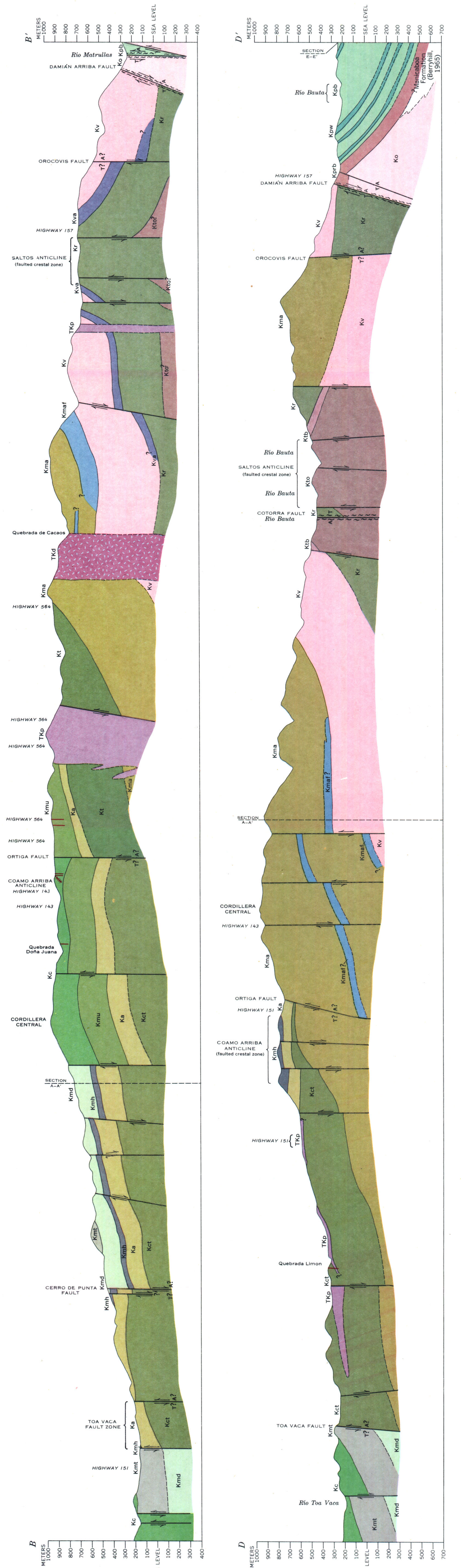
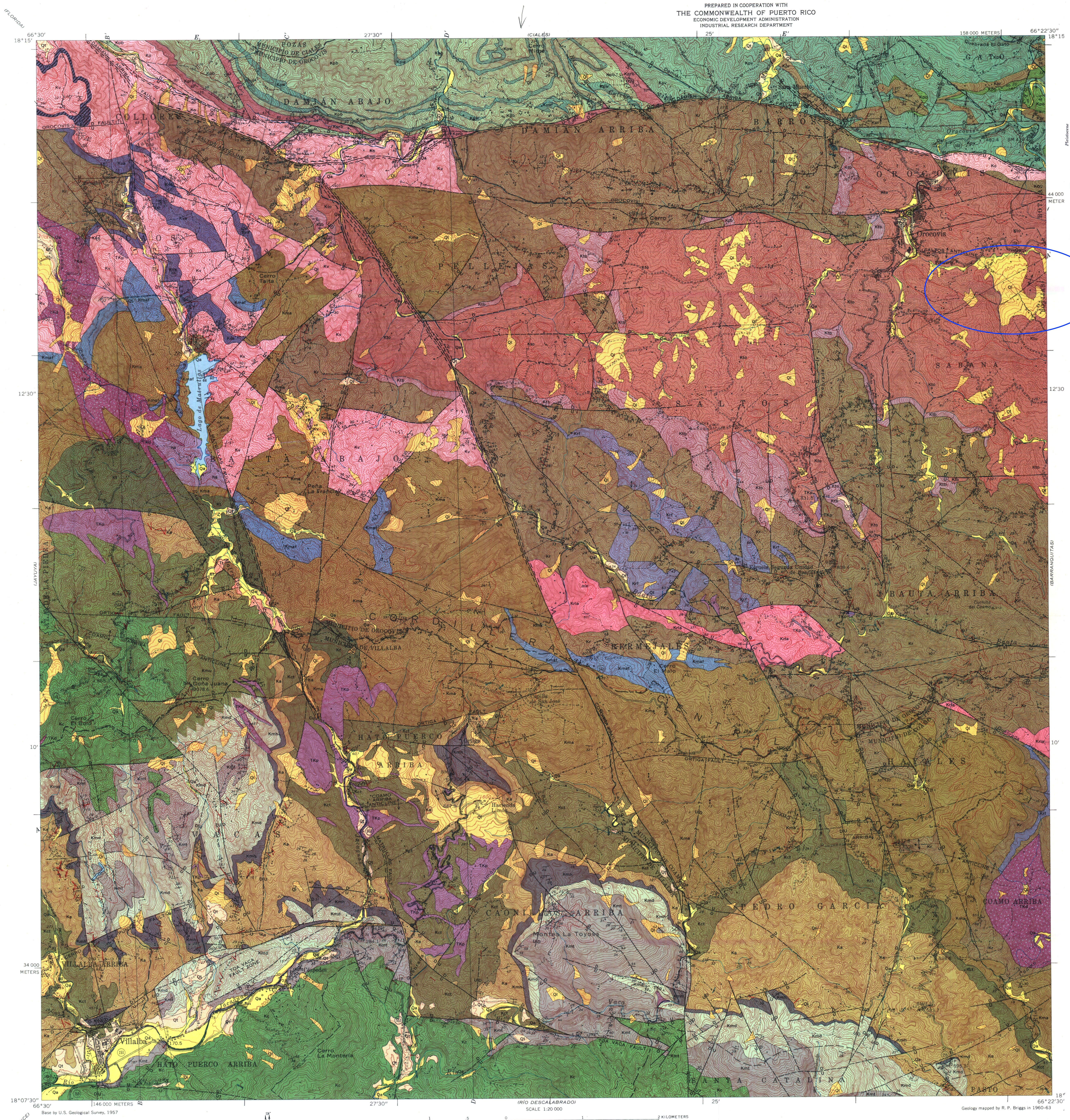
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

PREPARED IN COOPERATION WITH
THE COMMONWEALTH OF PUERTO RICO
ECONOMIC DEVELOPMENT ADMINISTRATION
INDUSTRIAL RESEARCH DEPARTMENT

MISCELLANEOUS GEOLOGIC INVESTIGATIONS
MAP I-615





Base by U.S. Geological Survey, 1957

SCALE 1:20 000

CONTOUR INTERVAL 10 METERS
DATUM IS MEAN SEA LEVEL

APPROXIMATE MEAN DECLINATION, 1971

Geology mapped by R. P. Briggs in 1960–63

E X P L A N A T I O N

Thickness in parentheses is from within the Orocovis quadrangle; thickness in square brackets is general thickness range.
Terminology used here in describing volcanic rocks is the same as that used previously by Briggs (1969).
References cited at ends of descriptions are reports in which the stratigraphic units were named or in which more detailed descriptions may be found

QUATERNARY

Holocene

Qa

Alluvium

(0 to 10+ m)—Sand, gravel, and clay in river and stream floodplains. In many stream channels boulders 2 m in diameter are common. Largest boulders are 5 m across

Pleistocene and (or) Holocene

Ql

Landslide deposits

(0 to 5+ m)—Clay and sand with boulders as large as 5 m in long dimension. Large deposits result chiefly from slow earth and rock flow on moderately to deeply weathered slopes

Qt

Terrace deposits

(0 to 10± m)—Clay, sand, and gravel deposits with upper surfaces above historic flood levels. Boulders more than 1 m in diameter are common. Sand grains in higher level deposits are largely weathered to clay

TERTIARY AND QUATERNARY

Miocene to Holocene

Lateritic soil and saprolite

(0 to 30? m)—Reddish-brown to yellowish-brown clay, locally containing residual boulders as large as 3 m in diameter. Original rock textures commonly are well preserved in the saprolite, despite essentially complete weathering to clay. Briggs, 1960

TERTIARY

Oligocene or younger

Tt

Terrace deposits

(0 to 10? m)—Crudely stratified alluvial deposits in which original sand and gravel and most boulders have been weathered to clay. Found only in the Río Matrullas valley from about 820 m elevation on the Cordillera Central to about 660 m, 6 km to the north-northwest. Geomorphic relations and degree of weathering suggest that deposition may have taken place as early as middle Tertiary time

UNCONFORMITY

CRETACEOUS AND TERTIARY

Upper Cretaceous to Eocene

TKd

Quartz diorite and diorite

Largely equigranular medium-grained quartz hornblende diorite, locally silicified and argillized. Porphyritic diorite with many large plagioclase and some hornblende phenocrysts is common along the borders of the elongate pluton in the northwest part of the map area and in thick dikes extending chiefly southeast from the pluton

TKp

Diorite porphyry and quartz diorite porphyry

Body at west-central edge of map area: diorite porphyry containing sparse to moderately abundant hornblende phenocrysts in a granular feldspathic groundmass; widely silicified and (or) argillized
Sill-dike complex in south-central and southwestern parts of map area: diorite porphyry having a granular feldspathic groundmass; abundant large phenocrysts of pyroxene commonly predominate over moderately abundant hornblende phenocrysts, and large plagioclase phenocrysts locally predominate over both pyroxene and hornblende

Dikes

(0.5 to 5± m wide)—Dips shown except on vertical dikes
Red, hornblende, feldspar, and (or) pyroxene diorite porphyry, similar in composition to some rocks included in TKp
Red with ×'s, dacite or andesite, commonly sparsely porphyritic. Most common phenocrysts are pyroxene; hornblende phenocrysts are relatively uncommon; quartz phenocrysts rarely occur. Finely to very finely granular groundmass
Blue, andesite, moderately to abundantly porphyritic. Plagioclase phenocrysts are most common; small pyroxene phenocrysts are common but subordinate to plagioclase. Groundmass is finely granular to aphanitic
Blue with ×'s, basalt or basaltic andesite, moderately to abundantly porphyritic. Pyroxene phenocrysts are most common; some small plagioclase phenocrysts. Outlines of altered minerals in thin section suggest that fine olivine was present. Groundmass is finely granular to aphanitic. Probably chiefly Late Cretaceous in age

ha **ha ×**

Hydrothermally altered rocks

Composed chiefly of very fine grained white, pale-pink, pale-gray, and pale-purple material streaked light brown, yellowish brown, and moderate red. These rocks are similar to rocks described elsewhere in Puerto Rico by Pease and Briggs (1960), Berryhill and Glover (1960), and Hildebrand (1961), and probably are largely quartz, kaolinite, and halloysite, with minor sericite, pyrite, and iron oxides

Upper Cretaceous

Santonian(?) to Maestrichtian

NORTH OF DAMIAN ARRIBA FAULT

Kpv **Kpr** **Kpo** **Kpv** **Kpb** **Kpw** **Kprb**

Pozas Formation

(1,500+ m) [2,000± m, Nelson and Monroe, 1966; possibly 2,850+ m, Briggs, 1969]

Kpv, *very thick and thick-bedded fine to coarse volcanic breccia and tuff; some medium- and thick-bedded mudstone and sandstone; some andesitic dacite lava in part of section above Revés Member. Stratification moderately well defined. Breccia fragments largely subround to subangular andesite lava in a muddy feldspathic tuff matrix. Breccias probably largely pyroclastic in origin, with some reworking, perhaps as lahars. Berryhill, 1965, p. 53–54*

Kpr, *Revés Member (30 to 100+ m) [30 to 250± m; Briggs and Gelabert, 1962]—Thin- to thick-bedded calcareous feldspathic sandstone with some thick lenses of calcirudite and recrystallized calcilutite. Briggs and Gelabert, 1962; Briggs, 1969*

Kpo, *Botijas Limestone Member (0 to 80± m) [0 to 140 m, Briggs and Gelabert, 1962]—Largely thick-bedded recrystallized calcilutite and calcarenite; some thick lenses of highly fossiliferous rudistid-bearing calcirudite; some medium and thick interbeds of calcareous feldspathic sandstone. Briggs and Gelabert, 1962; Briggs, 1969*

Kpb, *Blacho Tuff Member (750± m) [500 to 750± m; Berryhill, 1965]—Ash-flow deposits commonly interbedded with medium- to thick-bedded, generally fine volcanic breccia, medium to coarse tuff, and mudstone. The upper parts of ash-flow deposits locally have been removed by penecontemporaneous erosion; where present they consist of unwelded moderately indurated rubbly mixtures of ash, bombs (chiefly andesitic and dacitic lava), and lithic fragments. The center parts are welded, showing flattening of inclusions and parallel orientation of pumiceous and glassy fragments. Lower parts of ash-flow deposits consist of fine breccia and muddy tuff, and commonly rest on mudstone. Welded parts commonly are dense and resistant to weathering. More resistant and extensive welded units,* Kpw, *are shown separately. Ash-flow deposits range from dacitic andesite to rhyolite in composition. Berryhill, 1965, p. 57; Nelson, 1966a*

Kpw, *resistant and extensive units in the Blacho Tuff Member*

Kprb, *Río Bauta Member (100± m)—Thin- and medium-bedded calcareous volcanic sandstone, locally interstratified with lenses of recrystallized calcilutite and calcarenite and impure calcirudite as much as 10 m thick. About 10 m of conglomerate at base containing clasts of basalt and andesite lava in a matrix of clayey volcanic sandstone. Briggs, 1969*

UNCONFORMITY

SOUTH OF DAMIÁN ARRIBA FAULT

Kc

Coamo Formation

(400+ m) [1,500± m; Glover, in press]—Very thick and thick-bedded coarse pyroxene-andesite pyroclastic breccia, interstratified with some andesitic crystal-lithic tuff and andesite lava. Finely disseminated hematite is a common constituent. Glover, 1961; in press

Kmt **Kmd** **Kmh** **Kmu**

Maravillas Formation

(250 to 550± m)

Kmu, *Maravillas Formation, undivided (250 to 300± m) [250 to 560+ m; Mattson, 1967, p. B17]—Chiefly thick to thin beds of calcareous tuffaceous sandstone; some crystal and crystal-lithic tuff beds and lenses of tuffaceous calcarenite. Division into members precluded chiefly by sparse exposures and deep weathering. Mattson, 1967, p. B16–B18*

Kmt, *Toyosa Member (40 to 350 m)—Thin to thick beds of calcareous tuffaceous sandstone, locally interstratified with fine calcareous tuff breccia, tuffaceous calcarenite, and calcirudite. A lens of crystalline limestone about 50 m thick forms the walls of Río Toa Vaca water gap, and thinner limestone lenses occur locally elsewhere. Briggs, 1969*

Kmd, *San Diego Tuff Member (70 to 260 m) [50 to 300+ m; Glover, in press]—Crystal and crystal-lithic tuff and tuff breccia chiefly composed of crystals and crystal fragments of plagioclase and hornblende and inclusions of hornblende diorite and diorite porphyry. Locally calcareous. Tuff breccia predominates in exposures northeast of Villalba, but crystal tuff forms the bulk of the San Diego. Glover, 1961; in press*

Kmh, *Sabana Hoyos Limestone Member (0 to 140± m) [0 to 140± m]—Very thick and thick-bedded recrystallized calcilutite, calcarenite, and calcirudite and thin- to thick-bedded calcarenite, tuffaceous calcarenite, and calcareous tuffaceous sandstone. Crossbedding occurs locally in the thinner beds. Glover 1961; in press*

Ka

Achiote Conglomerate

(60 to 540 m) [60 to 1,800± m; Mattson, 1967, p. B15]—Largely very thick bedded cobble and boulder conglomerate containing clasts chiefly composed of andesite lava in a grayish-red to grayish-red-purple matrix of muddy volcanic sandstone. In upper part of Achiote near southeastern corner of map area, matrix is composed of cleaner moderately well sorted tuffaceous sandstone and lacks reddish tints prevalent elsewhere. Clasts generally well rounded, but subangular clasts common in most northwesterly outcrops. Basal few meters of Achiote commonly consists of medium to very thick beds of sandy mudstone with sparse to moderately abundant pebbles and cobbles. In south-central part of map area, near Ortiga, Achiote contains many basalt lava fragments derived from underlying Cotorra Tuff. Exposures in valley of the Río Jacaguas contain boulders as large as 2 m in diameter, apparently derived from the Malo Breccia. One lens of impure limestone, 2± m thick and less than 40 m in lateral extent, occurs in the middle Achiote in the southeastern part of the map area. Mattson, 1967, p. B13–B16; Glover, in press

LOCAL UNCONFORMITY

FAULT SLICE
NORTHEAST OF OROCOVIS

WESTERN PART
OF MAP AREA

EASTERN PART
OF MAP AREA

Kt

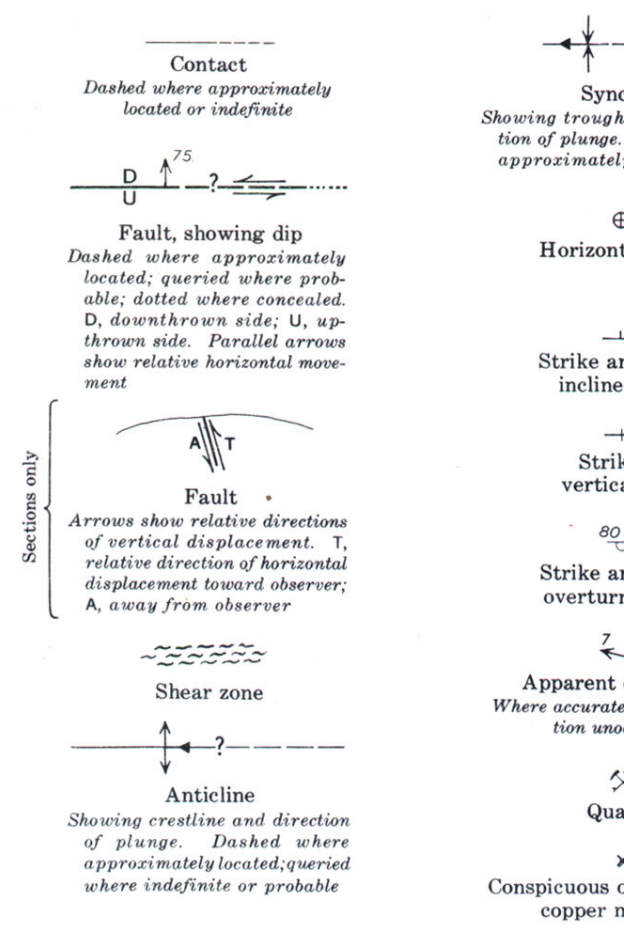
Tetuán Formation

(0 to 450± m) [0 to 1,500± m; Nelson and Monroe, 1966, p. C7]—Thin- and

Kct

Cotorra Tuff

(20 to 500± m) [0 to 500± m; Briggs, 1967, p. A27]—Chiefly very thick bedded basaltic crystal-vitric hyaloclastic tuff and tuff breccia. Tuff composed almost entirely of pyroxene crystals as much as 6 mm across in an indeterminate matrix interpreted as devitrified glass. Locally contains sparse feldspar and olivine (?) crystals. Breccia fragments, as much as 50 cm in diameter, are pyroxene basalt and olivine (?) basalt that are commonly



KEY FOR RAPID REFERENCE FROM MAP TO ENGINEERING GEOLOGY TABLE
Geologic map symbols in alphabetical order
Capital letters refer to tiers of table.
Letters in boldface refer to predominant rock types and characteristics

Map symbol	Tier	Map symbol	Tier	Map symbol	Tier	Map symbol	Tier
ha	**J**	Kmt	**H**	Kpw	**F**	Kva	**A**
Ka	**D**,G	Kmu	**H**,E	Kr	**G**,B,C,H	Kvm	**A**
Kc	**D**,A,B,E	Ko	**A**,C,G	Krf	**A**	Qa	**K**
Kct	**C**,A	Kpb	**D**,F	Krla	**A**	Ql	**L**
Kma	**B**,A,C,G,	Kpo	**H**	Kt	**G**,A,B,C	Qt	**K**
Kmaf	**A**	Kpr	**H**	Ktb	**C**,G	TKd	**I**
Kmd	**E**	Kprb	**H**,D	Kto	**B**,A,C,G	TKp	**I**
Kmh	**H**	Kpv	**D**,A	Kv	**G**,**B**,A,C	Tt	**N**

Dike symbols

▨	red line	red with ×'s	blue line	blue with ×'s
N	I	A	A	A

HOW TO USE THE ENGINEERING GEOLOGY TABLE

Columns are divided horizontally into tiers lettered A to N

Table to map—If the reader is looking for rock suitable for riprap, for example, he will search column 3 and find that tier B lists "Riprap—Good." Columns 1 and 2 of tier B show the rock types involved, the geologic map symbols, and the general area of the map in which these rocks are found. With these data the reader can then locate on the geologic map the sites where the desired material probably will be found.

Map to table—If the reader wishes to know, for example, the excavation and stability conditions along a proposed highway route, he can plot the route on the geologic map, find the geologic map symbols of the units crossed, and check with the key accompanying the table. Thus, if the area in question is labelled Kto, opposite this letter symbol the key lists **B**,A,C, and G, with the **B** in boldface. These letters refer to tiers and the desired information appears in column 3 of these tiers. The boldface **B** indicates that most of the Kto rocks will have the characteristics listed in tier **B**, while some of the Kto rocks will have the characteristics listed in tiers A, C, or G.

ENGINEERING GEOLOGY

Characteristics of fresh rock unless specifically stated otherwise (see column 1, tier M)

	Tier	1. ROCK TYPES AND GEOLOGIC MAP SYMBOLS (Percentage indicates proportion of the rock type within each map unit)	2. DISTRIBUTION	3. GENERAL ENGINEERING CHARACTERISTICS (see text below this table)	4. REMARKS
QUATERNARY	A	Very thick lava and lava breccia: 100% of Kmaf, Krla, Kvm, Kva, dikes shown by red with ×'s, blue, and blue with ×'s 70-80% of Ko. 10-20% of Kto. <10% of Kc, Kct, Kma, Kpv, Kt, Kv.	Chiefly in the east-central and central parts but locally present in most parts of the quadrangle.	Excavation—Difficult. Stability—Good. Strength—Good (A). Aggregate—Excellent. Riprap—Fair (B). Fill—Fair. Permeability—Low. Tunnel requirements—Minimum.	
TERTIARY AND QUATERNARY	B	Very thick and thick-bedded pyroclastic breccia and tuff, chiefly of marine origin: 80-90% of Kma, Kto. 30-40% of Kv. 10-20% of Kt. <10% of Kc, Ko, Kpv, Kr.	Widespread in east-central, central, and west-central parts of the quadrangle, locally near the southern border.	Excavation—Difficult. Stability—Good. Strength—Good (A). Aggregate—Good (A). Riprap—Good. Fill—Fair. Permeability—Low. Tunnel requirements—Minimum.	Commonly weather to boulders and clay, forming sources of many landslide deposits. Breccias are striking cliff-formers, most notably in Kma. Some material quarried from Kma for Lago de Matrullas dam.
TERTIARY	C	Very thick bedded hyaloclastic breccia and tuff: >90% of Kct, Ktb. 10-20% of Kt, Kv. <10% of Kma, Ko, Kr, Kto.	Chiefly in the area south of the Cordillera Central, locally elsewhere south of the Damián Arriba fault, which is near the northern edge of the map area.	Excavation—Intermediate. Stability—Fair. Strength—Good (B). Aggregate—Poor (A). Riprap—Poor. Fill—Good. Permeability—Moderate. Tunnel requirements—Minimum to moderate.	Relatively easily eroded, forming lowlands.
CRETACEOUS AND TERTIARY	D	Very thick and thick-bedded pyroclastic breccia and tuff, chiefly subaerial in origin, and very thick and thick volcanic conglomerate: >90% of Ka, Kpv. 70-90% of Kc, Kpb. 10-20% of Kprb.	Widespread along the northern edge of the quadrangle north of the Damián Arriba fault; otherwise chiefly in the southern part of the quadrangle.	Excavation—Intermediate. Stability—Fair. Strength—Good (B). Aggregate—Poor (A). Riprap—Poor. Fill—Good (especially Ka). Permeability—Moderate. Tunnel requirements—Moderate.	
CRETACEOUS	E	Very thick and thick-bedded pyroclastic tuff and breccia, marine: 100% of Kmd. 20-40% of Kmu. 10-20% of Kc.	Almost entirely in the southern one-third of the quadrangle.	Excavation—Moderately difficult. Stability—Good, locally fair. Strength—Good (A). Aggregate—Fair (A). Riprap—Fair (A). Fill—Fair. Permeability—Low to moderate. Tunnel requirements—Minimum.	
	F	Zones of welded tuff: 100% of Kpw. 20-30% of Kpb. <10% of Kpv.	Locally along the northern edge of the quadrangle north of the Damián Arriba fault.	Excavation—Difficult. Stability—Good. Strength—Good (A). Aggregate—Poor (B). Riprap—Fair (C). Fill—Poor. Permeability—Low. Tunnel requirements—Minimum.	Highly resistant to weathering and erosion, forming extensive lines of low cliffs.
	G	Thin- to medium-bedded tuffaceous sandstone and siltstone, moderately calcareous: 80-90% of Kr. 50-70% of Kt. 30-50% of Kv. 10-20% of Ko. <10% of Kma, Ktb, Kto.	Widespread in the east-central and central parts, but locally in the west-central and northwestern parts of the quadrangle.	Excavation—Moderately difficult. Stability—Good. Strength—Good (A). Aggregate—Good (A). Riprap—Fair (B). Fill—Poor to fair. Permeability—Low. Tunnel requirements—Minimum.	Commonly have closely spaced joints and weather to rhombohedral-shaped fragments and clay. Moderately weathered Kr was chief source of fill for Lago de Matrullas dam.
	H	Limestone and calcareous volcanic sandstone and siltstone: 100% of Kmh, Kmt, Kpo, Kpr. 80-90% of Kprb. 60-80% of Kmu. <10% of Ka, Kr.	Chiefly in the southern and southwestern parts of the quadrangle; locally in the east-central part; locally north of the Damián Arriba fault.	Excavation—Moderately difficult. Stability—Good. Strength—Good (A). Aggregate—Good (B). Riprap—Fair (A, B). Fill—Fair. Permeability—Low to high. Tunnel requirements—Minimum to moderate.	Locally cavernous deleteriously affecting cut-slope stability and foundation strength, and greatly increasing permeability.
	I	Diorite and diorite porphyry: 100% of TKd, TKp, and dikes shown by red lines.	Chiefly in the southeastern, west-central and northwestern parts of the quadrangle; locally in the south-central and southwestern parts, largely as moderately thick sills and dikes.	Excavation—Moderately difficult. Stability—Good, locally fair. Strength—Good (A). Aggregate—Fair (A). Riprap—Fair (B). Fill—Poor to fair. Permeability—Low to moderate. Tunnel requirements—Minimum to moderate.	Riprap for facing of Lago de Matrullas dam came largely from quarry in TKp on Hwy. 564, southwest of the dam. Relatively easily eroded, forming lowlands for most part.
	J	Hydrothermally altered rocks: 100% of ha.	Chiefly just west and south of Lago de Matrullas in the west-central part of the quadrangle.	Excavation—Intermediate. Stability—Fair, locally poor. Strength—Fair. Aggregate—Poor (A). Riprap—Poor. Fill—Poor. Permeability—Moderate. Tunnel requirements—Moderate to maximum.	
	K	Alluvium and terrace deposits: 100% of Qa, Qt	Chiefly in the Río Jacaguas valley in the southwestern part; moderate-sized deposits in the Río Matrullas in the extreme northwest and in the Río Orocovis valley near Orocovis.	Excavation—Easy. Stability—Poor. Strength—Fair. Aggregate—Fair (B). Riprap—Unsuitable, locally fair (C). Fill—Fair. Permeability—High to moderate. Tunnel requirements—Maximum.	Sand in Qt locally is almost completely weathered to clay. Where water table is variable and clay content is large, dewatering of Qa and Qt may be difficult. Qa is susceptible to flooding.
	L	Landslide deposits: 100% of Ql.	Locally throughout the quadrangle.	Excavation—Easy. Stability—Poor. Strength—Poor. Aggregate—Unsuitable. Riprap—Unsuitable. Fill—Poor, perhaps good for blending. Permeability—Moderate. Tunnel requirements—Maximum.	Most Ql deposits result from relatively slow and sporadic mass movement, and most are believed to retain a potential instability. Excavation or even moderate loading of these deposits may reinitiate movement.
	M	Moderately weathered rock: (Not shown separately on the geologic map, because less than 3% of the surface of the area exposes fresh rock. Disintegration and alteration due to weathering commonly ranges from 2 m to 10 m and locally may exceed 100 m in depth).	At the surface or overlain by thin soil in about 65 percent of the area.	Excavation—Moderately easy. Stability—Fair. Strength—Good (B). Aggregate—Poor (A). Riprap—Poor to unsuitable. Fill—Good to fair. Permeability—Moderate. Tunnel requirements—Maximum to moderate.	Moderately weathered Kr forms core of Lago de Matrullas dam.
	N	Lateritic soil and saprolite and older terrace deposits: 100% of areas shown by red stipple, and Tt.	At the surface in about 30 percent of the area, chiefly north of the Cordillera Central.	Excavation—Easy. Stability—Poor. Strength—Fair. Aggregate—Unsuitable. Riprap—Unsuitable. Fill—Poor, probably good for blending. Permeability—Low to moderate. Tunnel requirements—Maximum.	Plastic when wet, but commonly surface appears to drain moderately rapidly. Unsurfaced roads on lateritic earths are virtually impassable during rains.

KEY TO ENGINEERING CHARACTERISTICS
Words in boldface refer to column 3 of the table

Excavation facility

Easy.—Can be excavated by hand tools or lightweight power equipment. Some large boulders may require drilling and blasting for their removal. Dewatering and bracing of excavation walls may be required.
Moderately easy.—Probably rippable by heavyweight power equipment at least to weathered rock-fresh rock interface and locally to greater depths.
Intermediate.—Probably rippable by heavyweight power equipment to depths chiefly limited by the maneuverability of the equipment. Hard rock layers or zones of hard rock may require drilling and blasting.
Moderately difficult.—Probably require drilling and blasting for most deep excavations, but locally may be ripped to depths of several meters owing to closely spaced joints, fractures, or stratification or alteration.
Difficult.—Probably require drilling and blasting in most excavations, except where extensively fractured or altered.

Stability of cut slopes

Good.—These rocks have been observed to stand on vertical cuts where jointing and fracturing are at a minimum. However, moderately close (1-3 m) jointing or fracturing is common, so slopes not steeper than 3:1 (Vertical:Horizontal) are recommended. In cuts higher than 15 m, debris-catching benches are recommended. Where rocks are intensely fractured, slopes flatter than 1:1 may be required, and benches may be needed in cuts higher than 10 m.
Fair.—Cut slopes ranging from 2:1 to 1:1 are recommended; flatter where rocks are intensely jointed or fractured. Rockfall may be frequent if steeper cuts are made. Locally, lenses of harder rock may permit steeper cuts, provided jointing and fracturing are at a minimum. Benching recommended in cuts higher than 10 m.
Poor.—Slopes of 1:1 or flatter are recommended. These deposits commonly exhibit a deceptive temporary stability, sometimes standing on vertical or near-vertical cuts for periods ranging from hours to more than a year. However, ultimate and sudden failure is virtually assured with such steep slopes.

Foundation **strength**

Good.—Bearing capacity is sufficient for the heaviest classes of construction, except where located (A) on intensely fractured or jointed zones striking parallel to and near moderate or steep slopes or (B) in relatively soft rock on or near moderate to steep slopes, where slip planes may develop if heavy weights are distributed over small foundation areas.
Fair.—Choice of foundation styles is largely dependent on packing of fragments (in Qa, Qt), clay content, and relation to the water table. If content of saturated clay is high, appreciable lateral movement of clay may be expected under heavy loads. If packing is poor, settling may occur. Fluctuation of the water table may cause varying stresses on foundations.
Poor.—If stabilized by dewatering or other methods, landslide deposits may provide sufficient bearing capacity for light or moderate construction. However, cracking of concrete foundations has been observed in small structures built on landslide areas. Foundations set in underlying bedrock are recommended for heavy construction, with precautions taken to guard against failure due to lateral stress.

Tunnel support **requirements**

Minimum.—Support probably required for less than 10 percent of length of bore, except where extensively fractured.
Moderate.—Support may be required for as much as 50 percent of length of bore; more where extensively fractured.
Maximum.—Support probably required for entire length of bore.

Quality as source of **aggregate** for concrete and highway surface courses

Excellent.—Shape of broken rock commonly satisfactory for packing. Strength excellent with good resistance to abrasion. Heavy wear on crushing equipment. Possibilities of alkali-aggregate reactions should be investigated.
Good.—(A) Shape of broken rock locally may be elongate, yielding low packing efficiency. Strength excellent with good resistance to abrasion. Heavy wear on crushing equipment. Possibilities of alkali-aggregate reactions should be investigated. (B) Shape of broken rock satisfactory for packing. Strength good with fair resistance to abrasion. Light to moderate wear on crushing equipment.
Fair.—(A) Slight weathering may cause incipient granulation to several tens of meters depth, so coarse aggregate may be only a small part of crushing product. Shape of broken rock generally satisfactory for packing. Strength good with fair resistance to abrasion. Moderate wear on crushing equipment. (B) Screening and washing required. Locally clay in large quantities is a deleterious constituent, especially in Qt. Locally, the presence of large boulders and cobbles requires crushing or selective pit work. Strength and resistance to abrasion variable because deposits may contain a heterogeneous mixture of rock fragments.
Poor.—(A) Contain large quantities of clay or friable rock. Strength poor with little resistance to abrasion. (B) Shape of broken rock probably largely unsatisfactory for packing. Strength excellent with good resistance to abrasion. Heavy wear on crushing equipment.
Unsuitable.—Largely clay. Bloating characteristics not investigated, but locally may be a raw material for lightweight aggregate.

Suitability as source of **riprap** and dimension stone

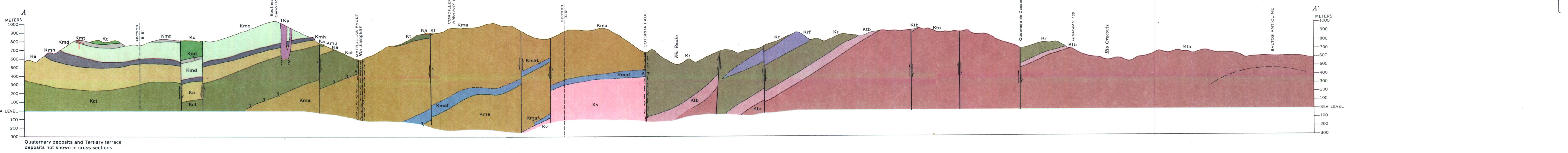
Good.—Durable high-density rock with joints commonly spaced sufficiently far apart to allow consistent removal of large blocks and from which blocks for shaping probably could be quarried without undue difficulty.
Fair.—Rock otherwise suitable but commonly with one or more of following deleterious characteristics: (A) rock only moderately durable; (B) unsatisfactory separation characteristics; (C) rock only available in limited quantities (refers to boulders in Qa and Qt).
Poor.—Largely rock of relatively poor durability.
Unsuitable.—Large masses have little or no structural integrity.

Quality as source of earth-and-rock **fill**

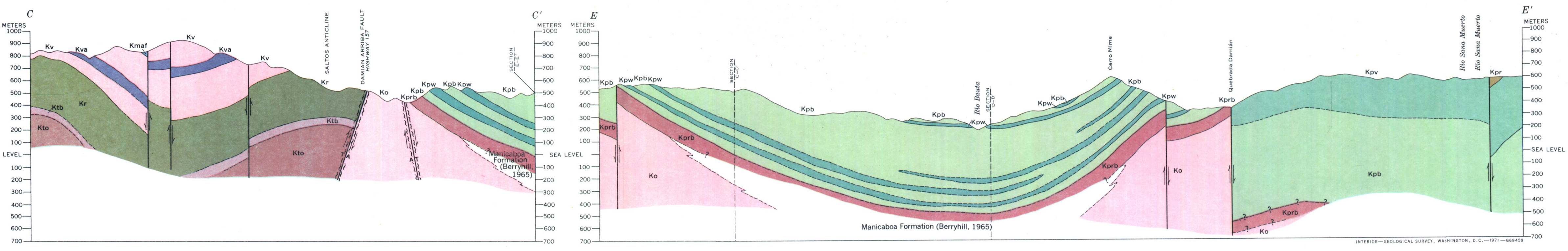
Good.—Material that when quarried will contain in addition to coarse fragments an appreciable portion of clayey fines as binder.
Fair.—Material that when quarried and crushed probably would require blending, but is otherwise satisfactory for the purpose.
Poor.—Material that would be difficult to upgrade to a suitable product.

Permeability

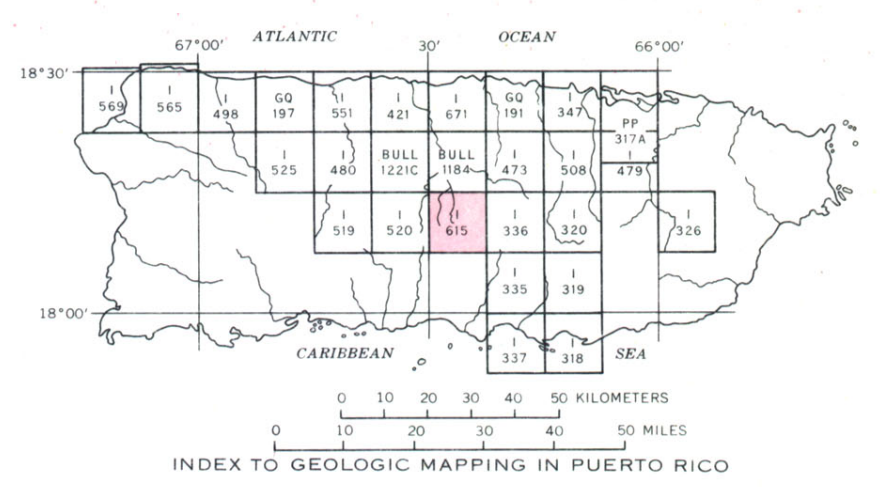
Low.—Essentially impermeable; coefficient of permeability K (Krynine and Judd, 1957, p. 182-183) probably approaches zero, except in zones of open joints, fractures, and bedding planes or in some pillow lavas and breccias where interstitial voids occur. In these cases, appreciable flow of water may be encountered.
Moderate.—Coefficient of permeability K probably less than 50×10^{-4} cm/sec (14 ft/day), except where open planar elements or voids occur with appreciable flow of water.
High.—Coefficient of permeability K for the most part probably greater than 50×10^{-4} cm/sec. In coarse alluvium, K may exceed $3{,}000\times10^{-4}$ cm/sec (847 ft/day). In cavernous limestone very rapid flow of water can occur.



Quaternary deposits and Tertiary terrace deposits not shown in cross sections



Manicaboa Formation (Berryhill, 1965)



INDEX TO GEOLOGIC MAPPING IN PUERTO RICO

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D.C.—1971—G69459

GEOLOGIC MAP OF THE OROCOVIS QUADRANGLE, PUERTO RICO

By
Reginald P. Briggs
1971

For sale by U.S. Geological Survey, price $1.50
Explanatory pamphlet accompanies map