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Palaeocene to middle Eocene flysch-wildflysch deposits of the Caribbean area: a chronological compilation of literature reports, implications for tectonic history and recommendations for further investigation

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ABSTRACT. **Literature reports upper Cretaceous to Middle Eocene flysch/wildflysch deposits from Mexico, Guatemala, Jamaica, Cuba, Puerto Rico, Barbados, Granada, Trinidad, Venezuela, Colombia, Ecuador and Peru. Early papers recording their widespread distribution and noting their tectonic implications are often overlooked by popular palaeogeographic and plate tectonic reconstructions of the Caribbean area. Detailed stratigraphic revision of some units has restricted their age of accumulation to the Palaeocene - Middle Eocene or to the K/T boundary event. Most of the deposits record violent interaction between the Caribbean and adjacent continental areas. They are classically attributed to a 'Laramide (Incaic) Orogeny'. An alternative explanation is that they record one or more impacts of extraterrestrial matter. Units that have not received recent stratigraphic study should be revisited. A possible impact crater in the Venezuelan Basin requires investigation.**

1. INTRODUCTION

Caribbean geological literature includes many references to 'Cretaceous-Middle Eocene' mixtures of disparate rocks, with various explanations of their origin. While the term 'flysch' appeared earlier, it was not until 1953 that Kugler published his recognition of wildflysch in Trinidad and Venezuela. The idea took hold in western Venezuela and new interpretations of huge olistolith/olistostromes, formerly mapped as autochthonous formations subsequently appeared. Authors concluded that coeval orogenesis had occurred in northern South America. Deposits in Venezuela and in Cuba were seen to record geological violence.

More recently, papers have quoted the deposits as a diachronous record of convergence between the Caribbean Plate and North and South America as it migrated from the Pacific.

The age and significance of the deposits are important for part of the tectonic history of the Caribbean region.

This paper provides a chronological record of reports and interpretations (Table 1). It follows with a discussion of tectonic implications, backed by a comprehensive bibliography. It shows that the deposits occur widely in the Caribbean and beyond. It suggests that the interval they record is shorter than currently understood and emphasizes that it is coeval. The violence the deposits record possibly resulted from impact of extraterrestrial material.

2. CHRONOLOGIC REPORT SUMMARIES

Guppy (1911) wrote of Barbados "*At Chalky Mount I saw a coarse conglomerate, the pebbles in which are of some size and are derived from a schistose or clay-slate formation, such as is found in the northern parts of Venezuela and Trinidad*". He considered these rocks to be Cretaceous.

Trechmann (1924) likened the Palaeocene-early Eocene Richmond Formation of Jamaica and its conglomerates to the flysch and Nagelflue of the European Alpine system and Switzerland, respectively. Conglomerates near the base of the section contain Cretaceous, rudist-bearing limestones, gneiss, schist, quartzite, clay slate, veined jasper-like rocks, chert, marble and various igneous rocks and occasional silicified wood. Trechmann remarked that while Hill (1899) had likened this unit to the coeval Scotland Group of Barbados, the latter did not contain such exotic lithic components.

Baldry (1932) followed by Barrington Brown (1938) interpreted some Tertiary deposits in Peru and Ecuador as the product of gravity sliding of unstable sediments into penecontemporaneous deeper environments.

In a 'pre-flysch' paper, Kugler (1936) noted the correlation of the Point-a-Pierre Formation of Trinidad with the Scotland Group of Barbados.

Hess (1938) recognized a serpentinized peridotite belt extending E-W across Guatemala,

Table 1. Table 1 Flysch andwildflysch deposits in the Caribbean area.

LOCATION/NAME	AGE	CONTENT
GUATEMALA Sepúr Gp.	Palaeocene-Eocene	Ophiolite, serpentinite, Campanian lmsts, Pz and Mz congl.
El Tambor Gp.	Maastrichtian	Ophiolite, serpentinite, wackes, phyllites, schists, Valanginian-Aptian and Cenomanian fossils in basalt interbeds.
CUBA Via Blanca Fm.	L. Campanian-Maastrichtian	
La Picota, Picara Fms.	L. Maastrichtian L. Maastrichtian-Danian	Ophiolites clasts
Cacarajíca, Peñalver, Amaro Fms.	K/T boundary	Megabeds of detrital limestone, limestone and chert breccia
Manacas Fm. (Vieja Mbr) Senado Fm.	L. Palaeocene-E. Eocene ?L. Eocene	Ophiolite, upper Jurassic-Cretaceous deep-water rocks
Vega Fm.	Palaeocene – M. Eocene	Cretaceous shallow marine carbonates, serpentinites, deep-water Mesozoic blocks
Vega Alta Fm.	L. Palaeocene-M. Eocene	Ophiolite, upper Jurassic-Cretaceous deep-water rocks
JAMAICA Richmond Fm.	Palaeocene-Eocene	Cretaceous rudist lmst., gneiss, schist, quartzite, chert, marble, igneous rocks
Fonthill Limestone Fm.	Middle Eocene	Upper, coarse breccias of the Richmond Formation. Exotic masses of the Richmond Formation, and Wagwater Conglomerate
DOMINICAN REPUBLIC Puerto Plata Blocks d'Ocoa	Middle Eocene Middle Eocene	Middle Eocene and older rocks Middle Eocene shallow-water lmst.
PUERTO RICO San German	?Eocene	Campanian-Maastrichtian limestone olistoliths
Sabana Grande	?Eocene	Sedimentary and volcanic blocks
Corozal Lstn.	Late Early - Early Late Palaeocene	Limestone breccia, volcanic ,metamorphic, sedimentary and plutonic rock fragmenst, resedimented lagoonal deposits in deep-water.
N. VIRGIN ISLES Tutu, Coki Point Fm	Campanian, Maastrichtian?	Flysch, megabreccia, Albian,Outer Brass lstn, Luisenhoj volcaniclastics,
BARBADOS Scotland Fm.	Middle Eocene	Schist, Cretaceous clay-slate, U Palaeocene-L. Eocene lstn.
GRENADA Tufton Hall Fm.	Eocene	Shale, volcanic greywackes
TRINIDAD Pointe-a-Pierre Fm.	Early Eocene	Cretaceous lmst.: Baremian-Albian, Cenomanian-Senonian, Palaeocene
Chaudiere Fm.	Palaeocene	Cretaceous quartzites, Senonian argillites, Maastrichtian, fossiliferous greywacke, Palaeocene coquina
Lizard Springs Fm.	Palaeocene-E. Eocene	Foraminiferal green shale
VENEZUELA Matatere Fm.	Palaeocene-Eocene	Palaeocene: Turonian lmst; Eocene: Albian lmst, igneous and metamorphic rocks, Bajocian-Bathonian Siquisique Ophiolites, gneiss, trondhjemites
Tarana area	Palaeocene-Eocene	Basalts, tuffs
San Quintín area	Palaeocene-Eocene	Volcanic rocks, gabbro, granulites
Garrapata Fm.	E. Eocene	Coniacian turbidites, greywacke, Querecual, lava, tuffs, diorites, gabbro, granulite, schist, quartzite, meta chert, serpentinite, erosional products from Villa de Cura
Río Guache Fm.	Palaeocene-Eocene	Sandy shale, fluxoturbidites, Cretaceous lmst., igneous rocks and micaschists
Paracotos Fm.	Maastrichtian?	Phyllitic shales, silts/sandstones, metagreywackes, Cenomanian and Maastrichtian lmst., volcanic rocks
Escorzonera Fm.	Palaeocene	Shales, sstns, lsmt., lava, andesite, metamorphic rocks, upper Cretaceous lmst.

Table 1 (continued)

Guárico Fm.	Palaeocene-E. Eocene	Jurassic calpionellid lmst., Albian-Turonian lmst.,
Mucaria Fm.	? Maastrichtian-Palaeocene	Campanian – Maastrichtian lstn., shale, Lower Cretaceous olistostromes.
Punta Mosquito/Carnero Fms.	M. Eocene	Silt, shale, sstn, Palaeocene-E. Eocene fauna, orbitoidal lmst., bioclastic turbidites, chert, volcanic rocks, andesite
Las Bermudez Fm.	Middle Eocene	
Villa de Cura nappe	Palaeocene-Middle Eocene emplacement	Cretaceous island-arc, gabbro, diorite, andesite, metavolcanics
BONAIRE Rincón Fm.	Eocene	Maastrichtian rudist lmst., conglomeratic lmst, tuff, porphyritic andesite
PANAMA Morti Tuffs	E-Middle Eocene	Slumped blocks of shallow-water deposits
COLOMBIA Luruaco Fm.	Palaeocene-Eocene	Silicified limestones, volcaniclastic sstns, tuffs, granite, granodiorites
Bahia Honda	Campanian-Eocene	Phyllites, quartzites, serpentinites, slumped blocks
ECUADOR Ancon Gp.	Middle Eocene	Olistoliths
Piñon, Cayo, San Lorenzo fms., Yungilla Fm., Silante Fm. San Eduardo Fm., San Mateo Fm.	Palaeocene-early Eocene Early Middle Eocene Late Middle Eocene	Cretaceous-Palaeocene MORB, volcanic arc deposits. Flysch, conglomerates Calcareous flysch Conglomeratic-fine grained turbidites
PERU Talara Gp.	Middle Eocene	Olistoliths

Cuba, Hispaniola and Puerto Rico in the north and Margarita, Los Roques, the Guajira and along the Central Cordillera of Colombia. The most probable age of the belt was late Middle Eocene.

In 1937, Trechmann suggested that exotic blocks of Cretaceous limestone within lower Eocene marls at Point-a-Pierre in Trinidad might have accumulated in the same manner as blocks of Pleistocene coral limestone moving downslope from elevated cliffs in modern Barbados. Trechmann also found caprinids and corals in irregular limestone lenses (slipped blocks) within the shales of northern Trinidad's Toco Bay and compared these with the Cuche Formation of the Central Range and the Barranquín Formation of Venezuela.

Senn (1940) mentioned blocks of hard, well bedded, grey, somewhat glauconitic, sandy and gritty limestones, rich in *Lithothamnium*, *Nummulites* and *Operculina* in the Joe's River Formation of Barbados, but not exposed in any normal sequence of beds. Senn supposed that they represented a formation similar in age to the *Pellatispirella* limestone that forms the roof of the Soldado Formation of Soldado Rock, Trinidad. Larger foraminifers from the block indicate latest Palaeocene to earliest Eocene.

Renz (1942) wrote about boulders of Upper Cretaceous and possibly Middle Cretaceous on Barbados. Liddle (1946) wrote, "*In the area occupied today by the Caribbean Coast Range and the Northern Range of Trinidad the Laramide orogenesis caused the definite emergence of a geanticlinal ridge. During the lower and middle Eocene, the Caribbean Ridge seems to have formed a low but continuously rising island festoon, furnishing the clastic material for an important Flysch formation along its northern slope and known as the Misoa-Trujillo formation of northwestern Venezuela and the Scotland formation of Barbados. The Pointe-a-Pierre formation of central Trinidad may represent a similar Flysch facies developed along the southern foot of the Northern Range*".

Wells (1948) wrote that limestone from the Central Range of Trinidad contained an 'Urgonian' reef coral fauna. The material came from a unit not known in place. It appeared only as loose blocks of limestone composed largely of worn fragments of corals, sponges, echinoderms, pelecypods and nerineid gastropods. This fauna showed strong affinities with the upper part of the Barranquin Formation of Eastern Venezuela.

Dorreen (1951) described the chaotic structure of the Talara shale of coastal northwestern Peru. The unit contained blocks of sandstone and shale, cobbles and pebbles of igneous or metamorphic rock, quartz (Andean and Amotape origin) and flow structures. Blocks of cross-bedded sandstone, fractured as if impacted, contained shallow-water shell fragments and echinoid spines; the surrounding shales contained a deep water foraminiferal assemblage.

Mencher *et al*. (1951) described Venezuela's Palaeocene Guárico Formation as reefal limestones (Morro limestone), shales, sandstones with clasts of igneous rocks, tuffs, agglomerates and flow. They represented shallow marine deposition that included reefs on the flanks of volcanoes.

González de Juana and Ponte Rodríguez (1951) referred to flysch in the north of the Maturín basin. In the same year, Suter (1951) referred to the 'remnant' formations of Trinidad's Central Range as slump masses and boulder components of conglomerates that never occur in normal sequence. They comprised limestone blocks of varying size and ages ranging across Maastrichtian, Turonian, Albian and Barremian. He also mentioned the presence of flysch in the Oligocene Cipero and Miocene Nariva and Karamat formations and, interestingly, suggested that these hydrocarbon-bearing units might include source beds.

In 1952, in an internal Shell report on the geology of the Sub-Andean zone between Altagracia de Orituco and Barinas, Venezuela, Jackson described the Cerro Amparo as a huge lens of boulder bed, including miliolid limestone, Turonian limestone with ammonite-bearing discoidal concretions, acid gneiss, granite, mica schist, and small boulders of Caprinid and orbitolinid limestones. The report noted that Renz had interpreted this as a tectonic wedge of Cogollo type limestone on basement.

Barr (1952) used the same Barbados analogue as Trechmann (1947) when discussing lower Cretaceous limestone blocks within the penecontemporaneous (Barremian-Albian) Cuche shales of Trinidad's Central Ranges. Since no *in situ* occurrence of the limestones was known, possible long distance transport involving slumping or turbidity currents might have occurred.

A year later, Kugler (1953) referred to the unit containing Trinidad's remnant formations, the Palaeocene Chaudiere Formation, as wildflysch. He also noted the occurrence of upper Cretaceous Gautier Formation within Chaudiere shales within Oligocene flysch. He described the Morne Diablo (Eocene), Morne Roche (Oligocene) and Whitestone Hill (Cretaceous Naparima Hill) as rootless masses in Oligocene and Lower Miocene clays. The Oligocene is not the subject of this paper, but here is evidence of Oligocene wildflysch deposition. It indicates compressional uplift that also predates the supposed arrival of the Caribbean Plate in Pacific origin models (see also the work of Vivas and Macsotay, 1995, on the olistostromic, late Eocene–early Oligocene Tememure Formation of north Central Venezuela).

Kugler (1953) wrote that correlation of Trinidad's Pointe-a-Pierre Formation with the lower Scotland Formation of Barbados had always been seriously considered. Both were typical flysch deposits. Echoing Liddle (1946), he remarked upon their great similarity with the Misoa-Trujillo of the Maracaibo region and Falcón, Venezuela. Kugler also wrote that the Morros of the southern part of Venezuela's Interior Range, from western Anzoategui to San Juan de los Morros, occurred in the Guayuta, Vidoño and younger shales. The 'morros', topographic highs of resistant allochthonous masses within more easily weathered shales, were characteristic expressions of wildflysch and provided clues to the distribution of such deposits. The olistostromes ranged up to several kilometres in length and before their true nature became recognized in the mid-fifties some were given formation rank (e.g., Escorzonera and Garrapata formations). Kugler suggested that some morros of coralline algae might have formed on thrusted highs that reached the photic zone.

In 1955, two groups, Renz *et al*. and Evanoff *et al*., presented papers describing allochthonous units in Venezuela. The latter authors credited Hess with recognition that limestone blocks within the Tertiary were allochthonous, but provided neither reference nor date.

Renz *et al*. (1955) described the Palaeocene to middle Eocene flysch of the Barquisimeto Basin as shales with numerous intraformational breccias and a boulder bed with clasts of the La Luna and Cogollo formations. Allochthonous slabs of La Luna occurred near the top of the shales. *Lithothamnium* reefs with Palaeocene larger foraminifers lay above. The conformably overlying Eocene began with a conglomeratic sandstone containing pebbles with larger Palaeocene foraminifers, followed by a thick section of shales with boulders of crystalline rocks, Cretaceous limestones and Palaeocene *Lithothamnium* limestones. Above lay ironstones and sandstones, including pebbles of Palaeocene rocks followed by shales alternating with layers of fine sandstone. Near the top, these shales contained early Eocene larger foraminifers. At the boundary between the lower and middle Eocene, a boulder bed contained metamorphics, granite and Cretaceous and Palaeocene limestones. The middle Eocene began with shales containing middle Eocene larger foraminifers. They included the Paraguito boulder bed (derived from the north?) with boulders of granite, metamorphic rocks, Cretaceous limestones and sandstones, and Palaeocene limestones. This unit extended along strike for more than 40 km. Renz *et al*. (1955) envisaged the Barquisimeto trough as bounded by a hinge line from which Cretaceous sediments and pre-Cretaceous metamorphic and igneous basement slumped. The composition of the slumped units changed with time. Post-Palaeocene boulder beds included pre-Cretaceous igneous and metamorphic rocks as well as Palaeocene *Lithothamnium* reef limestone. These were not present in the Palaeocene boulder beds. Olistoliths in the Palaeocene part of western Venezuela's Matatere Formation contained Turonian ammonites, while those in the Eocene part contained middle Albian species, indicating unroofing of a Cretaceous section in the provenance area.

In addition, Renz *et al*. (1955) discussed earlier interpretations that limestones within claystones and shales were lenses, and that igneous components were remains of intrusions into the shales. The mixture of igneous, metamorphic and sedimentary constituents and limestones of various ages and types, together with the lack of contact metamorphism showed such interpretations were incorrect. Alternative explanations such as Cretaceous islands exposed in Palaeocene-Eocene seas and tectonic melanges were ruled out because of wide distribution, not related to tectonic lineaments, the presence of angular to sub-rounded clasts and of igneous components showing little evidence of weathering or transportation and the great heterogeneity of material. Note here that the earlier interpretations are similar to explanations offered for lithologic variations in metamorphic rocks in the region (see later).

Kugler (1953) matched olistostromes of Trinidad with units known in Venezuela, summarizing them into four broad groupings: 1) organic-detrital limestones of the Barremian-Albian El Cantil and Barranquin formations; 2) bituminous, siliceous limestones of the Cenomanian-Senonian Guayuta Group; 3) fossiliferous, shallow marine Maastrichtian sandstones (no exact equivalents known from Venezuela, probably once present in Sucre and northern Monagas) and 4) fossiliferous Palaeocene limestones. Note here that metamorphic and igneous components seem to be absent from Palaeocene to Eocene deposits in Trinidad where they make a first appearance in the Oligocene.

Marchant (1956) described the extreme western part of Ecuador's Santa Elena Peninsula as a mosaic of Cretaceous and Palaeocene fault blocks. The Maastrichtian Santa Elena Formation cropped out as blocks faulted up among younger sediments. Different parts of the succession were exposed in different fault blocks isolated from each other. Igneous occurrences were confined entirely to areas of Cretaceous outcrop. At Punta Santa Elena, igneous components occurred as isolated boulders in an argillite. A large outcrop at Punta Suche appeared faulted on all sides against Cretaceous strata and showed grading into a massive conglomerate of big igneous boulders set in a clayey matrix. Marchant described the Clay Pebble-bed of southwest Ecuador as structureless clay containing a variety of pebbles, boulders or large blocks of hard quartzites, sandstones, clay, calcareous mudstone and, rarely, igneous rocks. Barrington Brown and Baldry (1925) had first attributed it to crush brecciation, and Barrington Brown (1938) to gravity sliding. Sheppard (1937) had suggested that these were the result of mudflows from the Andes, 150 miles away. Reviewing theories of Baldry, Barrington Brown and Sheppard, Marchant (1956) stated: "*A detailed refutation of these suggestions, which verge on the fantastic, cannot now be presented ….*" Instead, Marchant suggested a possible association with turbidity currents or earthquakes.

Bushman (1958) described shales, limestones and sandstones of the Carorita Formation of the Barquisimeto area, western Venezuela. Bushman noted similarities with Palaeocene and Eocene deposits, but deduced a Middle to Late Albian age for the Carorita (Aptian - Albian according to González de Juana *et al*., 1980). Above these lay siliceous limestones, black chert and dark grey limestones, which Bushman called the Barquisimeto Formation (Cenomanian-Maastrichtian) and considered to be the lateral equivalent of the La Luna Formation. Some of the limestones disappeared along strike because of 'abrupt facies changes laterally into marls or shales' (in 1968, Bellizia and Rodríguez concluded that these units form a large, coherent allochthonous mass).

In 1959 Evanoff *et al*. (oral presentation, 1955) described olistoliths in the Tertiary of western Venezuela. Small olistoliths of granite, diorite, quartzite, micaceous schists, and gneisses occurred along with larger and more abundant olistoliths of fossiliferous Cretaceous limestones (La Luna and Cogollo formations). Large olistoliths were Cretaceous shales, limestones and cherts (La Luna and Cogollo).

Baadsgaard (1960) wrote of Barbados "*The sediments which now form the almost chaotic mass* *of the Scotland Group were derived from a land mass probably made up in part of Cretaceous and Lower Tertiary rocks, and originally deposited to the southeast of the present island area. These sediments were later moved to the location of Barbados by sheet dislocation northwestwards into a trough which then existed along the axis of the main regional negative gravity anomaly*".

In 1960, Coronel and Renz reported on a zone, northwest of Barquisimeto, studied by Bushman who had described (1959) several thrusts to account for the observed stratigraphy. Coronel and Renz (1960) recognized numerous allochthonous Cretaceous masses from some 10 by 10 cm up to 4 by 3 km that they ascribed to submarine slumping, as observed by Renz *et al*. (1955) in neighbouring Carora.

Douglass (1961) noted the presence of orbitolines from the Murphy's and Chalky Mount members of Upper Scotland, Barbados. Described by Vaughan (1945) as *Orbitolina senni* Vaughan, their age was problematic: they appeared to be Albian, but occur in the Eocene. Vaughan had noted blocks of pre-Eocene rocks in the Scotland District in mud flows; and it was possible that the orbitolines came from these.

Salvador and Hotz (1963) presented a palaeogeographic map showing a regional flysch trough in the Barremian-Aptian and in the Albian along the north coast of Venezuela - Trinidad. They noted that the 'immensely thick' flysch deposits of Trinidad's Barremian-Aptian Tompire and lower Toco formations were metamorphosed.

Stainforth (1966) attributed the recognition of a gravitational origin for some Venezuelan deposits to Kugler, noting, however, that the idea was slow to be accepted. Renz *et al*. (1958) made no reference to such deposits and added that even then, some of the Morros of Guárico were still regarded as in place reef limestone or as tectonic wedges. He continued "*Any reader who already feels sceptical about the scale of slumping postulated in Lara should grit his teeth before reading on*". The mountains of north-central Venezuela were composed of various metamorphic and igneous rocks of Mesozoic age, mostly Cretaceous. The Villa de Cura Group, estimated to be at least 13,000 feet thick and forming a mountain range 180 miles long and up to 20 miles wide was completely allochthonous. Emplacement had involved successive slabs that inverted the original sequence and caused an apparent upward increase in metamorphic grade. Actually, Hess (1938) appears to have recognized the magnitude of the Villa de Cura slide (a suggestion noted as personal communication in a doctoral thesis, 1960; see Donnelly, 1971).

Pierce (1960) and Peirson *et al*. (1966) and Gonzáles Silva and Picard (1972) described allochthonous material in Palaeocene-Eocene flysch deposits of the Interior Ranges of north central Venezuela (Guárico and Paracotos Formations), the Barquisimeto Basin (Matatere Formation), and the Portuguesa Basin (Rio Guacha Formation). Material included Late Jurassic to Neocomian, calpionellid-bearing reef limestones, Aptian-Albian rudistid limestones and conglomerates, Aptian calpionellid pelagic limestones, and olistostromes of major, Upper Cretaceous source rocks (La Luna and Querecual formations, all of which were considered to have had a northern provenance: the rising 'borderland of Paria' discussed by Guppy (1911), Schuchert (1935) and Hedberg (1950).

Burke and Robinson (1965) described the Jamaican Richmond Formation; 2,500 feet of greywackes, mainly sandstones and siltstones, with conglomerates near the base where there is passage upwards by intercalation from the Wagwater conglomerate. It is characterized by graded bedding, load and flute casts, sandstone dykes, and slump structures in the upper part. The overlying, Middle Eocene Fonthill Limestone is a thinly bedded, marly, cream limestone (benthic and dominantly planktic foraminifers) with interbedded clastic limestones with large foraminifers and algal fragments. Coarse breccias occur in the upper part of the section, often graded, with blocks of the Richmond Formation up to 60 cm in size. There are local exotic masses of the Richmond Formation, some more than 50 feet across and local exotics of Wagwater Conglomerate.

In 1967, Kugler and Saunders again noted that the Palaeocene Chaudiere Formation carried slump masses of Cretaceous rocks and went on to discuss the upper Eocene San Fernando and Oligocene Nariva formations. These contained huge blocks of Palaeocene, glauconitic, coquina limestone, called the Soldado Formation, derived from the Central or Northern Range areas. The San Fernando Formation contained large blocks of Senonian argillites, Maastrichtian fossiliferous greywackes and Palaeocene coquina limestones. The Nariva Formation contained slump masses of Eocene, Palaeocene and upper and lower Cretaceous, often several hundreds of metres in length.

Osten (1967) described the Palaeocene to Middle Eocene Morán Formation that contains the lower, El Tocuyo Member, 1300 m, thick and the upper Botucal Member, 600 m thick. The Morán was a typical flysch, shaley in the lower part, with turbidites, greywackes and lenses of fossiliferous limestones. It became sandier upwards, passing into the thick, fine- to coarse-grained sandstones of the Butucal Member. Boulder beds and exotic blocks up to house size were common, usually of Cretaceous sedimentary units, but locally of granite. Some of the boulder beds have been named Pavia Boulder Beds (Bushman, 1963) and Paragüito Boulder Beds (Renz *et al*., 1955). Osten (1967) pointed out that these units were discontinuous and proposed to call them the Pavia facies. This corresponded closely to the unnamed Tertiary flysch facies of Coronel and Renz (1960). Osten considered large masses of Cretaceous rocks, up to 30 km^2 in area (olistostromes) associated with the Morán to be overlying, allochthonous material postdating the Morán.

In 1968, Dengo discussed the late Cretaceous, Palaeocene and Eocene Laramide orogeny that produced an elongate basin with flysch deposition of the Ocozocuautla Formation in SE Mexico.

Bell (1968) noted that Renz (1955) first used the term Garrapata for beds along the San Juan-San Sebastian road at the foot of Cerro Garrapata, a few kilometres northeast of San Juan de los Morros. The formation cropped out as discontinuous elongate bodies along the northern edge of the foothills belt. Coniacian turbidites occurred as blocks in the Late Maastrichtian - Early Eocene Guárico Formation. Clastic content (greywacke, lithic wacke, slate or shale, chert, bioclastic limestone, calcarenite, aphanitic limestone [Querecual], lava, tuff, diorites, granulite, schist, quartzite, meta chert) suggested derivation from a volcanic sequence similar to the Tiara Volcanic Formation (Villa de Cura).

Alvarez (1968) proposed the name Bahia Honda Group for the phyllites and quartzites of greenschist facies on the Guajira Peninsula. Emplacement of thrust sheets of Bahia Honda Group rocks, probably as gravity slide blocks, was followed by regional metamorphism and penetrative deformation in the Campanian-Eocene.

In 1969, Chase and Bunce described folded and slumped flysch in association with pelagic sedimentary rocks of Eocene and Oligocene age on Barbados. Stainforth (1966) described a deep marine trough that extended from Trinidad to Lara. Unstable uplift in the north supplied extensive flysch and wildflysch (Chaudiere, Guarico and Matatere) and giant slump blocks while the stable platform to the south accumulated the Guasare, Orocue and others. Violent orogeny in the Middle Eocene resulting in uplift of the early Tertiary trough, downwarp of the stable shelf, tilting and block faulting of the Maracaibo Block, volcanism in Guajira, Paraguana and Falcón.

Almy (1969) described the geology of southwest Puerto Rico. He noted the presence of the Bermeja Complex (serpentinite, chert, amphibolite, pre-Cenomanian), the Río Loco Formation (basaltic andesites, Cenomanian?), the Mayagüez Group (basaltic andesites, mudstones, limestones, Turonian-Maastrichtian), and the San Germán Formation (volcanic agglomerates, andesites, bioclastic limestones, Maastrichtian). The Mayagüez Group is subdivided into the Yauco Mudstone, with lenses of Maricao Basalt, the Sabana Grande Andesite, a thick lens, the Brujo Limestone, (massive bioclastic limestone), the Melones Limestone and the El Rayo Volcanics. The latter were associated with the Parguera Limestone, itself subdivided into: basal glauconitic calcarenite (Santonian-lower Campanian), with much non-carbonate clastic detritus at the base; middle foraminiferal (planktic) mudstones and minor calcarenites that show much slumping (Campanian-Maastrichtian); and an upper volcanic conglomerate with minor carbonate, grading up to very coarse bioclastic limestone with rare volcanic material (Upper Campanian-Maastrichtian).

Robinson *et al*. (1970) described the Richmond Formation turbidite sequence of Jamaica as greywacke sandstones and shales above basal conglomerates. Major chaotic units of wildflysch character occurred at the southern and northern ends of the Wagwater Trough. Thick conglomerates with sub-rounded fragments of volcanic rocks, granodiorite and Cretaceous limestones, together with broken and twisted slabs of Richmond mudstones and siltstones occurred interbedded with normal Richmond beds, possibly introduced by submarine slides triggered by early and middle Eocene, late Laramide fault activity.

Tomblin (1970) described the Tufton Hall Eocene flysch of Granada as thinly bedded shales and fine-grained volcanic greywackes with occasional calcareous beds, a few of which approach limestones.

Donnelly (1970) described the Tutu Formation, North Virgin Islands, built of wackes that contain detritus from the Albian Luisenhoj andesitic volcaniclastics and Outer Brass Limestones. The Tutu includes the Coki Point megabreccia, slump masses containing fragments of fossiliferous limestone from inches to more than 100 feet, containing fossils of Albian age. Similar units further west are metamorphosed to marbles within pseudo-dioritic hornfels, probably once the same as the megabreccia.

In 1971, Lockwood described lenses and large masses (100-300 m thick, estimated original area 25 km^2) of serpentinite within Mesozoic phyllites and metasiltstones (see Alvarez, 1968) in northwest

Guajira. Lenses of poorly sorted breccias grade upward into bedded serpentinite sandstone and shale. The sandstones show graded bedding, channeling and cross-bedding. The deposits are formed by submarine turbidite flows and by gravity sliding of large masses from a northern provenance.

Nagle (1971) attributed the San Marcos Olistolstrome (a several hundred metre thick chaotic unit containing clasts of various lithologies ranging from a few millimetres to two kilometres) of the Puerto Plate area of northern Dominican Republic to sliding triggered by a Middle Eocene earthquake.

Daviess (1971) concluded that shallow-water marine and terrestrial deposits of the Scotland Group underlay most, if not all, of the Barbados Ridge. They represented a major submarine slide or olistolith, sourced from the marginal region of Paria, or the Caribbean block. The slide consists of elements ranging from sand-sized grains to huge blocks measured in cubic kilometres,

Bellizia *et al*. (1972) discussed the Siquisique ophiolites that crop out on the northern border of the western Venezuela's Barquisimeto Basin, embedded within Palaeocene-Eocene turbidites. Allochthons ranged in size from centimetres to blocks of 'large dimensions' and fell into three main constituent groups: 1) spilitic basalts, tuffs, gabbros, anorthitic gabbros, serpentinized olivine basalts and peridotites derived from oceanic crust, 2) chert, limestones, shales and phyllites of the Barquisimeto and La Luna formations and 3) turbidites of the Matatere Formation. In addition, there were pebbles of gneiss and trondhjemites. Further west, in the Tarana region, Bellizia *et al*. (1972) recognized another allochthonous mass built of basalts and tuffs within Palaeocene sediments. In addition, in the San Quintín hills they observed an outcrop of volcanic rocks, anorthositic gabbros and granulites that were very similar to the Siquisique rocks. The authors noted similarities between these basalts and those of the El Carmen Formation of the Villa de Cura Group and with the volcanics of Tiara in the central part of the Caribbean Mountains.

González Silva and Picard (1972) described the Guárico Formation as flysch with abundant submarine slides and exotic blocks of various dimensions. The most important of these occurred in the Palaeocene section and resulted from the paroxysm of Cordillera de la Costa uplift and the end of the Villa de Cura emplacement. Allochthonous material includes metamorphics of the Palaeozoic Tinaco complex and the Mesozoic metamorphic belt of the Coastal Range, sedimentary units formerly unknown in normal outcrop (Garrapata and Escorzonera), units of the El Cantil, Querecual, Mucaria-San Antonio and Guárico flysch.

Hunter (1972) compared the flysch of the Guacharaca uplift (Falcón Basin) with the Punta Mosquito Formation of Margarita Island. González Silva and Picard (1972) discussed the Guárico flysch and noted that the Garrapata is of Eocene age.

Meyerhoff and Meyerhoff (1972) noted that structures in the strongly deformed Paleocene–Eocene of Barbados parallel similar structures on Tobago and that the lithologic content shows that the sediments were derived from a continent to the south.

Furrer (1972) reported upon occurrences of tintinnids (calpionellids) in Venezuela. They were noted first in aphanitic limestone in conglomerates at the base of the Oligo-Miocene Casupal Formation of southeast Falcón (1962, Bermúdez and Rodríguez). They also occur in the San Juan de Los Morros-Ortiz area of Guárico State. In the Parapara area Berriasian-Hauterivian species occurred in exotic blocks in the Paleocene - Lower Eocene flysch. Since all other rocks of that age in Venezuela were metamorphics, barren or with fauna of little stratigraphic value, Furrer suggested that his samples came from a Neocomian shelf, which rimmed the Caribbean, much of which was now in the metamorphic rocks of northern Venezuela. Aptian tintinnids occurred in the Corocito-Ortiz area in concretion-like cobbles of siliceous grey limestone of pelagic origins (*Praeglobotruncana*, *Planomalina* and radiolaria are also present). The locality also had blocks of El Cantil, Querecual, San Antonio and phyllites.

Bandy and Casey (1973) reported the presence of blocks of shallow-water deposits slumped into the lower to middle Eocene, radiolarian Morti Tuffs of eastern Panamá. Radiolarian-rich beds provide an association biostratigraphically and lithologically equivalent to Reflector Horizon 'A' (early-late Middle Eocene) of the Caribbean.

Maresch (1974) concluded that a southward-migrating foredeep of the Late Cretaceous to Palaeocene was followed by rapid uplift and gravity emplacement of the Villa de Cura complex.

Saunders (1974) wrote, "*Without the concept of wildflysch the complicated conditions of parts of the Trinidadian stratigraphy become impossible*".

Tardy *et al*. (1974) discussed the formation of flysch deposits during the Campanian-Maastrichtian in the Parras and Chicontepec (Palaeocene) foredeeps of N-NE Mexico.

In 1977 Stephan noted that olistoliths were abundant at certain levels as 'Complexes of Blocks' (the boulder beds of Renz *et al*., 1955), distinct from wildflysch, in the mountain front of the Guárico Basin. These complexes occurred at the major tectonic contact between the Villa de Cura-El Tinaco nappes and the Guárico flysch. In the Barquisimeto Basin, the same complexes occurred below the large allochthonous masses of the Barquisimeto Formation. Generally, the olistoliths reflected the composition of the overlying allochthon (i.e., the allochthon formed a lid to the underlying wildflysch, see later discussion on the Maturín Basin). He also noted the bipolar (north and south) sourcing of the olistoliths and suggested that allochthons allowed reconstruction of palaeogeography that existed to the north. The turbiditic Garrapata was recognized as a unit of piedmont and submarine slope environment where erosional products from the Villa de Cura nappe accumulated and where the little consolidated sediments were intruded by gabbro and diorite sills. Some of the coastal sites at this time were favourable for reef growth, especially in the Maastrichtian (Escozonera Formation). A calm episode allowed accumulation of the Paracotos Formation, possibly as the lateral equivalent to the Escorzonera. Towards the end of the Maastrichtian the high pressure (blue schist) metamorphic Villa de Cura complex of submarine basic volcanics and progressively larger masses of El Cantil, Querecual, Garrapata, Mucaria and Guárico arrived in the Guárico basin, forming the chaotic Los Cajones Member of the Guárico Formation.

Stephan (1977) also noted that the Venezuelan islands have the same components as the Caribbean Mountains: Mesozoic or older metamorphites together with oceanic island arc and continental material. The Netherlands Antilles include lower to upper Cretaceous volcanic-sediments overlain by lower Palaeocene flysch.

In 1977, Mac Gillavry described occurrences of rudists on Curaçao and Bonaire. The Seroe Teintje limestones occur as large slumped blocks in the Knip Group. The Zevenbergen limestones at or near the base of the Knip are also considered to be slumps, as are the Rincón limestones of Bonaire. Mac Gillavry observed this to be a widespread phenomenon since many Caribbean localities show rudists in slumps into deeper water deposits (intercalated between pelagic beds at Wagthus Point, St. Croix, slumped rubble beds in south Puerto Rico).

Mac Gillavry and Beets (1977) reported that the Rincón Formation of Curaçao consists of limestones, conglomeratic limestones and conglomerates. The conglomerates (which contain porphyritic andesite pebbles) are Eocene in age. The carbonates are Maastrichtian (rich fauna of *Globotruncana*). They interpreted the Rincón as a deep-water deposit containing slumped material.

Bourgois *et al.* (1979) described the Middle Eocene unit 'blocs d'Ocoa' of Hispaniola as marls and siltstones with olistostromes of shallow-water Middle Eocene limestones.

González de Juana *et al*. (1980) described limestones with graphitic matrix and Maastrichtian fauna mixed with conglomerates and volcanics in a phyllitic matrix in the Paracotos Formation that crops out in a tectonic window north of the Villa de Cura allochthon of north Central Venezuela. The Cojedes Formation, feldspathic sandstones and conglomerates, and the Mapuey Formation, limestones interbedded with phyllites, of the Faja Piemontina, were both Albian in age. These authors again noted that olistoliths of the Upper Cretaceous Querecual Formation occurred within the Guárico Formation as the Los Cajones Member and as the Caliza de El Totumo in the Ventana de El Tagual wildflysch. The Los Cajones Member also contained olistoliths of the Campanian-Maastrichtian Mucaria Formation and olistostromes built of olistoliths of various limestones (the Morro del Faro Member, with components dated from Lower Cretaceous to Lower Eocene). In the Interior Ranges of north central Venezuela, the Querecual was overlain by the Mucaria Formation, which in turn was overlain by the Palaeocene Guárico Formation.

Baldock (1985) describes three units from the Santa Elena Peninsula, Ecuador, as olistostromes with middle-late Eocene matrix fauna. The sediments reach 2-3 km thickness, thickening against faults in the north and south.

Duque-Caro (1984), wrote that late Cretaceous to middle Eocene, deep-sea pelagites and turbidites in the San Jacinto foldbelt, Colombia, are associated with mafic and ultramafic intrusive rocks and interbedded basaltic flows. To the south, these are underlain by 2,000 m of late Cretaceous turbidites. Duque-Caro described two landforms in the San Jacinto range. In the west there are single conical hills of intensely contorted pelagic and hemipelagic strata. Isolated masses rise from the surrounding flat terrain to 20 m. In the east conical hills (the Luruaco, San Jacinto and San Jerónimo, increasing in altitude southwards) rise from low-lying swampy terrain. These are narrow, elongated anticlines cored by Late Cretaceous cherts and siliceous mudstones and surrounded by Palaeocene to middle Eocene turbidites. The island-like appearance of the three anticlinorial elements separated by swampy terrains was interpreted by Duque-Caro (1979) as the remnant expression of a submarine volcanic chain.

In 1984 he presented a new interpretation that the Cretaceous cores had been emplaced through diapirism.

Mattson (1984) wrote that central Haiti contains Middle Eocene clastic rocks, limestones and andesite tuff and lava intruded by Upper Eocene granodiorite and dolerite. A submarine slide or olistostrome containing Middle Eocene and older rocks moved downslope to the north in the Puerto Plata area (northern Dominican Republic). It was uplifted and emergent before early Late Eocene time.

Bartok *et al*. (1985) described Bajocian - early Bathonian ammonite fragments from shales interbedded with pillow lavas of the Siquisique complex thus dating the Siquisique Ophiolites. These became emplaced in the Matatere Flysch during the Eocene. The Matatere also contained olistoliths of the Cogollo Group and of volcanic material. The latter became more abundant northwards towards Siquisique. Also in the Siquisique area there were olistoliths of the Barquisimeto Formation, again a flysch deposit, but distinguished by incipient metamorphism (Bellizia *et al*., 1972) and a Maastrichtian age (Bushman, 1959).

Guedez (1985) discussed a late Palaeocene to Middle Eocene flysch basin in the Monay-Carora area of Venezuela, surrounded by platform sedimentation. It suffered uplift in the late Middle Eocene.

Flysch of mainly Palaeocene age formed in elongated troughs between the Mexican Laramide fold and thrust belt and the Gulf of Mexico (Dengo, 1985).

Muñoz (1986) published his studies of the Punta Carnero Formation of Margarita, noting the presence of reef-derived bioclastic turbidites interlayered with deep marine shale. A basal wildflysch member contains polymict conglomerates of chert, limestone, volcanics, quartz fragments, olistoliths in a shaly matrix, blocks of coralline-algal limestones in shaly and sandstone matrix. There are palaeocurrent indications of northern and southern transport from sources interpreted to consist of metamorphic complexes bordered by Cretaceous and Palaeocene sediments. Allochthonous material includes phyllite, quartzite, high rank schists, fragments of acidic and ultrabasic igneous rocks, volcanics (mainly andesites), Cretaceous limestone clasts and bedded cherts, pre-Eocene reefal limestones, cobbles and pebble-size conglomerates, greywackes and shales.

Kaminski *et al*. (1988) described 'flysch' assemblages of agglutinated foraminifera from the Maastrichtian Guayaguayare and Palaeocene Chaudier and Lizard Springs formations of Trinidad. The Guayaguayare occurred in wells in southern Trinidad and as isolated slump blocks in Tertiary units in the Central Range. The Maastrichtian shales overlay the Turonian-Campanian Naparima Hill Formation.

Donnelly (1989) discussed the age of suturing along the Motagua Zone, central Guatemala, mentioning the presence of an ophiolitic slide mass above flysch (Sepúr Formation) containing late Campanian pelagic foraminifers.

According to Daly (1989), a regional hiatus of Danian to early Middle Eocene age in Ecuadorian forearc basins may record Piñon Terrane collision. It is followed by early Middle Eocene calcareous flysch of the San Eduardo Formation, in turn overlain with slight unconformity by late Middle Eocene to Late Eocene siliceous clastic flysch. The San Mateo Formation of the Manabi Basin is a flysch of mainly shallow-water, conglomeratic to fine grained turbiditic sandstone (with local small scale broken formations) passing to a finer grained equivalent called the Cerro Formation. Similar deposits occur in the Progresso Basin.

Donnelly *et al*. (1990a) discussed the Sepúr Group of Guatemala. It contains many olistostromes and abundant ophiolitic material from serpentinite grains to slide masses many kilometres wide. Shale-sandstone flysch of a submarine fan complex dominates the unit. They quoted Rosenfeld (1981), who noted the presence of a lower, polymict conglomerate with blocks of limestone and calc-alkaline volcanic and plutonic clasts. The limestones did not come from the underlying Campur Limestone, but instead resembled Campanian limestones found in the Motagua Valley. Rosenfeld determined that the Sepúr came from the south where a rising mass had fringing carbonates and locally exposed ophiolites. The Sepúr contains Palaeocene and early Eocene fossils. Donnelly *et al*. (1990b) also described the Maastrichtian El Tambor Group. This contains ophiolites, gabbros similar to those dredged from walls of the Cayman Trough, large masses (up to 80 km long) of serpentinites, wacke, phyllites and schists.

Blin (1990) described the Rio Guache section of the Portuguesa Basin. A lower section of sandy shales with fluxoturbidites contained olistoliths of Cretaceous black limestones, foraminiferal, algal, lamellibranch and gastropod limestones, quartz, igneous rocks and mica schists. An upper section comprised sandy/conglomeratic shale.

In 1990, Escalante described a cycle of turbidite deposition in Costa Rica that began in the Late

Cretaceous (Rivas and Las Palmas formations) and ceased toward the end of the Eocene (Brito Formation).

Tyson and Ali (1991) noted that the Palaeocene St. Joseph conglomerate of Trinidad contained clasts of the Naparima Hill Formation. They indicated late Cretaceous tectonism. The unit was followed by the Chaudiere (shaly to silty flysch, grain size increasing to north, arenaceous foraminifers) and Lizard Springs (calcareous mudstone, arenaceous foraminifers and *Globigerina* and *Globorotalia*). These two units showed clastic influx in the north, and clear water in the south. The Eocene Navet calcareous mudstone or marlstone, rich in planktic foraminifers overlay the Lizard Springs Formation. The northern equivalent, the Pointe-a-Pierre grits, comprised thick and thin-bedded sandstones showing load casts, pseudonodules, sole marks, massive and parallel-bedded sandstones, from proximal to distal turbidite fans.

Thournout *et al*. (1992) described the Palaeocene-Early Eocene accretion of Piñon Formation: MORB basalts and overlying arc deposits of the Early Cretaceous-Palaeocene Cayo and San Lorenzo formations; and Flysch deposits of the Yungilla Formation along the Western Cordillera of Ecuador.

Iturralde-Vinent (1994) concluded that the area south of the Canal Viejo de Bahamas Belt of Cuba was overlain by foreland basin deposits, with Palaeocene-early Late Eocene olistostromic and flyschoid rocks. The rocks indicate a bimodal source: local carbonates and cherts, exotic clasts from ophiolites and a southern Cretaceous volcanic arc, increasing upwards.

Driscoll *et al*. (1995) discussed the presence of late Cretaceous to Middle Eocene probable turbidites in the southwest of the Venezuelan Basin. Seismic reflection data showed a basal, onlapping stratigraphic section over acoustic basement in the Venezuelan Basin. Correlation from DSDP holes showed this to be older than middle Eocene (50 Ma) and younger than Senonian (88 Ma). Well-laminated acoustic character and onlap patterns suggest gravity flow infill. Maximum thickness (600 - 800 m) was limited to the structurally lowest part of the Venezuela Basin - the area of roughest basement. It appeared to represent the distal portion of a fan. The proximal part of this might underlie the Curaçao Ridge and might explain the large gravity anomaly in that region. If this interpretation was correct, and the flat lying, acoustically laminated sediments were the distal part of a large terrestrial system, then these sediments would provide valuable information about Caribbean Plate motion in the late Cretaceous and early Tertiary. The authors suggested DSDP determination of age and provenance.

Di Marco *et al.* (1995) described San Pedrillo Unit of the Osa Peninsula, Costa Rica. It contains blocks (10 - 100 m) of oceanic basalt, dolerite and minor gabbro and acidic cumulates of blocks of greywacke, red radiolarian chert and mudstone (as 1–100 m thick, dismembered beds), with shallow water limestones (cm- to m-sized clasts) in a hemipelagic sedimentary Middle Eocene matrix.

According to Kolarsky *et al*. (1995), the Gulf of Chiriquí, SW Panamá, has a basaltic basement of Jurassic? To Late Cretaceous age interbedded with Upper Cretaceous pelagic sedimentary rocks. A major hiatus inferred to represent an erosional event is followed by a basal section of coarse clastic rocks and algal/reefal carbonates of Early to Middle Eocene age (Lower Tonosí Formation). The Lower Tonosí at Punta Bucaro is a basal conglomerate and minor sandstone, interpreted to overlie basement, which contains clasts of basalt, sandstone and shale

In 1996, Bartok wrote that from the late Cretaceous through most of the Palaeogene emplacement of nappes occurred in the areas of the Western Cordillera of Colombia, in the Gulf of Venezuela and in eastern Falcón. Oceanic composition of the nappes was inferred from a klippe on Paraguaná (Santa Ana Mountain) similar to the Western Cordillera. Klippen in the Barquisimeto area were sedimentary portions of the nappes that had suffered low-grade metamorphism. They contained stretched Aptian to Santonian ammonites.

There are no reports of flysch/wildflysch in the Maturín Basin of Eastern Venezuela, yet such deposits occur both east and west. In 1997, James argued that such deposits underpin the thrusts of the Interior Range in this area. In 1997, I found exotic pebbles in Tent Bay, eastern Barbados. Bob Speed (personal communication, 2001) kindly identified the following: porphyritic diabase, basaltic scoria, clinopyroxene gabbro and porphyritic olivine basalt. In 2000, I found the following information in the library at Bridgetown. A reprinted book, first published in 1848 by R. H. Schomburg, described an outcrop of the Scotland Formation in Skeets Bay and states "*The author found on the beach a large, elliptical piece of red granite, 3' by 2'5"* " and also noted that a "*small collection of rocks from Barbados at the Literary Society in Bridgetown included a piece of porphyry*". Speed (personal communication, 2001) cautioned that such exotic rocks could be ships' ballast. He qualified this by remarking that exotic rocks have also been found in the interior of Barbados. Although the windward side of the island is the most dangerous for vessels, gaps in the reefs did allow passage. Maloney *et al*. (1971) and Almeida and Goddard (1974) reported finding exotic rocks on the windward side of Aves Island, once a source of guano. Goddard (personal communication, 2002) also found cannon and anchors here, supporting the ballast theory.

Montgomery (1998) described the Corozal Limestone of northern Puerto Rico. Thick beds of grey limestone breccia contain volcanic, metamorphic, sedimentary and plutonic fragments. Thin sandstone beds contain grains of feldspar, chert, minor angular quartz, volcanic rock fragments, articulated coralline algae, larger foraminifers, molluscs, echinoids, rare corals and abundant limestone fragments with pellets and miliolids. At the base of the SE section, blocks of up to 55 cm float in a carbonate mud matrix with 2 - 4 cm clasts. Long considered Palaeocene or Eocene in age, the unit is redated late Early - early Late Palaeocene and formed in a deep marine setting with abundant planktic foraminifers.

Pszczolkowski (1999) described several Late Cretaceous-Early Eocene units of Cuba that could be candidates for flysch/wildflysch deposits. The Campanian Moreno Formation of western Cuba (Northern Rosario Belt of the Guaniguanico Terrane) is a deep-water deposit (hemi-pelagic) with upwardly increasing amounts of shallow-water and volcaniclastic detritus recording the approach of a volcanic arc from the SW. The Cajarajícara Formation (upper Maastrichtian), Peñalver and Amaro formations ('massive megabeds'), of western and central Cuba are breccias of limestone and chert. According to Pszczolkowski (1999), they resulted from a single depositional event (earthquake, tsunami) close to the Cretaceous/Tertiary boundary. The Palaeocene Amaro Formation, biomicrites, marly limestones, breccias and polymict terrigenous deposits, is interpreted as forming close to synsedimentary faults. The Palaeocene-Early Eocene Manacas Formation, terrigenous shales, sandstones and conglomerates, limestones, boulders, olistoliths and a serpentinite 'slide', was derived from a volcanic arc to the south. The unit occurs interbedded with nappes of Jurassic-Cretaceous carbonates in the Sierra de los Organos (personal observation with Cobiella Requera, 2004).

Cobiella-Reguera (2000) referred to several terrigenous units (Monos, Durán, Yáquimo, Sirvén formations) of Campanian-Maastrichtian age, some with flyschoid appearance and upper Maastrichtian calcareous units rich in detrital limestones (Carlota, Cantabria, Jimaguayú, Arroyo Grande formations) of uncertain relationships to the Cuban megaturbidites.

Takayama *et al*. (2000) reported on a Cuban megaturbidite, the Peñalver Formation, whose age previously had only been constrained by the underlying Campanian-early Maastrichtian Via Blanca Formation and the disconformably overlying early Eocene Apolo Formation. Detailed palaeontological studies showed the presence of reworked material and constrained the age to between 65.4 – 65 Ma. The unit fines upward, shows fluid escape structures and contains altered vesicular glass fragments, and quartz grains with planar structure. The authors relate the Peñalver to deep-sea deposition resulting from action of tsunami associated with the K/T boundary impact on Yucatán. This is a spectacular change in refined age from an interval of some 10 or more million years to a single event.

In 2000, Higgs distinguished olistolitic mudflow deposits in the Palaeocene Chaudiere Formation of Trinidad from tectonic imbrications on the basis of (1) presence of gritty, non-laminated mudstone, typical of mudflows; (2) a spectrum of clast sizes, from mm to m or larger (some rafts 10's-100's m long could be genuine imbrics) and (3) presence of clasts always older than matrix (need not be so in tectonic melanges, or in mud diapirs with stoped blocks).

Macsotay and Peraza (2002) described the middle Eocene Las Bermudez Formation of eastern Margarita as diamictites with reworked Late Cretaceous pelagic limestones and lavas and beginning with an olistolith of lithic sandstones alternating with limestones and shales (Los Bagros Limestone).

Vivas and Macsotay (2002) noted that the Piemontine Nappe of northern Venezuela contains dark limestone and claystones of Campanian to Maastrichtian age within monotonous siliceous siltstone alternating with microconglomeratic lenses and sandstones. There are olistostromes of limestones with Early Cretaceous shelfal fauna. The top of the unit, called the Mucaria Formation, is formed by laminated siltstones and fine sandstones of Palaeocene age.

According to Cobiella-Reguera (personal communication, 2002), the Cuban wildflysch/ olistostrome deposits young to the east. Some, like the Manacas and Senado formations, formed in a very short time.

Anderson (personal communication, 2002) informs that sedimentary and volcanic blocks occur in the ?Eocene Sabana Grande Formation of Puerto Rico. Coastal exposures near Rincón include slide masses and at several localities Early Tertiary strata record faults, folds and slumps that suggest penecontemporaneous deformation as well as later tectonic structures

3. SIGNIFICANCE OF THE WILDFLYSCH DEPOSITS

Eardley and White (1947) defined wildflysch as a conglomeratic or breccia facies of the flysch in which giant boulders of 10 to 70 feet of more are embedded. It represents a submarine landslip or the collapse debris of submarine cliffs at the time of deposition of the flysch, or it is associated with the early growth of great nappes.

Kugler and Saunders (1967) subdivided turbidity deposits into those arising from orogenic processes and those from a paralic environment. Slide masses, generally well consolidated, with large blocks of hard rocks, characterized the former. This was wildflysch, with clay pebble beds, marl boulders beds and heterogeneous clay boulder beds in lutite with large arenaceous foraminifers. The latter comprised slide masses of homogeneous, paralic sediments and soft rocks, with churned and twisted masses in lutite with large arenaceous foraminifers.

Mutti (1992) remarked that structural deformation is the primary control of turbidite sedimentation in fold-thrust belts. Basins form through flexural loading and local faulting and folding. The turbidite system comprises an upslope erosional vacuity and a downslope depositional pile. Erosion occurs through shelf failure, slope failure, intrabasinal failure and canyon cutting.

Trechmann (1937) and Barr (1952) both remarked upon boulders moving downslope from the Quaternary coral cap of Barbados. Wilhelm and Ewing (1972) noted "*remarkable rock slides from the Campeche Escarpment into the abyssal plain*" and compared these to wildflysch. Hine *et al*. (1992) described how carbonate platforms on the Nicaraguan Rise are shedding 'megabreccias' into the adjacent basin (one of these has a fan shape, is 120 m thick, extends 27 km along slope and 16 km into the basin and contains individual blocks 330 m across by 110 m high).

Holcombe and Moore (1977) described an arcuate (concave to the north), E-W elongated belt in the southern Venezuelan Basin. Drilling at two sites recorded major breaks in the late Cretaceous (Santonian - late Palaeocene) and Cenozoic (early Eocene - early Miocene). This 'depositional scar' is 50 - 100 km wide and 400 km long.

Kugler (1953) saw the Trinidadian deposits forming along the southern flank of a rising Caribbean Range of which the Northern Range was the final offspring. The wildflysch of the Chaudiere Formation, with blocks of Cretaceous rocks that once covered the emerging range, foreshadowed uplift.

Kugler and Saunders (1967) attributed the source of shelfal Jurassic and Cretaceous sediments to the northern part of the Guayana Craton. Deposits of great thickness started to rise during the Laramide orogeny to form part of the 'borderland of Paria' (Schuchert, 1935; Hedberg, 1950) with the Eastern Venezuela geosyncline between it and the Guayana Shield. This provided slump-masses of Cretaceous rocks to the Paleocene Chaudiere Formation.

Stainforth (1966) defined the term 'gravitational deposits' for beds "*emplaced rapidly and more or less violently*". He described the emplacement of large olistostromes (up to 180 miles by 20 miles) as 'violent'.

Mac Gillavry (1974) discussed the significance of Eocene turbiditic detritus on Margarita Island. He noted that it is characteristically polymict, containing intraformational clasts, volcanic rocks and sediments from the preceding tectonostratigraphic phase, often slightly metamorphosed, and deeper-seated igneous rocks and metamorphics of a yet earlier phase.

According to Barr (1974), late Cretaceous orogeny produced strong tectonic episodes along both the northern and southern margins of the Caribbean. In the south the main trends of the Andean fold system were initiated through Trinidad, Venezuela and Colombia, with strong folding, overthrusting and metamorphism. Uplift and erosion led to widespread chaotic conglomerates (wildflysch) in the succeeding Paleocene and Eocene formations, which extended as far north of the continental margin as Barbados (300 km).

All these discussions consider flysch and wildflysch deposits of northern South America as products of gravity sliding from an unstable, local and perhaps coeval source, and erosion of dynamic uplifts of older rocks. In general, the deposits recorded a late Cretaceous - middle Eocene 'Laramide (Incaic) Orogeny'.

Stratigraphic dating is a major problem. If allochthonous material is abundant and autochthonous matrix is scarce or lacks fossils, the units will receive erroneously older ages and/or large age ranges. Some Venezuelan units (e.g., Garrapata, Escorzonera Formations) previously assigned to the Cretaceous (age of allochthonous material) are now recognized to be Palaeocene or Eocene in age. The Cuban Peñalver Formation is a striking, though older, example of this problem. Detailed stratigraphic investigation drastically reduced its age from an early Maastrichtian – early

Eocene interval to the K/T event (Takayama *et al*., 2000). Removal of reworked material results in a shortened age interval that converges to the upper limit. For many of the deposits in Table I this is the Middle Eocene.

Mixtures of oceanic, volcanic and continental margin rocks in continent-verging thrust systems argue for a plate boundary mechanism. Convergence of oceanic and continental crust normally results in slow subduction of the former. Violent uplift of very large allochthons around the Caribbean in what might have been a short time interval indicates rapid compression.

There is no indication of major plate convergence (James, 2005, fig. 7) and it would be hard to see how it could have operated for a short interval. Collapse of the continental margin is possible, but it would require previous obduction of oceanic and volcanic rocks and a triggering mechanism (large sea-level fall?). In addition, material would have moved oceanwards. Transpression is another possibility. It would have needed to act synchronously along the plate margins producing only continent-directed thrusting. In contrast, transpression that produced the folds, thrusts and foreland basins of northern Venezuela and Trinidad migrated from west to east from the Oligocene to Recent

Some of the deposits have been linked to the K/T boundary impact. Major impacts will create not only coeval deposits, but also a temporal and regional legacy of instability through resultant faulting and topography. Large bolide impacts are thought to be capable of influencing plate tectonics and producing extremely energetic phenomena (Marvin, 1990; Jones *et al*., 2002; Price, 2001).

Perhaps the deposits all relate to the K/T impact. Perhaps more than one impact occurred. A candidate for investigation lies in the Venezuelan Basin (Fig. 1). The Beata Crater (James *et al*., 1998) is known only from bathymetry derived from satellite data. Its relief is 700 – 800 m. It may be a composite feature comprising as many as four or more impacts ranging from up to 225 km in diameter to the smallest just perched on a larger rim. The depression is at least the same size as the postulated, buried Chicxulub crater of the Yucatán Peninsula. While the Chicxulub bolide hit continental crust on the northwestern tip of the Yucatán Peninsula, the Beata Crater lies on oceanic crust (probably thickened) southeast of the Beata Ridge, more or less in the centre of the Caribbean Plate. The feature is uninvestigated; its age is not known. Microtektites occur in the upper Eocene at DSDP site 149 in the Venezuelan Basin (Donnelly and Chao, 1973) and on Barbados (Saunders *et al*., 1984). Coeval tektites are described from Texas, Georgia and possibly Massachusetts (Glass, 1982). The Middle and Late Eocene planktic foraminifer record suggests impact influence (MacCleod, 1990).

4. CONCLUSIONS

Flysch and wildflysch deposits accumulated around the Caribbean area (and from Colombia to Peru) in the Palaeocene-Middle Eocene. Trinidadian and Venezuelan units were seen as complex autochthonous units (Cretaceous islands in Palaeocene-Eocene seas, tectonic melanges, limestones fringing volcanoes, igneous intrusions

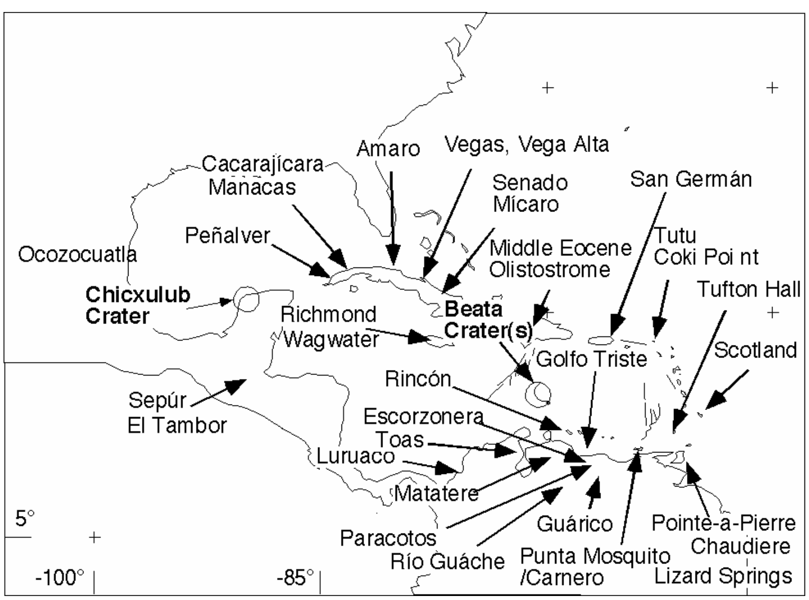

Figure 1. Occurrences of Palaeocene-Middle Eocene flysch/wildflysch deposits and location of the Beata Crater.

into shales) until Kugler introduced the gravitational concept in 1953. Many deposits contain extremely large olistoliths and are described as 'catastrophic' records of 'violent' deposition. Mixtures of ophiolites, island-arc and continental margin rocks show tectonism along the ocean/continent boundary. Accumulation terminated abruptly by the Middle Eocene. The overlying regional unconformity and shallow-marine, Middle Eocene coralgal limestones indicate wave base and the photic zone. Recent studies, carefully discriminating between allochthonous and matrix material, have refined the age of deposition of some units from Cretaceous/Late Cretaceous to early Cenozoic to Palaeocene-Middle Eocene. Consequently, similar deposits merit stringent stratigraphic study. Mixtures/juxtaposed rocks of disparate types/origins need to be examined in the context of wildflysch, particularly in the eastern Greater Antilles. The Palaeocene-Middle Eocene episode in the Caribbean area is known as the Laramide Orogeny, attributed to convergence between the Caribbean and neighbouring plates. An alternative explanation is that the deposits record a catastrophic event or series of events related to impact of extraterrestrial material. A circular depression (the Beata Crater or Crater Complex) on the floor of the Venezuelan Basin merits investigation.

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