# Chapter 7

https://doi.org/10.32685/pub.esp.36.2019.07
Published online 27 May 2020

## Tectonostratigraphic Terranes in Colombia: An Update Second Part: Oceanic Terranes

Jean–François TOUSSAINT[1] and Jorge Julián RESTREPO[2]*

1 jftoussaint@hotmail.com
Universidad Nacional de Colombia
Sede Medellín
Medellín, Colombia

2 jjrestrepoa@gmail.com
Universidad Nacional de Colombia
Sede Medellín
GEMMA Research Group
Medellín, Colombia

* Corresponding author

**Abstract** In Colombia, several oceanic, allochthonous terranes exist west of the San Jerónimo Fault, which is the western limit of large continental terranes. The main terranes are the Calima and Cuna in the Western Cordillera, the Tumaco Suspect Terrane in the southern Western Cordillera and the Tairona Terrane in the Sierra Nevada de Santa Marta. All of them are oceanic terranes that formed in the Pacific Ocean and moved northward to their present positions, where they were emplaced from Late Cretaceous to Miocene times. At least the Calima and Cuna are believed to be part of the Caribbean Plateau. Smaller oceanic terranes are found in the Cauca–Romeral Fault Zone (CRFZ).

**Keywords:** *Colombian tectonostratigraphic terranes, oceanic terranes, allochthonous terranes, Caribbean Plateau, transpressional collisional metamorphism.*

**Resumen** En Colombia existen varios terrenos oceánicos alóctonos al oeste de la Falla de San Jerónimo, límite occidental de los grandes terrenos continentales. Los principales son el Calima y Cuna en la cordillera Occidental, el presunto Terreno Tumaco en la parte sur de la cordillera Occidental y el Terreno Tairona en la Sierra Nevada de Santa Marta. Todos son terrenos oceánicos que se formaron en el océano Pacífico y migraron hacia el norte hasta sus posiciones actuales desde el Cretácico Tardío al Mioceno. Se cree que por lo menos los terrenos Calima y Cuna son parte del Plateau del Caribe. Pequeños terrenos oceánicos se encuentran dentro del Sistema de Fallas Cauca–Romeral.

**Palabras clave:** *terrenos tectonoestratigráficos colombianos, terrenos oceánicos, terrenos alóctonos, Plateau del Caribe, metamorfismo colisional transpresional.*

## 1. Introduction

Oceanic basement terranes (Figure 1) exist west of the San Jerónimo Fault, which marks the eastern edge of the Cauca–Romeral Fault Zone (CRFZ) (Figure 2). These terranes include the Calima and Cuna Terranes (Toussaint & Restrepo, 1989). Similarly, several oceanic terranes are mixed with continental terranes in the CRFZ located on the western flank of the Central Cordillera and on the eastern flank of the Western Cordillera. These terranes include the Ebéjico (Quebradagrande) and Pozo (Arquía) Terranes, among others. The newly defined Tairona Terrane, composed of oceanic basement, occurs in the Sierra Nevada de Santa Marta (SNSM) and on La Guajira Peninsula.

In this chapter, the boundaries and characteristics of the known oceanic terranes are determined, and new terranes are defined. Some of the names have been changed to comply with the recommendation of the initiators of the terranes tectonics (i.e., Coney et al., 1980; Howell, 1989) that the names of strati-

*Citation: Toussaint, J.F. & Restrepo, J.J. 2020. Tectonostratigraphic terranes in Colombia: An update. Second part: Oceanic terranes. In: Gómez, J. & Pinilla–Pachon, A.O. (editors), The Geology of Colombia, Volume 2 Mesozoic. Servicio Geológico Colombiano, Publicaciones Geológicas Especiales 36, p. 237–260. Bogotá. https://doi.org/10.32685/pub.esp.36.2019.07*

→

**Figure 1.** Schematic map of the tectonostratigraphic terranes in Colombia: (An) Andaquí Terrane; (Ch) Chibcha Terrane; (Y) Yalcón Terrane; (Ta) Tahamí Terrane; (K) Kogi Terrane; (Ca) Calima Terrane; (Tu) Tumaco Terrane; (Tai) Tairona Terrane; (Cu) Cuna Terrane; (CRUT) Cauca–Romeral Undifferentiated Terranes: strips formed by smaller continental and oceanic terranes, such as the Pozo (Arquía), Ebéjico (Quebradagrande) and Sinifaná–Amagá Terranes, among others.

graphic units not be used to name terranes. Following the common usage for naming terranes, we use names from the first indigenous cultures of America. The discussion of the continental terranes is presented in a different chapter of this book (see Restrepo & Toussaint, 2020).

## 2. The Calima Terrane

### 2.1. Introduction

The Calima Terrane is located in the Western Cordillera and probably also forms the basement of El Plato depression to the north of the Central Cordillera. The review by Etayo–Serna et al. (1983) suggests that several terranes named Buriticá, Sinú, and San Jacinto form this zone in the north and that the Dagua Terrane occurs in the south. Restrepo & Toussaint (1988) initially grouped all units with oceanic affinity into the *Western Andean Terrane*, and then Toussaint & Restrepo (1989) renamed it the Calima Terrane after a pre–Columbian culture of the Cisneros region in the Valle del Cauca. In Gómez et al. (2015a) practically all regions with oceanic basement were grouped into a single megaterrane called the Caribbean Terrane. The smaller oceanic terranes, such as the Pozo (Arquía) and Ebéjico (Quebradagrande) Terranes, which occur in a strip between the oceanic and continental terranes, were initially included in the Calima Terrane and were later separated from it (Restrepo et al., 2009a). Two smaller oceanic areas that are newly defined here, the Bocaná and Aburrá Terranes within the Tahamí Terrane, are also discussed.

The northern and southern parts of the Calima Terrane are composed of basement rocks with oceanic affinity (Case et al., 1971). The difference between the regions is that the southern part was affected by an important tectono–metamorphic event in the Late Cretaceous, but in the north, this event is featured only on the eastern border with the Quirimará Terrane (newly defined here), which includes the Sabaletas Schists (see below). Apparently, the transition from one area to another is progressive (Parra, 1983). The westernmost faults of the CRFZ mark the eastern boundary of the extensive oceanic terranes that are composed mainly of mafic rocks and deep–water sedimentites (Case et al., 1971; Irving, 1971).

Because the nomenclature, and possibly the nature of the rocks, is different in the northern and southern parts, with a transition at approximately latitude 4° 40’ N, we describe the two areas separately.

### 2.2. Distinguishing Features of the Northern Part of the Calima Terrane

The most important unit of the Calima Terrane, forming the basement, is the Cañasgordas Group, which comprises a basal basaltic unit called the Barroso Formation and a sedimentary unit called the Penderisco Formation that seems to be on top of and intercalated with the basalts (Álvarez & González, 1978; Irving, 1971; González, 2001). The original Barroso Formation included pillow lavas, flows, tuffs, and breccias but, as discussed below, has been subdivided into two units.

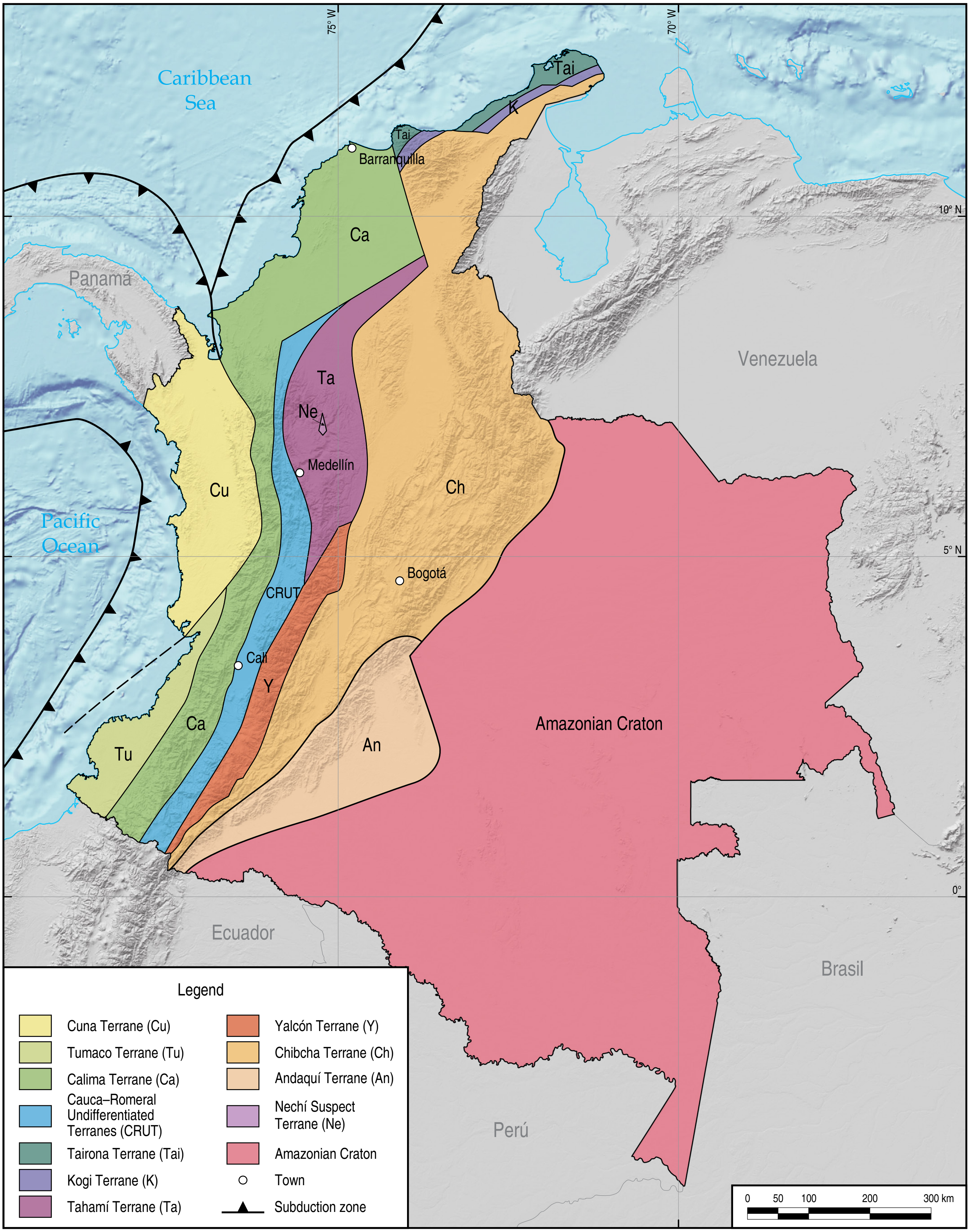
Since the work of Case et al. (1971), it has been known that the westernmost faults of the CRFZ are the eastern boundary of the large oceanic terranes that are composed mainly of mafic rocks and deep–water sedimentites. These authors also hypothesized that the oceanic basement of western Colombia was allochthonous and related to the Caribbean basement.

Based on the petrological and geochronological characteristics, Restrepo & Toussaint (1976) proposed that the basic volcanic rocks, mostly pillow lavas assigned to the Barroso Formation that are intruded by the Altamira Gabbro and the Sabanalarga Batholith, presently called the Santa Fé Batholith, represent an island arc that developed on top of oceanic crust.

Recently, it was proposed that the basic rocks that have been termed “Barroso” actually belong to two different units: the mainly pyroclastic Barroso Formation considered to represent a basic volcanic arc, and the San José de Urama Diabases, which are interpreted as part of an oceanic plateau (Rodríguez & Arango, 2013).

Although pillow lavas that are indicative of submarine eruptions are quite common, subaerial eruptions composed of red and green tuffs and breccias have been found near Altamira, Antioquia. For these rocks, geochemical analyses indicate an oceanic–crustal origin followed by gabbroic intrusions associated with an incipient arc (Zapata et al., 2017a).

The age of the volcanic rocks has been determined by several methods as Cretaceous, but dating with the K–Ar and Ar–Ar systems has been somewhat erratic. Ages from these systems range from 105 to 73 Ma (González, 2010; Sinton et al., 1998; Toussaint & Restrepo, 1981), and an abnormally old Ar–Ar age of 155 Ma was obtained for the San José de Urama Diabases (Rodríguez & Arango, 2013). Some of these ages, specifically the age from San José de Urama Diabases, could be unreliable due to the very low K content in the analyzed minerals. A better indicator of the minimum age of the Barroso Formation is the ages of the stocks that intrude the sequence, as discussed below.




Neogene
Paleogene
Cretaceous

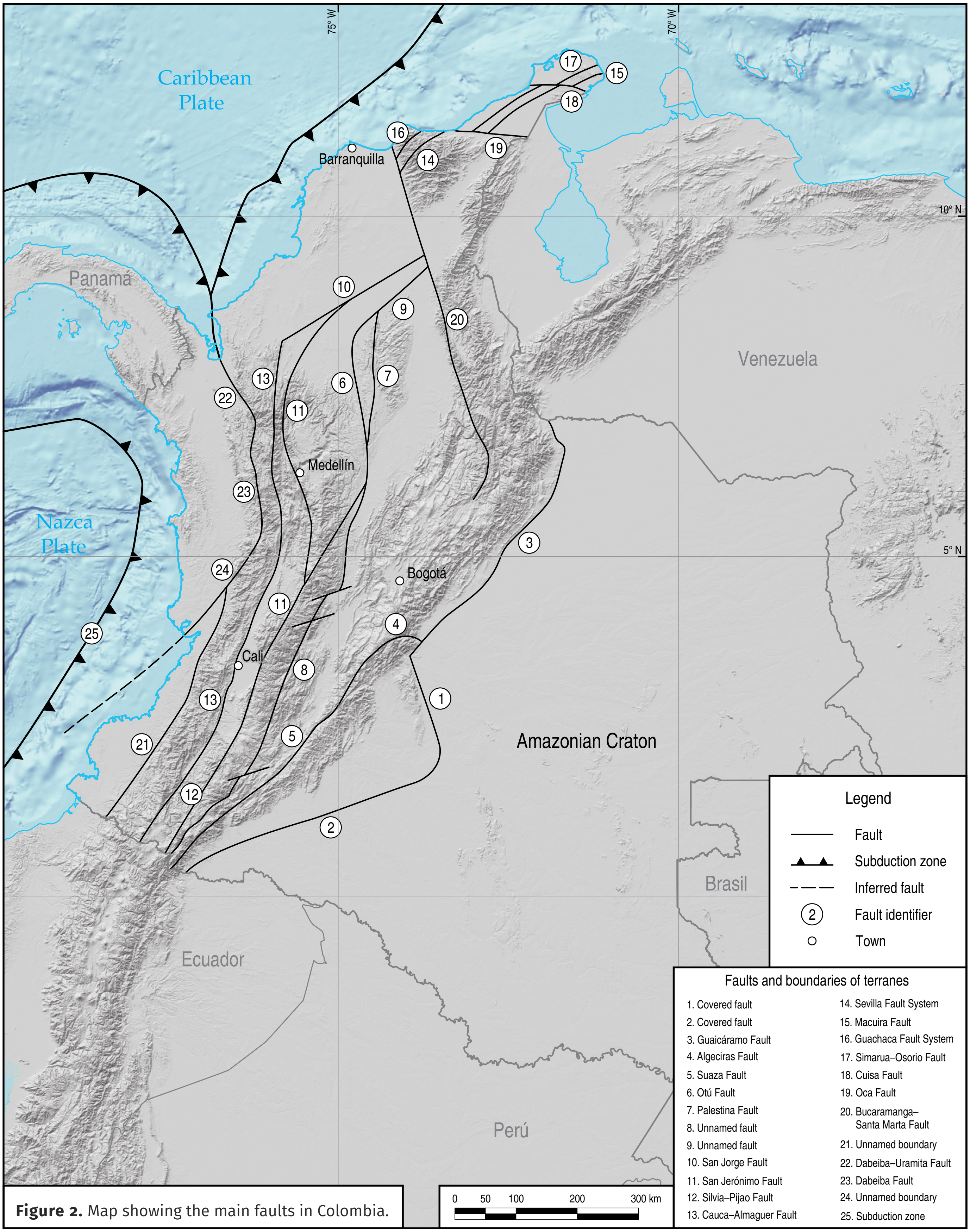



**Figure 2.** Map showing the main faults in Colombia.

The sedimentary succession contained within the Cañasgordas Group, named the Penderisco Formation, has been divided into a clastic sequence (the Urrao Member) and a mainly cherty sequence (the Nutibara Member), Álvarez & González (1978).

The Urrao Member is composed of several meter–thick turbiditic successions that are repeated for hundreds of meters, whereas the Nutibara Member is composed of cherts and lithographic limestones. The Urrao Member is predominant on the eastern side of the range, while the Nutibara Member is predominant on the western side. However, the relationships between them are not clear.

In Dabeiba, near the Calima–Cuna suture marked by the Dabeiba–Uramita Fault, Paleocene to Eocene fauna have been discovered in the Río Verde Unit, which is composed of basalts, radiolarites, calcareous cherts, and limestones (Bourgois et al., 1982a). This finding suggests that at least a portion of the Nutibara Member would not be Calima but rather would be related to a Paleocene – Eocene magmatism event of the Cuna Terrane, which accreted in the Miocene. It is currently unclear whether all the calcareous cherts that are attributed to the Nutibara Member in this area are Paleocene and belong to the Cuna Terrane or whether a Cretaceous portion remains in the Calima Terrane. Additionally, the only zone in the north where slates have been found is close to Dabeiba (Restrepo et al., 1979). This low–grade metamorphism was probably produced by the collision of the Cuna with the Calima Terrane.

The Paleocene siliceous limestones and cherts were highly deformed by Miocene tectogenesis, which is responsible for the main deformation of the sedimentary rocks of the Penderisco Formation. However, the presence of a Late Cretaceous to Paleocene event is not discarded.

Fossils are not very common, but those found have yielded ages that range from Albian to Maastrichtian (Etayo–Serna et al., 1980; González, 2001 and references therein). Ammonites near Buriticá are assigned to the mid–Albian (Etayo–Serna et al., 1980), and they likely represent interstratified cherts and fine clastic rocks within the Barroso Formation rather than the Penderisco Formation as previously thought (González, 2001). This age is confirmed by the intrusion of the Buriticá Stock into the sequence, forming a contact aureole (Feininger in Etayo–Serna et al., 1980); this stock has been dated at 100.5 Ma (Weber et al., 2015) and 93.9 Ma (Giraldo–Ramírez, 2017) by U–Pb in zircons. These ages agree well with a K–Ar date of 105 ± 10 Ma obtained from the Barroso Formation (Restrepo et al., 1991). If all of the basic volcanic rocks of the Barroso Formation formed in a short time, it is probable that they were completely established by the beginning of deposition associated with the Penderisco Formation. For this unit, Etayo–Serna (1989) reports Campanian to Maastrichtian fossils in turbidites near Peque on the western side of the sequence; recently, Turonian to Maastrichtian fossils have also been found at Ciudad Bolívar and Carmen de Atrato (Etayo–Serna cited by Rodríguez & Arango, 2013). The Cañasgordas Group was intruded by several plutons. On the eastern side, these plutons include the Buriticá Stock and the Santa Fé Gabbro (formerly the Sabanalarga Batholith); the Caicedo Gabbro and Altamira Gabbro mostly intrude the Barroso Formation. These plutons have been dated between 110.5 Ma and 71.6 Ma by U–Pb in zircons (Correa et al., 2017; Giraldo–Ramírez, 2017; Zapata et al., 2017b).

### *2.3. Features of the Southern Part of the Calima Terrane*

To the east of the southern part of the Calima Terrane are the Bolívar and the Riofrío Complexes, which consist of dunites, peridotites, banded pyroxenites, and gabbros cut by several hornblende pegmatites that have been dated between 112 and 95 Ma using Ar–Ar and U–Pb (Kerr et al., 2004; Villagómez, 2010). According to Bourgois et al. (1982b), the Bolívar Complex forms the base of the Diabasic Group and represents a portion of the proto–Caribbean basin that was overthrust onto the continent. Likewise, Nivia (1993, 1996) interpreted that these complexes represent the base of an obducted plateau.

Most of the southern part of the Calima Terrane is composed of basic volcanic rocks of the Diabasic Group or Volcanic Formation and by sedimentary and metasedimentary rocks of the Dagua Group, which has been divided into two formations: the Cisneros Formation, which is composed of metamorphic rocks, mainly phyllites and slates, and the Espinal Formation, which is composed of marine sedimentites, mostly mudrocks and turbiditic sandstones (Nelson, 1962). Several authors have proposed changing this nomenclature (Parra, 1983; Aspden, 1984) without reaching a consensus.

The Diabasic Group consists of spilitized diabase, K–poor tholeiitic basalts, and tuffs with interspersed cherts, siltstones, graywackes, and limestones. Trace element and REE analyses indicate a T–MORB that represents an oceanic plateau or a rift disturbed by a hotspot (Desmet, 1994; Kerr et al., 1997). The sedimentites that are interspersed with the basic rocks contain a few fossils from the Aptian – Campanian range (Etayo–Serna et al., 1982). Some small gabbro stocks associated with volcanic rocks have been dated at 99.7 Ma by U–Pb in El Palmar (Villagómez et al., 2011) and 94 ± 17 Ma by Rb–Sr isochron in El Tambor (Brook, 1984).

The Amaime Formation (McCourt, 1984), located on the western border of the Central Cordillera near Sevilla, is similar in composition and age to the Diabasic Group (Nivia, 1989). However, this formation could be an independent unit because it is separated from the Diabasic Group by an important fault network (Aspden & McCourt, 1986; Moreno–Sánchez & Pardo–Trujillo, 2003). According to the paleomagnetic studies of Estrada (1995), the Amaime Formation was probably generated in the Pacific at an equatorial paleolatitude.

The Cisneros Formation consists of siliceous phyllites and carbonaceous slates interspersed with metacherts, metagraywackes, and metalimestones that formed from low–grade metamorphism of pelagic sedimentites, particularly distal turbidites (Barrero, 1979). In the phyllites, *Zoophycus* ichnofossils are abundant. Bivalve molds indicate a Turonian – Maastrichtian age (Etayo–Serna et al., 1982). Some authors consider that the metamorphism was exclusively dynamic and that the phyllites are cataclasites (McCourt et al., 1984). The presence of schistosity affected by isoclinal folding that is associated with a second schistosity shows that large portions of the phyllites were produced by low–grade regional metamorphism, even though the presence of superimposed cataclasis is certain in several areas (Bourgois et al., 1982b).

The Espinal Formation is composed of siliceous shales, siltstones, and graywacke with rare cherts and limestones. Foraminifera and *Inoceramus* fossils suggest Campanian – Maastrichtian ages (Etayo–Serna, 1989).

However, the present apparent stratigraphy may be tectonically induced. Etayo–Serna et al. (1982) suggested that the Dagua Group can be divided into three segments with different textures and compositions, which were deposited contemporaneously and later tectonically stacked.

An important Late Cretaceous tectono–metamorphic event was caused by the oblique collision between plateau material of the Caribbean Plate and continental basement of the South American continent. At first, the collision was quite frontal, but later, major dextral movements occurred. Indeed, initially, the collision produced tectonic phases marked mainly by isoclinal folding, overthrust faults associated with schistosity and regional metamorphism, but the convergence then became more oblique, producing the great strike–slip faults that cut the previous structures (Toussaint, 1996).

Barrero (1979) assumed that the main tectonic phase that affected this region was Late Cretaceous and noted that phyllite of the Cisneros Formation dips mainly to the east, suggesting this observation as evidence of eastward subduction. Subsequent work by Bourgois et al. (1982b) indicated that the center of the Western Cordillera is formed by tectonic stacking of overthrust units based on the presence of folds that affect a first schistosity associated with isoclinal folds. The second schistosity, with a dip generally less than 30 degrees, is associated with folds dipping to the east. McCourt et al. (1984) placed a special emphasis on the large NNE faults that crosscut the previous structures. These authors attributed the faulting to Late Cretaceous tectonogenesis, but Toussaint (1996) argued that the inverse direction movements are subsequent to the Late Cretaceous regional metamorphism and are responsible for dynamic metamorphism that produced the cataclasites in the region. In the north, it is difficult to separate the Late Cretaceous tectonic event from the collision between the Cuna and Calima Terranes, which occurred during the Miocene.

The final accretion of the Calima Terrane to the continent appears to have occurred close to the Late Cretaceous – Paleogene boundary, beginning at approximately 70 Ma (the age of the youngest igneous zircons found in the Sabaletas Schists) and concluding before 58 Ma (the age of a dike that intrudes the schists; Zapata & Cardona, 2017). This age agrees well with the age determined in the southern part of the terrane, where Paleocene and Eocene sedimentary units partially cover the terrane borders with little to no deformation (see Geologic Map of Colombia by Gómez et al., 2015b).

## *2.4. Extent and Boundaries of the Calima Terrane*

Broadly speaking, the transition between the oceanic basement of the Calima Terrane and continental crust occurs along what is presently the CRFZ. However, it is important to note that the area has been subject to diverse tectonic phases with compressional, extensional, and especially large horizontal movements due to dextral–inverse transpression. The right–lateral faults were active during most of the Cenozoic. Thus, the limit is presently represented by the Cauca–Almaguer Fault (the westernmost fault of the CRFZ), but this fault is not necessarily the original boundary. This fault separates the Calima and Pozo (Arquía) Terranes.

The origin of the Caribbean Plateau has generally been attributed to the paleo–Galápagos hotspot, south of its present position (for a discussion regarding the paleo–Galápagos hotspot, see Nerlich et al., 2014, and references therein). The latitude of formation of the basic rocks was determined from paleomagnetic data to be nearly equatorial (Estrada, 1995) or between 2° S and 4° S (Hincapié–Gómez et al., 2018). Since its formation at that southerly location, there has been a northeasterly drift of the plateau that has resulted in the accretion of oceanic crust to the continental borders of the northern Andes and the Caribbean margin of South America (i.e., Kennan & Pindell, 2009). The interaction of the oceanic and continental terranes has produced slivers of both types of crust, dispersing large and small terranes that were accreted to the north. An example of these accretions is observed west of Medellín. The San Jerónimo Fault runs in a N–NE direction from Ecuador to an approximate latitude of 4° 40’ N, where it turns to a N–NW direction. After the change in direction, many microterranes, such as the Anacona, Quirimará, and Ebéjico Terranes, were left stranded in this area. Additionally, at the flexure point, extensive mylonites occur that were mapped as regional metamorphic rocks (González, 1980).

In the northernmost part of Colombia, the Calima Terrane is limited by an inverse fault that dips toward the south and confines the folded belt of the Caribbean within the Caribbean Plate (Toussaint & Restrepo, 1989). The location of the Calima Terrane in the Sinú region and El Plato depression is unclear. Research prior to Mora–Bohórquez et al. (2017) assumed that the Cauca–Almaguer Fault, also called the Romeral Fault in this region (Grosse, 1926), represents the boundary between the continental and oceanic materials to the E and W, respectively. However, geophysical research by Mora–Bohórquez et al. (2017) showed that between the Romeral or Cauca–Almaguer Fault and the San Jerónimo Fault with a NE direction in this region, the basement is composed of oceanic material. These authors consider that such basement may be associated with the Quebradagrande Complex, but we propose that it is more likely associated with the Calima Terrane; quite clearly, this basement is not from the Tahamí Terrane.

### 2.5. Post–Accretion Events in the Calima–Continental Terranes Supraterrane

An Oligocene to early Miocene magmatic belt including the Piedrancha Granodioritic Batholith (23 Ma; Álvarez & Linares, 1981), the Anchicayá Batholith (18 Ma; Brook, 1984), the Cumbitara Stock, El Vergel Stock (23 Ma to 22 Ma; Leal–Mejía, 2011) and the Tatamá Pluton (19 to 17 Ma; Brook, 1984) intrudes the previous rock associations. It is feasible that the final magmatic event of this belt is represented by the Tatamá Pluton, intruded shortly prior to the collision of the Cuna and Calima Terranes, which would have changed the position of the subduction zone.

Marine sediments were deposited during the Cenozoic in the Cauca River valley, for example, the Campanian – Paleocene Nogales Formation and the Eocene Chimborazo Formation (Pardo–Trujillo et al., 2003) on the western edge of the southern part of the Western Cordillera, and are similar to the sediments of the Pacific Group (van der Hammen, 1958) north of the Western Cordillera in the Sinú and San Jacinto regions, such as the Paleocene – Eocene San Cayetano Formation (Duque–Caro, 1984).

An important deformed belt developed in the northernmost part of the Calima Terrane, related to the Cenozoic subduction of the Caribbean Plate beneath the Northern Andes. Some of the sediments associated with this belt are exposed on the Caribbean Colombian coast, in Sinú, where they rest on the Calima Terrane units (see B&G Unión Temporal, 2006).

## 3. The Tumaco Suspect Terrane (Gorgona Terrane and Western Flank of the Southern Region of the Western Cordillera)

### 3.1. Introduction

A set of dunites, wehrlites, gabbros, and basalt flows that are covered by basic tuffs with *Inoceramus* in the Gorgona and Gorgonilla Islands were denominated the Igneous Complex of Gorgona by Gansser (1973). Etayo–Serna et al. (1983) considered that this assemblage represents the Gorgona Terrane.

The Guapi Ultramafic Complex, associated with a volcano–sedimentary sequence located to the west of the Western Cordillera (in a sparsely studied area), raises the question of whether the complex is associated with the Calima Terrane, with a southern extension of the Cuna Terrane, or with a new terrane that remains undefined. Due to a lack of thorough geological knowledge in this region, it is difficult to select among the hypotheses. In this article, these various units are included in the Tumaco Suspect Terrane, named after an important pre–Columbian culture.

### 3.2. Features of the Tumaco Terrane

The Igneous Complex of Gorgona includes mafic and ultramafic rocks with dunites, wehrlites, poikilitic or troctolitic gabbros, komatiites, basalt flows, volcanic breccias, and basic tuffs that contain *Inoceramus* (Gansser, 1973). Echeverría (1982) documented komatiites with spinifex textures, which are characteristic of the partial fusion of the mantle at a temperature of more than 1400 °C. Ages between 86 and 66 Ma reflect a seemingly continuous magmatic episode of ca. 20 Ma, with dates similar to those of the Caribbean Plateau (Espinosa–Baquero et al., 1982; Serrano et al., 2011; Walker et al., 1999). According to Estrada (1995), basalts with K–Ar dates of 86 ± 3 Ma had a paleolatitude of 25° S to 35° S. On the other hand, Serrano et al. (2011) considered that the Gorgona magmatism was due to the mixing of asthenospheric mantle material that was metasomatized by the subducted material of the proto–Caribbean Plate beneath the Antilles Arc. These authors discarded the hypothesis of magmatism related to the Galápagos Hotspot, considering that the continuity of Gorgona magmatism over 20 Ma was inconsistent with a moving plate passing over a hotspot.

The Guapi Ultramafic Complex includes harzburgites, lherzolites, serpentinized dunites, wehrlites, and gabbros associated with volcano–sedimentary formations that include basalts, breccias, and tuffs interbedded with cherts, siltstones, and Paleocene – Eocene limestones of the Timbiquí Formation (McCourt et al., 1990; Agencia Nacional de Hidrocarburos & Geología Regional y Prospección, 2011). Their presence on the west flank of the Western Cordillera prompts questions regarding which terrane these rocks belong to. This complex is intruded by smaller plutons, such as the Balsitas and El Salto Plutons, which are composed of hornblendic gabbro, quartz diorites, andesite porphyries, and tonalites for which McCourt et al. (1990) obtained ten K–Ar ages between 53 and 41 Ma. A more robust age of 53.25 ± 0.27 was obtained by U–Pb in zircons from a dike that crosscuts the complex (Agencia Nacional de Hidrocarburos & Geología Regional y Prospección, 2011), so a minimum Eocene age is indicated. The magmatism of the complex seems to be representative of oceanic arc activity developed on an oceanic basement, possibly disturbed by a high heat flow.

The Late Cretaceous to early Eocene age of the Gorgona Igneous Complex and the Guapi Ultramafic Complex (associated with volcano–sedimentary units) suggests that they constitute a different terrane from the Calima and Cuna Terranes. A similar hypothesis was suggested in a map presented by Guiral–Vega et al. (2015). However, until new data are available, the temporal relationships between the location of these ultramafic complexes and the accretion of the Calima Terrane remain unknown. Although the Calima Terrane includes the Miocene Alto Condoto Ultramafic Complex (Salinas & Tistl, 1992; Tistl et al., 1994), the Late Cretaceous to Eocene age excludes a similar origin between the two.

### *3.3. Accretion and Extent of the Tumaco Terrane*

An approximately N–S–oriented fault network separates the Tumaco Terrane from the Calima Terrane. These faults have no specific names in the most recent map published by the Servicio Geológico Colombiano (Gómez et al., 2015b). The faults are covered by recent sediments south of Buenaventura, continue south in Nariño near the town of El Charco, then extend near Ricaurte and finally end in Ecuador at the limit between the Piñón and Piñón–Macuchi Terranes (Litherland et al., 1993). Currently, it is difficult to specify the age and type of suture; however, an undated pluton attributed to the Piedrancha Batholith appears to crosscut the border. Although K–Ar ages ranging from 62 to 21 Ma have been reported from this batholith (González et al., 2002), the U–Pb age of 22.53 ± 0.18 Ma (Agencia Nacional de Hidrocarburos & Geología Regional y Prospección, 2011) would place the age of accretion as pre–Miocene. According to McGeary & Ben–Avraham (1985), the accretion of the Gorgona Terrane occurred before the early Miocene. The accretion of the Tumaco Suspect Terrane occurred after the mid–Eocene based on the age of 41 Ma of the youngest pluton mentioned above and before the early Miocene accretion of the Cuna Terrane.

The boundary between this terrane and the Cuna Terrane is represented by a NNE fault that crosses Buenaventura bay and extends offshore to the west of Gorgona Island. This fault was identified using seismology by McGeary & Ben–Avraham (1985), who assumed it represents a suture between two terranes.

### *3.4. Other Possibilities*

The existence of a Tumaco Terrane is feasible, but the hypothesis that these geological assemblages represent a southern extension of the Cuna Terrane (which is described later) cannot be discarded. Similarly, we cannot completely eliminate the possibility that the Guapi Ultramafic Complex is associated with the Calima Terrane, although it would be difficult to explain the in situ generation of the Guapi Ultramafic Complex.

## 4. The Cuna Terrane

### *4.1. Introduction*

The Cuna Terrane is located in the western part of Colombia, cropping out on the western flank of the Western Cordillera and in the Serranía de Baudó. It forms the basement of the Atrato River and Chucunaque Basins in Colombia and Panamá, respectively. This terrane extends to the Isthmus of Panamá.

For this area, the Ingeominas review by Etayo–Serna et al. (1983) considered that the west flank of the Western Cordillera is part of the Cañasgordas Terrane, that the Atrato River valley belongs to the Atrato–San Juan Terrane and that the Serranía de Baudó is associated with the Baudó Terrane. Restrepo & Toussaint (1988) initially named it the Panamá–Baudó–Mandé Terrane, and later, Toussaint & Restrepo (1989) defined it as the Cuna Terrane. Duque–Caro (1990) called it the Panamá–Chocó Block or Chocó Block. Gómez et al. (2015a) did not separate this area as a distinct terrane but associated it with a Caribbean Megaterrane that includes all terranes that contain oceanic basement. The Gorgona Terrane defined by Estrada (1995) may be a small terrane between the Calima and Cuna Terranes or may belong either to the Tumaco Suspect Terrane or to the Cuna Terrane. This research considers the Gorgona Terrane to be part of the Tumaco Suspect Terrane.

### *4.2. Features of the Cuna Terrane*

The Cuna Terrane includes a Cretaceous oceanic basement that was intruded in the NE by a magmatic arc of intermediate to acidic composition. It is represented by the Mandé Batholith with tuffs and breccias of the Santa Cecilia–La Equis Formation, the Acandí Batholith, and the Eocene Río Pito Pluton in Panamá. A thick succession of marine sedimentites was deposited in the Atrato River Basin, mainly between the Eocene and Miocene.

Bourgois et al. (1982a) argued that the oldest units in the Baudó Range are massive basalts, some with amygdules, and pillow lavas, diabases, and gabbros, dated at 70 Ma by K–Ar. Using Ar–Ar dating, Kerr et al. (1997) obtained ages between 77.9 Ma for a gabbro and 71.8 Ma for a basalt near Bahía Solano. These authors consider the rocks to be plateau basalts similar to those of the Caribbean Plateau. Planktonic foraminifera that were detected in sedimentary rocks interlayered with basalts suggest Coniacian to Maastrichtian ages (Bandy, 1970). These units are covered by chaotic volcano–sedimentary sequences characterized by basalts interspersed with limestones, radiolarites, and graywackes. Faunal ages range from Paleocene to lower Miocene (Bourgois et al., 1982a).

In the east and northeast region, volcanic rocks including basalts, andesites, latites, breccias, and tuffs are associated with cherts, siltstones, mudstone, and limestones that contain Paleocene – Eocene fossils, such as the Río Verde Formation (Bourgois et al., 1982a), the Santa Cecilia Formation, and La Equis Formation (Calle & Salinas, 1986). The Santa Cecilia–La Equis Complex, defined by Salazar et al. (1991), is composed of interlayered basic to intermediate lava flows and pyroclastic sequences. These authors initially included the Mandé Batholith in this complex, but the name was later limited to the volcanic portion. Near Dabeiba, a trachyandesite was dated at 41.5 Ma using K–Ar (Restrepo et al., 1991), whereas rocks of this unit dated with Ar–Ar produced ages between 55 and 37 Ma (Buchely et al., 2009). This magmatism also features the quartz diorite porphyries of Murindó and Pantanos, dated between 54.7 and 42.7 Ma by K–Ar, which contain important copper deposits (Sillitoe et al., 1982). Intense granodioritic to quartz monzonitic plutonism, which occurred during the Eocene, is represented mainly by the Mandé and Acandí Batholiths. The Mandé Batholith was dated by U–Pb in zircons at 45.3 ± 1.2 and 44.6 ± 0.9 Ma (Leal–Mejía, 2011), while other methods such as Ar–Ar and K–Ar produced ages between 55 and 45 Ma (Sillitoe et al., 1982; Buchely et al., 2009). This entire complex represents an island arc that developed over the Caribbean Plate, which was displaced dextrally compared to the NW corner of South America. In the northern part of the Cuna Terrane between the magmatic arc and the border of the Cuna Terrane with the Caribbean Plateau, the north Panamá deformed belt developed. This belt is composed of thick sequences of marine sedimentites deformed during the subduction of the Caribbean Plate beneath the Cuna Terrane. According to Montes et al. (2012), the emergence of the Panamá Arc, transported by the Caribbean Plate, commenced in the Eocene, although the arc collided with the NW corner of South America in the early Miocene (Toussaint & Restrepo, 1989). A younger age of collision is proposed by Restrepo–Moreno et al. (2017).

More than 6000 meters of marine sedimentary sequences were deposited in the Atrato River Basin between the Eocene and middle Miocene. The deposits include the Clavo, Salaquí, Uva, Napipí, and Sierra Formations (Haffer, 1967).

The Alto Condoto Ultramafic Complex, Viravira Complex, the Mumbú Ultramafic Complex, the Mutatá Ultramafic Complex, and La Cristalina Complex occur to the east of the Cuna Terrane and are composed of platinum–rich dunites, harzburgites, and lherzolites. They are Ural–Alaska–type complexes, products of the partial melting of an oceanic crust in a volcanic arc environment (Tistl et al., 1994). K–Ar isotopic dating of hornblende ranges from 21 to 18 Ma, or late Oligocene to early Miocene (Tistl et al., 1994). In the Viravira Complex, a few kilometers south of the Alto Condoto Ultramafic Complex, upper Eocene – lower Miocene cherts and limestones are intercalated with basalts.

The northeastern part of the Cuna Terrane features two important gravimetric highs of 90 mgal in the Serranía de Baudó and 130 mgal in the eastern region of the Cuna Terrane. These highs were interpreted to be the result of tectonic uplift in this region during collision with the Northern Andes (Case et al., 1971).

### 4.3. Extent and Boundaries of the Cuna Terrane

The Cuna Terrane is separated from the Caribbean Plate by a fault where the north Panamá deformed belt overrides the Caribbean Plate. This situation corresponds to the convergence between the Caribbean Plate and the Cuna Terrane that makes part of the Panamá Plate (Case & Holcombe, 1980; Bird, 2003). The border with the Calima Terrane features inverse faults with eastern and western dips, such as those of Dabeiba–Pueblo Rico and Uramita Faults (Restrepo & Toussaint, 1988). This fault system was generated during the collision of the Cuna Terrane with the NW corner of South America, when the Cuna Terrane attempted to subduct under the NW corner of South America. However, in some regions, such as around Dabeiba and along El Toro River on the road between Medellín and Quibdó, the most superficial area of the Cuna Terrane overthrust onto the Calima Terrane units (Bourgois et al., 1982a; Toussaint, 1999). In the Gulf of Urabá and around Buenaventura bay, the boundary is covered by late Miocene and Quaternary sediments. The boundary in the southern part of the Cuna Terrane, oriented N–NE, is marked by a nameless inverse dextral fault (see Gómez et al., 2015b) that segments the original suture.

The western boundary of the Cuna Terrane includes the subduction zone associated with subduction of the Nazca Plate beneath the Northern Andes and, in the northernmost region, a transform fault that borders the south Panamá deformed belt.

### 4.4. Accretion of the Cuna Terrane

The collision of the Cuna Terrane with the Northern Andes apparently occurred in the early Miocene both because the intense Eocene magmatism affected only the eastern edge of the Cuna Terrane but not the Calima Terrane and because the Miocene – Pliocene sedimentites cover the border in the Gulf of Urabá. In addition, the late Miocene – Pliocene Quibdó Formation discordantly overlies the early to middle Miocene Sierra Formation. Near Dabeiba, the Guineales Formation (Botero, 1936), deposited on the 9.3 Ma basalt of El Botón (Restrepo et al., 1991; Zapata & Rodríguez, 2011), appears to cover the border.

Duque–Caro (1985) and Montes et al. (2012) suggested that deep–water circulation between the Caribbean Sea and the Pacific Ocean was interrupted during the early Miocene, although O'Dea et al. (2016) argued that the interruption of marine exchange between the Caribbean Sea and the Pacific Ocean occurred only 2.8 Ma ago. In addition, Toussaint & Restrepo (1989) and Toussaint (1996) suggested that the collision of the Cuna Terrane with the Andean Block not only was responsible for the folding of the Cretaceous sedimentites of the Calima Terrane but also was a major cause of Miocene – Pliocene tectonogenesis that affected the entirety of the Colombian Andes, unlike the previous tectonogenesis that affected only specific terranes. Gómez–Vargas et al. (2017) suggested that the Penderisco Formation, associated with the Calima Terrane, was detached from its oceanic basement and was obducted during the collision.

Additionally, an important late Miocene to Pliocene magmatic event affected the whole Western Cordillera, at that moment already constituted by the accreted Cuna Terrane and the Calima Terrane. A shoshonitic belt that includes El Botón Trachybasalt, dated at 9.3 Ma by K–Ar (Restrepo et al., 1991) and at 11 ± 0.3 Ma by Ar–Ar (Rodríguez & Zapata, 2012), and several intrusives dated between 12 and 9 Ma by K–Ar and Ar–Ar (Rodríguez & Zapata, 2012 and references therein), mostly of monzonitic composition, extends between latitudes 5° 30' N and 7° 15' N. The magmatic belt migrated to the east and affected the Cauca River valley during the Combia magmatism between 10 and 6 Ma, which was responsible for the Au–Cu porphyries of the well–known "Middle–Cauca belt".

The late Miocene to Pliocene belt in the central and southern parts of the Calima Terrane is different from the early Oligocene – Miocene belt described above. The former includes the Piedrancha and Anchicayá Batholiths and El Pital and Tatamá Plutons, which are intrusions into the Calima Terrane prior to collision with the Cuna Terrane. Presumably, the two magmatic events were associated with different subduction zones.

The age range of the accretion of the Cuna Terrane to the Calima Terrane can be restricted because this event seems to have occurred after the intrusion of the Tatamá Pluton, dated at 17 Ma (Brook, 1984), and before the intrusion of El Boton Trachybasalt, dated at 11 Ma (Rodríguez & Zapata, 2012).

The Cuna Terrane represents an island arc generated on top of the Caribbean Plate farther south of its current position (Kennan & Pindell, 2009), which entered as a wedge between North and South America. The dextral movement in the Colombian west was blocked when the arc collided, allowing accretion of the Cuna Terrane to the Northern Andes. It is possible that the collision changed the direction of the fault displacement in the boundary zone between the Cuna and Calima Terranes. The formation of a bridge between North and South America allowed terrestrial faunal exchange between the two continents and implied an evolutionary mismatch between the Pacific Ocean marine faunas and those of the Caribbean Sea (Duque–Caro, 1985; Montes et al., 2012).

## 5. The Oceanic Terranes in the Cauca–Romeral Strip

### *5.1. Introduction*

As stated in the continental terranes chapter, the Cauca–Romeral strip is composed of continental and oceanic microterranes (Figure 3) resulting from the rupture of the collision zone between these domains. All of the recognized terranes form long N–S oriented strips, some only a few kilometers long and others several tens of kilometers. Within this strip, continental slivers correlatable with the Tahamí Terrane may be present as well as ultramafic bodies that have not yet been classified as terranes.

### *5.2. Ebéjico Terrane (Quebradagrande)*

We propose using the name Ebéjico Terrane instead of Quebradagrande Terrane to avoid confusion with the Quebradagrande Formation (Botero, 1963) or the Quebradagrande Complex (Maya & González, 1995). An additional reason for the change is to use a name related to pre–Columbian tribes or places, as has been common in past works.

The boundaries of the terrane are two faults of the CRFZ. To the east, the San Jerónimo Fault separates Quebradagrande from continental terranes such as the Tahamí, Anacona, and Yalcón Terranes, and to the west, the Silvia–Pijao Fault separates it from the Pozo (Arquía) Terrane south of the Arma Fault. North of this area, the Romeral Fault (sensu Grosse, 1926) separates the Ebéjico Terrane from the Amagá–Sinifaná Terrane (Restrepo et al., 2009a).

The lithology of the Ebéjico Terrane corresponds completely to the Quebradagrande Complex (Maya & González, 1995). It is composed of flows, pillow lavas, breccias, and tuffs of basaltic to andesitic composition interbedded with sedimentary rocks, including shales, arkoses, and cherts (González, 2001; Jaramillo et al., 2017; Rodríguez & Cetina, 2016). Manganese minerals that presumably formed on the ocean floor occur near Santa Bárbara, Antioquia (Durango, 1978). The basic rocks have undergone strong spilitization, forming abundant pumpellyite and chlorite that impart a green color to the greenstones (Restrepo & Toussaint, 1984). The unit forms a narrow and discontinuous belt with a maximum width of approximately 15 km that extends from Ecuador, where it is known as the Alao Terrane (Litherland et al., 1993), to the town of Liborina, Antioquia (Gómez et al., 2015a). The continuation of the terrane to the north of the Central Cordillera is not completely clear. Some authors (Mora–Bohórquez et al., 2017) have suggested

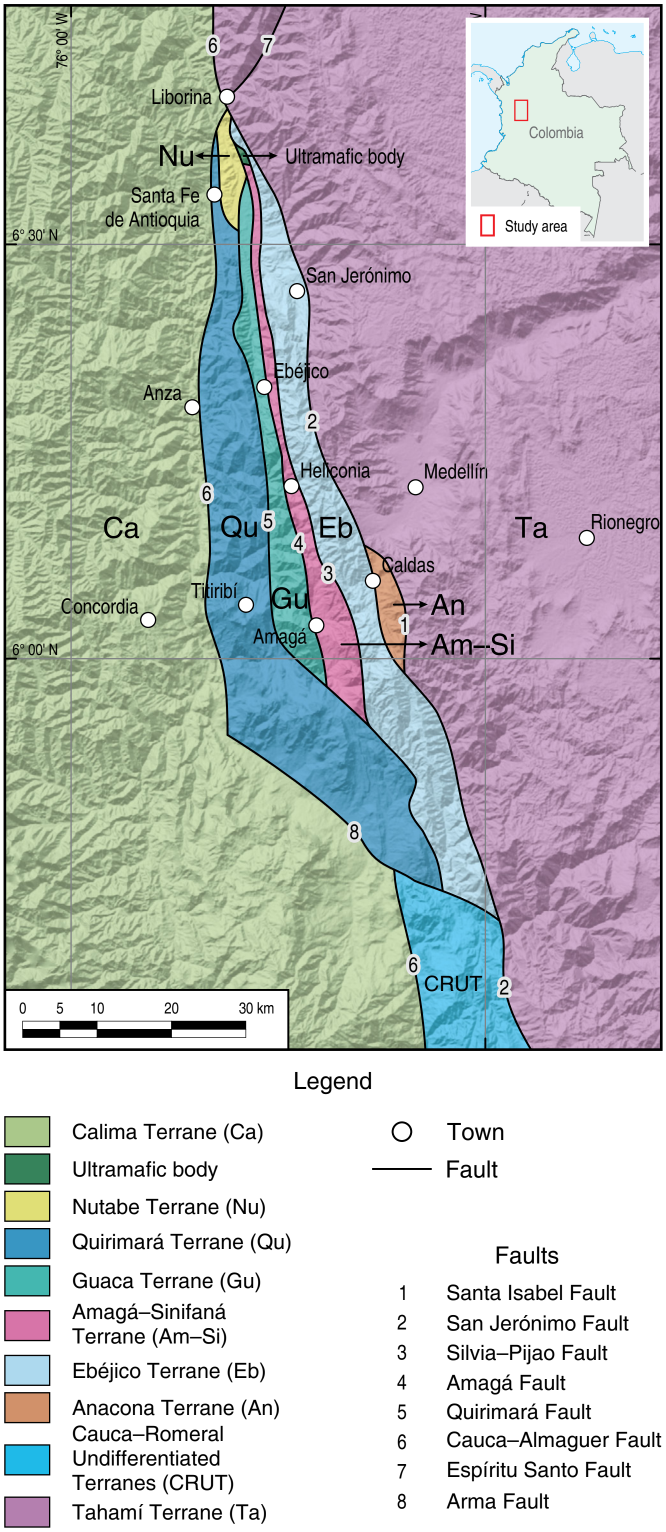



**Figure 3.** Schematic map of the small terranes in the Cauca–Romeral Fault Zone.

that it extends northward under the sedimentary cover of the Caribbean lowlands, but this continuity has not been proven. Cardona et al. (2012) seem to imply that the Quebradagrande Complex is not present in this area. On the surface, this terrane has not been mapped north of Liborina in the northern part of the Central Cordillera (Gómez et al., 2015a; Hall et al., 1972). However, recent unpublished mapping in the Liborina–Sabanalarga area has demonstrated the presence of low– to medium–grade metamorphic rocks that could be the northward continuation of the Quebradagrande Complex, although the nature of the metamorphism as dynamothermal or dynamic is debated. Guiral–Vega et al. (2015) and Jaramillo et al. (2017) suggest that metamorphism is dynamic in character and is associated with the important wrench faults that are present in the area. However, a close examination of thin sections shows that the mineralogy and microstructures of greenschists and muscovite–quartz schists correspond to dynamothermal metamorphism, followed by shearing and mylonitization along these faults. The San Jerónimo Fault proper also ends at Liborina. This truncation is probably because the Tahamí has a prong (the Liborina prong proposed here), the most westerly occurrence of the terrane, that seems to have squeezed the several CRFZ faults so that here they are separated by only a few kilometers. The possibility exists that a metamorphic Quebradagrande has been included in the Cajamarca Complex in previous mapping efforts. In fact, in the detailed mapping by Grosse (1926), this part of the diabases was considered to be a metamorphic variant, but this feature was apparently forgotten by subsequent field geologists. In a somewhat similar way, extensive mylonitic rocks produced by the shearing of the Quebradagrande Complex along the CRFZ, at an approximate latitude of 5° N, were mapped as regional metamorphic rocks equivalent to the Cajamarca Complex (González, 1980). Detailed mapping and petrological and geochronological studies are necessary to clarify this possibility.

The age of the Quebradagrande Complex based on fossils is Aptian – Albian (González, 1980) or Hauterivian – Albian (Botero et al., 1974). The unit has been difficult to date using K–Ar and Ar–Ar methods due to the alteration and very–low–grade metamorphism that is present almost everywhere, as well as the scarcity of zircons that has extensively hampered U–Pb dating. However, a U–Pb zircon date from a metatuff yielded an age of 114.3 ± 3.8 Ma (Villagómez et al., 2011), and a dioritic dike that is thought to be associated with Quebradagrande yielded a similar age of 112.6 ± 3.1 Ma (Cochrane et al., 2014). As such, an Early Cretaceous age is indicated for the unit. This age is valid both for the sedimentary rocks and for the volcanics because in the Arma fossiliferous locality, the authors collected volcanic rocks with *Trigonia* imprints and samples of volcanic rocks intercalated with sedimentary rocks; photos of these two samples were published by González (1980; see Figure 18). Some Late Cretaceous ages have also been reported. Botero (1963) considered the algal remains of the genus *Archeolithothamnion* to be indicative of a Late Cretaceous age, but in fact, the range of this genus extends from Late Jurassic to Neogene (Johnson, 1963). An age of 93.41 ± 0.51 Ma was obtained from a gabbroic intrusion supposedly related to the Quebradagrande volcanics, indicating a probable continuation of the magmatism to the Late Cretaceous (Jaramillo et al., 2017).

The origin of the Quebradagrande Complex is still debated. Although an island arc magmatic origin with possible remnants of a basal oceanic crust is recognized by most authors, the environment where the arc was formed is unclear. Nivia et al. (2006) suggested that the continental margin of South America was rifted in the Early Cretaceous, forming a marginal basin and a suprasubduction zone arc with Neoproterozoic (?) metamorphic rocks on both sides of the basin, followed by a final compressional event that closed the basin. This model was criticized for several reasons by Restrepo et al. (2009b), one of the reasons being the presence of belts exclusively composed of Quebradagrande or Arquía Complexes and completely limited by faults, with no intermingling between them. This condition is easily explained by a terrane model but is quite difficult to explain in an autochthonous model. On the other hand, models such as the one proposed by Villagómez & Spikings (2013) suggest that the arc was intraoceanic and related to a subduction zone that formed the Arquía Complex and that after the formation of these rocks, they were accreted to the continental border. Jaramillo et al. (2017) also argued for an oceanic arc but with a thickened crust; a major variation in this model is that the age of the arc is considered Late Cretaceous based on dating of granitoid rocks intruding the basic rocks.

The name of the terrane is taken from the present municipality of Ebéjico, Antioquia, where good exposures of the Quebradagrande Complex are found. This word is an indigenous term that was originally applied to a valley in the Western Cordillera where the city of Antioquia was first founded in 1541 (Aguilar–Rodas, 2001; Duque, 1967).

### 5.3. Pozo Terrane (Arquía)

The name of the Pozo Terrane is proposed for the terrane known by some authors as the Arquía Terrane because the names Arquía Group (Restrepo & Toussaint, 1976) and Arquía Complex already exist in the literature (Maya & González, 1995). Pozo is the name of an ethnic group that lived near the Arquía area, on the border between the Antioquia and Caldas Departments.

The Arquía Group (Restrepo & Toussaint, 1976) is a narrow belt of metamorphic rocks that include garnet amphibolites, serpentinites, greenschists, graphite–muscovite schists and quartzites. The units are crosscut by several faults and thus form discrete blocks. Some authors have called it a mélange (i.e., González, 2001; Rodríguez & Arango, 2013), but this term is not an adequate name since the definition of mélange requires a fine matrix that surrounds the blocks (Festa et al., 2010), which is not present in the area.

For the most part, the K–Ar and Ar–Ar ages of the Arquía garnet amphibolites yield Early Cretaceous ages (Restrepo et al., 2008; Villagómez & Spikings, 2013; Ruiz–Jiménez, 2014). The unit has been considered allochthonous, with the rocks formed in a subduction zone (Restrepo & Toussaint, 1976; Villagómez et al., 2011). However, P–T measurements by Garcia–Casco et al. (2011) have shown that the temperature gradient that formed these rocks is higher than those found in subduction zones, so a collisional origin has been proposed by these authors. Nonetheless, the association of metamorphic serpentinites with garnet amphibolites favors a subduction zone environment. In this same sense, Ríos–Reyes et al. (2017) proposed that the garnet amphibolites are retrograded eclogites similar to those found at Pijao and Barragán. An alternative autochthonous origin was proposed by Nivia et al. (2006), as discussed above for the Ebéjico Terrane, where the metamorphic Arquía rocks are considered Neoproterozoic rocks that formed part of the continental margin that was rifted during the Cretaceous. A similar autochthonous model was proposed by Cochrane et al. (2014).

The name of the group was extended by Maya & González (1995) to cover a complex that includes this unit, as well as several other metamorphic and even basic igneous rocks. The complex is located close to the Cauca River, extending along the western side of the Central Cordillera and the Cauca valley. Units such as the Bugalagrande Schists, the Sabaletas Schists, the Palestina–Balboa Schists, the Sucre Amphibolites, the Bolo Azul Complex, the Buesaco Schists, and the Complejo Río Rosario have been included in the complex. In Ecuador, its equivalent is the Alao Terrane (Litherland et al., 1994). In the original definition, high–P rocks such as the Pijao eclogites and Barragán blueschists and eclogites were not included, but modern usage has incorporated them within the complex.

Lithogeochemical analyses indicate that tholeiitic basalts with a MORB origin were the predominant protoliths of the basic rocks (Villagómez et al., 2011; García–Ramírez et al., 2017), although a small negative Nb anomaly indicates some affinity with IAT (Ruiz–Jiménez, 2014; Ruiz–Jiménez et al., 2012).

Due to the application of the name Arquía to different rank units, specifying in any article whether it is related to the Arquía "Group" (using the original definition and name given by Restrepo & Toussaint, 1976) or to the Arquía Complex is necessary. For example, the Sabaletas Schists (Toussaint et al., 1981) are considered part of the Arquía Complex, but in our opinion, they would not be part of the Arquía "Group". A similar situation is found for the newly defined Quimbaya Terrane (Chinchiná Gneiss) near Manizales (Restrepo & Toussaint, 2020). It may be part of the Arquía Complex but not of the Arquía "Group".

The terrane is separated from the Ebéjico Terrane to the east by the Silvia–Pijao Fault and to the west from the Calima Terrane by the Cauca–Almaguer Fault (Figure 4); both faults are part of the CRFZ (Maya & González, 1995).

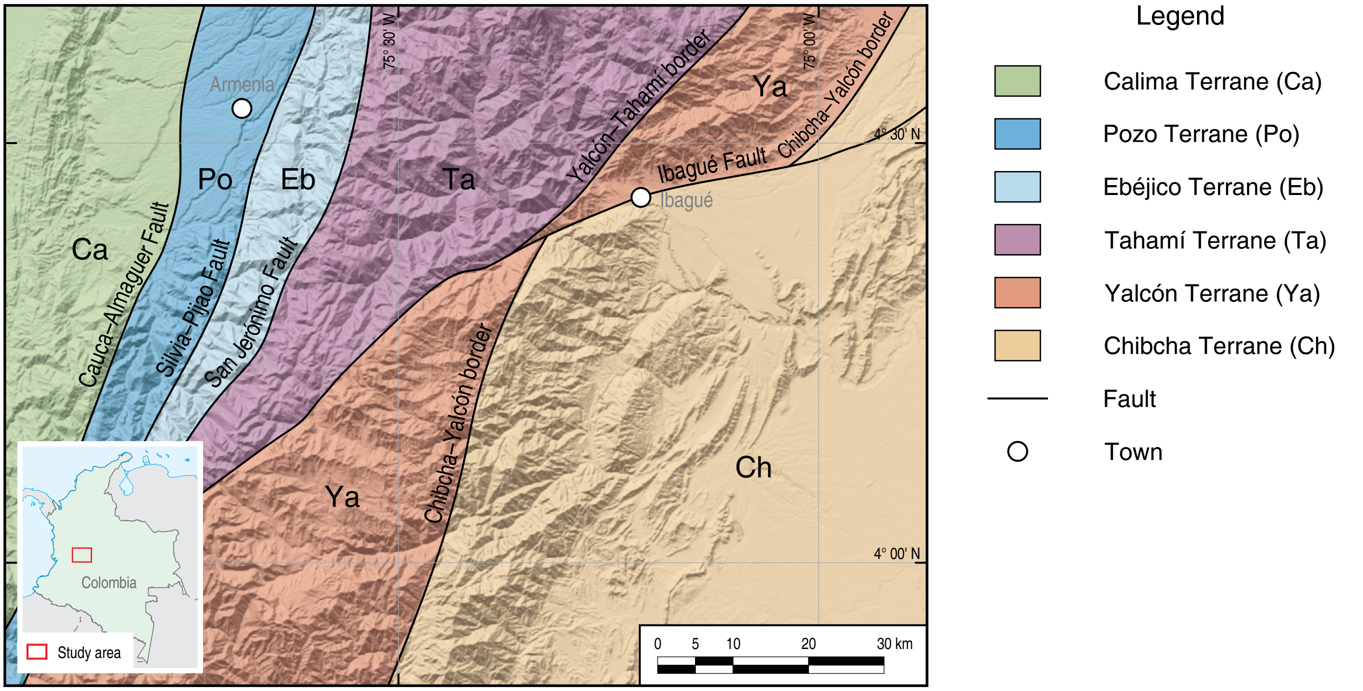



**Figure 4.** Schematic map of terranes and faults in the Ibagué area.

### 5.4. Bocaná Suspect Terrane

This suspect terrane occurs on the eastern side of the Aburrá valley (Medellín) and is composed mainly by amphibolites.

The main unit is the Santa Elena Amphibolite, which is composed of amphibolites, some of which are garnetiferous, and interbedded with quartz–biotite–graphite schists and some of which are associated ultramafic rocks (Restrepo, 2008). According to recent U–Pb zircon ages, metamorphism occurred in the mid–Cretaceous (Restrepo et al., 2012). This age is in contrast with the Triassic age of the contiguous La Espadera–Chupadero Amphibolites that compose part of the Triassic Aburrá Terrane (see below). The Santa Elena Amphibolites are geochemically different from La Espadera–Chupadero Amphibolites and are richer in incompatible elements (Restrepo, 2008). The age and composition are similar to those of the garnet amphibolites of the Arquía Complex, so perhaps they could be related in origin. The limits of the terrane are denoted by an inferred thrust fault that occurs at the base of the unit. The eastern side of the terrane was intruded by the Antioqueño Batholith, and on the western side, the Rodas Fault separates it from the Aburrá Terrane.

Bocaná was the name of Santa Elena Creek, which crosses the city of Medellín from east to west, in the indigenous language and means brackish water (Figure 5).

### 5.5. Aburrá Terrane

A dismembered ophiolite crops out along the Aburrá valley, composed of a large ultramafic body, El Picacho Metagabbros, and La Espadera–Chupadero Amphibolite. The ultramafic rock is composed mainly of olivine, in part serpentinized, chromium spinel and variable amounts of tremolite, talc, and chlorite. The presence of these three minerals is interpreted as the replacement of ortho– and clinopyroxenes during metamorphism (Correa–Martínez, 2007; Restrepo, 2008). Hence, the name Medellín metaharzburgitic unit is proposed for this unit (Garcia–Casco et al., 2020).

The metagabbros occur mostly on the western side of the valley, with Picacho Peak hosting the best exposure. They also appear as boulders in the extensive mass–movement deposits that are found on the western side of the Medellín valley. Metamorphic plagioclase and amphibole are the main minerals, with reddish–brown hornblende as a probable relict igneous mineral. The microstructures vary from granular gabbroic relict structures to well–foliated rocks that are practically lineated amphibolites. The unit is named the Picacho Metagabbros (Correa–Martínez et al., 2005). Hornblende–plagioclase metapegmatites are found in several places.

Fine–grained amphibolites underlie the ultramafic body, although the outcrops are difficult to observe due to the geometry of the ultramafic body and the abundant mass–movement deposits that cover the slopes of the Medellín valley. Lithogeochemical analyses of La Espadera–Chupadero Amphibolites show that these are of incipient island arc affinity (Restrepo, 2008), whereas the Santa Elena Amphibolites are richer in incompatible elements, representing a probable MORB origin. U–Pb analyses of La Espadera Amphibolite, metagabbros and metapegmatites yield Triassic ages (Restrepo et al., 2007; Restrepo et al., 2012). Apparently, the ages of approximately

Neogene
Paleogene
Cretaceous

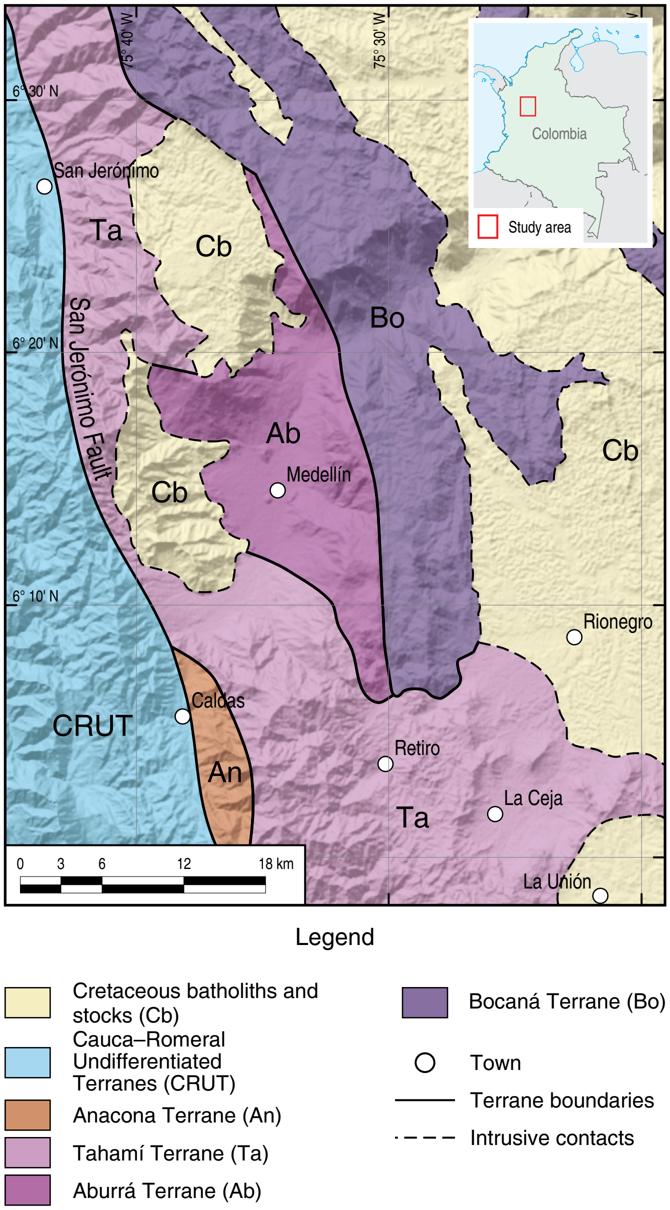



**Figure 5.** Schematic map of the terranes in the Medellín valley area.

228 Ma indicate the igneous formation of the mafic materials. The complex was named the Aburrá Ophiolitic Complex (Correa–Martínez et al., 2005).

Aburrá was the name of the natives that lived in the Medellín valley when the spaniards arrived. It is also the name of the valley where the city of Medellín and neighboring towns are located.

### 5.6. Quirimará Terrane (Sabaletas Schists)

This thin belt of intercalated greenschists and "blackschists", located between latitudes 6° 00' N and 6° 35' N, has been generally included in the Arquía Complex (i.e., Maya & González, 1995; Gómez et al., 2015a). The rocks in this belt are composed of albite–epidote–chlorite–actinolite schists intercalated with graphite–muscovite–quartz schists; according to Grosse (1926), garnet may also occur. They compose the wallrock of the famous Zancudo gold mines in Titiribí. In this unit, we also include the schists found at the western margin of the Cauca River near Santa Fé de Antioquia that were recently named the "Santa Fé de Antioquia Mylonites" (Correa et al., 2017).

The unit was named the Sabaletas Schists by Toussaint et al. (1981), who obtained Early Cretaceous ages (127 ± 5 Ma) from a greenschist using K–Ar dating; an age of 104 ± 5 Ma was also obtained using this method from actinolite in a metagabbro (Restrepo et al., 1991), and a younger age of 71 ± 3 Ma was obtained from actinolite (K–Ar) in a retrograded amphibolite (Ruiz–Jiménez, 2014). Vinasco & Cordani (2012) obtained an age of 127.5 ± 2 Ma by Ar–Ar dating. However, the real age of the unit has been debated. Rodríguez–Jiménez (2010) argued that the schists are intruded by dikes related to the Pueblito Diorite, dated at 233 Ma, whereas Giraldo–Arroyave (2010) dated by U–Pb zircons obtained from the greenschists at 72 Ma, which she considered a magmatic age. Similar Cretaceous ages were obtained using the same method by Correa et al. (2017) and Zapata & Cardona (2017). These apparently incompatible ages can be reconciled when it is observed that the Pueblito dioritic body and some schists lie to the east of the important Quirimará Fault, which is part of the CRFZ, whereas the Sabaletas Schists are on the western side of the fault. In this sense, the schists intruded by the Pueblito Dike would have no relation with the Sabaletas Schists; we propose that they would belong to different terranes, so the ages of the schists cannot be compared. As discussed in Restrepo & Toussaint (2020), the Pueblito Diorite and its surrounding schists are included in a new terrane named Guaca.

The age of metamorphism is post–70 Ma, but an exact age is unknown. However, it is quite likely close to the Cretaceous – Paleocene boundary, as discussed in the chapter on terranes with continental basement, for the accretion of the Cuna Terrane to the Tahamí Terrane (Restrepo & Toussaint, 2020). The Early Cretaceous K–Ar and Ar–Ar ages obtained from this unit remain unexplained; a possibility is that rocks with different ages but similar compositions were mingled during the accretion processes.

The unit has been considered to be composed mainly of mylonitic rocks (i.e., Correa et al., 2017; Zapata & Cardona, 2017), but a close petrographic inspection shows that they are actually dynamothermal schists affected locally by intense shearing and mylonitization (i.e., see Grosse's classic study, 1926, for petrographic descriptions). A shearing–related origin for the unit that would be associated with the accretion of the Calima Terrane to the western side of South America has been attributed by these authors. The dynamothermal nature of the schists probably implies a more complicated scenario, where the rocks underwent heating within the greenschist facies and even the epidote–amphibolite facies in addition to deformation produced by the accretion. Ruiz–Jiménez (2014) measured pressure conditions for an amphibolite found within the schists, finding a pressure between 6.7 and 7.0 kbar; under these conditions, the metamorphic rocks would have formed at depths on the order of 22–23 km. To explain this deep burial and subsequent exhumation, it is hypothesized here that these materials could have penetrated into the subduction zone that existed during the Late Cretaceous on the western side of the Tahamí Terrane. This subduction zone accommodated transpressional stress with strong right–lateral horizontal movement. Thus, this metamorphism could be called a *transpressional collisional metamorphism*, limited to a small area as opposed to normal collisional metamorphism. Subsequently, the right–lateral movement that had a vertical component could have exhumed the sliver. In this way, schists with mineralogic and microstructural dynamothermal characteristics would have been formed in a small area but with characteristics similar to those of regional metamorphism. Near the bordering faults, local mylonitization would have been intense. Presently, the nature of the protoliths is unknown. Although the mineralogical compositions of the rocks point to an ocean floor, rocks from this environment of approximately 70 Ma are unknown in the area. The limits of the sliver are the Quirimará Fault to the east, which separates it from the Guaca Terrane, and the Cauca–Almaguer Fault to the west, which separates it from the Calima Terrane. It should be noted that the Cauca–Almaguer Fault is considered the fault that places the oceanic rocks of the Calima Terrane in contact with other units of the Cauca–Romeral Terranes or even the Tahamí Terrane. Quirimará is an indigenous name applied to a hill formed by the schists west of the town of Ebéjico (Rodríguez–Pulgarín, 2011).

## 5.7. Nutabe Terrane (Sucre Amphibolite)

These amphibolites or metagabbros are strongly lineated rocks associated with serpentinized ultramafic rocks. The name Nutabe corresponds to a pre–Spanish tribe.

A hornblende K–Ar age of 284 ± 30 Ma has been reported (Restrepo et al., 1991), and more recently, ages of 260.7 ± 16.3 and 267.5 ± 16.2 Ma were obtained by U–Pb in magmatic zircons from these amphibolites (Correa et al., 2017). The body extends to the western margin of the Cauca River, where it is in fault contact with the northern extension of the Sabaletas Schists (also called the Santa Fé de Antioquia Mylonites) along one of the Cauca Faults. The history of metamorphism and accretion of this block has not yet been determined. The age is similar but somewhat older than the age of metamorphic rocks of the Tahamí Terrane.

## 5.8. Ultramafic Slivers

Several ultramafic slivers bounded by faults occur in this area, with the larger ones being the Heliconia and Sucre bodies. No special name is assigned for these very small terranes.

The Heliconia body is spatially associated with gabbros and the Pueblito Diorite. Several different origins have been proposed for ultramafic rocks. Rodríguez–Jiménez (2010) proposed that the three units are the components of a zoned body related to a suprasubduction zone, whereas according to Montoya & Peláez (1993), only the gabbro and the ultramafics are related, as parts of an ophiolite. Recently, the ultramafic unit was studied by González–Ospina (2016), who considered that it is an ophiolitic body related to the Medellín Metaharzburgitic Unit (Garcia–Casco et al., 2020). Neither the age of formation nor the age of emplacement have been defined for these rocks, although the fact that the Sucre body is spatially related to the Permian Sucre Amphibolites suggests a probable similar age.

In the CRFZ, several other similar slivers exist, such as the Planeta Rica Peridotites in the Córdoba Department (Dueñas & Duque–Caro, 1981), where an important nickel mine is located, and the Ginebra, Venus, La Tetilla, and Los Azules Ophiolitic Complexes (De Souza et al., 1984; Espinosa–Baquero, 1985; Nivia, 1987, 1991, 2001; Spadea et al., 1987) in the Cauca and Valle del Cauca Departments.

## 5.9. Nechí Terrane (Campamento)

Etayo–Serna et al. (1983) defined the Campamento Terrane to include these rocks. The name Nechí Suspect Terrane (Figure 6) seems to be a better name because it is based on the term “Nechí”, an indigenous name; it is also the name that was used originally for the basic–ultrabasic complex by Estrada (1967).

The terrane is composed of an ophiolitic complex located in the northern part of the Tahamí Terrane near the Nechí River between the towns of Yarumal and Campamento. It crops out along the axis of the Central Cordillera, on the northern side of the Antioqueño Batholith, and it is not part of the Cauca–Romeral Terranes.

This terrane is composed of serpentinized ultramafic rocks, gabbros, and basalts that are covered by flysch sedimentites known as the San Pablo Formation. All of the rocks are affected by very low– to low–grade metamorphism. The exact age is unknown. The age is pre–Late Cretaceous because the Antioqueño Batholith intrudes these rocks, but a maximum age is uncertain (Hall et al., 1972). The sequence was interpreted by Estrada (1967) as the Nechí Mafic–Ultramafic Complex, whereas Restrepo & Toussaint (1973) considered that it was part of a large obduction complex that emplaced ophiolitic bodies over the Tahamí Terrane during the Cretaceous. Presently, a portion of these bodies are included in the Aburrá Terrane. Mejía et al. (2017) considered that a marginal basin was formed in the area in Early Cretaceous before the intrusion of the Antioqueño Batholith; however, the details were not described.

According to Etayo–Serna et al. (1983), the eastern limit of the terrane is the San Lorencito–Corrales Fault, the western limit is the San Juan–Nechí Fault and the southern limit is de-

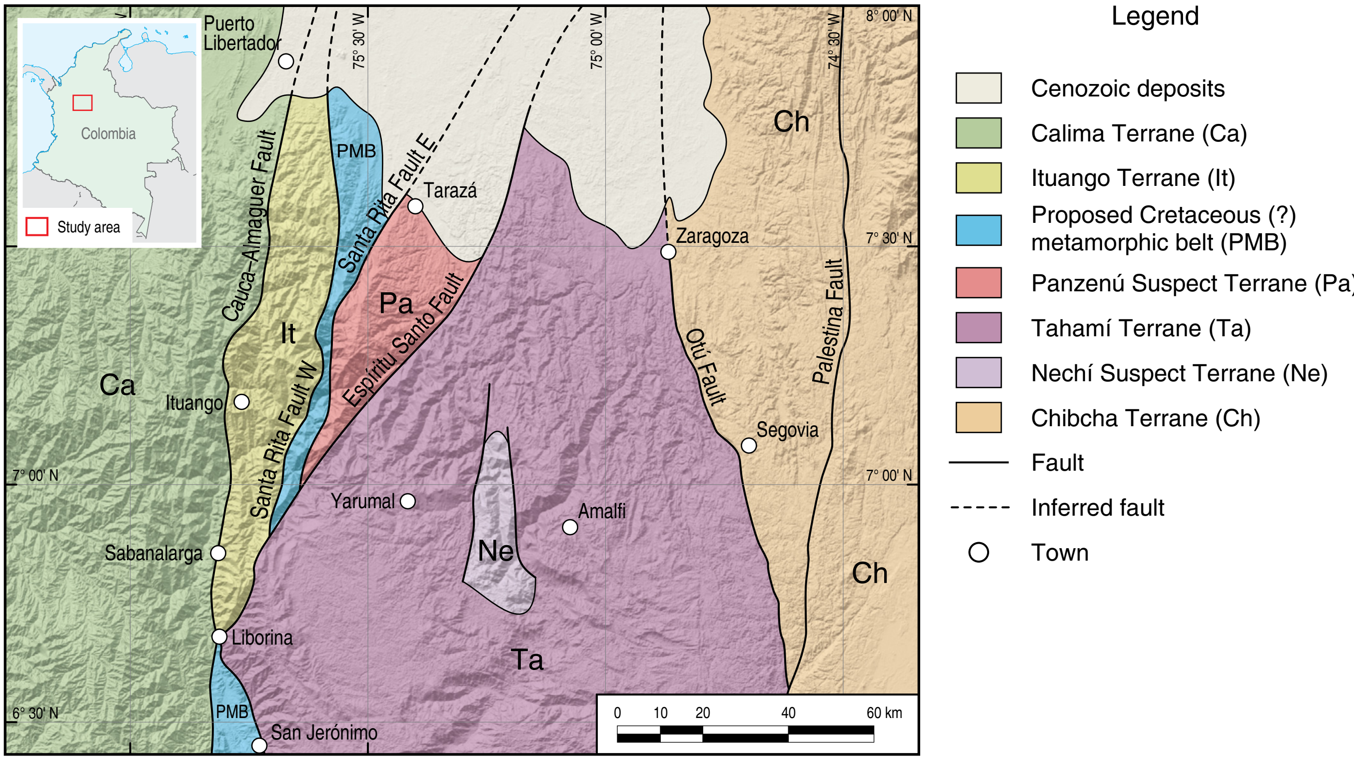



**Figure 6.** Schematic map of the Nechí Terrane.

fined by the Antioqueño Batholith. More field work is needed to determine whether the mafic–ultramafic complex is in situ or allochthonous.

## 6. The Tairona Terrane in the SNSM and La Guajira Peninsula

In a review by Etayo–Serna et al., (1983), the terranes with oceanic basement in northern Colombia are Santa Marta in the SNSM and Ruma in the LGP. Restrepo & Toussaint (1988) argued that these terranes are associated with the Calima Terrane, and Gómez et al. (2015a) suggested that they are associated with the Caribbean Megaterrane. This work groups them as a single Tairona Terrane, named after an important pre–Columbian culture in the SNSM (Figure 1).

The NW part of the SNSM corresponds to the Tairona Terrane formed mainly of muscovite and chlorite quartz schists, phyllites, slates, and some marbles. These rocks have been given several local names, such as La Gaira Schists, the Taganga Phyllites, and the San Lorenzo Schists. They were grouped as the Santa Marta Schists, whose magmatic age was dated by U–Pb in zircons between 91 and 80 Ma (Cardona et al., 2010). This metamorphism has been geochronologically difficult to determine, but these authors believe that metamorphism had already ended at 65 Ma. The granodioritic to quartz–monzonitic Santa Marta Batholith intrudes the previous metamorphic set and was dated by U–Pb between 56 and 50 Ma (Mejía–Herrera et al., 2008; Duque, 2010). Another stock, the Toribio Pluton, is also considered Paleocene. In the SNSM, the Tairona Terrane is linked to the Kogi Terrane (see Restrepo & Toussaint, 2020) by the inverse Guachaca Fault System. Several of these faults are oblique relative to the original boundary. The Buritaca Pluton, dated by U–Pb as 50 ± 1.5 Ma (Duque, 2010), appears to intrude the boundary between the terranes, which suggests their accretion in the early Paleocene–Eocene. In the LGP, the Tairona Terrane, limited to the SE by the Simarua–Osorio Fault that produced a strong mylonitization, overrides the Kogi Terrane. According to the Geological Map of Colombia (Gómez et al., 2015b), reef limestones associated with marls, mudstone, and sandstone of the Eocene Uitpa Formation cover the border, which suggests that the suturing between the Tairona and Kogi Terranes occurred in the Late Cretaceous – Paleocene.

In LGP, the Tairona Terrane includes the presumably Late Cretaceous Etpana Metamorphic Complex and is intruded by the Parashi Granodioritic Pluton that has been dated by U–Pb at 49 ± 1 Ma (Cardona et al., 2014). The presence of serpentinites with rodingite dikes is noted in the Etpana Complex and in the Cabo de la Vela. Schists, amphibolites, and phyllites from the Jarara and Carpintero Ranges are also found in this area. Cardona et al. (2014) hypothesized that an intraoceanic island arc environment developed in an allochthonous position during the Cretaceous and was accreted before the Eocene intrusion of the Parashi Pluton. Piraquive et al. (2017) suggested that units with oceanic affinity such as the Jarara Formation from the Tairona Terrane override continental units similar to the Macuira Gneiss

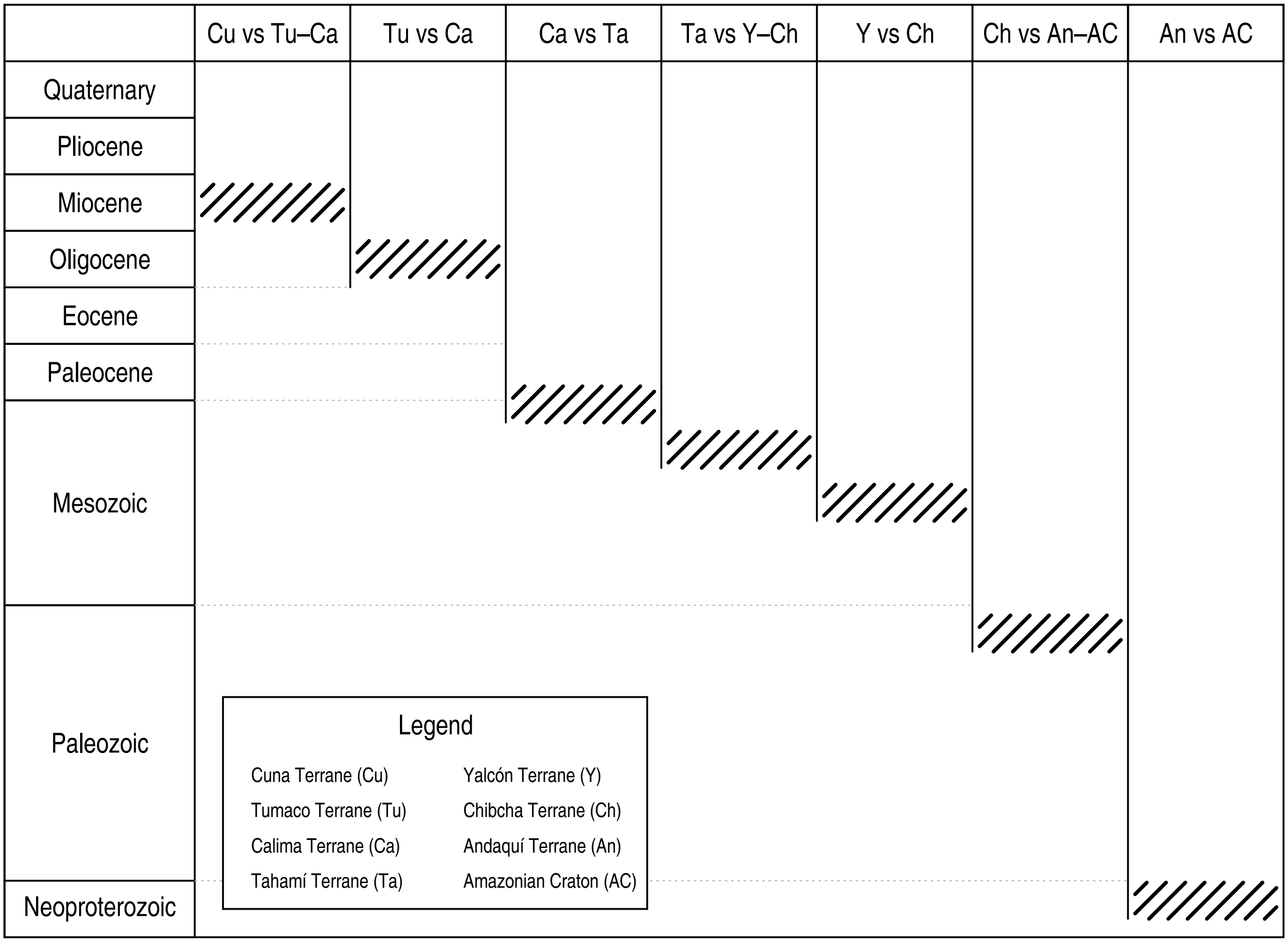



**Figure 7.** Timing of accretions of Colombian Terranes.

from the Kogi Terrane. These authors proposed that accretion occurred between the Late Cretaceous and the Paleocene.

The Tairona Terrane has certain similarities to the Calima and Tumaco Terranes. All have Cretaceous oceanic basements, but until more information is available, it seems more appropriate to treat them as different terranes.

## 7. Conclusions

With few exceptions, all the terranes west of the San Jerónimo Fault have oceanic crust. They probably formed south of their present positions and then moved northward to collide with the Tahamí Terrane in Late Cretaceous time or later (Figure 7). The accretion of the Calima Terrane occurred close to the Cretaceous – Paleogene boundary. Then, between the mid–Eocene and early Miocene, the Tumaco Suspect Terrane was accreted. Finally, the Cuna Terrane collided with the rest of the terranes during the Miocene (17–11 Ma), causing important changes in the geology of Colombia (Figure 7). Most of the terranes are part of the Caribbean Plateau. A special type of metamorphism is described here as collisional transpressional metamorphism, which produces dynamothermal metamorphism in small areas.

## Acknowledgments

We wish to thank Gómez et al. (2015c) for the excellent compilation of isotopic dates in Colombia. Without them, this work would have been much more difficult.

We are also grateful to Andrés PARDO–TRUJILLO and Yamirka ROJAS–AGRAMONTE, reviewers of this chapter. Their suggestions greatly improved the manuscript.

The authors especially wish to thank Professor Oswaldo ORDOÑEZ–CARMONA for the interesting discussions about the geology of western Colombia while sharing the teaching of geological field work. Although in some cases we do not agree, the difficult questions posed by professor ORDOÑEZ–CARMONA motivated new ideas regarding the numerous geological problems we discussed. The possibility of a Cretaceous unit between the Ituango Block and the Tahamí and Panzenú Terranes was discussed several times, as well as the importance of collisional metamorphism in the CRFZ.

We also want to thank Fernando ALCÁRCEL for drawing the final versions of the figures.

## References


Agencia Nacional de Hidrocarburos & Geología Regional y Prospección. 2011. Cartografía geológica a escala 1:100 000 de las planchas 340, 362, 385 y 409 localizadas en la Cuenca Tumaco, así como el inherente levantamiento de columnas estratigráficas y muestreo litológico para los análisis petrográficos, bioestratigráficos, geoquímicos, petrofísicos y radiométricos. Contrato 084 de 2010, unpublished report. 207 p.

Aguilar–Rodas, R. 2001. Fundación de la ciudad de Antioquia–1541. Academia Antioqueña de Historia, 144 p. Medellín.

Álvarez, J. & González, H. 1978. Geología y geoquímica del cuadrángulo I–7 Urrao. Ingeominas, Internal report 1761, 347 p. Medellín.

Álvarez, J. & Linares, E. 1981. Edades K/Ar del Batolito de Piedrancha y el Stock de Arboledas, departamento de Nariño. Boletín de Ciencias de la Tierra, (5–6): 113–118.

Aspden, J. 1984. The geology of the Western Cordillera and Pacific coastal plain in the departament of Valle del Cauca (sheets 261, 278, 279, 280 and 299). Ingeominas–Misión Británica, Internal report 1959, 61 p. Cali.

Aspden, J.A. & McCourt, W.J. 1986. Mesozoic oceanic terrane in the central Andes of Colombia. Geology, 14(5): 415–418. https://doi.org/10.1130/0091-7613(1986)14<415:MOTITC>2.0.CO;2

Bandy, O.L. 1970. Upper Cretaceous–Cenozoic paleobathymetric cycles, eastern Panamá and northern Colombia. American Association of Petroleum Geologists Bulletin, 54 (9): 1782.

Barrero, D. 1979. Geology of the central Western Cordillera, west of Buga and Roldanillo, Colombia. Publicaciones Geológicas Especiales del Ingeominas, (4): 1–75. Bogotá.

Bird, P. 2003. An updated digital model of plate boundaries. Geochemistry, Geophysics, Geosystems, 4(3): 1–52. https://doi.org/10.1029/2001GC000252

Botero, G. 1936. Bosquejo de la paleontología colombiana. Bachelor thesis, Universidad Nacional de Colombia, 116 p. Medellín.

Botero, G. 1963. Contribución al conocimiento de la geología de la zona central de Antioquia. Universidad Nacional de Colombia, Anales de la Facultad de Minas, 57, 101 p. Medellín.

Botero, G., Toussaint, J.F., Ospina, H., Ortiz, F. & Gómez, J. 1974. Yacimiento fosilífero de Arma. Universidad Nacional de Colombia, Anales de la Facultad de Minas, 58, p. 1–12. Medellín.

Bourgois, J., Azéma, J., Tournon, J., Bellon, H., Calle, B., Parra, E., Toussaint, J.F., Glaçon, G., Feinberg, H., De Wever, P. & Origlia, I. 1982a. Ages et structures des complexes basiques et ultrabasiques de la façade pacifique entre 3° N et 12° N (Colombie, Panama et Costa Rica). Bulletin de la Société Géologique de France, 24(3): 545–554. https://doi.org/10.2113/gssgfbull.S7-XXIV.3.545

Bourgois, J., Calle, B., Tournon, J. & Toussaint, J.F. 1982b. The andean ophiolitic megastructures on the Buga–Buenaventura transverse (Western Cordillera–Valle, Colombia). Tectonophysics, 82(3–4): 207–229. https://doi.org/10.1016/0040-1951(82)90046-4

Brook, M. 1984. New radiometric age data from SW Colombia. Ingeominas–Misión Británica, unpublished report 10, 25 p. Cali.

Buchely, F., Parra, E., Castillo, H., González, F., Dávila, C.F. & Romero, Ó.A. 2009. Realización de la cartografía geológica y muestreo geoquímico en las planchas 144, 145, 128, 129, 113 y 114 (1580 $km^2$). Contrato No. 390 de 2007. Ingeominas & GRP Ltda., 172 p. Bogotá.

B&G Unión Temporal. 2006. Cartografía geológica en los cinturones plegados Sinú–San Jacinto. Agencia Nacional de Hidrocarburos, unpublished report, 46 p. Bogotá.

Calle, B. & Salinas, R. 1986. Memoria explicativa: Geología y geoquímica de la plancha 165 Carmen de Atrato. Scale 1:100 000. Ingeominas, Internal report 1987, 140 p. Medellín.

Cardona, A., Valencia, V., Bustamante, C., García–Casco, A., Ojeda, G., Ruiz, J., Saldarriaga, M. & Weber, M. 2010. Tectonomagmatic setting and provenance of the Santa Marta Schists, northern Colombia: Insights on the growth and approach of Cretaceous Caribbean oceanic terranes to the South American continent. Journal of South American Earth Sciences, 29(4): 784–804. https://doi.org/10.1016/j.jsames.2009.08.012

Cardona, A., Montes, C., Ayala, C., Bustamante, C., Hoyos, N., Montenegro, O., Ojeda, C., Niño, H., Ramirez, V., Valencia, V., Rincón, D., Vervoort, J. & Zapata, S. 2012. From arc–continent collision to continuous convergence, clues from Paleogene conglomerates along the southern Caribbean–South America Plate boundary. Tectonophysics, 580: 58–87. https://doi.org/10.1016/j.tecto.2012.08.039

Cardona, A., Weber, M., Valencia, V., Bustamante, C., Montes, C., Cordani, U. & Muñoz, C.M. 2014. Geochronology and geochemistry of the Parashi granitoid, NE Colombia: Tectonic implication of short–lived early Eocene plutonism along the SE Caribbean margin. Journal of South American Earth Sciences, 50: 75–92. https://doi.org/10.1016/j.jsames.2013.12.006

Case, J.E. & Holcombe, T.L. 1980. Geologic–tectonic map of the Caribbean region. Scale 1:2 500 000. U.S. Geological Survey, series 1100. https://doi.org/10.3133/i1100

Case, J.E., Durán, L.G., López, A. & Moore, W.R. 1971. Tectonic investigations in western Colombia and eastern Panama. Geological Society of America Bulletin, 82(10): 2685–2712. https://doi.org/10.1130/0016-7606(1971)82[2685:TIIWCA]2.0.CO;2

Cochrane, R., Spikings, R., Gerdes, A., Winkler, W., Ulianov, A., Mora, A. & Chiaradia, M. 2014. Distinguishing between in–situ and accretionary growth of continents along active margins. Lithos, 202–203: 382–394. https://doi.org/10.1016/j.lithos.2014.05.031

Coney, P.J., Jones, D.L. & Monger, J.W.H. 1980. Cordilleran suspect terranes. Nature, 288: 329–333. https://doi.org/10.1038/288329a0

Correa–Martínez, A.M. 2007. Petrogênese e evolução do Ofiolito de Aburrá, Cordilhera Central dos Andes colombianos. Doctoral thesis, Universidade de Brasilia, 178 p. Brasilia.

Correa–Martínez, A.M., Martens, U., Restrepo, J.J., Ordóñez–Carmona, O. & Pimentel, M.M. 2005. Subdivisión de las metamorfitas básicas de los alrededores de Medellín–cordillera Central de Colombia. Revista de la Academia Colombiana de Ciencias Exactas, Físicas y Naturales, 29(112): 325–344.

Correa, T., Zapata, J.P., Rincón, A.V., Obando, M.G., Ortiz, F.H. & Rodríguez, G. 2017. Edades U–Pb y Ar–Ar obtenidas durante la cartografía 1:50 000 del borde occidental de la plancha 130 Medellín Occidental. XVI Congreso Colombiano de Geología. Memoirs, p. 1223–1228. Santa Marta.

Desmet, A. 1994. Ophiolites et séries basaltiques crétacées des regions caraibes et nordandines: Bassins marginaux, dorsales ou plateaux océaniques? Doctoral thesis, Université Henri Poincaré, 597 p. Nancy, France.

De Souza, H.A.F., Espinosa, A. & Delaloye, M. 1984. K–Ar ages of basic rocks in the Patia valley, southwest Colombia. Tectonophysics, 107(1–2): 135–145. https://doi.org/10.1016/0040-1951(84)90031-3

Dueñas, H. & Duque–Caro, H. 1981. Geología del cuadrángulo F–8 Planeta Rica. Boletín Geológico, 24(1), 35 p. Bogotá.

Duque–Caro, H. 1984. Structural style, diapirism, and accretionary episodes of the Sinú–San Jacinto terrane, northwestern Caribbean borderland. In: Bonini, W.E., Hargraves, R.B. & Shagam, R. (editors), The Caribbean–South American plate boundary and regional tectonics. Geological Society of America, Memoir 162, p. 303–316. https://doi.org/10.1130/MEM162-p303

Duque–Caro, H. 1985. La Cuenca del Atrato en el bloque del Chocó (Sudamérica noroccidental) y sus implicaciones estratigráficas y estructurales. VI Congreso Latinoamericano de Geología. Proceedings, 1, p. 61. Bogotá.

Duque–Caro, H. 1990. The Choco Block in the northwestern corner of South America: Structural, tectonostratigraphic, and paleogeographic implications. Journal of South American Earth Sciences, 3(1): 71–84. https://doi.org/10.1016/0895-9811(90)90019-W

Duque, F. 1967. Historia del departamento de Antioquia. Imprenta departamental, 1175 p. Medellín.

Duque, J.F. 2010. Geocronología (U/Pb y $^{40}Ar/^{39}Ar$) y geoquímica de los intrusivos paleógenos de la Sierra Nevada de Santa Marta y sus relaciones con la tectónica del Caribe y el arco magmático circun–caribeño. Master thesis, Universidad Nacional Autónoma de México, 189 p. México D.F.

Durango, J. 1978. Prospección geoquímica de las quebradas La Loma y Frías, Santa Bárbara, Antioquia. Ingeominas. Internal report 1770, 45 p. Bogotá.

Echeverría, L.M. 1982. Komatiites from Gorgona Island, Colombia. In: Arndt, N.T. & Nisbet, E.G. (editors), Komatiites. George Allen & Unwin, p. 199–209. London, UK.

Espinosa–Baquero, A. 1985. El Macizo de Ginebra, Valle, una nueva secuencia ofiolítica sobre el flanco occidental de la cordillera Central. VI Congreso Latinoamericano de Geología. Proceedings, 3, p. 46–57. Bogotá.

Espinosa–Baquero, A., Delaloye, M. & Wagner, J.J. 1982. Radiometric ages of the Gorgona Island (Colombia), Komatiitic ophiolite. Ofioliti, 7(2–3): 237–238.

Estrada, A. 1967. Asociación magmática básica del Nechí. Bachelor thesis, Universidad Nacional de Colombia, 88 p. Medellín.

Estrada, J.J. 1995. Paleomagnetism and accretion events in the northern Andes. Doctoral thesis, State University of New York at Binghamton, 170 p. New York, USA.

Etayo–Serna, F. 1989. Campanian to Maastrichtian fossils in the northeastern Western Cordillera, Colombia. Geología Norandina, (11): 23–31.

Etayo–Serna, F., González, H. & Álvarez, E. 1980. Mid–Albian ammonites from northern Western Cordillera, Colombia, S.A. Geología Norandina, (2): 25–30.

Etayo–Serna, F., Parra, E. & Rodríguez, G. 1982. Análisis facial del “Grupo del Dagua” con base en secciones aflorantes al oeste de Toro (Valle del Cauca). Geología Norandina, (5): 3–12.

Etayo–Serna, F., Barrero, D., Lozano, H., Espinosa, A., González, H., Orrego, A., Ballesteros, I., Forero, H., Ramírez, C., Zambrano–Ortiz, F., Duque–Caro, H., Vargas, R., Núñez, A., Álvarez, J., Ropaín, C., Cardozo, E., Galvis, N., Sarmiento, L., Alberts, J.P., Case, J.E., Singer, D.A., Bowen, R.W., Berger, B.R., Cox, D.P. & Hodges, C.A. 1983. Mapa de terrenos geológicos de Colombia. Publicaciones Geológicas Especiales del Ingeominas, 14(1): 1–135 p. Bogotá.

Festa, A., Pini, G.A., Dilek, Y. & Codegone, G. 2010. Mélanges and mélange–forming processes: A historical overview and new concepts. International Geology Review, 52(10–12): 1040–1105. https://doi.org/10.1080/00206810903557704

Gansser, A. 1973. Facts and theories on the Andes. Journal of the Geological Society of London, 129(2): 93–131. https://doi.org/10.1144/gsjgs.129.2.0093

Garcia–Casco, A., Blanco–Quintero, I.F., Ruiz–Jiménez, E.C., Toro–Toro, L.M., Moreno–Sánchez, M., Gómez–Cruz, A.J. & Vinasco–Vallejo, C.J. 2011. Thermobarometry of amphibolites from the Arquía Complex (Central Colombia): Geodynamic implications. XIV Congreso Latinoamericano de Geología y XIII Congreso Colombiano de Geología. Memoirs, p. 435. Medellín.

Garcia–Casco, A., Restrepo, J.J., Correa–Martínez, A.M., Blanco–Quintero, I.F., Proenza, J.A., Weber, M. & Butjosa, L. 2020. The petrologic nature of the “Medellín Dunite” revisited: An algebraic approach and proposal of a new definition of the geological body. In: Gómez, J. & Pinilla–Pachon, A.O. (editors), The Geology of Colombia, Volume 2 Mesozoic. Servicio Geológico Colombiano, Publicaciones Geológicas Especiales 36, p. 45–75. Bogotá. https://doi.org/10.32685/pub.esp.36.2019.02

García–Ramírez, C.A., Ríos–Reyes, C.A., Castellanos–Alarcón, O.M. & Mantilla–Figueroa, L.C. 2017. Petrology, geochemistry and geochronology of the Arquía Complex´s metabasites at the Pijao–Génova sector, Central Cordillera, Colombian Andes. Boletín de Geología, 39(1): 105–126. http://dx.doi.org/10.18273/revbol.v39n1-2017005

Giraldo–Arroyave, M.I. 2010. Esquema geodinámico de la parte noroccidental de la cordillera Central de Colombia. Master thesis, Universidad Nacional de Colombia, 146 p. Medellín.

Giraldo–Ramírez, W.E. 2017. Novas idades U–Pb (LA–ICP–MS) de rochas granitoides na região de Sabanalarga (Colômbia) e sua correlação com a evolução da Placa do Caribe. Master thesis, Universidade de Rio de Janeiro, 88 p. Rio de Janeiro.

Gómez, J., Nivia, Á., Montes, N.E., Diederix, H., Almanza, M.F., Alcárcel, F.A. & Madrid, C.A. 2015a. Explanatory notes: Geological Map of Colombia. In: Gómez, J & Almanza, M.F. (editors), Compilando la geología de Colombia: Una visión a 2015. Servicio Geológico Colombiano, Publicaciones Geológicas Especiales 33, p. 35–60, Bogotá.

Gómez, J., Montes, N., Nivia, Á. & Diederix, H., compilers. 2015b. Geological Map of Colombia 2015. Scale 1:1 000 000. Servicio Geológico Colombiano, 2 sheets. Bogotá. https://doi.org/10.32685/10.143.2015.936

Gómez, J., Montes, N.E., Alcárcel, F.A. & Ceballos, J.A. 2015c. Cátálogo de dataciones radiométricas de Colombia en ArcGIS y Google Earth. In: Gómez, J & Almanza, M.F. (editors), Compilando la geología de Colombia: Una visión a 2015. Servicio Geológico Colombiano, Publicaciones Geológicas Especiales 33, p. 63–419, Bogotá.

Gómez–Vargas, D., Duque, J. & Molina–Garza, R. 2017. Deformación de los sedimentos pertenecientes a la Formación Penderisco, en respuesta a la colisión del Bloque Chocó, flanco oriental de la cordillera Occidental. XVI Congreso Colombiano de Geología. Memoirs, p. 1827–1830. Santa Marta.

González, H. 1980. Geología de las planchas 167 Sonsón y 187 Salamina. Scale 1:100 000. Boletín Geológico, 23(1): 1–174.

González, H. 2001. Memoria explicativa: Mapa geológico del departamento de Antioquia. Scale 1:400 000. Ingeominas, 240 p. Medellín.

González, H. 2010. Geoquímica, geocronología de las unidades litológicas asociadas al sistema de fallas Cauca–Romeral, sector centro–sur. Tomo I. Ingeominas, unpublished report, 412 p. Medellín.

González, H., Zapata, G. & Montoya, D.M. 2002. Memoria explicativa: Geología y geomorfología de la plancha 428 Túquerres, departamento de Nariño. Ingeominas, 168 p. Medellín.

González–Ospina, L.J. 2016. Petrogénesis de los complejos ultramáficos de Heliconia–Angelópolis y del oriente de Medellín, Antioquia, Colombia. Master thesis, Universidad Nacional de Colombia, 108 p. Bogotá.

Grosse, E. 1926. Estudio geológico del terciario carbonífero de Antioquia en la parte occidental de la cordillera Central de Colombia, entre el río Arma y Sacaojal, ejecutado en los años de 1920–1923. Dietrich Reimer, 361 p. Berlin.

Guiral–Vega, J.S., Rincón–Gamero, J.J. & Ordoñez–Carmona, O. 2015. Geología de la porción sur del Batolito de Sabanalarga: Implicaciones para la teoría de terrenos al occidente de Colombia. Boletín de Ciencias de la Tierra, (38): 41–48. https://doi.org/10.15446/rbct.n38.46367

Haffer, J. 1967. On the geology of the Uraba and northern Choco regions, NW Colombia. Colombian Petroleum Company, COLPET. Internal report GR–351, 106 p. Bogotá.

Hall, R., Álvarez, J. & Rico, H. 1972. Geología de los departamentos de Antioquia y Caldas–Subzona II–A. Boletín Geológico, 20(1): 1–85.

Hincapié–Gómez, S., Cardona, A., Jiménez, G., Monsalve, G., Ramírez–Hoyos, L. & Bayona, G. 2018. Paleomagnetic and gravimetrical reconnaissance of Cretaceous volcanic rocks from the western Colombian Andes: Paleogeographic connections with the Caribbean Plate. Studia Geophysica et Geodaetica, 62(3): 485–511. https://doi.org/10.1007/s11200-016-0678-y

Howell, D.G. 1989. Tectonics of suspect terranes: Mountain building and continental growth. Chapman and Hall, 231 p. London, UK.

Irving, E.M. 1971. La evolución estructural de Los Andes más septentrionales de Colombia. Boletín Geológico, 19(2): 1–90.

Jaramillo, J.S., Cardona, A., León, S., Valencia, V. & Vinasco, C. 2017. Geochemistry and geochronology from Cretaceous magmatic and sedimentary rocks at 6°35’ N, western flank of the Central Cordillera (Colombian Andes): Magmatic record of arc growth and collision. Journal of South American Earth Sciences, 76: 460–481. https://doi.org/10.1016/j.jsames.2017.04.012

Johnson, J.H. 1963. The algal genus *Archaeolithothamnium* and its fossil representatives. Journal of Paleontology, 37(1): 175–211.

Kennan, L. & Pindell, J.L. 2009. Dextral shear, terrane accretion and basin formation in the northern Andes: Best explained by interaction with a Pacific–derived Caribbean Plate? In: James, K.H., Lorente, M.A. & Pindell, J.L. (editors), The origin and evolution of the Caribbean Plate. Geological Society of London, Special Publication 328, p. 487–531. https://doi.org/10.1144/SP328.20

Kerr, A.C., Marriner, G.F., Tarney, J., Nivia, Á., Saunders, A.D., Thirlwall, M.F. & Sinton, C.W. 1997. Cretaceous basaltic terranes in western Colombia: Elemental, chronological and Sr–Nd isotopic constraints on petrogenesis. Journal of Petrology, 38(6): 677–702. https://doi.org/10.1093/petroj/38.6.677

Kerr, A.C., Tarney, J., Kempton, P.D., Pringle, M. & Nivia, Á. 2004. Mafic pegmatites intruding oceanic plateau gabbros and ultramafic cumulates from Bolívar, Colombia: Evidence for a ‘wet’ mantle plume? Journal of Petrology, 45(9): 1877–1906. https://doi.org/10.1093/petrology/egh037

Leal–Mejía, H. 2011. Phanerozoic gold metallogeny in the Colombian Andes: A tectono–magmatic approach. Doctoral thesis, Universitat de Barcelona, 989 p. Barcelona.

Litherland, M., Aspden, J.A. & Egüez, A. 1993. The geotectonics evolution of Ecuador in the Phanerozoic. Second ISAG, 21–23: 215–218. Oxford, United Kingdom.

Litherland, M., Aspden, J.A. & Jemielita, R.A. 1994. The metamorphic belts of Ecuador. Overseas Memoir of the British Geological Survey 11, 147 p. Nottingham, England.

Maya, M. & González, H. 1995. Unidades litodémicas en la cordillera Central de Colombia. Boletín Geológico, 35(2–3): 43–57.

McCourt, W.J. 1984. Geología de la plancha 262 Génova. Scale 1:100 000. Ingeominas. Bogotá.

McCourt, W.J., Aspden, J.A. & Brook, M. 1984. New geological and geochronological data from the Colombian Andes: Continental growth by multiple accretion. Journal of the Geological Society, 141(5): 831–845. https://doi.org/10.1144/gsjgs.141.5.0831

McCourt, W.J., Muñoz, C.A. & Villegas, H. 1990. Regional geology and gold potential of the Guapi–Napi drainage basin and upper Timbiquí River, Cauca Department, SW Colombia, phase II. Ingeominas–British Geological Survey, unpublished report, 62 p. Cali.

McGeary, S. & Ben–Avraham, Z. 1985. The accretion of Gorgona Island, Colombia: Multichannel seismic evidence. In: Howell, D.G. (editor), Tectonostratigraphic terranes of the Circum–Pacific region. Circum–Pacific Council for Energy and Mineral Resources, Earth Sciences Series, 1: 543–554.

Mejía, D., Cardona, M., Serna, S. & Valencia, V. 2017. Metasedimentitas de San Luis, formación y cierre de las cuencas marginales del Cretáceo Inferior en la cordillera Central? XVI Congreso Geológico Colombiano. Memoirs, p. 1849–1850. Santa Marta.

Mejía–Herrera, P., Santa–Escobar, M., Ordoñez–Carmona, O. & Pimentel, M.M. 2008. Consideraciones petrográficas, geoquímicas y geocronológicas de la parte occidental del Batolito de Santa Marta. DYNA, 75(155): 223–236.

Montes, C., Bayona, G., Cardona, A., Buchs, D.M., Silva, C.A., Morón, S., Hoyos, N., Ramírez, D.A., Jaramillo, C.A. & Valencia, V. 2012. Arc–continent collision and orocline formation: Closing of the Central American seaway. Journal of Geophysical Research: Solid Earth, 117(B4): 1–25 p. https://doi.org/10.1029/2011JB008959

Montoya, D. & Peláez, I. 1993. Ultramafitas y rocas relacionadas de Heliconia, Antioquia. Bachelor thesis, Universidad Nacional de Colombia, 223 p. Medellín.

Mora–Bohórquez, A., Ibañez–Mejia, M., Oncken, O., de Freitas, M., Vélez, V., Mesa, A. & Serna, L. 2017. Structure and age of the Lower Magdalena Valley Basin basement, northern Colombia: New reflection–seismic and U–Pb–Hf insights into the termination of the central Andes against the Caribbean Basin. Journal of South American Earth Sciences, 74: 1–26. https://doi.org/10.1016/j.jsames.2017.01.001

Moreno–Sánchez, M. & Pardo–Trujillo, A. 2003. Stratigraphical and sedimentological constraints on western Colombia: Implications on the evolution of the Caribbean Plate. In: Bartolini, C., Buffler, R.T. & Blickwede, J. (editors), The circum–Gulf of Mexico and the Caribbean: Hydrocarbon habitats, basin formation, and plate tectonics. American Association of Petroleum Geologists, Memoir 79, p. 891–924. Tulsa, USA. https://doi.org/10.1306/M79877C40

Nelson, H.W. 1962. Contribución al conocimiento de la cordillera Occidental: Sección carretera Cali–Buenaventura. Boletín Geológico, 10(1–3): 81–108.

Nerlich, R., Clark, S.R. & Bunge, H.P. 2014. Reconstructing the link between the Galapagos hotspot and the Caribbean Plateau. GeoResJ, 1–2: 1–7. https://doi.org/10.1016/j.grj.2014.02.001

Nivia, Á. 1987. Geochemistry and origin of the Amaime and volcanic sequences southwestern Colombia. Master of Philosophy thesis, University of Leicester, 164 p. Leicester, UK.

Nivia, Á. 1989. El terreno Amaime–Volcánica una provincia acrecionada de basaltos de meseta oceánica. V Congreso Colombiano de Geología. Memoirs, I, p. 1–30. Bucaramanga.

Nivia, Á. 1991. Memoria explicativa: Mapa geológico departamento del Valle del Cauca. Ingeominas, 149 p. Bogotá.

Nivia, Á. 1993. Evidencia de obducción en el Complejo Ultramáfico de Bolívar. VI Congreso Colombiano Geología. Memoirs, I, p. 63–79. Medellín.

Nivia, Á. 1996. The Bolívar mafic–ultramafic complex, SW Colombia: The base of an obducted oceanic plateau Journal of South American Earth Sciences, 9(1–2): 59–68. https://doi.org/10.1016/0895-9811(96)00027-2

Nivia, Á. 2001. Memoria explicativa: Mapa geológico departamento del Valle del Cauca. Scale 1:250 000. Ingeominas, 148 p. Bogotá.

Nivia, Á., Marriner, G.F., Kerr, A.C. & Tarney, J. 2006. The Quebradagrande Complex: A Lower Cretaceous ensialic marginal basin in the Central Cordillera of the Colombian Andes. Journal of South American Earth Sciences, 21(4): 423–436. https://doi.org/10.1016/j.jsames.2006.07.002

O'Dea, A., Lessios, H.A., Coates, A.G., Eytan, R., Restrepo–Moreno, S.A., Cione, A.L., Collins, L.S., de Queiroz, A., Farris, D.W., Norris, R.D., Stallard, R.F., Woodburne, M.O., Aguilera, O., Aubry, M.P., Berggren, W.A., Budd, A.F., Cozzuol, M.A., Coppard, S.E., Duque–Caro, H., Finnegan, S., Gasparini, G.M., Grossman, E.L., Johnson, K.G., Keigwin, L.D., Knowlton, N., Leigh, E.G., Leonard–Pingel, J.S., Marko, P.B., Pyenson, N.D., Rachello–Dolmen, P.G., Soibelzon, E., Soibelzon, L., Todd, J.A., Vermeij, G.J. & Jackson, J.B.C. 2016. Formation of the Isthmus of Panama. Science Advances, 2(8): 1–11. https://doi.org/10.1126/sciadv.1600883

Pardo–Trujillo, A., Jaramillo, C.A. & Oboh–Ikuenobe, F.E. 2003. Paleogene palynostratigraphy of the eastern Middle Magdalena Valley, Colombia. Palynology, 27(1): 155–178. https://doi.org/10.1080/01916122.2003.9989585

Parra, E. 1983. Geología y geoquímica de la plancha 223 El Cairo. Scale 1:100 000. Ingeominas, Internal report 1914, 138 p. Bogotá.

Piraquive, A., Kammer, A., Bernet, M. & von Quadt, A. 2017. Exhumación del basamento metamórfico de las serranías de Jarara y Macuira a partir de termocronología y geocronología U–Pb LA–ICP–MS en circones. XVI Congreso Colombiano de Geología. Memoirs, p. 1509–1510. Santa Marta.

Restrepo, J.J. 2008. Obducción y metamorfismo de ofiolitas triásicas en el flanco occidental del terreno Tahamí, cordillera Central de Colombia. Boletín de Ciencias de la Tierra, (22): 49–100.

Restrepo, J.J. & Toussaint, J.F. 1973. Obducción cretácea en el occidente colombiano. Publicación Especial de Geología, (3): 1–26. Medellín.

Restrepo, J.J. & Toussaint, J.F. 1976. Edades radiométricas de algunas rocas de Antioquia, Colombia. Publicación Especial Geológica, (6): 1–15. Medellín.

Restrepo, J.J. & Toussaint, J.F. 1984. Unidades litológicas de los alrededores de Medellín. Primera conferencia sobre riesgos geológicos del Valle de Aburrá. Sociedad Colombiana de Geología. Memoirs, p. 1–26. Medellín.

Restrepo, J.J. & Toussaint, J.F. 1988. Terranes and continental accretion in the Colombian Andes. Episodes, 11(3): 189–193. https://doi.org/10.18814/epiiugs/1988/v11i3/006

Restrepo, J.J. & Toussaint, J.F. 2020. Tectonostratigraphic terranes in Colombia: An update. First part: Continental terranes. In: Gómez, J. & Mateus–Zabala, D. (editors), The Geology of Colombia, Volume 1 Proterozoic – Paleozoic. Servicio Geológico Colombiano, Publicaciones Geológicas Especiales 35, p. 37–63. Bogotá. https://doi.org/10.32685/pub.esp.35.2019.03

Restrepo, J.J., Toussaint, J.F., Zuluaga, J. & Hoyos, P. 1979. Algunas consideraciones sobre la geología de la parte septentrional de la cordillera Occidental. Publicación Especial (20): 1–26. Medellín.

Restrepo, J.J., Toussaint, J.F., González, H., Cordani, U., Kawashita, K., Linares, E. & Parica, C. 1991. Precisiones geocronológicas sobre el occidente colombiano. Simposio sobre Magmatismo Andino y su Marco Tectónico. Memoirs, I, 21 p. Manizales.

Restrepo, J.J., Frantz, J.C., Ordóñez–Carmona, O., Correa–Martínez, A.M., Martens, U. & Chemale, F. 2007. Edad triásica de formación de la Ofiolita de Aburrá, flanco occidental de la cordillera Central. XI Congreso Colombiano de Geología. Abstracts, p. 49. Bucaramanga.

Restrepo, J.J., Dunlap, W.J., Martens, U., Ordoñez–Carmona, O. & Correa, A.M. 2008. Ar–Ar ages of amphibolites from the Central Cordillera of Colombia and their implications for tectonostratigraphic terrane evolution in the northwestern Andes. VI South American Symposium on Isotope Geology. Proceedings in CD ROM, p. 1–6. Bariloche, Argentina.

Restrepo, J.J., Ordóñez–Carmona, O., Martens, U. & Correa, A.M. 2009a. Terrenos, complejos y provincias en la cordillera Central de Colombia. Ingeniería, Investigación y Desarrollo, 9(2): 49–56.

Restrepo, J.J., Ordóñez–Carmona, O. & Moreno–Sánchez, M. 2009b. A comment on "The Quebradagrande Complex: A Lower Cretaceous ensialic marginal basin in the Central Cordillera of the Colombian Andes" by Nivia et al. Journal of South American Earth Sciences, 28(2): 204–205. https://doi.org/10.1016/j.jsames.2009.03.004

Restrepo, J.J., Ibañez–Mejia, M. & García–Casco, A. 2012. U–Pb zircon ages of the Medellín Amphibolites (Central Cordillera of Colombia) reveal mid–Cretaceous tectonic juxtaposition of Triassic and mid–Cretaceous metamorphic complexes. VIII South American Symposium on Isotope Geology. Presentaciones memoria USB, 33 diapositivas. Medellín.

Restrepo–Moreno, S.A., O´Dea, A., Coates, A.G., Eytan, R., Farris, D.W., Jackson, J.B.C., Lessios, H.A., Collins, L.S., Stallard, R.F., Duque–Caro, H., Marko, P.B., Rachello–Dolmen, P.G., Keigwin, L.D. & Vermeij, G.J. 2017. Perspectives on the formation of Panamanian Isthmus. XVI Congreso Colombiano de Geología. Memoirs, p. 1872–1874. Santa Marta.

Ríos–Reyes, C.A., Castellanos–Alarcón, O.M. & García–Ramírez, C.A. 2017. Petrogenetic significance of the eclogites from the Arquía Complex on southwestern Pijao, Central Cordillera (Colombia Andes). DYNA, 84(200): 291–301. https://doi.org/10.15446/dyna.v84n200.48166

Rodríguez, G. & Arango, M.I. 2013. Formación Barroso: Arco volcánico toleítico y diabasas de San José de Urama: Un prisma acrecionario T–MORB en el segmento norte de la cordillera Occidental de Colombia. Boletín de Ciencias de la Tierra, (33): 17–38.

Rodríguez, G. & Cetina, L.M. 2016. Caracterización petrográfica y química de rocas de corteza oceánica del Complejo Quebradagrande y comparación con rocas de la unidad Diabasas de San José de Urama. Boletín de Geología, 38(3): 15–29. https://doi.org/10.18273/revbol.v38n3-2016001

Rodríguez, G. & Zapata, G. 2012. Características del plutonismo Mioceno superior en el segmento norte de la cordillera Occidental e implicaciones tectónicas en el modelo geológico del noroccidente colombiano. Boletín de Ciencias de la Tierra, (31): 5–22.

Rodríguez–Jiménez, J.V. 2010. Fábrica y emplazamiento de la Diorita de Pueblito, NW cordillera Central de Colombia: Análisis de fábrica magnética y mineral. Master thesis, Universidad Nacional de Colombia, 60 p. Medellín.

Rodríguez–Pulgarín, E.A. 2011. Identificación del municipio de Ebéjico (II). Revista Vinculando: Web versión. http://vinculando.org/vacaciones_viajes/turismo_sostenible/7_identificacion_del_municipio_de_ebejico_ii.html (consulted in October 2018).

Ruiz–Jiménez, E.C. 2014. Geoquímica y trayectorias P–T de las rocas metamórficas del Complejo Arquía, entre los municipios de Santafé de Antioquia, Antioquia y el río Arquía, Caldas. Master thesis, Universidad de Caldas, 132 p. Manizales.

Ruiz–Jiménez, E.C., Blanco–Quintero, I.F., Toro–Toro, L.M., Moreno–Sánchez, M., Vinasco, C.J., García–Casco, A., Morata, D. & Gómez–Cruz, A. 2012. Geoquímica y petrología de las metabasitas del Complejo Arquía (municipio de Santafé de Antioquia y río Arquía, Colombia): Implicaciones geodinámicas. Boletín de Ciencias de la Tierra, (32): 65–79.

Salazar, G., James, M. & Tistl, M. 1991. El Complejo Santa Cecilia–La Equis: Evolución y acreción de un arco magmático en el norte de la cordillera Occidental, Colombia. Simposio sobre Magmatismo Andino y su Marco Tectónico. Memoirs, II, p. 142–160. Manizales.

Salinas, R. & Tistl, M. 1992. A tertiary zoned ultramafic complex and komatiitic basalts from Condoto, Choco, NW Colombia. Zentralblatt Fur Geologie Und Palaontologie, 1(6), p. 1659–1676. Stuttgart, Germany.

Serrano, L., Ferrari, L., López–Martínez, M., Petrone, C.M. & Jaramillo, C. 2011. An integrative geologic, geochronologic and geochemical study of Gorgona Island, Colombia: Implications for the formation of the Caribbean Large Igneous Province. Earth and Planetary Science Letters, 309(3–4): 324–336. https://doi.org/10.1016/j.epsl.2011.07.011

Sillitoe, R.H., Jaramillo, L., Damon, P.E., Shafiqullah, M. & Escovar, R. 1982. Setting, characteristics, and age of the Andean porphyry copper belt in Colombia. Economic Geology, 77(8): 1837–1850. https://doi.org/10.2113/gsecongeo.77.8.1837

Sinton, C.W., Duncan, R.A., Storey, M., Lewis, J. & Estrada, J.J. 1998. An oceanic flood basalt province within the Caribbean Plate. Earth and Planetary Science Letters, 155(3–4): 221–235. https://doi.org/10.1016/S0012-821X(97)00214-8

Spadea, P., Delaloye, M., Espinosa, A., Orrego, A. & Wagner, J.J. 1987. Ophiolite Complex from La Tetilla, southwestern Colombia, South America. The Journal of Geology, 95(3): 377–395. https://doi.org/10.1086/629136

Tistl, M., Burgath, K.P., Höhndorf, A., Kreuzer, H., Muñoz, R. & Salinas, R. 1994. Origin and emplacement of tertiary ultramafic complexes in northwest Colombia: Evidence from geochemistry and K–Ar, Sm–Nd and Rb–Sr isotopes. Earth and Planetary Science Letters, 126(1–3): 41–59. https://doi.org/10.1016/0012-821X(94)90241-0

Toussaint, J.F. 1996. Evolución geológica de Colombia: 3, Cretácico. Universidad Nacional de Colombia, 277 p. Medellín.

Toussaint, J.F. 1999. Evolución geológica de Colombia durante el Cenozoico. Universidad Nacional de Colombia. CD ROM, 222 p. Medellín.

Toussaint, J.F. & Restrepo, J.J. 1981. Edad K/Ar de dos rocas básicas del flanco noroccidental de la cordillera Central. Boletín de Ciencias de la Tierra, (5–6): 71.

Toussaint, J.F. & Restrepo, J.J. 1989. Acreciones sucesivas en Colombia: Un nuevo modelo de evolución geológica. V Congreso Colombiano de Geología, Memoirs, I, p. 127–146. Bucaramanga.

Toussaint, J.F., González, H., Restrepo, J.J. & Linares, E. 1981. Edad K/Ar de tres rocas metamórficas del flanco noroccidental de la cordillera Central. Boletín de Ciencias de la Tierra, (5–6): 63–69.

van der Hammen, T. 1958. Estratigrafía del Terciario y Maastrichtiano continentales y tectogénesis de los Andes colombianos. Boletín Geológico, 6(1–3): 67–128.

Villagómez, D. 2010. Thermochronology, geochronology and geochemistry of the Western and Central Cordilleras and Sierra Nevada de Santa Marta, Colombia: The tectonic evolution of NW South America. Doctoral thesis, University of Geneva, 143 p. Geneva.

Villagómez, D. & Spikings, R. 2013. Thermochronology and tectonics of the Central and Western Cordilleras of Colombia: Early Cretaceous – Tertiary evolution of the northern Andes. Lithos, 160–161: 228–249. https://doi.org/10.1016/j.lithos.2012.12.008

Villagómez, D., Spikings, R., Magna, T., Kammer, A., Winkler, W. & Beltrán, A. 2011. Geochronology, geochemistry and tectonic evolution of the Western and Central Cordilleras of Colombia. Lithos, 125(3–4): 875–896. https://doi.org/10.1016/j.lithos.2011.05.003

Vinasco, C.J. & Cordani, U. 2012. Reactivation episodes of the Romeral Fault System in the northwestern part of Central Andes, Colombia, through $^{39}Ar$–$^{40}Ar$ and K–Ar results. Boletín de Ciencias de la Tierra, (32): 111–123.

Walker, R.J., Storey, M., Kerr, A.C., Tarney, J. & Arndt, N.T. 1999. Implications of $^{187}Os$ isotopic heterogeneities in a mantle plume: evidence from Gorgona Island and Curaçao. Geochimica et Cosmochimica Acta, 63(5): 713–728. https://doi.org/10.1016/S0016-7037(99)00041-1

Weber, M., Gómez, J., Cardona, A., Duarte, E., Pardo–Trujillo, A. & Valencia, V.A. 2015. Geochemistry of the Santa Fé Batholith and Buriticá Tonalite in NW Colombia–Evidence of subduction initiation beneath the Colombian Caribbean Plateau. Journal of South American Earth Sciences, 62: 257–274. https://doi.org/10.1016/j.jsames.2015.04.002

Zapata, G. & Rodríguez, G. 2011. Basalto de El Botón: Arco volcánico Mioceno de afinidad shoshonítica al norte de la cordillera Occidental de Colombia. Boletín de Ciencias de la Tierra, (30): 77–91.

Zapata, J.P. & Cardona, A. 2017. Unidades miloníticas asociadas a eventos colisionales del Cretácico Superior en el margen occidental de la cordillera Central. XVI Congreso Colombiano de Geología. Memoirs, p. 1889–1891. Santa Marta.

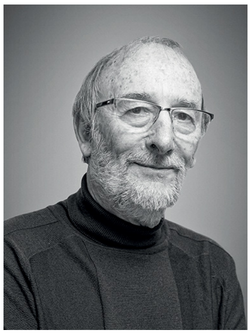
Zapata, J.P., Restrepo, J.J., Cardona, A. & Martens, U. 2017a. Geoquímica y geocronología de las rocas volcánicas básicas y el Gabro de Altamira, cordillera Occidental (Colombia): Registro de ambientes de plateau y arco oceánico superpuestos durante el Cretácico. Boletín de Geología, 39(2): 13–30. https://doi.org/10.18273/revbol.v39n2-2017001

Zapata, J.P., Correa, T., Obando, M., Rincón, A., Ortiz, F. & Rodríguez, G. 2017b. Redefinición cronoestratigráfica del Batolito de Sabanalarga. XVI Congreso Geológico Colombiano. Memoirs, p. 1472–1477. Santa Marta.

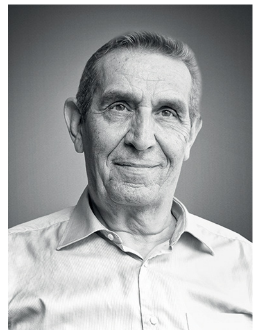
## Explanation of Acronyms, Abbreviations, and Symbols:

| | | | |
|---|---|---|---|
| CRFZ | Cauca–Romeral Fault Zone | REE | Rare earth element |
| IAT | Island arc tholeiite | SNSM | Sierra Nevada de Santa Marta |
| MORB | Mid–ocean ridge basalt | T–MORB | Transicional mid–ocean ridge basalt |

## Authors' Biographical Notes



**Jean–François TOUSSAINT** has a Doctorate degree from the Université de Paris. After working in Bolivia for some time, he arrived at Medellín to teach at the Universidad Nacional de Colombia, Sede Medellín, where he taught courses such as Structural Geology, Geotectonics, Regional Geology, and Geology of Colombia for approximately 35 years. He was awarded the titles of Honorary Professor and "Maestro Universitario" by the Universidad Nacional. Some of his interests are the geological evolution of the Colombian Andes in terms of plate tectonics and tectonostratigraphic terranes, playing tennis, and the history of human evolution.



**Jorge Julián RESTREPO** obtained a degree in mining engineering and metallurgy at the Universidad Nacional de Colombia in 1968 and a Master of Science degree in geology at the Colorado School of Mines in 1973. He was a faculty member of the Universidad Nacional de Colombia, Sede Medellín, for over 40 years and currently holds the titles of Emeritus Professor and "Maestro Universitario". He taught Mineralogy, Metamorphic Petrology, Regional Geology, Field Geology, and Geochronology. His research focused on plate tectonics applied to the geology of Colombia, tectonostratigraphic terranes, geochronology, and the geologic evolution of metamorphic and mafic/ultramafic complexes of the Central Cordillera. Other interests are photography, genealogy, and the study of passifloras.