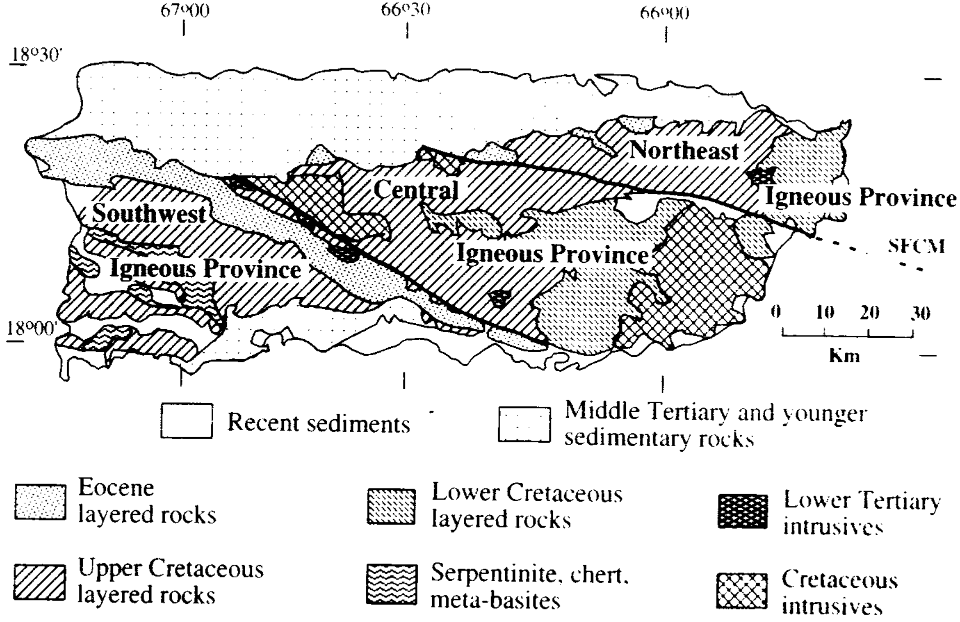
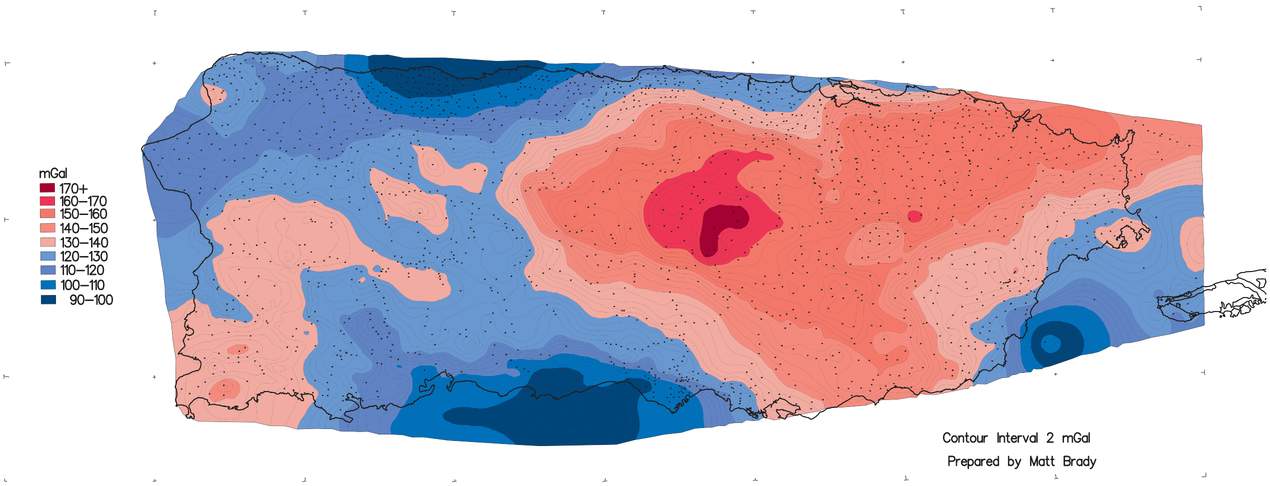
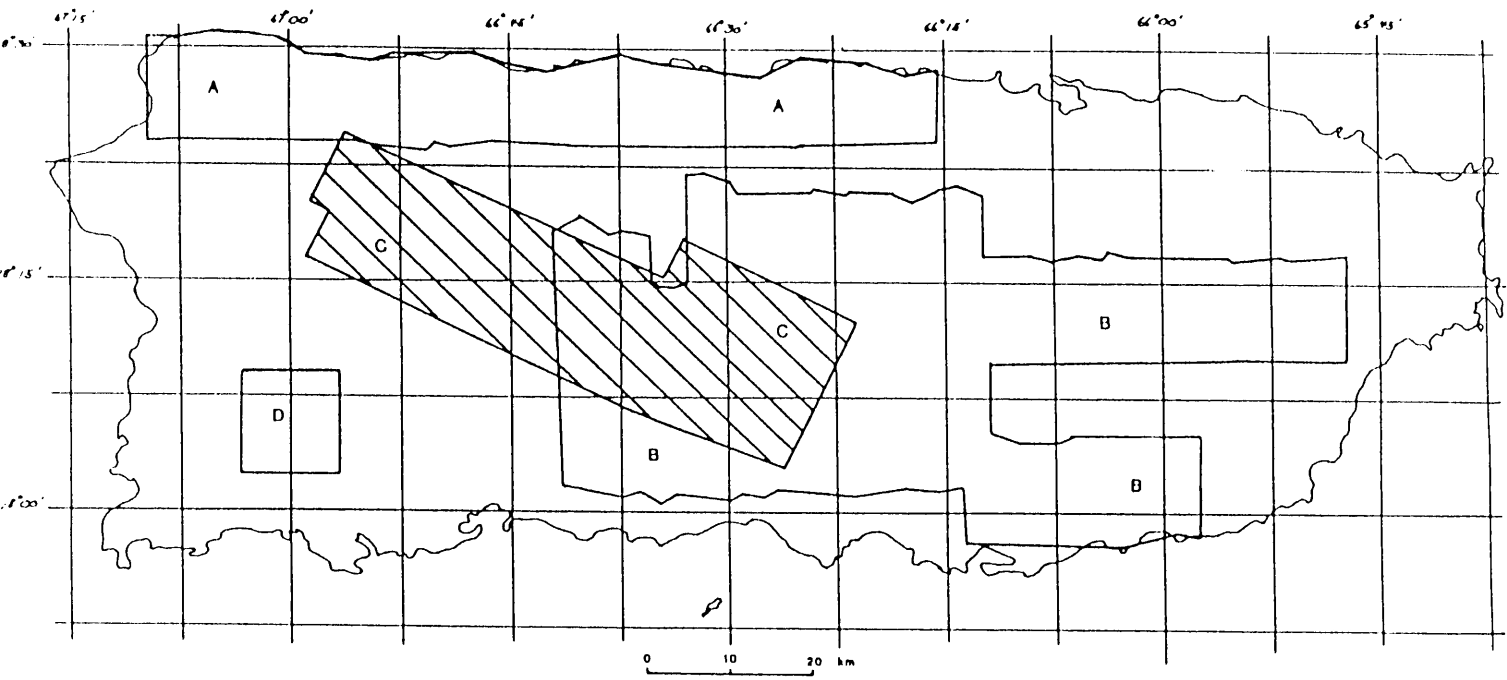


Figure 1. Geologic sketch map of Puerto Rico (based on Briggs and Akers, 1965; Cox and Briggs, 1973; U.S. Geological Survey quadrangle maps).



Bouquer Gravity Map of Puerto Rico



INDEX MAP OF AEROMAGNETIC SURVEYS IN PUERTO RICO

Explanation for index map of aeromagnetic surveys
in Puerto Rico

A. Aeromagnetic survey of north coast. Flown by Canadian Aero Service Ltd. in 1957 by A.D. Fraser. Published in Briggs (1961); specifications of survey: north-south flight lines with a spacing ranging from 0.8 to 3.2 km (0.5 to 2.0 mi) at an altitude of approximately 153 m (500 ft) above ground.

B. Aeromagnetic survey of central Puerto Rico. Flown by Canadian Aero Service Ltd. in 1957 for A.D. Fraser. Specifications of survey: flight lines north-south with spacings predominantly of 0.4 and 0.8 km (0.25 and 0.50 mi) and altitude draped at approximately 153 m (500 ft) above ground.

C. Aeromagnetic survey of Utuado batholith area. Flown by Fairchild Aerial Surveys in 1962 for Bear Creek Mining Co., now owned by Kennecott Copper Co. Specifications of survey: flight lines trend about N. 30° E. with a spacing of 0.4 km (0.25 mi) and altitude draped at approximately 153 m (500 ft) above ground.

D. Aeromagnetic survey of San German area. Flown by Canadian Aero Service Ltd. in 1957 for A.D. Fraser. Specifications of survey: flight lines north-south with a spacing of 0.4 km (0.25 mi) and altitude draped at approximately 153 m (500 ft) above ground.

Explanation for index map of aeromagnetic surveys - in Puerto Rico

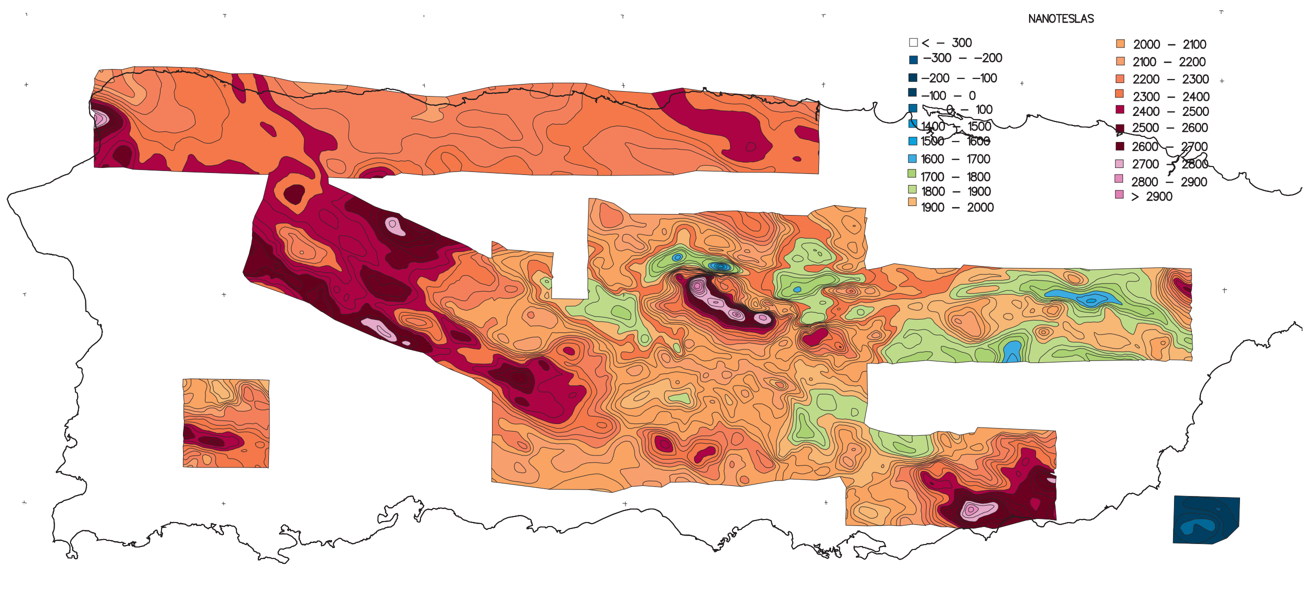
A. Aeromagnetic survey of north coast. Flown by Canadian Aero Service Ltd. in 1957 by A.D. Fraser. Published in Briggs (1961); specifications of survey: north-south night lines with a spacing ranging from 0.8 to 3.2 km (0.5 to 2.0 mi) at an altitude of approximately 153 m (500 ft) above ground.

B. Aeromagnetic survey of central Puerto Rico. Flown by Canadian Aero Service Ltd. in 1957 for A.D. Fraser. Specifications of survey: flight lines north-south with spacings predominantly of 0.4 and 0.8 km (0.25 and 0.50 mi) and altitude draped at approximately 153 m (500 ft) above ground.

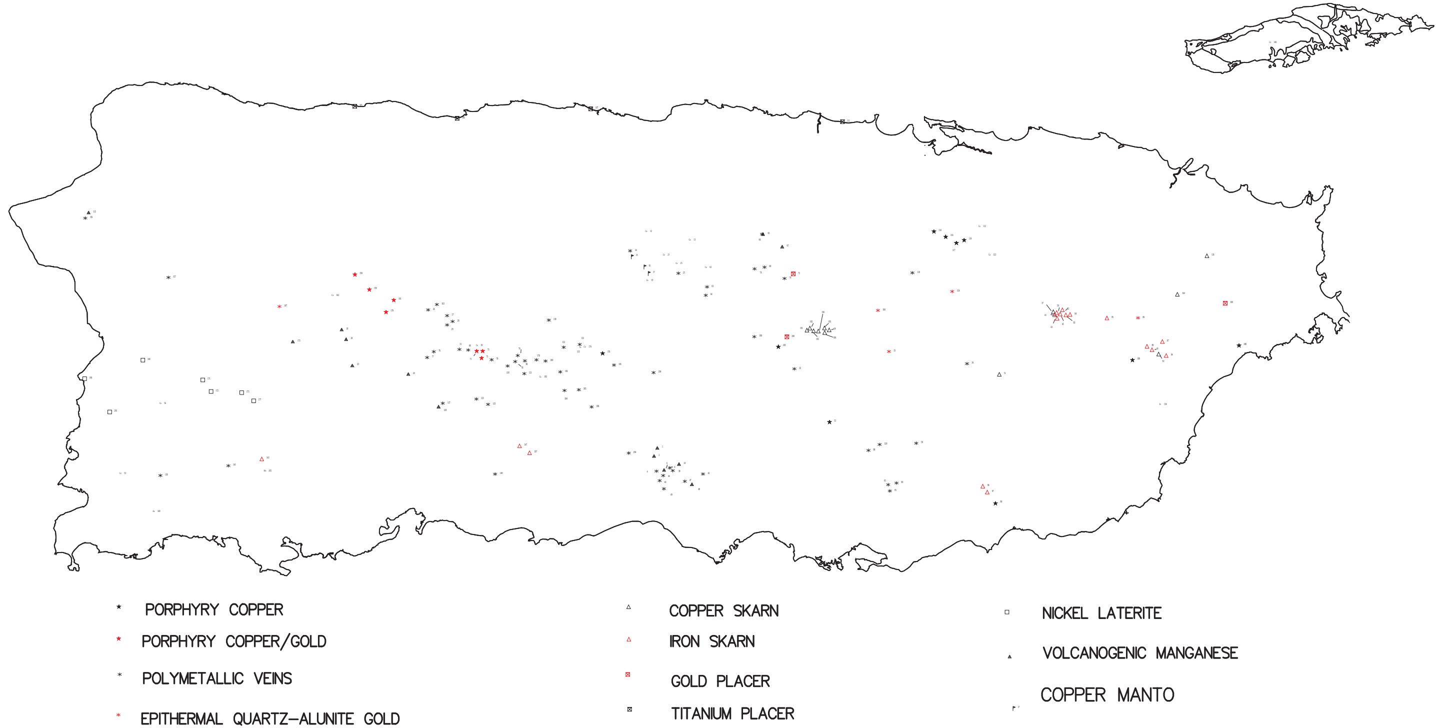
C. Aeromagnetic survey of Utuado batholith area. Flown by Fairchild Aerial Surveys in 1962 for Bear Creek Mining Co., now owned by Kennecott Copper Co. Specifications of survey: flight lines trend about N. 30o E. with a spacing of 0.4 km (0.25 mi) and altitude draped at approximately 153 m (500 ft) above ground.

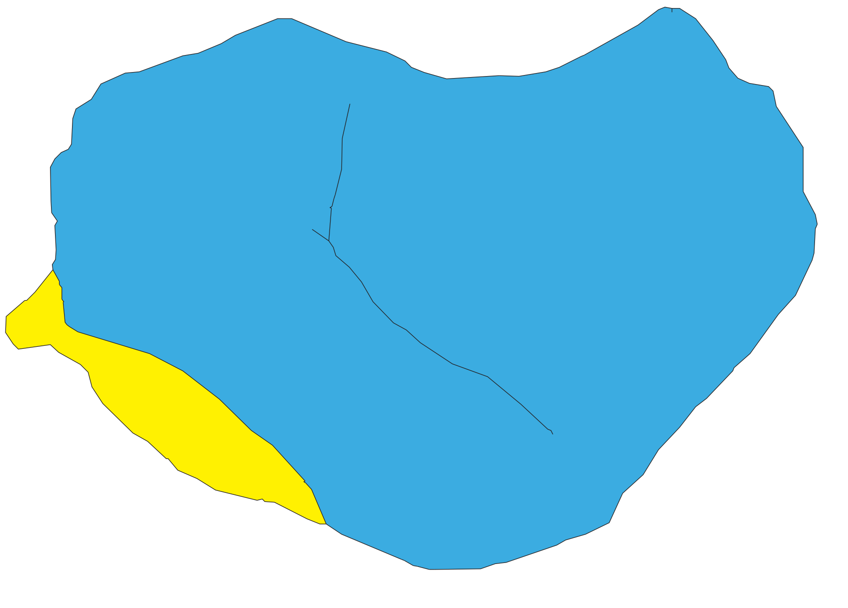
D. Aeromagnetic survey of San German area. Flown by Canadian Aero Service Ltd. in 1957 for A.D. Fraser. Specifications of survey: flight lines north-south with a spacing of 0.4 km (0.25 mi) and altitude draped at approximately 153 m (500 ft) above ground.

Magnetic Map of Puerto Rico



MINERAL RESOURCES DATA SYSTEM (MRDS) METALLIC OCCURRENCES

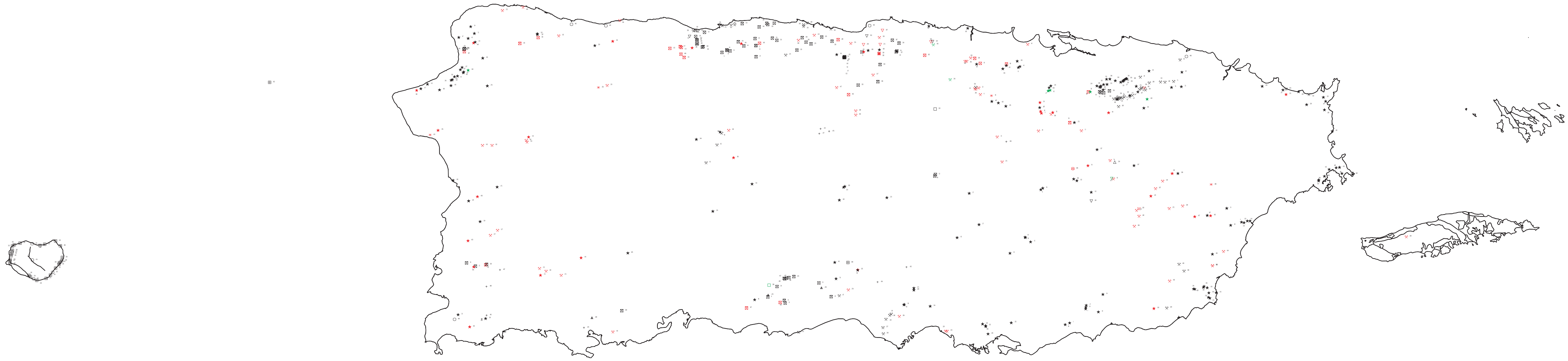




NONMETALLIC OCCURRANCES

MINERAL RESOURCES DATA SYSTEM (MRDS)

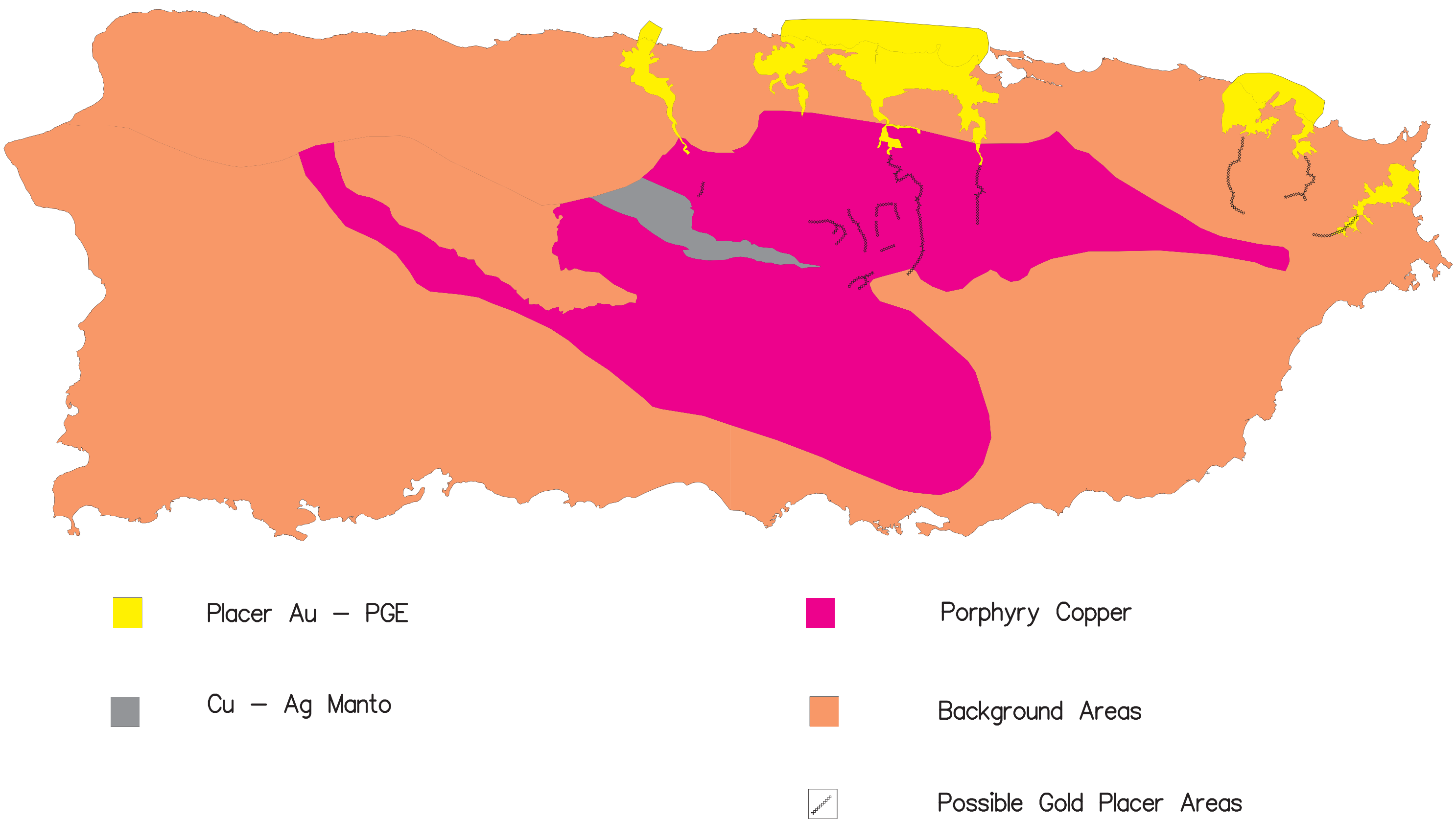
INDUSTRIAL OCCURRENCES



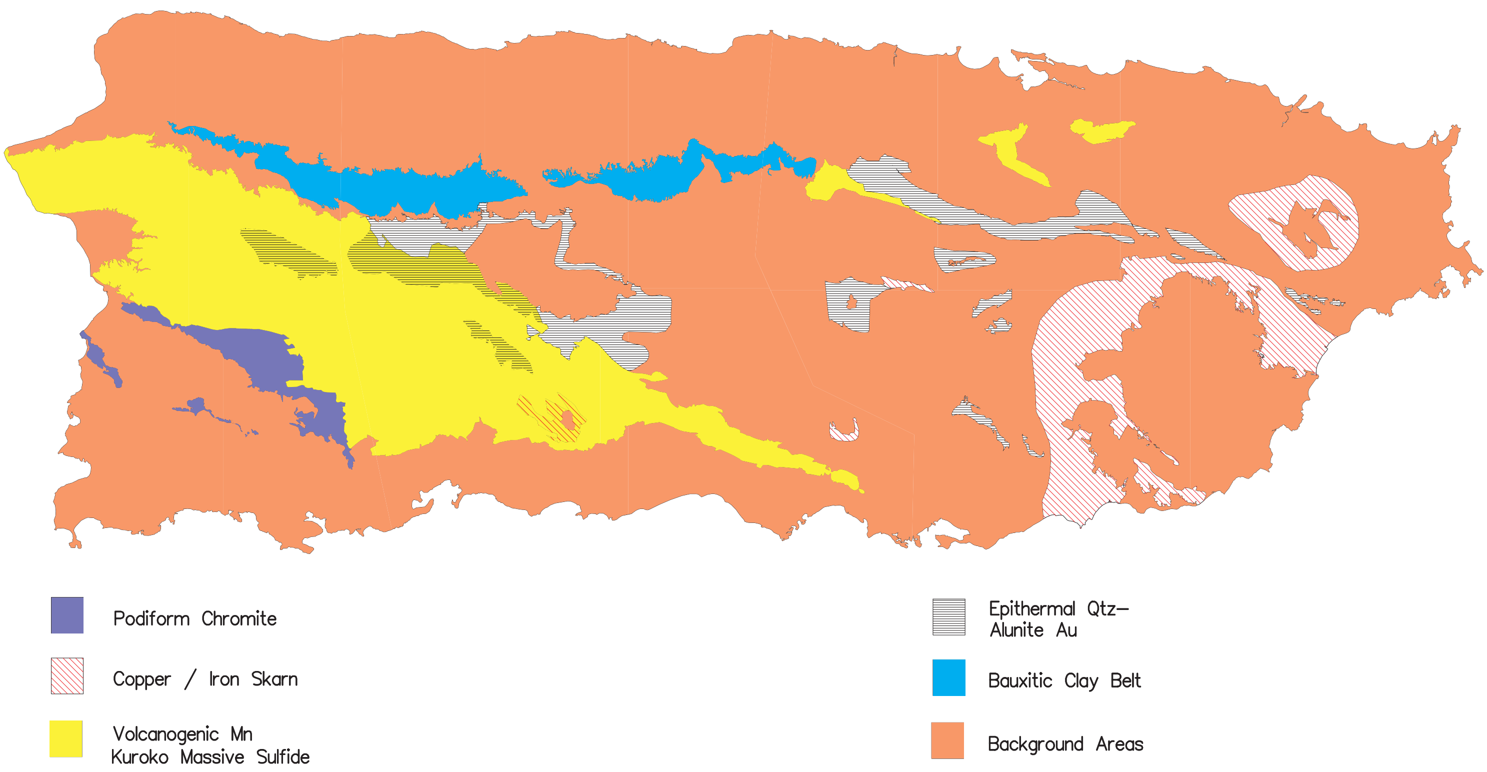
	ACTIVE 1991 PERMIT	PREVIOUS SITE
BARITE		
CLAY		
DOLOMITE		
GARNET		
GYPSUM		
LIMESTONE		

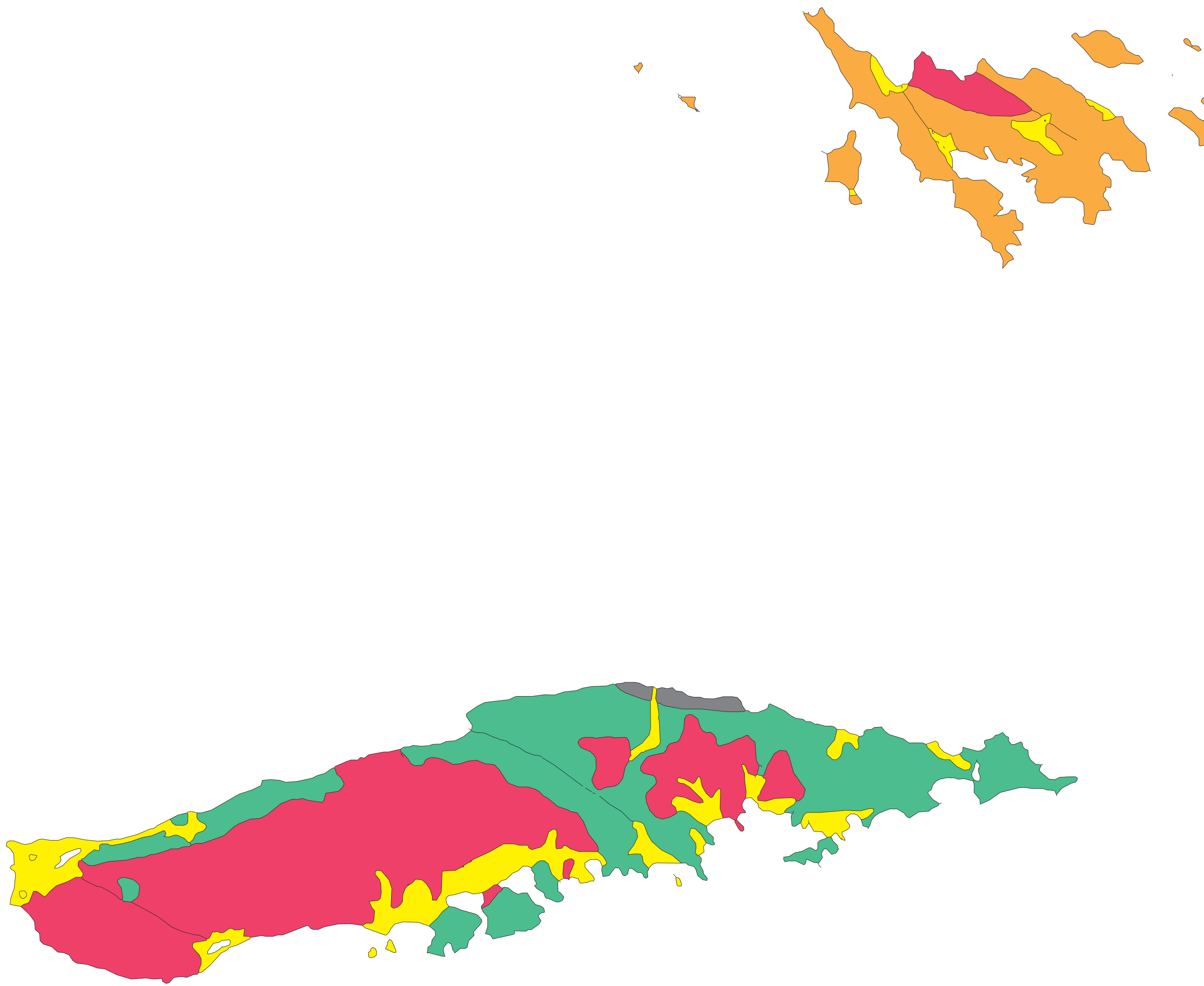
	ACTIVE 1991 PERMIT	PREVIOUS SITE
MARBLE		
PHOSPHATE		
SAND & GRAVEL		
SILICA		
STONE		
VOLCANIC ROCK		

Permissive Terranes For Metallic Mineral Deposits Of Puerto Rico

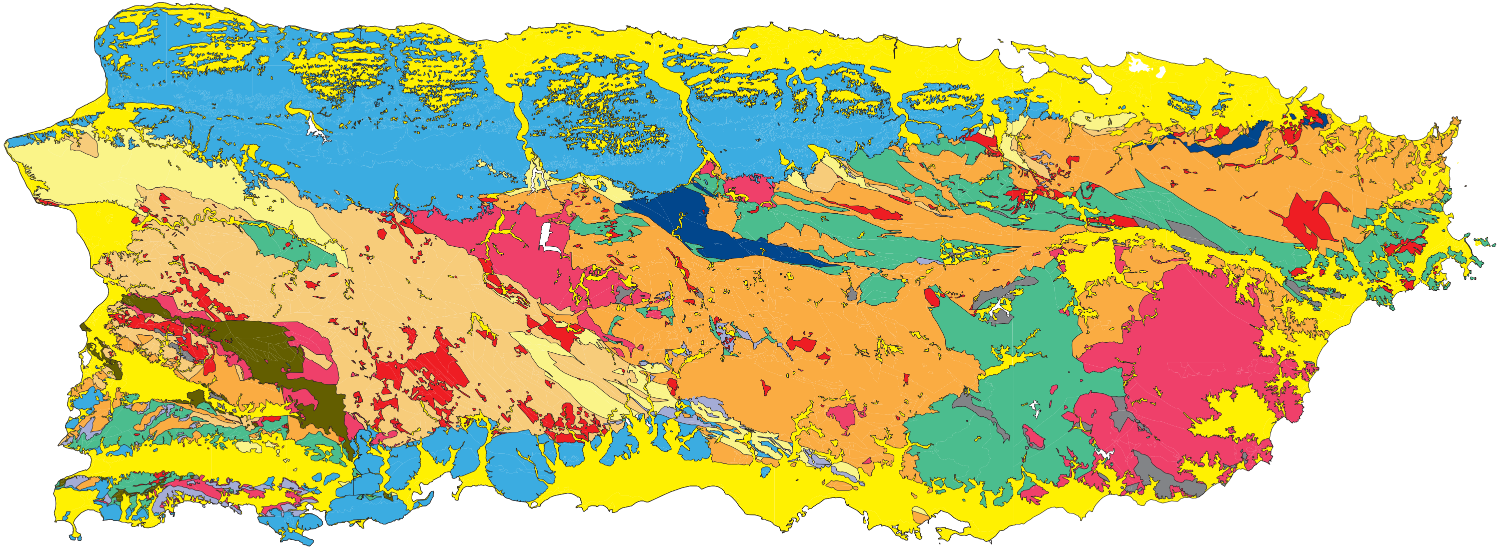


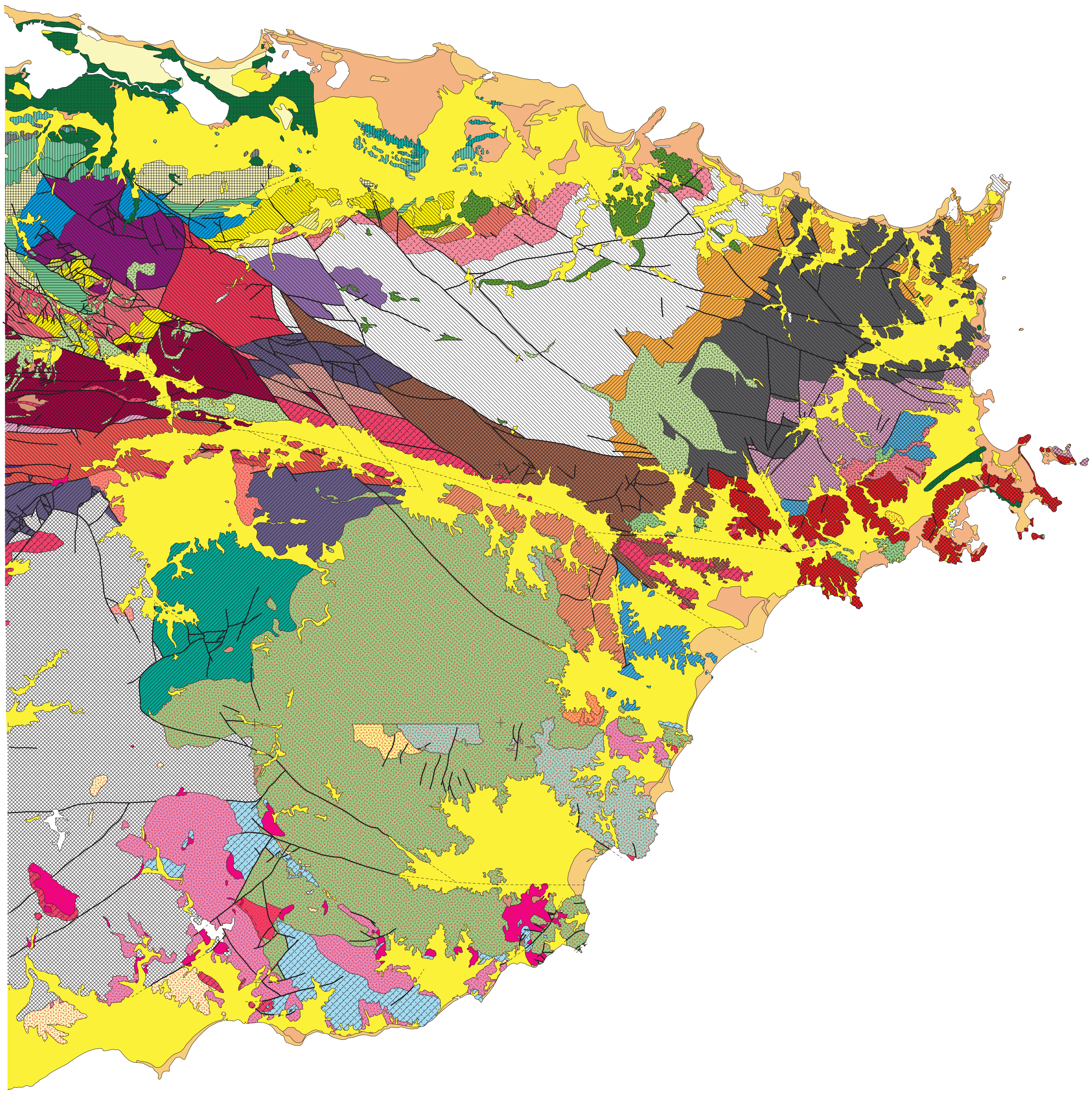
Puerto Rico Permissive Terranes

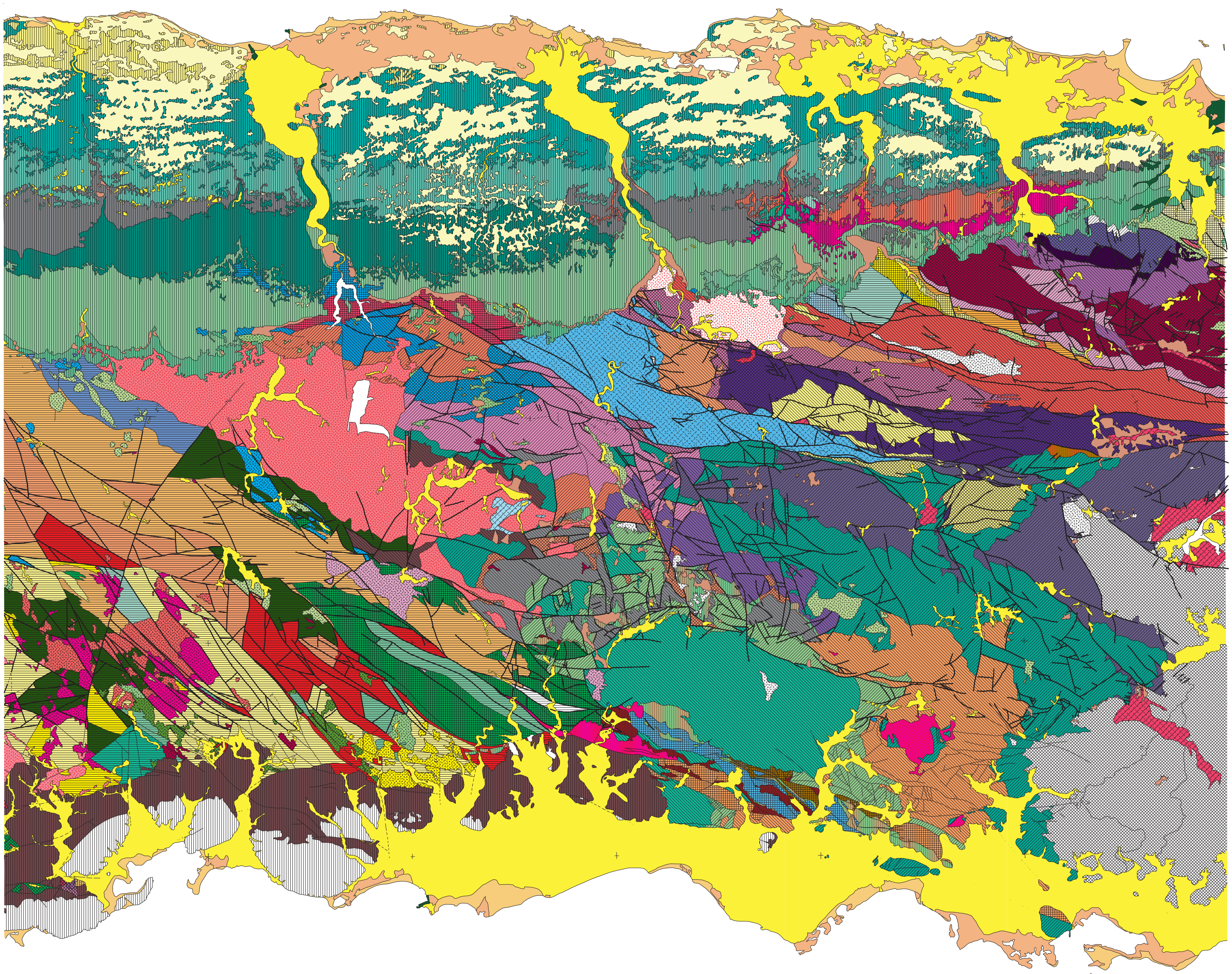


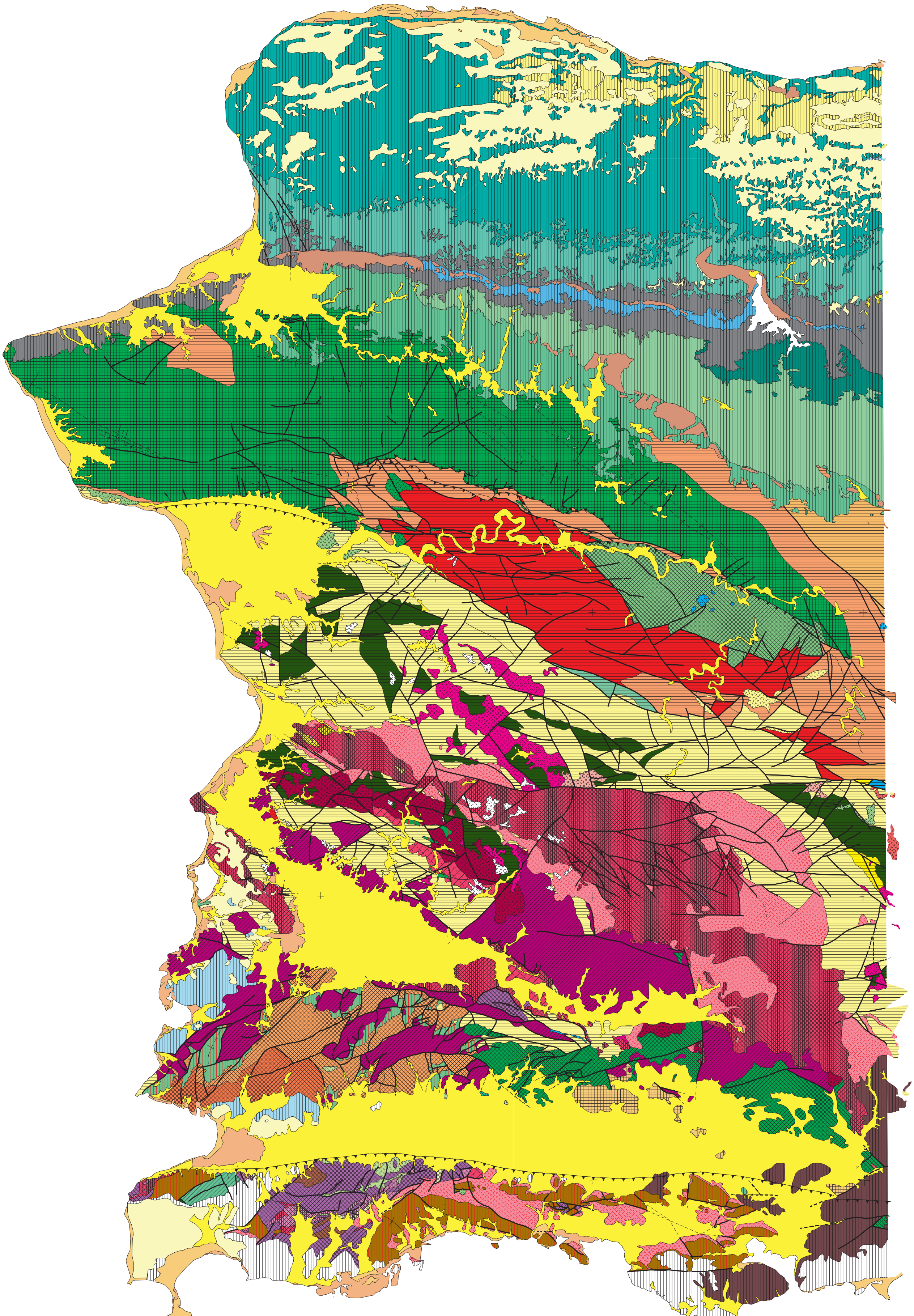


DEPOSIT TYPE	DESCRIPTION	ROCK UNITS AND STRUCTURES	EXAMPLE OF DEPOSIT TYPE	KNOWN OCCURRENCES	GEOPHYSICAL SIGNATURE	GEOCHEMICAL SIGNATURE	TRACT DELINEATION	COMMENTS
8A Podiform chromite	Irregular masses of chromite in ultramafic parts of ophiolite (Albers, 1986).	Deposits are restricted to dunite bodies within tectonized harzburgite and (or) the lower portions of ultramafic cumulates. These rocks are commonly serpentinized. Within Puerto Rico, outline of serpentinite (KJs, map __) defines host rocks. These map units are massive, but previously sheared and internally slickensided. Serpentinite is chiefly altered harzburgite. There is no evidence that serpentine extends ver	None	None	Magnetic Map - serpentinite antiforms of southwestern Puerto Rico produce large anomalies. Gravity Map - serpentinite antiforms of southwestern Puerto Rico show gravity lows. Imply extension of serpentinite below Quaternary alluvium into the Valle de Guanajibo.	Within USGS Bulletin 1693, no geochemical signature is recognized for this model. Our stream sediment geochemical samples show: a suite of element anomalies related to podiform chromite terrane in southwest Puerto Rico. Chrome values (2,000-10,000 ppm) occur in podiform chromite terrane.Cobalt values (50 - 2,000 ppm). Nickel anomalies (150-10,000 ppm) present in podiform chromite terrane.	Tract delineation based on outcrop pattern of known serpentinite map units.	
17 Porphyry Cu	Stockwork veinlets of quartz, chalcopyrite, and molybdenite in or near a porphyritic intrusion. The model name and number porphyry copper (17) is used when it is believed the mineral occurrence is part of a Cu porphyry system, but not enough information	Tonalite to monzogranite stocks and breccia pipes intrusive into batholiths, volcanic or sedimentary rocks.Within Puerto Rico, these igneous rocks intrude rocks of older age (not comagmatic). Molybdenum increases with depth of system, which indicates a deeper seated porphyry system.	Site no. MRDS no. Name 52 W701159 Rio Cuyon 114 W701043 La Muda	Site no.MRDS no.Name 98 W701166 Cacao 116 W701044 La Muda 117 W701045 La Muda 119 W701046 La Muda 176 W701091 Quebrada de la Mina 188 WALT003 Rio Santiago copper prospect 189 WALT004 Humaco copper prospect 203 W701109 Barranquitas prospect	Aeromagnetics - linear features and dominantly aeromagnetic high reflect the subsurface. Bouguer gravity - Utuado and San Lorenzo batholiths reflect lows.	The porphyry Cu model described in USGS Bulletin 1693 contains a geochemical signature of Cu, Mo, Au, Ag, W, B, Sr towards center; Pb, Zn, Au, As, Sb, Se, Te, Mn, Co, Ba, and Rb towards periphery. Geochemical analysis of Puerto Rico samples show anomalites for Cu, Au, Mo and Sn, contained mostly within the permissive terrain.	Known occurrences identify permissive lithologies. South of Utuado batholith - track delineated based on a combination of known occurrences, linear aeromagnetic signature, and geologic terrane. Aeromagnetics can be either high or low, depending on composition of surrounding lithologies.	The permissive area for porphyry deposits is very large, containing most of the Tertiary and mixed Cretaceous and Tertiary volcanoclastic lithologies (map __). Within this area of permissive terranes, promising areas are delineated with respect to known occurrences.
18B Cu skarn deposits	Chalcopyrite in calc-silicate contact metasomatic rocks (Cox and Theodore, 1986).	Tonalite to monzogranite plutons intrude carbonate rocks or calcareous clastic rocks. In Puerto Rico: Rio Blanco stock (TKh, map __) - intrudes calcareous Tabonuco Formation (KTa) and Hato Puerco Formation (Kh), Fajardo Formation (Kfa), Lomas Formation (Klo). San Lorenzo batholith (Ksl) and quartz diorite (Kpgq) complex intrudes metavolcanic rocks (TKmv), lava flows and	Site no. MRDS no. Name 92 W701128 Island Queen (Las Torres) 164 W701050 La Mine, Rio Blanca (Spanish adit)	Site no. MRDS no. Name 34 W701112 Rio Hondo (36-2) 37 W701115 Escuela prospect (Jaguar vein, Mamey vein) 51 GEM1111 Borinquen 126 W7011049 El Yunque 191 W701101 Rio Hondo (35-1) 192 W701102 Rio Hondo (35-2) 193 W701103 Rio Hondo (35-3) 194 W701104 Rio Hondo (35-4) 195 W701105 Rio Hondo (35-5) 196 W701106 Rio Hondo (35-6)	Rio Blanco area Magnetics - no coverage in Rio Blanco area. Gravity - Rio Blanco alteration too small to be seen. San Lorenzo batholith Aeromagnetics - only partial coverage of area, therefore, inconclusive. Gravity - there appears to be a halo (145-155mGal) around batholith, but it is unclear if this is an artifact of the batholith or mineralization.	USGS Bulletin 1693 shows geochemical signatures of Cu, Au, Ag, Pb, Zn, and Co for this model type. In Puerto Rico, geochemical sampling does not show major groupings of the signature elements around the Cu-skarn terrane.	Rio Blanco area - tract delineation based on 1:20,000 mapped alteration and pyrite occurrences. Known Cu skarn occurrences. Kfa & Klo have very little carbonate material. Delineated area to northwest of stock based on mapped copper occurrences and implied buried pluton based on 1:20,000 scale mapping. San Lorenzo batholith - interior boundary at edge of plutonic rocks. Exterior boundary - on northeast side - fault contact between Kr and Kl, buried under Qa, contact between carbonate bearing Torrecilla Breccia (Kt) and Los Negros Formation (Kln). Approximately 2 kilometers from plutonic rocks through Kabcj unit. Barranquitas stock - Pinas stock area - Tract delineated based upon known occurrences, fault-bounded Torrecilla Breccia (Kt)	Cu and Fe skarn - both deposits usually contain both Fe and Cu, assignment between these two models was based on what was perceived to be dominant metal.
18D Iron skarn deposits	Magnetite in calc-silicate contact metasomatic rocks (Cox, 1986).	For this deposit type, contacts of gabbro, diorite, diabase, syenite, tonalite, granodiorite or granite intrusions and carbonate rocks or calcareous clastic rocks In Puerto Rico: Rio Blanco stock unit (TKh) - intrudes calcareous Tabonuco Formation (KTa) and Hato Puerco Formation (Kh), Fajardo Formation (Kfa), Lomas Formation (Klo). San Lorenzo batholith (Ksl) and quartz diorite (Kpgq) complex intrudes metavolcanic rocks (TKmv), lava flows and breccias (Kgbcj), and calcareous Pitahaya Formation (Kpi), Torrecilla Breccia (Kt) and Robles Formation (Kr).	85 W701123 Keystone mine (La Mina,La Esperanza, Juncos mine)	Site no. MRDS no. Name 39 W701116 Aguayo prospect 41 W701117 Cane Field and Pastor prospects 43 W701118 Santiago and Pastor prospects 45 W701119 Suiza prospect 82 W701120 Mamey limestone deposits 83 W701121 Buen Suceso 84 W701122 La Caridad prospect 87 W701125 Deposit no. 5 89 W701126 Deposit no. 2 91 W701127 Deposit no. 3 94 W701129 Deposit no. 4 96 W701164 Yaurel (Los Cocaos) 97 W701165 Emajagua 143 W701136 Tibes 147 W701138 Barrio Tibes, Rio Portuges 197 W701140 Unnamed (47-1)	Rio Blanco area Magnetics - no coverage in Rio Blanco area. Gravity - Rio Blanco alteration too small to be seen. San Lorenzo batholith Aeromagnetics - only partial coverage of area, therefore, inconclusive. Gravity - there appears to be a halo (145-155mGal) around batholith, but it is unclear if this is an artifact of the batholith or mineralization.	USGS Bulletin 1693 shows a geochemical signature of Fe, Cu, Co, Au and possibly Sn for this model. In Puerto Rico, the geochemical analysis do not show anomalous patterns for these elements.	Rio Blanco area - known Fe skarn occurrence. Tract delineation based on known alteration and pyrite at 1:20,000 scale mapping. San Lorenzo batholith - coincident tract with Cu skarn. Mix of both Cu skarn and Fe skarn occurrences. See Cu skarn for tract delineation description. Los Panes intrusion - magnetite, resulting from partial replacement of hornblende; occurs along contact of Los Panes intrusion. Richest concentrations do not exceed 10 percent of rock. A.D. Frazer aeromagnetic map shows pronounced magnetic anomaly along southeast portion of intrusion (map I-335). Cerro el Gato - quartz diorite-grandiorite (TKqd) intrudes. Yauco Formation (TKy) - calcareous. Lago Garzas (TKly) - calcareous. Yauco Formation interbedded with Lago Garzas (TKly). Known Cu and Fe skarn occurrences.	Cu and Fe skarn - both deposits usually contain both Fe and Cu, assignment between these two models was based on what was peceived to be dominant metal.
20C Porphyry Cu-Au	Stockwork veinlets of chalcopyrite, bornite, and magnetite in porphyritic intrusions and coeval volcanic rocks. Ratio of Au (in ppm) to Mo (in percent) is greater than 30 (Cox, 1986).	Within Puerto Rico, porphyry Cu-Au deposits are associated with Eocene porphyry intrusions, which are mostly quartz bearing and tonalite in composition. These Eocene porphyries intrude rocks of same age (comagmatic).	Site no. MRDS no. Name 71 W701071 Piedra Hueca deposit 75 W701073 Cala Abajo deposit 161 W701014 Tanama Deposit 179 W701059 Helecho Deposit	Site no. MRDS no. Name 73 W701072 Sapo Alegre 158 W701012 Laundry Creek Prospect 159 W701013 Copper Creek	Aeromagnetics - linear features and dominantly aeromagnetic highs reflect the subsurface. Bouguer gravity - Utuado and San Lorenzo batholiths reflect lows.	USGS Bulletin 1693 describes the geochemical signature for the porphyry Cu-Au model as Cu, Au, Ag central to deposit, and Mo, Pb, Zn, Mn peripheral to these models. Geochemical analyses for Puerto Rico show: Molybdenum and tin anomalies contained within the permissive areas. Gold occurs both within and outside of permissive terranes. Anomalous copper values occur within permissive terranes.	Delineated by extent of volcanic clastic belt and known occurrences. South of Utuado batholith - Track delineated based on a combination of known occurrences, linear aeromagnetic signature, and geologic terrane. Aeromagnetics can be either high or low, depending on compositon of surrounding lithologies.	The model name and number porphyry copper (17) is used when it is believed the mineral occurrence is part of a Cu porphyry system, but not enough information is available to discriminate between porphyry Cu-Au (20c) or porphyry Cu-Mo (21A). The permissive area for porphyry deposits is very large, containing most of the Tertiary and mixed Cretaceous and Tertiary volcanoclastic lithologies. Within this area of permissive terranes, favorable areas are delineated with respect to known occurrences.
22C Polymetallic veins	Quartz-carbonate veins with Au and Ag associated with base metal sulfides related to hypabyssal intrusions in sedimentary and metamorphic terranes (Cox, 1986).	Near surface fractures and breccias within thermal aureal of clusters of small intrusions. In some areas peripheral to porphyry systems.	Site no. MRDS no. Name 66 W701034 Constancia mine 88 W701160 Cerro Avispa	Site no. MRDS no. Name 4 W701146 Unnamed (48-4) 8 W701148 Unnamed (48-6) 14 W701022 Unnamed (20-3) 25 W701029 Barrio Pasto deposits 26 W701064 Unnamed (32-1) 27 W701065 Unnamed (32-2) 28 W701066 Unnamed (32-3) 29 W701067 Unnamed (32-4) 31 W701069 Unnamed (32-6) 32 W701110 Unnamed (32-10) 36 W701114 Unnamed (37-1) 38 W701150 Unnamed (48-8) 42 W701152 Unnamed (48-10) 44 W701153 Unnamed (48-11) 46 W701154 Unnamed (48-12) 47 W701155 Unnamed (48-13) 49 W701157 Unnamed (48-15) 58 GEM1117 Rio Jajome 63 W701031 Unnamed (20-12) 64 W701032 Unnamed (20-13) 68 W701036 Cuchillos 69 W701070 Pellejas 70 W701037 Collcuchi, Sayre 74 W701039 Unnamed (21-7) 76 W701074 Unnamed (32-11) 77 W701075 Unnamed (32-12) 78 W701076 Unnamed (32-13) 79 W701077 Unnamed (32-14) 80 W701078 Unnamed (32-15) 81 W701079 Unnamed (32-56) 90 W701161 Carmen (50-3) 93 W701162 Carmen (50-4) 95 W701163 Carmen (50-5) 110 W701041 Unnamed (22-2) 118 W701080 Unnamed (32-17) 121 W701081 Unnamed (32-18) 123 W701082 Unnamed (32-19) 125 W701083 Unnamed (32-20) 127 W701084 Unnamed (32-21) 129 WALT001 Monte El Gato 130 W701086 Unnamed (33-1) 131 W701087 Unnamed (33-2) 132 W701088 Unnamed (33-3) 139 W701133 Palmarejo 141 W701135 Minillas, San German 149 W701139 Unnamed (46-2) 156 W701010 Unnamed (14-2) 157 W701011 Unnamed (15-1) 163 W701016 Unnamed (18-1) 178 W701092 Unnamed (33-7) 180 W701093 Unnamed (33-8) 181 W701094 Unnamed (33-9) 182 W701095 Unnamed (33-10) 184 W701097 Unnamed (33-12) 185 W701098 Unnamed (33-13) 186 W701099 Unnamed (33-14) 190 W701100 Unnamed (34-1) 198 W701107 Unnamed (35-7) 204 W701143 Unnamed (48-1)	None	The element Zn, Cu, Pb, Au and Ag are characteristic of this deposit type. These elements are present in the geochemical samples taken throughout the island.	No terrane drawn. The entire island is permissible for polymetallic veins, except the San Lorenzo and Utuado batholiths, and Oligocene or younger sediments.	The depositional environment for this deposit type is within near-surface fractures and breccias within thermal aureols of small intrusions or peripheral to porphyry systems. Due to the high degree of faulting and the abundance of intrusions, most of the island is permissive except for the large batholiths and the Oligocene and younger sediments. All of these occurrences were identified inh Cox and Briggs (1973), and their descriptions used to classify as polymetallic veins.
24C Volcanogenic manganese	Lenses and stratiform bodies of manganese oxide, carbonate, and silicate in volcanic-sedimentary sequences (Koski, 1986).	The marine Tertiary volcaniclastics with carbonates were found to contain all occurrences of manganese	Site no. MRDS no. Name 2 W701145 Juana Diaz mine 115 W701009 Aguada 128 W701085 Gatti prospect	Site no. MRDS no. Name 1 W701144 Unnamed (48-2) 6 W701147 Unnamed (48-5) 10 W701149 Unnamed (48-7) 18 W701060 Unnamed (31-2) 20 W701061 Unnamed (31-3) 22 W701062 Unnamed (31-4) 24 W701063 Monte Guilarte 48 W701156 Santiago 65 W701033 Mayaguez 67 W701035 Corazal 173 W701056 Unnamed (30-1)	Aeromagnetics - incomplete or no coverage over permissive terrane. Gravity - no detectable pattern over permissive terranes.	The geochemical signature for volcanogenic Mn deposits contained in USGS Bulletin 1693 are Mn, Zn, Pb, Cu and Ba. These elements do not show related patterns for Puerto Rico samples.	Manganese occurrences and deposits. Area permissive - contains volcaniclastic marine Tertiary lithologies.	Volcanogenic manganese deposits form most often when there is sufficient structure and porosity to permit subsea-floor hydrothermal circulation and sea-floor venting. The Juana Diaz mine produced manganese oxide from irregular chambers o limestone of the Juana Diaz Formation. Meyerhoff (1933) believes this manganese ore was deposited by meteoric waters which dissolved calcium carbonate and also precipitated manganese oxide.
25E Epithermal quartz-alunite Au	Gold, pyrite, and enargite in craggy veins and breccias in zones of high-alumina alteration related to felsic volcanism (Berger, 1986).	Through going fractures, centers of intrusive activity. Upper and peripheral parts of porphyry copper systems.	Site no. MRDS no. Name 35 W701113 Cidra 160 D002191 Cerro la Tiza	Site no. MRDS no. Name 86 W701124 Unnamed (39-1) 124 W701048 Unnamed (23-7) 187 WALT002 Rio Anasco	Aeromagnetics - coverage not available for large units. Gravity - inconclusive.	The USGS Model book, Bulletin 1693, shows geochemical presence of Au, Ag, and Cu higher in the system, and base metals increasing with depth. These elements did not define the permissive area for this deposit type.	Terranes drawn based on known 1:20,000 alteration. Called advanced argillic alteration associated with plutons. Known occurrences in most tracts. All hydrothermal alteration (TKhA) and meta-volcanic rocks (Kmv) included that is related to dacite, quartz latite, rhyodocite or rhyolite.	
28A Kuroko massive sulfide	Copper- and zinc-bearing massive sulfide deposits in marine volcanic rocks of intermediate to felsic composition (Singer, 1986).	Eocene island arc volcanics Cherts present Dacitic domes	None	None	Aeromagnetics - incomplete or no coverage over permissive terrane. Gravity - no detectable pattern over permissive terrane.	Copper and zinc anomalies with scattered gold anomalies occur in the western part of the massive sulfide terrane.	Area permissive delineated by intermediate to felsic marine Tertiary volcano-clastic lithologies. Associated occurrences of volcanogenic Mn.	While no known occurrences of Kuroko massive sulfide deposits have been described, there is a high probability that they are present in Puerto Rico. The permissive features include: marine volcanic rocks of intermediate to felsic composition; marine rhyolite, dacite, subordinate basalt and associated sediments; hot springs related to marine volcanism; island arc tectonic setting; evidence of associated deposits (volcanogenic Mn).
38A Lateritic Ni	Nickel-rich, in situ lateritic weathering products developed from dunites and peridotites. Ni-rich iron oxides are most common (Singer, 1986).	Relatively high rates of chemical weathering (warm-humid climate) of ultramafic rocks and relatively low rates of physical erosion. KJs - serpentinite is host rock Dunite source = good chrome resource Harzburgite source = poor chrome resource Host lithology is outline of laterite accumulation.	Site no., MRDS no., Name , Reserves, and Grades 166 W701051 Punta Guanajibo 1.03% Ni, 0.07% Co, .63% Cr, 2,100,000 ST, 19.03% Fe 201 W701052 Guanajibo 0.08% Co, 20.54% Fe, 0.51% Cr, 46,800,000 ST, .88% Ni 169 W701053 Las Mesas deposit 28.39% FE, 0.75% Cr, 25,000,000 ST, . 81% Ni, .12% Co 171 W701054 Rosario north deposit 20.76% Fe, .58% Cr 4,800,000 ST, .85% Ni, .07% Co 172 W701055 Rosario south deposit 12.47% Fe, .34 Cr, 1,100,000 ST, .71% Ni, .06% Co 175 W701057 Maricao west 22.05% Fe, .59% Cr, 5,000,000 ST, .98% Ni, .10% Co 177 W701058 Maricao east 29.45% Fe, .67% Cr 5,600,000 ST, 1.08% Ni, .11% Co	None	Gravity - serpentinite antiforms produce large anomalies. Aeromagnetics - coverage incomplete.	Enriched Ni, Cr, and Co represent geochemical signatures for this model. These elements and Mg are anomalous in the permissive terrane for this deposit type.	Known occurrences. All laterites contained contained within KJs. Ni laterites mapped at 1:20,000.	Laterite accumulation is restricted to the outcrop pattern of the serpentinite (KJs) zone. This area is believed to have been exhaustively explored for this type of deposit.
38C Karst Type Bauxite	Residual and transported material on carbonate rocks. Transported material may be felsic volcanic ash from distant source or any aluminous sediments washed into the basin of deposition (Patterson, 1986).		Kennedy bauxite concession.	Not plotted.	None	Aluminum and Ga not examined.	Based on Kennedy bauxite concession granted in 1961. Tract extends farther east and west and is restricted to the Lares Limestone. Bauxite sampled from sinkholes.	
39A Placer AU-PGE	Elemental gold and platinum-group alloys in grains and (rarely) nuggets in gravel, sand, silt, and clay, and their consolidated equivalents, in alluvial, beach, and eolian deposits (Yeend, 1986).	Oligocene and Quaternary sedimentary clastic deposits which have drained gold bearing lithologies and alteration.	None	Site no. MRDS no. Name 72 W701038 Palos Blancos 100 GEM1120 Luquillo Mountains gold placers 200 W701108 Rio Caliente	None	Some Au anomalies define drainages permissive for placer Au-PGE mineralization in the northeast part of the island.	Known occurrences. High energy drainage areas below known gold occurrences.	Gold placers were exploited by both the Indian, and then Spanish colonists during colonization. Gold placers were also exploited during the 1900's to 1930's. Remaining gold resources lie both in undiscovered remnant placer deposits, veins of gold-bearing quartz, and placers offshore are possible.
39C Shoreline Placer Ti	Ilmenite and other heavy minerals concentrated by beach processes and enriched by weathering (Force, 1986).	Rock types included in this deposit type consist of well-sorted medium-to fine-grained sand in dune, beach, and inlet deposits commonly overlying shallow-marine deposits. These deposit types typically are elongated 'shoestring' ore bodies parallel to coastal dunes and beaches.	None	Site no. MRDS no. Name 105 W701003 Hatillo 106 W701004 La Marina 107 W701005 La Boca 111 W701007 Rio Cocal	None	Ti anomalies in the volcaniclastic rocks in the western part of the island may indicate the possiblity of placer Ti deposits along the west coast.	Occurrences are restricted to individual beach dunes which are not visible at 1:200,000 scale.	
Copper Manto	Mantos (horizontal) and pipes (vertical) found in association as brecciated areas, small in two dimensions and long in the third dimension. Brecciation allows the flow of fluids and deposition of minerals.	Small lenses and veins found in the Blacho Tuff Member of the Pozas Formation. Subaerial volcanic lithologies are preferred host lithologies.	None	Site no. MRDS no. Name 15 W701023 Unnamed (20-4) 16 W701024 Unnamed (20-5) 17 W701025 Unnamed (20-6)	None	A few scattered anomalies for Cu occur in this terrane.	Tract delineated for copper-silver Manto deposits of Puerto Rico is controlled by surface exposure of subaerial volcanic rocks of the Pozas Formation.	









INTRUSIVE AND STRUCTURAL MAP

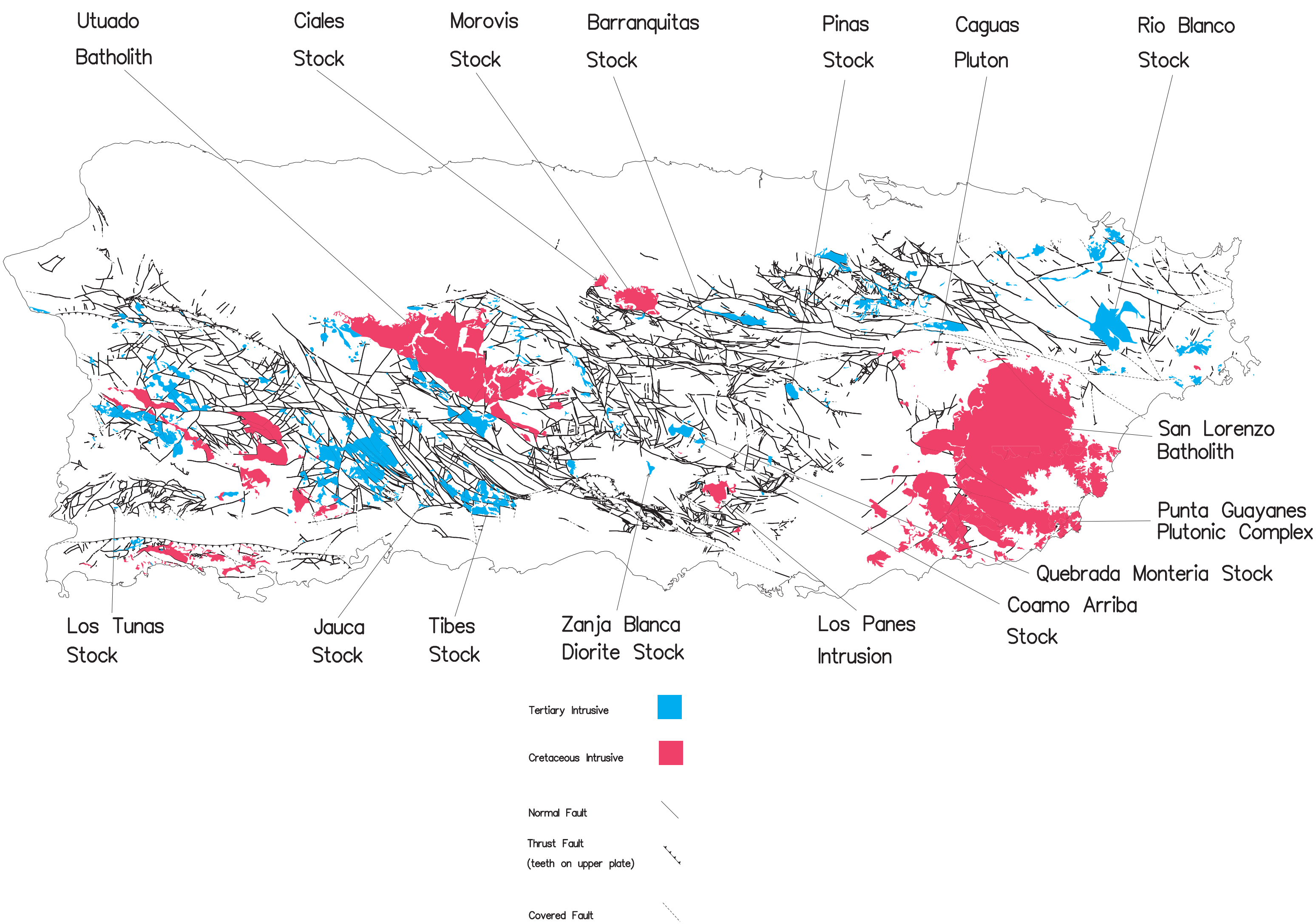
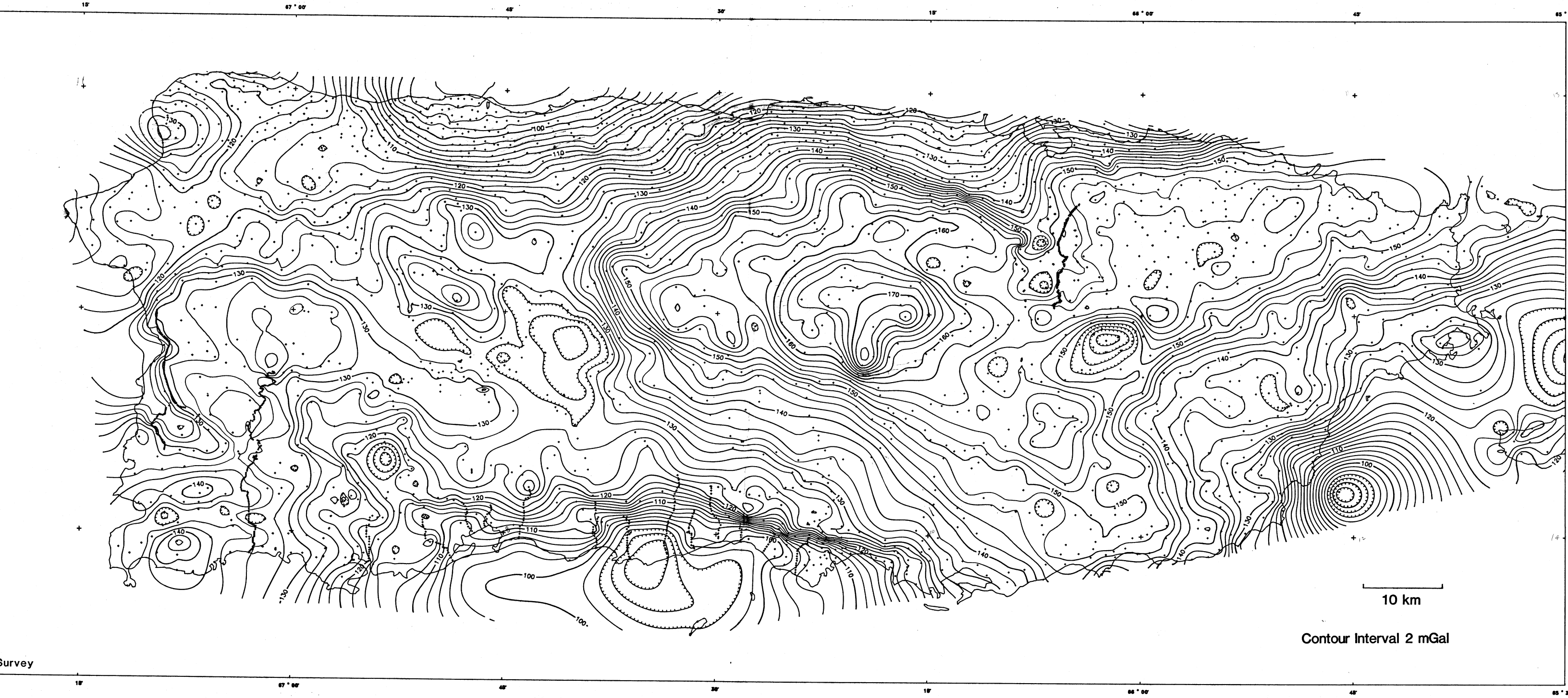
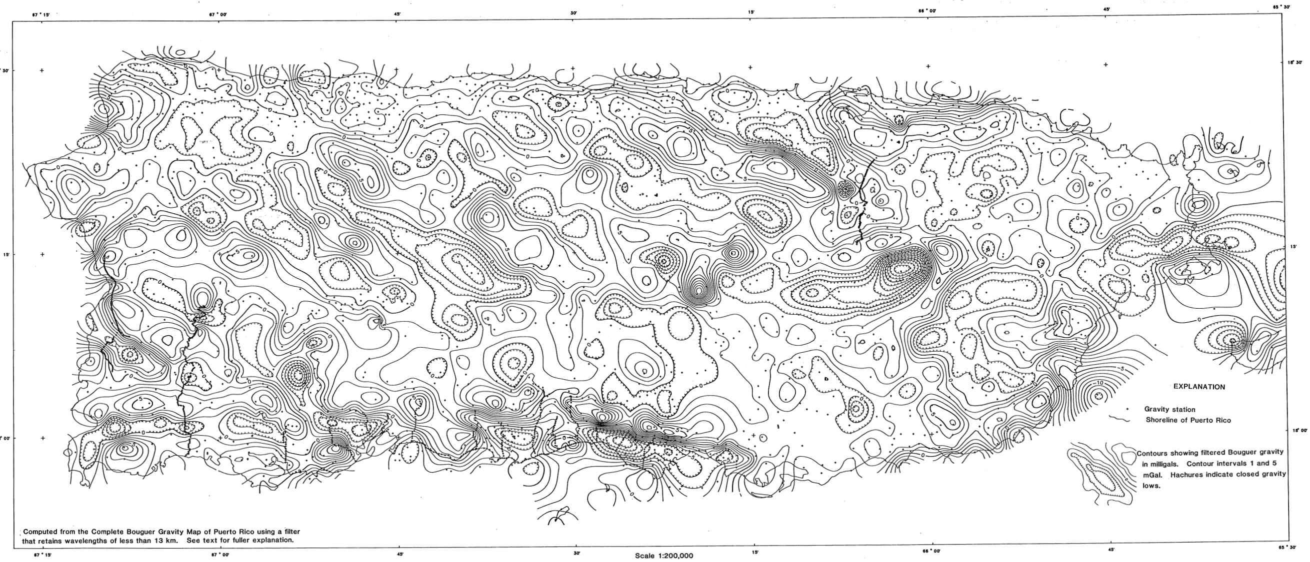


PLATE 1



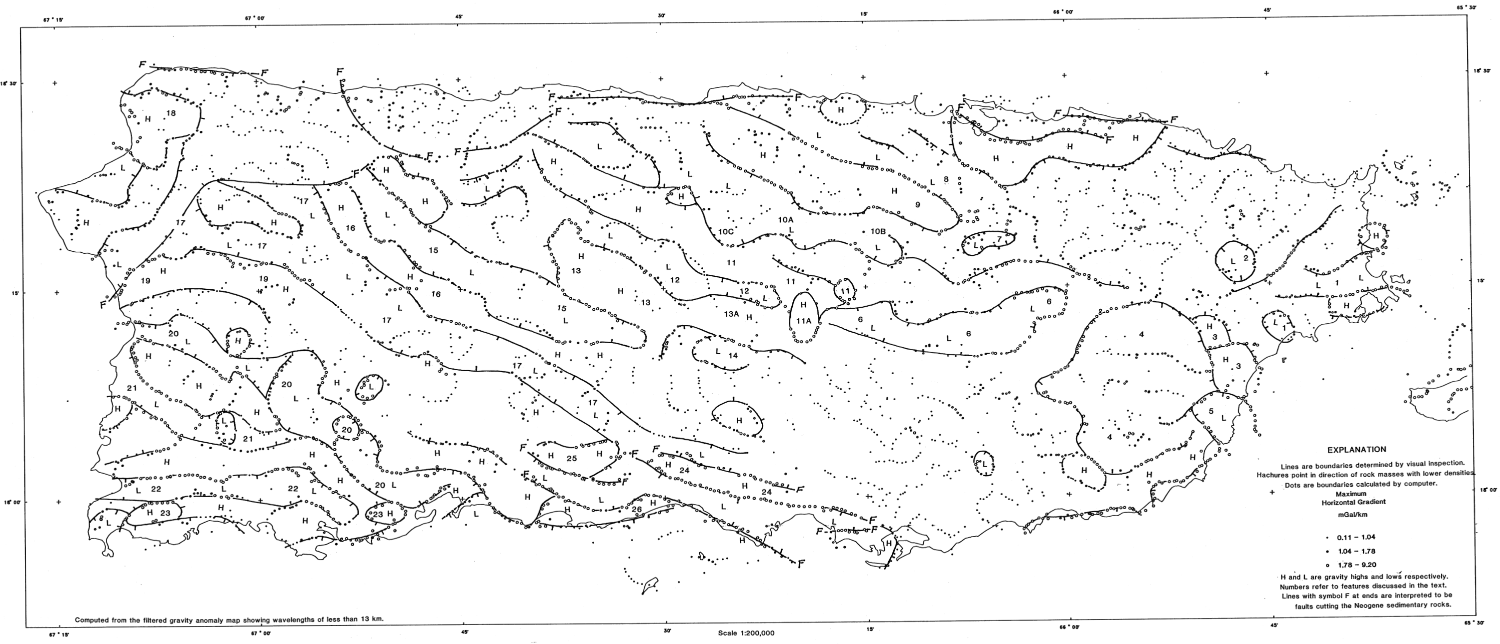
BOUGUER GRAVITY MAP OF PUERTO RICO

PLATE 2



FILTERED BOUGUER GRAVITY MAP OF PUERTO RICO

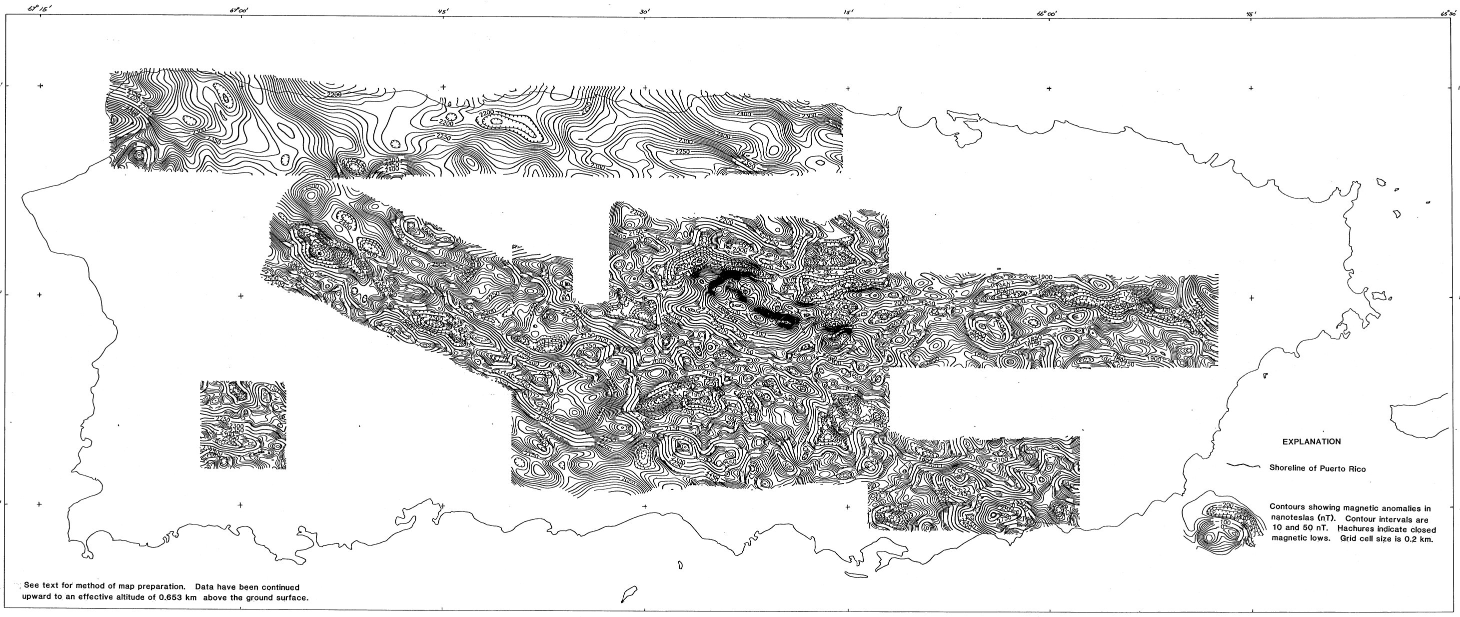
By Andrew Griscom and Nami E. Kitchen



GRAVITY BOUNDARY MAP OF PUERTO RICO

By Andrew Griscom and Nami E. Kitchen

PLATE 4



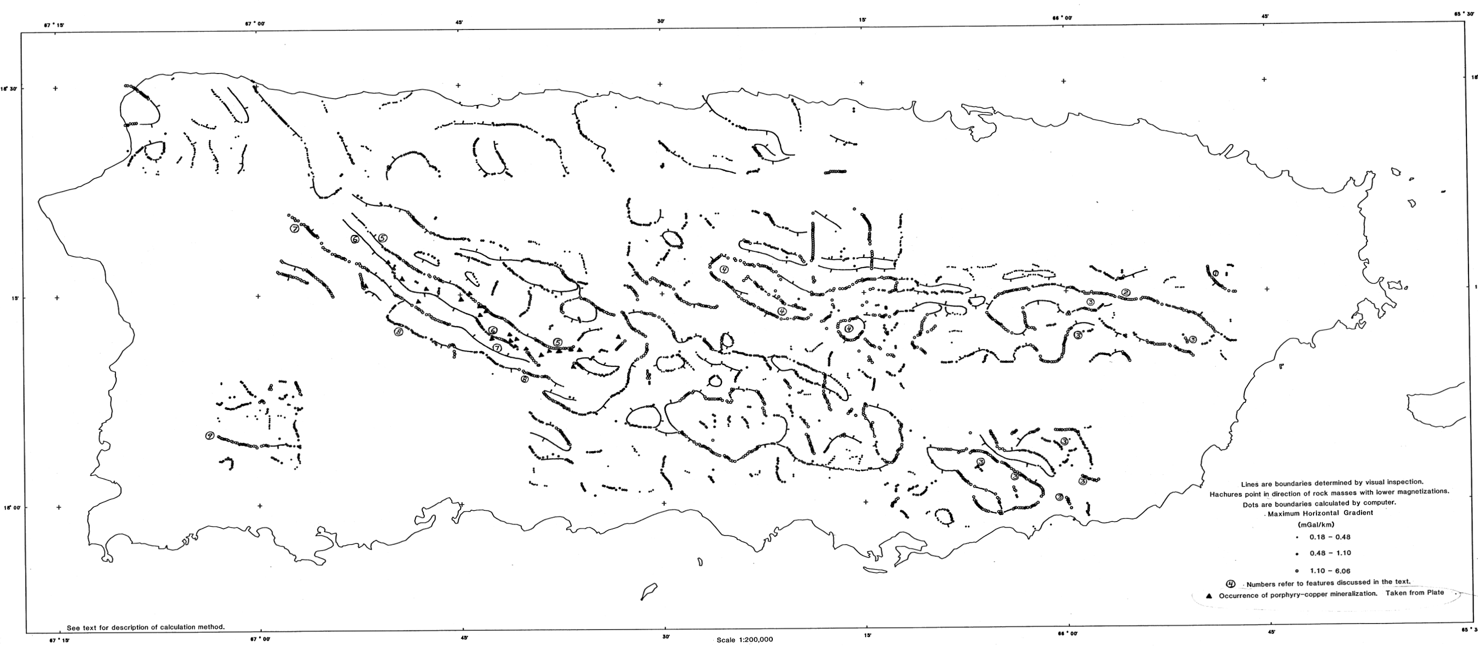
Scale 1:200,000

See accompanying index map for description of individual surveys.

MAGNETIC MAP OF PUERTO RICO

By Andrew Griscom and Nami E. Kitchen

PLATE 5



MAGNETIC BOUNDARY MAP OF PUERTO RICO

By Andrew Griscom and Nami E. Kitchen

Table 1. Estimates of the number of undiscovered mineral deposits at specified probability levels in Puerto Rico

Model number[1]	Deposit	No. of known	No. of known	Probability of undiscovered deposits					Level of
						.10			
18B	Copper skarn	2	10	1	4	8	-	-	Low
18D	Iron skarn	1	16	0	0	1	2	3	Moderate to high
20C	Porphyry copper-gold	4	3	2	3	5	8	10	High?
22C	Polymetallic veins	2	59	1	4	15	-	-	Moderate
24C	Volcanogenic manganese	3	11	1	3	8	-	-	Moderate
25E	Epithermal Quartz-Alunite Gold (low grade)	2	3	1	2	4	-	-	Low
28A	Kuroko-type massive sulfide	0	0	0	0	1	-	-	Very low
39A	Placer Gold-Platinum Group Elements	Ancient placer sites	3	0	0	-	-	1	Very high

1. Cox and Singer (1986).

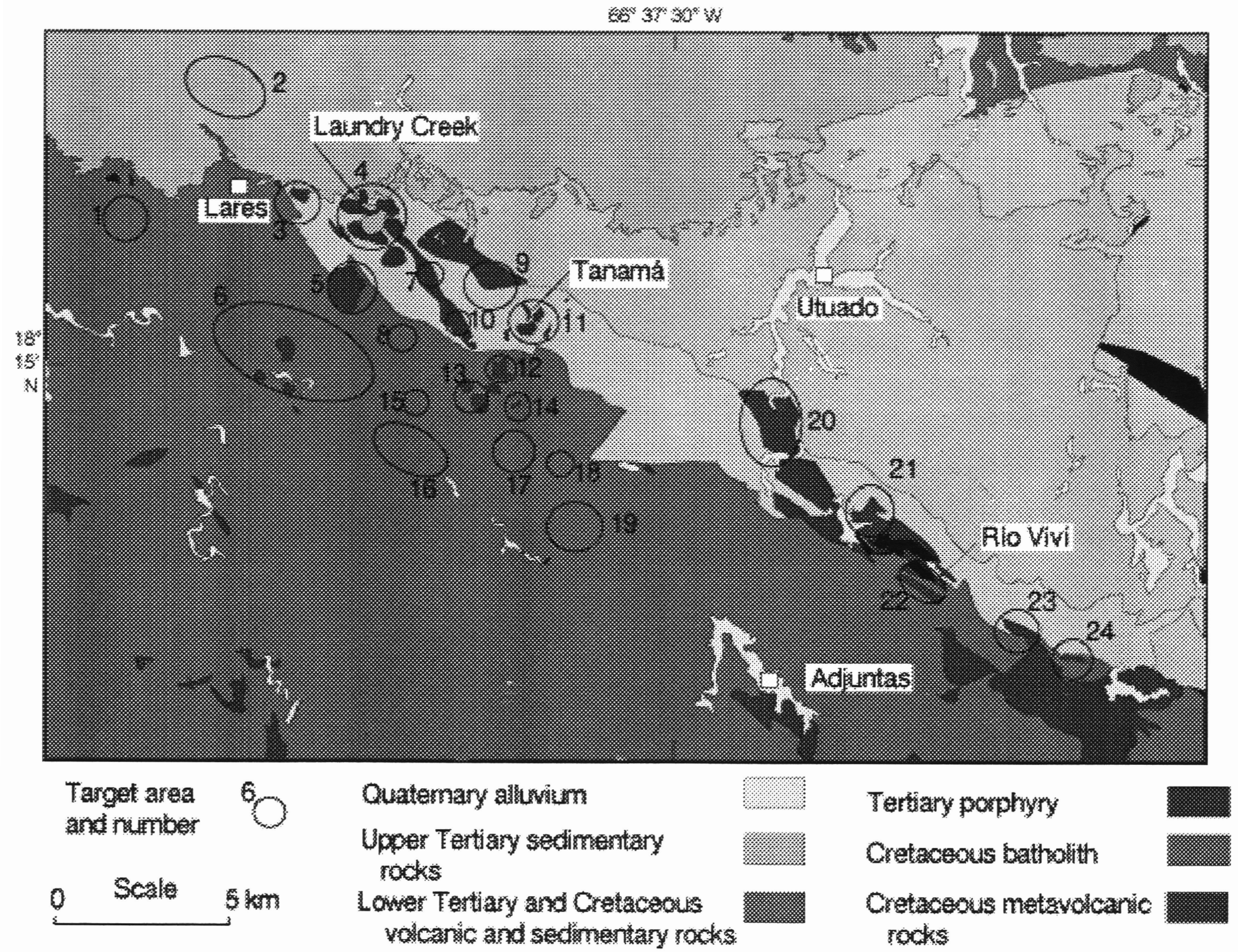
Table 2. *Geological, geophysical,and geochemical characteristics of favorable areas, and the probability of undiscovered deposits within the favorable tract for porphyry copper-gold deposits in the Lares-Adjuntas areas, Puerto Rico*

Tv, Tertiary volcanic and sedimentary rocks; Ti, Tertiary porphyritic intrusive rocks; Kv, Cretaceous volcanic rocks; Ki, Cretaceous plutonic rocks of Utuado batholith; TKd, Tertiary and Cretaceous diorite intrusions. Stream sediment geochemical values in parts per million; Cu, copper; Zn, zinc; Au, gold; Ag, silver; Fe, iron; Mo, molybdenum; Mn, manganese. Cp, chalcopyrite; py, pyrite;mt, magnetite; ND indicates no data. *p*[D] is the probability of an undiscovered deposits.

Map no.	Name	Geology	Aeromagnetic anomalies	Mineral occurrences	Stream sediment geochem-istry	*p*[D]
1	Magos	Tv, poorly exposed	5 highs, 500-1000 m diam. suggest igneous intrusions	None known	ND	0.01
2	Piletas	Covered by Lares Lms. Located on Tanama-Laundry Cr. trend	4 highs 500-1000 m diam. similar to pattern over known deposits	None known	ND	0.50
3	Lares East	Tv, poorly exposed	High	None known	ND	0.01
4	Laundry Creek	Ti stock, potassic alteration in small area	Complex pattern of high and low anomalies	Cp in quartz stockwork. Indicated 5 to 10 million tonnes at >0.4 percent Cu	Cu >1,000; Au, 0.006-0.01; plus Mo, Zn, Pb, Ag, and Mn	0.1
5	Matilde	Ti stock, no alteration, poorly exposed	Broad high	None known	Cu, 70-300; Zn,300-500	0.05
6	Platanos	Tv, plus small intrusives in a broad area of propyllitic and phyllic alteration. Two prominent unaltered Ti stocks.	Broad low, 1.5 x 6 km. West part correlates with alteration. Highs correlate with Ti stocks	Cp in small veins	Cu, 300-1,000; Zn,100-300; Mo down-stream	0.3
7	Copper Creek	Kv, Ti stock, potassic alteration	Small high	Quartz-mt stockwork, Cu stains. Ore-grade Cu in one drill hole	Cu >1,000; Au, .006-.01	0.1
8	Río Piedras	Mainly Tv, poor exposures	High	None known	Cu 70-300	0.01
9	Crimin-ales East	Mainly Kv, small Ti bodies. Extensive breccia, 0.6 x 1.5 km. Phyllic alteration	Broad low, 1.5 x 2 km in area that interupts a trend of highs.	Up to 0.34 percent Cu in outcrop	Cu 300-1000; Zn 300-500; Au, .006-.01; Mn >2500	0.6

10	Copper Creek Southeast	Ti stock, local potassic alteration	South flank of arcuate high	None known	Cu, 300-1,000	0.1
11	Tanamá	Ti stock intruding Kv, potassic alteration on north side, phyllic and argillic to south	Strong high	Known porphyry copper-gold deposit	Cu, 300-1,000 on northeast, weak Zn	0.00
12	Helecho	Ti stock, potassic alteration, surrounded by Tv with phyllic and argillic alteration	Isolated high surrounded by lows	Known porphyry copper-gold deposit, Reserves not published	Cu, 70-300; Mn >2,500 weak Zn	0.95
13	Cerro La Mira	Ti, poorly exposed	high	none known	Cu, 70-300; Zn 100-300	0.05
14	Helecho East	no exposures	high	none known	weak	0.01
15	Portillo West	Tv, poorly exposed	Small high, surrounded on west by lows	none known	ND	0.01
16	Guayabo Dulce	Tv, alteration	No significant character	none known	Cu, 70-300	0.01
17	Palo Seco	Ti, poorly exposed	high	none known	weak	0.01
18	Upper Tanamá	Tv, poorly exposed	No significant character	none known	Cu, 300-1,000; Mn >2,500	0.2
19	Cerro Lloroso	Ti stock	high	none known	Cu 70-300	0.01
20	Río Arecibo	Large, complex Ti porphyry stock	high	Cp and py in veins	Cu, 70-300; Au, .006-.01; Mn >2,500 plus Zn, Ag	0.2
21	Pellejas	Ti, Kv, and Tv	Isolated high on south side	Cp and py in veins	Cu 300-1,000; Mn >2,500	0.2
22	Río Viví	Ti stocks intruding Kv and Tv. Widespread alteration	Elongate high on south side	Known porphyry copper-gold deposit	Cu, 300-1,000 on south side	0.00
23	El Blanco	Small Ti stock	high	Cu stains	weak	0.01
24	Jauca	Small Ti stocks	highs	Fe skarn	Au, .006-.01; weak Cu	0.05

Table 2



66° 37' 30" W
18° 15' N
2
Laundry Creek
4
Lares
1
3
5
6
7
8
9
Tanamá
10
11
12
13
14
15
16
17
18
19
Utuado
20
21
Río Viví
22
23
24
Adjuntas
Target area and number
6
Quaternary alluvium
Upper Tertiary sedimentary rocks
Lower Tertiary and Cretaceous volcanic and sedimentary rocks
Tertiary porphyry
Cretaceous batholith
Cretaceous metavolcanic rocks
0
Scale
5 km

Table 1. Estimates of undiscovered mineral deposits at specified probability levels, for Puerto Rico.

MARK3 INPUT

Model number	Model	Known mineral deposits	Known occurrences	Probability .90	.50	.10	.05	.01	Level of prospecting
17	Porphyry Cu	2	8						
18B	Copper skarn	2	10	1	4	8	-	-	Low
18D	Fe skarn	1	16	0	0	1	2	3	Mod/High
20C	Porphyry Cu-Au	5	2	2	3	5	8	10	High?
22C	Polymetallic veins	2	59	1	4	15	-	-	Moderate
24C	Volcanogenic manganese	3	11	1	3	8	-	-	Moderate
25E	Epithermal Qtz-Alu Au (low grade)	2	3	1	2	4	-	-	Low
28A	Kuroko massive sulfide	0	0	0	0	1	-	-	Very low
39A	Placer Au-PGE	Historic placer sites	3	0	0	-	-	1	Very high

Table 2. Expected mean number of undiscovered deposits and the mean of metal (in thousands of metric tons) calculated to be in undiscovered deposits in Puerto Rico. [These numbers represent one run of the Mark3 simulator. Numbers shown here may be interpreted only as representative of the magnitude of metal content, for each time the Mark3 simulator is executed, different, but very similar results will be obtained. PGE-platinum group elements; --indicates no value.]

Deposit type	Mean no. of deposits	Copper	Molybdenum	Gold	Iron	Zinc	Silver	Lead	Manganese	Tonnage
Copper skarn	4.2	240	--	0.004	--	--	0.034	--	--	18,000
Iron skarn	0.4	--	--	--	18,000	--	-	--	--	38,000
Porphyry Cu-Au	3.4	3,200	21.1	0.25	--	--	0.920	--	--	610,000
Polymetallic veins	6.4	0.7	--	0.002	--	38	0.650	53.0	--	730
Volcanogenic manganese	3.8	--	--	--	0.055	--	--	--	44.0	120
Epithermal Quartz-Alunite veins	2.3	66.0	--	0.08	--	--	0.430	--	--	10,000
Kuroko-type massive sulfide	0.3	3.4	--	0.0004	--	7.1	0.023	1.6	--	190
Placer Au-PGE	0.03	--	--	--	--	--	--	--	--	6
TOTAL		3,500	21.1	0.34	18,000	45.0	2.1	55	44.0	680,000

TABLE 3. Summary probability estimates of metallic resources in selected types of undiscovered mineral deposits of Puerto Rico. (Results are reported in metric tons, rounded.)

	PERCENTILE VALUES			MEAN VALUES
Commodities	**90th**	**50th**	**10th**	
Copper	660,000	2,600,000	7,600,000	3,500,000
Molybdenum	0	9,000	62,000	21,000
Gold	85	270	690	340
Iron	0	10	6,800,000	18,000,000
Zinc	24	12,900	142,000	45,000
Silver	400	1,500	4,400	2,100
Lead	230	22,000	145,000	55,000
Manganese	6	5,900	157,000	44,000
Tonnage	134,000,000	504,000,000	1,460,000,000	680,000,000

MARK3 FLOW CHART

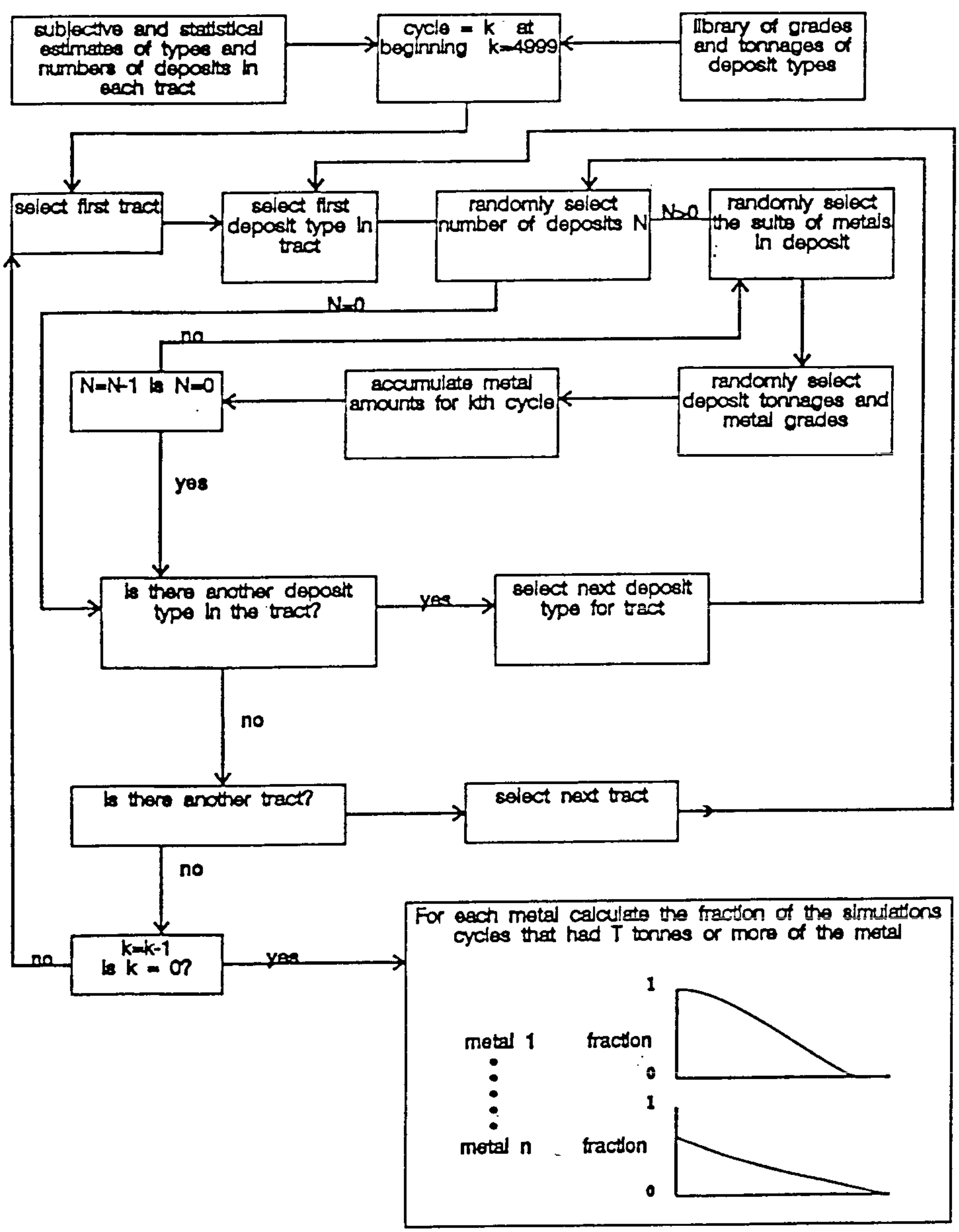


Figure 1. Mark3 flow chart of data used in calculating the contained metals in undiscovered deposits in Puerto Rico.

Figure 1: Side-looking airborne radar (SLAR) mosaic of Puerto Rico. Scale: 1:200,000; Projection: Polyconic.

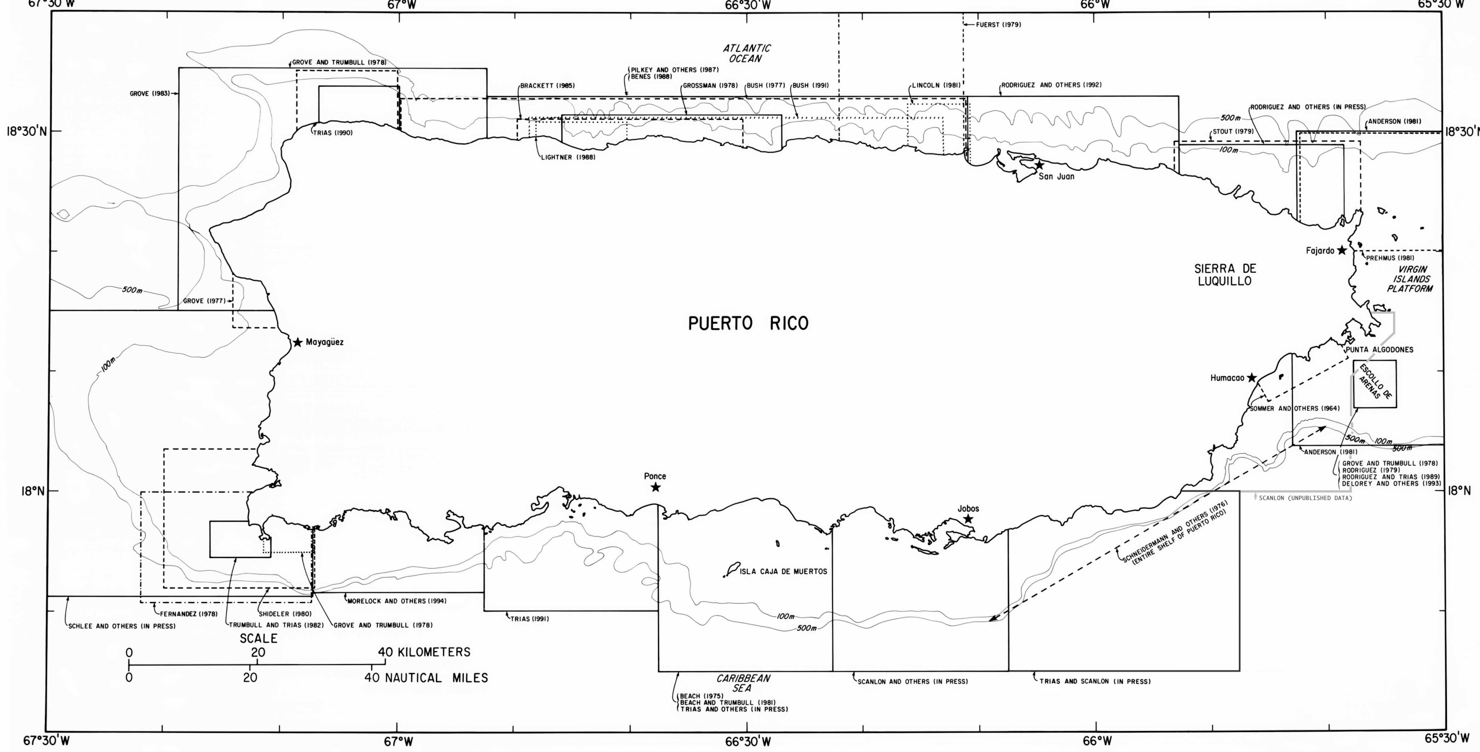


Figure 1. Index map showing sources of data used to compile the generalized map of surficial sediments.

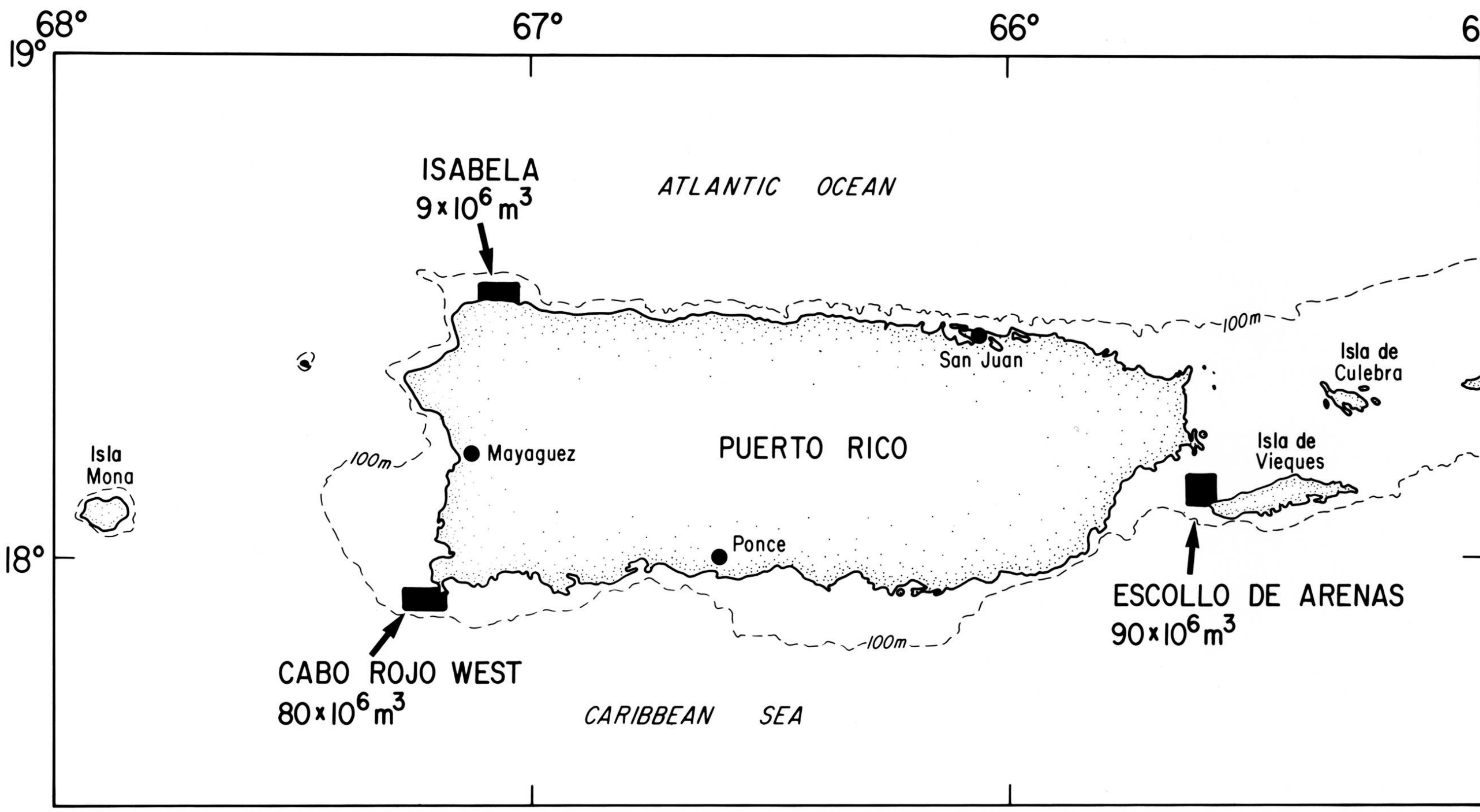


Figure 2. Map showing estimated sand volumes of the three offshore sand deposits discussed in this report. Volumes are from Trumbull and Trias (1982), Rodriguez and Trias (1989), Trias (1990), and Delorey and others (1993).

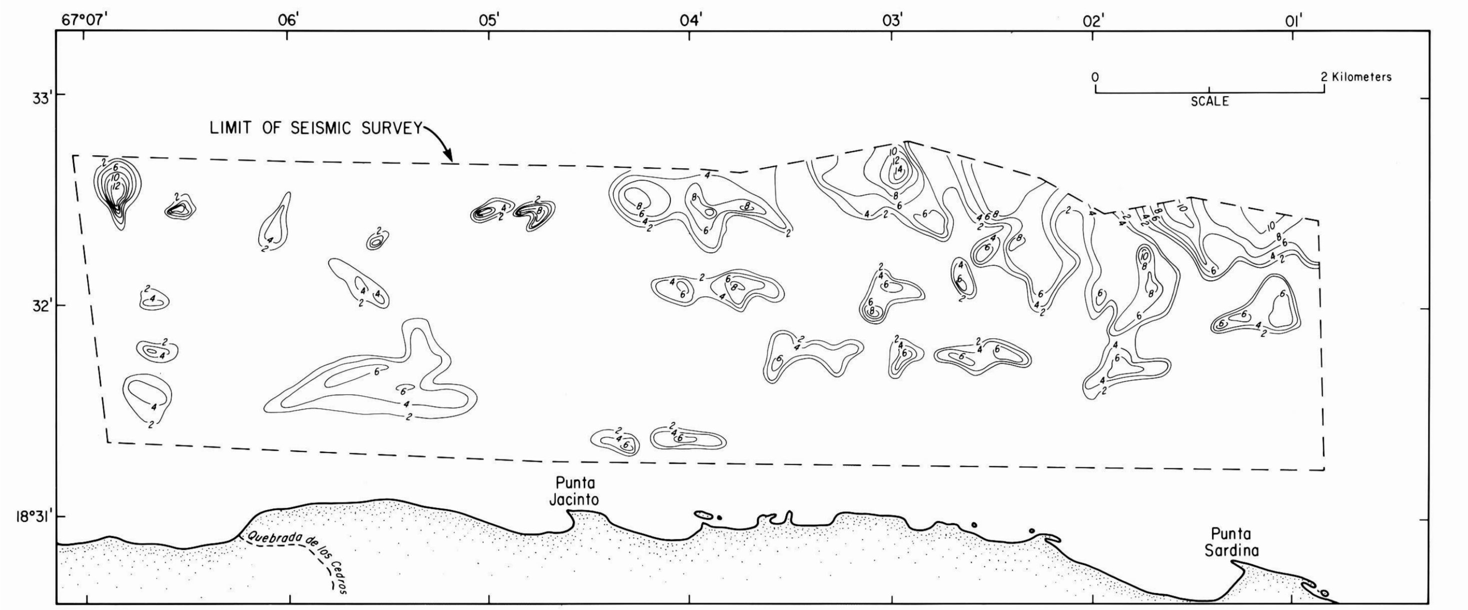


Figure 3. Isopach map of Isabela sand deposit (after Trias,1990). Thickness shown in feet. Contour interval is 2 feet. One foot equals .3048 meters.

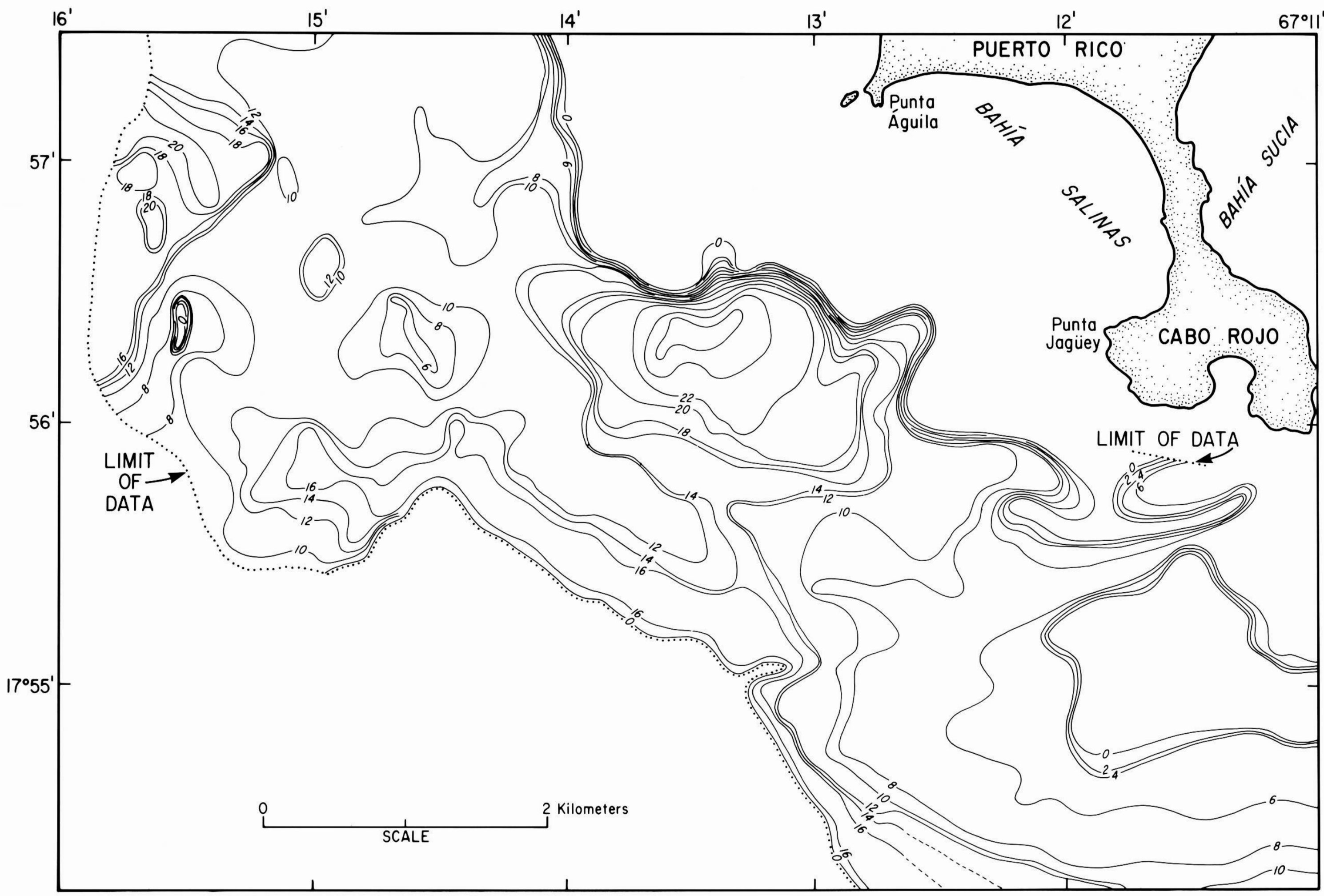


Figure 4. Isopach map of Cabo Rojo West sand deposit (after Trumbull and Trias, 1982). Thickness is shown in feet. Contour interval is 2 feet. One foot equals .3048 meters.

Figure 5. Aerial photograph of Escollo de Arenas. The Escolo trends about N. 40° W. from the northwest tip of Vieques Island. Image is approximately 4 km across.

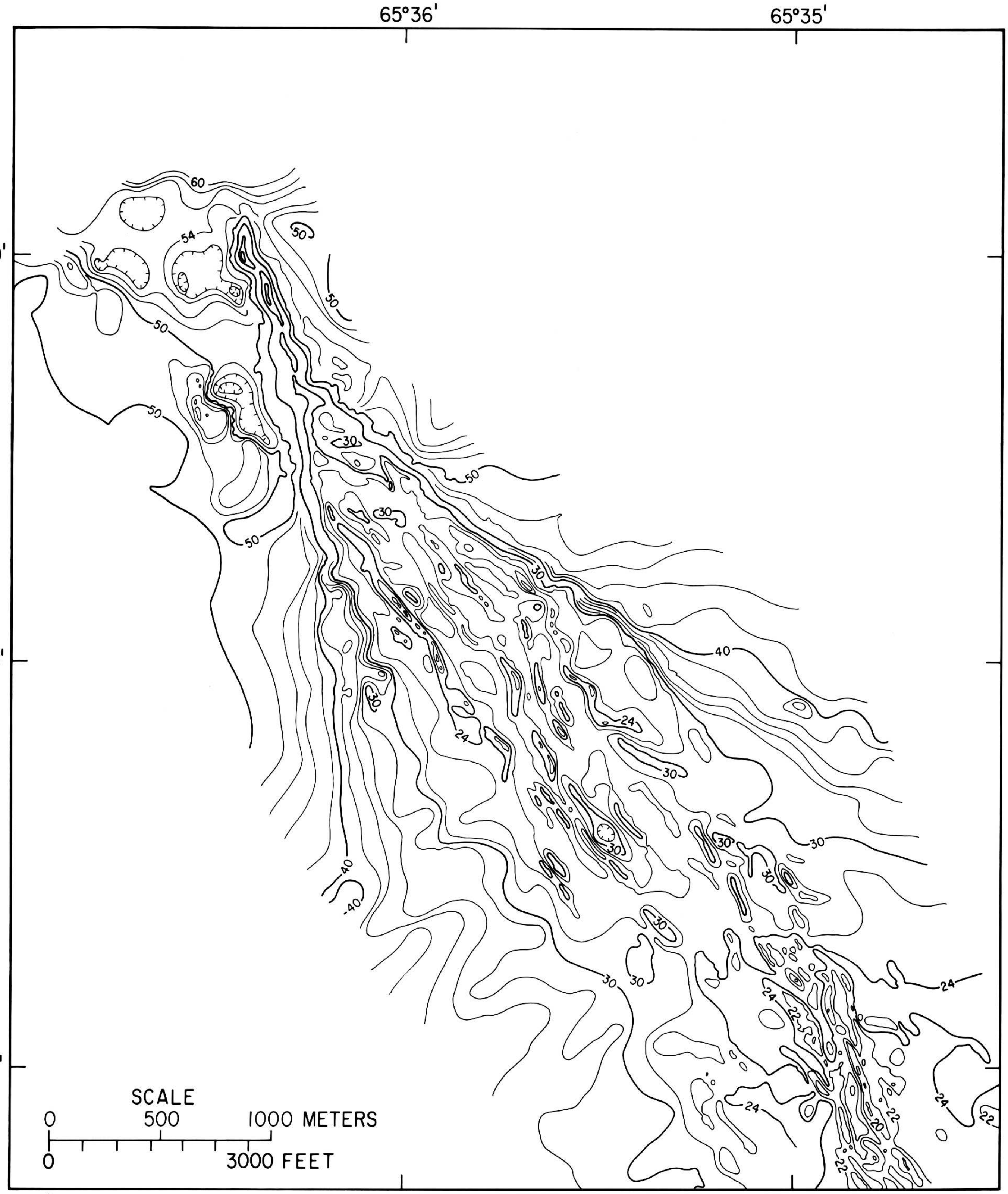


Figure 6. Bathymetric map of Escollo de Arenas before Hurricane Hugo (after Rodriguez and Trias, 1989). Contour interval is 2 ft. One foot equals .3048 meters. Hachures indicate closed low.

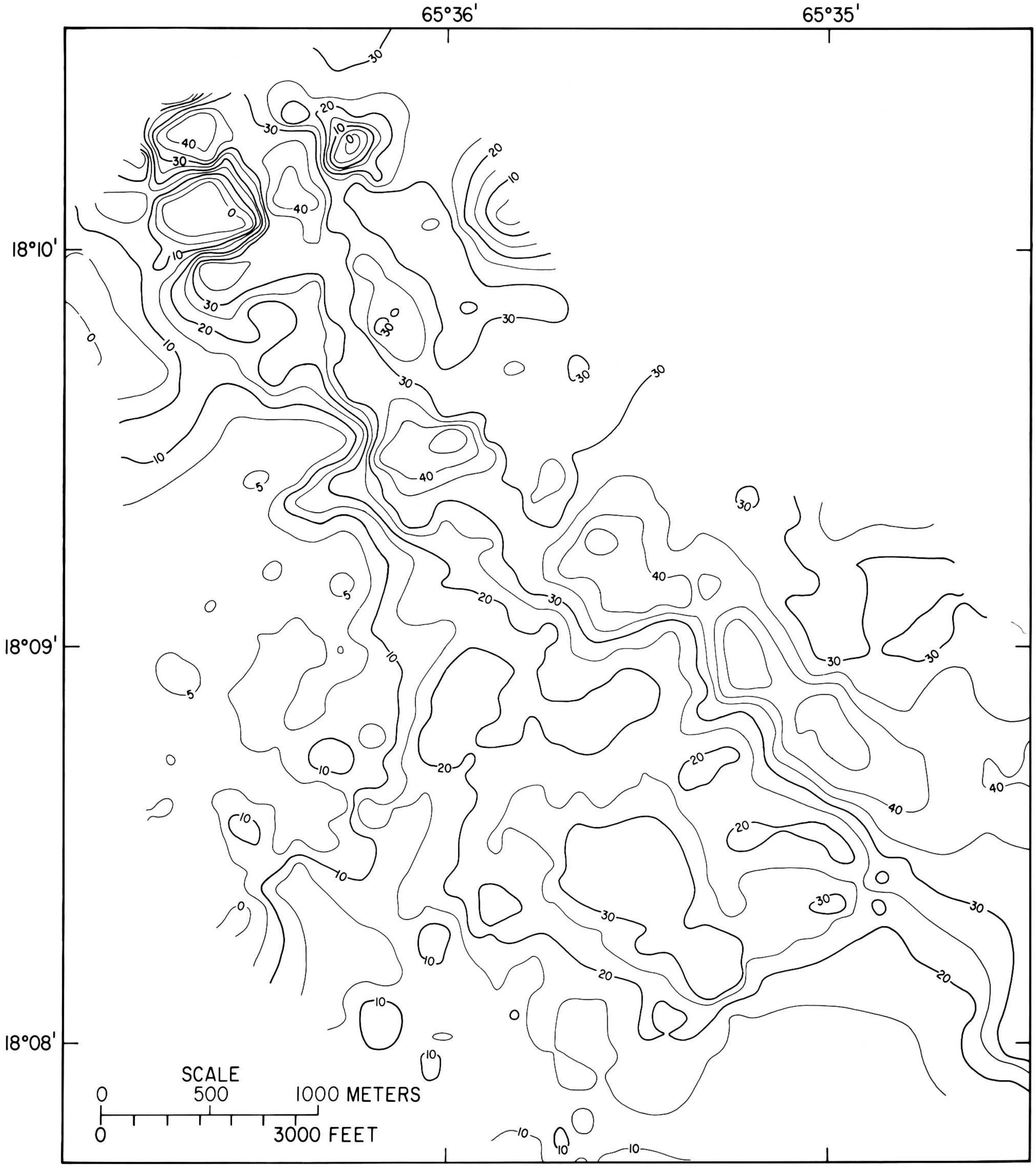
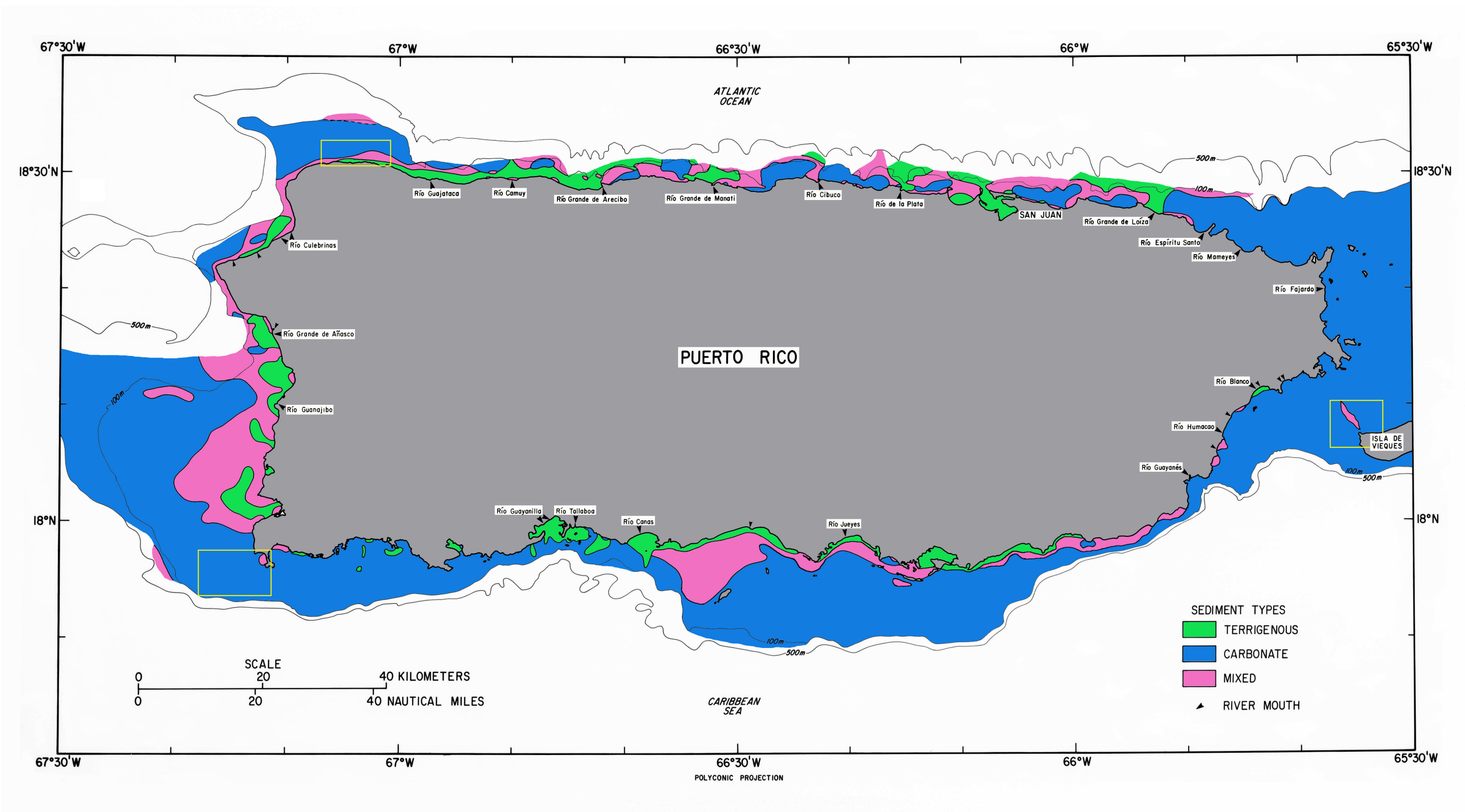


Figure 7. Isopach map of Escollo de Arenas sand deposit after Hurricane Hugo (after Delorey and others, 1993). Thickness is shown in feet. Contour interval is 5 ft. One foot equals .3048 meters.



Map 1. Generalized map of surficial sediments of the insular shelf of Puerto Rico.

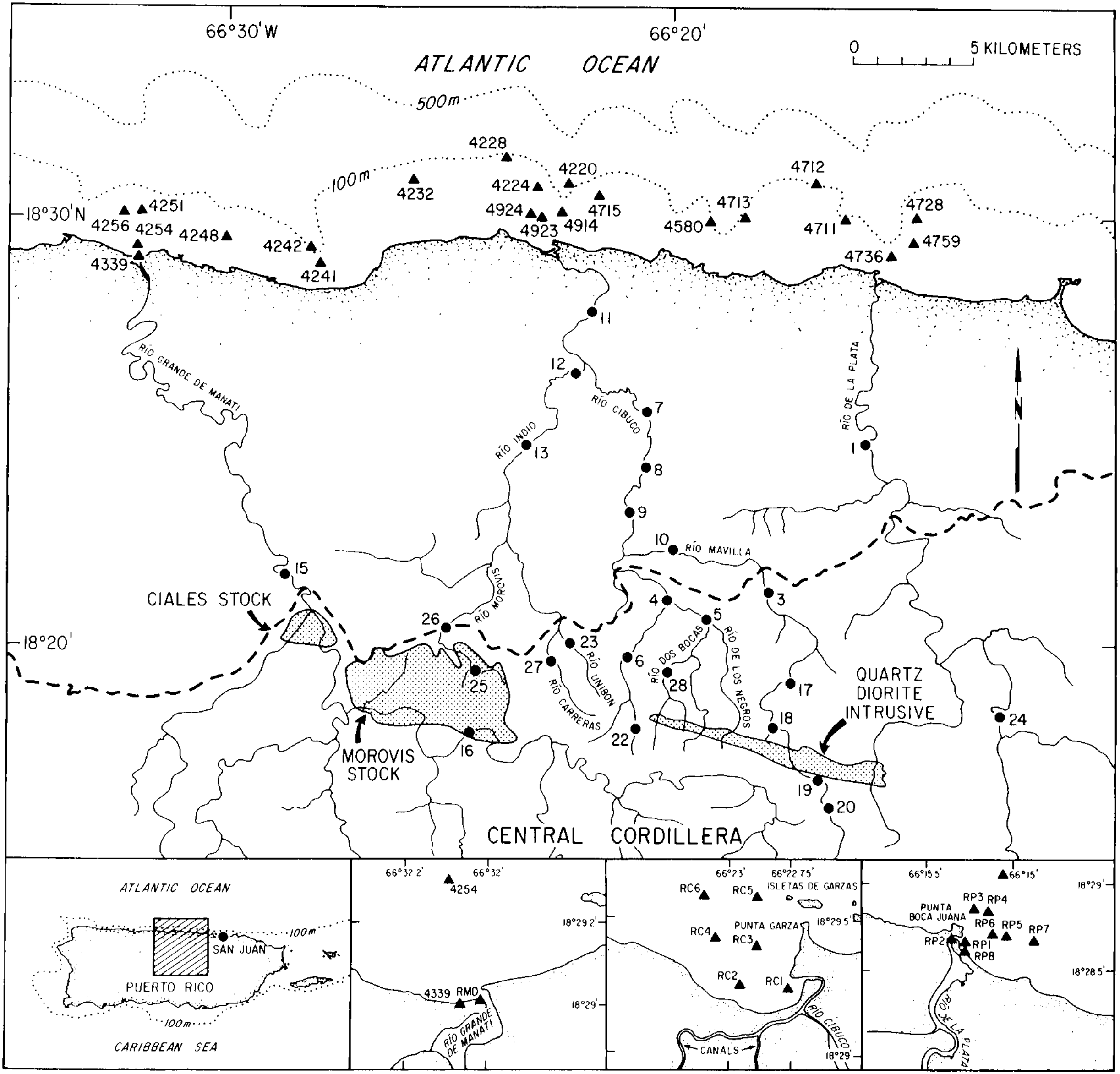


Fig. 1. Map showing the locations of river (dots) and shelf (triangles) samples from north-central Puerto Rico. The dashed line separates rocks of the volcanic-plutonic terrane (south) from the limestone terrane (north). Major intrusives (the Ciales and Morovis granodiorite stocks and a hornblende-rich quartz diorite to the east) are shown as stippled areas. Insets show the locations of the study area on the Island of Puerto Rico and the sample sites on the inner shelf near the river mouths.

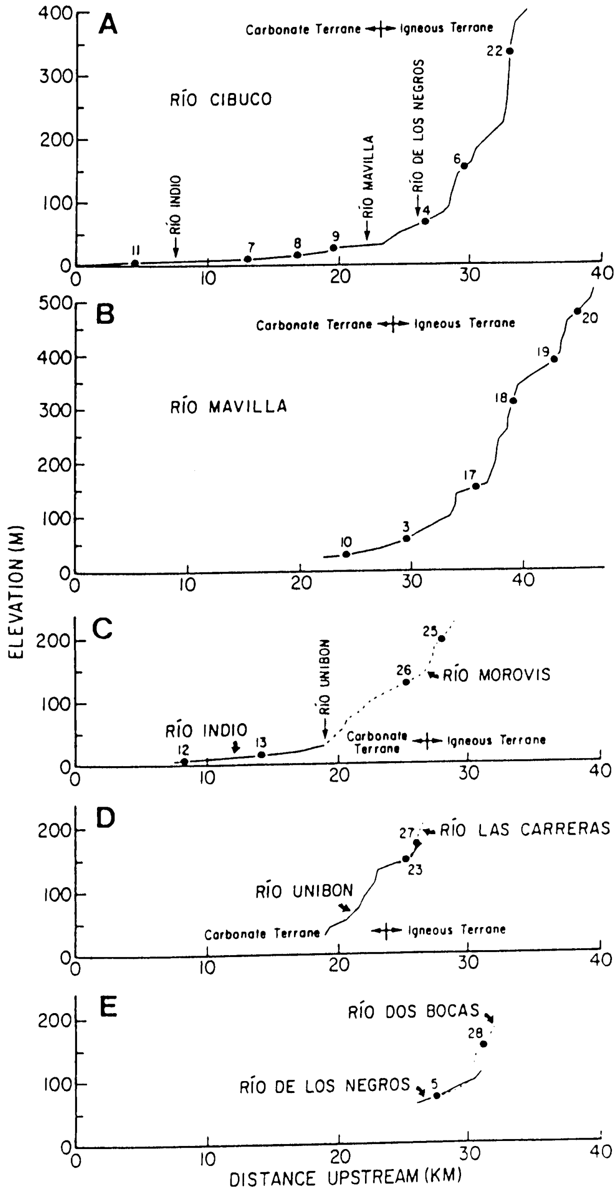
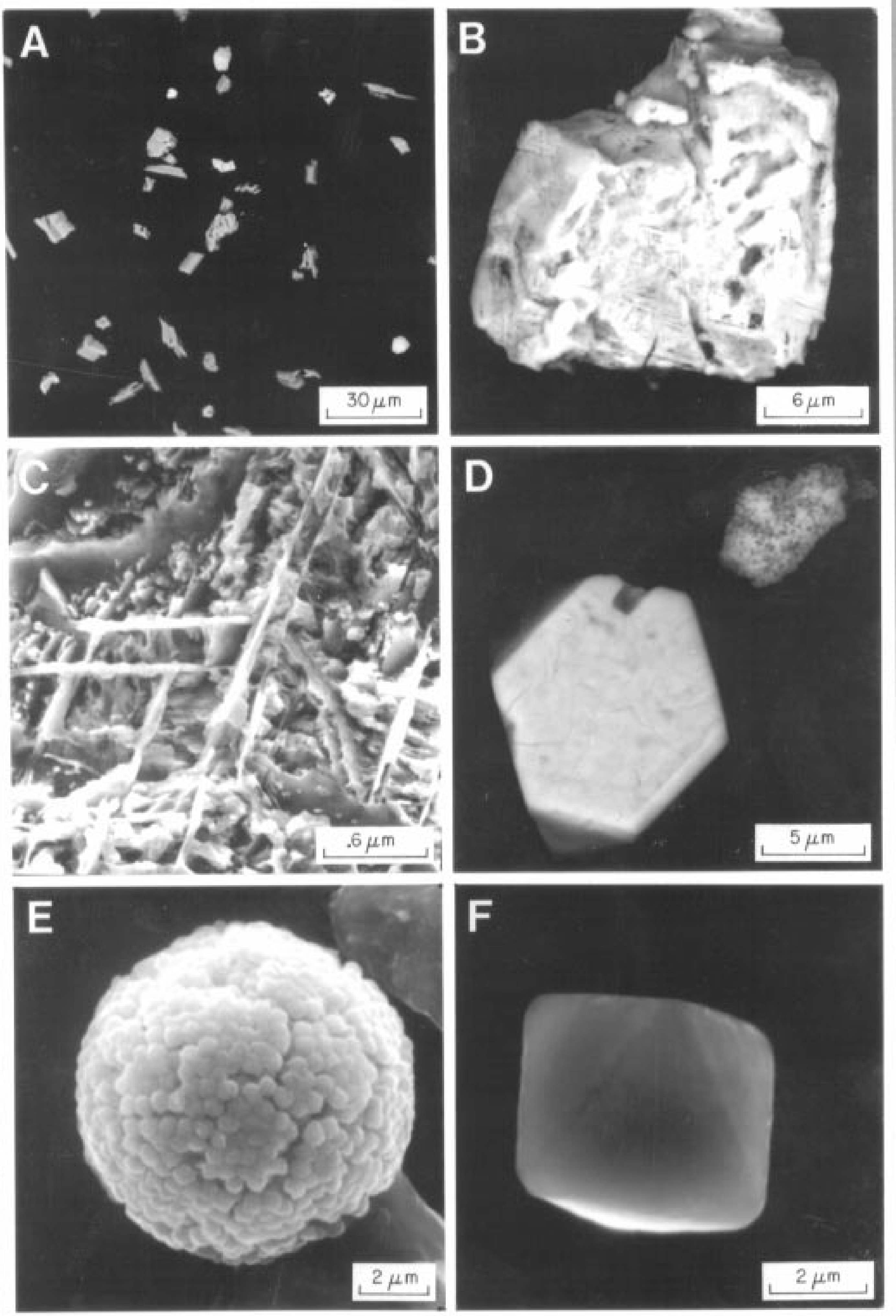


Figure 2. Cross sections of the river gradients from the Rio Cibuco and its tributaries showing the locations of samples used during this study. Distance upstream is measured from the north coast of Puerto Rico.



A
30 μm
B
6 μm
C
.6 μm
D
5 μm
E
2 μm
F
2 μm

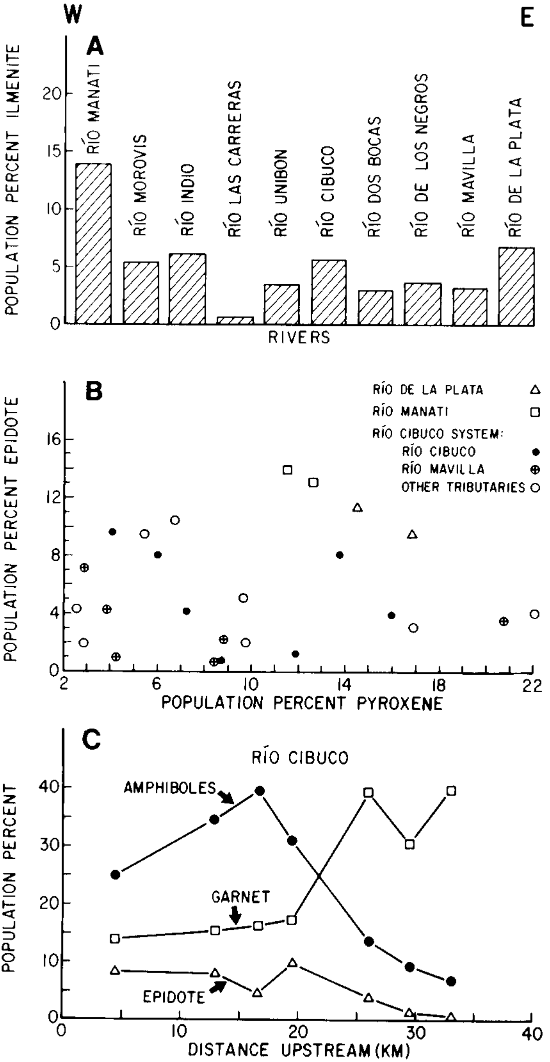
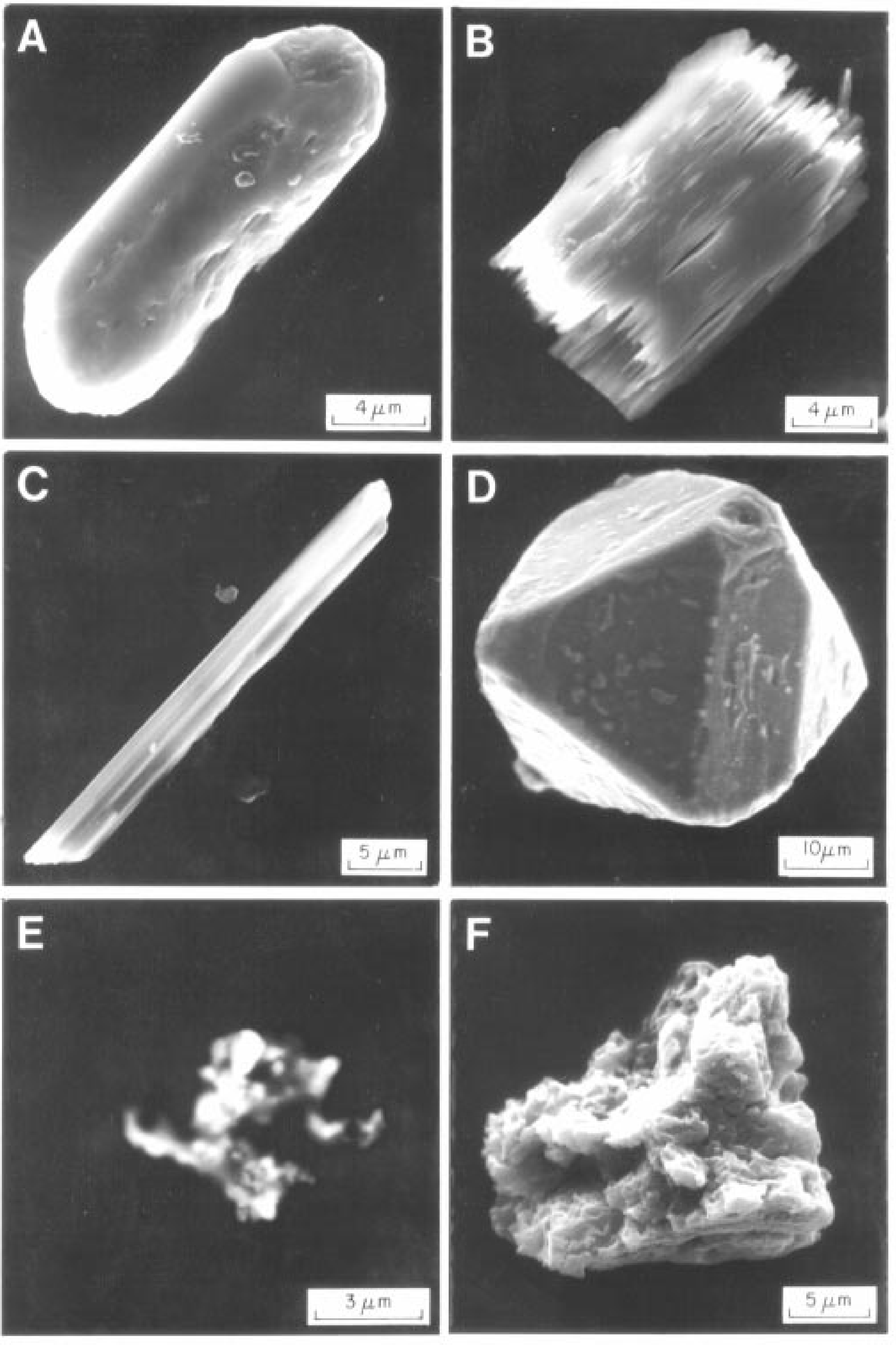


Fig. 3. Mineral variation in the silt fraction of sediments from rivers in north-central Puerto Rico. (A) Histograms showing the abundance of ilmenite. Data from rivers with more than one sample have been averaged. (B) Plot of epidote versus pyroxene group minerals. (C) Plot showing the variation in garnet, amphiboles, and epidote abundances along the Rio Cibuco in distance from the river mouth.


A
4 µm
B
4 µm
C
5 µm
D
10µm
E
3 µm
F
5 µm

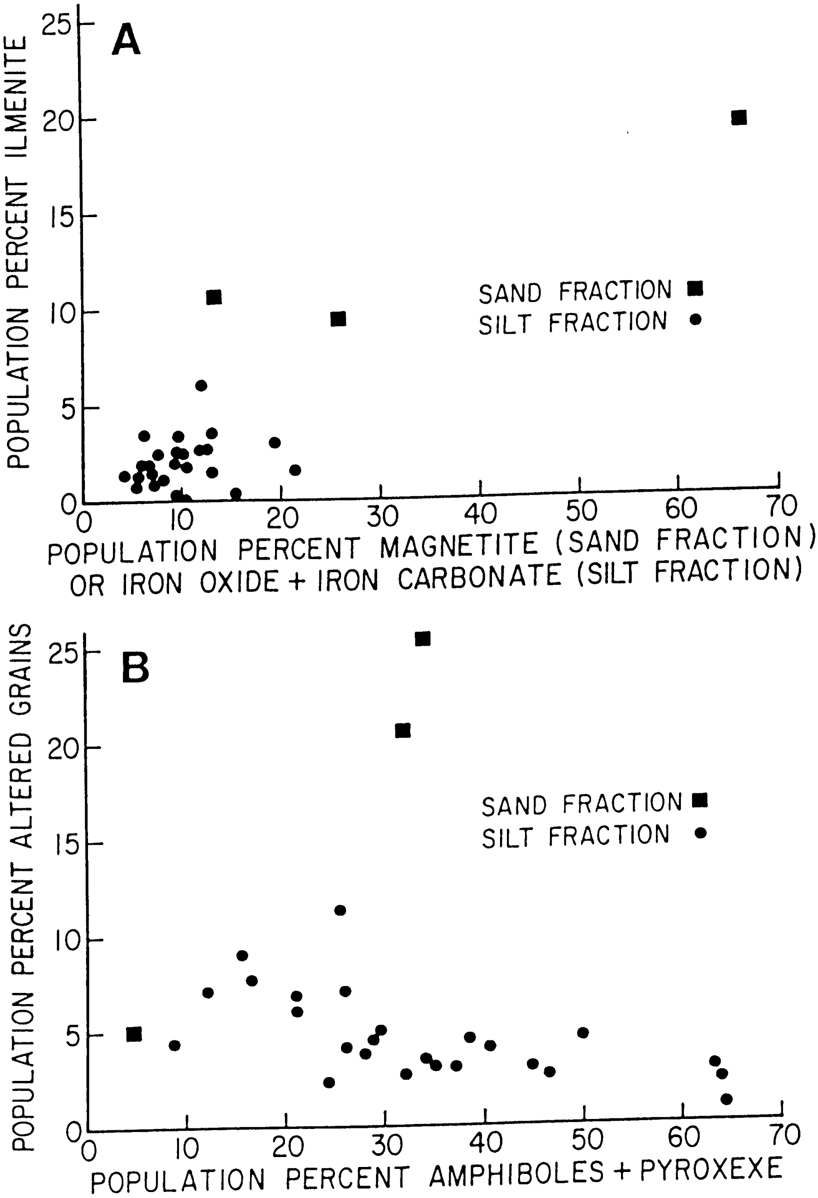
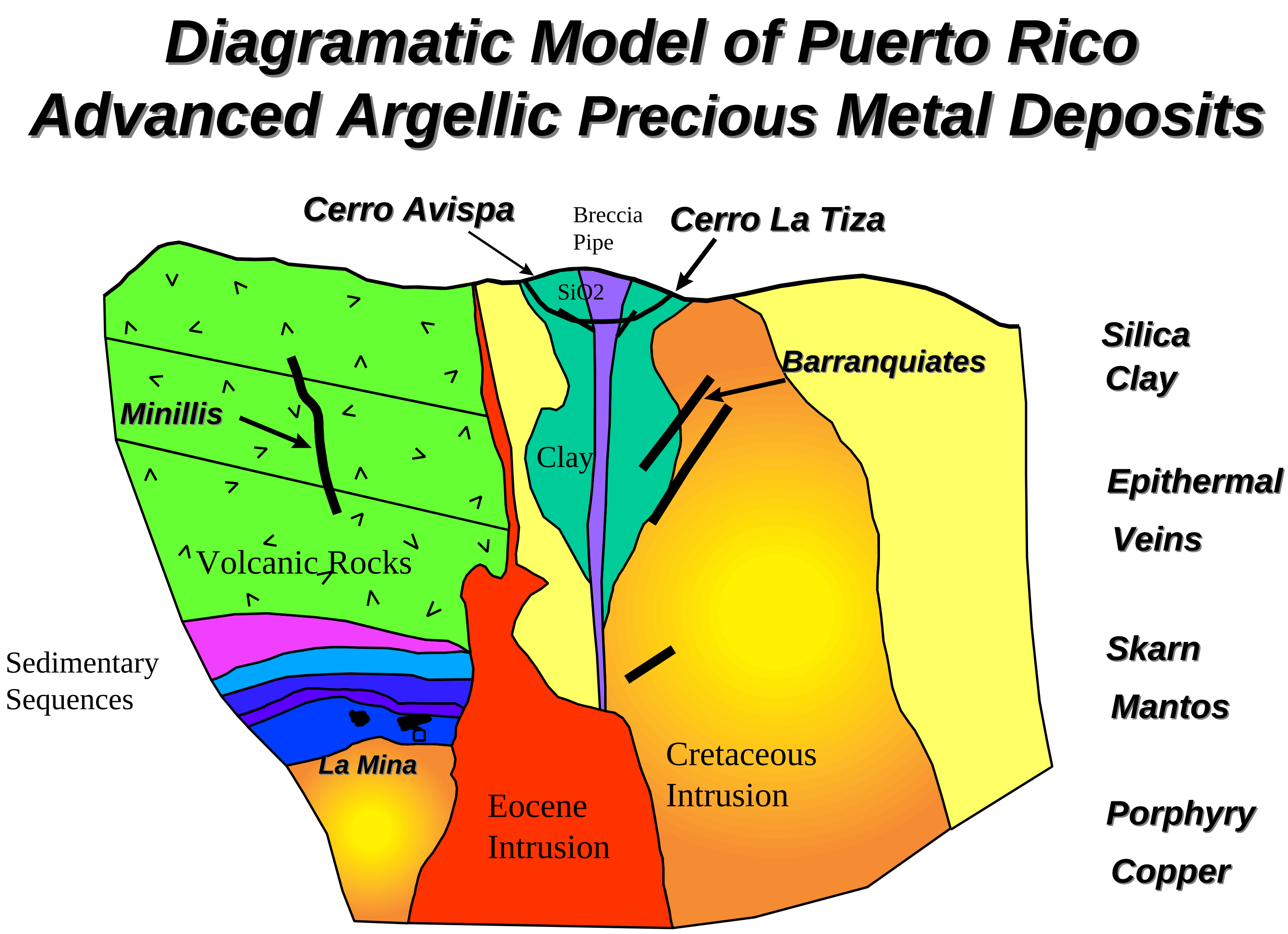


Figure 6. Heavy-mineral variation between the silt and sand fractions. (A) Histogram shows the generally greater occurrences of cerargyrite, chromite, gold, and garnet in the heavy-mineral silt fraction and zircon in the heavy-mineral sand fraction. (B) Plot showing the generally higher concentrations of altered grains and rock fragments in the sand heavy-mineral fraction.



Diagramatic model of advanced argillic precious metal deposits of Puerto Rico, including the relative position of porphyry copper/gold, skarns,/mantos, and epithermal vein gold deposits. Known deposit types of Puerto Rico are shown in bold print.

Information, pertaining to 1 degree blocks, shown in brown, refers to the "Index to topographic and other Map coverage." See "Catalog of topographic and other Published Maps" for available maps and map order forms.

SCALE 1:500,000

PUERTO RICO AND VIRGIN ISLANDS
7.5-MINUTE QUADRANGLES

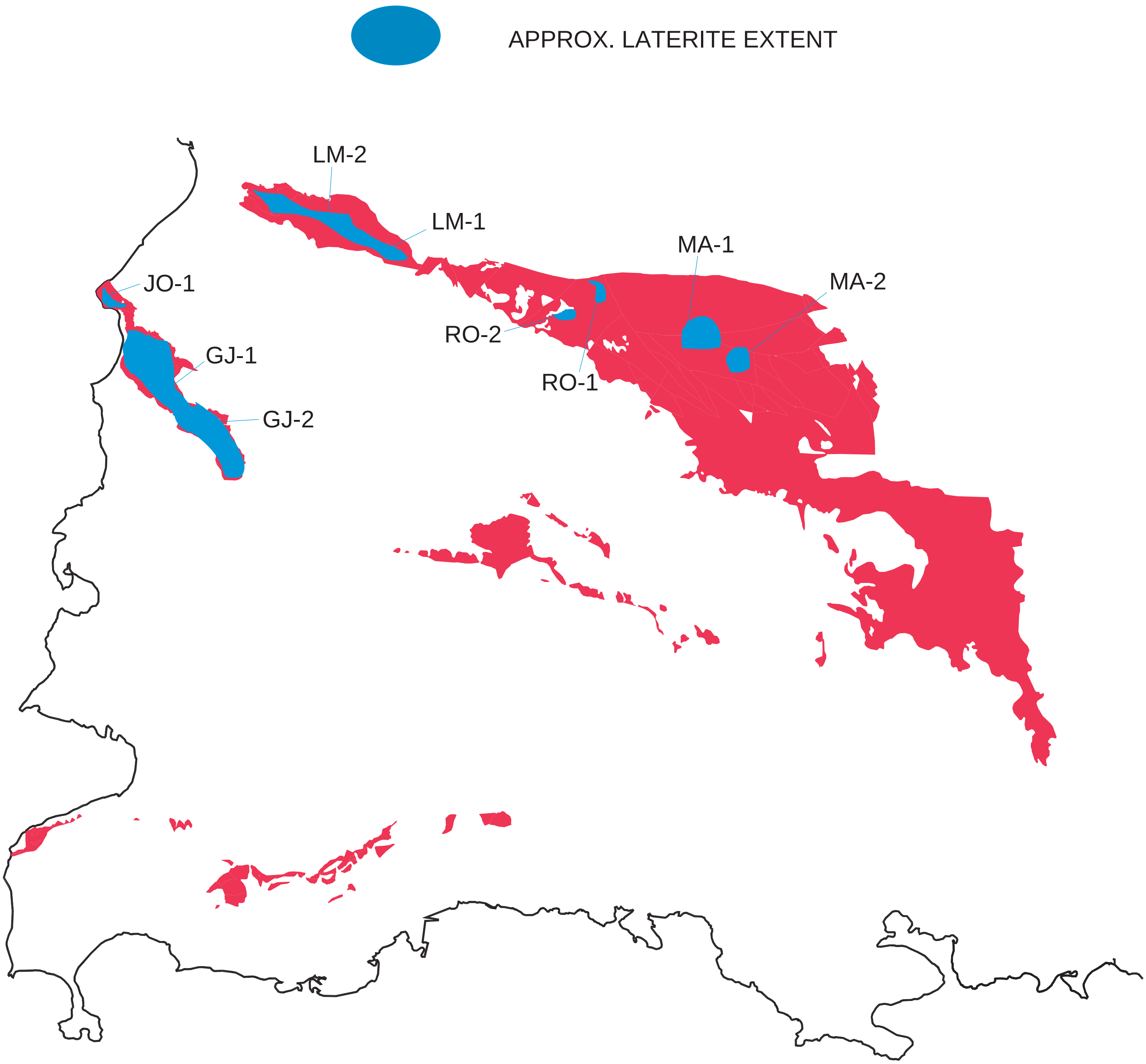
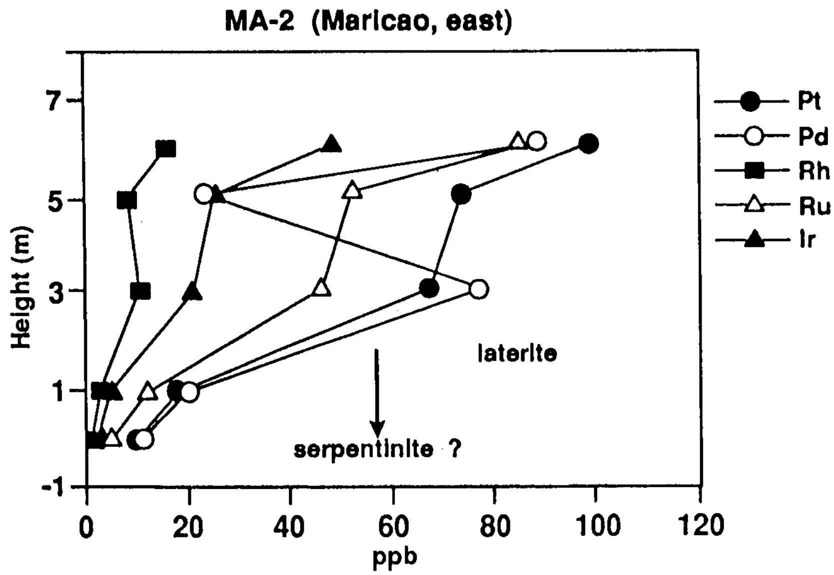
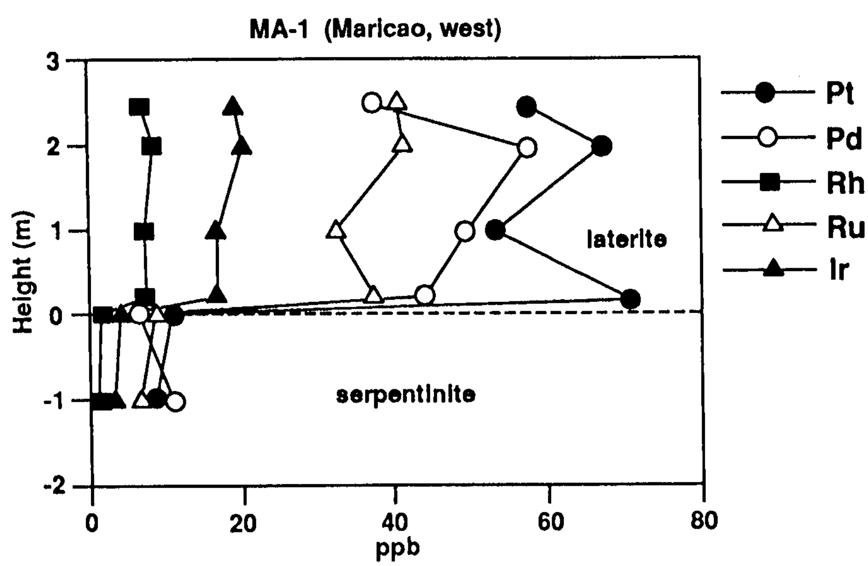
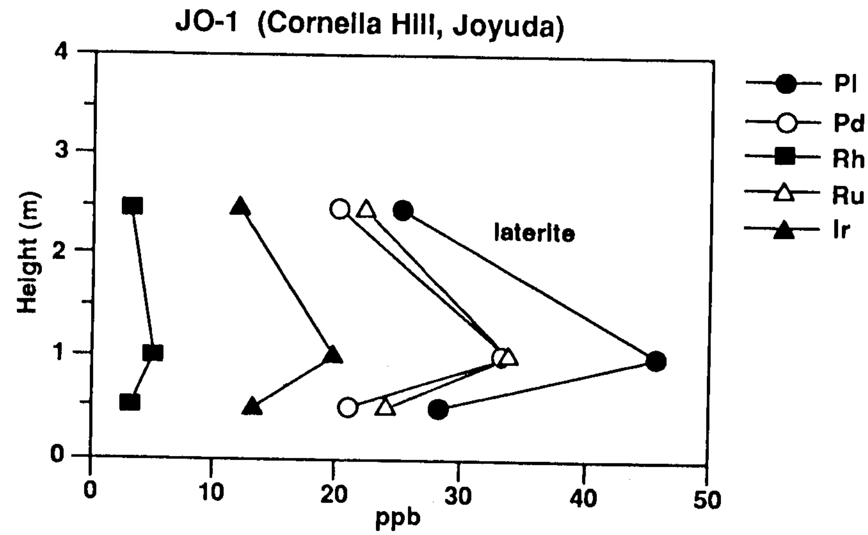


Figure Caption

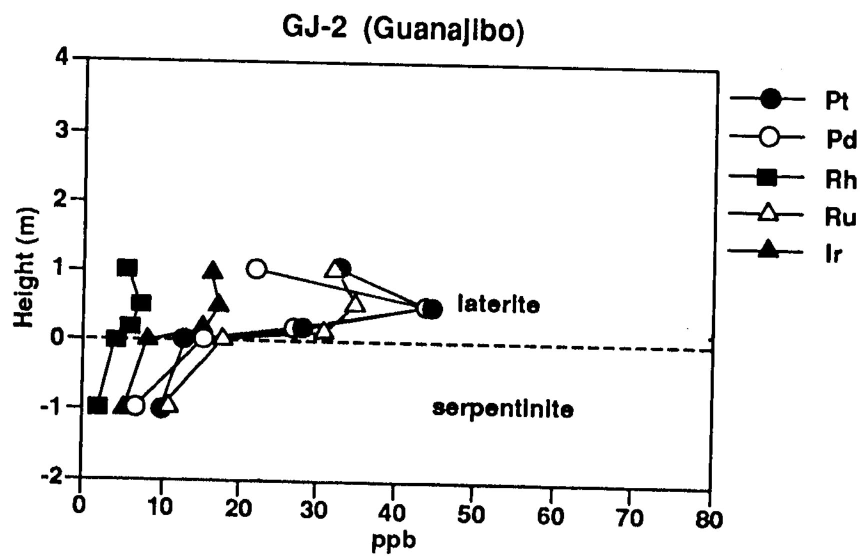
Figure 1. Ultramafic rocks of western Puerto Rico showing the extent of serpentinite and the outlines of overlying laterite and the locations of samples analyzed for this study. For each chart, the vertical axis shows distance from the laterite-serpentinite contact and the horizontal axis is concentration of PGE.


MA-2 (Maricao, east)
Height (m)
ppb
laterite
serpentinite ?
Pt
Pd
Rh
Ru
Ir
7
5
3
1
-1
0
20
40
60
80
100
120

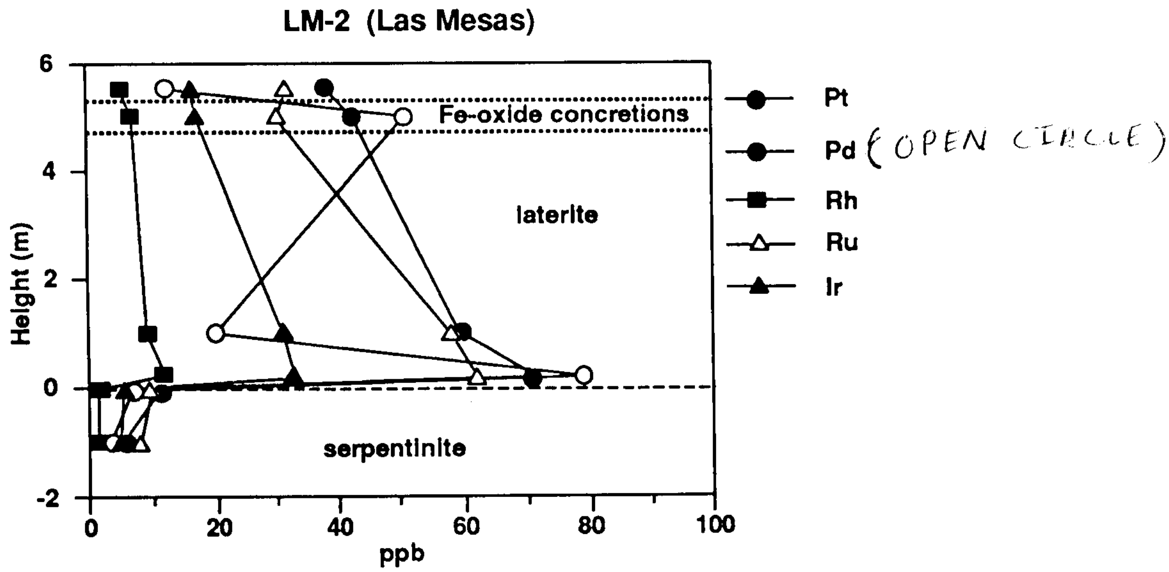

MA-1 (Maricao, west)
Height (m)
ppb
laterite
serpentinite
Pt
Pd
Rh
Ru
Ir
3
2
1
0
-1
-2
0
20
40
60
80

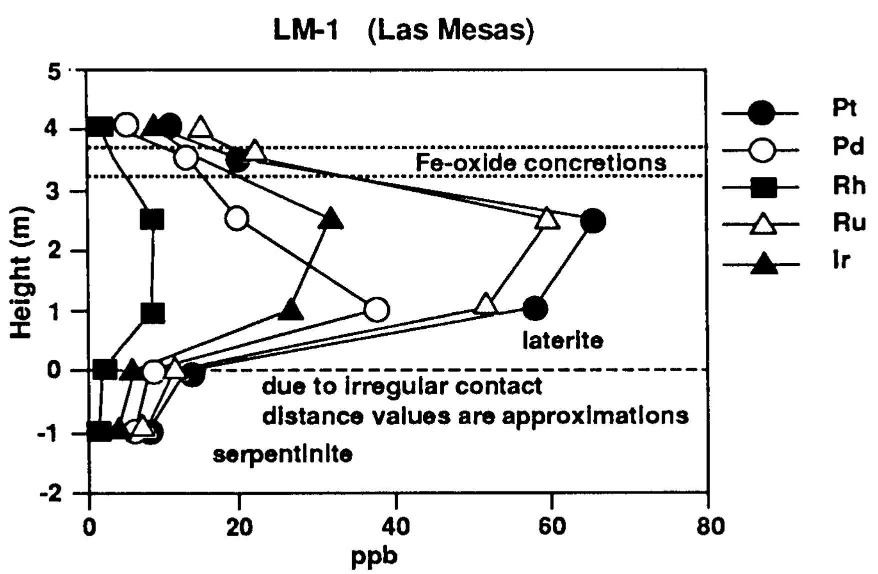


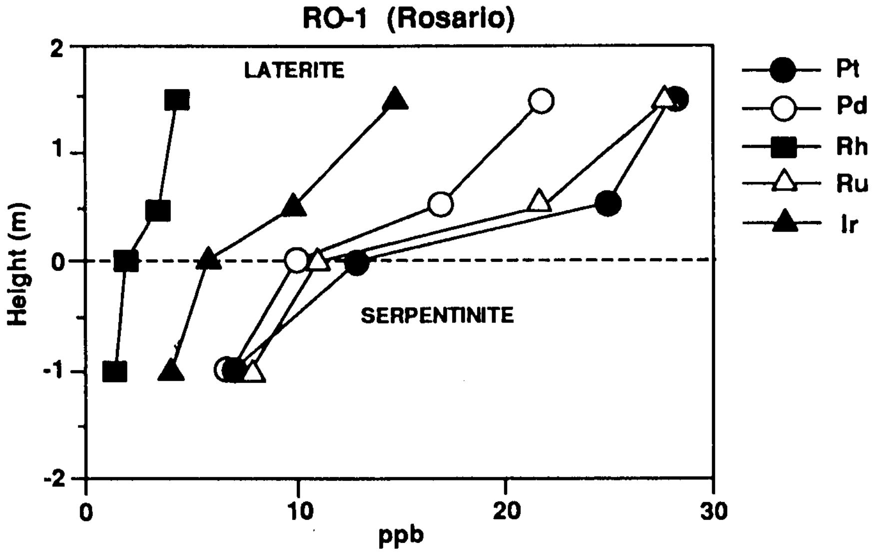
JO-1 (Cornelia Hill, Joyuda)
Height (m)
ppb
laterite
Pt
Pd
Rh
Ru
Ir



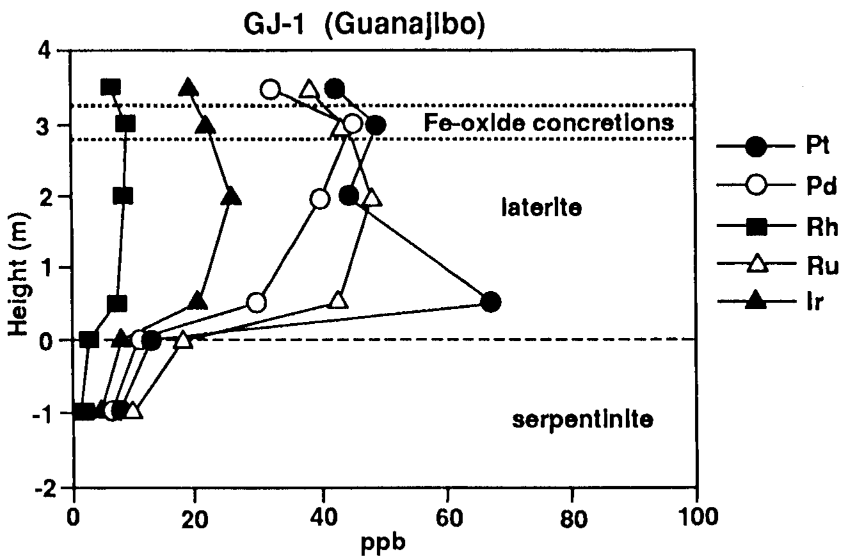
GJ-2 (Guanajibo)
Height (m)
ppb
laterite
serpentinite
Pt
Pd
Rh
Ru
Ir


LM-2 (Las Mesas)
Height (m)
ppb
Fe-oxide concretions
laterite
serpentinite
Pt
Pd (OPEN CIRCLE)
Rh
Ru
Ir


LM-1 (Las Mesas)
Height (m)
ppb
Fe-oxide concretions
laterite
due to irregular contact
distance values are approximations
serpentinite
Pt
Pd
Rh
Ru
Ir



RO-1 (Rosario)
LATERITE
SERPENTINITE
Height (m)
ppb
2
1
0
-1
-2
0
10
20
30
Pt
Pd
Rh
Ru
Ir



GJ-1 (Guanajibo)
Fe-oxide concretions
laterite
serpentinite
Height (m)
ppb
4
3
2
1
0
-1
-2
0
20
40
60
80
100
Pt
Pd
Rh
Ru
Ir

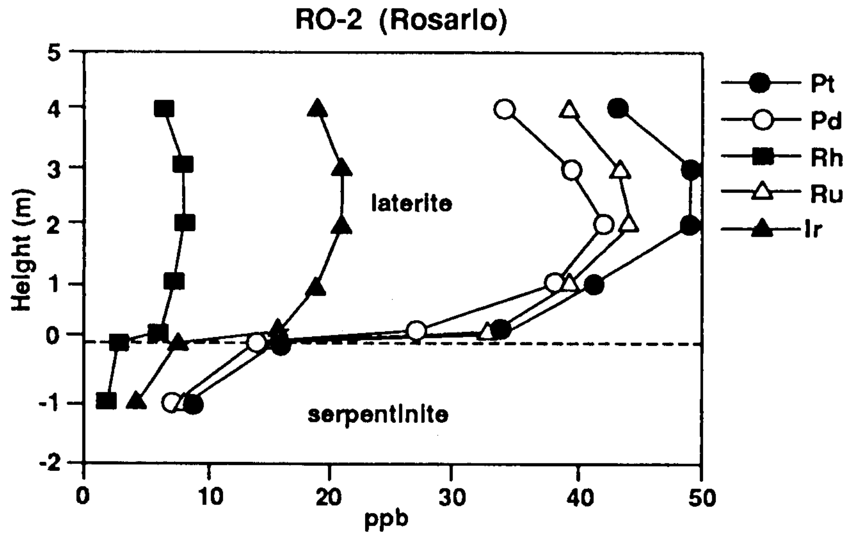

RO-2 (Rosario)
Height (m)
ppb
laterite
serpentinite
Pt
Pd
Rh
Ru
Ir
5
4
3
2
1
0
-1
-2
0
10
20
30
40
50

Table 1.--Summary of Ni-laterite resources (based on cutoff of 0.6 percent Ni)

Deposit	Average thickness, meters	Inferred resources, short dry tons	Metal content, percent			
			Ni	Co	Fe	Cr
Guanajibo	4.8	46,800,000	0.88	0.08	20.54	0.51
Punta Guanajibo	3.2	2,100,000	1.03	.07	19.03	.63
Las Mesas	5.6	25,000,000	.81	.12	28.39	.75
Rosario SE group						
North deposit	6.8	4,800,000	.85	.07	20.76	.58
South deposit	4.7	1,100,000	.71	.06	12.47	.34
Maricao SW group						
West deposit	7.6	5,000,000	.98	.10	22.05	.59
East depost	15.5	5,600,000	1.08	.11	29.45	.67
Total and average	5.9	90,500,000	.88	.09	23.20	.59

Table 2. PGE analyses (in ppb) of nickel laterites and serpentinites.

Locality	Sample No.	Height[1] (m)	Pt	Pd	Rh	Ru	Ir
Las Mesas 1	LM1.6	4	10	4.8	1.8	14	8.8
	LM1.5	3.5	21	14	3.3	22	15
	LM1.4	2.5	66	20	9.5	60	32
	LM1.3	1	58	38	7.7	52	27
	LM1.2	0	13	8.3	2.2	12	6
	LM1.1	-1	7.5	6.3	1.2	7.5	3.7
Las Mesas 2	LM2.6	5.5	38	12	4.9	32	16
	LM2.5	5	43	51	5.6	30	17
	LM2.4	1	59	20	9.4	58	31
	LM2.3	0.1	71	79	9.8	62	33
	LM2.2	0	12	7.4	1.4	10	10
	LM2.1	-1	5	3	1.5	7.9	7.9
Guanajibo 1	GJ1.6	3.5	42	32	5.6	38	19
	GJ1.5	3	49	45	7.9	44	22
	GJ1.4	2	44	40	8	48	26
	GJ1.3	0.5	68	30	7	43	21
	GJ1.2	0	13	11	3	18	8.5
	GJ1.1	-1	7.3	5.3	1.4	9.8	4.7
Guanajibo 2	GJ2.5	1	32	22	5	32	16
	GJ2.4	0.5	44	44	6.3	35	17
	GJ2.3	0.25	28	27	5.5	31	15
	GJ2.2	0	13	15	3.6	17	8.1
	GJ2.1	-1	8.9	6	1.5	9.3	5.1
Rosario 1	RO1.4	1.5	28	22	4	28	15
	RO1.3	0.4	25	17	3	22	10
	RO1.2	0	13	10	1.7	11	5.8
	RO1.1	-1	6.8	6.8	1.2	7.7	3.9
Rosario 2	RO2.7	4	43	34	6.1	39	19
	RO2.6	3	49	39	6.8	43	21
	RO2.5	2	49	42	7.1	44	21
	RO2.4	1	41	38	6.1	38	19
	RO2.3	0.1	34	27	5.4	33	16
	RO2.2	0	16	14	2.7	16	7.6
	RO2.1	-1	8.1	7.2	1.5	7.9	4
Joyuda	JO1.3	2.5	25	20	2.8	22	12
	JO1.2	1	28	21	3.1	24	13
	JO1.1	0.5	46	34	4.7	34	20
Maricao 1	MA1.6	2.5	57	38	6.5	40	19
	MA1.5	2	67	57	6.6	41	20
	MA1.4	1	53	49	6.1	32	17
	MA1.3	0.1	71	44	7.3	37	17
	MA1.2	0	11	7.1	1.5	8.7	4.2
	MA1.1	-1	8.6	11	1.2	7.1	3.3
Maricao 2	MA2.5	6	100	90	15	86	49
	MA2.4	5	74	24	8.8	53	26
	MA2.3	3	68	78	9.3	47	22
	MA2.2	1	19	21	2	12	4.8
	MA2.1	0	11	9.8	1	5.1	2

[1]Height above or below (-) the laterite-serpentinite contact.

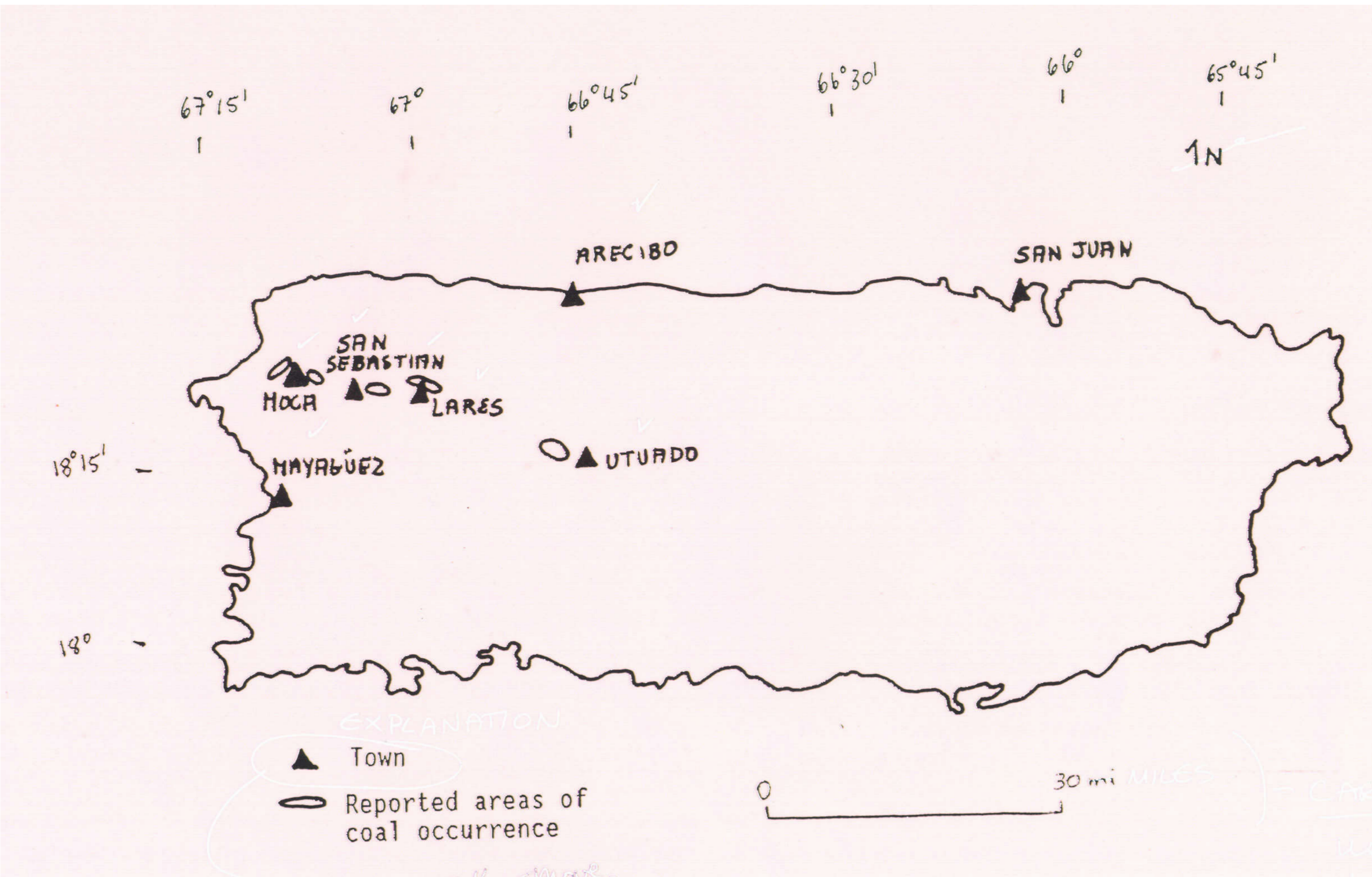


Figure 1. Reported coal occurrences in Puerto Rico.

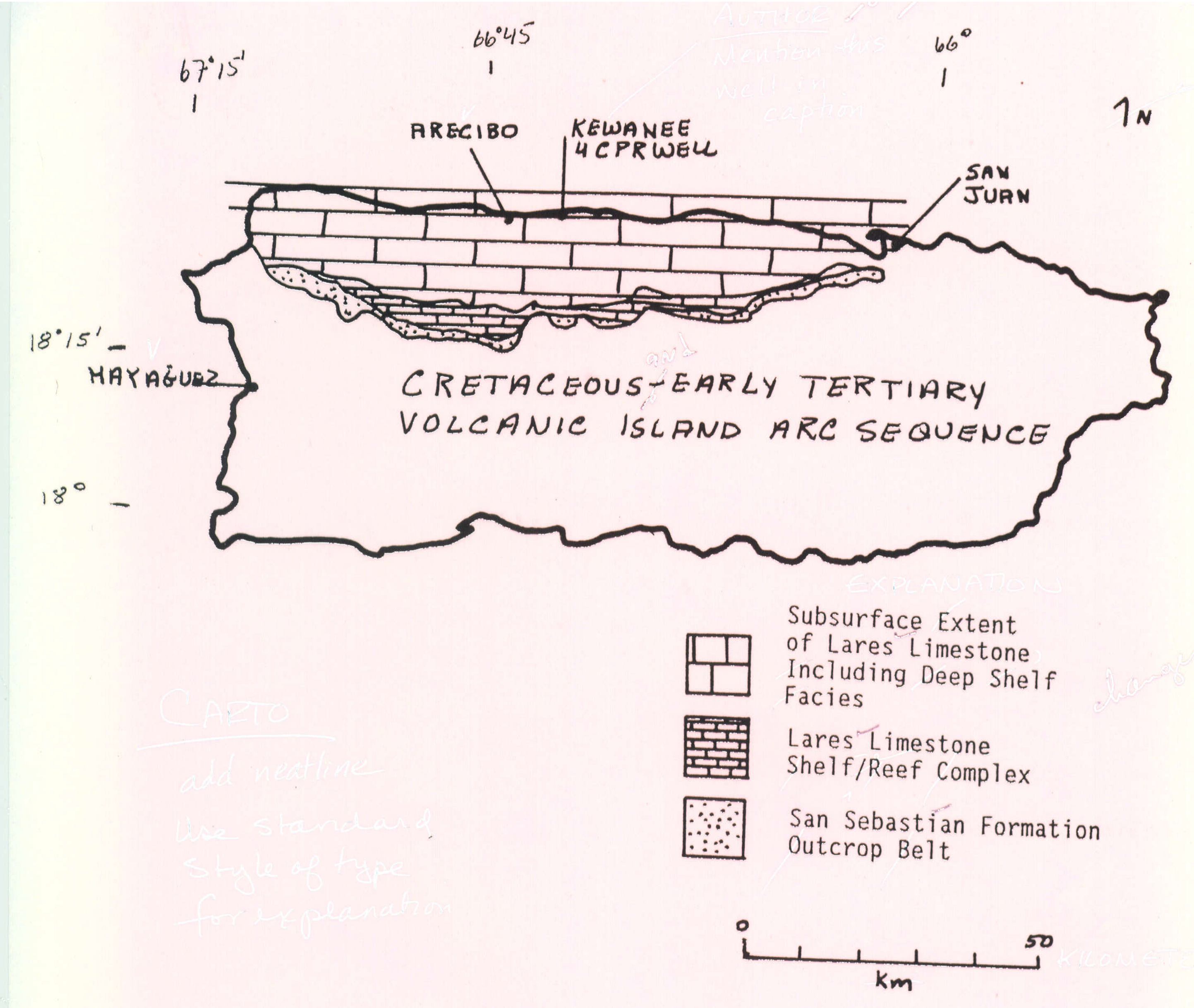


Figure 2. North Coast Tertiary basin and areas underlain by San Sebastian Formation and Lares Limestone. Modified from Frost and others (1983).

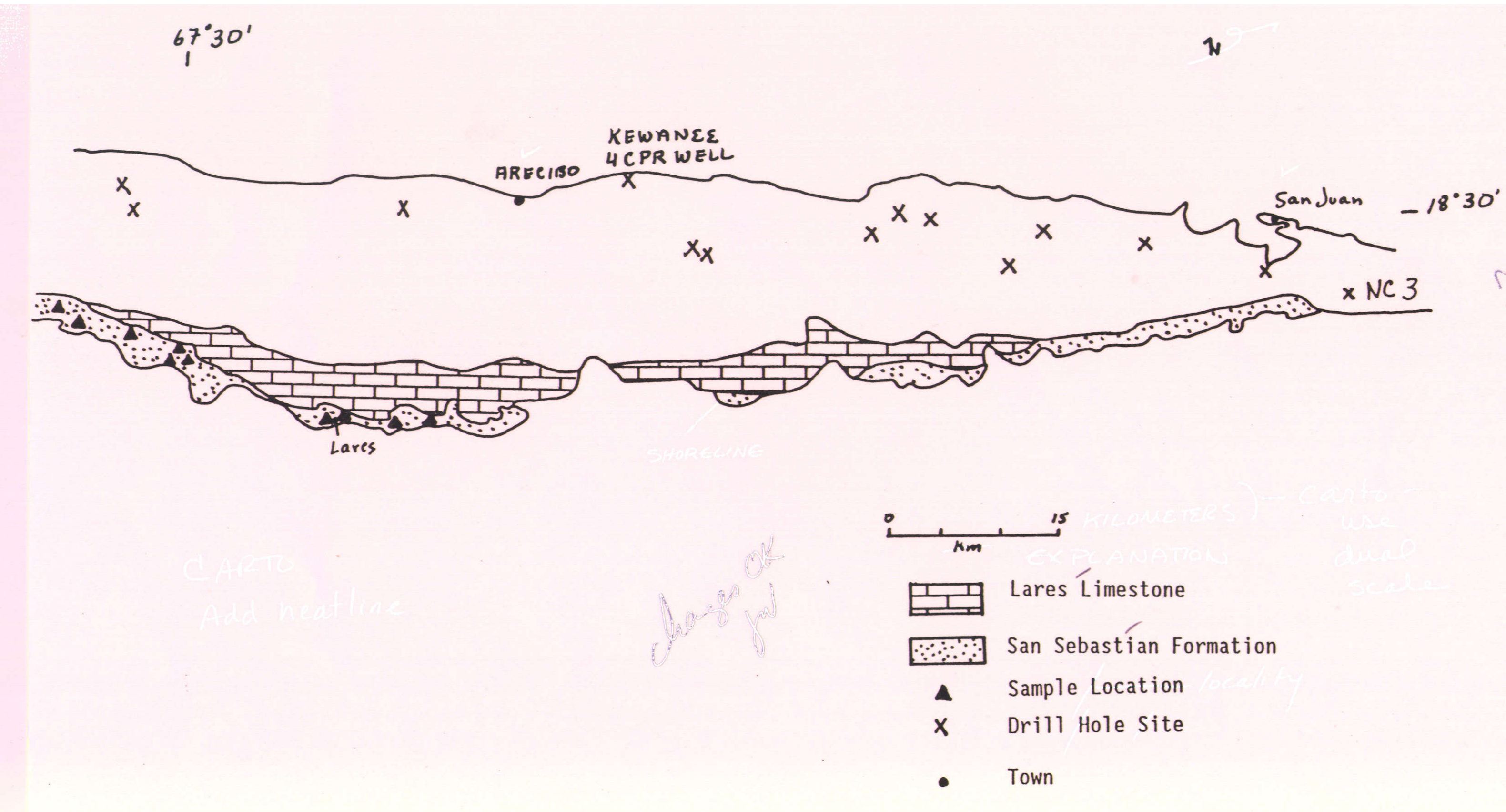


Figure 3. Sample localities and drill hole sites of the North Coast Tertiary Basin Project. Modified from Ueng and Larue (1988).

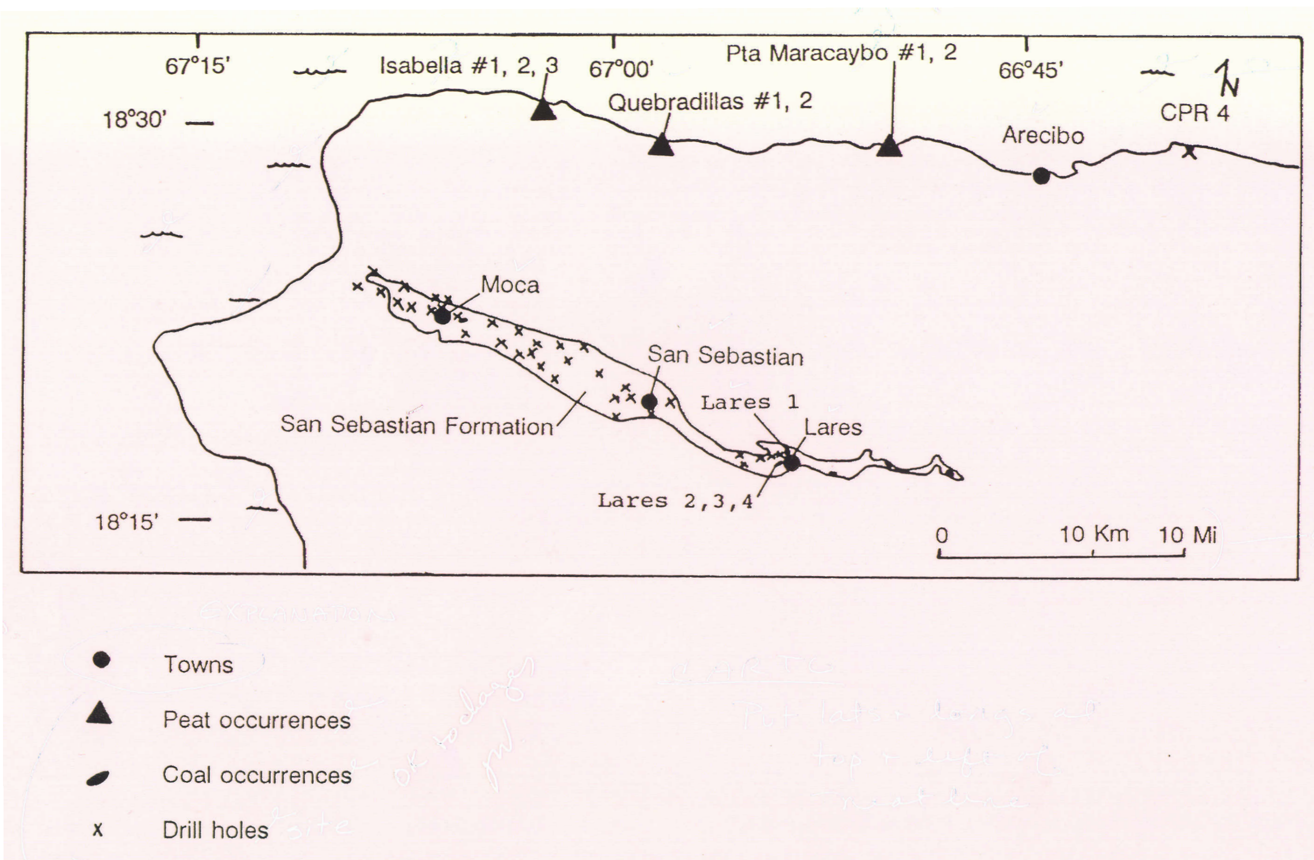


Figure 4. Areal distributions of localities sampled for coaly and peaty materials.

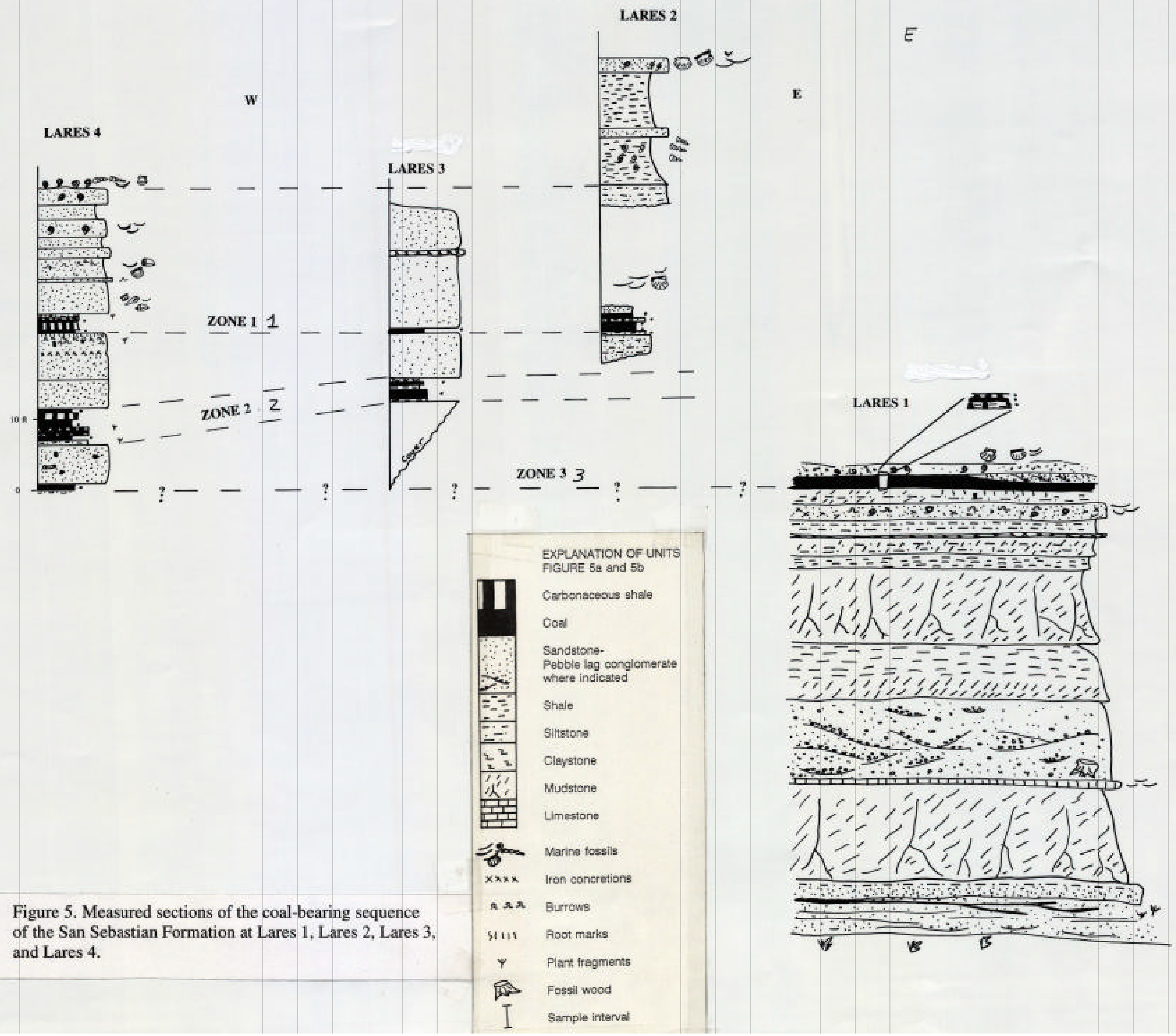


Figure 5. Measured sections of the coal-bearing sequence of the San Sebastian Formation at Lares 1, Lares 2, Lares 3, and Lares 4.

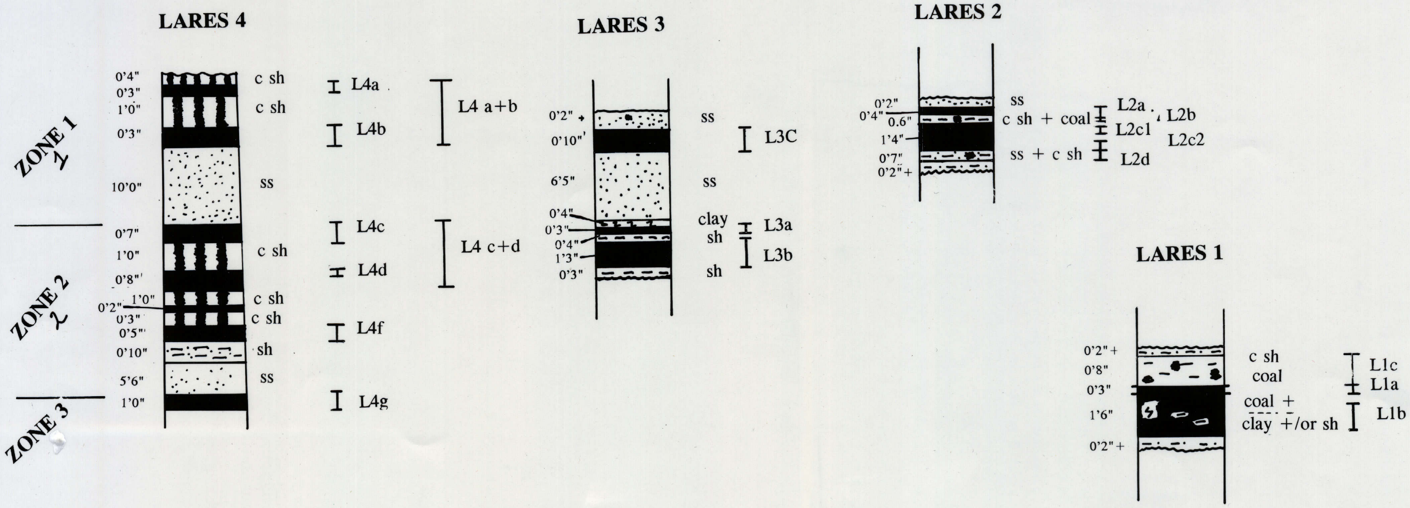


Figure 6. Coal zones at Lares1, Lares 2, Lares 3, Lares 4.

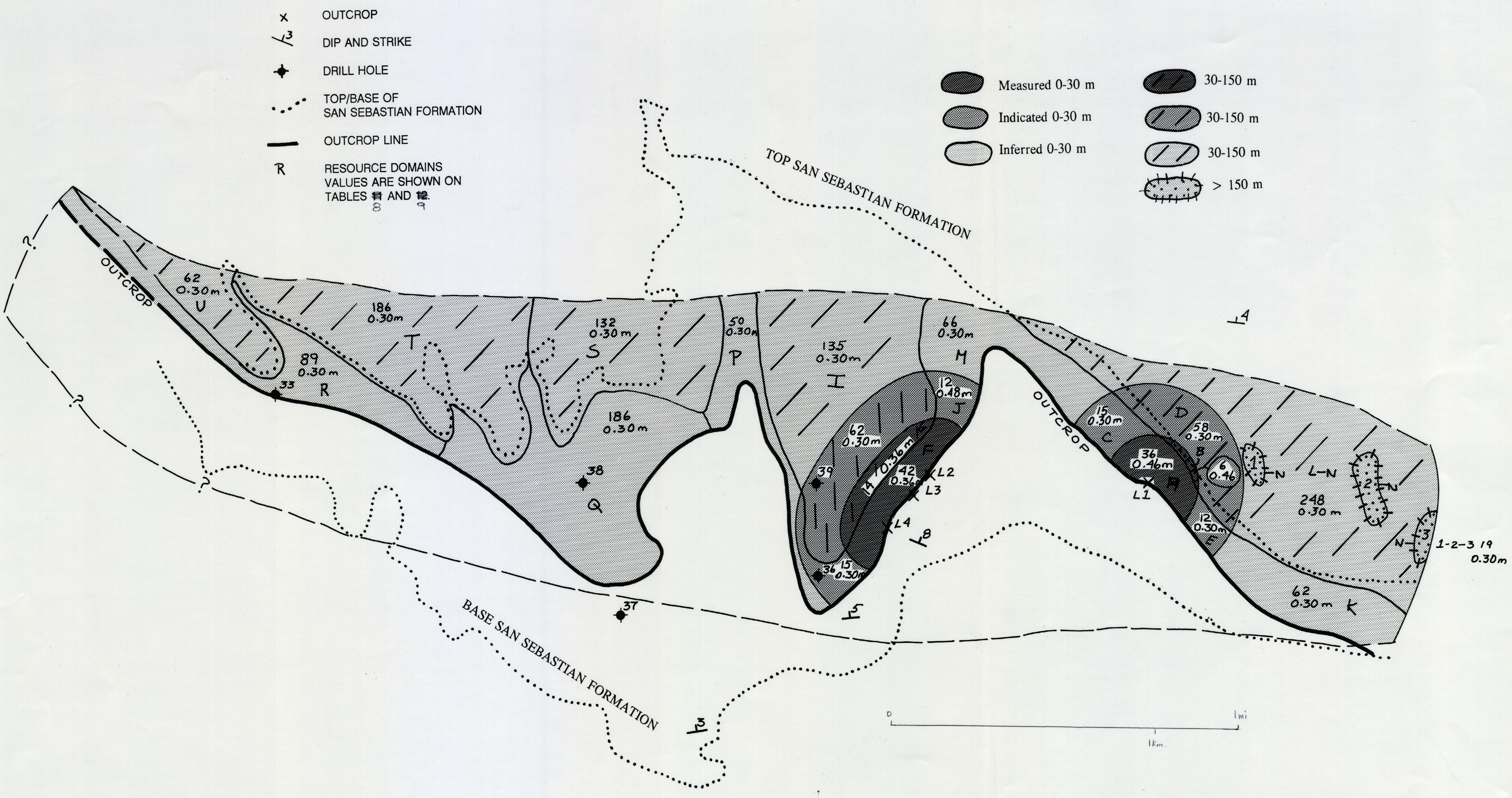


Figure 7. Areas of resource calculations within the Lares coal area.

Figure 7.

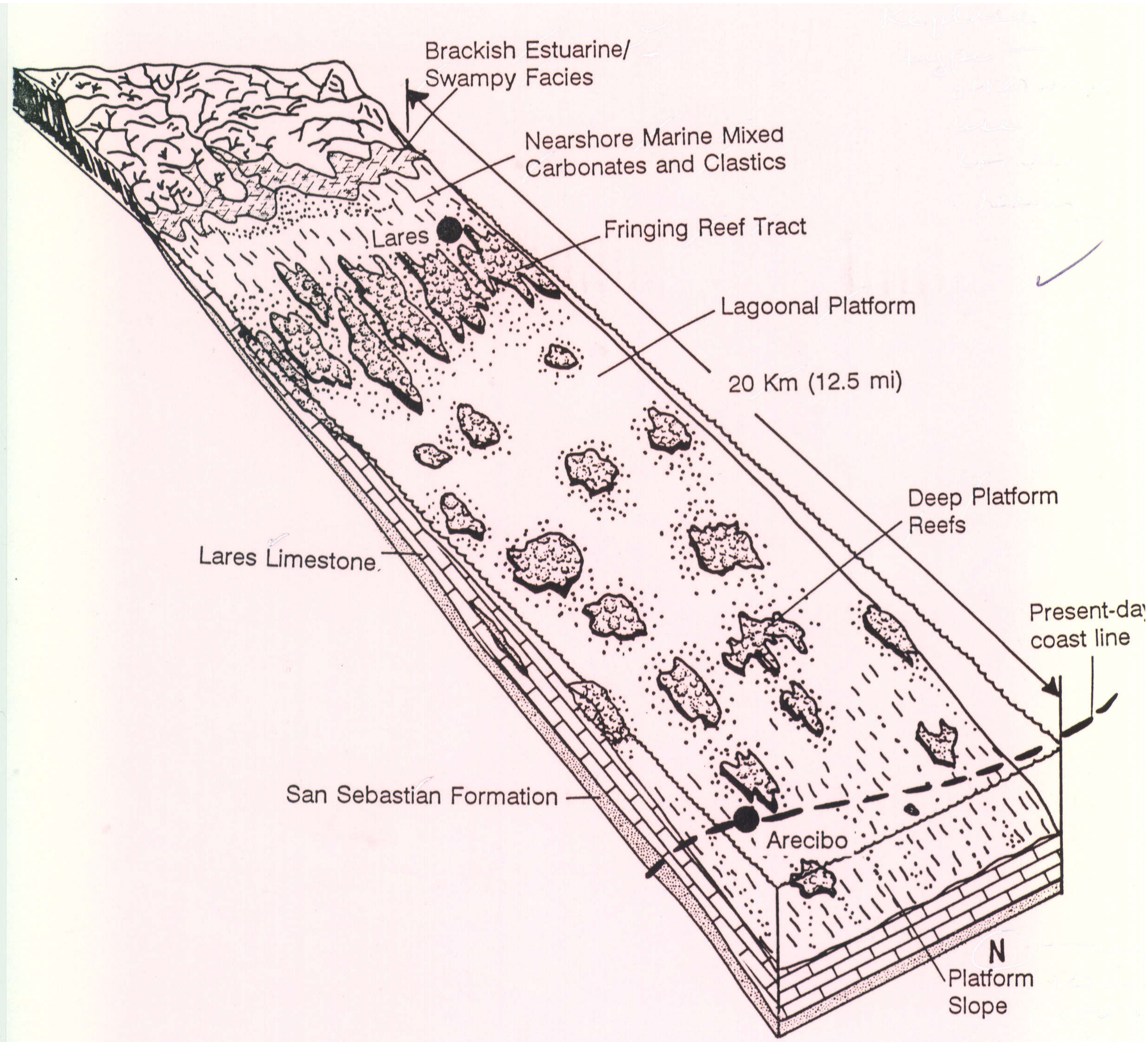


Figure 8. Schematic representation of the coal-bearing sequence (San Sebastian Formation) and it's relationship to the overlying Lares Limestone. In certain areas, the Lares Limestone has scoured out the underlying San Sebastian Formation. (Modified from Frost and others, 1983).

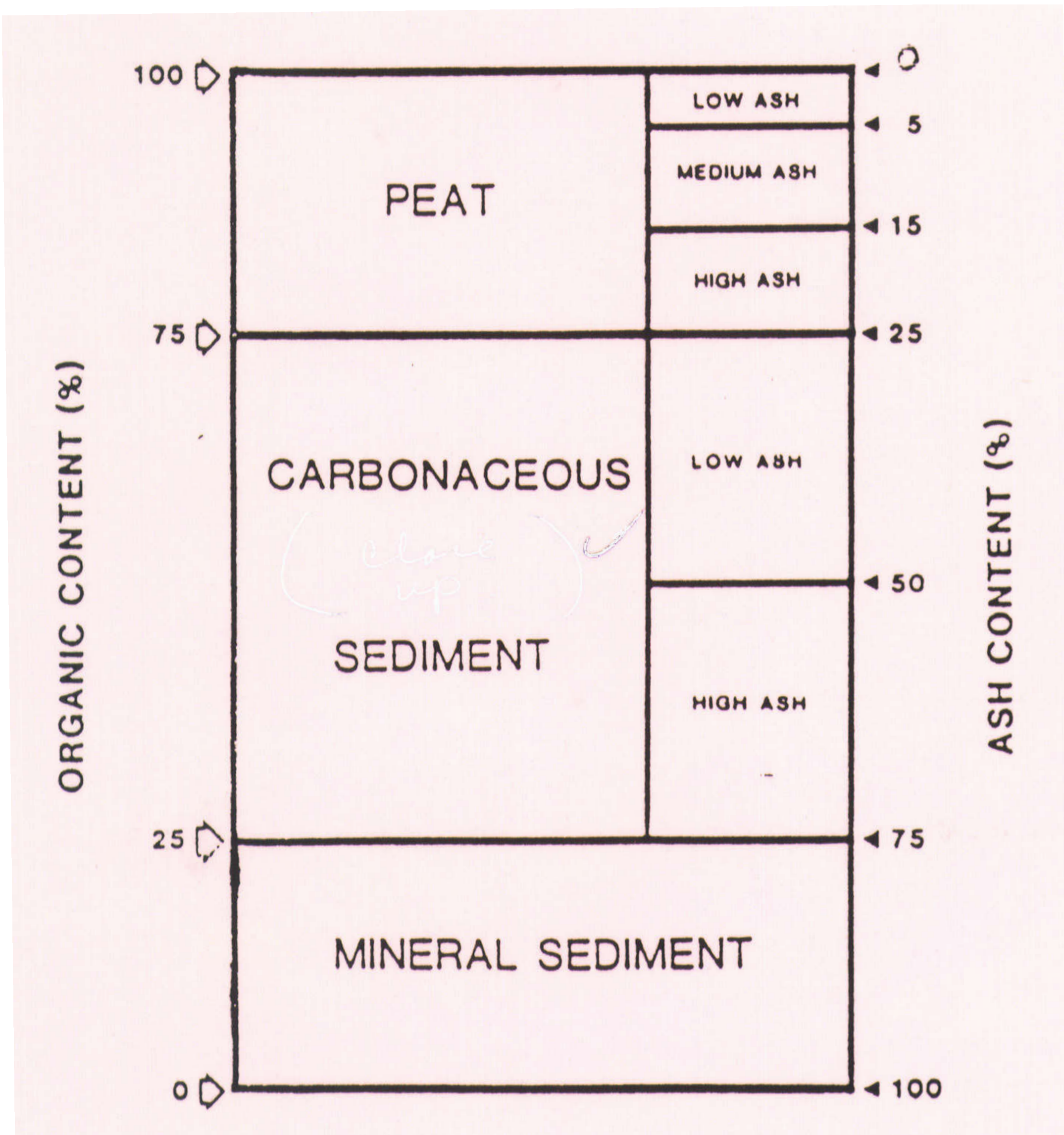
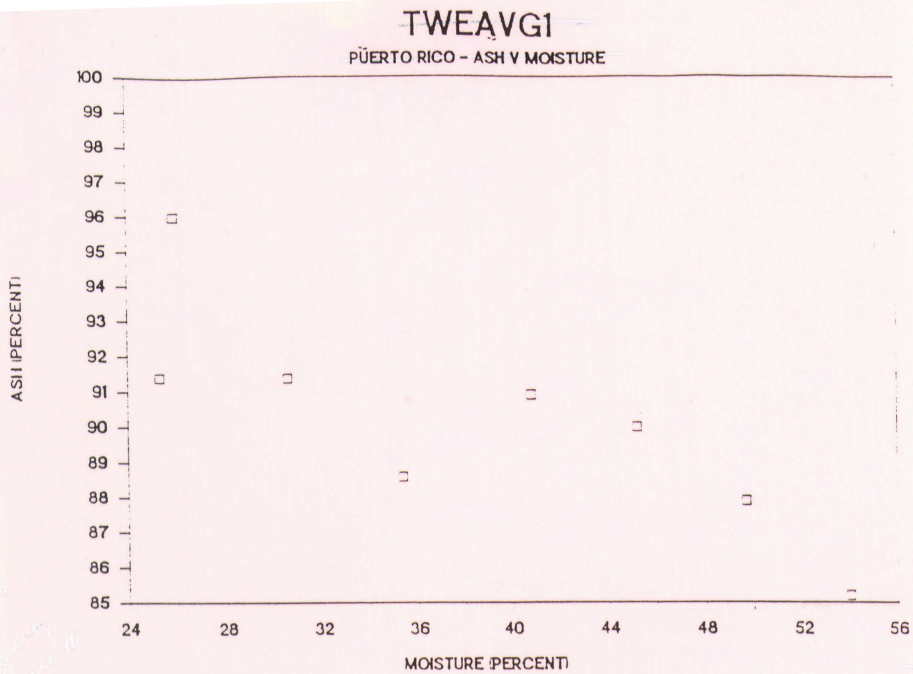


Figure 9. Peat classification (Andrejko and others, 1983).



SAMPLE NUMBER	MOISTURE PERCENT	ASH PERCENT
ISABELLA # 1	25.9	96.0
ISABELLA # 2	35.4	88.6
ISABELLA # 3	40.8	90.9
ISABELLA # 4	45.2	90.0
QUEBRADILLAS #1	25.3	91.4
QUEBRADILLAS #2	30.6	91.4
PUNTA MARCAYO #1	54.0	85.2
PUNTA MARCAYO #2	49.7	87.9

Figure 10. Moisture and ash percent of peat samples.