

APPENDIX 1

Clarita Formation

The stratotype (**CT** on DRFig. 48) is located on the Clarita River for which the Formation was named by Shelton (1952). A reference section studied and named here is exposed at Charco Chiva (**CR** on DRFig. 48), about 9 km east southeast of Boca de Marraganti, on the Tuquesa River. The Clarita Formation ranges in total thickness (This study involved only the upper part) from about 200 to 420m. In the Chucunaque Basin, the Clarita Formation conformably overlies the Porcona Formation. Its upper contact with the Tapaliza Formation is not exposed in the Tuquesa River. In the Membrillo River it is not exposed in one of the fault slices, but is represented in the other by an abrupt lithological change. In the Sambu Basin, it sits nonconformably or with a faulted contact on the Darien Formation. Contact with the overlying Tuira Formation in this basin is not observed, but is probably strongly disconformable given a gap of more than 6 m.y. between the units and their generally parallel strike. In western Darien, it rests with angular unconformity on the Darien Formation.

Tapaliza Formation

The Tapaliza Formation was named for the Tapaliza River, a tributary of the Pucuro River, in Esso Exploration and Production Inc, (Unpublished Annual Report), 1970. The stratotype (**TT**) is located on DRFig. 48 and runs for about 4 km above the confluence with the Pucuro River. Reference sections (**TR** on DRFig. 48) lie along the Tuquesa River at Charco Chiva and along the Marraganti River, about 10 km above its junction with the Tuquesa River. The thickness of the Tapaliza Formation ranges across the

Chucunaque-Tuira Basin from about 400m in the northwest to 1200m near Yaviza. The Tapaliza Formation is conformable with the underlying Clarita Formation and the overlying Tuira Formation; the contact is faulted on the Membrillo River (Fig. DR40).

Tuira Formation

The Tuira Formation was named in the Esso Exploration and Production Inc., Annual Report, (1970) without reference to a type section. The stratotype of the Tuira Formation, here defined, lies along the Tuira River, from the Clarita River northwestward to its junction with the Cube River. Reference sections (**TuR**) are located on the Tuquesa River (Fig. 2, Fig. DR42), and on the Tuira River, 6 km east of El Real to Pinogana. (**TuT** on DRFigs. 46, 48). The thickness of the Tuira Formation ranges from about 500m in the northwest to about 1000m around Yaviza. The upper contact of the Tuira Formation in the Chucunaque-Tuira Basin is apparently conformable and marked by an abrupt transition from sandstone to the more calcareous shelly facies of the Yaviza Formation. The lower contact is not exposed but is apparently conformable.

Membrillo Formation

The stratotype lies on the Membrillo River (**MT** on DRFig. 48). The thickness of the Membrillo Formation is about 150m. The upper contact of the Membrillo Formation is not exposed but there is an abrupt transition from mudstone to cobble conglomerate. The lower contact is not exposed. The Membrillo Formation is known only from the Membrillo River but extends westward into the Bayano Basin.

Yaviza Formation

The stratotype of the Yaviza Formation lies on the northern bank of the Chucunaque River, downstream from the western edge of Yaviza (**YT** on 48). A reference section is located on the Chico River below its junction with the Cubilele River (**YR** on DRFigs. 44, 49). The thickness of the Yaviza Formation ranges from about 140m in the northwest to about 300m around Yaviza. The upper contact of the Yaviza Formation is not exposed and there is probably a hiatus above it of more than 1 m.y. in all sections (Fig. 6), except the Membrillo River, where the base of the Chucunaque Formation is thought to be older than the rest of the formation and the Yaviza Formation is absent. Its lower contact is not observed.

Chucunaque Formation

The formation was named by Shelton (1952) without defining a stratotype. We here propose as stratotype the sequence on the Chucunaque River from south of El Salto to above Caleta on the Tuquesa River (**CT** on DRFigs. 41, 48-49). A reference section is located on the Chico River (**CR** on DRFigs. 44, 49). The thickness of the Chucunaque Formation is not less than 400m in the northwest and not less than about 1200m in the center of the Chucunaque-Tuira Basin. The lower and upper contacts are nowhere exposed in the area studied.

DATA REPOSITORY FIGURE CAPTIONS

DRFigure 40

Membrillo River section

DRFigure 41

Chucunaque River section

DRFigure 42

Touquesa River section

DRFigure 43

Tupisa River section

DRFigure 44

Chico River (Lower and Upper) section

DRFigure 45

Yaviza section

DRFigure 46

Tuira River section

DRFigure 47

Sambu-Venado River section

DRFigure 48 (Box A)

Map of Chucunaque River Basin with the location (black circles with numbers) of Panama Paleontology Project (PPP) sites in the northern Chucunaque River valley. Dashed line is the Pan American Highway; black squares are the site of settlements. Brackets in bold indicate location of type or reference sections. **MT** = Membrillo Formation, type section; **TuR** = Tuira Formation, reference section; **TR** = Tapaliza Formation, reference section; **CR** = Clarita Formation, reference section; **ChT** = Chucunaque Formation type section.

DRFigure 49 (Box B)

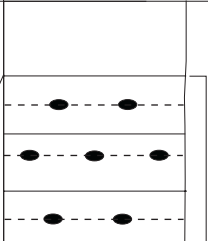

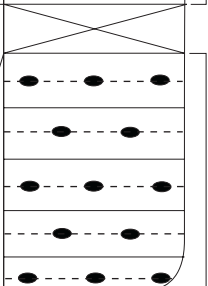

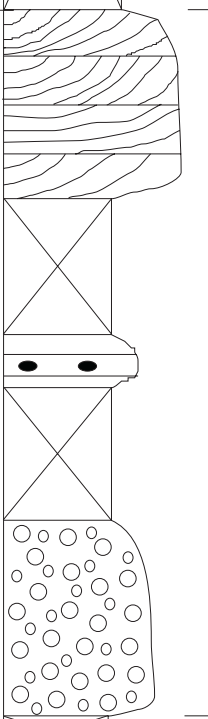
Map of the southern Chucunaque and Tuirá river basins. Symbols as for Fig. 4. **ChT** = Chucunaque Formation, type section; **ChR** = Chucunaque Formation, reference section; **YT** = Yaviza Formation, type section; **YR** = Yaviza Formation, reference section; **TuT** = Tuirá Formation, type section; **TuR** = Tuirá Formation, reference section; **TT** = Tapaliza Formation, type section.

DRFigure 50 (Box C)

Box C of Fig. 1. Map of the Sambu Basin. Symbols as for Fig. 4.

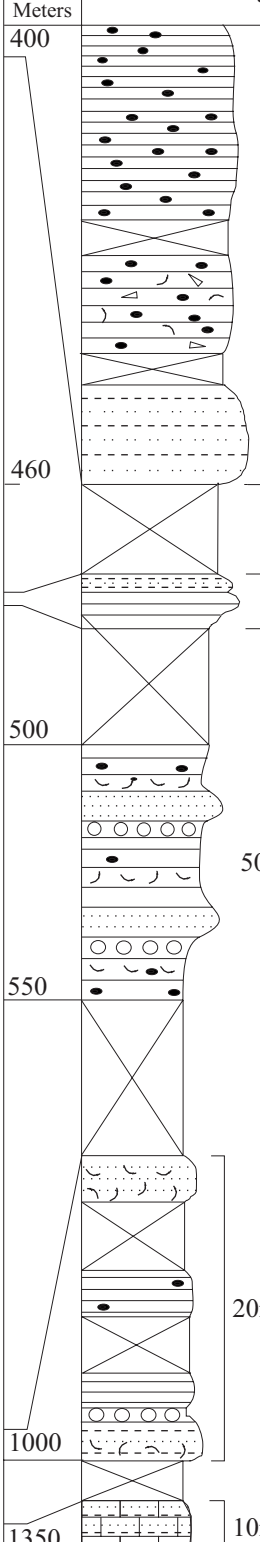
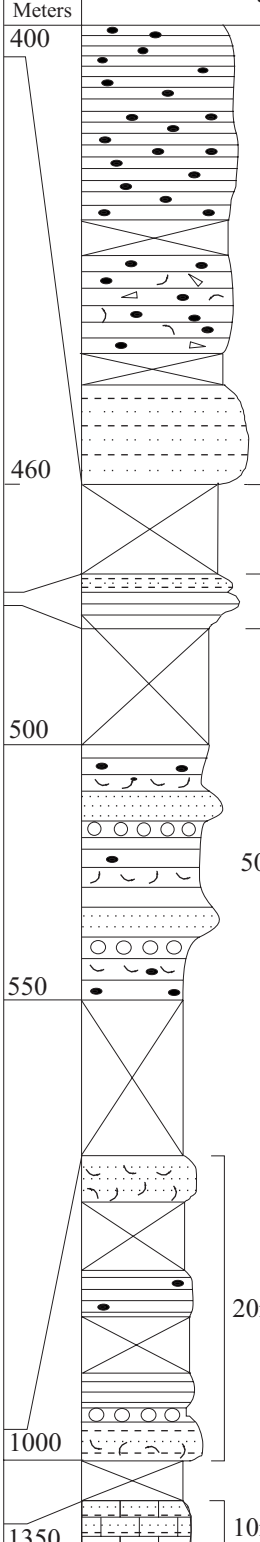
PPP SECTION 40, Membrillo River

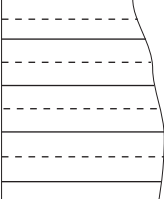
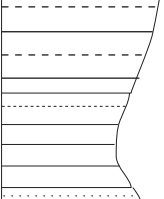
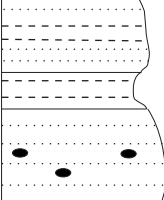
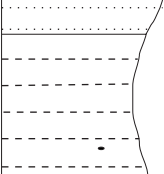
Page 1

Meters	Lithology	PPP site	Description	Formation		
0		 <div>2637</div> <div>2636</div> <div>2635</div> <div>2634</div> <div>2633</div>	No exposure	C H U C U N A Q U E		
150			Silty mudstone, grey-green, blocky slabby concretions			
300					 <div>2632</div> <div>2631</div> <div>2630</div>	No exposure
						Mudstone, blue-grey, massive, foraminifera visible, scattered concretions, especially near base
						No exposure
	No exposure					
350			No exposure			
Sandstone, volcaniclastic with strong lamination and large scale cross bedding						
No exposure						
Mudstone, blue-grey, blocky, with slabby calcareous concretions						
No exposure						
Conglomerate, cobble sized with dominantly basalt and other volcaniclastics						
395	No exposure					

PPP SECTION 40, Membrillo River

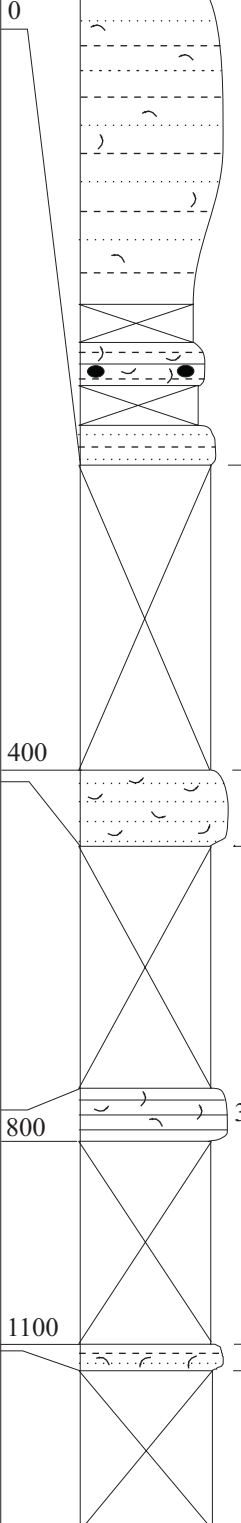
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Meters	Lithology	PPP site	Description	Formation	
400		2629	Mudstone, blue-grey, massive with slabby concretions	M E M B R I L L O	
			No exposure		
		2628	Mudstone, grey-green, conchoidal fracturing, scattered gasteropods and bivalves, forams visible, slabby concretions common		
		2627	No exposure		
460			Sandy siltstone, grey, massive bioturbated		
			No exposure		
		2625	Silty sandstone, laminated		
		2626	Mudstone, blue-grey,		
			No exposure		
500			2623		Mudstone, grey-green, conchoidal fracturing, frequent mollusk horizons with alternating 10-20 cm thick sandstone units, occasional cobble zones, and scattered concretions
			2624		
			2620		
			2622		
			2621		
550		2619			
		2618	No exposure	T	
			Silty mudstone with abundant mollusks	A	
		2617	No exposure	P	
		2616	Silty mudstone, grey-blue, with thin laminated volcanoclastic sandstone beds and boulder-sized concretions	A	
		2615		L	
		2614	No exposure	I	
		2613	Silty shale, grey, forams visible	Z	
		2606	Sandstone and siltstone, grey, with shell hash, and cobble horizons	A	
1000		2607	No exposure	CLARITA	
1350			Sandy limestone and limy bioclastic sandstone, cream weathering		

PPP SECTION 41, Chucunaque River				Page 1
Meters	Lithology	PPP site	Description	Formation
100		■ 886	Silty mudstone, massive, pervasively bioturbated, with abundant planktic forams.	C H U C
		■ 885		
		■ 2638		
		■ 2639		
200		■ 880	Mudstone, grey-green, blocky, unlaminated, very rich in planktic forams	U C
		■ 2640		
		■ 881	Sandstone, thin bedded, with occasional mollusks, Niacids, crabs, and fish	N A
		■ 882		
300		■ 883	Silty mudstone, grey -blue, abundant planktic and benthic forams.	Q U
		■ 884		
			Sandstone, massive, poorly sorted, occasional slabby concretions. Middle unit more silty and packed with forams	E
400		■ 2641	Siltstone, blocky, massive with occasional stringers of sandstone	

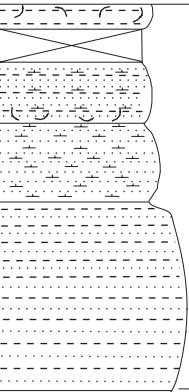
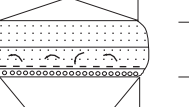
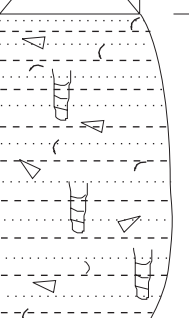
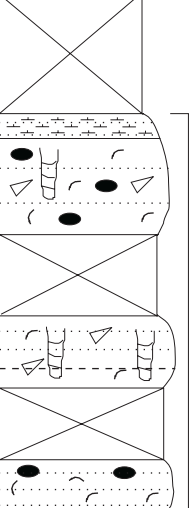
PPP SECTION 42, Tuquesa River

Page 1

Meters	Lithology	PPP site	Description	Formation
0		891		C H U C U N A Q U E
		890		
		888	Siltstone and sandstone alternating thin beds, calcareous, poorly sorted, muscovite and hornblende grains common scattered mollusks, fish scales; forams abundant.	
	30m	889		
			No exposure	
		887	Clayey siltstone and volcaniclastic sandstone, scattered mollusks	
		1618	No exposure	
			Clayey siltstone, blue green, rich in forams	
			No exposure	
400				
	5m	1617	Sandstone, volcaniclastic, gray, with common scattered bivalves	Q U E
			No exposure	
800	3m	1616 1615	Silty mudstone, grey-blue, rich in forams and Pecten	
		1999	No exposure	
1100	2m	1614	Siltstone and sandstone, clayey, blue-grey, pervasively bioturbated, with scattered mollusks	
			No exposure	

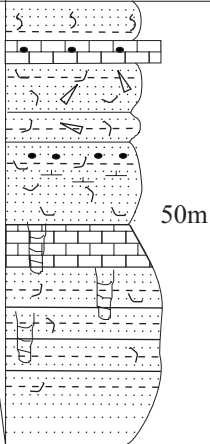

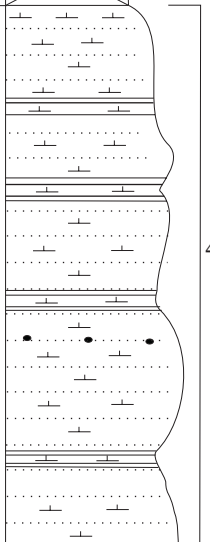
PPP SECTION 42, Tuquesa River

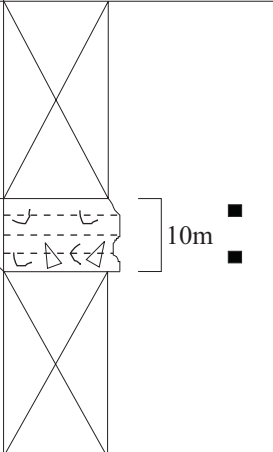
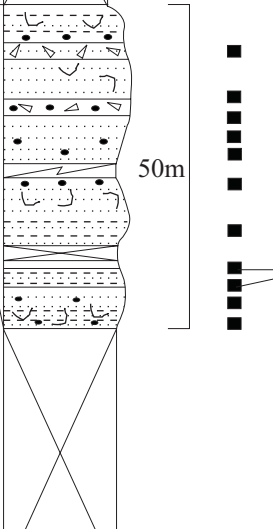
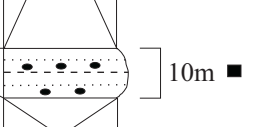
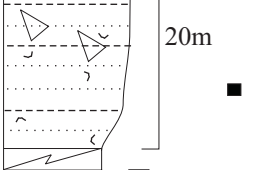
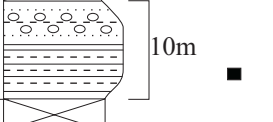
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Meters	Lithology	PPP site	Description	Formation	
1250		1613	Siltstone, silty sandstone and sandy limestone, thin hard beds; horizons with packed small bivalves.	CHUCUNAQUE	
		1612	Silty sandstone, massive extensive bioturbation		
		1611			
1300		1610	No exposure Pebble conglomerate, volcaniclastic sandstone and silty sandstone with scattered bivalves	YAVIZABA	
			No exposure		
1550		1609	Thin calcareous hard beds, blue-grey greywacke often with dense diverse mollusks, and abundant tubular arthropod burrows.		
		1608			
		1607			
1800		1606	No exposure Silty limestone hard beds underlain by sandy siltstone and clayey sandstone, blue-grey, abundant mollusks, arthropod burrows (shell-filled) and scattered concretions	TURIARA	
		1605			
		1604/1997	No exposure Sandstone, volcaniclastic, massive, and clayey siltstone, abundant mollusks, pervasive bioturbation, shell-filled arthropod burrows		
		1604/1603			
		1139	No exposure		
		1141			
		1140	Clayey siltstone and bioclastic and lithic sandstone, rich in bivalves, especially <i>Pecten</i>		
		1138			
		1137			

PPP SECTION 42, Tuquesa River

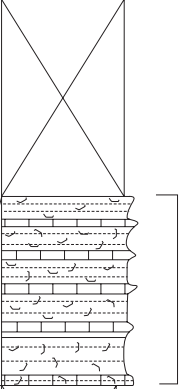
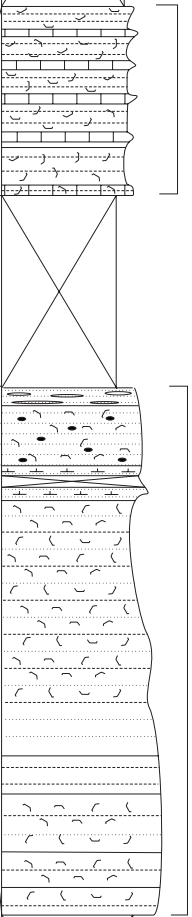
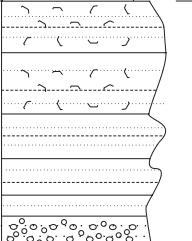
Page 3

Meters	Lithology	PPP site	Description	Formation
1800		1136	Sandstone, grey-blue, massive, bioturbated, often silty or clayey, with abundant shell hash, shell-filled arthropod burrows, abundant mollusks, occasional limestone hard beds. <i>Pecten</i> , cones, venerids, crabs, and occasional wood fragments	T U I R A
		1138		
		1135		
		1134		
		1133	Silty calcarenite with arthropod burrows	
		1133		
		1585	Silty and clayey sandstone, grey-blue, massive, pervasively bioturbated with scattered bivalves. Disconformable burrowed surfaces common, some crab specimen spresent	
		1132		
			No exposure	T A P A L I Z A
2900		1587-1592	Silty mudstone, benthic/planktic forams	Z
3000			No exposure	A
		1131	Cream weathering massive sandstone units, tuffaceous, alternating with thin calcareous, mudstone	C L A R I T A
		1130		
		1129		
		1128		

PPP SECTION 43, Tupisa River				Page 1	
Meters	Lithology	PPP site	Description	Formation	
0		1151 1150	No exposure	CHUCUNAQUE	
540			Clayey siltstone and silty mudstone, grey-blue, forams visible, mollusks common		
940			No exposure		
F		1149/1637	Clayey and silty, shelly sandstone, blue-gray, volcanoclastic. Abundant whole arcids, <i>Pecten</i> , turretellids and other mollusks. Shelly hard beds common, many units pervasively bioturbated, shell filled burrows, occasional ahermatypic corals, common, often large concretions	Y	
		1148/1636		A	
		1146		V	
		1145		I	
		1144		Z	
		1143/1626		A	
		1619			
		1620 1622 1621	No exposure	TUIRA	
1200		1623	Silty sandstone, medium-coarse grained, volcanoclastic, scattered concretions		
1300	No exposure				
F		1624/1142 1625	Silty sandstone, fine grained, massive, poorly sorted, pervasively bioturbated, scattered mollusks, including huge <i>Melangena</i> , and turtle scutes		
		1635	Conglomeratic volcanoclastic sandstone and clayey siltstone		
1550			No exposure		

PPP SECTION 43, Tupisa River

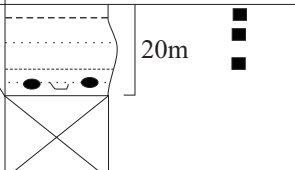
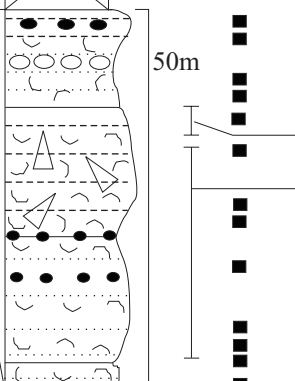
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Meters	Lithology	PPP site	Description	Formation
1550			No exposure	T U P I S A
		1634 1633	Volcaniclastic, shelly siltstone with frequent ledging calcareous hard beds 20-60 cm in thickness	
1920		1632	No exposure	
2100		1631	Volcanic sandstone, with abundant shell hash and whole mollusks. Minor calcareous hard beds, abundant concretions	
			Clayey, volcanic shelly sandstone, weathered, pervasively bioturbated,	
		1630	Calcareous, shelly siltstone and mudstone,	
			No exposure	
2950		1629 1628 1627	Clayey siltstone with scattered mollusks in the upper part. Extensive arthropod burrows and galleries in the lower part with a basal sequence of pebbly, volcanic conglomeratic sandstone	

[illegible]

PPP SECTION 44, Lower Chico River

Page 2

Meters	Lithology	PPP site	Description	Formation
600		1558 1168 1167	Volcanic sandstone, blue-gray, with fine shell hash, small mollusks and clayey siltstone and sandstone with dense shell hash and oyster lenses and irregular concretions	T U I R A
700		1557 1166 1165 1556 1164 1162	No exposure	
		1555 1554	Shelly, volcanic sandstone, pervasively bioturbated, frequent arthropod burrows with abundant turritellids, arcids and other gasteropods. Thin conglomerate horizons also present.	
		1161 1163 1160	Clayey and sandy siltstone pervasively bioturbated, pods of arthropod burrows, densely packed shell hash, abundant and diverse mollusks including turritellids, cerithiids, ? <i>Ensis</i> ,	
900		1555 1159 1554 1158	Volcanic, silty sandstone, pervasively bioturbated, large arthropod burrows and nested packed shells. Many small diverse mollusks and scattered large cerithiids in the uper part; large thick-shelled arcids, and other large mollusks in the lower part	

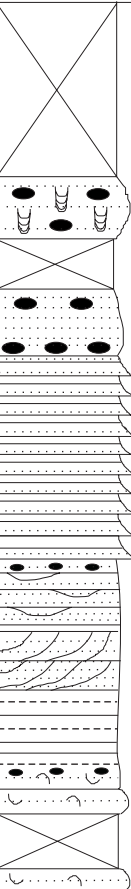
PPP SECTION 44, Upper Chico River

Page 3

Meters	Lithology	PPP site	Description	Formation
100		1552/53	Silty, shelly, calcareous, nodular sandstone, rich in diverse mollusks, especially cerithiids and arcids	Y A V I Z A
			No exposure	
			Volcanic sandstone and thin conglomerate	
200		1551 1550 1552/53 11571549	No exposure	T U I R A
			Volcanic lithic sandstone, blue gray, with turritellid bed at base	
			Silty volcanoclastic sandstone with lenses packed with mollusks, especially olives. Thin horizons of volcanic cobble conglomeratic sandstone.	
300			No exposure	
			Massive, volcanic sandstone	
			Shelly, volcanoclastic sandstone, with occasional conglomeratic horizons.	
400			Siltstone pervasively bioturbated with moderately dense shell hash and abundant mollusks.	
			Shelly, concretionary, blue-gray volcanoclastic sandstone, scattered mollusks, especially arcids, oysters, <i>Melangena</i> , <i>Crassostrea</i> mangrove fauna	
			No exposure	
500			Volcanoclastic sandstone	
600				
700				
800				

PPP SECTION 44, Upper Chico River

Page 4

Meters	Lithology	PPP site	Description	Formation
800		1544/45 1154	No exposure	T
900			Blue gray volcaniclastic sandstone. Discrete arthropod burrows filled with shell hash. Scattered small bivalves including <i>Corbula</i> , venerids, cardiids, and naticids	U
			No exposure	I
			Concretionary volcanic sandstone	R
			Turbidite sequence of evenly thin-bedded black shale and greywacke. Scoured base of the sandstone has load casts, flame structures.	A
1000		■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■	Thin bedded (2-3cm) siltstone and sandstone with frequent small scale channels	T
1100			Laminated fine volcaniclastic sandstone with low angle cross beds, greenish-gray, large whole leaves abundant.	A
			Laminated clayey siltstone	P
			Clayey siltstone and dark gray sandstone. <i>Pecten</i> shell bed prominent	A
			Large (up to 1.5m) concretions; shell hash abundant	L
1200			No exposure	I
			Laminated volcaniclastic sandstone	Z
			No exposure	A
			Laminated volcaniclastic sandstone	
1300				

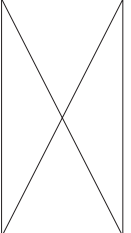


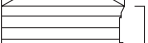
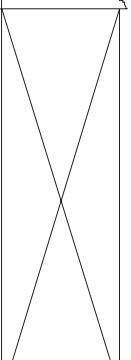
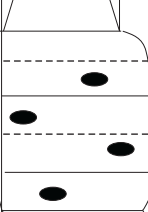
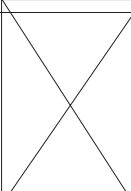
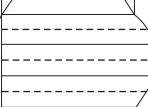
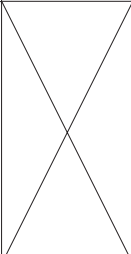

PPP SECTION 45, Yaviza

Page 1

Meters	Lithology	PPP site	Description	Formation
300		918	Coquina, shelly limestone with large densely packed bivalves, hash-filled burrows. Minor volcanoclastic sandstone and irreular concretions	Y A V I Z A
		913		
		912		
		911		
		914	Volcaniclastic greywacke and lithic sandstone, blue-gray, concretionary, with abundant mollusks, oyster reefs. Pervasive bioturbation. Basal volcanic conglomeratehas abundant shells	
		910		
		915		
		909	Blue-gray, lithic, shelly, sandstone with thick-shelled oyster beds, scattered shell hash, and calcareous hard beds.	
		908		
		916		
500		901	Volcanic, lithic, shelly sandstone, pervasively bioturbated, and with nested shells in large arthropod burrows at some horizons. Occasional thin calcareous hard beds. Concretions abundant.	T U I R A
		907		
		917		
			No exposure	
	600		906	
			No exposure	
800				

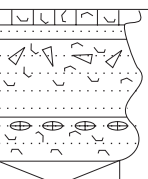
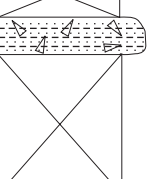
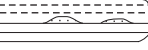
PPP SECTION 45, Yaviza

Page 2

Meters	Lithology	PPP site	Description	Formation
800			No exposure	T U I R A
1260	 10m ■	905	Volcaniclastic sandstone, massive	
			No exposure	
1300	 10m ■	902	Dark green, blocky mudstone with forams visble	
			No exposure	T A P A L I Z A
1500	 15m ■	903	Black-gray, volcaniclastic sandstone and siltstone, alternations, 2-5 cm thick comprising a turbidite sequence rich in pteropods,orbulinas, other forams and much plant debris.Concretions are numerous and huge.	
			No exposure	
	 5m ■	904	Black-gray, volcaniclastic sandstone and siltstone, turbidite rhythms, 5-10 cm thick, rich in orbulinas, other forams and much plant debris. Concretions are absent.	
1550			No exposure	
				

PPP SECTION 46, Tuira River

Page 1

Meters	Lithology	PPP site	Description	Formation
20		■ 1532	Nodular hard limestone with densely packed mollusks	Y
		■ 1533/34		A
		■ 1532		V
		■ 1525	Silty sandstone and clayey sandstone, blue-gray, pervasively bioturbated, nested shell filled burrows, scattered mollusks, snails encrusted with <i>Septastrea</i> , barnacles, vermetids	I
		■ 1526		Z
40		■ 1528	No exposure	A
		■ 1535, 1527		
		■ 1529	Laminated volcaniclastic fine sandstone hard beds alternating with clayey siltstone. Scattered mollusks	U
		■ 1530		I
60		■ 1531	No exposure	R
		■ 1536, 893		A

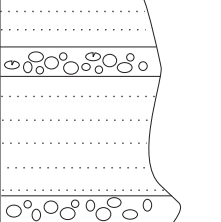


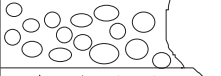

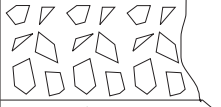

PPP SECTION 47, Sambu-Venado Rivers

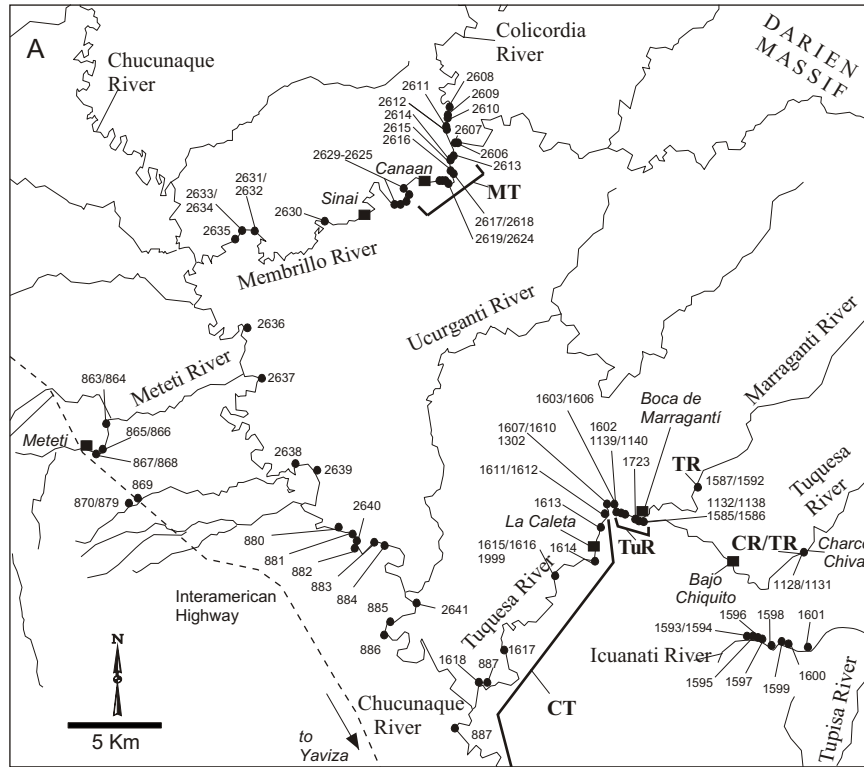
Page 1

Meters	Lithology	PPP site	Description	Formation	
20	Fault	2584	Silty shale with visible foraminifera	T U I R A	
		2585			
		2588			
		2589			
		2587			
		2586			
		2579	Volcaniclastic, calcareous, silty sandstone with visible foraminifera		
		2578			
		2577			
		2580/81	Blocky mudstone, dark brown with visible foraminifera		
	2582				
	2583				
	2603				
	2604				
	2605	Clayey fine sandstone, blue-gray, with diverse mollusks			
		Sparry calcarenite			
		Volcanic conglomeratic sandstone			
		Lithic sandstone with large-scale crossbeds			
40			No exposure		C L A R I T A
			Basalt		
			No exposure		
			Coarse volcaniclastic sandstone with mollusk hash and abundant large oysters		
			No exposure		
	80			No exposure	

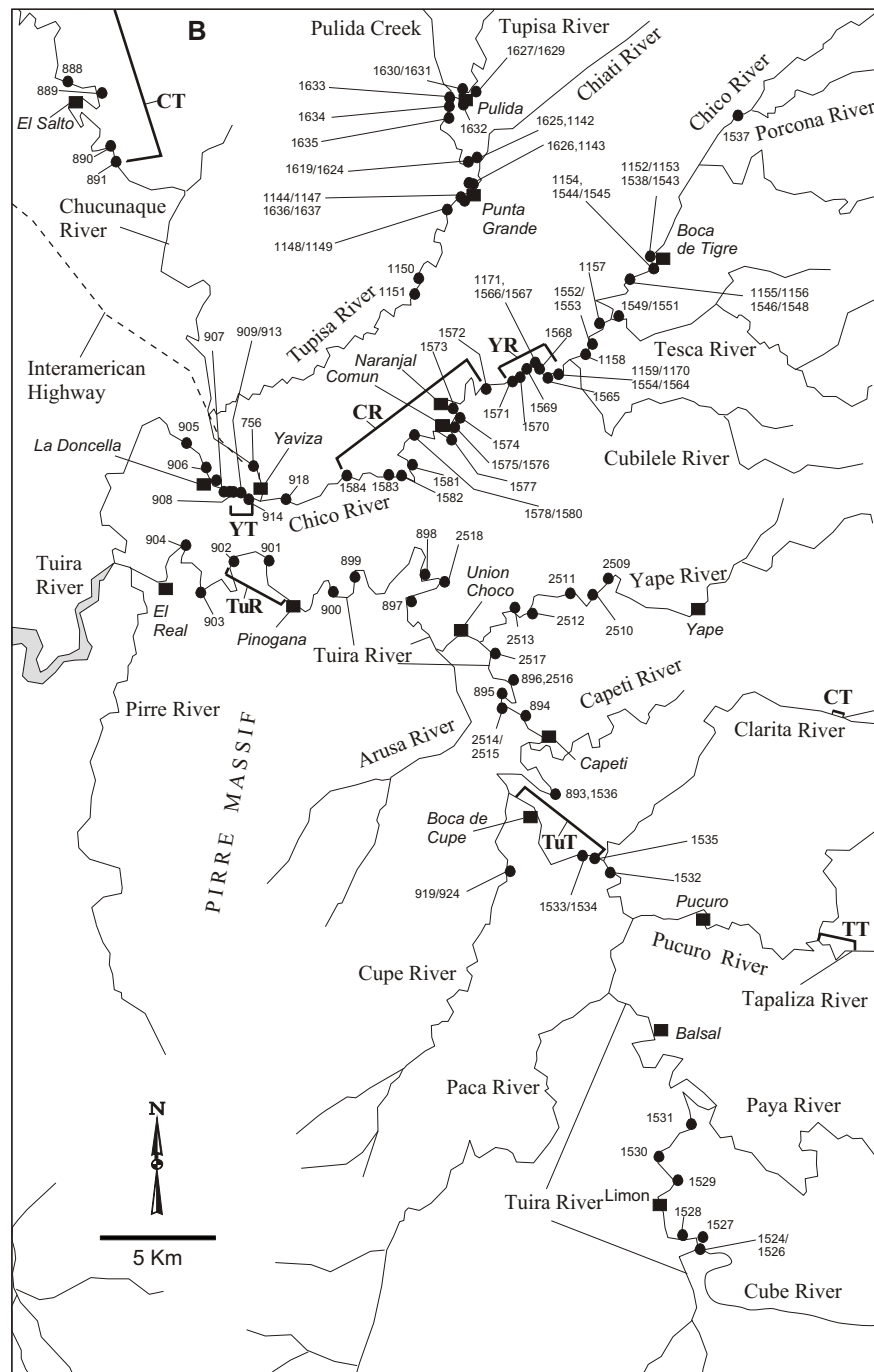
PPP SECTION 47, Sambu-Venado rivers

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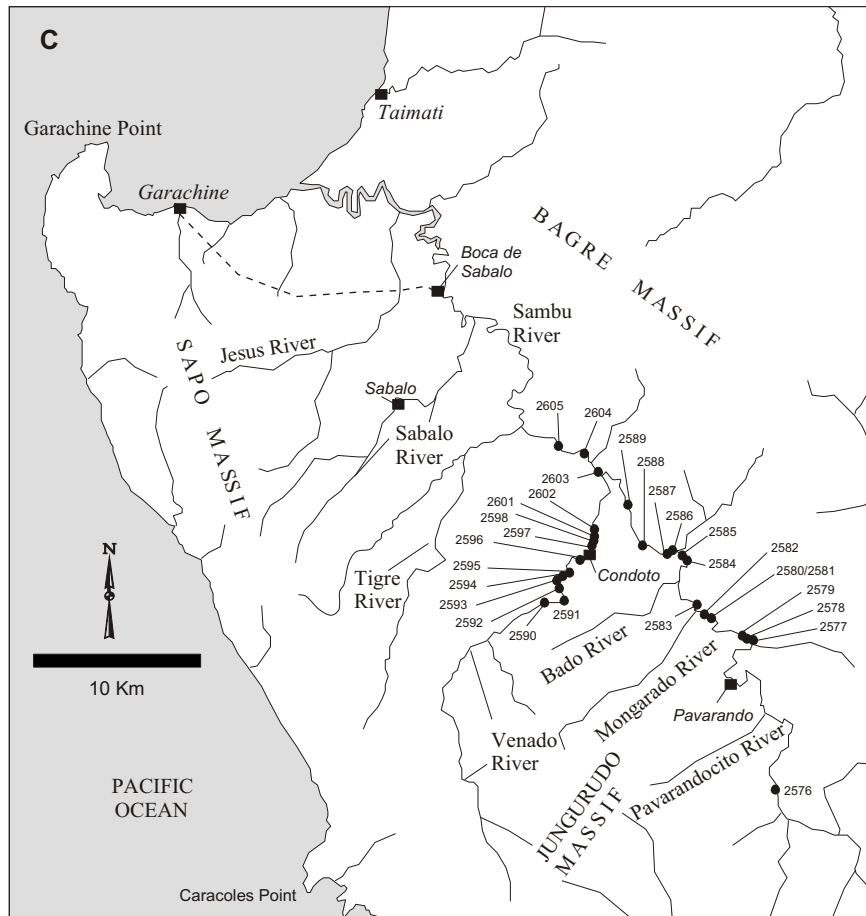
Meters	Lithology	PPP site	Description	Formation
100		2597	Basalt cobble-boulder conglomerate and volcanoclastic sandstone	CLARITA
			Basalt conglomeratic sandstone	
120		2596	Porphyritic basalt with Lahars	SAN BLAS COMPLEX
		2595 2594 2593	Porphyritic basalt and flow breccia	
			Volcanic boulder conglomerate	
		2592 2591	Porphyritic basalt and flow breccia	
			Basalt flow breccia	
		2590	Vesicular basalt	



DRFig. 48



DRFig. 49



DRFig.50