geothermal Research, 81*, 113–136. https://doi.org/10.1016/S0377-0273(97)00070-X

Paredes, J., Allard, J., Olazábal, S. X., Foix, N., Valle, M. N. and Tunik, M. A. (2024). Drainage reorganization and alluvial architecture of endorheic basins: The Lower Cretaceous record of the Chubut Group in the Golfo San Jorge Basin (Patagonia, Argentina). *Journal of South American Earth Sciences, 144*, 105031. https://doi.org/10.1016/j.jsames.2024.105031

Paredes, J., Foix, N. and Allard, J. (2021). Estratigrafía cretácica de la Cuenca del Golfo San Jorge. In R. E. Giacosa (Ed.), *Relatorio de Geología y Recursos Naturales de la Provincia de Chubut*.

Paredes, J., Foix, N., Guerstein, R. G., Guler, M. V., Irigoyen, M., Moscoso, P. and Giordano, S. (2015). A late Eocene-early Oligocene transgressive event in the Golfo San Jorge basin: Palynological results and stratigraphic implications. *Journal of South American Earth Sciences, 63*, 293–309. https://doi.org/10.1016/j.jsames.2015.08.009

Pedoja, K., Regard, V., Husson, L., Martinod, J., Guillaume, B., Fucks, E., Iglesias, M. and Weill, P. (2011). Uplift of quaternary shorelines in eastern Patagonia: Darwin revisited. *Geomorphology, 127*, 121–142. https://doi.org/10.1016/j.geomorph.2010.08.003

Plazibat, S., Rasgido, A. and Paredes J. M. (2019). Subsurface characterization of Cenozoic igneous activity at Cerro Dragón area (Golfo San Jorge Basin, central Patagonia): Implications for basin evolution and hydrocarbon prospectivity. *Journal of South American Earth Sciences, 96*, 102389. https://doi.org/10.1016/j.jsames.2019.102389

Rapela, C. W. and Pankhurst, R. (1992). The granites of northern Patagonia and the Gastre Fault System in relation to the break-up of Gondwana. In B. Storey, T, Alabaster, R. Pankhurst (Eds.), Magmatism and the Causes of Continental Break-up, *Geological Society, London, Special Publications, 68,* 209–220. https://doi.org/10.1144/GSL.SP.1992.068.01.13

Rapela, C. W., Días, G., Franzese, J., Alonso, G. and Benvenuto, A. (1991). El Batolito de la Patagonia Central: evidencias de un magmatismo Triásico-Jurásico asociado a fallas transcurrentes. *Revista Geológica de Chile, 18*,(2), 121–138.

Simpson, G. G. (1941). The Eogene of Patagonia. *American Museum Novitates, 1120,* 1–15.

Yang, J. and Faccenda, M. (2020). Intraplate volcanism originating from upwelling hydrous mantle transition zone. *Nature, 579*, 88–91. https://doi.org/10.1038/s41586-020-2045-y