

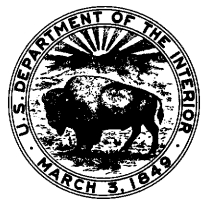
The Lower Cretaceous Figuera Lava and Fajardo Formation in the Stratigraphy of Northeastern Puerto Rico

By REGINALD P. BRIGGS

CONTRIBUTIONS TO STRATIGRAPHY

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*The Figuera Lava and the overlying
Fajardo Formation are redescribed and
assigned to the Lower Cretaceous Series*

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CONTRIBUTIONS TO STRATIGRAPHY

**THE LOWER CRETACEOUS FIGUERA
LAVA AND FAJARDO FORMATION
IN THE STRATIGRAPHY OF
NORTHEASTERN PUERTO RICO**

By REGINALD P. BRIGGS

ABSTRACT

The Figuera Lava, the oldest stratigraphic unit now recognized in northeastern Puerto Rico, and the overlying Fajardo Formation are redescribed and the name Figuera redefined and reinstated for formal use. Previously, lower Tertiary strata some distance from the type areas of the Figuera and Fajardo were correlated with the units by reconnaissance. Recent detailed mapping and paleontology now place the Figuera and Fajardo in the upper part of the Lower Cretaceous Series. The Figuera Lava is correlated tentatively with an as-yet-unnamed chemically similar volcanoclastic sequence in central Puerto Rico. Overlying this sequence is the Torrecilla Breccia, which is generally equivalent in time stratigraphy to the Fajardo Formation.

INTRODUCTION

In his report on the initial geological reconnaissance of the New York Academy of Science's "Scientific Survey of Porto Rico and the Virgin Islands," Berkey (1915, p. 61) referred to thin-bedded rocks in the vicinity of the town of Fajardo (fig. 1) as the Fajardo shales. This name was retained by Meyerhoff and Smith (1931, p. 284-288) in mapping the "Fajardo District" (an informally defined geographic unit approximating the area shown in fig. 1), and they named the underlying andesite lava unit the Figuera formation, after a point labelled Punta Figueras on recent maps.

Near Río Piedras, about 40 km west of Fajardo (fig. 1), thin-bedded rocks similar to those exposed at Fajardo rest on rocks similar in some respects to those near Punta Figueras. Meyerhoff and Smith extended the Fajardo and the Figuera to include the similar rocks at Río Piedras and assigned the Figuera and Fajardo to the Upper Cre-

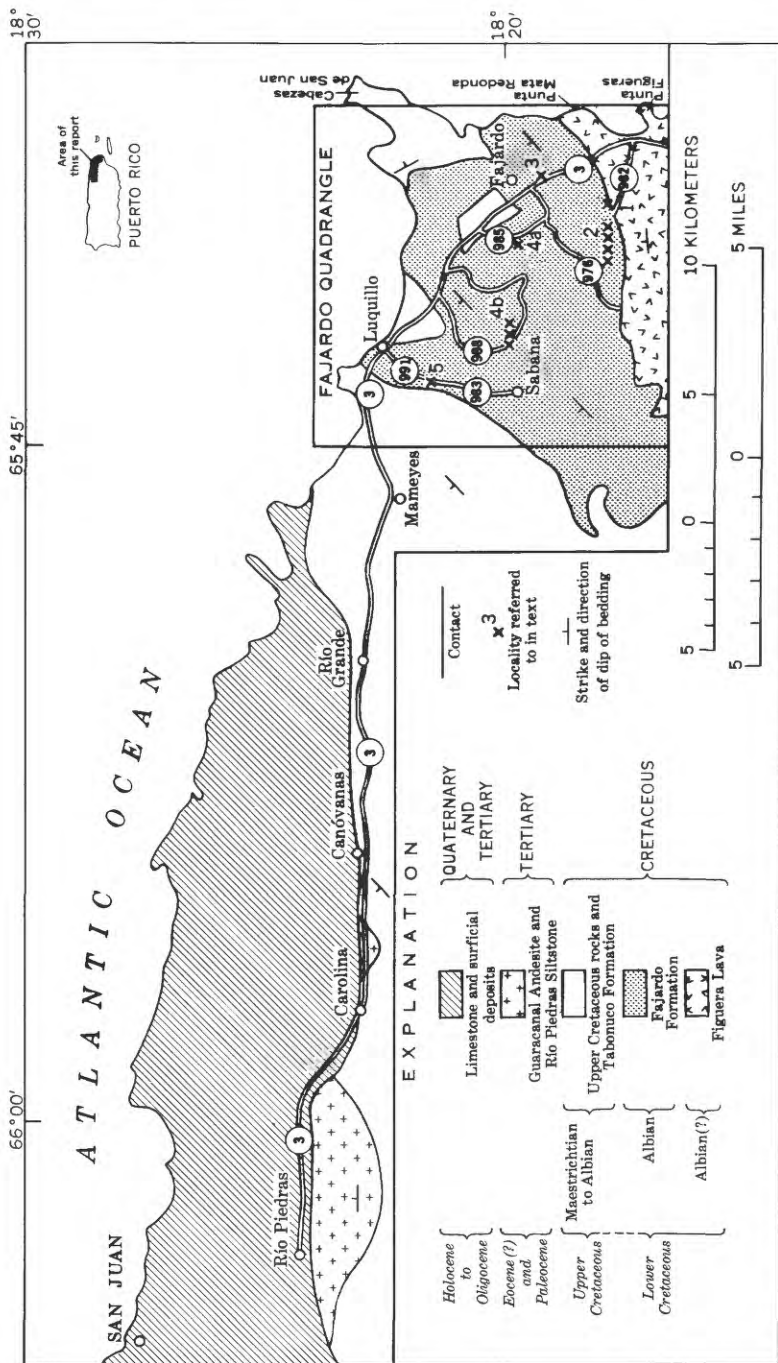


FIGURE 1.—Part of northeastern Puerto Rico showing the general distribution of the Figuera Lava and Fajardo Formation relative to younger rocks.

taceous Series. Kaye (1959, p. 22–29) accepted this correlation with reservations in his report on the San Juan metropolitan area, in which he applied the names Figuera volcanics and Fajardo formation to the rocks near Río Piedras. He referred the Figuera and Fajardo of the Río Piedras area to the Paleocene or Eocene on the basis of paleontological data more recent than those available to Meyerhoff and Smith.

More recently, a reconnaissance study by Berryhill, Briggs, and Glover (1960, p. 141–143) clearly demonstrated that the rocks at Fajardo and those near Río Piedras are unrelated. In their report, the Fajardo of Kaye was not included in the Fajardo Formation, and by inference the Figuera of Kaye also was not included in the underlying Figuera Lava. The Fajardo was assigned a Late Cretaceous age (Berryhill and others, 1960, p. 143). Pease (1968, p. 40–46) renamed the former Figuera and Fajardo of the Río Piedras area the Guara canal Andesite and Río Piedras Siltstone, respectively (fig. 1).

Detailed mapping now is complete in much of northeastern Puerto Rico, and a formal stratigraphic succession has been established for the strata between San Juan and Fajardo. Table 1 compares the stratigraphic positions formerly assigned to the Figuera and Fajardo with their positions as now known.

Other stratigraphic names used in the “Fajardo District” by Meyerhoff and Smith (1931) included the Guzmán formation, Hato Puerco tuffs, Guaynabo formation, La Muda Limestone, Río conglomerate, Luquillo formation, Trujillo Alto limestone, Juan Ascencio member of the Fajardo shales, and San Diego formation. Rocks overlying the Fajardo Formation in the vicinity of Cabezas de San Juan (fig. 1) were included in the San Diego formation (Meyerhoff and Smith, 1931, p. 289–290), but the name San Diego in current usage is applied to an entirely different rock unit elsewhere in Puerto Rico (Glover, 1961). The strata resting on the Fajardo now are included in the Tabonuco Formation (Seiders, 1971, p. 8–11). The Hato Puerco, Guaynabo, La Muda, and Trujillo Alto have been redescribed and adopted for current use by Kaye (1959), Pease (1968), and Seiders (1971). The Guzmán, Río, Luquillo, and Juan Ascencio have been abandoned.

FIGUERA LAVA

The Figuera Lava is here redefined and reinstated for a thick series of andesitic lavas that crop out in the hills west of Punta Figueras, the general type area of the Figuera formation originally designated by Meyerhoff and Smith (1931, p. 284–285).

Although recent maps label the point as Punta Figueras, a review of old maps shows a development of the name from Punta Figueroa to Punta Figuera to Punta Figueras. Meyerhoff and Smith were correct

TABLE 1.—Recent development of nomenclature for stratigraphic units in north-eastern Puerto Rico

[Kaye's (1959) nomenclature was for the southeastern part of the San Juan metropolitan area. Indicated present usage is from that area eastward along Hwy. 3 to Punta Figueras, after Pease (1968), Seiders (1971), and this report.]

Kaye (1959)	Present usage	Age
Fajardo formation. ¹ Figuera volcanics. ¹	Río Piedras Siltstone. ² Guaracanal Andesite. ²	Tertiary (Eocene? and Paleocene).
Trujillo Alto limestone. ³ Monacillo formation. ⁴	Monacillo Formation. ⁵	Early Tertiary(?) and Late Cretaceous (Maestrichtian or Campanian, possible Paleocene in uppermost part).
Frailes formation. ⁴	Frailes Formation. ⁶	Late Cretaceous (Campanian).
Guaynabo formation. ¹	Martín González Lava. ⁷	Late Cretaceous (early Campanian to Santonian).
	Canóvanas Formation. ⁸ Cambalache Formation. ⁸	Late Cretaceous (Santonian to Cenomanian).
Hato Puerco tuff. ¹	Hato Puerco Formation. ⁹	
	Tabonuco Formation. ¹⁰ Fajardo Formation. ¹¹	Early Cretaceous (Albian).
	Figuera Lava. ¹¹	Early Cretaceous (Albian?).

¹ Adopted from Meyerhoff and Smith (1931).

² Described and renamed by Pease (1968).

³ Adopted from Berkey (1915).

⁴ Described and named by Kaye (1959).

⁵ Trujillo Alto Limestone Member redefined and included in upper Monacillo Fm by Pease (1968).

⁶ In the area south of Río Piedras, Pease (1968) did not recognize the Frailes Fm, and included these rocks in the upper part of the Guaynabo Fm. The Frailes Fm, however, was recognized by Seiders (1971) in the area east of Río Piedras.

⁷ Originally described as a member of the Guaynabo Fm by Pease (1968). Raised to formational rank by Seiders (1971).

⁸ Named by Seiders (1971). Chiefly equivalent to middle and lower parts of the Guaynabo Fm as used by Kaye (1959) and Pease (1968) in the area south of Río Piedras.

⁹ Redefined by Seiders (1971).

¹⁰ Described and named by Seiders (1971).

¹¹ Here redescribed. Names retained, following original usage of Berkey (1915) and Meyerhoff and Smith (1931).

at the time of their mapping, so their form of the name is retained (American Commission on Stratigraphic Nomenclature, 1961, Art. 12(b), p. 652–653).

The lithologic term "lava" is preferred to "formation" because recent detailed mapping in the Fajardo quadrangle (fig. 1) by the present writer has demonstrated that lava is the predominant rock type of the unit. The term "volcanics" was used to describe the Figuera only in the Río Piedras area, where the name Figuera no longer is valid.

Meyerhoff and Smith designated no type section. The series of exposures along Hwy. 982 in the Fajardo 7½-minute quadrangle

between 50,740 N., 233,580 E. and 50,660 N., 233,720 E.¹ (fig. 1, loc. 1) is here so designated. In this section, fresh residual boulders of Figuera Lava are exposed in place in a matrix of weathered Figuera. The lava is composed of sparse, small (about 2 mm long) phenocrysts of plagioclase set in a very finely crystalline groundmass. Elsewhere, most of the lava is similar to that in the type section, but locally it is amygdaloidal, phenocrysts are larger (as much as 10 mm long) and are moderately abundant, and the groundmass is coarser. In a few outcrops the lava has grayish red and dark gray layers a few millimeters wide, the contacts of which range from gradational to sharp. These atypical Figuera rocks have not been examined in detail. However, they bear a superficial resemblance to welded ash-flow deposits, such as those described by Berryhill (1965, p. 51-58).

Conspicuous in the type section are veins of smoky "bull" quartz several centimeters wide. These were introduced along joints approximately parallel to as well as normal to the regional gross layering of the rocks. Smoky quartz also is present in the type section as large, apparently randomly distributed blebs.

Although veins and blebs of quartz are present throughout much of the rest of the Figuera Lava, they are not as common everywhere as they are in the type section. Quartz veins cut across pillow structure in Figuera Lava outcrops at Punta Mata Redonda (fig. 1) where interpillow material is composed chiefly of quartz. The veins and blebs of quartz in the Figuera may be deuteric rather than regional phenomena, because quartz veins are rare in the adjacent overlying Fajardo Formation. In outcrops of Figuera Lava along the southern border of the Fajardo quadrangle (fig. 1), and locally elsewhere, there also are large, widely-spaced, irregular blebs and some veins of a pale yellowish-green intimate mixture of quartz and epidote. Locally in the southwestern part of the quadrangle, the Figuera has been altered to a pyritic hornfels.

Pillow structure, although a striking feature of Figuera Lava outcrops at Punta Mata Redonda and a few other places, is not characteristic of the unit as a whole.

Lava probably makes up most of the Figuera, but lava breccia and intercalations of thin- to medium-bedded² well-stratified tuffaceous sandstone and siltstone and medium- and thick-bedded hyaloclastic tuff³ also are found within the unit. The Figuera Lava is essentially a

¹Puerto Rico rectangular coordinate system in meters. Tick marks for this system are placed on the margins of all U.S. Geological Survey topographic maps of Puerto Rico.

²Layering thicknesses after Ingram (1954): in centimeters—more than 100, very thick; 30-100, thick; 10-30, medium; 3-10, thin; 1-3, very thin; 0.3-1, thickly laminated; less than 0.3, thinly laminated.

³Terminology as used by Briggs, 1969, p. 2-6.

sequence of many lava flows, some probably several hundred meters thick and some having pillow structure, interlayered with marine volcanoclastic units ranging from very thin to tens of meters thick.

Only the upper part of the Figuera Lava is included in the Fajardo quadrangle (fig. 1); only that part has been mapped in detail at the time of writing (1972). Reconnaissance to the south suggests, however, that the unit grades downward from andesite to dacite, a chemical change similar in trend to that found in rocks of probable similar age in central Puerto Rico (Lynn Glover 3d, written commun., 1967). If the dacitic rocks to the south ultimately are not separated from the Figuera Lava, then the Figuera Lava may be the oldest stratigraphic unit exposed in northeastern Puerto Rico; the dacitic terrane to the south is highly faulted, and the base of the dacite sequence may be concealed by faulting. The present writer found no good exposures of the upper contact of the Figuera Lava. However, because the Figuera is a marine unit, because rocks in the overlying Fajardo Formation also have typical marine layering, and because the lower Fajardo contains no conglomerate, it is concluded that the contact between the two units is conformable within a continuous marine sequence.

In the Fajardo quadrangle, the Figuera Lava section is estimated to be at least 1,200 m thick. If the underlying dacitic rocks to the south are not separated from the Figuera, the Figuera Lava may total several thousand meters in thickness.

Age.—No fossils have been recovered from the volcanoclastic rocks of the Figuera Lava, and no radiometric age determinations have been made on Figuera rocks. However, the overlying Fajardo Formation probably is entirely latest Early Cretaceous (Albian), so the Figuera also is Early Cretaceous. It may also be Albian, for great thicknesses of lava can accumulate in relatively short intervals of geologic time.

FAJARDO FORMATION

The Fajardo Formation is here redescribed as the name of the thick volcanoclastic unit that underlies much of the Fajardo quadrangle (fig. 1). The general type area was designated by Berkey (1915, p. 61) and accepted by Meyerhoff and Smith (1931, p. 285–288) as the hills around the town of Fajardo (fig. 1). This type area also is accepted here, but it now is recognized that some of the area near the town is underlain by calcareous rocks assigned to the Tabonuco Formation (fig. 1; Seiders, 1971, p. 8–11).

Meyerhoff and Smith considered that thin-bedded fine-grained rocks like those at Fajardo predominate in the unit. However, a large part of the Fajardo Formation is composed of volcanoclastic rocks coarser

than those in the type area. North of a line running generally west-northwest from Punta Figueras through the village of Sabana (fig. 1), Eduardo Aguilar and the present writer were able to map four informal members in the Fajardo. These are, from bottom to top, (a) a lower coarse-grained volcanoclastic member, (b) a lower fine-grained well-stratified member, (c) an upper coarse-grained volcanoclastic member, and (d) an upper fine-grained well-stratified member. South of this west-northwest line, the Fajardo Formation was not divided because poor access and poor exposures make identification of these informal members difficult.

Member a is about 1,600 m thick, and is composed of thick- and very thick bedded tuff breccia interlayered with prominent but subordinate units a few meters thick that contain thin- to thick-bedded tuffaceous sandstone and siltstone and thick-bedded coarse tuff. The siltstone commonly is cherty. Typical rocks of member a are well exposed along Hwy. 982, between 50,870 N., 232,860 E. and 50,900 N., 232,050 E. (fig. 1, loc. 2), near the base of the Fajardo Formation.

Member b is composed chiefly of cherty tuffaceous siltstone and sandstone and ranges from about 130 m to about 500 m in thickness. As mapped by Aguilar and the present writer, it includes the type locality of the formation, placed by Meyerhoff and Smith (1931, p. 287) "one kilometer south of Fajardo." This is a small group of quarried hills centering about 54,070 N., 235,120 E. (fig. 1, loc. 3). Their description of these rocks can hardly be improved upon:

The beds are thinly stratified, and the closely spaced joints normal to the bedding planes give them a blocky fracture. Few of the layers exceed four inches [10 cm] in thickness, and most of them average about two [5 cm]. The rocks are exceedingly fine grained, and under the microscope the individual particles which can be isolated consist chiefly of angular fragments of volcanic glass, and, to a less extent, of mineral grains. The minute grains which compose the groundmass exhibit the polarization of quartz***. The buff color, which is such a striking feature of the formation in its deeply weathered exposures in the coastal areas, is due to the presence of interstitial hematite. Weathered specimens have an unusually low specific gravity, a feature which, in microscopic sections, may be traced to the abundance of cavities, formerly occupied by minute Foraminifera that have been dissolved in the course of rock decomposition.

(Meyerhoff and Smith, 1931, p. 288). The blocky fracture noted above causes development of a soil bearing small prisms of weathered rock. Exposures of fresh rock are relatively rare. Centers of some prisms in the soils are fresh and are neutral light to dark gray.

Member c is 800 to 1,100 m thick and bears a distinct resemblance to member a, except that it includes a higher proportion of thick-bedded coarse tuff and somewhat fewer and generally thinner interlayered zones of thin-bedded sandstone and siltstone. Its tuff breccias

are generally finer than those in member a; fragments are rarely more than 10 cm in diameter. No one really good section typically exposes member c, but relatively representative outcrops may be seen along Hwy. 985 between 55,000 N., 232,320 E. and 55,070 N., 232,590 E. (fig. 1, loc. 4a) and along Hwy. 988 between 55,240 N., 229,030 E. and 55,240 N., 229,780 E. (fig. 1, loc. 4b).

Member d is 170 to 250 m thick and lithologically is similar to member b, except that some cherty siltstones are black when fresh. A characteristic of member d, shared to a somewhat lesser extent by member b, is disturbed bedding interpreted as the result of penecontemporaneous submarine slump. A typical section where the thin-bedded fine-grained rocks of d are well exposed is in a quarry on Hwy. 991 at 58,130 N., 227,100 E. (fig. 1, loc. 5). In this quarry one of the better examples of penecontemporaneous slump is seen in a zone about 2 m thick paralleling gently dipping stratification. In this zone, blocks of typical sandstone and siltstone set in a clay matrix are contorted and fractured. Both member b and member d locally contain rare thick beds of tuff and fine breccia.

The undivided Fajardo south of the Sabana-Punta Figueras line contains tuff breccia, tuff, and tuffaceous cherty sandstone and siltstone, generally similar to the rocks north of the line in overall relative proportions but perhaps somewhat coarser on the average. The complex structure of the region makes accurate thickness measurements difficult, but the undivided Fajardo probably is more than 3,000 m thick.

The Fajardo Formation is largely noncalcareous, although it does contain some sporadic calcareous sandstone and siltstone beds throughout and some calcareous tuffs in the upper part of member c. The nature of its layering and the presence of marine fossils indicate that the Fajardo was deposited in a marine environment.

The report of Berryhill, Briggs, and Glover (1960, p. 143, fig. 6) can be interpreted to infer that the Aguas Buenas Limestone Member is in the basal part of the Fajardo Formation. This interpretation was not intended and has been rejected formally by the present writer (Briggs, 1969, p. 15). The Aguas Buenas Limestone Member is in the base of the Torrecilla Breccia (Briggs, 1969, p. 11-12) which is referred to in a following section.

The Fajardo rests on the Figuera Lava with apparent conformity and is overlain conformably by the Tabonuco Formation. The Fajardo-Tabonuco contact is gradational; the upper Fajardo contains some calcareous beds similar to those that compose most of the Tabonuco, whereas the lower Tabonuco contains subordinate cherty layers like those typical of the upper Fajardo (Seiders, 1971, p. 10).

Age.—The Fajardo Formation was considered Late Cretaceous by

Meyerhoff and Smith (1931, p. 266). Berryhill, Briggs, and Glover (1960, p. 143) were more specific, placing the age range of the Fajardo (exclusive of the rocks near Río Piedras erroneously so labelled) as probably Cenomanian to Turonian or Coniacian (early Late Cretaceous). On the basis of fossil collections by N. F. Sohl and others, however, Seiders (1971, p. 11) now places the overlying Tabonuco Formation in the Lower Cretaceous Albian Stage, and recent determinations from the Fajardo Formation are compatible.

W. A. Cobban identified an ammonite collected by the present writer from the Fajardo Formation type locality (54,070 N., 235,120 E.) as *Manuaniceras*, possibly *M. carbonarium* (Gabb), placing member b at "about the top of the middle Albian" (W. A. Cobban, written commun., 1967). In a collection from member d made by V. M. Seiders, Cobban (written commun., 1966) tentatively identified *Oxytropidoceras* sp., indicating a possible Albian age.

In summary, recent studies of fossil collections from the Tabonuco Formation, overlying the Fajardo Formation, place the Tabonuco in the Albian Stage (Seiders, 1971, p. 11). In the Fajardo Formation itself, one collection is quite definitely Albian, and another is suggested as Albian. Because member b, about in the middle of the Fajardo Formation, probably is middle Albian, it is not unreasonable to infer that the lower part of the formation also is Albian. However, the base of the Fajardo possibly could be older than Albian.

REGIONAL CORRELATIONS

The volcanic and plutonic terrane of Puerto Rico is divided into northeastern, central, and southwestern subprovinces by zones of large-scale strike-slip faulting across which no detailed lithostratigraphic correlations are possible (Cox and Briggs, 1973). Berryhill and others (1960, p. 142-143) proposed a general correlation of the Fajardo Formation in the northeastern subprovince with rocks of similar age in the central subprovince. Their correlation remains valid even though the Fajardo is now recognized to be Early Cretaceous rather than Late Cretaceous because the age assignment of the central subprovince rocks also has been changed (Briggs, 1969, p. 14). The Fajardo of probable Albian Age can be correlated with relative precision with the Albian Torrecilla Breccia (Briggs, 1969, p. 7-15). Similarly, the Tabonuco, Hato Puerco, Cambalache, and Canóvanas Formations and the Martín González Lava (table 1) (the sequence overlying the Fajardo in the northeastern subprovince) can be correlated generally with the Robles-Río Orocovis sequence of Albian to Santonian Age in the central subprovince (Briggs, 1971, p. 1), and the Figuera Lava, beneath the Fajardo, can be correlated with as-yet-unnamed pre-Torrecilla volcanic rocks of the central subprovince.

At this time, no reasonably precise unit-for-unit correlations can be made between the Cretaceous of the northeastern subprovince and the Cretaceous of the southwestern subprovince.

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