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The Pampatar Formation (Margarita Island, Venezuela), an Eocene rock unit which traveled about 900 km using a conveyor belt called the Caribbean Plate

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ABSTRACT. The Pampatar Formation is a siliciclastic unit located at the southeastern corner of Margarita Island (Venezuela). It is composed of interbedded sandstones, shales and conglomerates deposited in deep-water canyons and as turbiditic fans. The conglomerates represent canyon deposits and inner-fan-channel deposits, while the rest of the succession represents the entire range of submarine fan environments, from inner to outer fans. The age of the formation is Middle Eocene. The sandstones are dominated by lithic arenites, which are composed mainly by volcanic fragments and quartz, with minor proportions of plagioclases and potassic feldspars. The origin and evolution of the Pampatar Formation is related to the tectonic evolution of the southern margin of the Caribbean Plate and the northern margin of South America in the Cenozoic. Q-F-L and Qm-F-Lt diagrams shows evidence of a sediment source coming from the Caribbean volcanic arc and the accretionary prism, which fed the foredeep basin. Recent data, based upon detrital zircon dating, provides additional evidence of possible continental sources from positive areas located in the Perijá Range and from Guyana Shield or from the erosion of Cretaceous/Paleozoic rock units containing Guyana Shield age zircons. Paleogeographic reconstructions shows that since the Middle Eocene, continuous eastward advance of the Caribbean Plate, thrusted Paleogene sequences including the Pampatar Formation, into their current position (more than 900 km from its place of origin), along with diachronous emplacement of allochthonous terranes in northern Venezuela.

Keywords: Pampatar Formation, Margarita, Eocene, Caribbean Plate, provenance, paleogeography.

1. INTRODUCTION

The Pampatar Formation is a Middle Eocene clastic rock unit that crops out on Margarita Island, which is located off the northern coast of Venezuela, South America (**Figure 1A**),. 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 1B**), 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.

2. 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 2A**), parallel lamination, ripple cross-lamination and convolute bedding; many show classic **Bouma** (**1962**) sequences, including T_{ab} (**Figure 2A**), T_{bc} (**Figure 2B**) and T_{bcd}. Debris flow intervals are also common along the Pampatar section (**Figure 2C**).

The detailed analysis of the sandstones from Pampatar Formation, showed that they are mainly lithic arenites (43%), subarkoses (14%), sublitharenites (14%), arkosic arenites (13%) and lithic greywackes (12%). The lithic arenites (Figure 3) comprise a high percentage of volcanic fragments (up to 87%), quartz (up to 33%), chert (up to 25%), with minor proportions of plagioclase, potassium feldspar and metamorphic fragments. Matrix content is variable (up to 11% in lithic arenites, and 61% in greywackes). Carbonate cement is also found in most of the sandstones (up to 45% content). The petrographic analysis supports the idea that some matrix is the alteration product and deformation of volcanic fragments, so probably some sandstones were not greywackes originally.

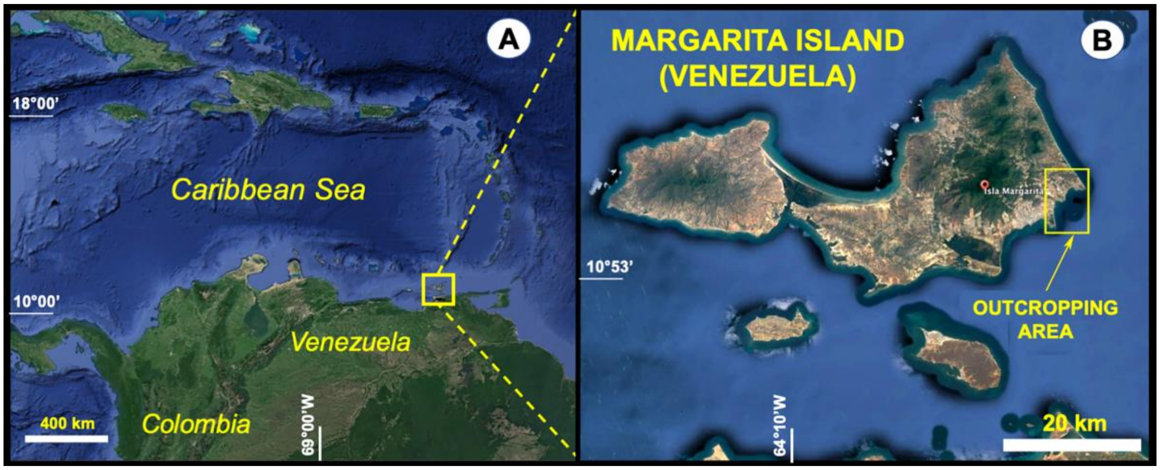

Figure 1. A) Map of the northern portion of South America with the location of Margarita Island. B) Location of the outcrop area of Pampatar Formation (Margarita Island, Venezuela). Map source: http://www.earth.google.com

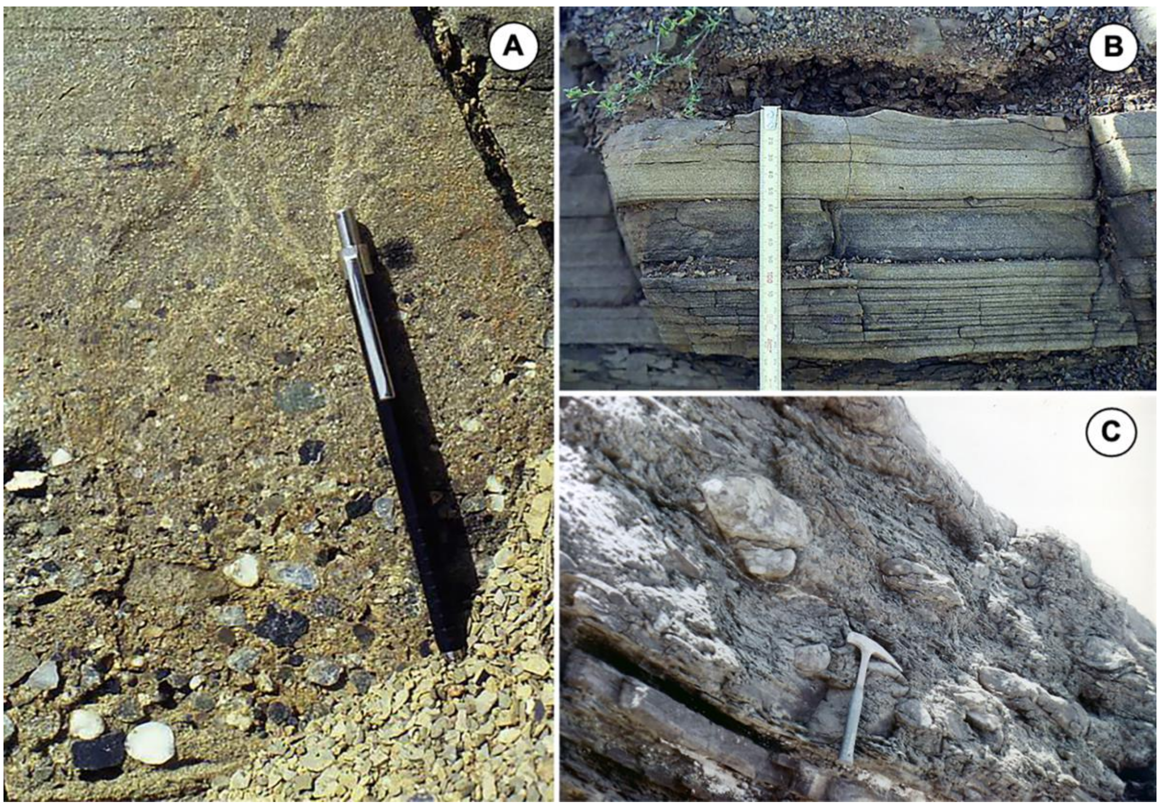

Figure 2. A) Fine pebble conglomerate-sandstones showing normal grading at the base and parallel lamination at the top (Tab), Punta Moreno outcrop. B) Parallel lamination and ripples at the top of a sandstone bed (Tbc), Pampatar outcrop, scale in centimeters. C) Debris flow interval: a chaotic mass of heterogeneous material, such as block fragments and mud), Punta Ballena outcrop, hammer scale = 33 cm.

Most of the samples shows also minor amounts (less than 2%) of zircon, tourmaline, epidote, zoisite, apatite, sphene and rutile.

The shales are dark grey in color, frequently silty, and with thickness varies from millimeters to dozens of metres. The shales are mostly barren, but some layers at the upper part of the formation contain abundant radiolarians and poorly preserved benthic foraminifers. 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.

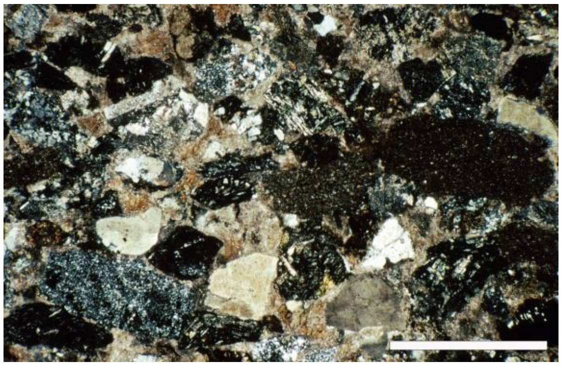

Figure 3. Example of a carbonatic lithic arenite with abundant volcanic fragments, quartz and chert. Graphic scale = 0.5 cm.

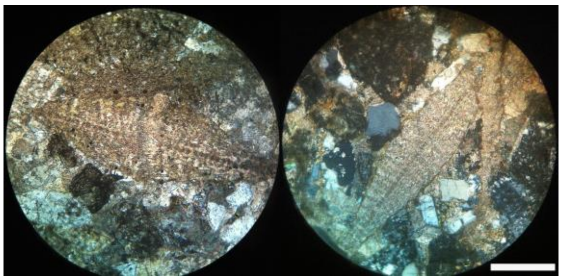

Figure 4. *Lepidocyclina* sp. in calcareous lithic arenites from the upper part of Pampatar Formation. Graphic scale = 1 mm.

Figure 5. Conglomeratic beds (dark rocks at the base), Punta Moreno section. Graphic scale bar = approx. 2 m.

Figure 6. Erosive unconformity between Pampatar Formation conglomerates (Eocene) above and a tuff/chert stratigraphic unit below (Upper Cretaceous), previously incorrectly assigned to the Los Frailes Formation. Scale pen = approx. 14 cm.

Calcareous cemented sandstones may contain *Lepidocyclina* sp., *Amphistegina* sp., *Asterocyclina* sp. and *Nummulites* sp., and are very similar to those found in the Punta Carnero Group, a geographically close and well-dated Middle Eocene (Lutetian-Bartonian) carbonate rock unit (**Muñoz, 1973**; **Moreno and Casas, 1986**). **Figure 4** shows some examples of the previously unpublished Eocene foraminifers from the Pampatar Formation. **Campos and Guzman** (**2002**) also studied some shale samples from The Pampatar Formation and reported that those samples were barren of calcareous nanoplankton.

Within the Pampatar Formation, two distinct informal conglomeratic subunits are recognized: Punta Gorda (at the base of the formation) and Punta Moreno (**Figure 5**). They are clasts supported (orthoconglomerates), polymodal, and sometimes exhibit normally graded bedding. The clasts within the conglomerates, were studied in detail by **Moreno and Casas** (**1986**), including more than 1,500 clast counts. They are composed of chert (35%), quartz (32%), andesites/tuff (29%), and small quantities (less than 1%) of plutonic fragments including hornblende-tonalite, grano-diorite and meta-andesite.

The basal contact of Pampatar Formation is exposed at the southeastern tip of Agua de Vaca Lagoon (northeast of Pampatar city), also known as Punta Gorda (**Taylor, 1960**; **Muñoz, 1973**). The contact is a sharp unconformity, where conglom-erates from the Pampatar Formation overlie an Upper Cretaceous stratigraphic unit composed of calcareous chert layers (containing radiolaria, *Hedbergella* sp. and *Heterohelix* sp.), interbedded with tuff layers (**Muñoz and Furrer, 1976**; **Casas et al., 1995**).

This chert/tuff unit was considered by **Rivero** (**1956**), **Muñoz and Furrer** (**1976**) and **Casas et al.** (**1995**) to belong to the Los Frailes Formation of Late Cretaceous age, but recent work by **Baquero et al.** (**2017**) obtained new geochrolological data from Los Frailes Archipielago and attributed the formation to the Eocene (35.7 ± 2.6 Ma). Therefore the Late Cretaceous unit that lies unconformably below the Pampatar Formation in Punta Gorda cannot be the Los Frailes Formation as described by previous authors. Given this new dating of the Los Frailes Formation by **Baquero et al.** (**2017**), the chert/tuff unit below Pampatar Formation at Punta Gorda, is a different unit, of Late Cretaceous age. This new stratigraphic unit needs to be properly named and formally described because there is no other similar unit in northern Venezuela to compare it with. None of the published studies about the

Pampatar Formation (**Muñoz, 1973**; **Moreno and Casas, 1986**; **Casas et al., 1995**; **Campos and Guzman, 2002**), described the basal contact of formation, but for the first time it is shown here in **Figure 6**. The upper contact of the Pampatar Formation is unknown, and, in some places, only recent alluvial sediments can be observed.

2.1. 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 et al., 1995**). 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.

3. 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

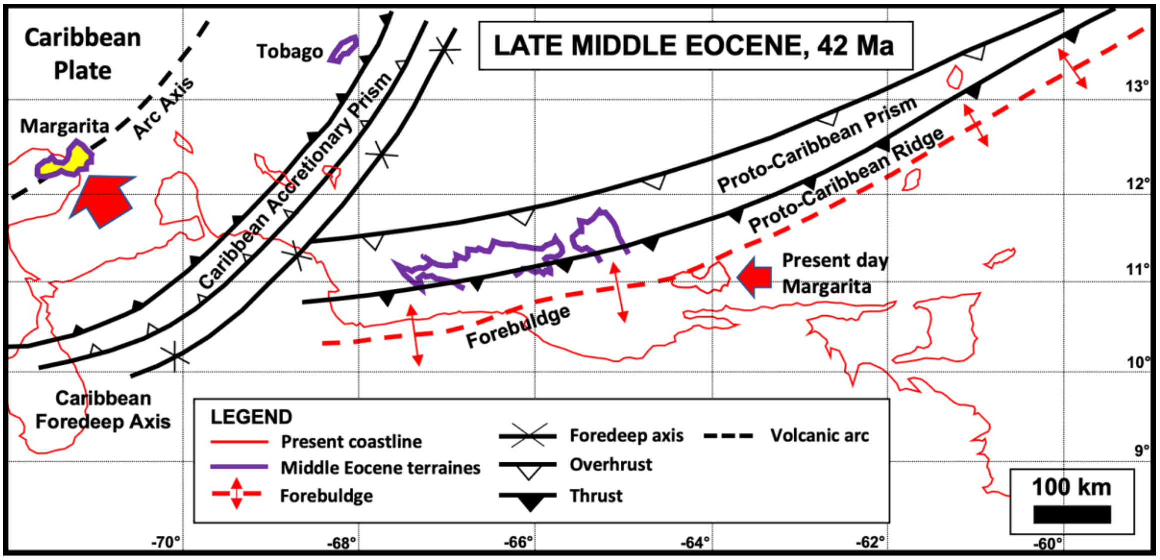

Figure 7. Palinspastic paleogeographic map for 42 Ma, (Middle Eocene), showing the tectonic context, and the possible location of Margarita Island (Pampatar Formation) at that time and also at the present time. Modified from Pindell and Kennan (2007).

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 Pampatar Formation 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 7**). 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 7). In detail, the Qm-F-Lt diagram shows a wider dispersion (**Figure 8**), 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.

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

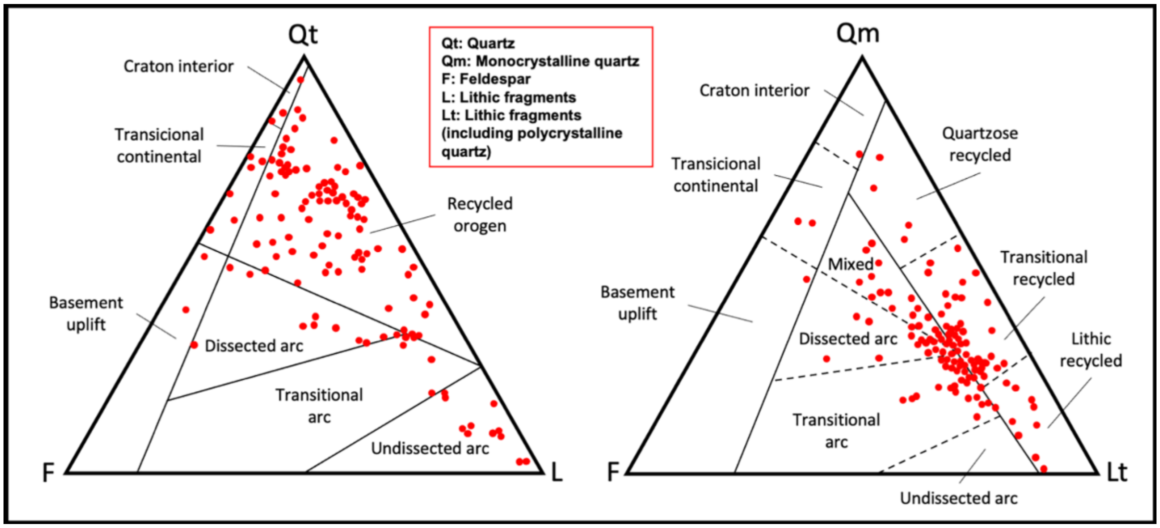

Figure 8. Dickinson provenance triangles (Q-F-L and Qm-F-Lt), using samples from Pampatar Formation (125 samples). Modified from Casas et al. (1995).

upon lithological comparisons that the Pampatar and Matatere formations are identical.

Finally, **Noguera** (**2009**) and **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.
- 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**).

4. Conclusions

The Pampatar Formation, located in Margarita Island (Venezuela), is a siliciclastic unit composed of interbedded sandstones, siltstones, conglomerates and mudstones; deposited in deep-marine channels and submarine fans during the middle Eocene time. The formation represents the sedimentation of a classic flysch type unit, where the transportation of clastic material occurred from shallow water towards the deep basin, through submarine canyons, and where the transport mechanisms were mainly mass-transport events (slumps, debris flows and grain flows) and bottom currents.

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.

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Authors Contributions. Conceptualization, data/references collection, analysis and original draft.

Data availability statement. All the samples collected for this study are stored at the Universidad Central de Venezuela (Department of Geology).

REFERENCES

Baquero, M., Mann, P., Grande, S., Urbani, F., Audemar, F. Mendi, D and Melo, L. 2017. New geochronology and radiometric age dates improve the definition and continuity of accreted tectonic terranes of northern Venezuela and the Lesser Antilles. *AGU Conference: Tectonic history of the Western Americas, Eastern Pacific Ocean and Caribbean and Scotia Seas from integration of tomographic and geologic studies. New Orleans, December 11-15,* Vol. T039.

Bouma, A. H. 1962. *Sedimentology of Some Flysch Deposits*. Elsevier, Amsterdam, 168 pp.

Campos, C. and Guzmán, O. 2002. *Estratigrafía secuencial y sedimentología de las facies turbidíticas del flysch eoceno de la Isla de Margarita, Nueva Esparta, Venezuela*. Unpublished Thesis, Universidad Central de Venezuela, 180 pp.

Carvajal, C. R. and Steel, R. J. 2006. Thick turbidite successions from supply-dominated shelves during sea-level highstand. *Geology*, **34**, 665–668. https://doi.org/10.1130/G22505.1

Carvajal, C. R., Steel, R. J. and Petter, A. 2009. Sediment supply: The main driver of shelf-margin growth. *Earth Science Reviews*, **96**, 221–248. https://doi.org/10.1016/j.earscirev.2009.06.008

Casas, J., Moreno, J. and Yoris, F. 1995. Análisis tectono-sedimentario de la Formación Pampatar (Eoceno medio), Isla de Margarita, Venezuela. *Asociación Paleontological Argentina*, Publicación Especial, Paleógeno de América del Sur, **3**, 27-33.

Castillo, M. and Mann, P. 2006. Cretaceous to Holocene structural and stratigraphic development in south Lake Maracaibo, Venezuela, inferred form well and three-dimensional seismic data. *American Association of Petroleum Geologists*, **90**, 529-565.

Covault, J. A., Normark, W. R., Romans, B. W. and Graham, S. A. 2007. Highstand fans in the California borderland; the overlooked deep-water depositional systems. *Geology*, **35**, 783-786, http://doi:10.1130/G23800A.1.

Dickinson, W., Sue Beard, R., Brakenridge, R., Erjavec, J., Ferguson, R., Inman, K., Knepp, R., Lindberg, A. and Ryberg, P. 1983. Provenance of North American Phanerozoic sandstones in relation to tectonic setting. *Geological Society of America Bulletin*, **94**, 222-235. https://doi.org/10.1130/0016-7606(1983)94<222:PONAPS>2.0.CO;2

Donovan, A. D. 2013. Depositional topography and sequence development. In: **H. H. Roberts, N. C. Rosen, R. H. Dillon and J. B. Anderson (Eds.)**, *Shelf margin deltas and linked down slope petroleum systems: Global significance and future exploration potential. Society for Sedimentary Geology*, **23**, 493-522. https://doi.org/10.5724/gcs.03.23.0493

Escalona, A. and Mann, P. 2011. Tectonics, basin subsidence mechanisms, and paleogeography of the Caribbean-South American plate boundary zone. *Marine and Petroleum Geology*, **28**, 8-39. https://doi.org/10.1016/j.marpetgeo.2010.01.016

González de Juana, C., Iturralde, J. and Picard, X. 1980. *Geología de Venezuela y de sus cuencas petrolíferas*, Volumen **II**. Ediciones Foninves, Caracas. 1029 pp.

Hernandez, H. 1949. *Reconocimiento geológico de la región Boca del Rio SE y geología de la zona N de Pampatar, Isla de Margarita, Estado Nueva Esparta.* Unpublished Thesis, Universidad Central de Venezuela, 154 pp.

Levander A., Schmitz, M., Ave Lallemant, H. G., Zelt, C., Sawyer, D. S., Magnani, M., Mann, P., Christeson, G., Wright, J., Pavlis, G. and Pindell, J. 2006. Evolution of the southern Caribbean plate boundary. *EOS*, Transactions, American Geophysical Union, **87**(9), 97-100. https://doi.org/10.1029/2006EO090001

Macsotay, O. and Feraza, T. 2005. Middle Eocene foreland sediments covered by late Oligocene foredeep turbidites on Margarita Island, northeastern Venezuela. Transactions of the 16th Caribbean Geological Conference, Barbados. *Caribbean Journal of Earth Science*, **39**, 105-111.

Moreno, J. and Casas, J., 1986. *Estudio petrográfico y estadístico de la secuencia flysch Eocena de la Isla de Margarita*. Unpublished Thesis, Universidad Central de Venezuela, 177 pp.

Muñoz, N. G. 1973. Geología sedimentaria del flysch Eoceno de la Isla de Margarita, Venezuela. *Universidad Central de Venezuela, Geos*, **20**, 5-64.

Muñoz, N. and Furrer, M. 1976. *Cretáceo alóctono en el Eoceno de Margarita II Congreso Latinoamericano de Geología*, Ministerio de Minas e Hidrocarburos, Vol. **II**, 1321-1324.

Noguera, M. 2009. *Analysis of provenance of late Cretaceous – Eocene turbidite sequences in northern Venezuela, Tectonic implications on the evolution of the Caribbean.* Unpublished Thesis, University of Georgia, 202 pp.

Noguera, M., Wright, J., Fournier, H., Urbani, F. and Baquero, M. 2017. U-Pb de cristales de zircón detríticos de la Formación Matatere, estados Lara y Yaracuy. *Boletín Academia Nacional de la Ingeniería y el Hábitat*, **37**, 950-983.

Pindell, J.; Keenan; L., Maresch; W., Stanek, K., Draper, G. and Higgs, R. 2005. Plate-kinematics and crystal dynamics of circum-Caribbean arc-continent interactions: Tectonic controls on basin development in Proto-Caribbean margins. In: **H. Lallemant and V. B. Sisson (Eds.)**. *Caribbean-South American plate interactions*. The Geological Society of America, Special Paper, **394**, 7-52. https://doi.org/10.1130/0-8137-2394-9.7

Pindell, J.; Keenan; L., Wright, D. and Erikson, J. 2009. Clastic domains of sandstones in central/eastern Venezuela, Trinidad, and Barbados: heavy mineral and tectonic constraints on provenance and palaeogeography. In: **K. James, M. A. Lorente and J. Pindell (Eds.)**, *The origin and the evolution of the Caribbean plate*. Geological Society of London, Special Publication **328**, 743-797. http://doi:10.1144/SP328.29

Pindell, J. and Kennan, L. 2007. Cenozoic kinematics and dynamics of oblique collision between two convergent plate margins: The Caribbean-South America collision in eastern Venezuela, Trinidad and Barbados. In: **L. Kennan, J. Pindell and N. C. Rosen (Eds.)**, *The Paleogene of the Gulf of Mexico and Caribbean Basins: Processes, Events and Petroleum Systems*. GCSSEPM 27th Annual Bob F. Perkins Research Conference, 458-553. http://doi:10.5724/gcs.07.27.0458

Plink-Bjorklund, P. and Steel, R. 2002. Sea-level fall below the shelf edge, without basin-floor fans. *Geology*, **30**(2), 115–118. http://doi:10.1130/0091-7613(2002)030<0115:SLFBTS>2.0.CO;2

Rivero. F. 1956. *Léxico Estratigráfico de Venezuela. Ministerio de Minas e Hidrocarburos, Caracas*, Publicación especial **1**, 532-535.

Shagam, R., Kohn, B., Banks, P., Dasch, L., Vargas, R., Rodriguez, G. and Pimentel, N. 1984. Tectonic implications of Cretaceous–Pliocene fission-track ages from rocks of the circum-Maracaibo basin region of western Venezuela and eastern Colombia. In: **W. Bonini, R. Hargraves and R. Shagam (Eds.)**, *The Caribbean–South American plate boundary and regional tectonics*. Geological Society of America, Vol. **162**, 385-412. https://doi:10.1130/mem162-p385

Shanmugam, G. 2007. The obsolescence of deep-water sequence stratigraphy in petroleum geology. *Indian Journal of Petroleum Geology*, **16**, 1-62.

Shanmugam, G. 2021. The turbidite-contourite-tidalite-baroclinitehybridite problem: orthodoxy vs. Empirical evidence behind the "Bouma Sequence". *Journal of Palaeogeography*, **10**(9), 1-32. https://doi.org/10.1186/s42501-021-00085-1

Taylor, G. 1960. Geología de la Isla de Margarita, Venezuela. *III Congreso Geológico Venezolano, Ministerio de Minas e Hidrocarburos*, Vol. **II**, 838-893.

Xie, X., Paul Mann, P. and Escalona, A. 2010. Regional provenance study of Eocene clastic sedimentary rocks within the South America–Caribbean plate boundary zone using detrital zircon geochronology. *Earth and Planetary Science Letters,* **291**, 159-171. https://doi.org/10.1016/j.epsl.2010.01.009

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