MAYA
REVISTA DE GEOCIENCIAS

AN EOCENE ROCK UNIT WHICH TRAVELLED ABOUT 900 Km USING A CONVEYOR BELT CALLED THE CARIBBEAN PLATE - PAMPATAR FORMATION (MARGARITA ISLAND, VENEZUELA)

JHONNY E. CASAS[1]
[1] Escuela de Petróleo, Universidad Central de Venezuela

INTRODUCTION

The Pampatar Formation is a Middle Eocene clastic rock unit that crops out on Margarita Island (Figure 1), which is located off the northern coast of Venezuela. The formation consists of around 1,600 m of stratigraphic section, composed of interbedded sandstones, siltstones and shales, with some thick conglomerates and minor amounts of limestone. Most of the outcrops are well exposed along the east-southeast coast of Margarita (Figure 2), in the vicinity city of Pampatar. The study and review of this formation aims to discuss and summarize its stratigraphic and sedimentological features, the paleogeographic context, and recent findings about the provenance of its sediments in the context of the tectonic evolution of the southern margin of Caribbean Plate and northern margin of South America during the Cenozoic.

GEOLOGICAL SETTING

The Pampatar Formation is composed of shales (45%), sandstones and siltstones (40%), conglomerates (14%) and limestones (1%). The sandstones are grey when fresh, but weather to brownish and olive colors. Most of the sandstones are fine-grained and their thicknesses varies between 1 cm and 10 m, with a median of 3 cm (Casas et al., 1995). In outcrop the sandstone beds, show many sedimentary structures, such as, normal grading (Figure 3), parallel lamination, ripple cross-lamination and convolute bedding; many shows classic Bouma (1962) successions, including Tab, Tbc and Tbcd. Debris flow intervals are also common along the Pampatar section (Figure 4).

Figure 1. Location of Margarita Island (Venezuela) and the Pampatar Formation outcrops


Figure 2. Pampatar Formation outcrops along Punta Ballena, Margarita Island.


Figure 3. A) Fine pebble conglomerate-sandstones showing normal grading at the base and parallel lamination at the top (Tab), Punta Moreno outcrop.

Within Pampatar Formation, two distinct conglomeratic subunits are recognized in Punta Gorda and Punta Moreno geographical locations (Figure 5). They are normally clasts supported (orthoconglomerates), sometimes exhibiting vertical gradation.

The clasts within the conglomerates, were studied by Moreno & Casas (1986) and included more than 1500 counts. They are composed of chert, quartz, meta-andesites, porphyritic andesites, dacites, tuff, meta-tuff, sandstones/meta-sandstones, siltstone and mudstone fragments, plutonic fragments like hornblende-tonalite and granodiorite, and a high number of aphanitic fragments that could not be differentiated due to alteration.


Figure 4. Debris flow interval: a chaotic mass of heterogeneous material, such as block fragments and mud), Punta Ballena outcrop, hammer scale = 33 cm.


Figure 5. Conglomeratic section at the base of an outcrop from Pampatar Formation, Punta Moreno, Margarita

The sandstones are mainly lithic arenites (43%), subarkoses (14%), sublitarenites (14%), arkosic arenites (13%) and lithic grauwackes (12%). The lithic arenites (Figure 6) are composed by high percentage (up to 87%) of andesitic volcanic fragments (Figure 7), quartz (up to 33%), with a minor fraction of plagioclases and potassic feldespars. Carbonatic cements are also found in some samples. Matrix content is variable (up to 11% in lithic arenites, and 61% in grauwackes). It is composed of clay fraction and carbonates. The petrographic analysis supports the idea that some matrix is the alteration product of volcanic fragments. Most of the samples shows minor amounts (less than 2%) of zircon, tourmaline, epidote, zoisite, apatite, sphene and rutile (Casas *et al*., 1986).

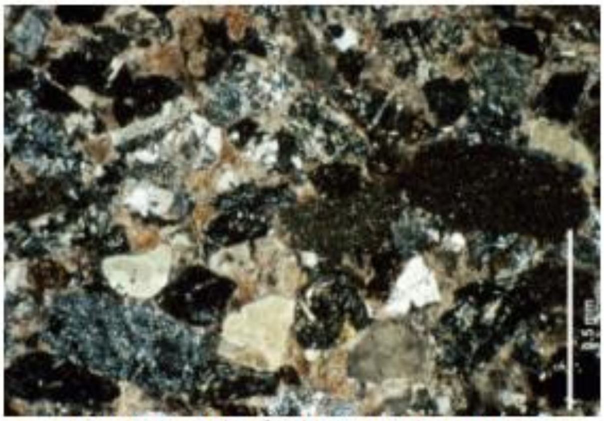

Figure 6. Example of Lithic Arenite in Pampatar Formation. Graphic scale = 0.5 cm.

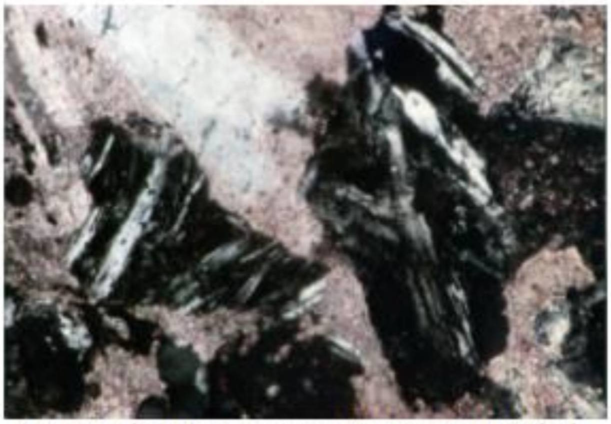

Figure 7. The Lithic Arenites in Pampatar contain high quantities of andesitic fragments. Graphic scale = 0.5 cm.

Shales are mostly barren, but some layers at the upper part contains radiolarian, bad preserved planktonic and bentic forams. Hernandez (1949) reported a thin limestone layer (within the thickest shaly section), containing *Asterocyclina asterisca*, *Asterocyclina sp.*, *Neodiscocyclina (Discocyclina) anconensis*, *Operculinoides sp.*, *Gumbelina sp.* and *Globorotalia sp.* Sandstones and calcareous sandstones may content *Nummulites sp.*, *Lepidocyclina sp.*, and *Asterocyclina sp.* (Figure 8), similar to those found in Punta Carnero Formation, a close and well dated late-Middle Eocene formation (Muñoz, 1973; Casas, 2022).

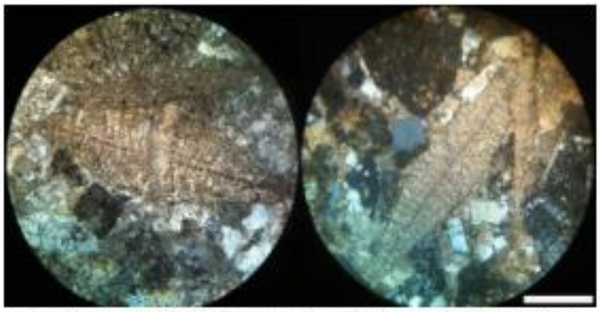

Figure 8. *Lepidocyclina sp.* in calcareous lithic arenites from the upper part of Pampatar Formation. Graphic scale = 1 mm.

SEDIMENTARY ENVIRONMENT AND MECHANISMS

The Pampatar Formation is composed of sedimentary beds deposited in deep-marine channels and submarine fans thought mass-transport events (debris flows and slumps) and bottom currents (Casas, 2022). The tectonic setting during the sedimentation of the formation in the middle Eocene, was mainly controlled by its proximity to the Caribbean volcanic arc (Pindell and Kennan, 2007). Also, its geographical location in the tropical zone at that middle Eocene time, possibly allowed storms and hurricanes, to remove sediments and induce liquefaction processes to feed canyons and submarine fans. Sedimentation at that time was probably controlled by several short-term mechanisms, including tectonic instability of the sea floor, volcanic activity/earthquakes and storms/hurricanes. Mid-term mechanisms may also contribute to trigger processes of submarine mass-transport, such as, depositional/hydrostatic loading and ocean-bottom currents. Many of the previous mechanisms, acted individually or in tandem to deliver sediments to the bottom of the basin. Long term mechanisms as relative sea level changes may also influence patterns of sedimentation of the Pampatar Formation, but the current data and the lack of a detailed chronostratigraphy, does not allow any conclusion about this. Campos and Guzman (2002) discussed a sequence stratigraphic interpretation for the Pampatar Formation, assuming old paradigms like: high sand content representing a lowstand system tract and low sand content representing a transgressive/highstand system tract, but these simplistic ideas have been debunked during the last twenty years by many authors (e.g., Plink-Bjorklund and Steel, 2002; Carvajal and Steel, 2006; Covault et al., 2007; Shanmugan, 2007; Carvajal et al., 2009; Donovan, 2013).

The detailed sedimentological interpretation of the Pampatar Formation was explored by Moreno and Casas (1986) and Casas et al. (1995), who indicated that these rocks are interpreted as deep-water deposits, deposited in submarine canyons and fans, where the conglomeratic units represent the filling of submarine canyons localized in the slope/upper fan, in which the fundamental sedimentary mechanism were grain supported flows and slumps. On the other hand, the thick silty shale section with olistoliths within the Pampatar Formation, represents typical slope deposits. The rest of the section is composed of interbedded sandstones and mudstones, where the sandstones exhibit different traction structures (Casas et al., 1995) developed under the general term of bottom-current reworked sands, following the terminology of Shanmugan (2020). The different sand/shale proportions represent a wide variety of sub-environments within the deep-marine fans (from proximal to distal). Casas et al. (1995) concluded that the Pampatar Formation represented the sedimentation of a classic flysch type unit, where the transportation of terrigenous material occurred from shallow waters towards the deep basin, through submarine canyons, and where the transport mechanisms were mainly slumps, debris flows, grain flows and bottom-currents.

PALEOGEOGRAPHIC CONTEXT AND DISCUSSION

The origin and evolution of the Pampatar Formation are related to the tectonic evolution of the southern margin of Caribbean Plate and northern margin of South America in the Cenozoic. Recent data based upon detrital zircon (DZ) dating, provides evidence and more constraints for provenance interpretation and paleogeographic reconstructions in the South American and Caribbean Plate contact. DZ analyses by Xie et al. (2010) in only one sample from the Pampatar Formation, was dominated by Mesozoic and Paleozoic ages, and the lack of Guyana shield ages suggested to the authors that this source area was separated from the Paleogene basinal area on Margarita Island on the Caribbean Plate. Ages in the ~130–650 Ma range from the same Pampatar Formation sample also excluded the Andean arc system as a dominant source for this deep-water sequence. Xie et al. (2010) mentioned possible sources for the Pampatar Formation that could include the Perijá Range and the Merida Andes, which have large areas of basement with these ages (González de Juana et al., 1980). Xie et al. (2010) also point out that fission-track data from western Venezuela and eastern Colombia published by Shagam et al. (1984) and Castillo and Mann (2006) suggested that the Merida Andes were first uplifted in the northwest during the Oligocene-Miocene, followed by uplift of the southeast margin during the Late Miocene.

Unfortunately, these assumptions from Xie et al. (2010) are based upon only one sample, with a small number of dated grains, so the results may have a high uncertainty. Instead, Noguera (2009) analyzed three samples from the Pampatar Formation with a total of 236 dated grains with a 95% confidence level. The oldest detrital zircon grain from three samples of the Pampatar Formation was of late Archean age (2,626.8 ± 16.6 Ma), while the youngest grain was of Eocene age (49.1 ± 0.9 Ma). Other grains indicate ages of early Proterozoic (2,084 Ma), middle Proterozoic (1,220 Ma and 1,054 Ma), early Cambrian (535 Ma) and middle Triassic (239 Ma). Grains of ages between 120 and 200 Ma are absent from Pampatar Formation samples. Younger grains from same samples group at 49.1 Ma (Eocene).

Most accepted models for the evolution of the Caribbean (e.g., Pindell et al., 2005; Pindell and Kennan, 2007; Pindell et al., 2009) suggest a middle Eocene configuration, where a volcanic arc (Aves Ridge) on the eastern edge of the Caribbean Plate moved eastwardly as a consequence of the oblique collision between South American and the Caribbean Plate (Figure 9). During migration of this arc eastward, turbiditic sequences were deposited on the continental margin along the northern edge of the South American Plate (Pindell and Kennan, 2007) and crop out today in different places along the Cordilleran Belt, from western to eastern Venezuela, Curaçao, Margarita, Barbados and Grenada in the Caribbean. Noguera et al. (2017) cited examples of these turbiditic units, such as the Midden Curacao and Lagoen formations in Curaçao; the Matatere, Pampatar, Los Arroyos and Río Guache formations in Venezuela; and the Scotland Group in Barbados.

Casas et al. (1995) performed a modal count method on 100 sandstone samples from Pampatar Formation, and for this review, 25 new additional samples along the Pampatar stratigraphic column were added to the analysis. When plotted all samples (125) on the provenance diagrams of Dickinson et al. (1983) the results for Q-F-L triangle indicate affinities to recycled orogeny, volcanic arc and transitional continental

(Figure 10). In detail, the Qm-F-Lt diagram shows a wider dispersion, including mainly transitional recycled, mixed zone and volcanic arc (mature and transitional). This association is interpreted in terms of uplift and erosion of a subduction-accretion complex with contributions from a magmatic arc during middle Eocene time.

The analysis performed by Noguera (2009), in samples from the Pampatar and Matatere formations, found detrital zircon (DZ) ages peaking at 59 Ma and 50 Ma (Paleocene), probably marking the arrival of the Leeward Antilles volcanic arc to western Venezuela at 55-60 Ma (Levander et al., 2006; Escalona and Mann, 2011). Noguera (2009) also found DZ peaking between 50 and 40 Ma (Middle Eocene), at the time when thrusts associated with the emplacement of the Lara nappes probably occurred (Pindell et al., 2005; Escalona and Mann, 2011). Noguera et al. (2017) stated that the sedimentary deposits from the Pampatar Formation and the northern section of the Matatere Formation (located in western Venezuela), showed a statistical similarity for age results with U-Pb in DZ, suggesting similar sources for both formations and also geographically close depocenters. Macsotay and Feraza (2005) also mentioned, based upon lithological comparisons, that the Pampatar and Matatere formations are identical.

Finally, Noguera et al. (2017) concluded that volcanic and continental sediments in these two turbidite units (Pampatar and Matatere) were shed from at least three general locations:

- A northern source located at the Caribbean volcanic arc and the accretionary prism which fed the foredeep basin (in agreement with Casas et al., 1995 results).
- A southern source from the Guyana Shield or from the erosion of Cretaceous/Paleozoic rock units containing Guyana Shield ages (Casas, 2022).
- A western source found in the positive areas of the Cordillera of Colombia, including the Perijá Range and the Guajira Peninsula.

The material from the volcanic arc observed in the sandstones and conglomerates of the Pampatar Formation is represented by volcanic lithic fragments (tuffs and andesites), feldspars and many volcanic glass fragments, altered to chlorite and zeolites (Casas et al., 1995; Casas, 2022).

CONCLUSIONS

Q-F-L provenance triangle indicates affinities to recycled orogeny, volcanic arc and transitional continental. The Qm-F-Lt shows a wider dispersion, including transitional recycled, mixed zone and volcanic arc. This association was interpreted in terms of uplift and erosion of a subduction-accretion complex with contributions from a magmatic arc during middle Eocene time.

The interpretation shows that the Pampatar Formation was probably deposited in the accretionary prism between the foredeep and the volcanic arc, and the new evidence collected by Noguera (2009) based upon detrital zircon ages, suggest that volcanic and continental sediments of the Pampatar Formation were shed from three general locations: the Caribbean volcanic arc/accretionary prism, the Guyana Shield (or from the erosion of Cretaceous/Paleozoic rock units containing Guyana Shield ages), and also from positive areas of the Perijá Range (probably the Guajira Peninsula).

Paleogeographic reconstructions made by Pindell and Kennan (2007) show that since the middle Eocene continuous eastward advance of the Caribbean Plate, thrust the Paleogene sequences including the Pampatar Formation, into their current position (more than 900 km from their place of origin), along with diachronous emplacement of allochthonous terranes in northern Venezuela.

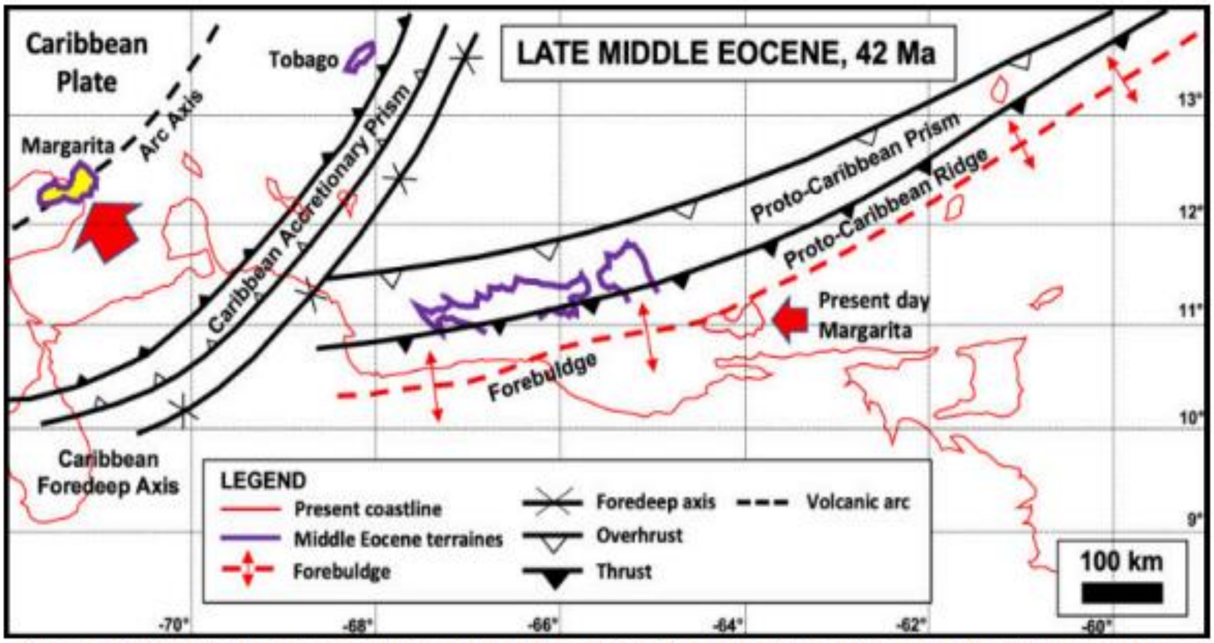

Figure 9. Palinspastic paleogeographic map for 42 Ma, (Middle Eocene), showing the depositional context, and the possible location of Margarita (Pampatar Formation) at that time. Modified from Pindell & Kennan (2007).

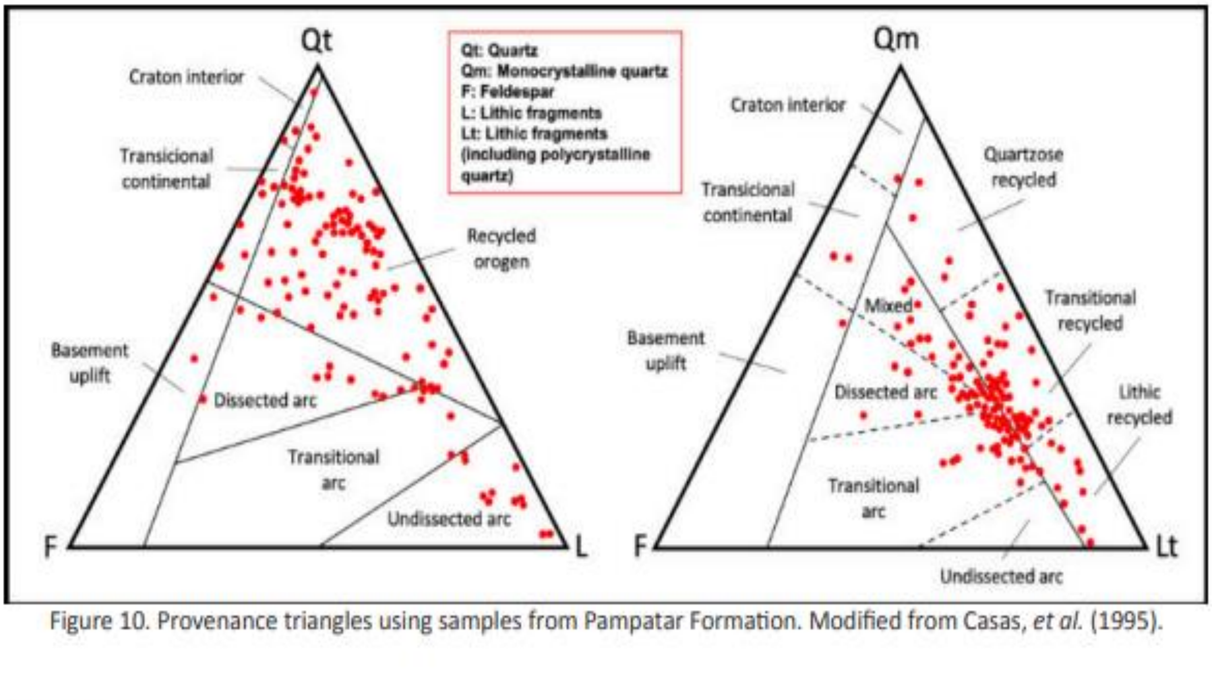

Figure 10. Provenance triangles using samples from Pampatar Formation. Modified from Casas, *et al.* (1995).

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