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OF THE INTERIO
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PROJECT REPORT

Colombia Investigations
(IR)CO-32

GEOUOGY OF QUADRANGLES H-12, H-13, AND PARTS OF 1-12 AND I-ll, '"

Prepared in cooperation with the ^
Instituto Nacional de Investigactones Geol6gicos -Mineras under the auspices of the Government of Colombia
|i and!" the Agency: for International; Development
. Department of
Sf^'.W-.-.-.«(,- .;".:'" t' ;*-, ' *«&*&
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0^ S^ Geblogicaf Survey %*i>fv.^
OPEN FII£ REPORT W- &&

report is preliminary" and^has notr ten edited or reviewe4 fot confer- j mity "with Geological Survey standards or nomenclature

GEOLOGY OF QUADRANGLES H-12, H-13, AND PARTS OF 1-12 AND 1-13,

(ZONE III) , IN NORTHEASTERN SANTANDER DEPARTMENT, COLOMBIA

By

^

Dwight Er Ward) and Richard Goldsmithj U. S. Geological Survey

and

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< CONTENTS

ABSTRACT .... INTRODUCTION ....

History of the project
Acknowledgments .... Geography ....
, Location and access. ...... Topography, drainage and climate
Culture. ....
Exposures. ....
Previous work .... Present investigations. .... Definitions and usage......
.Rock classifications. . . .
ff||^>^: Locations. .... PRE-DEVONIAN METAMORPHIC ROCKS ......

f::,lj*ijfi Bucaramanga Gneiss. .... Definition .... Distribution .... Description. ....
Age and stratigraphic relations. Correlation. ....
^Silgara Formation . .X.£"' ...... V4--' ;..&-" " .;-. -^'/ '(.' '+..'. . ^ .. '
Definition . * . . . .

y ivi;.'?-/'. .- Distribution ....

Page
1
9
10
11
14
14
16
20
22
25
28
32
32
34
35
35
35
35
35
45
49
50
50
50

Page
, Stlgara* Formation cont'd. .... Thickness. .... Qiiebrada Silgara .... Piedecuesta-Aratoca belt .... Pamplona Chitaga area. ....
/
Berlin-Silo-Mutiscua area. ....

/ Relationship of the Silgara Formation to the

Bucaramanga Gneiss ....
Age and correlation. .... Orthogneiss" .... Definition .... Distribution ....
Contacts ....

Description. .... Summary..........................
> Age ....
IGNEOUS ROCKS. ....

Batholiths and plutons. ....
t Dibrite and tonalite i
|J . Diorite of Rio Guaca. .... ^;>-^': - /
Diorite and tonalite %of Rio Surata area ......
r Fine-grained tonalite ....

;;-i»Vr , -

ft V Age and correlation ....

'?f'v' ~ o:; . -. . Tonalite and grandiorite of the Paramo Rico Pluton.
La Corcova Quartz Monzonite. ....
Quartz monzonite, granite and quartz porphyry. .....

51
53
56
60
61

65
67
70
70
72
74
75
82
83
85
89
89
89
90
92
93
93
97
102

ii

Page
, _ f
IGNEOUS ROCKS--Continued ....- Batholiths and Plutons cont'd.-.........
Durania Granite ......,....... 104
Santa Barbara Quartz Monzcnite. 106
Pescadero Granite ....« HI
The Mogotes Batholith .... 115 Quartz monzonite of the Mogotes batholith .... 116 Granodiorite of the Mogotes batholith .... 117 Age of the quartz monzonite and granodiorite
of the Mogotes batholith. ....-.'.. H9
Rio Negro batholith .... 120 Granodiorite of the Rio Negro batholith .... 121 Quartz raonzonite of the Rio Negro batholith ...... 132 Rhyolite in the Cocas Formation 134
Dikes. .... 135 Felsic dikes. 136
Mafic dikes .... 137 Lampropfiyre dikes 137
Dacite porphyry 137
H Basalt and diabase. .... 138 Age of dikes. .... 139 Structure of the igneous rocks 140
SEDIMENTARY ROCKS 143

; j, Devonian system. .... 144 <|? Floresta Formation. .... 144 Metamorphosed Floresta Formation 146

lii

- Page
SEDIMENTARY ROCKS continued .... Carboniferous, Permian and Triassic systems 150
Surata Group 150
Diamante Formation. 151
Tiburon Formation 164
Bocas Formation 172

Jurassic system 186
Jordan Formation 186
Giron Formation. 201
Cretaceous system, Middle Magdalena Valley section. 214
Tambor Formation .... 1 . . 216
Rosa Blanca Formation. 225
Paja Formation 234
Tablazo Formation. 238
Simiti Formation 245
Salto Formation. 247
La Luna Formation. 249
Umir Formation 262
Cretaceous system, Maracaibo section of Colombia. ..... 265 Uribante Group ....'........... 265
Tibu and Mercedes Formations. 266
Aguardiente Formation 272
Capacho Formation 276
La Luna Formation 281
Colon and Mito Juan Formations. 297

iv

Page
SEDIMENTARY ROCKS continued .... Tertiary and Quaternary, Middle Magdalena Valley section. . . 301 Lisama Formation .... 302 Chorro Group 303
La Paz Formation. .... 303 Esmeraldas Formation. 314
Chuspas Group. .... 317 Mugrosa Formation 317
Colorado Formation. 318
Real Group .... 329 Mesa Group .... 330 Tertiary and Quaternary, Maracaibo Basin, Colombia 338 Barco Formation. 338
i
Los Cuervos Formation. .... 340 Mirador Formation. .... 342 Carbonera Formation. .... 344 Surficial deposits. .... 347 Glacial deposits 347
Terrace and alluvial fan deposits. .... 350 Colluvial deposits 354
Alluvium .... 355 METAMORPHISM 356

Regional dynamothermal metamorphism .... 356 Bucaramanga Gneiss .... .357
Silgara Formation. 361
Floresta Formation .... 363 a

METAMORPHISM continued. .... Regional dynamothermal metamorphism cont'd. ....
Orthogneiss. 364
Retrograde rnetamorphism 365
Contact metamorphism. 367
Summary and discussion. 3o8
STRUCTURE. 371

Structural features of the metamorphic rocks. 371
Structural trends and major structural features 374
Bucaramanga-Silgara-Cepita belt. 375
Piedecuesta Aratoca-Mogotes belt. 376
/ ,
Berlin-Vetas-Paramo Santurban area 377
Pamplona-Chitaga area. 378
Baraya-Guaca-San Andres belt ....'...... 378
Summary. 379
Lineaments.......................... 380
Mylonite. 381
Faults of pre-Cretaceous age. 384
Bucaramanga fault 386
Structural features east of the Bucaramanga fault 393
Western flank of the Santander massif. 394
Surata'fault. 395
Cristalina fault. 397
Tona fault. 397
Picacho syncline. 398
Picacho and Scvilla faults. 398
t ' » ^
Rio Manco, Rio Umpala and Rio Perchinquez faults. 399

vl

1

Page
J
STRUCTURE--continued ....

Structural features east of the Bucaramanga
fault cont'd. ....
Eastern flank of the Santander massif. 400
/ >
Mutiscua and Rio Sulasquilla faults 401
Laguna fault. 402

Socota and Angosturas faults. .... 402 \
Morro Negro fault and Carbonera syncline. 403

Babega fault. 404
Pamplona fault. 405

Chitaga' fault 405
Pamplonita syncline 407
Central area of the Santander massif 408
/
Rio Cucutilla fault1 408
f
Rio Charta fault. 409
Ventanas fault. 409

Servita fault 410
t

. Malaga structural basin 411

Baraya fault 413
Alto de Guaca fault. 413
Morro Las Penas fault. 414
/ /
Rio Listara fault. 415

Angosturas syncline. 415
Cerrito structural basin. 416

Structural features west of the Bucaramanga fault 419
Suaroz fault 420

vil

STRUCTURE Continued .... Structural features west of the Bucaramanga fault, cont'd .
Mesa area. 422
Plateau area west of the Suarez fault. 424
El Espino fault 425
La Plata and Rio Negro faults 426
Middle Magdalena basin .... 427 Pre-Tertiary belt 427
Solferino fault. 428
Sardina fault. 429
/ /
Rio Cachira fault. 429
Lebrija fault. .... 430 Vanegas structural embayment .... 431 Vanegas anticline .... 431 Vanegas syncline and Cuestarica fault . 432 Arevalo syncline. 432
Rio Sucio anticline and Naranjo syncline . . 433
San Vicente faulted and folded area. 433
Nuevo Mundo sync.1 ine and La Salina fault . . 434
. Las Monas anticline 435
Provincia fault 435
Provincia anticline 436
GEOLOGIC HISTORY 437
REFERENCES CITED 454

viii

ILLUSTRATIONS
Page
Plate 1. Geologic map of quadrangle H-12, H-13, and
parts of 1-12 and 1-13. .... In pocket
Figure 1. Index map of the report area. 9a
2. Index map of quadrangles and their subdivision
of the southern half of Zone II 9b
3. Cross sections along Bucaramanga to San Gil highway,
. Santander, Colombia from Rio Chicamocha to
Aratoca (see Plate I) 52a
4. Distribution of igneous rocks, southern half
of IMN zone III. 72a
5. Histograms showing estimated modes of minerals
i

in igneous rocks 75a
6. Frequency of thin sections of igneous rocks 79a
7. Section along ridge west of Alto El Portachuelo . . 148a
8. Type locality of the Giron Formation. 202a
9. Age and nomenclautre of Cretaceous and younger
Formations 214a
10. Diagram of the environment of deposition of
the facies of Rosa Blanca Formation 233a
11. Pattern of faults and lineaments in the vicinity
of the Bucaramanga fault 386a

ix

TABLES
Page

Table 1. Location, analytical data, and calculated whole-
rock Rb-Sr ages of samples collected in the
Santander and Norte de Santander, Colombia^ . . . .
2. Location, analytical data, and calculated K-Ar
ages of samples collected in the Santander
massif, Santander and Norte de Santander,
Colombia. ....
3. Mineral assemblages of metamorphic rocks, southern-half of Zone III, Santander and Norte de
Santander, Colombia ....
4. Summary of the geologic history of the Santander Massif, Colombia. ....

46

47

358

438

GEOLOGY OF QUADRANGLES H-12, Hr-13, AND PARTS 0? 1-12 AND 1-13, (ZONE III), IN NORTHEASTERN SANTANDER DErARTMLUT, COLOMBIA By
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ABSTRACT

A program of geologic mapping and mineral investigation in
Colombia was undertaken cooperatively by the Colombian Institute Nacional de Investigaciones Geologioc-Mineras (formerly known as che Inventario Minero Nacional), and the U. S. Geological Survey, sn
by the Government of Colombia and the Agency for International Develop ment, U. S. Department of State. The purpose was to study- and evaluate mineral resources (excluding of petroleum, coal, emeralds, and alluvial gold) of four selected areas, designated Zones I to IV, that total

2 about 70,000 km. The work in Zone III, in the Cordillera Oriental,

was done from 1965 to 1968.
The northeast trend of the Cordillera Oriental of Colombia
swings abruptly to north-northwest in the area of this report, and divides around the southern end of the Karacaibo Basin. This section of the Cordillera Oriental is referred to as the Santander Massif.

The effects of Precambrian regional dynamothermal rcetainorphism and
i i
plutonism on Precambrian geosynclinal deposits reached thn upper
i
amphibolite facies in the Bucaramanga Gneiss. The geosynclinal
Silgara Formation was subjected to similar conditions
5- -in Late Ordovician and Early Silurian time but reached only the green-schist or lower amphibolite facies. Orthogneisses generally show a
i
; .concordance of foliation and lineation with the neighboring Silgara Formation and the Bucaramanga Gneiss , as well as similarities in i " grade of metamorphism. Regional dynamo thermal metamorphism in Late
Jo- Permian and Triassic time reached, low grade in the Floresta Formation
and caused recrystallization of limestone of the Diamante Formation.
The Bucaransanga and Silgara metamorphic rocks show evidence of retro-

gressive metamorphism accompanied by high activity or potassium and water, but whether this occurred at the time the Floresta was metamorphosed or later is not clear.
Batholiths, plutons, and stocks of igneous rocks in the Santander
massif range from diorite to granite. Radioactive age data indicate
that most belong to a single plutonic interval. These are
referred to as the Santander Plutonic Group and are
Jurassic and Jurassic-Triassic. Two suites of this group are pink granite and quartz monzonite, and gray quartz monzonite and granodiorite. Con-
; tact relations indicate that the pink and more granitic rocks are
younger than the gray and more mafic rocks, but radioactive age data
,. **e in conflict with this. Undated plutonic rocks that are not clearly elated to the group are assigned to relatively older or younger aqe
. Positions.

3

West of the Bucsramanga fault rhyolite makes up a small body
at one locality and fonns an intrusive sheet with granophyre and in-trusive breccias in Triassic sedimentary rocks at another locality. Its age is unknown, but it probably is younger than the Santander Plutonic Group.
Felsic, mafic, and lamprophyric dikes are common in the batho-
liths, plutons, and adjacent rocks, and most appear to be genetically related'to the larger igneous bodies, whereas rarer dikes of dacite porphyry, basalt, and diabase are not related. Basalt and diabase dikes are widely scattered and have been found nearly as high in
the section as the Jurassic-Cretaceous boundary. Dacite porphyry
is the only igneous rock that intrudes Cretaceous rocks.

10-

!2

With the uplift that accompanied emplacement of batholiths in
Latest Triassic and Jurassic time, erosion of the roof rocks furnished fine-grained redbeds and conglomerates of the Jordan Formationjfollowed
by erosion of the batholiths themselves that provided the coarse-grained and conglomeratic arkosic sediments of the Giron Formation in thick accumulations off the flanks of the uplift. This period was followed
j by marine invasion and sedimentation of the Cretaceous period. In the : I

iMagdalena Valley area, Lower Cretaceous sedimentation began with i i ;quartz sands of the Tambor Formation and continued with fossiliferous i i
«limestone of the Rosa Blanc a Formation, black shale of the Paja Forma - ; tion, fossiliferous limestone, glauconitic sandstone and black shale
i f'
i of the Tablazo Formation, and still more black shale of the Simiti Formation. In Late Cretaceous time, calcareous black shale with chert
, and phosphatic beds in the upper part of the La Luna Formation were
i
deposited during the time of most widespread marine transgression. Thereafter gray shale and limonitic beds of the Urair Formation
, accumulated as marine conditions were gradually succeeded by continental , deposition including coal beds in the latest Cretaceous.
i
Cretaceous deposits over the area are mostly uniform in character
if not in thickness, and remnants of these rocks that have escaped erosion in the massif are similar to the Cretaceous rocks of the
1 Magdalena Valley to the west and the Maracaibo Basin to the east.

5

West of the Bucaramanga fault are three areas of rather distinct structural character: 1) A wedge-shaped, down-faulted block between the Bucaramanga and Suarez faults is mostly an area of mesas, tilted slightly westward, and capped by basal Cretaceous sandstone. At the thin north end of the wedge, Quaternary gravels and mudfows accumulated in the fault-formed basin and now form the dissected terrace on which Bucaramanga, the main city of the region, is located. 2) A plateau belt bordering the mesas west of the Suarez fault consists mostly of dissected beds, undu-lating to steeply dipping, of the thick Giron Formation. 3) West of the plateau area all sedimentary rocks from Jurassic to Teritary plunge westward into the deep trough of the Nuevo Mundo syncline. This narrow syncline is on the deeper eastern side of the geosynclinal area of the Magdalena Valley basin. Most of it is separated from the shallower
part of the geosyncline to the west? by the north-trending La Salina fault, which places Upper Cretaceous rocks on the east side in contact with Oligocene and Miocene rocks on the west.
1 In the high country that continues south and east of the metamorphic and igneous rocks of the Santander massif, two north-trending structural basins are separated by the regional Servita fault. The western basin contains sedimentary rocks ranging from Devonian to Upper Cretaceous
and is complexly faulted.. Rocks of the eastern basin range from Lower Cretaceous to Eocene and have undergone congressional folding that is intense toward the west. I

5-

Kany faults were napped to t:he east and west of the Bucaramanga
: fault, and many more are indicated by lineaments on aerial photographs. Most have trends within a range of north-northeast to north-northwest, mostly parallel to the trend of structure. Only a few major faults cut across this trend. On the east and west flanks of the Santandar
i massif, belts of sedimentary rocks that include mostly Cretaceous
1 formations have escaped erosion on the downthrown sides of long faults.
I On the east flank the downthrown sides are on the west, and on the
' , west flank the downthrown sides are on the east, which suggests either
; - ' more active uplift of the flank areas or collapse of the central area
! ; relative to the flanks.

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INTRODUCTION

Purpose and scope
The southern half of Zone III of the Colombia Inventario Minero
Nacional (IMN) , is principally in the Department of Santander, but also embraces small parts of the neighboring Departments of Norte
de Santander and Boyaca (fig. 1). Zone III is one of four areas in Colombia selected for mapping and field investigations. The work was conducted by the Inventario Minero Nacional, now included as part of
the Institute Nacional de Investigaciones Geologico-Mineras (INGEOMINAS) , an agency established under the Ministry of Mines and Petroleum of the Colombia Government to work in collaboration with the United States Geological Survey (USGS). The work was partly financed by the Agency for International Development, U. S. Department of State.
This report is concerned with the southern half of Zone III
and summarizes results of mapping and investigations made during the. period October 1965 to September 1968. The area covered includes all or parts of four quadrangles of the Colombia Gauss grid system:
H-12, H-13, 1-12, and 1-13 (fig. 2). The geology of the area is shown in plate 1. The total area mapped is 10,370 square km.

History 01 r.ne rnrgjecc
Four Colombian geologists and a USG3 advisor (D. E. wsrd), began
field work October 30, 1965, in Zone III. The group was very fortunate. to have the company of Dr. Jaime de Porua, geologist of the Unlversidai Industrial de Santander, on initial trips to become familiar vith the sedimentary geology. Richard Goldsmith, advisor in igneous and meta-morphic geology, joined the group in December 1966. The number of geologists assigned to the Zone III area ranged from 13 to 17.
In January 1966, field work was started in the Surata area northeast
of Bucaramanga. From there the mapping was expanded into the surrounding area by assigning specific areas to each geologist. Also in 1966, a photogeologic map of Zone III was completed by Geophoto Services, Inc., under a contract with IMN. In the later part of the contract period, all geologists in the zone were assigned to a one-month field check of the preliminary photogeologic maps. Although deep weathering, vege-tative cover, and locally complex structure prevented accurate photo-geologic mapping of many parts of the zone, the final photogeologic maps were helpful in field mapping and in interpretation of regional structure.

A reconnaissance of phosphate rock in Colombia was made in
the second half of 1966. When it became evident that major resources
of phosphate rock are present in Zone III, phosphate investigations
were later assigned to a separate group within IMN.

II;

Achno ?« n^n 1 3

§-~

The material presented in this report was gathered by the folio-wing geologists of IMN -IKGEOMINAS who worked
much of the time under difficult conditions, and "but Tor vhose perserverance and enthusiam the report vould not have "been possible;

< !

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From

October 29, 1955
August 10, 1967
October 29, 1965
February 10, 1966
February 2, 1966
. December l6, 1965
January 8, 1968
February 10, 1966
January 10, 1967
July 10, 1967 "
January 10, 1967
September 10, 1967
June 10, 1967
February 6, 1966
October 29, 1965
June 10, 1966
October 29, 1965

IP-
December 1969
Present
Do.
Do,
Do.
Do..
Do,
Septerriber'10, 19&7
September 10, 1967
September 1^, 1968
June 15, 1968
July 15, 1968
February 15, 1968
December 31, 19&7
October 31, 1367
January 9, 1967
December 31,

11

- Smaller unpaved roads cross the range in the southern part of
the zone to connect the main highways. The piedmont slopes to the Magdalena in the northwestern part of the area (H-12) on the
western side of the Magdalena Valley are relatively inaccesible.
The right-of-way of the Ferrocarriles Nacionales which passes down the Lebrija gorge to the Magdalena Valley provides some access to this country. Short dead-end roads lead from the principal roads to some
of the smaller towns.
Most of the area between the roads is accessible only by
mule, horse, or foot. No place in the zone is more than a day's
ride or walk from a road.

IT,

Topography, drainage, and climate
The southern half of Zone III can be divided into ueve.ral topo-graphic regions. (1) One is the massif proper which comprises the main high range, and slopes to east and to the west as
far as the break in slope at the Bucaramanga
f
Front. (2) Another is the somewhat lower drainage basin of the Rio Chicaraocha to the south and southeast. Altitudes of ridges in this basin range from 2,000 to 2,600 m, whereas the river flows from 1,200 to 500 ra northwesterly across the range. (3) Another region includes the mesas which extend from Bucaramanga to the southern limit of the zone and which border the main high range and the Chicamocha basin on the west. These, are, from north to south, the Mesa de Ruitoque, Mesa de Los Santos, and the Mesa de Barichara; they range from 2,250 to 1,300 m. The basin in which Bucaramanga lines at about 1,000 m and the valleys between the mesas are considered to be part of the region of the mesas. (4) A fourth region includes the plateaus west and northwest of Bucaramanga and west of the region of the mesas, and the ridges and valleys west of the plateaus. General altitudes
here are 1,200 to 1,000 m. (5) The fifth region is the Magdalena Valley, at an altitude of 100 m. -

The massif forms a three-way divide between the Rio Magdalena

/ / drainage to the Garribeon Sea on the west, the Rio Zulia-Rio

Catatumbo drainage into Lake Marac aibo and the Caribbean Sea on
/
the northeast, and the Rio Orinoco and the Atlantic Ocean on the

east. The principal rivers draining the massif into the Magdalena / / '
are Rio Chicamocha and Rio Suarez which combine to form Rio

Sogamoso west of the Mesa de Los Santos (pi. 1). Only a small part /
of Rio Suarez lies within the zone.

/ / / North of the Rio Chicamocha-Rio Sogamoso drainage is Rio

Lebrija with its major tributaries: Rio de Ora, draining the mesas
/
and the front of the massif south of Bucaramanga, and Rio Surata,

Rio Negro, and Rio Cachiri draining the west front of the massif north

and northeast of Bucaramanga.

Rio Chicamocha is the dominant stream draining the southern

part of Zone III. It flows roughly northwest out of the massif*
/
its larger tributaries, Rios Manco, Umpila, Perchiquez, Guaca, and
/
Servita flow into it from the north and north-east. Only Rio Onzaga

flows into it from the south. South-flowing Rio Servita is the largest

tributary of the Chicamocha and drains much of the east side of the

zone.

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t anv nivcr, Mtit.uci? th tc^rseratur? c'ran-ins little rith fie
The ranno indiurnal temperature varies only slightly from
clouc'y to sunnv se?snn. ?.e an 'annual t^r^oraturss at altitudes lov;r=r than 3ucaran*nnqa at 1, 0 caters ranqe fror> ?:>° to ?.7°C. T>r«Teratur2S at'oucaramanga ranne from rf-^S'C. In tlie liinh paVano,at altitudes
of 3200 to 3,500 notcrs, mean-annual tGrnperatures are 7°to 10°C. Rainfall varies seasonally and in total amount from nlace to ']
:, place. In the Bucaramanga aroa total annual rainfall is about 1,000
. X

to 1,500 mm. in t'.i^ canyon of lio Chicapoclia, annual rainfall is
about 500-1,000 mm. Only on the higher flanks of the range and in the southern part of the zone is annual rainfall about 1,500 to 2,000 mm. The largest amount of rain throughout most of the zone falls in two seasons with maxima in May and October. Little rain normally falls during December, January, and February. '
The paramo is cloudy during most of the year. Precipitation is
sometimes in the form of snow at elevations near 4,000 meters or higher. However, no records are available for this area. Sub-freezing temperatures are not uncommon during the clear nights of the
dry season.

19

Cult'ire

T;ucara>nanra '.:ith a population of a hout 22n,"'T: (I rj4) is the largest city in the zone and is thr- center for industry, trade, and transportation, "'enijiarly scheduled airline service is available with other cities of Colonel a an^ v/ith sons smaller towns in Santander' and "'orte de Santander. Hood roads connect riucara^jv-a v.'ith '3o?ota, the cities of t!ie Caribbean coast and with Venezuela to the northeast. A branch line of the Ferrocarriles ^acional de
*

Colonbia connects 3ucara:nanna vith tlie main Jogota to Santa M.arta line in the ;!ancaler,a "alley.
In Norte de Santander, Pamplona, an educational center of
about 20>n^0 inhabitants, is the next larr«st city in the rnutVrn half of Zone III. >! umerous smllcr tov?ns of less than 7,^0^ inhabitants arp scattered over the zone mainly near ?ucarar.anna
/

and to the southeast in the u nper reaches of Rio Chicamocba and its tributaries, ".ost of the nonulation is rural. The T.ost thinly
/
oonulated sector is the hinh narano above 3^200 meters and the zone of cloud forest K °lc'/ tMs, d.o"n to about P.TI raters. The hull' o^
^se nonulation lives at r.ltit'.Hes '^eloi 1 TO neters.

onu u

Exposures
The slopes of the range vary froin heavily wooded to cleared
with many small farms. The lower limit of forest is apparently being driven upward as the expanding rural population clears land
for new farms at continually higher elevations. Cloud forest is
now largely limited to the less accessible areas above 2,500
This wooded zone between the treeless paramo at about 3,100
and the cultivated lower slopes has been breached at many places, : usually in the areas of major roads. More forest remains on the west slope of the range than on the east slope within Zone III, except in the headwaters of Rio Cucutilla in northern H-13. Exposures are poor in the forested areas and movement is extremely difficult. Slopes are steep and streams are usually choked with vegetation.
Some streams have abundant outcrop, but others are filled with rubble. Cascades and waterfalls are common in small streams and at the headwaters of nearly all streams,making ascent difficult.
Deep weathering is characteristic, with the greatest depth of ; weathering on hilltoos and snurs at elevations of 1500 to 2500 meters. This was particularly noticed along the Bucaramanga front. Somewhat fresher rock is exposed on lower slopes along the front near Bucaramanga where erosion is currently active.

The canyon cf Rio Chicamocha and the drainage area around it lie
in a partial rain shadow and the climate is semi-arid. Here the vegetation is sparse and xerophytic, the soil less deep>and outcrops somewhat more abundant. In part, of course, the relative abundance of outcrop is the result of the deep dissection by the river. The barrenness of much of the Chicamocha drainage area east and southeast of Pescadero is due in part to high permeability of the granular soil derived from granite. However, south of the Chicamocha basin at higher elevations there is more rain,and the forest cover increases. The extreme south part of the zone is heavily wooded and exposures are poor.
The southeastern corner of the zone north and south of
Malaga is relatively open with little forest. This is primarily farming country,and exposures and access are relatively good. Local relief, however^ is as much as 1000 meter.
The country above the tree line (about 1100 meters) is relatively open. Outcroos are fairly abundant,especially in the more dissected parts and where glaciation has scoured off weathered rock.
Alluvial fill of Pleistocene and llolocene age covers bedrock
fn some of the larger valleys and basins, such as in the Bucaramanga basin, in the Guaca area, and near Mogotes. However, as most valleys are narrow with steep sides,such fill is not generally a problem.

The area of mesas south of Bucaramanga offers good exposures
in open country, readily accessible except for some of the steeper canyons walls of Rios Chicamocha, Suarez, and Sogamoso and their tributaries. The plateau country west of Bucaramanga is similarly open, at least in the Lebrija area. However, farther north, west,and northwest, the country is extensively covered with brush and forest on the slopes. Farms are mainly on the ridges. Rio Lebrija and its tributaries have cut canyons into this country with slopes covered in part by forested land-slide debris. Exposures are good in
many of the gorges, but they are rather inaccessible. The
railway right-of-way provides access down the Lebrija gorge. Toward the Magdalena Valley farms alternate with forest and the climate is hot and humid.

Previous^ VJork
The gold mining area of California and Vetas has been known
and worked since the 16th Century, and was apparently worked by Indians in pre-Colombian times. An entertaining as well as scholarly summary of the literature on gold region in Santander prior to the 20th century has been made by V5_cente Restrepo (1888, republished in 1937). Mention is made of the mines, but with little detail, by Modes to Bargallo (1955) is his book on mines and mining in Spanish America during the Colonial epoch.
Recent literature on economic deposits in the zone is not particularly extensive. Many of the reports are general or summary reports such as those by Sinqewald (1950) and l.'okittel (1957) in
which mineral localities were reported from a variety of secondary sources. Radelli (1961) in a theoretical paper attempted, to relate
the epochs of mineralization with magmatic deposits over the entire Colombian Andes.
Host of the studies are of individual mines or prospects,
investigated briefly, such as the report by Gilberto Botero R. (1945). A few individual mines or prospects were investigated intensively.
The gold mining area of California and Vetas has received by far tha
most attention (Wokittel, 1954; Nelson, 1955; Pagnacco, 1962; Arce,
1951; Bueno, 1955a, I955b; Champetier de Ribes and Alvarez, 1961). Reports on nonmetallic minerals in Santander have been made by Martinez (1962,
1964) on lime, gypsum, and barite deposits; and by Jimeno and Yepes
(1963) on gypsum deposits near Los Santos. A survey of phosphate
deposits of ColonMa by Cathcort and 7a:,ihr-ino (1067), with rof^ronco
to the denosits within the i-i.»o <Troa has ! r> on recently nuhlishod. 2f)

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Relatively little work has been done op. the general geology of the Santander massif. Until recently only passing references have
been made to the geology of the nassif by Hettner
(1892), Stllle (1907), Cugster (1922), Scheibe (1938), Oppenheim (1914), and Trumpy (1943). These men either made brief tours or described areas of the Eastern Cordillera primarily south of the Santander massif. Hettner (1892, p. 15-30) gives an excellent account of the early discoveries and scientific expeditions into the Eastern Cordillera and describes briefly two profiles across the area of the Santander massif. More recently Burgl (1959, 1961, 1964) and Radelli (1961, 1962) have made observations on the stratigraphy of the Eastern Cordillera including the Santander region. Julivert (1958, 1959, 1961a, 1961b, 1963) is probably the first to do any detailed geologic work in the massif. Some of his work deals with the structure and crystalline rocks of the massif, . particularly the area near Bucaramanga. This work is summarized in a recent regional synthesis (Julivert, 1970).
Probably the first map to show the geology of the massif was
the 1944 Geologic Map of Colombia compiled by the Servicio Gcologico Nacional at a scale of 1:2,000,000. A later revised edition of the nap compiled by H. Hubach and L. Radelli with the cooperation of
H. Burgl, was published at a scale of 1:1,500,000 in 1962. These maps are, of course, very general.

Mapping of small areas near Bucaraniar.ga has been done by faculty and students of the Universidad Industrial da Santander. Recent maps at a scale of 1:50,000 chiefly of sedimentary rocks have been made by Oulivert, Barrero, and Navas (1964) in the Hesa de Los Santos area and by Tellez (1964) of the contiguous Mesa de Barichara area to the south. More recently, F. Cediel (1968) has
^ '

made a study of the Giron Formation at the type section along Rio Lebrija and in adjacent areas.
The areas of sedimentary rocks in and flanking the Magdalena Valley have been studied intensively by geologists of oil companies holding concessions in the region. Although not published, their work has been incorporated in the geologic maps of Colombia (Servicio Geologico Macional, 1944, 1962).

Present investigations
In order to provide a systematic and adequate geologic
background for evaluation of possible mineral deposits encountered in the zone,a program of regional geologic mapping v/as established. The mapping was done by geologists; each assigned individual planchitas measuring 10 to 15 km. Base maps used in the. field and for primary compilation were preliminary topographic maps at a scale of 1:25,000, and contour interval of 50 meters or 25 meters published by the Institute Geografico Agustin Codazzi, Bogota. Field mapping was expedited by use of aerial photographs at a scale of 1:60,000.
One yeologist, usually with an assistant, mapped a planchita in from one to two, or rarely three months. The time spent per planchita depended on access, relief, complexity of the geology^ and the exoerience of the geologist. The field assistant arranged for local guides, handling mules, clearing trail, trans-porting samples, and other tasks. Periods of field work
lasted 20 to 30 days but at times lasted as long as 50 days.

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Traverses were made along trails and streams. Trails are
abundant and provided rapid coverage. However, generally only
weathered rock can be seen and outcrops are few and generally
slumped. On the other hand, the soil and rock chips exposed and
churned up in the trails by the hooves of horses and mules provide
a fairly continuous look at the lithology of underlying rock, if not at the structure.
Streams were variably useful. Some are so steep and filled with brush, and cascades and waterfalls are so common, that the time spent on such a stream did not justify the result of the traverse. Some streams have abundant outcrops, but others are filled
with alluvium or colluvium. In some places adjacent streams show quite opposite characteristics. The larger streams, excluding
the main rivers, at low altitudes were the easiest to traverse.
At low water these are more satisfactory than at high water,
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when outcrops are covered and the swift current and large volume of water prohibited wading. In general, the smaller streams and the heads of streams are too steep and forested to be of use in traverse.
Streams in the high paramo, where not filled with terrace or glacial deposits, provide excellent exposures. The dissected paramo in the north part of the area offers good exposures, but steep gradients of streams in the headwater areas and the jagged character of the ridges considerable scrambling necessary.

About 700 thin sections were made; however, few geologists had
the time or petrographic training to make a study of them, tfost petrographic description was done by the technical advisors. Photogeologic maps of the zone at a scale of 1:50,000 were
prepared under contract by Geophoto Services, Inc. These proved to be useful in outlining general distribution of igneous and metamorphic
versus sedimentary rocks and in indicating the location of possible faults and lineaments to be checked in the field. They were not particularly helpful within areas of metamorphic rocks.

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Localities of minerals or rocks of possible econo.rr.c value encountered during the napping were noted and briefly checked
during mapping. Detailed investigations and evaluations were made at the completion of the mapping phase of the program. This work usually consisted of detailed sketch mapping and sampling, and the measurement of strati graphic sections if warranted. Mineral investigations on the California . and Vetas gold mining area were carried out by a special team who worked continuously throughout the duration of the project. Preliminary semi-quantitative geochemical sampling was done in the California area and at two lead-zinc prospects in the southern part of the zone. Mo geophysical work was done although a geophysical advisor visited several of the sites and offered recommendations *!o drilling was done under the Inventario program,but a Japanese team carried out a small drilling program at La Baja near California under a separate concession not connected with the Inventario. Phosphate investigation was initiated as a separate phase of the Inventario after the early realization of the amount and significance of the phosnhate resources in Colombia.

Definitions and usage

Rock Classifications.--

The classification of igneous rocks used in this report is
that given by Compton (1962, p. 276, 254-255). Rocks present in
the map area with more than 10 percent quartz are:
Granite - ratio of potassium feldspar (including microperthite)
or albite to plagioclase> An 10 is greater than 2:1.
Aphanitic equivalent - rhyolite !
Quartz monzonite - ratio of potassium feldspar to plagioclase>
An 10 or more calcic between 2:1 and 1:2. Aphanitic
equivalent dellenite (quartz latite)
Granodiorite - ratio of potassium feldspar to plagioclase
>-An 10 between 1:2 and 1:7. Aphanitic equivalent -

; dacite
Tonalite - ratio of potassium feldspar to plagioclase 2»An 10
less than 1:7. Aphanitic equivalent dacite or andesite
Only the following rocks with less than 10 percent quartz are

Present in the map area:
Diorite - ratio potassium felcisoar to nlagioclase less than 1:7.
: Plagioclase is andesine. Aphanitic equivalent-andesite.
Basalt, diabase - Aphanitic (basalt) to fine-grained (diabase)
1 rocks with potassium feldsoar to plagioclase ratio less
1 than 1:7. Plaqioclase is labradorite or more calcic.

Rock classifications are based on visual estimates cf modal compositions in thin section. All estimates were >r>y

R. Goldsmith.

The use of metamorphic rock names follows Compton (1962, p. 293
302) with the addition of terms indicating the nature of the original rock as deduced from relict primary structures, texture, and mineral assemblages where it is considered more descriptive; e.g meta sandstone, meta-wacke, meta-siltstone. Modifiers used with rock names are given in order of increasing abundance. For
brevity in some cases only significant minerals are used as modifier in a rock name even though the amount of this component

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of mineral assemblages that need not be repeated as modifiers, as blotite gneiss and not biotite-quartz-feldspar gneiss.
Use of the terms lineation and foliation is standard and also follows Compton (1962 , p. 305-307). -However because compositional layering can reflect relict bedding as well as metamorphic differentiation or lit-par-lit injection, we do not consider compositional layering to be eauivalent to foliation unless a preferred mineral orientation parallels the layer ir.q. In most of
the rocks of high metamorphic grade, a preferred mineral
orientation parallels layering. With emphasis on mineral orientation
as a criterion of foliation, the distinction between relict primary structures and superimposed metamornhic structures can he kept more clearly in mind. Similarly with layering renovcd <is a criterion of touation, foliation is useful as a rneasureable property of a non layered rock with a Preferred' mineral orientation such as a biotite granite qner,

Locations.--

Locations are referred to in the text in one of three ways, depending mainly on the size of the location. General locations are given with reference to towns or prominent topographic feature that can be readily located by reference to the geologic Quadrangle maps or to the index map, figure 2. Areas or localities that cannot be indicated in this way are designated by the coordinates given on the 1:100,000 geologic map (plate 1) where the planchitas are numbered 1-12 along the left margin and lettered a-h across the top. Thus, a locality might be referred to as plate 1A, b4-NE. Where more precise locations are Telt to be necessary, reference
is made to the topographic maps at 1:25,000 scale of the Institute Geografico de Colombia Agustin Codazzi. These maps,
planchitas, are 10 kilometers north-south by 15 kilometers east-west and are partitioned by a grid into one-kilometer squares. Coordinates of the grid from north to south are lettered from A through 0, and coordinates from west to east are numbered
1 through 15. Positions within a single square kilometer of the grid can be further fixed by indicating the quadrant where it is located, NVi, HE, SVI, or SE. Thus'a location would be given as planchita 110 III-C, 0-13 NU. Planchitas can be located by referring to figure 2. Names of quebradas, fincas,and haciendas are used when accurately known, but experience' has shown that these are not always accurately located or named on the planchitas.

PRE-DEVONIAN METAMORPHIC ROCKS

Bucaramanga Gneiss
Definition.--The name Bucaramanga Gneiss is here introduced for a layered sequence of metasedimentary rocks of high .inetamorphic grade consisting primarily of pelitic, semipelitic, and arenaceous paragneiss and schist, and subordinate calcareous gneiss, marble, hornblende gneiss, and amphibolite. The Bucaramanga Gneiss also
includes zones of migmatite of two types: one in which the paragneiss
is mixed wiuh gneissic granitic rock, and the other in which both
are cut by many small masses of non-foliated granite of much younger
age. The type locality may be considered the mountain front just
east of the city of Bucaramanga.
Di s tr ibu t ion.--The Bucaramanga Gneiss crops out in three belts in the southern half of Zone III. The westernmost belt here named the Bucaramanga belt lies east of the Bucaramanga fault in the vicinity, of Bucaramanga. It extends northv/ard with a wide mixed contact zone into the Rio Negro batholith. To the northeast the belt is overlain by the lower grade metamorphic rocks of the Silgara Formation. The east side of the belt is bounded by the Santa

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Barbara batholith. The belt tapers southward between the Bucaramanga "fault and that batholith to the Cepita area where it appears west of the Gucaramanga fault. Further south, in 1-13, the gneiss crops out ^n thin elongate roof-pendants shot through with dikes along the east edge of the Moqotes bathoTith. . :

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The second belt of Cucaramanqa Gneiss, here named the central
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be!t>extends from the Carl in area in northern H-13, north reyond the /
map area, and from the California-Cachiri area to the Morro Msvado area west of Mutiscua. To the west the belt is overlain by Mesozoic and Cretaceous sedimentary rocks. To the east and south it is over-lain by the lower grade rocks of the Silgara Formation. The belt is separated in the Tona area from the ^ucaramanna belt to the southv;est, by younger intrusions, the overlying sedimentary cover, orthogneiss
and by slightly lower grade rocks of the Silgara Formation.
The third and smallest belt of the Bucaramanga Gneiss,.here
called the eastern belt, trends north near the east edge of the
map area in quadrangle H-13 near Chitaga and south of Pamolona. Here the gneiss lies in separate fault blocks. ! Description.--The rock types in the.three belts of Bucaramanga Gneiss are more or less similar, although proportions differ. The
gneiss in the Bucaramanga belt is well displayed along the Bucarananga-Pamplona highway and on the road from Bucaramanga to Surata. The
gneiss consists of interlayered neta-pelites, semi-pelites, and meta-arenites, with thin local layers of calc-silicate rocks and
marble. Hornblende gneiss and amphibolite are subordinate and restricted to zones near the calc-silicate horizons. Detailed stratigraphy within the gneiss was not worked out. The scale of layering in the paragneiSS varies widely, but gross compositional layering is a few centimeters to a few meters thick.

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Layers of pelitic schist and gneiss alternate with layers of meta-arenite, and "broader zones either chiefly politic or chiefly arenaceous alternate vith one another. The pelitic gneiss contains sillimanite and cordierite. The cieta-arenitcs are siostly biotite-feldspar-quartz gneiss and minor biotitic quartzite with thin micaceous partings containing sillimanite. Arenaceous zones con-tain sparse thin layers of gray quartzite. A band of epidote-amphibole rock in the gneiss east of Bucaramanga can be traced southward to where it is truncated by the Bucaramanga fault between Bucaramanga and Piedecuesta. This band may coincide with a narrow-zone of diopside-bearing calc-silicate rocks and marble exposed on the ridge between Rio t Surata , and Tona. Layers of amphibolite and calc-silicate rock also crop out to the north along the slopes on
the west side of the Rio Surata. Marble was seen at one place near Jaboncillo about on the northward projection of the epidote amphibole rock. The amphibolite and calc-silicate rocks may be a good marker horizon, but they were not systematically traced during Inventario

mapping.

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Mlgxatite zones containing paragneiss nixed with au^sn gneiss
and granitic gneiss (pDbm) ars abundant in the Bncarssa^a Gneiss adjacent to the La Corcova pluton, but these rocks are deeply weathered. Lit-par-lit gneiss and nonmappable zones of augen gneiss in paragneiss are exposed on the road from Los Curos to Guaca between the La Corcova pluton and the Santa Barbara batholith* Lit-par-lit migmatitic gneiss of meta-arenite affinity can be seen in good exposures at the junction of Rio Tcna and Surata. Ortho-gneiss zones are less abundant north of Bucaramanga. Granitoid layers in the lit-par-lit gneiss are biotite augen gneiss or gray to light-gray, fine- to medium-grained biotite quartz nonzonite gneiss. Scnec where dikes in Vuicu small masses of La Corcova quartz monzonite or granodiorite ,are abundant are shown by an over-print pattern on the map (plate 1A).

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The central belt of Bucaramanga Gneiss in the Berlin-California-
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Cachiri area contains similar rocks and is much better exposed.
Good, easily accessible, exposures are on the road from Berlin to : Vetas and on the adjacent paramo. Excellent, but rather inaccessible, exposures are present over much of the high country north of Vetas and east of Cachirif. East of Cachiri, exposures were sufficiently that !
good to shov/arenaceous gneiss, pelitic gneiss, and hornblendic
i
gneiss, respectively, predominate in successive zones from vest to \ \
east. Westerly dips predominate, suggesting that, if the section is , not overturned, the hornblende gneiss is stratigraphically the lowest rock type. However, pelitic gneiss reappears on the east side of the belt, near the orthogneiss. Possibly the sequence is folded. Distribution of the rock types to the south in the California and Vetas areas is much less straightforward.

Rock types in the central belt are similar to those in the Bucaramanga belt, except that more hornblendic gneiss is present, commonly in thin layers intercalated with layers of other composition. Quartzite, biotite-feldspar-quartz gneiss, biotite-quartz-feldspar gneiss, sillimanite-biotite-quartz-feldspar gneiss with and without muscorite cordierite-si11imanite-quartz-feldspar gneiss with and without muscovite, hornblende-biotite-quartz-plagioclase gneiss, hornblende-quartz-plagiociase gneiss, amphibolite, and granitoid layers of different compositions' are the predominant rocks. Some
of the layers with sillimanite and biotite are schistose. ; The central belt contains many discrete masses of orthogneiss
as well as extensive areas of migmatite in which the granitic portion is orthogneiss. Most of the hornblende gneiss is spatially related
to the mignatite. If the hornblende gneiss is a stratigraphically lower unit of this part of the belt as was suggested above, migmatite in the central belt may be restricted to the oldest and lowest rocks
; of the belt.
; The trend of the gneiss is mostly north-northwest, but on the
east side of the belt, north from Vetas, the trend is northeast.
i To the east the gneiss is overlain by lower grade metasedimentary
! rocks assigned to the Silgara Formation.
- - 52-- 40

In the eastern belt, the roc'<s are "less well exnosed and seem to
be more limited in composition East of Chitaga ths dominant rock type is layered cordierite-sillinanite-Motite-quartz-feldspar gneiss, ?nuch injected by muscovito pegmatite presumably related to the Durania granite, and by light-gray granite that resembles the La Corcova quartz monzonite. Mo orthoqneiss was observed. Some amphibolite was noted north of Chitaga on the road to Pamplona. Coarsely crystalline marble crops out on the Chitaga-Cacota road 3 km southeast of Cacota, planchita 110 IV. A, G-ll NVi. The belt west of Pamplona passes northward into highly sheared orthogneiss and minor oaragneiss. The gneiss dips tov/crd and presumably under the Silgara Formation in the Morro negro area. However, the Ourania granite intervenes between the two units.
Migmatitic gneiss contains granitic material in 1 it-par-lit fashion, or irregular lenses. In places only remnants of paragneiss are preserved as dark seams or lenses rich in biotite and aluminum silicates in otherv/ise light-colored quartz-feldspar rock. Texture of the granitic material ranges from equigranular, or inequigranular, to pegmatitic, commonly vrithin one exposure. Granitic layers range from augen gneiss to light-gray aolitic gneiss
and weakly foliated equigranular to inequigranular granitic gneiss. Generally the layers and foliation in these rocks are folded in Plastic fashion.

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Seme of the granitic material is clearly introduced,
particularly that resembling phases of the larger masses of orthogneiss and that which has relatively sharp and discordant contacts. Other material could be locally derived or be in large
part recrystallized and possibly mobilized within the paragneiss
of chemical composition originally close to that of
granite. Some of the gneiss, particiilarly the impure meta-arenites and semipelites, have a pronounced granitoid texture although the layered sedimentary character of the rock is obvious. These rocks have a migmatitic aspect where strongly folded and recrystallized. Some hornblende gneiss with appreciable feldspar also has a migmatitic appearance.
The bulk of the granitic material in the migmatitic gneiss appears to be introduced rather than derived through the simple recrystallization of the parent rock, primarily because of disproportionate volume relationship. " Much more granitic material present than could have been supplied by the parent rock alone. I«arge but not nappable zones of granitic gneiss (orthogneiss) in the Bucaramanga Gneiss are common in some areas, such as the ^gmatitic zones flanking the La Corcova quarts monzonite in the Bucaramanga belt in H-12.

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A different type of mignatite is forned vhere the Eu-c
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Gneiss is cut by nonfoliated granite or by quartz-monzonite»

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This type of ntgmatite

I occupies a zone east of La Corcova south through Sevilla and north I
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toward the Rio Surata. A similar migmatite constitutes the gneiss

north and northeast of California.

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The -Bucaramanga Gneiss is clearly derived primarily fron
sedimentary rocks. Quartzite, and quartzite-rich gneiss represent meta-arenites, most of which appear to have been subgraywackcs containing
appreciable detrital feldspar and mica. Biotite-quartz-feldspar J
gneisses, with or without muscovite and sillimanite, are semipelitic
|
Quartz-biotite-feldspar gneiss and biotite-cordierite-quartz- i
i

feldspar gneiss, and biotite cordierite-feldspar quartz gneiss with j a high content of quartz are transitional in composition from wackes ! to pelites represented by biotite-sillimanite-cordierite gneiss and i j
biotite-muscovite-sillimanite quartz feldspar gneiss. ' Prograde !
muscovite may or may not be present, depending on grade of 1
i
metamorphism. However, secondary muscovite after aluminum silicates ' is fairly, abundant. Feldspar is normally plagioclase, but some
j orthoclase is present in some sillimanite-bearing rocks, cordierite-bearing rocks without muscovite, and in granite layers in migmatitic
gneiss. Some of the hornblendic gneiss and amphibolite contain I
qviartz and biotite in varying amounts. These are probably paragneiss; other hornblende-gneiss poor in quartz may be of igneous origin.
j Calc-silicate gneiss and marble are very subordinate. The epidote-
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aaphibole layers, because of their paucity of sodium and association
vith diopside-bearing layers and marble, were probably derived from calcareous strata.

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Age and strati graphic relations.--The Bucaramanga -Gneiss is host! for all the igneous and mera-icneous rocks recognized in Zone III and ,
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appears at least in part to underlie the : Silgar£ Formation. It is thus all or in part the
i
oldest rock unit in the zone. A whole rock-sample of biotite gr.aiss :

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(see IMN-13199, table 1) from a cut on the road from Berlin to Vetas t ' /
gave a Rb/Sr whole-rock age
I

of 680 j^ 140 m.y. This sample has a considerable margin of error and j could be as young as Cambrian. On the other hand, a much older age
, __"..--.--- - ' ! might be marked by subsequent events. , Hornblende from
i

a sample of hornblende gneiss taken near Ocana from Bucaramanga gneiss i
west of the Bucaramanga fault gave a potassium-argon age of 945 £ 40 j

i
m.y. (IMN-12263, table 2). This age is clearly Precambrian. Tschanz; (written commun., 1968) reports a date of 940 +_34 m.y. on a horn- j i
blende granulite from the west side of the Sierra Nevada de Santa j Marta. Other Precambrian ages from the Sierra Nevada and western ;

j Venezuela, however, are around 1,300 m.y. Precambrian granites in |
the / Guaviare region of the eastern llanos of Colombia give ages of about
i 1,205 m.y. (Pinson and others, 1962). Most radiometric ages from the Guyana Shield of eastern Venezuela and Guyana according to
Tschanz, however, are older and range from 1,570 to 2,100 m.y., being chiefly.1n the 1,800-2,100 m.y. range.

Table 1. Location, analytical data, and calculated whole-rock Rb-Sr ages of samples collected in the Santander and Norte de Santander, Colombia (from Goldsmith and others, 1971).

(Analysts: R. A. Hildreth and W. T. Henderson; decay constants
locations of samples in map area are shown on plate 1.)

4- 1.39 x

Sample
No.

IMN-12264

DIN-12256

DIN-13199

Sample location
Latitude

7°39'N.

7°15'N.

7°16'N.

Longitude
73°16'W.

72°48'W.

72°54'W.

Rock type,
formation, or
intrusive body

Riebeckite
granite

Granite gneiss
(orthogneiss)

Biotite gneiss
(Bucaramanga
Gneiss)

Rb
(ppm)

92.6

190

186

Sr

(ppm)

17.0

90.2

152

Rb87 /Sr86

15.78

6.13

3.54

Sr87 /Sr86

0.7406

0.7433

0.7387

Radio-
genic Sr
Total Sr 87

0.048

0.052

i
0.046

Rb-Sr
age 3-'
(m.y.)

160 + 30

450 + 80

6SO + 140

Sample locations:

IMN-12264 Riebeckite granite, Department of Santander; boulder near outcrop, Rio Cachira; planchita 97-III-B, coordinates E-12 NE, quadrangle G-12.
i
IMN -1.2256 Granite gneiss, Department of Norte de Santander; road cut, Q. El Picacho, planchita 110-III-B, coordinates H-4 NE, quadrangle H-13.

IMN-13199 Biotite gneiss (Bucaramanga Gneiss), Department of Santander; road cut, Volcan Amarillo; planchita 110-111 -A, coordinates G-ll SW, quadrangle H-13.

R7

I/ Initial Sr /SR assumed to be 0.705

The Bucaramanga Gneiss may reflectAcycle of Precambrian orogany, i [tentatively placed around 940-945 m.y. that is younger than orogenies ! recorded to the north and east.
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;[The contact of the Bucaramanga gneiss with the overlying
I Silgara Formation could not be determined with certainty.

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Correlation. The Bucaraman^a Gneiss probably corresponds to the i "basement" of Hea and Whitman (i960, p. 3^) and the Perija Series of | Sutton (19^6) in the western Serrania de Perija, State of Zuxia,
i
Venezuela. The description of the Iglesias Series (Kundig, 1933) and \
\
the Santo Domingo Gneiss in the Merida Andes by Sutton (1946) reseirible that of the Bucaramanga Gneiss. Possibly the Sierra Nevada Formation in the Merida Andes (Bass and Shagam, I960) is also equiv-alent, but a definitive description of this unit is not available* Radioinetric data from the Sierra Nevada Formation (Bass and Shagam, I960, p. 38l) indicate that the age of the Sierra Nevada could be Early Paleozoic*
The basement, in the Serrania de la Macarena cast of the ! Cordillera Oriental and the related Garzon massif in the Cordillera , Oriental in central Colombia are probably Precambrian (Gansser, 195*0 !
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Other Precambrian rocks of dated equivalent age are in the j
Sierra Nevada de Santa Marta (Tschanz and Cruz, written comnrun.,1968)»

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Silgara Formation
Definition.--The Silgara Formation is a sequence of typically
thin and cyclincally bedded metamorphosed clastic rocks consisting of slate, phyllite, meta-siltstone, impure metasandstone, metawacke end metawacke grit with minor amounts of calcareous slate and phyllite. The formation is here named after Quebrada Silgara in northeasters
/ /
quadrangle H-12 south of Rio Cachiri where much of the formation
is well exposed across a 15 kilometer-wide belt. Even though the
base of the Silgara has not been established with certainty, the
/
Silgara Formation appears to overlie the Bucaramanga gneiss.

* Distribution.--Tie most extensive exposures of the Silgara Formation
i

are in a rather inaccessible belt extending from south of

! Matanzas in quadrangle H-12 northward beyond the limits of the ;
s

quadrangle northwest of Cachiri. This belt includes the type area of the formation. Many of the rocks can be seen along a trail
/ f /
parallel to and south of the Rio Cachiri from Cachiri westward to
/
the Rio Negro batholith.
A second extensive but narrower belt of the Silgara lies west
of the Bucaramanga fault from near Piedecuesta south to Aratoca, in H-12, 1-12 and 1-13. These rocks are relatively well exposed along the Bucaramanga-San Gil highway south of Pescadero and along part of the road leading from Los Curos to Los Santos.

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Another extensive area of the Silgara Formation, pas
wrapping around orthogneiss and Bucaramanga Gneiss, extends from
i south of Berlin^ north-ward through the Silos-Beriiif area through Mutiscua to beyond the limits of the geologic maps* The Silgara''
crops out again to the east in fault slices in a belt northwest, west,! and southwest of Pamplona where it is invaded by orthogneiss and
Durania granite.
Isolated exposures of Silgara* Formation crop out to the south
in 1-12 and 1-13 between the Mogotes batholith and the overlying Devonian and Mesosoic sedimentary rocks as far south as the Mogotes area, The Silgara Formation also crops out below the Floresta Formation
east of the Bucaramanga fault from Coverachia to the San Andres area (l-13, H-13)and northward to the Berlin area in H^13
Thickness. The thickness of the Silgara Formation cannot be |

! determined in the type area* The section is incomplete because this

belt is bounded by the Rio Negro batholith to the vest and by the unconf ormably overlying Giron Formation or by the Surata fault to
the east. Further south, where in contact with the Bucaramanga Gneiss, much of the section has been cut off by the Surata fault
on the east. In outcrops along Quebrada Silgaref and (^uebradas to the east across the 15-kilometer wide belt in the type area, the steep
| foliation is in zones that alternately dip east and west, a relation-ship which suggests appreciable folding. The foliation is probably, la part, an axial plane foliation of slaty cleavage and may not represent the attitudes of bedding. Stratigraphic thickness may, therefore, be much less than the 15-kilometer outcrop width of the belt.

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An Incomplete stratigraphic section/measured alono the Bucararoanga-San Gil highway between Pescadero and Aratoca (fiq. 3).

The section is cut off at the north end by the Pescadero granite and at the south end the Silgara is much faulted and obscured by unconformably overlying Mesozoic sedimentary rocks. The section dips generally southward, but is much folded. Nevertheless, making allowance for observed faults and folds, the approximate thickness of the faulted and folded section from Pescadero to the Mesa de San
Pedro area is 3,700 meters. South of the Mesa de San Pedro area about 700 meters of section is indicated, but it is not certain how this correlates with the northern part of the section. It is possible that rocks of the Floresta Formation of Devonian age are present I in the upper part of the section near Aratoca.
Other sections of the Silgara' Formation are either more
fragmentary or less carefully manned than the Quebrada Silgara or Pescadero-Aratoca sections.

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Quebrada Silgara'. --
In the Quebrada S'ilgarrf area the rocks are dark
green, greenish gray, and aray slat?, DhyTHtxs tfGtasiltstone, fine-grained auartzite, and brown to gray meta-'.-acke. All are within the greenschist facies of regional metamorphism. Bedding is typically
laminar to thin and is cyclic, particularly in the fine-grained
rocks. In some quartzite, for examole, dark laminae are about 0.5
mn thick and the alternating gray silicious layers are 2 to 3 nun

thick. Metawacke beds are thicker, but rarely exceed a meter ; i '
a sequence of metav/acke beds with nhyllitic partings may be collectively much thicker. Graded bedding is common in metawacke and the bases of

beds are conglomeratic. i
, Phyllites in the Ouebrada Silgara area are typically quartzitic.
In order of increasing abundance they are composed of chlorite,
sericite, and quartz. In the metasiltstone and phyllitic
metasi Its tone, quartz generally exceeds 50 percental agioclase
is about 5 to 10 percent; and the remainder is muscovite and chlorite,
with muscovite being five to ten times more abundant than chlorite. - The more

/ pelitic rocks contain about 25 percent quartz, and about 75 percent muscovite and chlorite with some biotite. Muscovite anain is
normally much r:ore abundant than chlorite. Granhitic nhyllite is
composed of quartz and muscovite, traces of chlorite,and evenly distributed finegrained graphite. Some phyllite contains small

i

oorphyroblasts of chlorite and mannetite. The magnetite oornhyroblasts
i are relatively abundant in chloritr-noor and chlorite-free quartz-muscovite ohvllite.

Some greenish-Tray p'nyllite contains laminae of calcite, but no distinct lines tone or marble ^eds v.-ere observed in this area. Dark gray to black graphitic slate with pyrite is present in some places, and white to light-greenish-gray quartz-sericite phyllite >in others. Some white sericite-auartz phyllitic me tas! Its tone shovs little apparent metamorphism in outcroo, but the metamorphic
fabric is clear in thin section.
Dark laminae in thinly laminated quartzite are rich in serciTe, chlorits,magnetite, and biotite. Heavy-mineral suites in quartzite, metasandstone and metasiltstone consist of tourmaline, apatite, sphene, zircon, allanite (rare), and rutile. Tourmaline and zircon are the most abundant. Blue-green tourmaline is characteristic of the SiIgara7 Formation in all belts.
In the meta-wacke, clasts of quartz as granules and pebbles
usually exceed 50 percent of the rock. Clasts of plagioclase and potassium feldspar also form an appreciable comnonent. Biotite,
chlorite, and muscovite occur in the matrix and in nart may be
detrital. Metasiitstones and fine-grained meta-sandstones contain
small clasts of white potassium feldsnar as well as bluish-gray
quartz oebbles. Some chloritic meta-siItstones contain no muscovite; their composition is approximately 50 percent ouartz, 10 percent chlorite, 35 percent feldspar, and small amounts of opaque minerals. Metawacke beds make uo about 10 percent of the section in the Ouehrada Silgara'area.

The grade of metamorphism in the Silgara belt increases to the

south. The meta-arenite beds show little change with this increase of

'metaraorphism, but the more pelitic beds are changed to porphyroblastic

4 phyllite and schist. Porphyroblasts in the phyllite are andalusite and i

5 - jCordierite and sillimanite, as fibrolite, is present near the contact of i

i ' '. the Bucaramanga Gneiss. East of the Rio Surata the schists are coarse-

j
^grained and not porphyroblastic. No staurolite was observed in the
i
< Silgara' belt and traces of garnet occur only in the southern part. A
i
3 layer of marble about 2 meters thick below a thick section of meta-

' -- sandstone was observed in the area southwest of Matanzas.

East of the Suratl'-l'.j'-.anr.s.s fault south of '.'.itanzas is a thick
section of intertedded mct^aeke and coarse-brained bioti-ce-i-iusco schist locally injected by orthogneiss. These rocks xay "be near the base of the Silgara* section. They are well exposed alone the read from Bucaramanga to Surata'10 to 12 kilometers south of Matansas, where
* /
the road is east of the Rio Surata.
Piedecuesta-Aratoca belt. The rocks in the Piedecuesta-Aratoca
belt are similar to those in the Quebrada Silgara except that metawacke beds are absent. The metamorphism in this belt ranges from greenschist facies to lover amphibolite facies (staurolite grade). Garnet and staurolite are relatively coninion, in contrast to their absence in the

metamorphism between the two areas. The grade of neteanorphism of
; * ; the Piedecuesta-Aratoca belt appears to be lowest near Aratoca.

The stratigrapnlc section along ths road from Pescadero to
Aratoca mentioned earlier is illustrative of much of the rock in this belt (fig. 3). The lower part of the section (see fig. 3) is primarily thin-bedded to laminated greenish-gray to brownish-gray quartzite with minor quartz mica schist. These rocks are intruded by : many dikes of Pescadero Granite. The upper part of these beds con- j tains a zone of raetaporphyry. Further south, the section is more pelitic. The rocks are chiefly quartz-mica schist with some garnet and staurolite. Minor beds of green to black amphibole schist and chlorite schist are present near B 1. The amphibole schist consists of about 70 percent trenolitic hornblende
and 25 percent sausstaritized plngloclase, with minor biotite, epidote, and apatite. Section B-B 1 continues the section up and back toward
the north. Here the rocks are stratigraphically above those in
section A-A T. In section B'-B the rocks are chiefly interbedded mica schist and met a-sands tone that become more muscovitic and quartzose
i? | toward B and the start of section C-Cf at the next major curve in the » I road. In the lower part of the section B-B f are thin beds of
* i pseudo diorite',1 a porphyroblastic hornblende-bear ing rock represent-5c-jlng metamorphosed argillaceous calcareous beds. At the start of
*J section C-C 1, and continuing for about a kilometer along the road, are abundant beds of clean white quartzite and silvery riuscovite

of greenish-gray silty-phyllite and phyllitic meta-ciltGtone and fine-grained, thin-bedded to laminar-bedded R

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^.^__._.15-cross-bedding,graded bedding, and intraformational brecciasi and eiimp structures on a fine scale* These rocks continue to the i area of Mesa de San Pedro. The upper part of the section, from the Mesa de San Fedro area to the south, is less clear because of folds
and faults. Black graphitic phyllite near Mesa de
San Pedro is apparently bounded by faults. Near Aratoca, the grade of netamorphism is less than elsewhere along the section but rocks are similar to those to the north except for the presence of light-i tan sandstone and a fine-grained conglomerate that crop out on the i road facing Aratoca. The sandstone nay belong to the Floresta
I
j Formation.

A dark-gray, schistose rock (metaporohyrv in section A-* 1)
v/ith fairly uniform, aucen-lik\2 feldspar meaacrvsts up to 3 mm
long is a ineta -trachyandesite (?) norohyry consisting of plagioclase in clusters and individual megacrysts, rare hornblende megacrysts, and a groundmass of fine-grained biotite and plagioclase and accessory apatite, eoidote, allanite, and rutile. A somewhat similar but coarser-grained rock is present in the Silgara south of Matanzas (109-IV-D, A-3, W). ; The Silgara Formation observed vest of Pescadero and to the north is similar to the section along the Pescadero-to Ar atoe a highway described above. Silvery garnet^staurolite schist underlies the Mesozoic rocks capping the Mesa'de Los Santos. Thin meta-wacke beds were noted near the contact with the Pescadero Granite on the road from Los Curos to Mesa de Los Santos.
Rocks of the Piedecuesta-Aratoca belt in 1-12 and 1-13
and southward to the Mogotes area they are similar to those described above. Hear Mogotes metawacke- beds are again present as in the
i
Silgara Belt. East of i'ogotes tovard Onzaga, the qrade of
metanorphism is again-lower and the rocks are not clearly distinouishable from the overlying Floresta Formation which is slightly metamorphosed
in this area. It is possible th*t part of the area mapped as

a' Formation has been confused with the Floresta Formation.

In eastern I-i3 near Covarachia, greenish-oray phyllits beneath the Floresta Formation is interlayered with orthooneiss but is too thin to show on the map. Farther north, near San Andres and Guaca, the Silgara is of medium metamorphic grade and is more readily distinguished from the overlying Floresta Formation of low metamorphic grade.
Parnplona-chitaga belt.- - The Silgara Formation in this belt consists largely of mica schist with lesser interbedded meta-sandstone and metawacke. The rocks are of middle to high metamorphic grade and resemble the Silgara" Formation in the area south of Matanzas. The Silgara Formation at Morro Negro appears to overlie the Bucaramanga Gneiss to the east in the Cacota area, although the rocks are separated by the intervening Durania granite and orthogneiss.' . : East of Chitaga, in planchitas 110-IV-C and 121-II-A,layered cordierite-sill imam"te gneiss of the Bucaramanna Gneiss is overlain by Sillimanite-bearing SChist and minor meta-quartzite. An interval of micaceous quartzite at the base of the schist forms a distinct scarp. This ; quartzite may be the base of the Silgara Formation, and has been tapped as such in this part of Huadranole H-13. The same sequence Of Schist- quartzite-cordierite-bearing gneiss also was Observed north of Berlin,south of Volcan Amarillo, 110-III-A, G-ll SVf.

X I ' Berlin-Silos -Mutiscua Area. -- The Silgara Formation in the Benin Silos-Hutiscua area resembles the Pescadero-Aratoca section -j-cept for the presence of carbonate beds but apnears to be a different
part of the formation than that to the east in the Psmolona belt.
The rocks are quartzite and lesser associated ouartz-^ebble conglomerate, silvery to light-^ray auartz Muscovite schist with §Bmet, Staurolite, or SillimanitC (depending on the grade of meta-morphisis), gray garnet biotite-muscovite schist, and minor calc-silicate beds, dark^ray marble, and white to light-gray" to pink and green layered marble.

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In the M.utiscua area, the Silgara arpears to lie in a north-- plunging syncline vjhose east li'^r- has boen truncated close to the axial plane by a fault along the valley. Vlestv/ard from Mutiscua
one passes apparently down section in the west lirr.b from inter!ayered white, gray, and buff marble and nuartz mica schist through a thick section of micaschist into fairly pure quartzite and quartz pebble metaconglomerate. In some places mice> schist appears to underlie the quartzite, possibly disconformablv, but this could not be
proven in the field. The quartzite or the underlying mica schist generally lies on orthogneiss^a relationshio observed in many traverses in the Berlfn-Silos-Kutiscua area. This contact bounds
on the east most of the mass of orthogneiss that extends from Rio

! Caraba northward, follows the northern nose of this mass, and appears again on the north side of the wedge of orthogneiss southeast of Horro itevado. From the evidence o f a fw t^'*rs°s, it s^rr^ likely that the quartzite is present around the south and east side of the large mass of orthogneiss northeast of Horro ilevado as well. Quartzite and metaconglomerate at sillimanite grade of metanorphism
s

crop out on the west and north sides of the Rio Caraba mass of orthogneiss in the Ri'o Caraba area. These rocks are exposed on the Bucaramanga-Pamplona highway north of the Rio Caraba.

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Quartsite and quartz-pebble conglomerate are also present on
Lama Palencia south of Berlin. Unfortunately, tae Santa Barbara batholith nearly encloses these outcrops so their spatial relationship to the orthogneiss in this area cannot be confirmed. Schist along the highway to Pamplona, east of Berlin, contains "beds of vhite quart zite> and quartzite crops out along the southern edge of the orthogneiss northeast of Berlin. Infolds of apparently the sane quartzite are present within the orthogneiss immediately to the north. Similar quartzite crops out in the Vetas-California area still farther north. However, no quartzite or metaconglomerate
was observed near the contact of the Silgara' with the orthogneiss

in Rio Caraba west of Silos, or along the south side of the It£o i
Caraba massr

Careful mapDing and walking out beds x^herever possible would

probably reveal the stratigraphic significance of this au^rtzite and metaconglomerate. It was thought at one time durinq the mapping that the nuartzite and metaconglcmerate and the underlying schist represented the base of a sedimentary sequence younger than the orthogneiss. Hov/ever, it was found that these rocks were not always present near the orthogneiss and furthermore that in places the orthogneiss was intrusive into metasediments of which the quartzite seemed to be a part. Hov/ever, orthogneiss of two different ages may be present.
The quartzite and metaconglomerate may mark the base of the SiIgara" Formation. The schist and the gneiss below, with perhaps older quartzites, may all belong to the Bucaramanga 'Gneiss. However, 1n the Silgara belt and the area south of Matanzas, no quartzite or meta-conglomerate equivalent to the quartzite and meta-conglomerate
of the Silos-Mutiscua area was observed. Unite quartzite in the Pescadero-Aratoca section appears to lie well within the Silgara' Formation.

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South of Berlin in quadrangle H-13 the sequence is somewhat
similar to that at Musticua. West of fossiliferous marble and barren quartzite of the Floresta Formation a thick sequence of gray-green silty phyllite passes westward into light-gray to silvery white
' muscovite-quartz schist and interbedded quartzite. Toward the con-tact with the orthoqneiss near Alto El Purgatorio are black graphitic garnetiferous phyllites, with, in the lower part, thin-bedded inter-bedded marble and quartzite observed only in float blocks. The con-tact with the orthogneiss is not exposed. Lineation in the underlying orthogneiss and fold axes in the phyllite have similar attitudes suggesting probable synchronous deformation. The top of the Silgara' Formation here has been drawn somewhat arbitrarily to the west of the i

fossiliferous marble and the associated quartzite.
Relationship of the Silgara''Formation to the Bucaramanga gneiss.-

»

A difference in gross lithology exists between the Silgara Formation and the Bucaramanga Gneiss. The Silgara Formation tends to be more quartzitic and thin^bedded to laminated,with abundant quartz-rich silty phyllite, and biotite-poor quartz muscovite phyllite, and schist particularly in the upper part. The Bucaramanga Gneiss, on the other hand, is thicker bedded and contains biotite-rich and hornblende rocks Even so, considerable similarity in rock types exists between the two formations,particularly in what may oe the lower part of the Silgara, and no consistent distinctive horizon indicating a stratigraphic break useful in mapping was found to mark the boundary between the two informations.

Structural attitudes suggest that the Silgara' Formation overlies
the Bucaramanga Gneiss but are not everywhere clear and more detailed mapping is probably needed in these areas. For example, in the Paujil district, in quadrangle H-12, 3-d, north of Bucaranarr/a, metawackes of the Silgara can be followed along strike into the Bucaramanga Gneiss with no discernable break. East of Mutiscua, quartzite and schist, possibly near the base of the Silgara, seem to trace to the west into highly metamorphosed paragneiss of the Bucaramanga Gneiss. Quartzite
and meta-pelite flank orthogneiss in the Quebrada Los Salados-Que-
brada Grande area, quadrangle H-13. However, this may be coincidence, for the rocks east and above the quartzite appear to be a different sequence of rocks from those west of the quartzite. For example,
marble layers present to the east were not observed to the west.
The contact as drawn coincides rather closely with the sillimanite isograd. Sequences of thin-bedded rocks containing appreciable quartzite and quartzitic metasiltstones are assigned to the Silgara Formation and sequences of thicker-bedded metapelites and meta-arenites are assigned to the Bucaramanga Gneiss. The former are typically at low to medium grade and the latter are typically at

nigh grade.
Some of the medium-grade meta^andstones and schists mapped
as part of the lower part of the Silgara' as for example south of Hatanzas, are thicker bedded and lithologically similar to some high-
grade paragneisses in the Bucaramanga Gneiss. These rocks may be
a Gneiss and the boundary between the Silgara Formation and

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Bucaramanga Gneiss may lie at a high horizon. It is also possible
that the Bucaramanga Gneiss represents the lower and more metamorphosed part of a .single sedimentary series of which the Silgara Formation is the upper and less metamorphosed part. The pattern o£ isograds would support this interpretation. However, in most places where the Bucaramanga Gneiss and the Silgara Formation are separated from
one another by igneous intrusion or faults, the two units generally
can be distinguished on the basis of bedding characteristics.

Age and correlation. Hear Floresta, in the Department of Boyaca south of the map area, at the southern tip of the Santander massif, in the type area of the Floresta Formation, unmetamorphosed Floresta Formation containing fossils of Middle Devonian ace restsunconformably upon metasedimentary rocks similar to the Silgara" Formation. Similar relationships have been observed in the Mogotes area and near Covarachia. The Silgara Formation is certainly pre-Middle Devonian, and a period of regional metamorphism, uplift, and erosion must have occurred between the time of deposition of the Silqara"
and the deposition of the Floresta. Orthogneiss whose minimum aqe based on radiometric dates is Ordovician (table 1) intrudes the lov/er part of the Silqara Formation, indicatinq that the Silqara is no younqer than Ordovician. Because of the uncertain stratiqraohic
in some places to the underlying Bucaramanga Gneiss, it
cannot be unequivocally said that all the Silqara'as maoped is younqer than the Bucaramanqa Cneiss. Radiometric dates on the Bucaramanna Sneiss are Precambrian. The Silqara Formation is tentatively placed in the lower Paleozoic and is probably Ordovician or Cambrian aqe.

The Silgaia Formation has been observed in several places north

of the map area. It crops out west of Durania,
apparently continuous with the Silgara Formation northwest of Pamplona in H-13, and in a belt on the west side of the Aguablanca batholith
. from north of the road from Sardinata to Ocarfa between the batholith and Alto El Pozo (86-II-D, H-13 :w) south to the Villa Caro area. Silgara Formation crops out at slinhtly hinher^grade in a belt further west along the same road in the Rio Tarra area east of Abrego. The ^ Silgara Formation in the Ouebrada Silgara belt near Cachiri continues northward beyond the limits of the map area at least as far north as Cachira' in quadrangle G-12. Slates possibly belonging to the Silnara Fonr.atior, were observed .east of the Bucaranumqa fault near Guam?.! i to,

quadrangle F-12. The Silgara Formation is possibly the equivalent of the Gue.iar

Group of the Serrania de la Hacarena as described by Trumpy (1943)
The description of the rocks of the Gue.iar Group as thin-bedded ouart-zite, sandstone and micaceous locally phvllitic shales, somewhat resembles the descrintion of the Silgara Formation. However, the
Gtiejar Group is unmetamorphosed to only sliqhtly metamorphosed and the section is thin. Hubach (1957, n. 162) cites thicknesses of 150 to 160 meters on the east side of the Hacarena, but says that fqrther to the
viest £000 meters of Gu'ejar is orcsent. The Guejar Group contains fossils of Late Cambrian and Ordovician ane.

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The Silgara Formation is oossibly also equivalent to the puetair.a Group cropping out in the area ectst of Bogota'. The Hi-staira, as described by Campbell (1965) consists in part or all of continental strata slightly metamorphosed and highly folded. These beds are overlain unconformably by unmetamorphosed Middle Devonian strata. Campbell estimates the thickness of the Quetame to be about 2,750 meters. ; In the Barinas Basin of southeastern Venezuela, the unfossiliferous Bella Vista Formation and the overlying Caparo Formation, considered to be of Ordovician and Cambrian age, are 3,009 raters thick (Pierce, 1960, p, 217-221. The Bella Vista Formation is metaraporphosed to greenschist facies and consists of schists, phyllites, and quartzitcs. The Caparo 'Formation is less metamorphosed and consists of lightly metamorphosed siltstone, silty shale, and contains a Middle Ordovician sandstone. The base of the Bella Vista Formation is not exposed but it
is presumed to overlie metamorphic rocks of higher grade and older age
in the adjacent Merida Andes. In the Merida Andes the Ordovician and Cambrian systems are apparently represented by the Sierra Nevada Formation (Bass and Shagam, 1960),which has been dated by Rb-Sr on muscovite as 410 m.y. (Bass and Shagam, 1960, p e 38l).

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The Silgara Formation is crcbably equivalent to unfcssiliferous meta-sediinents of low metamorchic nrade lying helov/ uniratamorphosed
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rocks of Devonian aqe on the v/est flank of the Serrania de Perija (Tschanz and Cruz, v/ritten con?un., 196C; Trumny. 1943; and Radelli,
1962) and possibly to part of the Perija Series of Sutton (1946) in
the east flank of the Serrania. Hea and '-.'hitman (1960, p. 354-355} restrict the Series de Perija to metamorphic rocks of greenschist
facies overlying gneisses and schists of possible Precambrian aqe (PerijS series of Sutton). Accordina to their definition of the
Series de Perijci, it could be equivalent to the Silgara Formation; however they sugqest a tentative Early Devonian age for the rocks.
Qrthognelss
Def i ni ti on. Quartzo-feldsnatni c gneiss ranging in composition from granite to tonal He is widely distributed in the high-and medium-grade metamorohic rocks of pre-Devonian age in the core of the massif.
These rocks are on the whole massive but contain septa of foliated metasedimentary rocks and thin screens of hornblende nneiss and amphibolite,SOme Of which appear to be metamorphosed dikes. Only the diorite gneiss was mapped separateLy,
The massive asnect of these rocks, the oeneral lack of layerino
except on a gross scale, the presence of endogenous inclusions in
some of them, and the fact that compositions are those of magmatic rocks have led to the use of the name orthonneiss for these rocks.
South of Matanzas and v/est of Tona(in H-12 and M-li)orthonnoiss occurs
as sills and diko.s in the wcMlium-orado rocks of the Silnara Fomtion.

r- n I ' -'

Two styles of emplacement of the orthoqneiss are evident. In one
the orthogneiss is intimately related to migmatito. In this tho orthogneiss consists of somewhat inhoniogeneous masses that grade into migmatite in which the gnaiss appears as septa or sill-like masses of different sizes in paragneiss of high rcetamorphic grade. This type is transitional with lit-par-lit gneiss containing about equal arrounts of paragneiss and granitoid gneiss. This kind of orthogneiss is prevalent and well displayed in the Paramo de Santurban and the extensive nrigma-tite zone that continues north and northwestward to the northern edge of quadrangle H-13. Areas of migmatite with small masses of orthcgneiss were described with the Bucaramanga Gneiss.
The other type of orthogneiss forms large, discrete, mappable units. These have fairly sharp contacts, although in some places
they may pass into migmatite as does the large mass of orthogneiss northeast of Berlin. This type of orthogneiss is not confined to the high-grade metamorphic rocks but may be .present in medium grada or even greenschist facies rocks, as, for example, in the Onzaga area in 1-13.

71

The style of emplacement of the orthogneiss Is probably a
function of the depth at which emplacement or formation took place
in the crust. The orthogneiss in the Paramo de Santurban area is clearly an integral part of a paragneiss-orthogneiss complex. Other areas of orthogneiss, except those forming migmatite, are not clearly a part of such a complex. The more discrete the mass, the higher and possibly the later it was emplaced. Hence it is possible that orthogneiss of more than one age is present in the massif. ; However, all the orthogneiss is clearly of pre-Devonian age, but \ some may be older and some may be younger than the Silgara Formation. The suggestion that quartzite and metaconglomerate in the Silgara' night be younger than soine crthoqnsiss has been pointed cut.

^Distribution. The general distribution of the orthogneiss is indicated in figure 4. Most of the orthogneiss is in the northern part of the

map area in H-13, to the southv/est, north, and northeast of Berlin. Narrow wedges of orthogneiss crop out in fault slices in a belt
west of Panplona and extending south to the vicinity of ChitagS and
Silos. Orthogneiss crops out along the east side of the Santa i Barbara and Hogotes batholiths to the southern end of the zone in the vicinity of Onzaga.

7;'1

The masses of orthogneiss cropping out in t^ southern part of the zone east of the batholiths have been Intruded and cut cut by younger granite or are partly covered by younger sedimentary or metasedimentary rock so that the actual size of these masses and their original contacts are obscure. In some places, however, it appears tnat the nature of their contacts with the enclosing medium-and high-grade metasedimentary rocks is similar to that observed in the northern part of the map area.
The presence of narrow zones of orthogneiss flanking the Santa Barbara batholith in the area south of Berlin suggests that orthogneiss was fairly continuous before intrusion of the batholith. The isolated masses o£ orthogneiss near Santa Barbara weie

probably part of the mass of orthogneiss near Tona prior
to the intrusion of the batholith.
It is possible that in Some (places during the mapping, sheared younger plutonic rocks have been mistaken for orthogneiss. However, shearing of the younger plutonic rocks is restricted to narrow zones that have pronounced cataclastic textures, whereas the orthogneiss has a pervasive crystal 1 ization foliation without evident cataclasis.

Contacts.--Contacts of the laroe masses of orthogneiss are con-cordant in most places with foliation in the enclosing rock. This can be seen clearly at the contact of the orthogneiss with the Silgarcf Formation in the Ri"o Caraba west of Silos and along the Bucaramanga-
X

Pair.plona highway below Alto El Pichacho west of Berlin, quadrangle H-13
X

Tabular bodies of orthogneiss in the Silgara Formation in the Tona and Rio Surata' areas have contacts that transect laminae in the host rock at low angles. ~
Some pegmatite injection and a slight coarsening of grain size of
X

schist in contact with orthogneiss is evident at the junction of Rio
x

Mataperros and Quebrada Pescadero east of Berlin in quadrangle H-13. /

viest of Silos in the Rio Caraba, the amount of gneissic pegr.iaLile and /

granite in schist and paragneiss of the Silgara Formation increases toward the contact with the orthogneiss.
Southeast of Covarachia a sill of lineated orthogneiss lies in
X

markedly sheared ,gently dipping siliclous phyllite of the Silgara Formation. The main mass of orthogneiss below is also quite sheared and locally has been converted to laminated mylonite. The shearing post dates the emplacement of the orthogneiss and the metamorphism of the Silgara' Formation, but it is probably a localized late dynamic phase of the metamorphism. The unmetamorphosed Floresta Formation, lying about 50 meters above, shows no evidence of deformation.

The above observations shov/ that some of the orthoqneiss is
at least intrusive into rocks as VOUPQ as the Silgara' Formation and that it was metamorphosed at th? same time as the recks it intruded. Whether emplacement occurred peneconteicoraneously with the roetamorphism or much earlier is not certain. On the supposition that plutonism and regional metamorphism are co-related processes, we are inclined to the viev/ that the orthogneiss is syntectonic or penecontemporaneous v/ith the regional metamorphism
of the Silgar/Fornation, The evidence does not rule out, however, the possibility of some of the orthogneiss having been emplaced
after the metamorphism of the Silqara Formation but prior to the deposition of the Floresta Formation.
"Description. The orthogneiss has a considerable range of texture and composition. The rocks are primarily recognized by their quartzo-feldsnathic composition, their notilayered character, and their pervasive gneissic structure. The orthogneiss usually has a marked lineation as well as foliation. In sone nlaceslineation predominates, in other places foliation predominates. The rocks range in composition from granite to tonalite and dioritej however, quartz-monzonite and granodioritc predominate. THe histograms of estimated modes in figure 5 indicate the range in composition. They also show

a v/eak bimodal distribution of abur/hnco of plagioclase, potassium feldspar, mi r,;U3coviU'.

IS

The different kinds of orthogneiss werrj not seoaratsd in the field mapping and their relative ainounts are known only approxiir.ately.
Some idea of the relative amounts can be obtained, however, from the following descriptions.
Coarse-grained biotite augen gneiss composed of plagicclase, quartz,
and biotite with large augen of pink potassium feldspar is the pre-dominant rock in the eastern side of H-13 v/est of Pamplona. The
amount of biotite differs from place to place. Augen gneiss is also present in the mass of orthogneiss northeast of Morro Nevado (Fig. 4). It
s

/also a subordinate type in the Rio Caraba mass and in a'few places
south of Alto El Picacho. Farther south, the belt of Bucaramanga
s S

Gneiss passing southward across Rio Mancos and Rio Umpala in south-western H-13 and northwestern 1-13 contains lit-par-lit augen gneiss. Augen gneiss also constitutes parts of the orthogneiss along the east side of the Santa Barbara Batholith in H-13 and 1-13. It was observed near Santa Barbara and east, west, and south of Molagavita. Augen
r

gneiss is also present in the Bucaramanga c,neiss west of Rio Surata (H-12, planchita 109-IV-D, b-7),although it is
not shown on the map.

Biotite flaser gneiss characterized by small, often flat lenses
of feldspar and quartz set in an anastomosing fabric of biotite, fquartz,

^

and feldspar is a common type. It grades into lineated to foliated biotite-quartz-feldspar gneiss in which biotite is less abundant and
I

in discontinuous streaks. Composition is usually quartz inonzoniiic to X' v: granodioritic. These gneisses are fairly abundant in the Rio Cataba mass of orthogneiss, less so in the Tona mass and in places.east of the Santa Barbara batholith. J
-.-'I.

A strongly lineated, weakly foliated, eqigranular to slightly inequigranular pinkish-gray gneiss of granitic to quartz-raonzonitic composition with scattered uniformly oriented biotite crops out, in much of the Rio Caraba and Paramo de Santurban areas. It also crops^ out northwest of Tona in southeastern H-12. An associated rare bio^tite-
;*
free muscovite gneiss crops out locally. 5
A widely distributed but volumetrically small type is a granite
gneiss with flat lenses of quartz and with muscovite and biotite in discontinuous subparallel arcuate foliae. These rocks contains a sodic plaglioclase: oligoclase or rarely albite. The light-colored granitic types are alaskitic and contain only 1 to 2 percent biotite. Some of these have lenses and rods of feldspar and quartz that impart a 'granulite" texture. There is no evidence, however, that these rocks ever were granulites of the granulite metamorphic facies. At the contact of orthogneiss with the Silgara' Formation west of Alto El Picacho and also west of Tona is a fine-grained, pale pink to cream alaskite gneiss having marked lineation. Similar rock was observed associated with quartzite southeast of Mutiscua. In the field this reck
s difficult to distinguish from nu>tn jrmdotoue.
77

The orthogneiss near Tona is a gray to ijroenish-^ray hcri-.blc:;id£ biotite flaser gneiss of granodiorite to tonalite composition. It appears to be less mafic to the east and south. The gneiss contains lenticular oriented fine-grained dark-gray inclusions of the type usually considered to be cognate. Similar gneiss occurs east of the Mogotes and Santa Barbara batholiths and near Onzaga. South of Molagavita and south of Covarachia in 1-13 gray non-foliated to slightly gneissic granodiorite and tonalite occur in the same areas vrith more gneissic rock. These less foliated rocks are interpreted as plutonic rocks synchronous with other orthogneiss but which did not undergo the degree of deformation during crystallization
that tlie orLliugneiss did elsewhere.

In some places the predominantly uniform biotite orthogneiss contains muscovite layers. These layers are interpreted as local zones of high water vapor pressure in which retrograde muscovite has formed from feldspar during crystallization or metamorphism. Mo aluminum silicates are present in those rocks. Diorite gneiss locally strongly sheared, crops out in
"fault slivers between Silos and 3abega in H-13. These rocks have been mapped separately as a dioritic phase of the orthogneiss. They consist of hornblende and plagioclase with little or no quartz.

Layers- of crchcqneiss in 1 It-par-lit gneiss are of sorr.avr.at variable composition, although nearly all are poor in mafic minerals. They are either medium grained and granitoid, locally pegmatitic, and intimately mixed and plastically folded with the paragneiss, or they are distinct layers of uniform augen gneiss, flaser gneiss, or fine-grained gray biotite-auartz-feldspar gneiss.
General composition of orthogneiss is shown in figure 5, Augen gneiss is composed of about 30 percent quartz, 25 percent oligoclase, 40 percent microcline, and about 5 percent mafic minerals,chiefly biotite and chlorite. Accessories are apati te, iron oxide, and zircon (fig. 6). Alteration products are sericite and chlorite.

The flaser gneiss and granitic gneiss differ little in
composition. Quartz, plagioclase, and microcline and orthoclase are present in about equal amounts, or the potassium feldspar is slightly more abundant, .iicrocline is the predominant type of potassium feldspar, as in the augen gneiss. However, microperthite is present in sone biotite gneiss and biotite flaser gneiss. Orthoclase is common in others. Plagioclase is usually oligoclase to albite. Granitic gneiss has less than 5 percent biotite, whereas flaser gneiss approaching granodiorite may have up to 15 percent biotite, but normally contains 10 percent or less. Some specimens of granite <meis3 contain trace amounts of hornblende.

The granodicrite qnciss like that at Tona contains about 15 to
,25 percent quartz, 50 to 65 percent andesine to calcic-oligoclase, and 0 to 5 percent orthoclase with biotite and hornblende. Some flaser gneiss approaches this composition with 5 to 15 percent ortho-
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; clase or microcline, 30 percent quartz, and 45 to 55 percent oligo-

clase to andesine.

T,n.
,t the 9r«n1tl c

c«n«,,n is an present sporadically in all
traces of garnet.
The texture of the *rthogn.1s, is crystalloblastic ,n «nn
although the rock *ay be strongly lineated or foliated in hand specie Cataclastic and rehealed cataclastic textures . P-ent

crystallization foliation, particularly in the gneiss within rocks

the higher grades of metamorphisra.
S« augen gneiss has sublenticular potassiu, feldspar .egacrysts

gneiss was subjected to differential nove^nt. However, none of the minerals appear to be particularly crushed. Quartz in .any specks
* lenticular n«saics, but is not usually strained. Kicas tend to
be in U^inae of locally shredded flakes that interleave with larger
unoent .nuscovite flakes. Son, species do show cataclasis, but these
l are from aroas of late shearin, affecting othor rocks also. .
{JO

Plagioclase is unzoned or has only a faint relic oscillatory
zoning. In many rocks it has larqe clinozoisite or zoisite inclusions suggesting a history of saussuritization folloved by recrystallization angonson ation Qf ^ zoisite or clinozoisite component in^ larger grains. Perhaps this reaction took place under high activity of
H?0 accomoanied by shearing. The plagioclase with the large eridote grains is typical of the tonalite and granodiorite orthogneiss. In some specimens of these rocks the plagioclase is albite,suggesting greenschist facies conditions of metamorphism. Some plagioclase in migmatite is antiperthitic.
Hicrocline and orthoclase are the common types of potassium feldspar. In contrast to the younger batholithic rocks of the Santander massif discussed below, microperthite is rare.
Myrmekite in adjacent plagioclase is common. In some specimens
the potassium feldspar is large, mottled, and poikiloblastic. Muscovite in some specimens appears to have been derived from preexisting minerals in the gneiss, possibly from feldspar, and like the epidote has recrystallized from sericite derived froii altered feldspar. Mafics tend to be clustered in laminae. Biotite is typically greenish-brown to brownish-green.

Summary. The composition of the orthogneiss, its homogeneous, nonlayered character, the presence of cognate inclusions, and local dis-cordant contacts indicate a primary intrusive igneous origin for these rocks. Microscopic textures, structures, and the mineral parageneses s,of the orthogneiss indicate that it has undergone metamorphism during or after emplacement. That foliation and lineation of the orthogneiss and adjacent rocks are roughly concordant indicates that this meta-norphisin was regional in extent. Mineral parageneses and degree of recrystallization of the orthogneiss conform to a considerable degree
: with the grade of metamorphism of the surrounding rocks. Most
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orthogneiss mapped is either pre- or syn-metamorphic or both. Some
rocks mapped as orthogneiss could be locally sheared younger intrusions,

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Age. The orthogneiss is unconfcrmably overlain by tha Floresta
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Formation of middle Devonian age. Orthogneiss intrudes the Silgara Formation of probable Cambro-Ordovician age, and the Bucaramanga
gneiss that contains rocks of Precambrian age. From field evid&rvje
the orthogneiss could range from early Devonian to Ordovician, but
could be in part of Precambrian age. A Pb-Sr whole-rock radiometric ^determination on a specimen of orthogneiss from the Rio Caraba mass
« 'northeast of Berlin (IMN-12256, table 1) gave an age of 450*80 ra.y.
indicating'a late Ordovician age for the gneiss. A K-Ar radiometric
.- determination on hornblende from meta-diorite northeast of Ocana, north
of the map area in quadrangle F-12 (IMN-12262, table 2) gave' an age of 413-30 m.y. This rock is correlated with dioritic rock in the
5 Bucaramanga gneiss. Radiometric ages of 436 m.y. and 484 m.y. on biotite
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* from pegmatite from the Serrania de la Macarena (Pinson and others, 1962)
**'- confirm a plutonic episode in Colombia about this time. However, a

* problem remains in that the orthogneiss is also intimately associated I . .

with high-grade paragneiss of the Bucaramanagaj Gneiss in such a way that both rocks appear to have formed during the same plutonic-raetamorphic event. A Fb-Sr whole.rock age on paragneiss gives a Precambrian age
. (IMN-13199, table 1), although the age admittedly is somewhat
questionable. If this orthogneiss were also Precambrian then it means 'that during the Ordovician metamorphism the rock did not remain a closed
; system and the age was reset. Another interpretation is that whereas
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paragneiss formed during the Precambrian high-grade metamorphism, it
later underwent anatexis and a second high-grada metaimrphisia in

1 Ordovician time, during which time the orthogneiss was emplaced. The
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2 structure and texture of much of the orthogneiss suggest a two-stage
history of nvjtamornhism, and we postulate that the event-; Occ.rr-i in tha Pr<;catrbrinr; and Ordovi clan. / <-»
() u

Because some of the orthogneiss is so intimately associated with
the migmatitic phases of the Bucaramanga gneiss
from which Precairbrian radiometric ages are obtained, we must
.conclude that some or much of the orthogneiss is of Precambrian age.

s. This puts into question the observation that orthogneiss intrudes rocks i of the Silgara Formation. Either the Silgara Formation is not lower 'Paleozoic, but Precambrian, or othogneiss of more than one age exists.
* The latter probability is the most likely considering the evidence reviewed. We suggest that the larger distinct masses of orthogneiss are
the
' /younger, or Paleozoic age, whereas the smaller masses intimately associated with migmatitic gneiss are Precambrian. The other alternative
is that the Precambrian ages from the Sucaramanga gneiss are erroneous.
This does not seem likely.

04

IGNEOUS ROCKS

A number of batholiths, plutons, and stocks throughout the
Santander massif (fig. 4) consist of nonfol?.ated igneous rocks^
types range from diorite to granite. Gradational phases, similarity of rock types within as well as among different batholiths and plutons, stratigraphic relationships, and radiometric ages (tables 1,2) indicate that most of the igneous rocks belong to a single plutcnic interval. Age data indicate contemporaneity of rocks of most of the batholiths. The rocks of these dated batholiths are sufficiently distinctive so that undated batholiths can be correlated with them

with some confidence. The name Santander Plutonic Group is here i i

introduced as a useful term to embrace the major batholiths of the Santander massif. The Santander Plutonic Group can be divided into two suites: 1) pink granite and quartz monzonite, and
2) gray quartz-monzonite and granodiorite. A difference in relative age between the two suites has been suggested, although field relations and radiometric age determinations conflict. The rocks of both are assigned to the Jurassic and Ourassic-Triassic (pi- 1) Plutonic rocks not clearly related to the
Santander Plutonic Groun are assigned inferred relative positions in the map explanation.

The larger bathol'iths are predominantly pink quartz monzonite
and granite. Gray colors are generally restricted to smaller masses which are composed of granodiorite, tonalite, and diorite, the only exceptions are the white Durania Granite and the gray La Corcova Quartz Monzonite, although this too has a local porphyritic pink phase.
Contact relations indicate that generally the pink^ more granitic rocks are younger than the gray> more mafic rocks. However radiometric age determinations do not every/here support this
s

view. K-Ar ages on biotite from gray granodiorite on the Rio
Negro batholith gave a Middle or Early Jurassic age/./hereas K-Ar
ages on biotite from the pink Santa Barbara Quartz Mcnzonitc and the Pescadero Granite gave aqes on the Jurassic-Triassic boundarv. The gray La Corcova Quartz Monzonite gives a K-Ar age similar to that
of the pink granites (table 2, spec. 13197). We are inclined to think that the Jurassic age is aberrant rather than reflecting a spread in the time of plutonism.
The pink granites include the Pescadero Granite, quartz
monzonite of the Rio Negro and Mogotes batholiths, and the Santa
S f

Barbara Quartz Monzonite. Gray granodiorite of the Rio legro batholith, in spite of the younger radiometric age, and granodiorite of the Mogotes batholith are considered to be penecontemporaneouSj although field relations suggest they are slightly older than fehe
pink phases. The La Corcova Quartz Monzonite occupies a somev/hat arnbinuous position: relatively younger than tonal ite and qrartodiorito, but similar in aqe to the pink qnnites. *!o relative nosition for
the Durania Granite has been determined,

flf,

Bathol it-is in the northern oart of Zone III north of the area mapped, whose rocks on lithologic grounds are correlated with the suite of pink granites and quartz monzonites in the southern half of the zone are the batholith west of Sardinata, centering on Quebrada Aguablanca (Aguablanca batholith) and the coarser grained phases of the igneous complex in the Ocana and Abrego areas (OcalTa batholith). A batholith of gray granodiorite lying mainly east of Rio Tarra between the Aguablanca and Ocana batholiths is -correlated
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with a gray granodiorites of the Mogotes and Rio Negro batholiths. A K-Ar radiometric age on biotite from quartz monzonite of the Aguablanca batholith (IMN-13201, table 2) indicates a Jurassic-Triassic age similar to the Santa Barbara Quartz Monzonite and Pescadero Granite. Possibly the Rio Tarra and the Ocana batholiths
S"

are somewhat younger, corresponding to the younger age from the Rio Negro batholith. i
A compilation of estimated nodes and types of feldspar of the
major piutonic rock units is shown by histograms in figure 5. These histograms show qualitatively the absolute and relative amounts of essential minerals in the different rock units Fisur e 6 shows the distribution of some accessory minerals among some rock units. Samples
1 of the quartz monzonitic and sparser samples of the qranodioritic phases I of both the Rio Negro and Moaotes batholiths have been combined in
i
i the set of histograms for each batholith. This accounts for the
! weak bimodal and asymmetric form of the histograms.

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An insufficient r.urcbsr of sarr.oles of some rock types are
available for really meaningful histograms, and nany nontypical rocks are included in the samples, but on the whole the similarities and differences seen 1n the field and hand specimen among the different rock units is borne out by the diagrams. Many of the details of the figures will be referred to later. However, attention is called to the general similarity in form of the histograms and the curves of accessory mineral abundance of the Santa Barbara Ouartz
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jnonzonite and the quartz monzonites of the Mogotes and Rio negro batholiths, ignoring the granodioritic part of the histograms.

_____ _ . . _ _._ -Batholiths and plutons ----- ._ .._._._ Diorite and tonalite
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Oiorite of Rio Guaca .--A small stock of hornblende diorite crops
X '

out on the west side of Rio Guaca and its junction with the Rio Chicamocha in northeast 1-13. The rock is intruded by quartz-
i monzonite of the Mogotes batholith,which near the contact contains hornblende,suggesting contamination from the diorite. The
Bucaramanga fault cuts it on the east side. The diorite is
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mediun'-qrained.v/ith somewhat irreqularly distributed white I

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I

plagioclase in a dark matrix composed of hornblende grains of j

i

different sizes. The rock is somewhat altered and crushed near ;
faults. In thin section the rock is hypidiomorphic granular in texture. Major minerals are indistinctly zoned extensively sericitized plagioclase, and bluish-green hornblende. Accessories
are sphene, apatite, and epidote, plus traces of quartz and ;
potassium feldspar. ;
On the east side of the Rio Guaca acros-s from the diorite is a fine-
i
grained tonalite or diorite clearly intrusive into the
/ '
Silgara Formation. It is not certain

whether this rock is oart of the same body as the diorite to the i
west. Superficially, it resembles fine-grained tonalite and diorite that are fairly common as small masses throughout the zone. These rocks usually contain some ouartz. Mo thin section is available from this mass-rtfo determine the possible equivalency of these rocks is critical, as the diorite and the fine-grained diorite or tonalite lie on opposite side of the Bucaramnnga fault.

Diorite and Tonaiite nf Rio Surata area. A small mass of tonalite and diorite - almost 3 kilometers long, largely altered and
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crushed by faulting,is exposed in the Rio Surata just north of its
s

junction with the Rio Tona in northwestern H-12. To the west the tonalite is in contact with amphibolite-bearing gneiss and paragneiss, and to the east it is bounded by a fault along which in places the rock has been converted into chlorite schist. The tonalite in a few places, however, can be seen clearly to intrude metasedi-mentary schist and gneiss.
The rock is medium-grained,equigranular, and gray-green in
color. Inclusions of fine-grained diorite are common. In thin section the texture is hypidiomorphic where hot crushed. Ouartz

ranges from 1 to 15 percent, zoned andesine from 40 to i
60 percent, brownish-green biotite from 0 to 25 percent, and blue-green hornblende from 0 to 45 percent. Accessories are potassium feldspar,
»

spheae, apatite, iron oxide, and secondary chlorite and enidote.

Numerous small masses of tonal He and diorite of similar composition and texture cut the Bucaranianga Gneiss both north and south of Bucsramanga and are cut in turn by white to oink quartz monzonite and granite, (eg). Similar rock v/as observed along the Bucaramanga fault near Umnala. Hone of these masses are of mappable size. They nave been observed from the Umoala area to the
s /

Rio Negro batholith and may be related to the diorite in the Rio Guaca and small masses of fine-grained tonalite scattered throughout the zone, as well as to the larger mapoable masses.
Tonalite (t) similar in texture and composition crops out
south of Cachiri in northwestern H-12 within a small stock of quartz-monzonite. Another stock of tonalite intrudes the Bucaramanga Gneiss about 4 kilometers to the east.

91

Fine-grained tonalite.--Scattered throughout the metanorphic ard igneous rocks of tho southern half of the zone are masses 01 fine-grained tonalite, r.cst too snail to show on the maps, cornposed principally of plagioclase and hornblende. Th:y appear to be dikes or small stocks and are most abundant in areas of La Corcova Quartz Monzonite. Many sir.all masses are encountered on the road to Los Curos /

from Guaca in the Rio Mancos area and on the Bucaramanga-Pamplcna highway near and east of La Corcova. The more mafic phases of the
La Corcova Quartz Monzonite are similar in texture and approach the composition of the fine-grained tonalite. These rocks may represent a mafic phase of that unit. On the other hand, fine-grained tonalite is clear3.y cut by. quartz monzonite correlated with the la Corcova nn i

northern quadrangle 1-13, about 6 kilometers southwest of San Andres. The fine-grained tonalite has a uniform salt-and-pepper texture
and is usually nonf oliated, the one exception noted being a small mass cropping out on the Bucaramanga-Paraplona highway in northeastern H-13> below Morro Kegro. Typical rock is composed of about £0 percent zoned andesine, 10 to 20 percent quartz, 0 to 10 percent potassium feldspar,
^d 30 to UO percent biotite and hornblende, plus accessory apatite, sphene, iron oxide, and secondary epidote and chlorite.

no
*J M

Age and correlation. - - Whether all the tonalite and die-rite are of the same age is open to question. These rocks are post-metanorphic,
/

probably younger than the metamorphisra of the Silgara Formation, but some may be late metamorphic. They are cut by La Corco7a Quarts

Monzonite and
could be as young as Triassic. Some tcnalites resemble certain less gneissic phases of orthogneiss in the Onzaga and Capitanejo area, and metadiorite in the Vetas-California-Cachiri area. Some of. these rocks might be as old as Ordovician, because they resemble nonfoliated metadiorite near Ocana that gave a radiometric age of UlO m.yi

(table 2).Tonalite and grandiorite of the Paramo Rico Pluton.--The

Paramo Rico pluton covers an area of
j about 50 square kilometers centered on Paramo Rico in northeastern
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H-13. The southern appendage north of Berlin (fig. 4) is bounded chiefly by faults . The pluton is comoosed almost entirely of
tonalite and granodiorite (tgd). Small stocks of La Corcova quartz monzonite and quartz monzonite, aplite, and porphyry on its southv/est
: and northwest corners,respectively, are not considered part of the
i pluton. Granodiorite predominates in its southern part and tonalite 1n its northern part. Its contact with the Santa Barbara
batholith is concealed.

The

pluton consists of gray medium- to coarse-grained tonalite and granodiorite. Fresh and accessible exposures can be seen on the
, s

road from Berlin to Vet as, about 5 kilometers north of Berlin, and near

* California where fresh rock crops out on the banks of the Rio Vetas
below the town .
/
In the southern appendage north of Berlin, the rock is coarse
grained, somewhat inequigranular, gray, and nonfoliated. Near contacts and in apophyses it is slightly gneissic and of granodiorite composition. Dark fine-grained inclusions interpreted as autoliths are common. Mafic minerals tend to form clots. Sphene is a prominent accessory. The rock weathers spheroidally where massive to produce conspicuous corestone boulders. ;

The contact cf the tonalite and granodicrite with the Santa
Barbara Quarts I-Ionzonite is not exposed. The toxulite clearly intrudes the Bucara.nanga gneiss in the Paramo Rico area and is overlain unconformably by the Tambor Formation of Early Cretaceous age. Dikes of alaskite, aplite, and La Corcova Quartz Monsonite cut the tonalite, but no dikes of Santa Barbara Quartz Monaonite or Pescadero Gremite were observed. Near California, the tonalite is cut by quartz ffionzonite, aplite, and quartz porphyry. Small masses of gneissic tonalite are exposed in road cuts on the Berlin to Vetas road west cf Vetas. These are probably offshoots from the main mass of tonalite.
In the northern part of the pluton, the rock is medium grained and
somewhat more equigranular and is predominantly tonalitic rathsr than granodioritic.
In thin section the rock is hypidiomorphic and contains weakly zoned to nonzoned subhedral tabular plagioclase with complex twinning, large subhedral hornblende, brownish-green biotite,and interstitial quartz
and clear (limpid) potassium feldspar. Finer grained rocks lack
potassium feldspar. Estimated modes are 10 to 1$ percent quartz, U£
to 60 percent andesine, 5 to 1J? percent hornblende, £ to 20 percent biotite, and 0 to 10 percent potassium feldspar. Typical accessory minerals are sphene, apatite, iron oxide, and rare allanite. Chlorite and epidote are common alteration products. A trace of augite was observed in one thin section.

This rock, particularly in its southern part, shows textural end compositional similarities to granodiorite in the Rio Ilegro and Hogotes batholiths. It is oldar than the La Corcova Quartz Monsonite, but perhaps not much older. It is certainly pre-Giron and later than the major regional metajnorphism which is considered to be Ordovician. The tonalite and granodiorite could be as old as Silurian or as young as Triassic. Its age is probably toward the young end of this range.

La Corcova Quartz Monzonite A gray, fine- to medium-grained quarts monzonite which makes up
the main mass of the La Corcova pluton (fig. 4) is. here named the La Corcova Quartz Monzonite from exposures in the vicinity of La Corcova on the Bucaramanga-Painplona highway. The Pluton is remarkably linear and bounded by faults along most of its length. It is 35 km long and about 3 km wide. Dikes of the La Corcova Quartz Monzonite
are particularly abundant north of the pluton east of Bucaramanga. However, dikes and small masses of La Corcova are widespread
elsewhere in the zone. They are present in the California
district, near Vetas, in the Paramo Rico stock, and in granodicrite of

/ the Rio Negro batholith. No dikes of the La Corcova have been observed
in the Santa Barbara batholith, nor have the Santa Barbara c^uarxz Monzonite or Pescadero Granite been seen tc cut the La Corcova. Small stocks of La Corcova Quartz Monzonite crop out northeast of the main mass in quadrangles K-12 and H-13. Rock resembling the La Corcova is
present as small bodies in Bucaramanga gneiss east of Chitaga. Smaller masses of La Corcova are present near Vetas and i-Iorro Nevado, H-13. A gray quartz monzcnite in northern 1-13 scuth of Ssn Andres is tentatively correlated with the La Corccva Quartz Monzonite. La
Corcova Quartz Monzonite is well exposed on the road from Los Curos to Guaca in quadrangle H-12, Here, exposures of the intrusive contact of the La Corcova with the Bucaramanfa Gneiss can be seen, A porphyritic phase is exposed west of La Ccrcova and on the road to Tona near
s

the Rio Tona. A minor fine-drained biotite-rich phase with sor::o hornblende is exposed ear.t of La Ccrrova.

Typical La Core ova Quartz Hcnsonite is fine £r^lrv~-"i to med5un
grained, mostly equigranular and sugary tsutured -with evenly disseminated bictite. It is gray -where fresh, but weathers to light gray or to yellowish gray. In places it shows a little flow structure. VJhere massive, it tends to weather spheroidally forming core&t0KG boulders. In thin section the texture is xenomorphic to subhypidio-morphic granular, or aplitic. The rock is composed of 30 to 3$ percent quartz, 2£ to \£> percent zoned oligoclase, 30 to L£ percent potassium feldspar, predominantly microcline, about 3 percent biotite, and traces
to 2 percent muscovite. Accessories are apatite, iron oride, and
zircon; alteration products are chlorite, epidote, and sericite. The amounts of epidote ?>re uni\5iiXDy high for s rocV: otberv^^^; ar.peavi.pp
to be relatively low in calcium (figs. 5 a^d 6). Most of -the epidote is in plagioclase. The relatively abundant epidote and the ubiquitous
nuscovite suggest high 1^0 activity in the deuteric stage. The
oligoclase is tabular to stubby with irregular margins , and is normally zoned. The microcline has a pronounced grid pattern, but some potassium feldspar is perthitic. Kicrope£,Katite is present in scr.e specimens.
The biotite is brownish green to greenish bro^n and tends to be shreddy.

The composition of typical La Corcova Quartz Monzonite is distinctive. The abundances of plagicclace and quartz are less than in "She other quartz monzonites, and the abundance of potassium feldspar is slightly greater (fig. 6). The abundance of potassium feldspar is unsuspected in the hand specimen because the potassium feldspar is white instead of pink. It should also be noted that microcline is the common potassium feldspar rather than the micro-perthite common in the pink quartz monzonites. The La Corcova contains the least allanite of any of the rocks.
The porphyritic phase (JT<clp) forming the mass near Tona
(quadrangle H-12) contains pink potassium feldspar phenocrysts in a fine- to radium-grained matrix identical to,though slightly coarser grained than,normal La Corcova Quartz Monzcnite. In thin section, the texture is similar to that in the normal phase, except that, microcline is large and poikilitic.. Plagioclase is slightly more abundant than micrccline and is calcic rather than sodic oligoclase. Biotite is also slightly more abundant.

A. biotite-rieh phase with sinilar sugary, line-grained texture is present locally in masses too small to be mapped. Thir. rock secns to be gradational in composition with both tbe La Corcova and to the fine-grained tonalites described in a previous section. Outcrops of .this type of rock can be seen on the Los Curos-Cuaca road south arid east of the Rio Kanco, and at a few places on the Bucaramanga~?ar;:piona high-way east of La Corcova. Sorne of this rock is slightly porphyritic with white plagioclase phenccrysts. Texture is similar to that of the La Corcova but tends to be hypidiomorphic -with tabular calcic-oligoclase to andesine. Potassium-feldspar tends to be microperthite rather than microcline. The amounts of quarts and potassium feldspar are less, whereas the amounts of plag.icclass and biotite are greater than these
in the La Corcova. Hornblende is present, and sphene is an accessory. Muscovite is lacking. Inclusion of estimated modes of these rocks in
the histograms of figure 5 probably gives the histograms their somewhat bimodal and asymmetric character.

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' A K-Ar age on muscovite frcm the normal La Ccrcova (table 2, specimen 13197) is similar to K-Jlr ages frcra biotite frcm rocks fro^i
the principal batholiths of the massif. The age of the La Corcova Quartz Monzonite relative to other rocks of the Santander Plutonic Group
is uncertain. Dikes of La Corcova cut granodiorite of the Rio Negro batholith and tonalite and granodiorite of the Paramo Rico stock, as well as fine-grained tonalite. At one outcrop on the road to Tona,
pink quartz monzonite of the porphyritic phase of the La Corcova cuts jthe normal gray quartz monzonite. Wo crosscutting relationships of La Corcova -with the Santa Barbara Quartz Honzonite, Pescadero Granite, or j
pink quartz monzonite of the Rio Negro and 1-Iogotes batholiths -were seen. . The La Corcova would thus appear to occupy an intermediate position in time between the gray granodioriuie igneous rocks and the pink and mere granitic igneous rocks. The strongest argument for the penecontempo-raneity of the La Corcova Quartz Monzonite with the pink quartz monzonites of the batholiths is that phases transitional in texture and composition seem to exist between them. The distinctive texture of the La Corcova is observed in rocks of medium- grain size rather
than the typical fine grain size of the La Corcova,.and in rocks containing potassium feldspars pinker than those in the La Corcova. Thus, the typical La Corcova grades into medium-grained and porphyritic rocks
like those which make up the bulk of the Santander Plutonic Group.
This is particularly striking when samples of the La Corcova porphyritic phase are compared, for example, with porphyritic granodiorite of the
Rio llegro and Mogotes batholiths, and the La Corccva norn.al phase with
the more biotitic of the quartz nonzcnltes of the Rio iiegro and
tiogotes batholiths. There does not seem to be a clear transition,
. However, to pink to pinkish-white mafic-poor granite such as the
1 Pescaderc.

101

Quartz rncnzcnite, prsniie, and cuartz DcrDhyr
Stocks and plugs of pinkish-gray to light-gray and light -tan
quarts monzonite, granite and quartz porphyry, and rare granodiorite are scattered in the Silgara Formation and the Bucaramanga Gneiss in the northern parts of H-12 and H-13- Many of these stocks and plugs are
s

east of the Rio Negro batholith. Other stocks and sill -like masses are qitea north and northeast of the main mass of La Corcova Quartz Monzonite. Some of the small stocks in the area of the big bend of
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the Rio Surata south-southwest of Katanzas contain porphyritic rock. Most of these rocks are deeply weathered and fresh rock is difficult to obtain. An isolated stock of light-colored quartz monzonite 11 kilometers north-northwest of Mutiscua (H-13) appears to be similar to those in the Matanzas area.
The small stocks and plugs of quartz monzonite and granite differ somewhat in texture and composition from one another. Some tan to light-gray rocks resemble the La Corcova Quartz Monzonite in that they have the same sugary texture and evenly disseminated biotite, although they are medium grained rather than fine grained. Some masses contain Muscovite and resemble certain border rocks of the Rio Negro batholith.
* few are light pink like some quartz monzonite in the Rio Uegro b*tholith.

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Quarts monzonite, aplite, and. porphyry (cgp) form a composite
stock near California in quadrangle H-13 and appear to be similar to 7>ale-pink phases of the quarts rr.onzonite granite and quartz porphyry. l!uch of "Giis reck in this area has been extensively fractured, leached, and impregnated with silica and sulfides, .primarily auriferous pyrite. This composite stock contains outcrops of rock of the La Ccrcova type as well as dikes of rhyodacite and dacite porphyry.
The bulk of the rock near California is fine-grained, .pale-pink
to white, locally medium-grained granite or quartz monzonite with characteristic bipyramidal quartz phenccrysts. Two phases have been noted: a porphyritic phase with quartz and feldspar phenocrysts, and an even-grained aplitic phase. Some fresh rock contains disseminated fine-grained biotite similar to that in the La Corcova Quartz Konzonite. The texture is aplitic in thin section,'..ath equant nonzoned oligoclase and perthitic potassium feldspar.
The stocks and bosses described above appear to differ enough to suggest that they are not all of the same age or origin* Some appear to be related to the La Corcova Quartz Monzonite; others to the quartz monzonite of the Rio Negro batholith; and yet others are not clearly related to any of the other major plutonic units. They all, however,
been assigned to a single unit on the geologic map. Conglomerate
the Bocas Forir.aticn of Triaesic age contains pebbles of rocks of
unit. Some or all ofths quartz monzonite, granite, and porphyry therefore, of Triassic or older age, possibly Permian.

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The Durania Granite is a white muscovito granite forming
srcall plutons and stocks in a north-south belt extending from the Paraplona area in eastern K-13 north to and beyond the towns of Durania

and Villa Sucre in Norte de Sanbander beyond the limits of the nap area, |
!lhe granite is narked for the town of Durania, near -which the typical granite is well displayed.
The largest mass of Durania Granite is in the Pamplona pluton
17 kilometers long by U kilobit era wide south of Pamplona in noi'theastern H-13 (fig* U). -A. smaller mass crops out to the south
near the Silos-Chitaga road, and another small mass lies partly

pegmatites with the same minerals as the granite are relatively abundant in the metasedimentary rocks surrounding the Durania Granite
.and are obviously related to it. Some of these pegmatites have been exploited for mica and feldspar near Boohalerna north of the map area. Elsewhere, garnet' and tourrnalina are prominent.

104

The Durania Granite is T,<iiite, equigranular, medium- to coarse-grained, and slightly gneissic in places. It weathers readily by disaggregation to grus. Major constituents are subequal amounts of quartz, inicrccline, and plagioclase (albite to sodlc oligoclase). The plagioclase is shown as oligoclase in figure 5. Muscovite is prominent generally in amounts up to $ percent, rarely 10 percent. Accessories include garnet, tourmaline, iron oxide, and zircon. One atypical
specimen contained no potassium feldspar. Only three specimens suitable for thin sectioning were obtainable, and two of these came from north
of the rr«ap area.
The age of the Durania Granite is not known. The youngest formation
it is seen to cut is the Silgara Formation. It is late or post-metamcrphic and is overlain by the Tibu'Formation of early >liddle Cretaceous age. The range of possible ages of this rock is from Ordovician to middle Cretaceous, It is more likely, however, to fall between the Devonian and Jurassic. Because of the uncertainty in age of this granite and because of its different lithology, it is not included in the Santander Plutonic Group, and has been placed arbitrarily belcxv it on the map explanation.
A K-Ar age determination on muscovite collected by Paul Duran from
a pegmatite cutting Bucaratnanga Gneiss east of Chitaga thought to be related to ths Durania Granite gave an age of 432-457 m.y. (table 2, specimen 14362). This indicates that either the Durania Granite is Ordovician in age rather than younger,or that the pegmatite is not reIc-ed to the Durania granite. The age is in the range of radiometric agrs shown by the orthogneiss (tabler, l. and 2).

Santa Barbara Quartz Monzonite The Santa Barbara Quartz Monzonite is a fairly uniform, coarse-grained and inequigranular biotite quartz monzonite that makes up the bulk of the Santa Barbara batholith. The quartz monzonite and the batholith are named for the settlement of Santa Barbara, which is near the center of the Trass (fig. k) -

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The Santa Barbara Quartz Monzonite batholith extends from
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near Berlin, in east-central quadrangle H-13, southward to the
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Bucaramanga fault near the junction of Rios Chicamocha and Guaca. The batholith is about 60 km long and its width ranges from
5 to 12 km. Its shape is linear and its borders are only locally faulted. Two small plugs of Pescadero Granite occur at its northern end near Berlin. The rock within the batholith is almost entirely a fairly uniform, coarse-grained, pink, quartz monzonite.

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Although the Santa Barbara Quartz Honsonite is largely confined to
the Santa Barbara batholith, small areas of quartz monzonite crop out to the east, east of Rio Angosturas in the southern part of northeastern H-I3, and in an area near Laro del Ortices south of San Andres in 1-13. The quartz raonzonite has been recognized at places within the 1-Iogotes batholith north of Mcgotes and near San Joaquin.
The Santa Barbara Quartz Monzonite is megascopically coarse grained, somewhat inequigranular, and orange-pink to purplish-gray with
"" prominent orange-pink to grayish-red potassium feldspar, white plagio-clase, and gray quartz, and 2 to 3 percent biotite. In inequigranular phases, potassium feldspar forms phenocrysts as large as 20 nun. In
more equigrauular ' phases, potassium feldspar may be as much
as 1$ ran in long dimension, plagioclase 12 mm, and rounded quartz 5 mm. Mafics tend to be in small clusters, locally as much as 5 HEI in diameter. Quartz, potassium feldspar, and plagioclase are present in subequal amounts, but generally the potassium feldspar is slightly more abundant than the plagioclase (fig. £).

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jji thin section, the typical quartz nonscnite is hypidiomorphlc inequigranular with sub tabular to equant, slightly zoned oligoclase
and calcic albite. Centers are usually saussuritized, whereas rims
are fresh. Potassium feldspar is dusty microcline and fine string and j rod or screen perthite. Biotite is greenish brcwn and usually altered to chlorite and clustered with apatite. Typical accessories are sphene, apatite, iron oxide, zircon, and allanite. Alteration ; products are chlorite and epidote. A few grains of hornblende were
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noted in the quartz rconsorate in the Berlin area. Except for having more samples containing sphene, the relative amounts of'accessory minerals are more or less similar to those in the quartz monzonite of
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the Mogofcas batholith (fig. 6)*
In the darker-colored more mafic phase, the plagioclase is tabular
and well zoned. The plagioclase is calcic oligoclasejand accessory hornblende may be present with biotite. Plagioclase is more abundant
than potassium feldspar. . :

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The quartz monsonite weathers readily to grus and forms a some:me,t porous soil with a consequently low water table. Slopes in saprolit-3
! on the Santa Barbara at one place measured UO degrees.
i The rock is well exposed, although quite weathered, on the road
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ifrom Los Curos to Guaca where it crosses the width of the batholith.

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!Weathered outcrops are accessible southeast of Berlin from the road
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from Berlin to Baraya and Guaca.
: A. darker colored, medium-grained phase with £ to 10 percent biotite and a trace of hornblende crops out in places. This rock is exposed on the Los Curos-Guaca road just east of Quebrada El Retire
; west of the Rio Umpala (H-13, 12-I-C, J-5).
Dikes of pink aplite locally in swarms cut the
quartz monzonite. These are more resistant to weathering and stand
out as ledges. These can be seen on the Los Curos-Guaca road west of
the turnoff to Santa Barbara (H-13, 121-I-C, J-6, J-7, J-8).

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Conglomerate and arkose of the Giron Formation of Jurassic are
contain detritus from the Santa Barbara Quartz Monscoite}
unroofing and erosion of the
Santa Barbara must have taken place prior to Giron time. Two K-Ar
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._jradioraetric ages on biotite from the Santa Barbara Quartz Monsonite-i

i (table 2) give ages of 192^7 and 19U-7 m.y. These ages are in accord

i . with a radiometric ago obtained from a biotitic phase (similar to

quartz monzonote of the Mogotes batholith) of the Pescadero .Granite
to the west (table 2). In addition, a whole-rock K-Ar age determina-

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tion on a specimen of phyllite taken south of Berlin about 1 km horizontally and probably less vertically from the contact of the batholith gave an age of 198-7 m.y. These ages are about on the boundary of the Jurassic-Triassic boundary. Considering the probable * slow -cooling rates of a batholith this siaa (Winkler, 196.7, p. 83>
& _
Hamilton, 196£, p. 71), it is likely that the actual age of displace-ment is latest Triassic rather than earliest Jurassic^ however, the
age designation here given is Jurassic-Triassic.

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Pcccaciero c^-nite

The Pescadero Granite (Jrirgp) is a fine-grained, orange-pink, leucocratic granite named for exposures in the vicinity of Fsscadero
'in the municipality of Umpala (H-12). The Pescadero granite forns an elongate, somewhat irregularly shaped pluton lying west of the Bucaramanga faalo from north of Lcs Curos to the vicinity of Cspita o.i Rio Chicaniocha. To the -west the granite intruder, iHetasetiirr.erits of the Silgara* Fcnaation. The Pescadero granite in this area could be considered part of the Mogotes batholith, because the main mass of Mogotes to the south contains rock like the Pescadero, and a biotitic phase in the Pescadero is similar to biotite quartz monzonite of the Mogotes*
The Pescadero is overlain unconfonnably by the Jordan Formation
of Jurassic age whose basal conglomerate contains fragments' of Pescadero-type rock. Rhyolite dikes that cut the Jordan south of the town of Los Santos are apparently younger. To the north, the Pescadero granite passes into a rhyolite porphyry exposed along the road south of Piedecuesta. This rock, which is similar to dikes within the main mass, has not been mapped separately. , The Pescadero Granite weathers to a light-colored, porous, sandy
soil. Near Los Curos, the granite is appreciably brecciated and
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weathered. In the canyon of the Rio Manco to the south, however, the granite is fresh, although intensely jointed and faulted owing to/its Proximity to the Bucaramanga fault.

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A contact zone in which numerous aplite and pegmatite dikes of
the Pescadero cut the Silgara Formation is well exposed along the Bucaramanga to Bogota highway l.Lj. km south of the bridge over the Rio Chicamocha at Pescadero.
_: Some evidence suggests that the original intrusive contact of the Pescadero with Bucaramanga gneiss on the east lies along the site of the Bucaramanga fault. This is suggested by outcrops in fault slices
northwest of Umpala in tributaries of the Rio Manco --ihich expose ;
fairly sharp, apparently intrusive contacts between granite and gneiss. Typical Pescadero Granite is orange-pink, very fine to fine-
grained, equigranular to slightly porphyritic, with phenocrysts of potassium feldspar only slightly larger than the average grain of the rock, and a few scattered clots of mafic minerals. Some of the rock
has vugs containing drusy quartz, but these are believed to be related
- to faulting. The rock is typically leucocratic. Albite or sodic :

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oligoclase, orthoclase and microperthite, and quartz are present in
from subequal amounts to a UO to 2£ ratio of potassium feldspar to albite-oligoclase (fig. 5). Accessories are sparse with generally less than 1 percent iron oxide, muscovite, biotite, zircon, and apatite.
The microperthite ranges from a string-and-rcd type to a braid perthite. , Kicropegmatite is common. Muscovite is tabular and contains small
! ' !

,grains of exsolved iron oxide. Some inuscovite(?) is in radial i ^
Aggregates. The plagioclase is generally not zoned. Porphyritic
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phases contain phenocrysts of albite and rarely quartz; the remainder
'Of the quartz is in micropegmatite or graphic texture.

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JL medium-grained orange-pink biotite granite and quartz ir.cnzonite similar to some biotite quarts raonsonite in the Mogctcs plutcn to the south crops out in places northeast of Pescadero along the Rio Manco.
It was this rock fron which biotite was obtained for the K-Ar age :determination on the Pescadero granite (t«.ble 2). It is slightly

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; coarser grained and contains more biotite than the typical Pescadero but is apparently related genetically to it. This rock is slight?iy inequigranular in thin section and hypidio:Tiorphic. Relative amounts
i
of minerals are about the same as in the typical Pescadero, except that biotite or chloritized biotite is present . in amounts up to 3 percent. Plagioclase is tabular, zoned, and is calcic albite or sodic oligoclase. Kany grains of quartz and particularly orthoclase : contain inclusions of the tabular plagioclase. Orthoclase is slightly i
jperthitic; quartz tends to have an equant or bipyramidal habit. Allanite is a sparse accessory in addition to the .suite normal in. the Pescadero.
Dikes within the Pescadero Granite consist.of pegmatite, aplite, and porphyritic rhyolite and rhyodacite. The porphyritic rhyolite dikes
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have phenocrysts of albite or sodic oligoclase and less abundant
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phenocrysts of quartz, orthoclase, and chlorite (apparently after ibiotite). The matrix is microcrystalline with nebulous subspherical jfeldspars and quartz, or distinct spherulites of quartz and potassiin |
i feldspar. Some samples of rhyodacite have a felty texture with small
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'euhedral feldspars. The textures are similar to those of the
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porphyritic rhyolite south of Picdecuesta.

113

Two pluglike masses of Pescadero Granite cut the Santa Barbara
Quartz Monscnite and ice t a sedimentary rocks south cf Berlin in north-west H-13. Another mass, poorly known, is located at the Rio Cueutilia at the extreme north edge of quadrangle H-13. Pescadero granite contain-
5 ing a little muscovite crops out in the Bucarananga gneiss northeast of Chiitaga in H-13« An area containing abundant small bodies of Pescadero Granite is located near San Joaouin in quadrangle 1-13. Pescadero Granite crcps out here and there in bodies too small to map
in the Mogotes batholith and Santa Barbara Quartz Monzonite.
c - A K-Ar radiometric determination on biotite from the biotitic rock
in the Pescadero Granite gave an age of 193±6 m.y. (table 2). This
falls between the two ages obtained from biotite. in the vSanta Barbara batholithj it places the Pescadero, and by extrapolation the quartz monzonite of the Mogotes batholitb^ in the same age group. They are
' *- at least, peneconteriporaneous, if not all of vir-tually identical age.

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The Mogotes batholith
The Mogotes batholith, ona of the larger batholiths in the
southern half of the zone, is in quadrangle 1-13, southwest of the Bucaramanga fault (fig. 4). The batholith is about 40 kilometers long and 15 kilometers wide at its widest part; the average width is about 10 kilometers.

The batholith consists of several distinctive rock types. The
main mass is a light pinkish-gray to pinkish-white biotite quartz monzonite and granite (Trc) predominantly medium-grained equigranular. Coarse-grained phases similar to the Santa Barbara Quartz ftonzonite and fine-grained pink phases similar to the Pescadero Granite croo out within the main mass. The Pescadero Granite (OTrgo) north of the main mass is considered part of the batholith. A mappable mass of Pescadero Granite is near San Joaquin. Tov/ard Onzaga the rock is a porphyritic granodiorite and granodiorite (JTrgd). Dikes of rhyolite, rhyolite porphyry, aolite, quartz latite, and lamprophyre are fairly common, particularly in the southern part near Mogotes. A small stock of rhyolite near Onzaga is just south of the map area.
Most of the eastern margin of the batholith is bounded by the Bucaramanga fault. The batholithic rocks are intrusive into screens or roof pendants of Bucaramanga Gneiss in places west of the'fault. /
Elsewhere the batholilh .intrudes the Silgara and Floresta Formations or the orthogneiss.

Quartz monzonite of the Ho^otes batholitb

The quartz monacnite of the Mcgotes batholith is orange pink,
pinkish gray or pinkish white, equigranular to subporphyritic with a grain size of 1 to 3 mm. The subporphyritic rocks have grains of potassium feldspar only slightly larger than the average grain size of the rock. The rock weathers readily to grus and makes a cr^am-colored to buff soil, becoming a deeper orange color where derived from more biotitic rock.
j The typical rock is leucocratic and contains subequal amounts of
j
white oligcclass, pink potassium feldspar, and gray quartz (fig. 5)
and less than 3 percent biotite. Less biotitic varieties contain more
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I potassium feldspar than plagioclase and more biofcitic varieties contain 5 ~iless. It should be noted that the histograms (fig. £) include modes of 1

; samples of the granodiorite near San Joaquin.
i In thin section the texture of the quartz monzonite of the
Mogotes batholith is hypidiomorphic and slightly inequigranular. Oligoclase is tabular and nornally zoned. The potassium feldspar is
a rod or bead microperthite. Quartz Li in subequant grains or is interstitial. Greenish-brown biotite is in laths, commonly with inclusions of apatite. Accessories .rre apatite, iron oxide, zircon,
and allanite, with secondary chlorite, epidote, and serioite. Sphene
is present only in relatively biotit^-rich rocks approaching grano-
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diorite in composition. Some fine-drained varieties are white in
and aplitic in texture. They contain albite or sodic Oligoclase, micrographic 'or rdcropegmatitic texture is coi.uion as in some of
the Poccadero granite. The porphyritic varieties differ only in haviry
s of rnicrou.jrlhUc. ']] P

Rock
similar to the Santa Barbara Quartz Monzonite and the Pescadero granite crops out within the main mass of quarts rnonzonite. Pink dikes in the Mogotes area have the usual graphic and spherulitic textures of dikes
s- in the Pescadero. Biotite is in very thin flakes recalling the thin muscovite flakes with the exsolved iron oxide in the Pescadero Granite. Dikes of porphyry have a mosaic groundmass of quartz, plagioclase, and ortboclase with phenocrysts of plagicclase, quartz, orthoclase and
platy biotite. i : Histograms of the quartz monzonite of the Mogotes batholith (fig. £) approach those of the Pescadero Granite with which it is associated.

The influence of Pescadero-like samples included in the modes probably i
accounts for the slight difference in form of the histograms from those
s

of the Rio Negro batholith. ;

Granodiorite of the Mogotes batholith . \
East _and southeast of San Joaquin is a gray inequigranular to equigranular granodiorite similar in appearance and composition to the granodiorite at the southern end of the Rio Negro batholith. As in the
_ Rio Negro batholith, the contact of the granodiorite with the quartz monzonite is not clear. It may be gradational.

117

The grancdiorite of the Mogotes batholith is gray tc pinkish gr^y, medium to coarse grained with scattered large orange-pink crthoclase phenocrysts and smaller grains of gray quartz, white plaaioclase, and black biotite. Equigranular phases wi.th grains ranging from 2 mm to 2 cm ' make up an appreciable percentage of the rocks in this area. They resemble much of the rock in the Kogotes batholith to the northwest but with somewhat more biotifce and fewer but larger potassium feldspars. In thin section the-porphyritic type is hypidiomorphic with phenocrysts of relatively large perthitic orthoclases and smaller tabular-zoned ardesine or oligoclases. Quartz is anhedral to interstitial. Biotite, iron oxide, sphene, apatite, and rare hornblende tend to be in clusters. Sphene, allanite, zircon, apatite, iron oxide, and epidote and chlorite are accessory and secondary minerals. Oligoclase and andesine are more abundant than potassium feldspar. Hafics make up 5 to 10 percent of the rock. Brownish-green biotite typically has numerous inclusions of apatite. Equigranular phases of the granodiorite have a similar composition. Although relatively few samples of the granodiorite from the Mogotes batholith were available, the rock appears to contain more
s

allanite than the granodiorite of the Rio Nagro batholith which it otherwise resembles.
In some places, gray granodiorite without pink feldspar
resembles the less foliated granodicritic phases of the
adjacent orthognciss. It is possible that some areas of orthogneiss have been mapped as granodiorite of the Mogotes batholith.

Aee of the cuartz monzcnite and ^ranodiorite of the Mogotfis batholith _

The quartz monzonite of the Mogotes batholith is probably related
to the Pescadero Granite and the Santa Barbara Quartz Monzonite, on
the basis of the general similarity of lithology of the three rocks, their gradational facies, and their stratigraphic and structural relations with older and younger sedimentary rocks. The sample from the Pescadero Granite from which the radiometric K-Ar Jurassic-
Triassic age was obtained (table 2) is lithologically quite similar to
the quartz monzonite of the Mogotes batholith. This quartz monzonite is probably also Jurassic-Triassic in age. The granodiorite is
considered to be of about the same age because it appears to be a
phase of the same batholith..

110

Rifo Ne^ro batholith
The southern end of the R£O Negro mass of quartz monzonite,
granite, and granodiorite lies east of the Bucaramanga fault in northeastern H-12 (fig. 4). The west side of the batholith is obviously cut off by this fault. The southern end of the batholith is a thin tail projecting southward along the fault toward Rio Surata. The pluton is at least 50 km long and extends north for an unknown distance. At the quadrangle boundary the batholith is 14.5 km wide. Farther north, beyond the map area, the batholith is about 20 kin wide. From its trend, it is doubtful that it is continuous with
the Ocana batholith in the Ocana-Abrego area.

The batholith is composed of pink to pale-pink quartz
monzonite and granite (Jc) in its northern part. North of the
/
quadrangle along the Rio Cachira, a gray phase was encountered west of La Vega and a pink phase east of La Vega. Near Rio Negro and
south of Santa Cruz is gray to pinkish-gray granodiorite (Jgd). The southern tail of the batholith consists of the granodiorite with appreciable tonalite, both cut by pink to white medium-grained
quartz monzonite .(eg) which predominated toward the Rio Surata'.
A small isolated mass of similar pink quartz-monzonite intrusive
I Into tonalite is exposed in the area of Los Jardines and Pan de
t

Azucar, east of Bucaramanga. _.. _ ... _.___..___

120

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.. Grancdiorite of the Rio IJeero batholith

; The southern end of the Rio Negro batholith in the vicinity of Rio Negro and along and south of the Rio Santa Cruz consists of gray granodioritej usually porphyritic, and subordinate equigranular tonalite resembling tonalite of the Paramo Rico pluton. The grano-diorite in this area has many inclusions and septa of Bucaramanga

v* __

gneiss and its southern border is an extensive mixed zone.
(The Bucaramanga fault forms the western border of the granodiorite. To the north of the Rio Santa Cruz, the ~
granodiorite is in contact with more felsic pink to white quartz monzonite and granite. Little is known about this contact, and it may be gradational. The northeast contact is a mixed zone with bulh Ihe Bucaramanga Gneiss and the Silgara Formation. The southeastern contact is a sharp and fairly straight contact with the Bucaramanga" gneiss.
*-- s

Scattered outcrops of the granodiorite of the Rio Negro batholith
can be seen on the road from Rio Negro to Santa Cruz and on the spur
road southeast from Sardinas at the junction of the Rio Santa Cruz and Quebrada Guayana,

121

Typical granodicrite is gray, medium- to coarse-grained , and sub - porphyritic with scattered phenocrysts of large orange-pink potassium feldspar and slightly snaller white plagioclase set in a matrix of gray quartz, biotite, and smaller feldspar grains. The rock is nonfoliated to slightly gneissic. In thin section the texture is hypidioraorphic . The rock is composed of about 10 to 20 percent quarts, U5 to 60 percent euhedral to subhedral, zoned andesine, 10 to 20 percent potassium feldspar, chiefly microcline, and 5 to 10 percent biotite. Hornblende is present only in a few tonalitic rocks. Quartz and potassium feldspar, except where the latter form phenocrysts, tend to be interstitial. Common accessories are sphene, apatite, allanite, rare zircon, and secondary chlorite and epidote. The presence of the

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granodiorite phase can be readily detected in the asymmetric and bimodal naturfe of the histograms of the Rib Uegro batholith (fig. £). The distribution of accessory minerals, in the granodiorite resembles that of tonalite, except for a difference in sphene content (fig. 6). Small masses of tonalite within the granodiorite show compositional textural similarities to the masses of fine-grained- tonalite and described in an earlier section. These rocks are dark,
fine grained, equi=;ranular to slightly porphyritic, and consist of about 10 percent quartz, 6£ percent tabular, zoned andesine which
locally forms phenocrysts 0 to 5 percent microcline, 10 to 2$ percent
\

blue-green hornblende, and 5 to l£ percent brownish-green biotite.
and so-crJary minerals are identical to those in the
ite, Thn ^rinodiorite is cut by rare dikes of diabase and
aplite that r^..~;-bles the La Corcova Quartz Monzcnite. ST
it

122

Quartz nonsorrUe of the Rio Negro babholith i
Quartz monzonite of the Rio Negro batholith is a pink to light-gray, equigranular to subporphyritic, UK dium-grained biotite quartz monzonite consisting of about £ percent black biotite, and approximately equal amounts of gray quartz, -white plagioclase, and orange-pink to pale-pink potassium.feldspar* Porphyritic phases have phenocrysts of pink potassium feldspar and locally phenocrysts of plagioclase also. The rock is generally quite weathered and fresh exposures are not readily ; i

accessible but may be seen along some of the streams east of the Bucaramanga fault. The quartz monzonite weathers to a yellowish light-gray soil that is locally orange where the rock is more mafic. The texture of the quartz monaonite in thin section is hypidio-aiorphic. The rock is composed of 2£ to 35 percent quartz, 2£ to U5 percent indistinctly zoned subhedral oligoclase, 20 to UO percent anhedral microcline and raicroperthite, and 1 to 10 percent biotite. Accessory minerals are z5.rcon, sphone, allanite, apatite, iron oxide, and secondary chlorite, epidote, and sericite. The abundance and distribution of accessory minerals are similar to those in the quarts monzonite of the Mogotes batholith (fig. 6).

,« . * -. . , ..L opt in olaces. ... ,, _,_ white to pale-pink granite crops /near contacts with the Silgara

Formation. The composition and texture of this rock is similar to that
of the main mass, except that it contains albite rather than oligoclase and as much as J> percent muscovite, whereas biotite and iron oxide together are less than 2 percent.

JL 1 \) T*

In comparison with, the quartz monsonite of the Mogotes batholith,
[s

the quarts monzonite of the Rio Negro batholith is less pink, somewhat ,more biotibic, and potassium feldspar is rcicrocline rather than micro-pert hit e»
-; Two K-Ar age determinations on biotite from granodiorite near Santa Cru2 (IMW-1089U, table 2) gave ages of 172±6 m*y. and 17716 ra.y. {
or Middle to Early Jurassic. This age is about 20 million years
i
: younger than the ages of the other batholiths dated in the zone with /
which the Rio Negro batholith had been thought to be roughly coeval.
~ Accordingly, the Rio Negro batholith is shown as of Jurassic age on
- r plate 1. The quartz monzonite is presumably penecontemporaneous with the granodiorite, although field relations suggest it might be slightly younger. In spite of the biotite age,
the rocks of the Rio Negro batholith are included in the Santander Plutonic Group because of their petrographic similarity to other rocks
in the group.

133

Rhyolite in the 3ocas Formation Sheets of apparently intrusive rhyolite, granophyre, and breccia within the Bocas Fornation in northern H-12 west of the
1 Bucaramanga fault.
-! The rocks are greenish white, pale tan, light gray, purplish gray !to pinkish gray, and aphanitic, porphyritic or fragmental. Breccias contain greenish-gray, pinkish-gray, and red fragments. Some of the
I rocks have prominent gray spheroids with white rims in an aphanitic !grayish-white matrix with rare green mafics. Scattered small pyrite
- crystals are present in some samples. Some rocks are flow banded.
In thin section many of the rhyolitic rocks have a spherulitic
i texture similar to phases of the Pescadero granite, others are fine-i
igrained aplite composed of plagioclase, quartz, and orthoclase with
- rare opaque minerals and traces of zircon. Small clusters .of orange biotite are present in some samples. Porphyritic varieties have -phenocrysts of quartz and orthoclase. Samples of breccia have fragments of the rocks described above. Some fragments contain

1 spherulites, others are aplitic. Some contain tiny laths of plagio- i |clase. Abundance of mafic minerals differ from fragment to fragment k* the breccias. Some fragments appear to be of sedimentary rock with clastic quartz grains. Much of the opaque material present is red-
i

I brown oxides of iron. Where present t orthoclase phenocrysbs are
f
Perthitic. Plagioclase has low relief and appears to be albite or oligoclase. Zircon is about the only, identifiable accessory
Mineral. Fractures in some specimens are filled with quartz and less
with fine-grain ed biotite.

13$

Dikes

Felsic, mafic, and lamprophyric dikes are common in the batholiths and plutons of the Santander massif and in the adjoining rocks. Most appear to. be differentiates or otherwise genetically related to the rocks of the major batholiths and plutons, because they bear

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mineralogical and textural similarities to them. Aplite, pegmatite, and felsite porphyry dikes similar in composition to the host rock are common in the quartz monzonitic and granitic rocks, Lamprophyre dikes are also common. Dikes of fine-grained tonalite, fine-grained diorite,
or andesite porphyry predominate in granodioritic and t'onalitic rocks. Dikes of a distinctive dacite porphyry, basalt, and (Ha^ase are . more restricted and do not seeis to be related to tbff ba.thol1.thic suite. A few of the dikes are shown on the geologic maps, but most are too small or too closely grouped to be shown and have been omitted.

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Felsic dikes t-~Felsic dikes other than aplita and pegmatite, so^ie of which have already been briefly described or mentioned (see Durania. granite, for example) range from rhyolite porphyry or vitrophyre to dellenite (quartz latite). Rhyolites are white to pale pink, light gray, or gray black to gray green v/here aphanitic* Phenocrysts of albite to sodic-oligoclase, rounded quartz, and less commonly ortho-clase are set in a crypt ocrystalline, spherulitic, or granular matrix of quartz and feldspar, plus unresolved semiopaque material. Graphic texture is present in some specimens. A. few flakes of biotite are normally present, as well as iron oxide and alteration products. In dellenites, phenocrysts are predominantly oligoclase, -with some quartz, i

and minor orthoclase. The matrix is sirdlar to the rhyolite s but is
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generally microaplitic rather than cryptocrystalline or spherulitic. Dellenite dikes are particularly prominent in the Santa Barbara Quartz Monzonite southeast of Berlin, but they also are found in less well exposed areas of this and other quartz monzonitic batholiths and

-i * . relatively abundant , . , , _ plutons. Felsic dikes are / near Fescadero and Aratoca, but only

a- few of those near Pescadero could be shown on the geologic map.

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Mafic dikes.- -Fine-grained, gray to dark-green, equigranular to locally porphyritic dikes cf andesite and fine-grained diorite are common in
the granodiorite of the Rio llegro batholith as well as in the Kogotes batholith and in the areas of the La Corcoxra Quarts Monzonile. In porphyritic dikes phenocrysts are commonly zoned subhedral andesine or euhedral hornblende crystals smaller than the plagioclase set in a diabase matrix of plagioclase and hornblende. Trace amounts of quartz are present in some samples, and pigeonite was found in one. Accessories are sphene, iron oxide, apatite, biotite, and alteration products are chlorite, epidote, and calcite.
Lamprophyre dikes*-** ^ Lamprophyre dikes are common in the Mogotes and Rio Negro batholiths. They are fine grained, dark gray, slightly porphyritic with small hornblende phenocrysts. The texture of the groundmass is subdiabasic ; laths of mostly saussuritized plagio-clase and greenish-grown hornblende are commonly altered to chlorite, and quartz, in amounts of 10 to l£ percent, is present as interstitial grains as is minor orthoclase. Minor biotite is usually chloritized. Apatite, sphene, allanite, iron oxide, epidote, and chlorite are the common accessories. Zircon is rare. Normally zoned euhedral plagio-clase forms small phenocrysts in some saiqples.
Dacite porohyry.--Dikes of dacile porphyry are common in the |California district. These dikes are the only igneous rock in the zone

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that cut rocks of Cretaceous age. East and southeast of Cachiri these dikes cut the Ciron Forrcation cf Late Jurassic age and the overlying (Tambor Formation of Early Cretaceous a?e.

137

The dacite porphyry is gray, fine grained to apha.iij.tic with
prominent large euhedral plagioclass phenccrysts as much as 2 cm Icnr arid rare smaller phenocrysts of rounded quartz and amphibole. The plagioclase is zoned and complexly twinned andesine or calcic- oligo-
5- clase. Mafic minerals are generally altered, but some chlcrite is
i; pseudomorphic after hornblende. Hornblende preserved in one specimen is a jade-green color. This same specimen was the only cne with potassium feldspar as irregular grains in the groundjnass. The ground-
1 mass in thin section is composed of a mosaic of fine-grained quartz
J and plagioclase. Accessory minerals are sphene, apatite, iron oxide, and rare allanite. Alteration products are sericite, calcite, and chlorite. A similar rock with smaller (7 rim) plagioclase phenocrysts
' vas observ.ed just east ' of the Bucaramanga fault near Rio f Negro. This rock, too, has bright-green amphibole as rare phenocrysts and smaller
: ~ grains in the groundmass.
Basalt and diabase*- * A few black to deep-gray-green aphanitic to fine-grained dikes of basalt and diabase are present chiefly along the Bucaramanga front on either side of the Bucaramanga fault. They cut high-grade paragneiss east of Bucaramanga and the Rio Negro batholith
o north ' of Rio / Negro; they are found in the area of intrusive rhyolite Vest of the Bucarainanga fault in northern H-12, and cut the Jordan
: Formation as dikes and sills near Rio Negro and Mesa de Los Santos.

' * Similar dikes are widely scattered though sparse elsewhere in the zone « cut rocks a*id'nearly~as""high in th^ section as the Gircn-Tambor boundary. Some
°£ the dikes, particularly those in the uet'furiontary recks, are so
altered that their initial composition caia:ot be determined.
130

The fresher rocks have a diabasic texture v/ibri labradorite laths
and intergranular diopsidic augite or pigeonite. Chlorite and iron oxides plus calcite and epidote are alteration products. The altered mafic igneous sills and dikes in the Bocas and Jordan Formations west of the Bucarair.anga front have features and alteration products similar to the fresh rocks and are probably also diabase. One sill in the Jordan Foririation near Rio Negro contains interstitial potassium feldspar.
Altered dikes, possibly originally diabase, have altered
platioclase laths in a chloritic matrix or with intergranular pyroxene. Larger chlorite flakes are pseudomorphs of mafic mineral phenocrysts. Age of dikes,. ~-The aplites, pegmatites, rhyolites, and dellenites, as i

well as the lamprophyres and mafic dikes, all are probably contemporaneous with the major batholiths and, therefore, are Jurassic-Triassic in age. The dacite porphyry of the California area is post-Early Cretaceous in age and may correlate with porphyry in the /v" +

Ocana area which has been dated as 127-3 m.y.,or Early Cretaceous (IMN-.109S:>3, table 2). Other felsic dikes assigned to the Triassic might be also Early Cretaceous. The .basalt and diabase are Jurassic or younger. If the emplacement of these rocks was controlled by movement on the Bucaramanga fault (see section on structural geolcgy), their age may be much younger.

139

The northern and southern ends of the batholiths are leas straight where not cut off by faults. The wide contact zone in which granodiorite o£ the Rio X Negro batholith has intimately intruded the
i Bucaraiaanga Gneiss near Santa Cruz, (quadrangle H-12), is located at a \ i place where the contact of the batholith trends nearly east-west. The t * , north end of the La Corcova Quartz Monzonite is similarly quite
t irregular. The south contact of the Mogotes batholith has an irregular pattern suggesting that the contact dips south at a low angle. This i view is supported by the observation that this part of the batholith
J ~; and the adjacent metasediraentary rocks are shot full of dikes. This
; contact zone in the metasedimentary rocks, however, is no rttore than
i1 1500 m wide. The north end of the Santa Barbara hatholit-h broadens

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near Berlin where a roof pendant of r.etaraorphic rocks partly separates
: the main mass from an equant area of the quartz monzonite southeast of
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- n X

Berlin. The presence of quartz monzonite about three kilometers i
i southeast of El Portillo (121 1-3, C-ll NW) in a small exposure ; S surrounded by quartz monzonite-wash at the base of the Giron Formation
j suggests that the granite lies at no great depth under much of this

, ! northern area. The general map pattern of the north end of the Santa

Jo- _x

\ B^bara batholith suggests that its surface is spoon-shaped, plunges
n \

southward, and is tilted to the east so that the west contact is
steeper than the east contact. The shape of the batholith at depth is
unknown. Possibly the northern contact dips to the south following the
it E*ain of the metamorphic rocks. However, a small plug of quartz
^ a°h7.onite lithologically similar to^that of the Santa Barbara batholith estops out about 10 km north of Berlin, a relationship that suggests a
- - »-»*« , . ,i .... r ,--.,...,,.: . . ,,,..,.

northward rather than a southward dip. 141

IV-

The alignment of the batholiths suggests a strong north-south structural control of their emplacement. As the Santander Plutonic
Group is of Jurassic to Triassic age, this control has to be Triassic
I
or older. Jurassic sediments which contain material derived from the batholiths were deposited in elongate north-south trending troughs, possibly bounded by faults (see p. 384). Structural control of these ' troughs is possibly inherited from or is a continuation of the same
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I control that guided the emplacement of the Santander Plutonic Group. These relations imply the presence of a fundamental north-south structural grain to this part of the Cordillera Oriental during the
| Triassic period. Such a structural grain appears to have prevailed
i

on into the Tertiary and Quaternary as is evidenced by the position of i i

s

I the Magdalena Basin. \ | Little information is available on structural features within the

iI ' batholiths. Dike swarms in the southern end of the Mogotes batholith
trend generally east-west although some north-striking dikes have been observed. In the Pescadero area dikes are oriented either roughly east-west or north-south to north-northwest-south-southeast. Near the
; northern end of the Santa Barbara batholith, dikes trend north-
i

! northeast and northwest. Flow banding and other primary structural features within the batholiths were not mapped.

SEDIMENTARY ROCKS

Because they are the source of the country's petroleum and natural
gas, the rocks of the Cretaceous and Tertiary systems are the best known, and the units mapped during the present survey are those recognized in the petroleum-producing areas of the middle
Magdalena Basin to the west and the Maracaibo Basin to the northeast. The pre-Cretacecus rocks, which are considered "basenent" rocks by the petroleum industry, are less known and consequently have been the source of the most problems and have received the most original study during the investigations reported here.
The post-Paleozoic sedimentary rocks display no noticeable
alteration of their sedimentary characteristics due to cietaniort>aic processes, which is in contrast to the Paleozoic rocks where, with increasing age, the sedimentary character has been altered to phyllite, schist, and gneiss by regional dynamothennal metamorphism. The Devonian rocks are the oldest ones that retain enough of their sedi-mentary character to be recognized more or less generally as a forraa-tional unit with definite upper and lower boundaries.

._..-_ - _ .. . __. __ Devonian system . -_. _ . ._, Floresta Formation
The name "Floresta Series" was first
introduced into the literature by Caster (1939, p. 10) for Devonian
beds discovered by A. A. Olsson and Teo'filo Ram/re?, in 1935 (Dickey,
;- 1941, p. 1789) in the vicinity of the village of Floresta in the Department of Boyaca. Caster's work was the first detailed study of
the fossils of the Floresta beds. Since then other studies have been made by McNair (1940), Caster (1942), Royo y Gomez (1942), .and a study of the Floresta and adjacent areas by Botero (1950) - Botero intro-duced the name Floresta Formation for the Devonian beds that overlie
. schists and gneisses and which are overlain by clay slates
^

and argillites of the Cuche Formation of Permian and Carboniferous age, which crops out apparently only in the Floresta area. On the basis of abundant fossils, the age of the Floresta beds has been generally recognized as of Middle Devonian. Since the Devonian beds were found at Floresta, beds with similar fauna and lithology have been found widely in the Cordillera Oriental of Colombia, including the area re-ported here. A summary of the present knowledge of the Devonian faunas has been published by Morales (1965).

In the-area of this report, mention was made by Hubach (1957, p.
70) that beds underlying the Cretaceous strata north of Guaca may be of Devonian age. During the course of the present survey, Devonian beds were found a few kilometers north of Bucaramanaa vmere pre-Mesozoic rocks are exposed in a small area west of the Bucaramanga fault. Because of limited exposures and complicated structure, it was not possible to measure and describe a section in the usual manner. How-
ever, descriptions made at several places reveal the general character
of the formation in its relatively unmetamorphosed state, \-

145

^^J^g-vLPJ*!ptions oT exposures of the Floresta Formation which outline its gen enl stratigraph y about 6 kilo meters north of Bucaram^nga, Department of Santander.(mada
A. Castro, October, 1968)

x

1. Old Bucaramanga-Rionegro highway, east of the junction
with the nev highway (planchita 109 IV-C, D-15 SB)
Diamante Formation (lover feeds only): .
Sandstone, dark-purple and gray, hard, silty,
slightly micaceous, fine- to very fine grained,
thin bedded; interbeds of medius-hard, friable, argillaceous purple siltstone, ff. 38° E.?,
67° SE.? ....

. . . . -unconformity- --------- Ploresta Formation:
Argillite, purplish-green, hard, siliceous, thin-
bedded. .... Sandstone, greenish-gray, hard, micaceous, medium-grained, in beds up to 50 cm thick,
R. 3° E., 67° SE. ....

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Meters

2. Bucaraacanga-Rionegro highway, (planchita 109 BT-C, D-15 Center)
Floresta Formation:
Sandstone, purplish-gray, hard, medium-grained, fej.dspathic, slightly micaceous, thin-bedded; interbedded near the top with thin-bedded sili-
°

ceous argillite, N. ^5 E., 18 SB. .... (Quebrada La Loaera., which contains alluvivcny lies between the exposures described above and those that follow* This qy»gbrsda garlis the northeiii end of the regional Suarez fault that terminates at the Bucarairanga fault.)

14 T

3. Quebrada SantuarLo, frca the confluence vith the Quebrada La Lcniera upstream northwestward for
600 m to fault contact with the Bocas Formation
(planchita 109 IV-C, C-15 SW)
Floresta Formation:
Siltstone, greenish-gray, hard, argillaceous,
thin-bedded. .... ?
Covered interval .... ?
day stone, dark-gray, silty, micaceous, N. 8l° E.?,
Wv° SEc? ..*........,........ ?
Siltstone, dark-gray, hard, argillaceous, slightly calcareous, micaceous, fossiliferous, with
fragments of bryozoans, brachiopods, and tril-
obites 1
Covered interval .... ?
daystone, gray, silty, micaceous, slightly calcarec_i,
H. 15° E., vertical .... ?
Covered interval .... ?
j
; daystone, dark-gray, silty; contains pyrlte in
|
I disseminated grains and along joints and fractures,
! H. 3° E., vertical .... ?
Covered interval .... ?

145

Meters

SUtstone, dark-gray, hard, argillaceous, mica-ceous, thin-bedded; contains veinlets of calcite,
N. 22° W., 78° HE. ....
Covered interval ....
Siltstone, dark-gray, argillaceous, micaceous, thin-bedded, N. 15° W., 78° BE. ....
Covered interval ....
Limestone, dark-gray to black, hard, fine- to medixsa-crystalline, in beds of 50-6*0 cm; contains veinlets
of calcite, N. 10° E., 68° 3E. .... Covered interval (fault contact with Bocas .
Formation) ....
Bocas Formation:
Colluvium with angular fragments of hard, yellowish-gray, plane-bedded feldspathic sandstone and yellowish-gray siltstone ....

14:>

Considering the width of the belt in which the above-described exposures occur and the generally steep dips that were measured, but disregarding the unpredictable effects of faulting, the thickness of the section is estimated at 350 to 400 meters. At the type section near Floresta, 145 km south of Bucaramanga, the thickness of the for-mation is estimated at 600-700 meters (Botero, 1950, P- 259). The formation is not highly resistant to weathering and tends to form rounded topography without conspicuous relief.
The normal contact of the Ploresta Formation with underlying rocks
is not known in the Bucaramanga area, but about 2 kilometers west of San aoaquin, where the Floresta presumably overlies pre-Devonian meta- rorphic rocks (planchita 136-III-C, H-13 Wl/2), massive beds of con-glomerate with sub-rounded pebbles of white quartz form a basal section 20 meters or nore in thickness.

145

North of Bucaramanga, the boundary between the Floresta and the overlying Diamante Formation is not well-exposed or well-defined even though this contact is apparently one of unconformity. However, the fine-grained beds of the Floresta are noticeably argillitic, slaty or phyllitic as compared with the claystones and siltstones of the Diamante. The fine-grained rocks of the Floresta Fontsation tend to display phyllitic surface textures, and this is usually more noticeable east of the Bucaramanga fault.
The fossiliferous bed found in Quebrada El Santuario is poorly
exposed, but 600 meters to the north, highly fossiliferous beds crop out on the upper slopes to the west of Quebrada La Loraera (109 IV-C, C-15 NW). Apparently the calcareous fossils and cement have been leached from a hard, calcareous siltstone leaving a rather soft, porous, light yellowish-brown rock with abundant molds and casts of fossils that are mostly fragmentary. Bryozoans are very abundant, brachiopods are common, corals, trilobites, and gastropods are relatively rare. Samples were submitted to the U.S. Geological Survey from this location and yielded the following information:

Pholidops sp.
Dictyostrophia cf. l>. cpoperi Caster corals: tabulate, indeterminate rugose horn, indeterminate
syringoporoid, indeterminate
trilobites: Phacopina? sp. (free cheek) Phacops? sp.
echinoderms: debris, indeterminate ostracods: undetermined
gastropod: high-spired, undetermined According to the report, most of the identifiable species are the
same as those described.by Caster (1S39) frora the Floiesta area. The lithologies of the fossiliferous beds are also quite similar.

1

F0ssiliferous beds that are thought to be of Devonian age have
been found in several other places in the report area:
North of Guaca, planchita 121-HI-B. C-2 NE
East of Guaca, planchita 121-HI-B. F-5 SE
Kortheast of San Andr^s, planchita 121-IH-O. C-4 SE
Southeast of Mogotes, planchita 136-m-C. G-10. G-12 ». H-12 «/2 sxcept for «. of the bryozoans. deformation of the beds has usually

distorted the fossils beyond recognition.
Xn the northern half of Zone XXX, rloresta beds were found during
the field checking of photogeologic maps during the contract period with Geophoto servi.es. Xnc. » planchita 76-.-D. the beds are ex-posed north of la. Mercedes along the Min highway to Convened and along the road fro, « Mercedes to Teora... Fossiliferous sables were collected about 1 kilometer north of Las Mercedes (planchita 76-1- ». 0-7 SW) that appear to be identical in fossil content and lithology to those submitted for study from north of Bucararanga.

14T)i

Metamorphosed Flpresta Formation.--Very lightly meta-
morphosed Floresta Formation overlies the Silgara Formation
near Mogotes and San Joaquin in the southwestern
part of the map area in quadrangle 1-12 and 1-13. Because meta-morphism in the Silgara Formation in this area is fairly low grade, it is difficult to distinguish the two formations in the absence of exposures of the basal beds. R. Calpa (written commun., 1968) has indicated that approximately 750 to 1,000 meters of the Floresta Formation is present near Mogotes. Fossiliferous horizons lie
an estimated maximum of 250 to 300 meters above the basal sandstone and conglomerate in dark-gray marble and in gray and dark-gray phyllitic argillites and calcareous metasiltstone. Associated light
gray marble is barren. Bryozoans from the Floresta hare have been identified by Srta. Diana Gutierrez of the Servicio Geologico Nacional, Bogota, as types common in the Devonian.

14 fi

The Floresta Formation occunies an extensive belt along
the east sides of the Mogotes and Santa Barbara batholiths. In quadrangles 1-13 and H-13 rocks probably belonging to the Floresta Formation crop out in the northern part of the map area north of Mutiscua. The Floresta Formation in the southern part of this
belt shows a very low grade of metamorphism, but its metaraorphic grade increases northward, although apparently the highest grade reached is still within the greenschist facies in the area southeast of Berlin and southwest of Silos.

The FT oresta Formation in the belt from Covarachia to Silos is well exposed west of Guaca on the road from Guaca to Los Curos and north of Guaca on the road from Guaca to Berlin west of Barava and northeast of El Portillo. Nov/here has the complete section been seen with certainty, although the base of the formation may be present southwest of Molagavita, and southwest of San Andres. Dark graphitic Slately phyllites low in the section in some places are associated with marble and fossiliferous beds. The section shown in figure 7 is probably representative of part, probably the lower

part, of the Devonian section in this belt. The marble is dark gray to light gray and is similar to that in the Mogotes area. Conglomerate and quartzite are present in the slopes west of San Andres, but it was not determined if these beds are basal.
Higher in the section are qreenish-gray to tan meta-sandstone, meta-siltstone and silty phyllites. Purplish-gray argillite is present locally. Light-gray and dark-gray marble similar to that in the Mogotes area crops out near Molagavita, a few kilometers north of Guaca, north of El Portillo, the Silos area, and near Hutiscua.
1 possils were found in the Covarachia area (136-III-D.E-15),
gavita area (136-I-D, D-2, E-2). North of Guaca (121-III-B, C-2),
north of El Portillo (121-I-li, E-4, F-3). The assemblages consist Pnndpally of bryozoa and crinoid fragments.

140

The thickness °f tne formation in this belt,along the east side
of the massif is almost impossible to estimate because of the folding and faulting. The width of outcrop suggests that the formation might be thicker here than in the Mogotes area or in the Bucaramanga area. The contact with the underlying SiIgarcf Formation is in some places clear, but throughout most of the belt it is indistinct, particularly in the area from north of Guaca to Silos. The contact in this zone is somewhat arbitrarily drawn to include
the fossiliferous marble beds and associated black phyllite,which
are considered to be near the base of the section. Near El Portillo, black graphitic phyllitic slates mid minor interbeddcd tan-colored meta-sandstone and gray slate lying to the east of the i fosslliferous marble horizons seem to pass by interbedding into the Diamante Formation of Permian age. The Diamante limestone in this area as well as in the Mutiscua area is somewhat recrystallized

Surata Group
This, term is here used in place of "Surata series"
which Dicfcey (1941. p. 1790, used for fossiliferous Paleozoic beds which are exposed between the H*o Surata and Puent, de Tierra on the old highway from Bucaramanga to Bocas. The beds were mapped and a section was -aeasured and described by Navas (1962,. The na^e Surata is retained as the group na*e for the two units here recognized as

t

the Diamante and Tiburon Formations.

160

Di arrant a Formation (PCd) . This unit is here named for the lower part of the Surata series described very briefly by Dickey (1941, p. 1790) and includes the lower part of the section that was mapped and described by Navas (1962). The name is derived from quarries of Cementos Diamante S.A. which obtains limestone for manufacture of cement from the upper beds of this formation a few kilometers north of Bucaramanga. The type section is in these quarries and northwestward along the old Bucaramanga-Rionegro highway where it extends along the east side of Quebrada La Mona for a distance of approximately 2 kilometers. This section is described below.
A total of 440 meters of Diamante was measured at the type
locality. Of this, the lower 139 meters is dark purple to dark purplish-gray, fine- to medium-grained sandstone of varying hardness, and interbedded claystone of similar color. Some of the sandstones are feldspathic and micaceous, and some near the middle are coarse-grained to conglomeratic with quartz pebbles up to 7 mm in diameter. A middle section of 97 meters has dark gray shale with interbedded dark gray limestone in the lower half and greenish-gray silty claystone in the uPper half. The upper section of 204 meters is dark gray, fine- to fcedium-crystalline, slightly argillaceous limestone with small amounts °f interbedded silty claystone or argillaceous sandstone at some levels.

i:

-Type stratigraphic section of the Diamante Fo rr at Vg n
of the Surata Group in quarries of Ceinentoa Pi am/ante S ^ A,. |planchita 109 IV-D, _E-1 SW) and along; the old .Bucargimangri-ioO

Rionegro highway (planchlta IV-C. D-15 SB and E-15 NEl.

v

Municipality of Bucaranianga, Department of SantanAer . (Measured and described by A. Castro in September, 1963)
Meters

Tiburon Formation (lower beds only):
Conglomerate, dark-gray, hard, massive; semi-
rounded pebbles of limestone and dolomite from
\
the underlying Diamante Formation, and a few of
chert, 2 to 6 cm in diameter, in a matrix of
light-gray sandy limestone. .... 19. k
. . . . -unconformity- ------.--
Diamante Formation:
Limestone, light -gray, argillaceous, slightly hard,
with thin interbeds of light greenish-gray,
calcarous, silty claystone. Unit is highly
sheared and fractured, N. 15° W., 36° NE. .... 18. k Claystone, gray, sandy, calcareous, medium-hard,
thin-bedded, with basal bed 1.2 m thick and other
thinner, lenticular beds of hard, dense, light-
gray limestone 12.3
? Claystone, gray, sandy, calcareous, medium-hard,

I thin-bedded, containing lenticular beds of dark- i

*-

{ gray, hard, argillaceous limestone up to 15 cm '

*

; thick. Argillaceous and micaceous, calcareous,
thin-bedded, light -brownish-gray sandstone near
the middle and top, N. E., 6l° SE. ...._ ~

'

11.5

Meters
Covered
Limestone, dark-gray, hard, fine- to msdium-crystalline, fossiliferous, in beds 2.0 to 3»5 m thick; thin lenses of gray calcareous
\
chert; slight gassy odor on fresh fracture,
N. U° W., 58° HE. .... Covered
Limestone, dark-gray, hard, fine- to meditna-crystalline, in beds 15-30 cm thick; contains

(approx.)
17-5

fossil fragments, K. 3° B., 62° SE.

16.0

(approx.)
11.0

Limestone, dark-gray, hard, massive, fossiliferous
with fragments of brachiopods and crinoids . . '. 7»0 Chert, light-gray, hard, very calcareous in beds
up to M) cm thick. Dissolved calcite leaves
porous weathered surface .... 1.0 Limestone, dark-gray, hard, fine- to medium-
crystalline, slightly argillaceous, in beds
20-60 cm thick separated by thin beds of
argillaceous, calcareous, friable, grgy sandstone. Contains pyrite in disseminated grains and filling
small fractures, N. 6° W., 78° HE. 28.0

Meters

Limestone, dark-gray, hard, fine- to medium-

crystalline, slightly argillaceous, in beds i
i
O.lf-1.2 m thick. Bedding planes have thin . j
i
films of graphitic material, N. 2° W., j

72° HE. 52.0

Limestone, dark-gray, hard, fine- to medium- |
i
crystalline, slightly argillaceous, in beds
i
10-20 cm thick, N. 10° W., 76° HE. ...... 1^.0;

Claystone, greenish-gray, medium-hard, silty, |

slightly calcareous, in beds 5-12 cm thick,

N. 2° E., 58° SE. 51-0

Shale, dark-gray to black, weathering reddish-

brown, and dark-gray, hard, argillaceous lime- j

stone in basal 1 meter .... 12.0 >

Shale (50 percent), dark-gray to black, and lime-

stone (50 percent), hard, dark-gray, in beds up

to 1 meter thick. Shale is more abundant in

the upper part, limestone in the lower part, I
!
N. 10° E., 78° SE. .... 29.0 :
i
Limestone, dark-gray, hard, fine- to medium- i
i i
crystalline, slightly argillaceous at the base, !

N. 9° E., 79° SE. 1*.8

54

JO-

(The section above is mostly in limestone quarries; that which follows starts 500 meters along strike to the north and continues along the old Bucaraiaanga-Rionegro highway.)
Partly covered sandstone, dark-purple to greenish-gray in the basal part, fine- to medium-grained, argillaceous, feldspathic, micaceous; light yellowish-gray, micaceous and more argillaceous
in the middle part -which is interbedded with hard, violet-gray limestone in beds up to 15 cm thick. i At the top is greenish- to yellowish-gray, thin-bedded, slightly micaceous claystone, N. 5° £.,
35° SE.

Partly covered sandstone, dark-purplish-gray, medium-hard, fine- to medium-grained, felds-pathic, micaceous, in beds up to 30 cm thick; middle and upper parts contain thin beds of dark-purple, micaceous, sandy claystone, N. 2° E.,
31° SE.

Sandstone, light-yellowish-gray, hard, medium-grained, micaceous, in massive beds up to
3 m thick ....

16.2

17-2

Meters

Claystone, yellowish-gray, medium-bard, thin-bedded; sandy, micaceous, and thicker beds
near tha top, N. 26° E., 39° SE. .... Sandstone, light-ysllowish-gray, hard, fine-grained, slightly micaceous, in beds up to 50 cm thick; argillaceous, feldspathic, highly mica-ceous, greenish-gray near the top in beds up to
1 meter thick .... Sandstone, dark-purple, medium-hard, fine- to very fine grained, argillaceous, feldspathic, mica-ceous; medium- to coarse-grained, harder beds
at the top are conglomeratic with quartz
pebbles up to 5 mm in diameter .... Sandstone, dark-purple, medium-hard, fine- to very fine grained, argillaceous, feldspathic, micaceous, interbedded with friable, purple, sandy claystone in the lower part, and conglomeratic in the middle with small quartz pebbles, N. 21° E., &° SE.

8.2

9-5

11.0

22.0

15G

Meters

Sandstone, dark-purple, hard, medium- to coarse-
grained, feldspathic, micaceous; conglomeratic
in the upper beds with quartz pebbles up to
7 mm in diameter; friable, silty, dark-purple

o o claystone in the middle, N. 20 E., 35 SE. . 16.2!
Claystone, purple, silty, slightly micaceous,
!
friable .... 5-5'

I Sandstone, grayish-purple, hard, medium-grained, I
i
micaceous, in beds 15-^0 cm thick; contains
interbedded argillaceous siltstone, N. 20° E.,
fcL° SE. 5-5
Sandstone, dark-purple and gray, hard, silty,
slightly micaceous, fine- to very fine grained,
thin-bedded; contains interbedded medium-hard, t
friable, purple argillaceous siltstone ...... 1^.0
Total thickness of the Diamante Formation M4O.O
I

- - - - .....» -unconformity- ---------
Floresta Formation (upper beds only):
Argillite, purplish-green, hard, siliceous, thin- i
bedded .... 11.0 '
Sandstone, greenish-gray, hard, medi-um-srained,
micaceous, in beds up to 50 cm thick, N. 3° E.,
6?° SK. 7.5

The Diamante Formation is apparently unconformable over the Floresta Formation, but the boundary has not been found sharply defined. The beds of the Floresta display a slightly phyllitic character as compared with those of the Diamante. At the top of the Diamante, the limestone pebble conglomerate of the Tiburon Formation marks a sharp boundary of unconformity.
The type section of the Diamante Formation is not far from the regional Bucaramanga fault to the east, and small calcite-filled fractures are common in many of the steeply-dipping limestone beds. Northward from the type section, the Diamante Formation is in" contact with the Bucaramanga fault in a low indistinct ridge that extends for nearly 8 kilometers. Southward from the type section it is covered by unconsolidated Quaternary deposits of the Bucaramanga terrace and dees not reappear beyond it except for one small fault slice exposed in Planchita 120-II-B, D-5 SW and E-5 NW.
Fossiliferous beds are few and thin in contrast to the Cretaceous limestones of the region which contain many highly fossiliferous beds. collected from limestone outcrops in the general area of ths
section were identified by paleontologists of the U. S. Geological urvey. Ages for those collections which could be dated most closelv *ange from Middle Pennsylvanian to Middle Permian. The following reports were received:

Paleontologist reporting: R. E. Grant, 3/27/68
Sample N-. DW4/63 (IMN 13850); Location: planchita 109-IV-D, F-l NW
Stratigraphic range: Permian
Fossils contained: brachiopods: Kochiproductus sp. Neospirifer sp.
Waagenoconcha sp. (most
common in Middle Permian)
crinoids: numerous columnals and some
plates
Sample No. DW5/68 (IMN 13851); Location: planchita 109-IV-D, Fl SW
Stratigraphic range: Late Paleozoic
Fossils contained:
brachiopod: Linoproductus sp.
bivalves: see report next following
crinoids: numerous columnals, indeterminate
echinoids: spines, indeterminate

150

Paleontologist reporting: John Pojeta, 5/17/68 Sample No. DW 5/68 (IMN 13851) (USGS 23268-PC) Location: planchita 109-IV-D, F-1SW Stratigraphic range: Late Paleozoic
Fossils contained:
pelecypods: Myalina sp.
Aviculopecten sp. ; nuculanid pelecypod of the Phestia-Polidevcia
type
Paleontologist: J. T. Dutro, Jr., 6/4/68
Sample No. DW 40/-8 (IMN 13908) (USGS 23332-PC)

Location: pianchita 10S-IV-C, D-15 ME i
Stratigraphic range: Pennsylvanian, probably Middle Pennsylvanianj resembles fauna described from Tarma Group
of Peru by Newell and others (Geol. Soc. America Memoir
58, 1953) | Fossils contained:
brachiopods: Cancrinella? aff. C_. villiersi (d'Orbigny) Anthracospirifer aff._A. opimus (Hall)
Composita aff. C. subtilita (Hall)
Cleiothyridina cf. C. barbata Chronic
echinoderms: debris, indeterminate
tabulate coral: Chaetetes? sp. . bryozoans: fragments, indeterminate
worm tubes: indeterminate

inn

Paleontologist reporting: R. C. Douglass, 6/13/68
Sample No. DW 39/68 (IMN 13907); Location: planchita 109-IV-C, D-15 NE

Stratigraphic range: Early Permian (late Wolfcamp equivalent) Fossils contained:
fusulinid foraminifer: Monodiexodina sp.
Sample No. DW 43/68 (IMN 13911); Location: planchita 109-IV-D, E-l SW
Stratigraphic range: Early Permian (late Wolfcamp to early Leonard equivalent)
Fossils contained:
Schwagerinid fusulinids resembling thick-walled Parafusulina Sample No. DW 44/68 (IMN 13912); Location: planchita 109-IV-D, G-l NE
Stratigraphic range: Middle Pennsylvanian]
Fossils contained:
foraminifers: Climacamina sp. :
Bradyina sp. !
Fusulinella sp. ;

Foraminifers are reported here from the Diamante Formation for
the first time. The other fossils, principally brachiopods, were studied previously by J. S. Williams and reported by Trumpy (1943, p. 1294) to be of either Mississippian or Early Pennsylvania!! age.
The limestone section of the upper part of the Diamante Formation indicates that at least this part of the unit was originally widespread, but that subsequent erosion has removed all but rather limited remnants in the mapped area. Dark gray limestones that are thought to be part of this section crop out intermittently about 40 km east of the type section in a belt in quadrangle H-13 that extends approximately 35 km north-northeast from El Portillo in b-5 SW to Mutiscua and beyond in
b-3 E-l/2. The unit overlies Devonian rocks and is in turn overlain
i
by beds of Triassic (Bocas Formation), Jurassic (Giron Formation) or Cretaceous (Tambor Formation) age. Two single specimens of brachiopods that were found were submitted to the U.S. Geological Survey:
Paleontologist reporting: R. E. Grant, 3/27/68 ;i
Sample No. DW 3/68 (IMN 13849) (USGS 23266-PC) ;
1

Location: planchita 121 I-B, 1-6 SW '
Stratigraphic range: Permian (Leonard equivalent)
Fossils contained:
brachiopods: Meekella sp. (resembles those of Leonard age
in southwestern U.S.)
cf. Orthotichia sp.
No report was received on two single specimens of horn corals

the same locality.
162

jhe limestones show evidence of recrystallization to coarser
calcite which tends to obscure finer features of th-2 fossils. Near Mutiscua, the recrystallization is much stronger and the rock displays textures approaching that of marble. North of Mutiscua, phyllitic shales occur in some places at the top of the Diamante, underlying Cretaceous rocks.
At El Portillo, some of the beds of the Diamante contain dolomite. Barite mineralization occurs in one such zone in veins sufficiently large to be mined in small surface pits. Another dolomite zone about 10 meters thick occurs lower in the section and is exposed for a dis-tance of about 100 meters.
On the basis of similar fossils and lithologies, the Diamante
Formation is correlated with Carboniferous and Permian rocks in northern Colombia. C. Tschanz (written commen.) describes folliliferous rocks near Manaure, at Rio Seco north-of Valledupar, and in the Chundua mountains, that are all assigned to the Carboniferous. This confirms
* s
earlier mention of Carboniferous rocks in the Serrania de Perija by
^

Trumpy (1943, p. 1295) and of Carboniferous and Permian rocks by

^ '

"iller (1962, p. 1571). !

163

Fusulinids of Permian age have been reported from unnamed beds
/ /
near Manaure in the Serrania de Perija, Department of Magdalena (Thompson and Miller, 1949), which are of an age equivalent to Wolfcamp, Leonard, and Guadalupe of West Texas. Other fossils are abundant, including crinoids, brachiopods, gastropods, and cephalopoda (Trunipy,

1943, -p. 1925; Miller and Williams, 1945).
Tiburon Formation (TrPt).--This unit is here named for the upper
part of the Surata series of Dickey (1941, p. 1790) and includes mostly massive beds of conglomerate with pebbles of limestone from the under-lying Diamante Formation imbedded in a fine-grained gray, calcareous matrix. It corresponds to the calcareous conglomerates in the upper part of the section measured and described by Navas (1962). .The name is derived from the Club Tiburones which is near the best exposures
of the unit about 2 kilometers north of Bucaramanga. This section is

described below.
Because of the covered intervals, the measurement of a continuous section was net possible. The thickness of exposed beds totals 212 meters. On the basis of the attitudes measured in the belt of outcrops, which is about 600 meters wide, the Tiburon Formation is estimated to be from 450 to 500 meters thick at the type locality.

164

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15-

Meters

Siltstone, light-gray, medium-hard, argillaceous,
calcareous, slightly micaceous, conglomeratic
near the base with limestone pebbles up to
12 cm in diameter; near the middle are irregular
lenses of similar conglomerate up to 0.8 m thick, j
i
with abundant limestone pebbles and few of . |

i
dolomite and sandstone up to 6 cm in diameter. ... 25.0
Covered interval .... ?
Conglomerate, dark-gray, hard, massive, with pebbles
of limestone, few of sandstone and very few of black calcareous chert, from 1-lU- cm in diameter, mostly
2-5 cm, in matrix of fine- to medium-crystalline j
limestone; near the middle are 7*5 m of light-gray,
slightly argillaceous limestone, medium-hard, in i
beds 1.0-1.5 m thick 28.0;
Covered interval .... ? !

Limestone, light- to dark-gray, medium-hard, argilla- i
. ceous, slightly micaceous, in beds 30-^5 cm thick, j

N. k° E., 6° SE. .... 6.0 i i
Conglomerate, dark-gray, hard, massive, with pebbles
mostly of limestone, few of dolomite and sandstone,
from 1-8 cm in diameter, in matrix of fine-crys-
talline light-gray limestone. 8.0

1 C, G

Meters
Covered interval .... ?
Conglomerate, dark-gray, hard, massive, with pebbles
of hard, gray limestone that reach cobble size
(up to 22 cm) near the base, in iratrix of fine,
light-gray limestone; some pebbles contain frag-
(approx.)
ments of crinoids, N. 2° E., 65 SE. 30.0
Covered interval .... ?
Conglomerate, dark-gray, hard, massive, with pebbles
mostly of limestone from 2-12 cm in diameter,
mostly. 3-5 cm> in matrix of fine, light-gray lime-
stone; near the middle are 8 m of light- to dark-
gray, medium-hard, argillaceous limestone in beds
0.8-1.5 m thick, N. 6° W.?, 56° HE. 27-5
Covered interval .... ?
(The basal part of the Tiburon described below is above
the type section of the Diar^inte Formation in plan-
chita 109 IV-D, F-l MS.)
Conglomerate, dark-gray, hard, massive; pebbles are
mostly of gray limestone from 0.5-8 cm in diameter,
mostly 1-3 cm, in matrix of fine, light-gray line-
stone; some pebbles are fossiliferous with fusulinids .
and fragments of brachiopods and crinoids ...... k.O

Covered interval .... Conglomerate, dark-gray, hard, massive; abundant pebbles of gray limestone and dolomite, very few of chert, 2-6 cm in diameter, firmly imbedded in
\
matrix of fine, light-gray limestone; size of pebbles and number of dolomite pebbles increases
in upper part and some sandstone pebbles are present; limestone pebbles predominate at the top,
up to 16 cm in diameter ....
- - - - - - . -. -uaeoiifornity- --------- Diamante Formation (upper beds only):
Limestone, light-gray, slightly hard, argillaceous, with thin interbeds of light-gray, calcareous,
silty, claystone, highly fractured ....

Meters

(approx.)
" 10.0

19

o

Although there are noticeable variations in pebble size and ir.
; the ratios of pebble material from bed to bed, the conglomerates display remarkable uniformity throughout the formation. Limestone
!

1 'pebbles predominate in all beds in colors of dark to light gray and
s " rarely pink. Dolomite pebbles are numerous in some of the lower beds 'and have a highly fractured appearance. A few are present throughout
j
;the formation. A few pebbles of sandstone and a very few of chert are i
5 ,present also. On weathered surfaces the limestone pebbles and the
i
matrix weather rather uniformly to a smooth surface? whereas the raore
^ resistant dolomite, sandstone/ and chert pebbles stand out in relief.
: In most of the conglomerate beds the subangular to subrounded
i
pebbles are rather densely packed and firmly cemented by the fine-grained calcareous matrix. This matrix is similar in texture and
color to some of the limestone pebbles and suggests that it originated largely from the fine materials derived from the erosion of the lime-stone beds which supplied the pebbles. Quartz grains, locally ranging up to pebbles 5 mm in diameter, are present in the matrix of some beds,

The limestone pebbles are fossiliferous to the extent that would
be expected from the sparsely fossiliferous source beds of the
i

Diamante Formation. Some of the conglomerates in the lower part

«

apparently have greater concentration of pebbles containing fusulinids, 5- but even there they probably do not represent more than 5 percent of the pebbles. Three of these pebbles submitted to the U.S. Geological Survey for fossil identification yielded the following results:
; Paleontologist reporting: R. C. Douglass, 12/12/66
' Sample No. IMN 10824; Location: planchita 109-IV-D, H-l NE Stratigraphic range: Permian (probably equivalent of Leonard
of West Texas)

Fossils contained: i
Pebble A: foraminifers: Parafusulina sp. thick-walled form
Parafusulina sp. thin-walled form
i
bryozoans: rare, indeterminate i
Pebble B: foraminifers: Climacamina sp. common
Parafusulina sp. thin-walled form
Pebble C: foraminifers: Parafusulina sp. thin-walled form ostracods: common, undetermined

*; M

170

The boundary of the Tiburoh with the underlying Diamante
is not well exposed, but the change in lithology across this h
is very conspicuous and quite evidently one of unconformity. In the
area of the type section south of Rio Surata, the contact with the over-*~lying Bocas Formation is covered by unconsolidated Quaternary deposits ! * iof the Bucaramanga terrace. North of the river, the reversal of dips iin the Bocas Formation as compared with those in the Tiburon suggests
* that the contact there is a fault surface.
* Areal distribution of the Tiburo'n Formation is virtually limited
: to the narrow outcrop which extends northward 2 kilometers from the
major portion of the type section on the south side of Rio Surata. At
its northern er.a, this outcrop tcniaatoB at the

north (planchita 109 IV-C, D-15 NE) .
Xn the oepartment of Ma^lena, Permian heds «ith fusulinids have
^en reported in the Serr^a de Perija' near «anaure (Thompson and
Killer, X949,. and farmer south, on the Hio Mula, limestone Elders in conglomerate contain Pennian fusulinids (Trumpy, 1943, P. 1^>- «* conglomerates are in red beds that contain volcanic material and have
been assigned to the Late Triassic (Trumpy, 1943, p. 1292).

m

17

The age of the Tiburon Formation can be indicated only approxi-
mately as older than the Diamante Formation of Carboniferous to Permian age, from which it was derived, and younger than the Bocas Formation the age of which is probably, but not conclusively, Triassic. The lithology of the Tiburon Formation, its relationship to the underlying Diamante Formation, and its position immediately west of
the Bucaramanga fault seem to indicate that it was derived almost exclusively from Diamante beds in higher areas just east of the fault. The eroded material was deposited abruptly over Diamante beds west of
t: the fault. The origin, transportation, and deposition of the constitu-
* ent sediments may have all been confined to an area of less than 100

square kilometers.
Bocas Formation.--Tne Bocas Formation was first referred to as
the "Bocas series" by Dickey (1941, p. 1790) to include the "less fossiliferous series from Puente de Tierra to Bocas" overlying
the "Surata series" along the highway north of Bucaramanga. The

beds were thought to be of Paleozoic age.

-Type strati graphic section of the Bocis Formation*
the lower part mearmrad. along; the Bucar^raar»ga«*Rlane.^ro highway from Calera San Luis to Quebrada Santa Siena (planohita 109 IV- A, j~l*l S^) , and the upper part measured a outhward from the
village of Bocas along the r^ ilroad to the contact with the Jordan Formation (planchita 109 IV-C. A~12_5^ and. 3-12 NEK Municipality of aucnr^m^nga , Department of S^nc^ndert.
(Measured by E. Aya, September, 1968) Meters
Jordan Formation (lower beds only):
I Sandstone, reddish-brown and greenish-gray,
hard, very fine grained to silty, slightly
calcareous, in beds up to 1 meter thick,
°

H. **5 E., 35 SE
Bocas Formation :

Silt stone, greenish-gray to reddish-brown, argillaceous, micaceous, slightly calcareous,
in beds up to 1.1 m thick; highly fractured normal to the bedding, N. 30° E., 38° SB.;

. H. U6° E., 33° SE. ....

(change of strike indicates possible faulting) Silt stone, greenish-gray, slightly calcareous, massive; contains gray, calcareous nodules up to h mm in diameter; exposure nearly parallel to the strike, N. 15° W., V3° HE.; N. 22° E.,

o « o

° SE.; N. 5° E., 1*3 ° SE.
Covered interval (change of strike indicates possible faulting) ..*...«.. Sandstone and siltstone, greenish-gray, hard, calcareous, massive, conglomeratic with granules Of dark-gray chale, H. 86° E., 50° SE. .....

5.0

120.0

(approx.)
. 65.0

50.0

12.0

174

Meters

Conglomerate, greenish-gray, hard, massive, with subangular pebbles of gray limestone, dark-gray shale and quartz in calcareous sandy matrix,
H. 65° E., 38° SB. .... Shale, dark-gray and gray, calcareous to noncal-careous; calcareous, pyritiferous nodules up to 20 mm in diameter and 5 i&za thick .... daystone, dark-gray, calcareous, slightly mica-ceous, thin-bedded; contains calcite -filled fractures, N* 36° E., 78° SS. ....

20.0

8.0

10.0

Covered interval that probably includes dark-gray
(approx.)
shale and daystone .... 85*0 (The above section ends at a probable fault extending north-northeastward through the 'ym age of Bocas and
up the valley of the Rio Negro. The section that

f follows was measured along the Bucaramanga-Rionegro
highway from near the limestone kiln at San Luis for
about 500 meters northwestward to the Quebrada Santa ELena.)

175

Meters

daystone, greenish-gray, slightly hard, with inter-
bedded dark-gray shale; somewhat crumpled,
N. kO° W., 75° SW. 31*0
Siltstone, greenish-gray, medium-hard, slightly
micaceous, N.-S., 30° W. 30.0
Siltstone, greenish-gray, hard, calcareous, micaceous,
in beds up to 10 cm thick, N. 12° E., 5k° W. . . . 16.0 Shale, dark-gray, slightly hard; contains fragmentary
plant fossils 8*0
Siltstone, greenish-gray, hard, calcareous, "oluisu at
the top 6.0
Shale, dark-gray, easily weathered 5-8
Siltstone, greenish-gray, hard, calcareous, slightly ;
micaceous, H. ^3° W., 51° SW. .... 7.0 ,

Shale, gray, micaceous, easily weathered .... 4.0 I
Shale, dark-gray, sandy, calcareous 2.4
Sandstone, greenish-gray, hard, fine-grained, slightly i
calcareous, N. 5° W., 34° SW. 2.6
Shale, dark-gray, easily weathered 1.0
daystone, greenish-gray, soft, massive 17.7
Siltstone, greenish-gray, hard, calcareous, in beds
25-75 cm thick 19.5

17G

5-

Meters

Sandstone, greenish-gray, hard, medium-grained,
feldspathic, N. 32° E., 67° NW. 1.0
Siltstone, greenish-gray, argillaceous, medium-
hard 14-.0
Sandstone, light-gray, hard, feldspathic 1.8
Shale, black, carbonaceous, -with lenses of dark
sandstone 2.2
Siltstone, dark-gray, medium-hard, with intercalations ,
of black shale in the upper part, N. 25° E., ^5° NW. . 3.1 Sandstone, dark-grey to black, hard, medium-grained, calcareous, micaceous; contains fragments of black
shale, impressions of fish scales? and plant fossils,
N. 5° E., 55° HW. 9.5
Siltstone, greenish-gray, calcareous, medium-hard ... Wi-.O Sandstone, greenish-gray, hard, coarse-grained,
feldspathic, fractured, N. 50° W., U2° SW. ..... 3«0
Total thickness of Bocas Formation 589 6
- - - - - - - - - fault contact ?----------

177

Meters

Diamante Formation (upper beds only) * Limestone, dark-gray, hard, fine-crystalline, highly fractured, slightly fetid; contains scarce fossil shell fragments and abundant veinlets of vhite calcite, N. 10° W.,
76° SW. ....

day, reddish-brown, highly weathered, (probable fault zone)
- - - - quartz monzonite, pink, coarse-grained-

ij-0.0?

20.0?

171)

The dark siltstone, shale, and claystone of the Bocas are not

highly resistant to weathering and erosion, and the resulting topography

is well dissected but > does not display great relief.

The soils are of a yellowish- to orangish-brown and are distinctive
i
- in some areas. j i
Fossiiiferous samples of the Bocas Formation were submitted to
« i
the U.S. Geological Survey for identification and age determination.
i
The following report was received on the first samples:

170

This report states further that the globose gastropod of samples
DW 35 and DW 34 is most common in North America in the Middle and Late Pennsylvanian. The conchostracans (one of four types of branchiopods which belong to the same order, Crustacea, as ostracods) are probably indicative of fresh-water rather than marine conditions.

Ostracods were reported later as follows:
Paleontologist reporting: I. G. Sohn, 3/5/68
| Stratigraphic range: indeterminate for all samples _
Samole No, Location (planchita)
10- : DW 32 (IMN 12241) 109-II-C, E-7 SW

DW 38 (IMN 12247) 1G3-IV-C, A-12 SE

DW 33 (IMN 12242) 109-II-C, A-6 NE

Fossils contained
Abundant ostracods, indeter-minate, in limestone .
Abundant ostracods, indeter-minate, in limestone pebbles of a conglomerate.
Smooth, indeterminate
ostracods. Ostracods on
a weathered surface of the
rock could be either
Paleozoic or Mesozoic in
in age.

IB]

1C-

The report states further that the presence of conchostracar.s,
the nesting of valves in the ostracods and their smooth cross sections suggest but do not prove a nonmarine environment and a post-Paleozoic age for the limestone in which the fossils occur. Also the samples submitted may represent both Paleozoic marine and post-Paleozoic non-marine rocks.
Because of the poor state of preservation of the fossils, more samples were submitted, some from new localities and some from locations sampled previously. A report was received for two of the new locations:
Paleontologist reporting: I. G. Sohn, 9/6/68
Stratigraphic range: probably post-Paleozoic
Sample No. Location (planchita)
; DW 35/68 (IMN 13903) 121-III-B, G-8 SE

DW 36/68 (IMN 13904) 121-III-B, H-8 SE

Fossils contained
Two poorly preserved
ostracods, indeterminate. One incomplete mold of
ostracod that could be
from either the
Theriosynoecum group of
Early Cretaceous age or
possibly Tungchuania of
Triassic age.

00O (<

Northward from the area of the type section, the Bocas is
exposed in a narrow belt between the Bucaramanga fault en the
east and a fault contact with the Giron on. the west. This belt widens
into a large area of exposure in the north-central part of quadrangle
H-12 where the Bocas is well exposed along the road southwestward from the

I main highway toward Cuestarica (planchita 109-II-A). The upper 230 i
meters of the Bocas in this area is described with the overlying
section of the Giron Formation (see p. 207). Rhyolite and intrusive breccia intrude this large area of Bocas beds in a belt west of and parallel to the Bucaramanga fault. Between the Bucaramanga fault
and the intrusive breccia, the Bocas contains a. central section of clean, i
' light gray, highly fractured guartzite. The quartzite belt is more than 1 kilometer wide at the northern margin of quadrangle H-12 and
i narrows gradually southward until it pinches out southwest of Rionegro. ; It is not present in the area of the type section. ! About 15 km northeast of Bucaramanga, in a block of sedimentary
rocks downfaulted against pre-Devonian rocks on the northwest, the Bocas Formation overlies Pre-Devonian metasediments of the Silgara' Formation. In the south-central part of quadrangle H-13, the Bocas overlies the Floresta Formation in several places. It is usually
j overlain by beds of the Giron Formation, but in some places by the
i

, Jordan Formation.

18 4

Because' of the various ages that have been suggested for the
Bocas Formation, based on poorly preserved plant and invertebrate fossils, it has been necessary to reevaluate the previous age assign-ments in the light of the newer information. A Triassic age now seems raore likely than Carboniferous, as indicated in previous reports, and this change is made for the following reasons: :
1. Invertebrate fossils in the older Diamante Formation that
were originally thought to be of Mississippian and

i Pennsylvanian age are now thought to be of Middle

Pennsylvanian to Early Permian age. This change is re-
inforced by the finding of fusulinid Foraminifera of similar
age that are reported here for the first time.
2. The thick limestone pebble conglomerates of the Tiburon Formation that overlies the Diamante Formation were derived

from the Diamante beds and can therefore not be older than i
i Middle to Late Permian. j

!

3. Ostracods in the Bocas Formation, although not identifiable with certainty, display characteristics that are more
!

suggestive of post-Paleozoic than of Paleozoic forms, and
i

one of the conchostracans present strongly resembles a
Triassic form. ;

1 u

Considering the similarity of lithology and fossil concent (poorly preserved gastropods, bivalves, ostracods, and conchostracans or estherids) of the Bocas to the Los Indies Formation near Fundacion in Department of Mgdalena (G. Tschanz written conimun.)> the Bocas Formation appears to be correlative with the Los Indios. This suggested correlation is further strengthened by the lithologic similarities of the overlying formations, the Jordan- Formation of the Bucaramanga area to the Guatapuri Formation that overlies the Los Indios.
Jurassic System
Jordan Foriration
The Jordan Formation was first recognized by Cediel (1968,
p. 66) in his study of the Giron Formation in the Bucaramanga area.
i
The type section is 1 kilometer west of the village of Jordali on the
north slope of the canyon of Rio Chicamocha (planchita 135 -II-B, D-3
*- and E-3). The Jordan there includes two facies (Cediel, p. 67) divided
by a transitional zone of approximately 10 meters that does not indicate
any pause in deposition. ;
i - i i Upper facies (200 m) uniformly reddish-brown siltstone and very
fine grained sandstone, well-stratified in beds from 30-80 cm thick.
Lower facies (llOO m) principally coarse-grained, greenish-gray
sandstone in beds up to 1 meter thick and a few beds of
greenish-gray shale up to 2 meters thick; a few thick beds with
cross stratification contain conglomeratic zones with pebbles
up to 2 centimeters in diameter.
"e base of the section is not. exposed, but elsewhere in the area the
°rdan overlies phyllitic and schistose metamorphic rocks. _

18G

Acid volcanic rocks associated with the Jordcih in the area of the
type section are referred to as welded tuffs (Cediel, 1968, p. 67). One bed 30 centimeters thi ck in the upper facies of the type section is composed principally of angular fragments up to 1 centi-meter in diameter of acid volcanic and metamorphic rocks. About 2 kilometers to the northeast, on the trail from Los Santos to Jordan, two thicker beds of this tuff are exposed and are separated by 80 meters of siltstone and sandstone.
For the beds overlying the Jordan in the area of the type section,
' S

Cediel, 1968, p. 58) has proposed the name Los Santos Formation in
\ place of Tambor Formation, with the type section of the Los Santos in

, the same area as that of the Jordan. He found angular discordances i
1 up to 30* between the two formations in the area of the type sections. i *
In the present report, the conglomeratic beds immediately overlying the Jordan at the type section are mapped as a thin section of the Girdn Formation which is in turn overlain by the Tambor Formation
(Los Santos Formation of Cediel).

1 , '

\ The Jordan Formation has previously been included in the Giron
I Formation, and on maps of the mesa area south of Bucaramanga by Julivert and others (1964) and Tellez (1964) , the lower shale member in j
1 the Mesa de Los Santos area corresponds approximately to the Jordan

I , ,
\ formation. North of the mesa the Jordan is covered by the Giron.

5-

In the western part of Mesa de Los Santos, the Jordan Formation
is exposed in a large area where erosion has removed the overlying

Giron and Tambor Formations that form the cap of the mesa. In the i
| precipitous western slope of Quebrada del Angelino (or Quebrada
Grande on planchita 120-IV-£, H-l and 1-1), the Jordan section may be more than 800 meters thick. The base is not exposed.
In the Bucaramanga area, the Jordan Formation is well exposed in
i /
j the canyon of Rio de Oro south of Bocas where it overlies the Bocas Formation. A section measured Is given below.
The Jordan measured section is almost uniformily fine
grained and reddish-brown in color throughout. South of Piedecuesta r
i
! where the forntation overlies pre-Devenian phyllitcs, tho lower 50
i i
; meters contain conglomerates with fragments of porphyritic igneous rock that are derived from a phase of the Pescadero Granite-which crops i out nearby. This conglomeratic lower section of the Jordan can be traced southward to the beveled edge of the formation on the eastern
i
j slope of Mesa de Los Santos. Northward the conglomerates grade to feldspathic sandstones. A description of the lower conglomeratic section of the Jordan is given below.
The basal conglomeratic section is slightly overturned
i and the beds dip steeply toward the east. Westward, and higher in
. the section, dips are normal and steep to the west. The section is
I

jmostly reddish-brown siltstone and includes units of harder, very fine
t

to medium-grained feldspathic sandstone up to 11 meters thick.

188

- StratlgrapMc section of the Jordan Formation ^ga
along tfre railroad on the west side of the canyon of ther.R^o de Pro south of Bocas (planchita 109 IV-C, B-12, B~13, C-13 and D-13)» Municipality of Bucaramanga, Department cf Sant^nder. (Measured and described by E. Aya, September, 1968)
Meters

Giron Formation (lover beds only): '
1 . .

- 1 Conglomerate, gray, massive, with sub-angular
i
! pebbles of white quartz and few pebbles of volcanic

I
!

1 rocks, black chert and shale in coarse, sandy, mica-
; ceous, sldLghtly calcareous matrix, N. 25° E.,
1*3° SE. 10.0

- i ---.-.... -unconformity- ----------
Jordan Formation!
Siltstone, reddish-brown and greenish-gray, hard, :
slightly calcareous, with interbeds of reddish-
i '
brown, slightly calcareous claystone 26.0
Sandstone, reddish-brown, hard, fine-grained to I
silty, slightly calcareous and micaceous, in beds '
1.0-2.5 m thick, H. 32° E., 18° SE. .... 15.0 Sandstone, reddish-brown, hard, fine-grained to
silty, slightly calcareous and micaceous, with
interbeds of soft reddish-brown shale, N. 75° W., ;
10° SW. 15.3

Sandstone, reddish-brown, hard, fine-grained to
silty, slightly calcareous and micaceous, in beds
1-3 m thick, horizontal 11.0

on

5-

Meters

Silt stone, reddish-brown and greenish-gray inter-
bedded, hard, slightly calcareous and micaceous,
N. 60° E., 1° SS. 1*0.0
Siltstone, greenish-gray, hard, slightly calcareous
and micaceous 5.0
Sandstone> greenish-gray, slightly calcareous,
conglomeratic vith granules of white quartz,
N. 20° W., 5° SW. 2.5
Sandstone, reddish-brown, hard, fine-grained to
silty, slightly calcareous and micaceous; inter-
headed with siltstone of similar color and hard-
ness, N. 20° W., 10° SW. 37.5
daystone, dark-gray, slightly calcareous and mica-
ceous, highly fractured, N. 30° W., 23° SW. 7.0
Siltstone, reddish-brown, argillaceous, slightly
calcareous; interbedded with reddish-brown shale
and fine-grained, thin-bedded sandstone, N. 25° W.,
25° SW. 21.0

daystone, greenish-gray, medium-hard, massive,
slightly calcareous, with thin interbeds of sandy
claystone; contains small calcareous concretions . » 23 5

ion

1 0 '

Meters

Sandstone, greenish-gray, hard, fine- to medium-
grained, slightly calcareous, with interbeds of
massive, slightly calcareous claystcne, N. 25° W.,
20° SW. 18.0

Sandstone, dark-gray to black, hard, coarse-grained,
slightly calcareous, somewhat feldspathic; conglom-
eratic in lower 5 m with small pebbles of black
shale; contains scattered grains of chalcopyrite,
N, 80° E., 17° SB. .... 21.0 Covered by vegetation .... 55»0 Claystone and silt stone, medium-hard, slightly cal-
careous and micaceous .... 3.9 Sandstone, greenish-gray, hard, medium-grained,
slightly calcareous and micaceous, in beds up to 1 m
thick, N. 65° E., U0° SE. .... 20.0 Sandstone, reddish-brown, hard, fine-grained, slightly argillaceous and calcareous, micaceous,
N. 60° E., kO° SE. .... 1*.5 Sandstone, reddish-brown, hard, fine-grained to
argillaceous, slightly calcareous and micaceous,
with softer interbeds of reddish-brown claystone,
N. 65° E., 58° SE. 65.8

If!

Meters

Sandstone, reddish-brown, medium-hard, very fine-grained to silty, somewhat micaceous, with thick sections of softer, slightly calcareous, reddish-brown claystone; sandstone contains calcite-filled veinlets up to 5 mm wide, N. 50° E., 33° SB. . . . Sandstone, reddish-brown, hard, fine-grained to silty, slightly calcareous, slightly micaceous in some beds, in beds up to 1 m thick; contains small, greenish-gray calcareous concretions throughout, and small pebbles of black shale in the middle, N. 33° E.,
30° SE.

Claystone, reddish-brown, medium-hard, slightly cal-- careous, massive, N. 30° E*, *tf>° SE. .... Sandstone, greenish-gray, hard, fine-grained to
silty, slightly calcareous .... Claystone, reddish-brown, medium-hard, with harder interbeds of reddish-brown siltstone and fine-grained sandstone, N. ^5° E., SE.
Sandstone, reddish-brown, hard, fine- to medium-grained, slightly calcareous and micaceous, with interbeds of soft, reddish-brown claystone, N. U6° E., 70° SE.

10U.O

15.0

5.0

18.5

28.5

191:

, 35 SE«

Covered by vegetation; probably sandstone and clay-stone similar to those above .....*...< Sandstone, reddish-brown and greenish-gray, hard,
very fine-grained to silty, slightly calcareous,
in beds up to 1 m thick, N. ^5
Total thickness of Jordan Formation
Bocas Formation (upper beds only) :
Siltstone, mostly greenish-gray, some reddish-brown, argillaceous, micaceous, slightly calcareous, in
beds up to 1.1 a thick; highly fractured normal to the bedding, N. 30° E., 38° SE. ....

Meters

35.0

5-0
657.0

120.0

193

5-

Meters

Conglomerate, pale-reddish-brown, with subangular
to subrounded pebbles of pink porphyry up to 15 cm
in diameter and fewer small pebbles of gray
quartzite 1.5
Siltstone, reddish-brown, soft U-.9
Conglomerate, pale-reddish-brown, with pebbles of -
pink porphyry and pinkish-gray quartzite up to 2 cm
in diameter 0.6
Siltstone, reddish-brown, soft 9*6
Conglomerate, pale-reddish-brown, with subangular
pebbles of pink porphyry up to 3 cm in diameter
and fewer pebbles of white quartz and gray quartzite,
in a lenticular bed that changes laterally to coarse-
grained feldspathic sandstone; porphyry pebbles contain quartz and biotite phenocrysts .... 0.6 Siltstone, reddish-brown to pale-reddish-brown) contains
pink feldspar grains up to 1 mm in diameter . » . . 8.7 Conglomerate, reddish-brown, weathered, with subangular
pebbles of pink biotitic porphyry and siliceous
aphanltic igneous rock up to 12 cm in diameter;
other pebbles are of pink quartzite, feldspathic con-
glomerate containing pebbles of greenish-gray phyllite,
and white quartz 2.2

inn

Meters

Siltstone, reddish-brown, soft; contains grains of
pink feldspar ....
5-1 Conglomerate, pale-reddish-brown, with pebbles of light-yellow, reddish-brown, and greenish-gray
phyllite up to 2 on in diameter ....
. . . . - -.. -unconformity- ----..---
Silgara Formation (pre-Devonian metasediments):
Phyllite, light-yellow to reddish-brown and greenish-
gray, sericitic, weathered ....

2.3

0.6

190

One kilometer north-northwest of the conglomeratic section described,
: the lower beds of the Jordan ara less conglomeratic. An estimated
800 meters of the formation is partly exposed from the basal contact
with pre-Devonian phyllite westward along a low ridge toward the main
_ highway (planchita 120-II-D, G-10 NW and G-9 NE). At the highway and

s westward to Rio de Oro, the beds are concealed by alluvium for a dis-
s

tance of about 250 meters. From the Rio de Oro northwestward, about
300 meters of fine-grained reddish-brown sandstone and siltstone in
the upper part of the formation are partly exposed along the ridge that extends to the top of the hill that is situated immediately to the west of Piedecuesta (planchita 120-II-D, G-9 NW, G-8 NE, and F-8 Si/2). At

the top of this hill the Jordan is overlain with slight angular uncon- i
fonaity by weakly consolidated conglomerate beds of the Girdn Formation. Thus the Jordan Formation may be more than 1,100 meters thick at Piedecuesta, but large changes in strike and dip that occur under the alluvial cover between the two exposed sections leaves this figure open to question. |

About 200 meters below the top of the Jordan southwest of
, Piedecuesta (planchita 120-II-D, G-9 NW), a single 3-tr.ster thick layer of pale reddish-brown igneous reck containing abundant fragments of white
' feldspar crystals and sparse fragments of gray to brown porphyry appears to represent a welded volcanic ash flow concordant with the teds of the Jordan. The content of igneous rock of this type in the formation increases toward the area of the type section about 26 kilometers to
the south. - ; From the type section of the Jordan northward, the intermittent exposures of the formation indicate that it is continuous possibly as far as the exposures south of Bocas Elsewhere, however, only isolated exposures occur. Structural and stratigraphic relation-ships suggest that these are mostly remnants of a once widespread unit of considerable thickness that have been preserved from erosion in downfaulted blocks. Such exposures occur in the Rionegro area west
of the Bucaramanga fault (H-12 f c-3), northeast of Bucaramanga along Rio Surata (H-12, d-3), west of Guaca (H-13, b-7), and southwest of Chitaga (H-13, b-5, c-5). I

In quadrangle H-12, except for the conglomeratic lower beds such
as those described the formation is very uniform reddish-brown siltstone and fine-grained sandstone. The formation is apparently :conformable and transitional with the underlying Bocas Formation north
I

|of Bucaramanga, but south of Piedecuesta it lies on pre-Devonian metasediments. The upper boundary with conglomerates of the Giro'n is one of unconformity which is quite noticeably angular in parts of the Mesa de Los Santos area (H-12 r c-7).
East of Guaca in quadrangle H-l3, b~7 r b-8, in addition to the
beds that are typical of the formation in H-12, thick conglomerates
in the upper part of the section contain pebbles mostly of pre-Devonian ir.Gtasediir.cnt3 and arc overlain v/ith angular unconformity by Giron conglomerates that contain abundant quartz pebbles (planchita 121-III-B, 1-7), But southwest of Chitaga (planchita 121-II-A, F-l NE)" the Jordan-Giron boundary is conformable and gradational over 100 meters of section or more. Hard reddish-brown siltstone of the Jordan decreases upward
as conglomeratic beds of the Giron increase. j
;

No fossils have been found in the Jordan Formation, and therefore
age determination must be based on other evidence. The assignment of
an Early Jurassic age is based on two main considerations:

1

1. The. conglomerates near the base of the Jordan in the Piedecuesta area (H-12, d-6) contain angular pebbles of
i
the porphyritic phase of the Pescadero granite (Trgp) that
crops out nearby. A radioactive age determination of the granitic phase (JTrgp) yielded an age of 193±6 million years which is near the Triassic-Jurassic boundary of 190 million years. Pink feldspar similar to that of the Pescadero
granite is abundant in the sandstones and siltstones of
the Jordan in this area.
2. The very thick Girdn Formation (4,650 meters according to
F. Cediel, 1968, fig. 6) rests unconformably over the Jordan
Formation in the Bucaramanga area and also unconformably
beneath the Tambor Formation of Early Cretaceous age.
The Jordan Formation is very similar in lithologic character to
the Guatapuri Formation in the southern part of the Sierra de Saata Marta about 325 km to the north-northwest. However, the Guatapuri contains much more volcanic material. Both are unconfonnablv under-lain by formations that have similar lithologic characters and fossil content, the Bocas Formation in the Bucaramanga area and the Los Indies-Formation in the Sierra cle Santa Mar^a. The Los Indies and Guatapuri
are both assigned to the Triassic (C. Tschanz, personal conunan.).
The Jordan Formatio.i may be the lateral equivalent of the Bata Formation of Liassic age in the Guavio quadransle (K-12) which has a irn of some 1,115 meters (D. H. McLau^hlin, personal coirnn-jin.).

2 £i 0

......__._. _ - ._. Giron Formation - -- - - . The term "Giron series" was first used by
Hettner (1892) for the thick assemblage of sandstones, conglomerates, and reddish-brown siltstones that are widely exposed west of Bucaramanga and named for the town of Gir6n. Also included were rocks that are
now recognized as the Bocas, Jordan, and Tambor Formations. The series was referred to the Lower Cretaceous.
Other writers made references to the Giro'n (Schuchert, 1935;
w^" ^' ^

Oppenheim, 1940; Dickey, 1941; and Trumpy, 1943), but further field
^

study was not made until Langenheim (1954) designated the exposures in the gorge of Rio Lebrija as the type section (H-12, c-3, c-4) and defined the limits there as the unconformable boundaries with the underlying Bocas Formation and the overlying Tarobor Formation. He i
divided the section of approximately 3,500 meters into a lower sandy member of 750 meters, a middle shaly member of 1,250 meters, and an upper sandy member of 1,500 meters.

203.

Further1 study of the Giron Formation was made by vTulivert (1958) ,

s

and later a more detailed study of the Rio Lebrija section was ituds
by Navas (1963) ^ who measured a section totalling 2,650-2,690 meters

in seven facies:
- ; 120-150 m Upper conglomerate
230 m Red shales
700 m Upper arkosic sandstones and conglomerates
850 m Upper red shales alternating with sandstones
170 m Lower arkosic sandstones and conglomerates
550 m Lower shale with interbedded conglomerate and
sandstone in the upper middle part.
30-40 IP. Conglomerate with pebbles of igneous rocks.
Navas -(1963, fig. 1, p. 29) shows that, with the exception of the upper conglomerate and the lower arkosic sandstones and basal conglom-/
erate, the facies can be traced from the Rio Lebrija section southward

toward Zapatoca and Los Santos.
The latest study of the Giron Formation was made by Cediel (1968) ,
At the Rio Lebrija type section (fig. 8), he measured a total of 4,650

of Giro'n in seven lithologic facies (Cediel, 1968, p. 26-28)
top to bottom these facies are:

G (1080 n») - sandstone, coearse-grained, in cross-stratifled beds up to four meters thick. Conglomeratic beds are present and increase in number in tha upper part. Grain size diminishes toward the Lop of tha unit and thickness of beds decreases to AO-80 cm. Highly muscovitic beds are present locally. Colors change upward in the unit from greenish gray at the base to yellowish gray and finally to grayish yellow.
F (250 m) - sandstone (70 percent) and interstratified red beds (30 percent) of siltstone and claystone in beds up to one meter thick. The sandstones are greenish-gray and conglomeratic with quartz pebbles. The red beds are grayish-red to reddish-brown. At the base are dark-gray beds.
E (1040 m) - sandstone, medium-grained, in beds up to 70 cm thick that grade laterally and vertically to shale and in some places to claystone. Conglomeratic beds are present but less
frequently than in the lower facies. Bluish gray is the
dominant color, varying to dark gray toward the base and top
and to yellowish gray in the middle. Cross-stratification is well-developed locally. This facies is generally characterized by irregular stratification and frequent devciopront of fine sandstone and shale or claystone with small lenses of carbonaceous material containing poorly preserved plant remains.

D (650 m) - red beds (60 percent) of siltstone and sandstone, and interstratifled sandstone (40 percent-) in beds up to one meter thick. The red beds vary in color between grayish-red and dark reddish-brown. The sandstones are greenish-gray and in the upper part they contain numerous beds of conglomerate with quartz pebbles. At the base are a few scattered small lenses of carbonaceous material with poorly preserved plant remains. ~ .
C (430 ra) - sandstone, medium- to coarse-grained in cross-stratified beds up to 2.5 m thick. Numerous conglomeratic
beds contain pebbles exclusively of quartz up to four centimeters in diameter. The sandstones are generally very hard, well-sorted, and vary in color betv;een greenish gray and light olive gray.
B (590 m) - sandstone (60 percent), medium- to coarse-grained, and interstratified red beds (40 percent) of siltstone and claystone. Sandstone is light bluish-gray in cross-stratified beds up to one meter thick. Scattered beds of conglomerate contain quartz pebbles of varying color. The red beds grade laterally to greenish-gray shales and finally to sandstones. They vary in color from grayish-red purple to grayish-purple.

A (610 :ti) - sandstone, coarse-grained, conglcraeratic, medium iight-gray and light-gray, in thick cross-stratified beds up
to two meters thick. Thin beds of conglomerate contain quartz pebbles, and a few also have limestone pebbles up to four
centimeters in diameter. Lenses of bluish-gray shale up to
three meters thick make up not more than 5 percent of the
facies.
In the Giron Group (distinct from the Giron Formation), Cediel
(1968, fig. 6) includes an eighth facies, (H), the Tambor Formation, which he proposes to re-name the Los Santos Formation (ibid. p. 58). In the canyon of Rio Lebrija, the Giron overlies beds of the
Bocas Formation with angular unconformity according to Cediel (fig, 8), but investigations for the present report indicate that a fault contact is present here that continues far to the north as the eastern boundary of the Giron.
Near the northern boundary of quadrangle H-12, a thin sequence of
the Giron is well exposed on the road to Cuestarica. This section is shown beloxi/. - It does not contain the conglomeratic beds that are typical of the Giron in thicker sections.

5-

Meters

Siltstone, reddish-brown, micaceous, with three inter-
beds up to 30 cm thick GJL -fine-grained, reddish-brown
»x --

sandstone .... 5.8 Sandstone, pale-reddish-brown, fine-grained, feldspathic,
in beds 0.2-1.8 m thick .... 7.9 Sandstone, greenish-gray, fine-grained, micaceous,
feldspathic, conglomeratic with pebbles of greenish-
gray siltstone and pink, fine-grained, micaceous
sandstone up to 2*5 cm in diameter; light-gray and
less conglomeratic near the top 15.2
Total thickness of the Giron Formation 135-3
; .... -unconformity- ---------- .
i
Bocas Formation (upper beds only) :
Siltstone, greenish- to bluish-gray, with thin inter-
i

| beds of reddish-yellow weathered shale occurring in ti
| subangular pebbles up to 10 cm in diameter; pebbles
i are smaller in the top 30 cm 7.3

5-

55-

During his study of the GIron Formation, Langsnheiia (1954, p. 6) found fossil ferns in the middle shaly member in Quebrada Honda, A collection from this locality was studied and reported by J. H.
f ^
Langenheim (1959, 1961). On the basis of six genera recognized from this locality (Pecopteris, Callipteridium, Asterotheca, Rhodea, Calaroites, and Carpolithus) and the stratigraphic position above the Bocas Formation (in which two Early Pennsylvanian plant fossils were identified), the age of the assemblage was considered to be probably Late Pennsylvanian and not younger than Permian (Langenheim, J. H., /
1959, p. 118). In another collection of plant fossils from the Giron just south of Floridablanca in the Quebrada Mensuli, two genera, rtilopbyllum cp. and ___________ Elatccladus sp., were identified, (which indicate a Jurassic age (ibid., p. 110).
s

Plant fossils and ostracods were collected by Bruckner (1954) in
/
the Rio Lebrija section of the Giron at Quebrada Las Palraas (the same as Quebrada Honda of Langenheira). The genus Callipteridium was identified by R. Krausel in Germany and confirmed by N. J. Jongmans in Holland, with the age indicated as Carboniferous and not younger
than Permian. The ostracods were identified by E. Triebel in Germany
as members of the genus Darwinula known from the Carboniferous. However, as Bruckner (ibid., p. 113) points out, so little is knox*n
about ostracods in the Permian and Triassic, that a younger age for
these ostracods is possible.

r* n O iy- (J O

In his study of the Giron Formation, Cedlal (1968, p. 50) states
2 that plant remains or silicified wood occurs :ln all seven of the facies of the Rio Lebrija section, and he mentions in particular those
in basal red beds of facies B and in gray beds of facies F. They are
no better preserved than those found in the Quebrada Honda beds
(facies E). Most are ferns, but sphenopsids (horsetail rushes) are
also represented. No raicrofossils were found.

5-

10-

15- :

20.fJ

The type section of the Giron is in a large triangular area of
exposure in the central part of quadrangle H-12. Within this area it ranges in thickness from zero on the eastern side of the Mesa de Los Santos (H-12, d-7) to possibly 4650 meters at the type locality
i

5 "| (H-12, c-3, c-4). The thick section extends in a north northeast- i i
| trending belt east of and parallel to the outcrops of the Cretaceous and Tertiary formations that dip steeply westward into the middle
1 Magdalena Valley basin. North of Bucaramanga this thick section ends against a fault that places it in contact with the Bocas Formation.
' D ~ Where the Bocas crops out over a large area near the northern border
i *

of H-12, the unconformable section of Giron above it is thin.-'
South of Bucaramanga, the thick section of Girolrc thins eastward over
Mesa Ruitoque (H-12, d-6), and thins more rapidly to zero over Mesa
de Los Santos (H-12, d-7, d-8). On the basis of his study of .the geometrical form and extent of the basin in which the Giron sediments

4

accumulated, the lithologic associations and their cyclical nature,
and the character of the petrology and facies of the sediments, Cediel
s ,

(1968, p. 81) concluded that the Giron Group is a typical raolasse
deposit in which the principal rock type is subgraywacke according to
- 1 - 4-^

the classification of Pettijohn (1957, p. 291). He states (Cediel,
*s
| 1968, p. 79) that the character of the Giron deposition makes it
I doubtful that the facies that have been described in the Rio Lebrija section can be regarded as laterally continuous units as shown o'n
^

: "^Ps by Navas (1963, fig. I), by Julivert et al (1964) and by Tellez
- ', '
\ (1964).

LA

; °-

The contact of the Giron with the underlying Jordan Formation is
one of angular unconformity which is as great as 10 -15 in the eastern part of Mesa de Los Santos. The contact with the overlying Tarabor is generally regarded as one of unconformity in the area of quadrangle
H-12 and H-13 where isolated remnants of the Tarabor overlie many different rocks and represent the beginning phase of the Cretaceous deposition that probably covered the entire area. In the area west and south of Bucararcanga, however, the boundary is not so sharply defined. It is placed where well-sorted and well-bedded sands of the Tarabor first appear in the section above the poorly sorted conglomeratic sands of the Giron. Reddish-brown si It stones at the top of the Giron are mottled with sharply defined light greenish-gray in irregular patterns i
that in some places appear to be controlled by bedding planes and in others to be controlled by fractures normal to the bedding. Reddish-brown siltstones occur also in the lower part of the Tambor, but their coloring is usually lighter than those of the Giron, and light greenish gray siltstones and mudstones are also present. The stratigraphic sequence and lack of angular unconformity between the Tambor and
Giron (well-illustrated near the top of Mesa Ruitoque, H-12, d-6) suggest that after the rapid deposition of the Giron there was a period
of little or no new deposition, and some re -working of the upper
beds of the Giron to produce the lower beds of the Tambor.

21.1

Another large area of exposure of the Giron formation in
2 , the southern half of quadrangle H-13 is associated with a
3 large, structurally complex synclinal feature that includes sedimentary
4 ; rocks from the Devonian to the Upper Cretaceous. The great variation 5 ~' in thickness of the Giron Formation is as evident here as it is in the
6 Bucararaanga area. No Giron occurs between the Devonian and Lower
Cretaceous rocks on the western side of the synclinal area (H-13,
8 b-5 SW), whereas a few kilometers to the east the formation is more
than 700 meters thick (H-13, b-5 SE). Feldspathic to arkosic
°~ conglomerates and sandstones are predominant in the section. The
11 feldspar is pink in color, similar to that of the Santa Barbara Quartz
Honzonite to the west from which it was probably derived.
1 Other than the two large areas of exposure of the Giron Formation
! that have been discussed, the formation elsewhere is usually thin or
' 5~ missing altogether as a result of non-deposition or erosion. Probably both conditions are responsible for the present distribution of the
Giron.
The Giron beds are clearly derived mainly from the erosion of large
areas of crystalline rocks. In the region of this report they are the
rocks now exposed mostly east of the Bucarsmanga fault. Quartz
s pebbles derived from igneous rocks and quartzite pebbles from meta-
' 1
rocks are the most common coarse materials that have survived disintegration and decomposition in the source areas and the
r*gors of transportation to sites of deposition. Only where source
- and deposition sites are comparatively close together have fragments
of the original whole rocks been deposited a:> yuch.
o o

15-

Despite the wide area of distribution of Gircn-type sedimentary
rocks in northern and eastern Colombia and western Venezuela, the
age and correlation of the formation have long been the subjects of
' much uncertainty and speculation. Ages assigned to the formation in
: the area of the type section have ranged from Carboniferous to Cretaceous. As noted before, ages based on meager plant and invertebrate fossils range from Carboniferous to Jurassic. The Giron has generally been correlated with the La Quinta Formation of western Venezuela which is similar in lithologies, in its variable thickness (up to 3000 meters), and in its grading into light-colored sandstones
of the overlying Lower Cretaceous (Oppenheira, 1940, p. 1613). The
La Quinta has been assigned to the Upper Jurassic on, the basis of fossil remains of a ganoid fish of the genus Lepidotus (ibid., p. 1611). ' The investigations for the present report have not encountered any new fossil evidence, but other new information lends support to a Jurassic age for the Giron. As discussed under previous headings, new fossil evidence from the rocks of the Surata Group and the Bocas ,Formation now places these rocks in the Carboniferous to Permian and Triassic respectively, whereas formerly they were all placed in the Carboniferous, Further evidences for a Jurassic age of the Giron are the radioactive ages of the igneous rocks from which the sediments were largely derived (table 2, sample nos. IMN-10924, -11045, and -11547). These ages (192 - 7 million years to 194 - 7 million years) are near
the Triassic-Jurassic time boundary of 190 million years, and as noted
*n the discussion of the Jordan Formation, fragments of the porphyritic Phase of one of these rocks, the Pescadero Granite, occur in the lower
- beds of the Jordan near Piedccucsta.

91& i

10 ~

Cretaceous s'/ster.i, Middle Magdalen a Valley section
In the western part of the report ares, (quadrangles H-12 and 1-12)
the Cretaceous sedimentary rocks have been ciapped in accordance with
the standard nomenclature adopted by representatives of the Colombian petroleum industry (Morales et al, 1958, p. 647). In the eastern part (quadrangles H-13 and 1-13), this nomenclature is used to a lesser extent than that of the Maracaibo Basin of northeastern Colombia and western Venezuela that is treated in several publications (Kotestein
^ ^

et al, 1944; Button, 1946; Roberts et al, 1959; Trump and Salvador,
V

1964). Figure 9 shows the age and general relationship of the Cretaceous and younger formations in the two provinces.

!3

15- Deposition during the Cretaceous covered the area between the Magdalena Valley of Colombia and Lake Maracaibo in Venezuela, but
uplift of the Cordillera Oriental has caused the sedimentary rocks
N

there to be stripped away by erosion except for isolated blocks that
have been preserved by downfaulting. Thus the sedimentary rocks of the
two areas are similar in many ways even though the formation names (except for the La Luna Formation) are different. In some places in the southern part of the report area, some map units are taken from the Magdalena Valley section and some from the Maracaibo Basin section.

T\ f.

5-

The studies of the Cretaceous rocks by the petroleum industry
have included much work with the raacroiessils and micrcfossils found
in them. Therefore no paleontologic stales were included in the :investigations for the present report. Various reports which include
; s~'

!information on the Cretaceous faunas are those by Sutton (1946),
! - ^ ^ .
iMorales et al (1958), Burgl (1961), and Etayo (1964). Ammonites have
! been especially useful in dating the stritigraphic sequence of the ,Cretaceous in the Cordillera Oriental (Surgl, 1961, p. 163-165). Forarainifera, pelecypods, echinoids, and score rarely gastropods are other forms that are present and useful in varying degrees. The studies of fossils have indicated that the forroational units mapped in the Cretaceous of the middle Magdalena Valley transgress time boundaries and are older in the south than in,the corth (fig. 9). This is
. especially noticeable in the formations of the Lower and Middle Cretaceous.
The Cretaceous section reaches a Eaadmum thickness of more than
4000 meters in the middle Magdalena Valley, and in the area of this report the maximum thickness may exceed 3500 meters beneath the
./
Tertiary section in the western part of S-12 (Morales et al, 1953, *ig. 4). The formations are generally thinner over the Cordillera ;Oriental to the east, and total thickness there may have been not more Ithan half of that in the Magdalena Valley.

215

s-

Tambor Formation
The type section of the unit is in continuity
with that of the Giron Formation in the valley of the Rio Lebrija (planchita 109-IV-A, E-2, F-2, G-2) between kilometers 92 and 95 of the
I railroad from Bucarainanga to Puerto Wilches (Morales et al, 1958, p.
j
I 643). The name was first used by H. D. Hedberg in 1931 in an unpublished report, and was supposedly derived from a village of that name nearby. No village of that name is present in the area, but the Hacienda Tambor is located four kilometers to the north. Much of the formation is not well-exposed at the type locality because the canyon of the Rio Lebrija is nearly parallel to the strike of the beds as it cuts across them. A better section is exposed a short distance to the south where Quebrada Piedra Azul cuts the beds more nearly normal to the strike t# __ _ A section measured in this quebrada is given below.
The 366 meters of Tambor measured is much less than the
650 meters reported at the type section. About 25 kilometers farther south, where the Rio Sogamoso cuts through the Cretaceous section, the Tambor is estimated to be more than 500 meters thick. About 18
kilometers north of the type section of the Tambor, the formation is well-exposed along the road to Cuestarica. The description of this section is also given below. In this section there is conglomerate sandstone only near the base, and the pebbles are of siltstone, whereas at Quebrada iedra Azul, the sandstones are conglomeratic to some extent
throughout the section and the pebbles are of quartz.

21B

section ..of T^nbor measured in Quebr^da .Pi.edra .Azul be 'ttinin--^ about 100 .meters from .the confluence with the Rio Lebrija and extending; upstream to the west and southwest for approximately one kilometer
a 109 IV-A, 1-2 NW and 1-1 E*) , aimiolpality of
Lebrija, Department of Santar/ler.
(Measured and described by F» Kontero. October. 1.96.8) .

r Meters

Rosa Blanca Formation (lover buds only):
Limestone, dark-gray, hard, massive, highly j
fossiiiferous .... 8.0 '
. *

Tambor Formation: jI
(Partly covered) claystone, reddish-brovn, medium- !
i

hard, fractured, with interbedded hard, reddish- j
brown calcareous claystone and reddish-brown and i
gray, medium- to fine-grained, micaceous, partly ;
feldspathic sandstone, N. 11° E., 52° EW. .... 2*.6]
Sandstone, light-gray, hard, fine-grained, micaceous, j
crossbedded, slightly conglomeratic with quartz ' j

pebbles up to Ij- cm in diameter .... 16.1 i
Covered .... 3^.7 ;
Sandstone, light-gray, fine-grained, micaceous, cross- }

I bedded, slightly feldspathic and conglomeratic . . 26A -

I Covered, probably sandstone similar to that above and !

I i
bel°w .... 68.7 !
Sandstone, light-gray, hard, fine-grained, micaceous, !
croasbedded, conglomeratic in some beds with pebbles t
of quartz up to k cm in diameter .... 22.3 '

217

Maters

Claystone, greenish-gray, soft; contains two beds
1.1 and 1.2 meters thick of grayish-white, con-
glomeratic sandstone, N. 10° E., 52° KW. . * * * . 10.8
Sandstone, light-gray, hard, fine-grained, micaceous, crossbedded, conglomeratic in some beds with pebbles
of quartz up to k cm in diameter .... 31 »7
Covered 9.6
Sandstone, light-gray, hard, fine-grained, micaceous, crossbedded, conglomeratic with numerous pebbles of
white quartz and few of iledspar, in massiv? beds
k to 6.5 m thick; contains a few beds of greenish-
gray claystone .... 118.2 Conglomerate, brownish-gray, hard, crossbedded, with
pebbles of white quartz, claystone and feldspar up
to k cm in diameter in matrix of dark-gray, micaceous,
silty sandstone 2.3
Claystone, reddish-brown in lower half, greenish-gray
above, hard, siliceous, micaceous, N. 16° E.,
52° KW. 0.9
Total thickness of Tambor Formation 366.3
- - . - - -.._.. -unconformity- ----------

2.10

Meters

Giron Formation (upper "beds only) :
Sandstone, greenish-gray, hard, fine- to very fine
grained, crossbedded, highly conglomeratic vith
abundant pebbles of white quartz, feldspar, clay-
stone, and few of muscovitic chloritic schist;
some beds are light-gray, very fine grained, non-
conglomeratic .* < 98.7

210

- Stratigr^phic section of the Taabor Formation ...ir.egsurc
along the road from about 1.5 to 1.0 kilometers northeast of Costarica (planchita 109 I-B, 1^15 SE and J-15 NE). Municipality of Rioneqro, Department of Santander.,
(Measured and described by R. Vargas, September, 1968)
I Meters i
i
Rosa Blanca Formation (lover beds oiily) : ;
(Partly covered) shale, yellowish-gray, very sandy,
slightly fissile, with thin interbeds of yellowish-
to bluish-gray fissile shale 23.3
Covered .... 2$.k
Tambor Formation: ;
Covered; sandy, fine-grained, reddish-yellow soil . .' 2^.9 Sandstone, reddish-yellow, medium-hard, fine-
grained, micaceous, in beds up to 6 m thick, with
interbedded bluish-gray to reddish-brown sandy
shale .... Ih.Q Sandstone, reddish-yellow, medium-hard, fine-grained,
In beds up to 1 m thick, with interbeds of bluish-
gray sandy shale .... 17*3 Covered; clayey and sandy reddish soil 13*3
Shale, reddish-yellov, sandy, with interbeds of fine- ;
grained, reddish-yellov sandstone 8*3
Sandstone, reddish-yellow, fine-grained, micaceous . U.2
Covered; reddish, clayey soil 3.0
Shale, bluish-gray, sandy, micaceous 6.0
Sandstone, light-yellowish-3ray to yellowish-brown, with interbeds of bluish-gray sandy shale up to 20 cm

5-

Meters

Shale, reddish-brown, with bluish-gray spots and
few thin interbeds of fine-grained, pale-reddish-
brown sandstone .... 1^.2

Sandstone, pale-reddish-brown to light-yellowish-
gray, fine-grained 3*5
Shale, light-reddish-yellow to light-bluish-gray,
i
with irregular sandy zones 7*3
Sandstone, light-reddish-brown to light-yellowish-
gray, fine-grained, micaceous 8.2

Shale, reddish-brown, sandy, micaceous .... 2.0 i
Sandstone, light-reddish-brown to light-yellowish-
gray, fine-grained, micaceous, with 2.0 meters of :
i
sandy, micaceous shale in the lower half . . * . . 20.5
SULtstone, reddish-brown with patches of greenish- to .

i

bluish-gray, micaceous .... ^.8 i
!

Sandstone, light-reddish-brown to light-yellowish- I
i i
gray, fine-grained, micaceous 10.3
i
Sandstone, light-yellowish-gray, fine-grained, with <
thin interbeds of greenish- to reddish-gray sandy j
i
clay . ... 16.8 '

221

Meters

Sandstone, light-yellowish-gray, fine- to medium-
grained, micaceous, somewhat feldspathic, con-
glomeratic near the base with pebbles of greenish-
gray siltstone .... 6.9 Shale, very dark gray, sandy, micaceous .... O.k Sandstone, light-yellowish-gray, fine-grained .... 2.1 Total thickness of Tarnbor Formation 25*4-. 3
. . . . -unconformity- ----------
Giron Fornation (upper beds only):
Sandstone,, pale-reddish-brown, fine-grained,
micaceous, somewhat feldspathic, in beds 0.3-1.0 m
thick; interbeds of micaceous, reddish-brown shale
up to 0.3 m thick 66.7

9 0 >
£< «_< *

5-

Eastward from this eastern margin of the middle Ma^daiena basin,
the Tambor thins considerably. In the eastern half of quadrangle H-12, and in H-13, it ranges from 100 to 250 meters. Where the beds are inclined, it usually weathers as a distinct ridge, and south of
; Bucaramanga» Tambor sandstone forms the cap of several of the mesas of that region.
The lower boundary of the Tambor is one of unconformity, although
this is not always evident where the upper beds of a thick Giron section have been reworked into cleaner and better sorted beds of the lower Tambor. The upper boundary is conformable with the overlying Rosa Blanca Formation. Fossils of Late Hauterivian age have been reported from upper neritic facies of the Tarabor near Totumal, about
i
100 kilometers north of the area of the present report (Morales et al, '/
i 1958, p. 647), and Valanginian to Early Hauterivian fossils from the
i

Leiva area about 100 kilometers to the south (ibid., p. 648). The top
of the Tambor is thus indicated to be older in the south than in the north. The age range in the lower beds of the formation is not known
; because fossils have not been found in this part of the section.

223

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15-

East of the Eucararaanga fault, where dovmfaulted blocks of
Cretaceous rocks have been preserved from erosion, the Tambor
i
! overlies rocks ranging in age from pre-Devonian to Jurassic. This is
i indicative of the original blanketing nature of this and younger
j Cretaceous formations over a planed-down pre-Cretaceous erosion
!

i surface. The basal beds are conglomeratic in many places but vary
!

greatly in this respect, in some places the coarser materials are angular fragments of Giron conglomeratic sandstone and conglomerate,
i
in others only well-rounded small pebbles of white quartz.
Although the Tambor in the western (middle Magdalena Valley) part
; of the report area does not appear to correlate with rocks of equivalent age in the eastern (Maracaibo Basin) part (fig. 9), there
; is a good "facies correlation with A thin basal section of the Tibu
' Formation in which clean somewhat conglomeratic quartzitic sandstones overlie" pre-Cretaceous metamorphic or igneous rocks or Giron beds in the Pamplona area (H-13, c-2). The thin, basal sandstones of the Tibu are quite persistent northward and are present in the type section of *s
the formation 135 kilometers to the north (Notestein et al, 1944,
^ig. 4, p. 1176). The dark-gray fossiliferous limestones that make up the major part of the Tib(f Formation are similar to those of the Rosa Blanca Formation of the western section. In western Venezuela, the basal sandstones of the Tibu are much thicker and constitute the
.x

Rionegro Formation from which fossils have been collected that range . S

*n age from Hauterivian to Aptian (Trump and Salvador, 1964, p. 5).

224

5- I

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[Rosa Blanca Formation
In an unpublished report of 1929 by 0. C. Wheeler (Morales et al, '1958, p. 648), the Rosa Blanca Formations in named for
: *£
! Cerro Rosa Blanca, a high ridge in quadrangle H-12, b-5 NE . The type
i
! section, however, is generally accepted as the one in the canyon of /
j the Rio Sogaraoso (planchita 120-I-D, A-8), upstream about 1.5 kilometers from the highway bridge over the river at El Tablazo.

i There the formation consists of about 425 meters of hard, bluish-gray, i | coarse-textured, fossiliferous, massive limestone with many marly beds i
S that grade into black, shaly, very fine-textured limestone at the top,
i It is conformable with the underlying Tarobor and overlying Paja
j Formations.
I The Rosa Blanca is better exposed in the Quebrada Pujaraanes,
j about four kilometers north-northeast of the Rio Sogameso location;
! and a section measured follows.

15-

L
99"
Ll fcw »

- Straticcraphife section of the 'Rosa Blanca Formation
measured in the- Quebrada-^Pu.lamanes about 2 kilometers upstream from the confluence wtthhfeba--Queterada Ag-uablanoa (planchita 120 I-B. G-9 E£. G-10 W*). Municipality of Giron- Department of Santander.
(Measured and described by F. Montero, September, 1968)
Meters

La Paja Formation (lower beds only):
i
Covered; apparently soft shales of the La Paja ! 'Formation .... ?

Rosa Blanca Formation: i
Limestone, dark-gray, hard, massive, medium-textured,
in beds from 0.6-2.0 m thick; abundant thick- '
shelled fossils in top and basal beds, fewer else-
where, N. 25° E., 1*3° NW. .... 11^6.0 Limestone, gray, hard, fine-textured, nonfossiliferous,
with few interbeds of black, fissile, calcareous
shale from 2-10 cm thick, N. 20° E., 46° NW. ...
Covered interval ...... Limestone, dark-gray, hard, massive, medium-textured, abundantly fossiliferous with pelecypods and echinoids,
in beds O.U-1.8 m thick; few interbeds of dark-gray to
black, fissile, slightly calcareous, fossiliferous shale from 10-70 cm thick; shale beds more frequent
in the lower part, and fossils more abundant to the extent of forming beds of coquina up to 15 cm thick,

58.0
15.0

N. E.,

.; <*>

Meters
Covered interval .... 3«0
Limestone, dark-gray, hard, massive, medium-textured, abundantly fossiliferous .... 39.6 Shale, black, fissile, slightly micaceous, calcareous, slightly silty near the base, fossiliferous with
pelecypods, N. 25° E., 54° NW. .... 15-1 Covered; contact with Tambor Formation apparently occurs
about 10 meters below the base of the black shale
described above 10.0
Total thickness of the Rosa Blanca Formation ^27.9
Tambor Formation (upper beds only):
Covered interval .... 20.3 j
i
Claystone, gray, green, violet,, soft, slightly micaceous, j
N. 20° E., Vf° NW. .... 29.0 i Sandstone, gray to grayish-white, hard, fine-grained,
micaceous, N. 2° E., kQ° NW. .... 10.0+

227

Stratigraphic "" ' .section of tho Rosa Blanca Formation
wO

aJ.<mg. the road from about- 1*0/0^6 kilometers northeast
of Cuestafrica (planchita 109 I-B, J-15 NW) , Municipality of Rionegro, Department of Santander.

(Measured and described by R« Vargas, September, 1968) i Meters \

i
Paja Formation (lover "beds only): i
Shale, very dark gray, sandy, weathers dark-brown; j
i i
contains several widely separated beds of very j
i
dark gray, hard, fine-textured, argillaceous lime-
stone from 20-70 cm thick and one 20 cm bed with
cone-in-cone structure 55-9
Rosa Blanca Formation:
Limestone, .dark-gray, hard, fossiliferous, pyritiferous
at some levels, in beds 0.3-1.0 m thick, with softer,
thin interbeds of highly fossiliferous argillaceous
limestone 27-2
Covered; numerous blocks of limestone 17-2
Limestone; three beds are gray, hard, nonfossiliferous;
two interbeds are gray, hard, argillaceous, and
highly fossiliferous with small pelecypod shells . . k.J
Limestone, gray, hard, argillaceous, highly fossili-
ferous with small pelecypod shells 3-5
Limestone; three beds are gray, hard, fosailiferous; -
two interbeds are gray, hard, argillaceous, highly
fossiliferous with small pelecypod shells .... k.$

990 fc- tw *'

Meters

5-

10-

15-

Limestone, gray, hard, argillaceous, highly fossili-
ferous with small pelecypod shells .... 15.2 Limestone; three thicker beds are gray, hard, argilla-
ceous, highly fossiliferous with small pelecypods,
alternating with three thinner beds that are gray,
hard, crystalline .... 5»5
Limestone, gray, hard, crystalline, fossiliferous, in
beds 0.3-0.8 m thick; one bed argillaceous, highly
fossiliferous 4.1
(Partly covered) sandstone, yellcwish-gray, hard, fine-grained, interbedded with, soft, sandy, yellowish- to
bluish-gray shale .... ^3.0
Limestone, gray, hard, sandy, fossiliferous with small
pelecypod shells 2.3
Limestone, gray, hard, sandy to very sandy, glauconitic
in some beds, argillaceous and highly fossiliferous
i
near the base 3.5,

i
Limestone, light-gray, hard, slightly sandy, slightly I glauconitic, slightly fossiliferous, argillaceous at i
i
the base 5-2
i
Limestone, gray, hard, oolitic, weathers pale-brown . . 0.9

230

Meters

(Partly covered) shale, yellowish-gray, very sandy,

slightly fissile, with thin interbeds of fissile,

yellowish- to bluish-gray shale 23.3

Covered; fine- to medium-grained sandy soil, yellowish- i i
to brownish-gray .... 29 A !

Total thickness of the Rosa Blanca Formation 189.3

Tatnbor Formation (upper beds only):
!

Covered; sandy, fine-grained, reddish-yellow soil ... 2^.9
I

Sandstone, reddish-yellow, medium-hard, fine-grained, j
i
micaceous, in beds up to 6 m thick; with interbedded ,
i i
bluish-gray to reddish-brown sandy shale 7b*Q

231

The age of the Rosa Blanca Formation ranges from H<?uterivian in
the south to Barremian in the north, and the presence of heavy-shelled molluscs, and rounded, re-worked limestone pebbles indicate deposition
under upper neritic, near-shore conditions of a shallow marine environment (Morales et al, 1958, p. 648). In lithologic character,
if not in age, it is similar to the Tibu Formation of the Maracaibo Basin section (fig. 9).

15-

232

A detailed petrographic study was made of the Rosa Blanca section
2 . exposed in Quebrada Lagunetas (planchita 120-IV-C.* £-7, F-7, 7-8) in
^

3 the area west of the Mesa de Los Santos by I. de Julivert (1963).
4 Figure 10 taken from this study shows the various zones that were

5- "

15-

identified on the basis of the nomenclature and classification of
'

Folk (1959, 1962), and the depositional environments which they indicate. The lowermost zone of dolomite and doloraitic limestone
with thin beds of gypsum (satin spar) up to two centimeters thick, a zone of bioiiths formed by the deposits of calcareous algae, and presence of pyrite in all the beds indicate that a restricted environment was present that was favorable to the deposition of
^

evaporites (I. de Julivert, 1963, p. 27). Two kilometers south of
S

this section, across Rio Sogamoso on the western slope of Mesa de Los Santos, individual gypsum beds in this lower zone reach thicknesses of more than 2 meters and are being quarried for the cement industry. Two other quarry sites are located 2.5 and 3.8 kilometers to the south and south-southeast respectively. The size outline of the evaporite basin has not been fully defined at this writing, but it is clear that the evaporite facies is well-developed. This deposit is treated further in the section on economic geology.

9 ')')
^ < t *

Paja. Formation

15-

The type locality for the Paja Formation is Quebrada La
!j X
;Paja where this stream enters Rio Sogamoso one kilometer upstream from

'the highway bridge at El Tablazo (planchita 120-I-D, A-8 NW). The

!formation was named and described by 0. C. Wheeler in an unpublished-

I report of 1929 (Morales et al, 1958, p. 650). The section reaches a

j maximum thickness here of 625 meters and is composed of thinly
i
jlaminated, slightly calcareous, silty, and micaceous black shales. The

|lower 250-300 meters contain limestone concretions, septarian nodules
!

and calcite veins. The section is not well enough exposed to measure
1

a continuous section*, and the upper beds are included in- the descrip-
; _ _._.._. '

tion of the type section of the overlying Tablazo Formation (see below).

1 About 42 kilometers north of the type section, the Paja Formation
i

j is well-exposed along the road to Cuestarica.

Boundaries are conformable and well-defined
!
. with the underlying Rosa Blanca and overlying Tablazo Formations.

I In this section, described below, concretions are abundant in i

I only one zone in the lower half of the formation. They increase in
i

jabundance southward toward the type section. Farther south, in the i\
\ southwestern part of Mesa de Los Santos, they have been reported
! /
jthroughout the formation (Tellez, 1964, p. 16), and also gypsum in thin i
jlaminae intcrbedried with the shale. These gypsum platelets were
I

gathered as a source of gypsum for the cement industry until thicker

beds that, oe quarried were discovered in the lower part of the Rosa

Formation on the southwestern slopes of the mesa. A study of
jthe gypsum resources in the Paja Formation in this area was made by "iJimeno and Yepos (1963).

234

Strati %r~rphic s action of the Pa'Ja Formation. aloni-;
the road from about -600 meters east to 500 meters west of the village of _ Cuestarica (planchita 109 I-B, J~3> Municipality of Rioneg;ro, Department of Santander. (Measured and described by R. Vargas , September, 1968) i

Tablazo Formation (lower beds only):
Sandstone, light-yellow to light-pink, hard, fine-
grained, in beds 0.3-0.8 m thick, with interbeds
of yellow to light-brown, sandy, micaceous shale,
N. 50° W., 37° SW. ....
Shale, light-reddish-brown, slightly micaceous . . . Paja Formation:
Shale, very dark gray, sandy, very micaceous .... Shale, very dark gray, micaceous, alternating' in thin beds with grayish-black sandy shale; contains two
1 m thick beds of hard shaly sandstone at 3 and 30 m above the base of the unit, N. 56° W., 35° SW. .. Shale, gray, calcareous, with thin beds of fine-textured, very dark gray limestone near the top . Shale, very dark gray, fissile, weathers brown; lover beds have abundant impressions of ammonites up to 5 in diameter, N. 55° W., 3V SW. ....

Meters

57-9Ji
2.3 1! i

i
11.0!

98..3!

k.Q\

101.3

Meters!

Shale, very dark gray, calcareous, in.th limestone concretions from 0.1-2.0 m in diameter which contain ammonites (up to 50 cm in diameter) and gastropods, some of which are pyritized; contains "beds of fibrous white gypsum up to 1 cm thick, N. 65° W., 25° SW. . .
Shale, very dark gray, weathers dark-brown ...... Limestone, very dark gray, hard, fine-textured, argillaceous .... Shale, very dark gray, sandy, weathers dark-brown; contains- several widely separated beds of very dark
gray, hard, fine-textured, argillaceous limestone
from 20-70 cm thick and one 20-cm bed with cone-in-
cone structure ....

Total thickness of the Paja Formation
Rosa Blanca Formation (upper beds only):
Limestone, dark-gray, hard, fossiliferous, pyritiferous at some levels, in beds 0.3-1.0 m thick, with softer
thin interbeds of highly fossiliferous, argillaceous limestone ....

13-1

3-0

55-9;
328.5:

27.2

238

i The Paja thins rather uniformly toward the eastern part of the I

report area. At Quebrada Lissgura (H-13, b-8 SW) the section is only

A.

41 meters thick. Although it is shown as a thin map unit in the
, southeastern part of H-13, it is probably not more than 25 meters thick. Because it is less resistant to erosion than the adjacent Rosa j
Blanca and Tablazo Formations, it forms an erosional valley between these formations where the beds are tilted. : As in the case of the Rosa Blanca and Tarabor Formations, the Paja
beds are older in the south than in the north of the middle Magdalena Valley (fig. 9). The formation ranges from Barremian to Aptian in the south to Aptian in the north. This time transgression has been revealed by a study of the ammonite.fauna found in the lower part of
i ' "-
i the formation in various places (Morales et al, 1958, p. 650). - A similar strong transgression at the top of the formation is not evident.
Inasmuch as the Paja Formation thins so greatly from west to east, there is no formational unit with which it may be correlated in the
; Maracaibo Basin section (fig. 9). At the top of the Tibu Formation,

, however, tnere is a strong break from limestone to black shale in the i 1 base of the Mercedes Formation. Shales make up a large part of the
| lower third of the Mercedes in the area of the Barco Concession
i (Notestein et al, 1944, p. 1177). * '

Ifllll

5-

Tablazo Formation
The type section for the Tablazo Formation is at EL Tablazo

x

where the highway from Bucaramanga to San Vicente crosses Rio Sogaraoso which cuts through the strong ridge formed by the Tablazo at this

! point. The formation was named in an unpublished report of 0. C.
!

'Wheeler who reported a section of 150 meters consisting of extremely
j fossiliferous, massive-bedded limestone in the upper part and marls or clayey limestone in the lower part (Morales et al, 1958, p. 651). It is conformable and gradational with the underlying Paja Formation and conformable with the overlying Simiti Formation. A section was measured at the type locality (see below) .
The Tablazo at the type locality is more calcareous than it is to
the north and northeast. About 42 kilometers to the, north, the section ! contains much more sandstone > as indicated in a second measured section shown below. The 278 meters measured in this section may include some repetition due to faulting which is indicated by erratic strikes and dips near the middle of the outcrop. According to the report of
x s

Tellez (1964, p. 17), sandstone is also dominant in the Tablazo section ; south of Barichara (1-12, c-2 SW) about 50 kilometers south-southeast of the type section. The thickness is about the same.
From the belt of Cretaceous rocks where the type section is
located, the Tablazo thins eastward, although probably not as much as the Rosa Blanca and Paja Formations. At Quebrada Lisagura (H-13, b-8

A

, the section of 114 meters includes dark gray shales and fossilif-
erous limestone, with sandy beds and sandstone prominent only in the
!

lupper quarter of the unit.,..

230

15-

Type section of the Tablago Formation on the norcti.
side of the Rio Sogamoso at £1Tablazo, from about 300 meters upstr^am to 200 meters downstreaa from the highway, bttdoce (planchita 120 I-B, J-7. S£)_, Municipality of Giron. Department of Sant^nder.
(Measured and described by A, Castro, Septembert 1968)

Meters

Simiti Formation (lower beds only): |
- i
Covered; apparently soft black shales
Tablazo Formation:
Limestone, gray, hard, fine- to medium-textured,
glauconitic, thin-bedded changing to massive-bedded
i
at the top, N. 18° E., 3° NW. .... 2.6!
i
Limestone, dark-gray, hard, mediuia-textured, slightly '
fossiliferous; finer textured, more massive, and i
harder at the top, N. 20° E., 37° NW. 5.2;
Limestone, dark-gray to black, hard, massive, fine- i
to very fine textured, pyritic; light-gray, fine-
to medium-textured and fossiliferous at the top,
N. 23° E., 38° NW. 1*.9
Limestone, dark-gray to black, hard, massive, medium-
textured, glauconitic, pyritic; middle beds are
thinner, fossiliferous, nonglauconitic, N. 22° E.,
36° NW. 6.7
Covered 6.1
Limestone, dark-gray, hard, massive, medium-textured,
slightly glauconitic 1.0
Sandstone, yellowish-brown, medium-hard, argillaceous,
- ...__._ calcareous, glauconitic, slightly micaceous 5-5

n

Meters,
Covered 22.0;

i Limestone, gray, hard, massive, mediuzn-textured, !

i
fossiliferous in the upper part 6.3;
Sandstone, gray, hard, thin-bedded, fine- to very
fine grained, calcareous .... l.OJ
i
Limestone, light-gray, hard, thin-bedded, fine- to very j
fine textured .... l.V
Limestone, light-gray, hard, medium-textured, glauconitic i
in a few beds, in beds up to 1 m thick k.6
I

Covered .... k.Q*
j
Limestone, dark-gray to black, hard, medium- to coarse- i

i
textured, veins of calcite, in beds up to 50 cm thick . 2.0! Sandstone, dark-gray to black, thin-bedded, fine- to medium-grained, argillaceous, calcareous, micaceous,
N. 16° E., 38° NW. 2.1,
Limestone, dark-gray to black, hard, massive, coarse-
textured, fossiliferous; fine- to medium-textured
and veins of calcite at the base .... *j.k
Limestone, dark-gray, hard, massive, fine- to medium- j
textured; lighter colored and coarser textured at ;
the base 7.7
Covered 26.9

2 f- (J

Metersi
i
Sandstone, brown, medium-hard and porous, thin-bedded, ;
I

fine- to medium-grained, argillaceous, micaceous, |

slightly calcareous 3.6i

Covered 14-3;
i
Limestone, dark-gray, hard, medium-textured, in beds j
i
up to hO cm thick, N. 15° E., kO° NW. 2.0-

Sandstone, gray, thin-bedded, medium-grained, micaceous, :

calcareous 0.8

Covered 25-6

Limestone, gray,.medium-hard, medium-textured, highly !

fossiliferous with fragments of pelecypods 1.0

Limestone, dark-gray to black, hard, medium-textured-, ;
!

thin calcite veins, in beds up to kO cm thick ... 1.0;

Sandstone, dark-gray, hard, massive, medium-grained, ;
i
micaceous, slightly calcareous, N. 17° E., 39° NW. . 4.6'

Covered 19.2

Total thickness of Tablazo Formation 186.5

Paja Formation (upper beds only): i

Shale, black, brittle, laminar, silty, micaceous, :i
slightly calcareous 1.0
i
Limestone, dark-gray to black, hard, massive, fine-
i
to medium-textured 1.0

Meters j
Shale, black, laminar, silty, micaceous, slightly calcareous, interbedded with dark-gray, thin-
bedded, micaceous and argillaceous siltstone . . . Covered; appears to be soft black shale ...... Shale, black, brittle, laminar, slightly micaceous, with thin plates of selenite gypsum; contains ellipsoidal calcareous concretions from 15-25 cm in largest dimension; in the middle are lenticular beds of dark-gray, hard, fine- to medium-textured lime-stone up to 1 m thick ....

16. 2

i 60.0!

30.0

Stratigraphic section of the_Tabl«zo Formation along:
the road from about 500 meters went to 1600 meters west of the village of CuestaricaXpIgnchita 109 1-3, J-13), Municipality of Rionegro, Department of Santander. (Measured and described by R, Vargas, September, 1968)
i
i Meters
i
Simit^ Formation (lower beds only): |
Shale, very dark gray, fissile, micaceous 75-0;
Tablazo Formation: j
Limestone, gray, hard, massive, highly fossiliferous
with pelecypods l8.0j
Shale, very dark gray, weathering yellowish to reddish, |
i0 - vlth thin interbeds of light-tan to gray, highly I
porus fine-textured siliceous rock (tripoli?), |
N. 58° w., 1*5°'sw. .... W-o.
Sandstone, light-yellow to pale-brown, hard, massive, i
fine- to medium-grained, glauconitic and micaceous, |
* N. 5° E., 65° SE. ....- - 55-7:

I ' 1 Shale, very dark gray, weathering yellowish-brown, with ,

i !

I local units of fine-textured, highly porous siliceous ;

! i

ii rock (tripoli?) .... ^5-2

Tripoli'?', light-tan, medium-hard, fine-textured, very :

porus, siliceous, in beds 40-80 ca thick, N. ?0° W., . 45° sw. 19-1;
Shale, very dark gray, micaceous .... 33«^|

'; i it f 'i i . .

0

Meters;
Sandstone, light-yellow to light-rose, medium-hard, fine-grained, in beds SCWSO era thick; interbeds of yellow to light-brown, sandy, micaceous shale . ,
Shale, pale-reddish-brown, slightly micaceous . ,

57-9;

i 2.3;
Total thickness of Tablazo Formation 277.6i
Paja Formation (upper beds only):
Shale, very dark gray, sandy, very micaceous 11.0

5-

Ib-

Due to the variation in lithologic composition, the Tablazo does
not display a uniform, characteristic outcrop pattern as do such formations as the Tambor and Paja. Because the sandstones are more iresistant to weathering than the limestones, in areas underlain by this
: formation there appears to be more sandstone in the section than is
i

factually the case.
An age variation in the Tablazo, from Late Aptian-Early Albian in
the south to Albian in the north (fig. 9), has been postulated on the
x-

. basis of fossils found in the underlying Paja and overlying Simiti
s

Formations (Morales et al, 1958, p. 651). Lithologically, the Tablazo is similar to the Mercedes Formation of.the Maracaibo Basin section, which is of Late Aptian-Early Albian age. , Simiti*Formation
The Simiti Formation .was named by geologists of the
i
;International Petroleum Company (Colombia) in 1953 for the excellent

S

outcrops on the south side of Cienaga (marsh) Simiti on the /
west side of the Rio Magdalena in the southern part of the Department of Bolivar (Morales et al, 1958, p. 651). There the formation is 410 meters thick and consists of soft, platy, carbonaceous, gray to black, locally calcareous and concretionary shale. The concretions reach a size of three meters in longest dimension where they are most abundant in the uppermost part of the formation. Thin conglomeratic streaks containing small pebbles, phosphate nodules, fish teeth and sand occur

I locally very near the top. The contacts with the underlying Tablazo

and overlying Salto Formations are conformable and correspond to well-idefined changes in lithology.

X

Because it has very few resistant beds, the Simiti is characteristically expressed as a valley in the topography, and a good exposure of the whole formation was not found in the report area.
Some of the beds near the base and top are described with the Tabltzo _ ._ La Luna Formations.
and /Estimates of the thickness of the Simiti in the Cretaceous belt west of Bucaramanga range from 460-550 meters. The following description of the Simiti in wells of the La Cira-Infantas and Llanito oil fields in quadrangle H-ll east of the report area is given by Taborda (1965, p. 8):
"In the subsurface, the shale is very calcareous and contains
thin beds of argillaceous limestone. The shale is very hard, dark brown to brownish-gray to black, with calcite-filled joints, The
i
interbedded limestones are usually thin, very dense, dark brown to black, and commonly pyritic. Fossils are rare and consist of flattened pelecypod shell fragments,"

s

In Llanito No. 1, the Simiti measures 598 meters and in Infantas
No. 1613 it measures 655 meters.
The age of the Simiti is based on ammonites of early, middle and late Albian age found in the area of the type section. Late Albian
s

forarninifers are also present (Fetters, 1954).

c _

10-

u
15-

Eastward from the Magdalena Valley, the Siraiti Formation becomes progressively sandier and less shaly, particularly in the lower part.
In the Matanza area (H-12, d-2 SE) sandstone units are prominent, and
the formation is estimated to be 600 meters thick or more. Thirty kilometers farther east, in the faulted belt of sedimentary rocks that
, X"

I extend north and south of Mutiscua, thick sandstones are predominant and the unit forms the most prominent ridge of the Cretaceous section. Here the formation is typical of the Maracaibo Basin and the name
**

Aguardiente Formation is used. The upper part of the Siraiti retains its shaly character to a large extent and is correlated with the Capacho Formation of the Colombian part of the Maracaibo Basin.
Salto Formation
This unit was named by the committee of petroleum
i
jcompany geologists who agreed on the standard nomenclature of the 1 . -s

\ stratigraphy of the middle Magdalena Valley (Morales et al, 1958,
p. 652). The type section is in the Quebrada El Salto about 80 kilometers north of the northwest corner of quadrangle H-12. There
! the unit contains dark-gray, dense, hard limestone with numerous interbeds of black, calcareous, thinly laminated, medium-soft shale
with ovoid concretions developed locally.. The formation there is 50 meters thick.

247

5-

In the" area of the present report, the Salto has not been
recognized as a continuous, well-developed, distinct unit and has therefore not been mapped as such. This is true also to the west in quadrangle H-ll where the Salto has not been found in wells of the de w'
Mares Concession (Taborda, 1965, plate II). In the Investigations of the La Luna Formation and adjacent parts of the section, no beds have been found that correspond to the formation as it is developed to the north (E. K. Maiighan, personal coramun.). In any event, the unit is of limited thickness and underlies the Salada Member of the La Luna Formation so that it tends to be part of the distinctive ridge formed
x

by the La Luna between the less resistant Simiti and Urair Formations,
The age of the Salto is Late Albian to Cenouianian, based on
^

ammonites and other fossils (Morales et al, 1953, p. 652).

M
15-

The name of this unit was first used in the
Serrania de Perija in the northwestern part of the state of Zulia,
X

Venezuela, by Garner (1926). Because of its wide regional extent, the is-'
name has been retained in northeastern Colombia (Morales et al, 1958, p. 653), where it is subdivided into the Salada, Pujamana, and Galembo Members. The members were first named in an unpublished report of
0. C. Wheeler for Quebradas Pujamana and Salada and Cerro (hill) del
x

Galembo all of which are near the Rio Sogamoso where it cuts across the La Luna in H-12, b-5 SW. In this type area, the Salada Member contains hard, black, thin-bedded limy shales with slaty appearance in outcrop. A few thin beds of fine-textured black limestone are present and streaks and concretions of pyrite. Limestone concretions of elliptical cross section and 10-15, centimeters in largest dimension are characteristic of this member. The Pujamana Member contains gray to black, calcareous, thin-bedded shale. In the Galembo Member, hard, black, thin-bedded calcareous shale is predominant, with thin inter-beds of argillaceous limestone. Discoidal limestone concretions containing ammonites reach eight meters in maximum dimension, and thin layers of bedded blue-black chert are present. Persistent phosphatic beds near the top of the Galembo contain abundant bone and vertebrae fragments of fish, and rare teeth. The contact of the La Luna with the underlying Simiti Formation is conformable. That with the overlying Umir is one of unconformity and represents a varying amount of erosion of the La Luna Formation prior to deposition of the Umir shales as has been revealed by studies of the phosphate resources of
- the La Luna Formation (E, K, Maughan, personal commun.).

5-

The following tabulation shows the thickening of the members of
the La Luna Formation from the area of the type section and Quebrada La Sorda westward about 55 kilometers to the wells of the La Cira-Infantas and Llanito oil fields:

Thickness of members of the La Luna Formation

Member

section
Rio Sogamoso

Q-ebrada La Sorda

10-

La Cira-Infantas &
Llanito oil fields
(quadrangle H-ll)
Galembo 180 m

Pujamana ?
Salada 50

43 m
156
61

247 m
213-234
107-131

j A section of the La Luna measured at Quebrada La Sorda, about 12
2 'kilometers north-northeast of the type area follows.
>o
.7

2:10

OI~

Quebrada La Sorda (pl:mchita 109 III-D, F-ll NE« F-12 NW) ... Municipality of LebrJja, Department of Santander*
(Measured by J. Abozaglo, A. Castro, F. Pachon, R« Duran,
P. Saenz and ifi. Maughan, November, 196?)
\

& _

15-

Meters

Umir Formation (lever beds only):
Sandstone, dark-gray, hard, calcareous, glauconitic;
contains black phosphatic grains 1.5
. - - -.. -. - -unconformity- ----------

La Luna Formation: _ i
i Galembo Member i
i
Shale (poorly exposed), dark-gray, laminated with i
i
calcareous concretions 3-2

i Shale, dark-gray, hard, with interbeds of gray |
. calcareous chert; contains foraminifers 5.6
Shale, dark-gray, hard, laminated 1.0;
i
Chert, dark-gray, calcareous; at the base is a dark- j
yellowish-brown, calcareous phosphatic bed k cm i
thick, containing phosphorite pellets, foraminifers, |

i and veinlets of calcite .... 0.3!

Shale, dark-gray, hard, calcareous and siliceous,
varying to argillaceous and chert/ limestone, .
in plane regular beds 2-20 cm thick; contains :

| foraminifers, few scattered grains of apatite and :
i few calcareous concretions up to ?5 cm in diameter;
more siliceous in the upper part 20.0

251

I

Meters

Shale, dark-gray, calcareous, phosphatie 2.2
Chert, dark-gray to black, calcareous, slightly ;
phosphatic, foraminiferal, in beds 5-10 cm '
thick, -with interbedded siliceous shale 2.1
Chert, dark-gray to black, calcareous, in beds i
1-10 cm thick, -with thin interbeds of calcareous j
* i
siliceous shale 2.3
Limestone, dark-gray, hard, siliceous, slightly i
phosphatic 0.3
Chert, dark-gray to black, and siliceous shale in
- beds 1-3 cm thick , ... 2.9

Shale, black, slightly calcareous, thin-bedded ... 2.0 ii
Chert, dark-gray, and siliceous shale in beds j
1-5 cm thick 1.5
Phosphorite, yellowish-brown, calcareous, with]
abundant grains of apatite .... 0.2 Chert, dark-gray, calcareous, and calcareous
siliceous shale 0.3

Phosphorite, yellowish-brown, calcareous, with
abundant grains of apatite .... 0.3 Chert, dark-gray, calcareous, and calcareous
siliceous shale in beds 1-10 cm thick 1.1

Meters

Shale, dark-gray, slightly calcareous and
phosphatic 0.2
Phosphorite, yellowish-brown, hard, calcareous,
with abundant phosphatic pellets; 2*4-.7^ percent
PgOr in channel sample 1.5
Limestone, dark-gray, hard, siliceous, phosphatic
near top .... Q.k
Phosphorite, yellowish- to dark-brown, hard,
calcareous, with abundant phosphatic pellets;
contains teeth of fish 0.3
Limestone, light-gray, hard, fine-textured 0.1
Limestone, yellowish- to dark-brown, hard, siliceous, argillaceous in some beds, slightly phosphatic,
in plane regular beds 2-8 cm thick 1.1
Shale, dark-gray, hard, calcareous, thin-bedded,
slightly phosphatic in the upper part 0.6
Phosphorite, yellowish- to dark-brovn, hard, veiy calcareous; contains abundant pellets and cylindrical particles of apatite and fish remains ...... 0.2 Shale, dark-gray, hard, calcareous, slightly
phosphatic- 0.6

r '»

Meters

Phosphorite, yellowish- to dark-brown, hard,
calcareous, abundant phosphatic pellets, fish
remains and foraminifers; contains lens of dark-
gray, siliceous, phosphatic limestone up to 10 cm
thick 0.2
Shale, "dark-gray, calcareous, with thin phosphatic
"bands 0.3
Chert, black, dense, calcareous 0.7
Shale, dark-gray, calcareous, finely banded; scattered
concretions near the top 1.0
MMMMBMM

Total, thickness of Galembo Member ^2.5
Pujamana Member
Covered 12.9
Shale, dark-gray, calcareous, slightly phosphatic,
with small calcareous concretions near the top . . 5«8
Covered .... 1^.3
Shale (poorly exposed), yellowish-brown 8.5
Shale (poorly exposed), yellowish- to dark-gray,
calcareous, laminated .... k.O
Shale, dark-gray, calcareous, thin- to medium-bedded; contains concretions with asphalt impregnation;
10-cm bed of black chert near the top 17*8

.38

<"> T

5-

Meters

Shale, dark-gray, calcareous, with scattered
concretions; black chert beds near the base ... 6.8
Shale, dark-gray, hard, calcareous, with few
lenticular beds of limestone and small calcareous
concretions .... 19.^
Covered 3.2
Chert, black, lenticular-bedded, with thin inter-
beds of dark-gray, hard, calcareous shale . , . 1.5
Limestone, dark-gray, hard, and calcareous shale
in regular plane beds 6.5
Covered 3.2
Shale, dark-gray, hard, calcareous, with calcareous
concretions 13.0
Limestone, dark-gray, hard, fine-textured,
lenticular .... Q.k
Limestone, dark-gray, argillaceous, with black chert
beds at the base and ellipsoidal to spherical
calcareous concretions near the top where the beds
change along strike to purer limestone 1.6
Shale, dark-gray, finely laminated, with lenticular
beds of gray, fine-textured, concretionary
limestone 2.U

255

Meters

Limestone, gray to light-gray, fine-textured,
slightly argillaceous 0.7
Shale, dark-gray to black, calcareous, in thin
beds; calcareous concretions vary from 10 cm
, i
to 2m 2.5
Covered 31-3

Total thickness of the Pujamana Member 155.8
Salada Member
Limestone, dark-gray, hard, argillaceous; con-
tains spherical concretions and few beds of
black chert 11.5
day-stone, light-gray, soft 0.1
Limestone, dark-gray, argillaceous to silty, with
calcareous concretions; beds of black chert near
the top and bottom, and large calcareous con-
cretions at the top .... k.O
Claystone, light-gray, soft 0.6
Limestone, dark-gray, hard, argillaceous, with few
thin layers of soft, light-gray claystone from
3-8 cm thick; several beds of black chert and a
middle zone with ellipsoidal calcareous con-
cretions .... ii.l

5-

Meters ,
Limestone, dark-gray, hard, argillaceous, I

i
scattered concretions, In regular plane beds
5-20 cm thick .... 13.3 ,
Limestone, dark-gray, hard, fine crystalline; i
contains veinlets of calcite and small impreg- i
I i

nations of asphalt .... OA i
Limestone, dark-gray, hard, argillaceous, |
scattered concretions, calcite veinlets, frsg- ;
ments of fossil shells 2.2
Limestone, dark-gray, hard, fine-crystalline,
calcite veinlets 0.5

Limestone, dark- and light-gray banded, argillaceous, j

i
thin-bedded, calcareous concretions 0.6
Limestone, gray, hard, lenticular, calcareous con- ;
i
cretions with ammonites near the top .... 0.*4- ;
Limestone, dark-gray, hard, argillaceous, thin- '
bedded, small to large calcareous concretions
near the top, very few thin beds of black chert . . 6.8

Limestone, dark-gray to black, hard, argillaceous, i
thin-bedded, small pyrlte concretions and fractures .
filled with asphalt 3.0

Meters

Limestone, dark-gray to black, hard, argillaceous, thin-bedded, small pyrite concretions and lenses
of gray, more crystalline limestone from 3-6 B.
long 7.2
Limestone, dark-gray to black, hard, argillaceous, thin-bedded, abundant spherical calcareous con-
cretions with ammonites as the nucleus in some
specimens 2.0
Limestone, dark-gray, hard, argillaceous, fine-
textured, thin-bedded, interbeds of dark-gray
shale lj-,5
Total thickness of Salada Member 6l.2
Simiti Formation (upper beds only):
Shale (partly covered), dark-gray, medium-hard,
laminated 16.3
Covered 9.0
Siltstone, black, hard, thin-bedded, argillaceous in
upper beds '.................. x 3.6
Shale, black, soft, laminated 3.It-
Sandstone, gray, hard, fine-grained, calcareous ... 0.8
Shale, black, soft, laminated .... O. 1*
Sandstone, gray, hard, fine-grained, calcareous;
irregular bands of light- and dark-gray 2.8

2f>0

The unique lithology and extent of the La. Luna Formation make it exceptionally useful in mapping field geology in the Cordillera Oriental. The lithologies involve varying mixtures of clay, carbonate and chert which result in siliceous to calcareous shales, argillaceous to cherty limestones, and porcellanite to pure chert as illustrated by one face of the quartz-clay-carbonate-chert
^

tetrahedron of rock classification (Krumbein and Sloss, 1963, p. 154). The Saiada and Galembo Members are characteristically composed of hard beds 5-20 centimeters thick with very regular and uniform bedding planes, properties that are not characteristic of any other part of the sedimentary rock section. These beds have been highly fractured by the regional deformity so that they slump into a rubble of angular * blocks and fragments that provides a good material for surfacing local roads« The beds of the Saiada and Galembo Members are resistant enough that the La Luna crops out as a sharp ridge. However, because of the limited thickness of individual beds and fractured condition due to regional deformity, they have limited competence and tend to slump and contort more in the manner of thin-bedded rocks. Where folding has occurred, the softer beds of the middle Pujamana Member are contorted even more. Much of the slumping and contortion that is common in the

i La Luna ridge has apparently resulted from removal by erosion of the i' i s
1 adjacent less resistant shales of the Simiti and Umir Formations.

15-

Freshly broken surfaces of the Galembo limestone and shale, have a strong odor of gas, and asphalt occurs in fractures in some places. Lens-shaped bodies of asphaltite are mined locally, one of which is located in Quebrada La Sorda in the Galembo Member This body has apparently developed along a fracture that cuts obliquely across the bedding without involving appreciable movement. The lens has been mined by short underground tunnels extending along its strike from the northeast and southwest sides of the quebrada for distances of 50-60 meters. The lens is about eight meters wide at its known maximum, but its vertical dimensions are not known. Gas odor is very strong in the mine tunnels.
Phosphatic beds in the Galenibo Member are persistent over a wide
area of northeastern Colombia and western Venezuela, and their economic potential is . being investigated. The phosphatic zone in the lower part of the Galembo Member at Quebrada. La Sorda ' can be traced at least 20 kilometers along strike both to the north and south, and it probably extends even farther.

2GO

Eastward from the type area of the La Luna members in thf»
Magdalena Valley, the formation is probably thinner, but the beds are commonly too contorted to measure sections accurately. The formation

; is included in the down-faulted blocks of Cretaceous rocks in the i
5- ; northeast part of quadrangle H-12 and the northwest part of H-13, and i
, a small area of outcrop about three kilometers southeast of Guaca
(H-13, b-7 SW) represents the youngest Cretaceous reck remaining in
1 that area. In the eastern half of H-13, the La Luna is included in
1 ' down-faulted blocks in several places. The formation in this part of IC - the report area and in the western part of Tachira in Venezuela has a two-member character (Trump and Salvador, 1964, p. 6). The lower part,
1 unnamed, consists of gray to black calcareous shales interbedded with ' j gray cryptocrystalline limestone and calcareous chert, with dark gray I to black limestone concretions up to one meter in diameter. The upper
I

:5~ part is ^ bedded black chert in uniform layers 5-20 centimeters thick. Siliceous limestone and phosphatic beds are also present. The
, lower portion is similar in lithology to the Salada Member and the iupper part to the Galembo Member of the middle Magdalena Valley. In
, /
western Venezuela the upper member is named the Tachira Chert (Trump
'"" jand Salvador, 1964, p. 6).

261

Based on ammonites, pelecypods and foraminifers, the La Luna
ranges from the early Turonian in the Salada Member to late Turonian and possibly early Coniacian in the Pujamana Member, and to Late Turonian, Coniacian, and possibly Santonian in the Galembo (Morales et al, 1958, p. 653, 654). A time transgression is indicated in the Pujamana-Galembo boundary. In the eastern part of the area, the La Luna ranges from late Turonian to late Coniacian (Trump and Salvador, 1964, fig. 2).
Umir Formation
According to Taborda (1965, p. 10), the name
Umir was probably first used by L. G. Huntley in 1917 for shale exposed on the west side of Cerro del Umir near the southwest side of the report area (H-12, a-7). He included what is now known as the Lisaraa Formation of Paleocene age (Morales et al, 1958, p. 655). In 1925, T. A. Link redefined the formation, confining it to the Cretaceous part of the section. A definite type section has not been designated.
The lower part of the formation contains dark bluish-gray to
black shales with carbonaceous and micaceous laminations. The upper part is composed of soft, dark-gray to greenish-gray shale with a few interbeds of hard, fine-grained sandstone and thin seams of coal. Thin layers, lenses', and small concretions of brown clay ironstone are Present in varying amounts throughout the formation. In oil wells drilled in the Magdalena Valley (quadrangle H-ll), the Umir is gray, 8°f t, thinly laminated, carbonaceous shale (Taborda, 19"65, p. 10). Coal beds are up to three meters thick in some places, and bands and nodules of siderite are common.

The Umir is unconformable over the La Luna Formation which w^s
eroded to varying degrees before deposition of the Urair sediments. In the western half of quadrangle H-12, conglomeratic basal beds of the
Umir up to five meters thick contain a few coarse sand grains and small *>- quartz pebbles, glauconite, and varying amounts of phosphatic pebbles and nodules derived from phosphatic beds of the La Luna Formation
In the Surata area (H-13, a-2), the basal Umir
is a zone of hard, massive beds up to 20 meters thick that grade gradually from dark-gray phosphatic limestone at the base to brown limonitic sandstones more typical of the Umir at the top.
The Urair grades conformably into the overlying Lisama Formation in
the report area. To the west, however, in some well's drilled in the
y
Magdalena Valley, Taborda (1965, p.. 10) states that the Lisama has been completely eroded and the Umir is unconformably overlain by younger
s Tertiary beds.
Because it is predominantly soft, incompetent shale, the Urair
tends to form broad valleys. Consequently, continuous exposures
showing true dips have not been found where the full section can be measured and described. The best exposures were found in the upper
part of the Umir in road cuts along the new highway from Bucaramanga
to Barrancabermeja in planchita 120-I-B, E-2 NE. These beds are described in the measured section of the overlying Lisama Formation.

. 4)

Although the Umir appears to form a regular and uniform outcrop
area in the western part of quadrangle H-12, structural deformations make the formation appear much thicker than it actually is. This is
x

4 well-illustrated north of where Rio Sogamoso crosses the Umir (H-12, b-5, b-4). Immediately north of the river, the dips at the boundaries with the underlying and overlying formations are much steeper than
those near the middle of the outcrop belt, and farther to the north, remnants of the Lisama overlie the Umir east of the main outcrop belt
of the Lisama.
On the basis of well-established foraminiferal zones and supported
by ammonites, the Umir is assigned an age of Campanian-Maestrichtian and possibly Danian (Morales et al, 1958, p. 656 and'fig. 5). The faunal evidence indicates a mid-neritic origin for the Campanian and
»

lowermost Maestrichtian parts of the Umir and an upper neritic -to continental origin for the beds above.
The Umir Formation correlates faunally, lithologically, and chronologically with the Colon and Mito Juan Formations in the Maracaibo Basin of Colombia and western Venezuela (fig. 9). It correlates also with the Upper and Lower Guadalupe Formations as defined by" Inventario geologists and the lower part of the Guaduas Formation farther to the south in the Cordillera Oriental (D. H. McLaughlin, personal commun.).

2 f i

Cr-etaceous system, Maracaibo section of Colombia Uribante Group
In this report, the Uribante Formation as used by
Notestein et al (1944) has been raised to group status and the Tibif, Mercedes, and Aguardiente Members to formation status. Trump and Salvador (1964, p. 3) have noted that the Uribante Formation named by Sievers (1888) for the Rio Uribante in the state of Tachira, Venezuela 9 was poorly defined originally and has since been used in a rather inconsistent manner. As a formation, the Uribante contains such a variety of lithologies that reference to it has to be In terms of the three subdivisions. These express the different lithologies quite well and are still sufficiently thick and widespread to be referred to as formations.
In field mapping in the eastern part of quadrangle H-13, it has
been found necessary to map the usually poorly exposed Tibu and Mercedes together as one unit and the Aguardiente as another to give a two-fold division of the Uribante Group on the geologic map of quadrangle H-13.

Tibu and Mercedes Formations (Kjtr?.),--These formations v/ero naiaed
for the Rio Tibii and the Mercedes Valley in the Barco Concession area
s

of quadrangle F-13 (Notestein et al, 1944, p. 1177). There the Tibtf
has basal, coarse-grained, pebbly sandstone 5-12 meters thick overlying
- - igneous and metamorphic rocks. Above the sandstone is gray, dense,
fossiliferous limestone with a few interbeds of shale and fine-grained sandstone in the lower half. Above the limestone there is a sharp but
1 conformable boundary with dark-gray shales at the base of the Mercedes
Formation. The Mercedes consists of interbedded limestone, shale and
"'" sandstone. The shale is dark-gray to black, micaceous, and carbona-
ceous, and is most abundant in the lower third of the formation. Sandstones are gray, fine- to medium-grained, commonly glauconitic,
and some are very calcareous. They are most numerous in the upper
half. The limestones are similar to those of the Tibu, and some are sandy. Limestone and shale are predominant at the top of the Mercedes.
A partially exposed section of the Tibu and Mercedes Formations southwest of Pamplona in quadrangle H-13 is given below. The basal sandstone section of the Tibu is not well-exposed, but apparently it is much thicker than in the area .of the type section 130 kilometers to the north. The actual contact with the underlying granite is not exposed in this section, but in exposures elsewhere in this area it is very sharp, with only slightly conglomeratic sandstone making a ;depositional contact. Above the limestone section of the TibtT, the
i

ibasal part of the Mercedes contains sandstone, limestone and shale, but of the Mercedes is shale with a few interbeds of sandstone.

266

Strati graphic section of the Tibu and Mercedes
Formations in Quebrada El Volcari (pl^nchita 110 II-C, D-6 3JQ, Municipality of Pamplona t Department of North Sant~nder. (Measured and described by F. Montero t October, 1968)

5-

Aguardiente Formation (lower beds only) :
Sandstone, yellowish-white, hard, feldspathic, mica-
ceous, with few interbeds of dark-gray shale
10-30 cm thick *............
Mercedes Formation:
Shale, black and dark-gray, brittle, calcareous in some beds, with few interbeds of fine-grained, argillaceous, micaceous, yellowish- to brownish-gray sandstone of low hardness .... Shale, black and dark-gray, brittle, micaceous, with few interbeds of fine-grained, argillaceous, mica-' ceous, yellowish- and grayish-brown, fairly soft, sandstone in beds UO-80 cm thick ...» Covered
Shale, black and dark-gray, brittle, micaceous ... Covered
Sandstone, yellowish- and brownish -gray, fine-grained, argillaceous, micaceous, in beds 2.0-3.5 m thick, with thin interbeds of brittle, micaceous, black and dark-gray shale ...

Meters

60.0

30.5

19 8
58.0
16.1
12.7

12.3

Meters

Shale, dark-gray, brittle to fissile, micaceous,
with few interbeds of fine-grained, argillaceous,
yellowish-gray sandstone 25-60 cza thick, " <
N. 5° W., 68° SW. 39.0
Covered 56.0
Shale, black and brownish-gray, brittle, micaceous,,
with few interbeds of fine-grained, argillaceous,
yellowish-gray sandstone 31.0
Sandstone, brownish-gray, fine-grained, argillaceous >
slightly micaceous, fairly soft 6.0
Limestone, dark-gray to black, hard, crystalline, fossiliferous, with veinlets of calcite; thin Inter-
beds of dark-gray shale and of argillaceous gray
sandstone 15-30 cm thick, N. 1° W., 53° NE. ... 9-7
Sandstone, brownish-gray, hard, fine-grained,
argillaceous, micaceous, with thin interbeds of
micaceous black shale 12.6
Limestone, dark-gray to black, very fine crystalline, slightly argillaceous, with 20-cm bed of black
shale in the middle 7.8
Shale, gray, laminar, micaceous 8.7

2fi O

Meters

Sandstone, yellowish- and brownish-gray, hard, fine-grained, argillaceous, in beds 0.9-2.2 m thick,
N. 14° W., vertical 19.5
Total thickness of Mercedes Formation 339-7
Tibu Formation:
Limestone, dark-gray, hard, fine-crystalline, fossili-
ferous, N. 1° W., vertical 2U.O
Sandstone, light-yellowish-gray, hard, fine-grained,
argillaceous, micaceous, slightly calcareous ...
Limestone, dark-gray, hard, fine-crystalline, fossili-
ferous, N. 1^ W., vertical ....
Covered .... Sandstone, light-yellowish-brown, hard, fine-grained, argillaceous, micaceous, N. 10° W., vertical ....
Covered - - - - -

1-7

50.6
28.7

66.7
Sandstone, light-yellowish-white, very hard, fine- to medium-grained, micaceous, in beds 1-3 m thick,
N. 10° W., vertical ....
Covered - - - -

. . . . 26.0
. . . . 15.0
Total thickness of Tibu Formation 222.1
. . . . 30.0?

Granite, white, medium- to coarse-grained,
weathered ...---

Covered

The Tibu and Mercedes rarely produce a prominent outcrop. The contact between them, and the contact of the Tibu-with underlying metaraorphic and igneous rocks, are obscured by colluviura and are seldom definable on aerial photographs. In contrast, the boundary '-between the Mercedes shales and the massive sandstone section of the ;Aguardiente is usually well-defined. As a result of these circum-stances, it has not been found possible or practical to map the Tibu
and Mercedes as separate units. They are mapped as one unit between
the underlying pre-Cretaceous rocks and the overlying Aguardiente.

L

In the measured section, the 222 meters thickness of the Tibu' Formation compares with 107-166 meters in the type locality, and the 340 meters
of the Mercedes compares with 149-201 meters in the type locality
^

(Notestein et al, 1944, p. 1177). The larger figures in the Pamplona
area are more typical for these formations farther to the south in quadrangle H-13.

270

The thin basal sandstone section of the Tibu Formation is
equivalent to the Rio Negro Formation of western Venezuela where it is much thicker and where fossils ranging in age from Hauterivian to Aptian have been collected from thin sandy limestones in the state of
/ "^
- Tachira (Trump and Salvador,. 1964, p. 5). With regard to its position at the base of the Cretaceous section, as well as lithologically, it is correlative with the Tambor Formation of the Magdalena Valley section, although it may be somewhat younger than the Tambor (fig. 9). In similar manner, the limestone section of the TibtTmay be correlated
- '" with the Rosa Blanca and the Mercedes with the Paja and Tablazo formations in terms of lithology and stratigraphic sequence if not in age. Except for the basal sandstone, the Tibu and Mercedes correspond /
to the Apon Formation of western Venezuela where the distinction between the two units disappears toward the northeast (Trump and
- " Salvador, 19&, p. 4).
Unpublished reports of early studies of molluscs and echinoids
from the Tibu Formation south of Sardinata (quadrangle G-13) indicate
,/
a late Aptian to early Albian age (Notestein et al, 1944, p, 1178).
In western Venezuela, more extensive faunal studies of the Apon Formation, including ammonites, indicate a late Aptian to middle Albian \>f
age according to Sutton (1946, p. 1643) or Aptian to early Albian according to Trump and Salvador (1964, p. 5). The Tibu and Mercedes
roay be assigned a similar age range except for the basal sandstone of
S

; the Tibu which probably extends the range of that formation into the ;Barremian.

271

Oil is produced from the Tibu and Mercedes Formations in the Tibu
and Socuavo fields of the Barco Concession in places where fracturing provides permeability (Notestein et al, 1944, p. 1177).

Aguardiente Formation (Kia).--This formation is named for Filo del Aguardiente (Aguardiente Ridge) in the north central part of quadrangle G-13 (Notestein et al, 1944, p. 1177). There is consists of more than 200 meters of extremely hard and calcareous, gray or light-green, coarse-grained, cross-bedded glauconitic sandstone. Black, micaceous, carbonaceous shale is present in thin beds and laminae,, and there are a few thin limestone beds in the lower part. It is considered conformable with both the underlying Mercedes and the overlying Capacho Formations in Colombia, but a disconformity is postulated with the underlying Apon Formation in Venezuela (Sutton, 1946, p. 1646).
A section of the Aguardiente exposed along the Bucaramanga-
Cucuta highway immediately east of Pamplona is described below. The formation is well-exposed, but dips to the west indicate that the beds are locally overturned. This section is much thicker (440 ra) than that of the type locality (200 m) 75 kilometers to the north, the sand-stones are not calcareous or glauconitic, and no limestone beds are present. The character and thickness of the Aguardiente in the Bamplona area continues southward in quadrangle H-13. A section measured in Quebrada Lisga*ura south of San Andres (planchita 121-I1I-D, ""3, H-4) is 388 meters thick, has no limestone beds, and contains Slauconite only near the base.

27

- Stratlgraphic se ction of the As^iardiente
along the highway east of Pamplona (planchita 110 II-C, C-9 and_C-10) , Municipality of Pamplona, Department of North Santander.
(Measured and described by F. Montero, October, 1968)

Meters

Capacho Formation (lower beds only): !
Shale, black, brittle to fissile, micaceous, with i
interbeds of fine-grained, micaceous, glauconitic, I
i
brownish- to yellowish-gray sandstone that is j
partly conglomeratic with pebbles of quartz; two j
15-cm beds of hard conglomerate 6.0
Aguardiente Formation: ;
Sandstone, yellowish-white to light-yellowish-gray,
hard, fine- to medium-grained, feldspathic, (mica-
'. ceous, glauconitic, in beds 1.2-2.6 m thick, N. 21° E.,
! 1*8° HW. 22.0

Sandstone, light-yellowish-gray, hard, medium-grained j
to coarse-grained at the base, conglomeratic, mica- i
ceous, with lenses of carbonaceous, micaceous, !
brittle black shale up to 70 cm thick that are more ;
. . . . . . 150.0

Sandstone, light-yellowish-gray, hard, medium-grained,
conglomeratic, micaceous, with numerous lenses of i
!

carbonaceous, micaceous, brittle black shale, j
N. 26° E., 51° NW. 160.0
Shale, black, brittle to fissile, micaceous,

numerous at the top, N. 27° E., 53° KW,

N. 26° E., 37° NW. 8.5
273

Meters

Sandstone, yellowish-white to yellowish-gray, hard, micaceous, feldspathic, with numerous interbeds
of black shale 0.3-1.6 m thick, N* 15° E.,
76° m.
Sandstone, yellowish-vhite to yellowish-gray, hard, micaceous, feldspathic, with few interbeds of -
black shale 10-30 cm thick .... Total thickness of Aguardiente Formation
Mercedes Formation (upper beds only):
Shale, black and dark-gray, brittle to fissile, calcareous in part, with interbeds of fine-
grained, micaceous, argillaceous, yellowish-
and brownish-gray, fairly soft, sandstone ...

20.0

60.0

30.5

274

The thick and resistant nature of the massive sandstone beds of
the Aguardiente Formation makes it an easily distinguishable map unit both in the field and on aerial photographs. Structural complexities
do not usually obliterate this character as is often the case with the
5- thinner or less competent units.
Fossil molluscs, Exogyra aff. boussingaulti, have been reported
from the Aguardiente near Gramalote in quadrangle G-13 (Notestein et
v/

1 al, 1944, p. 1178). In the more calcareous phase of the formation,
1 the foraminifer Orbitolina lenticularis (equivalent of 0. concava
": texana) is characteristic of the Aguardiente of northern Tachira
*/
(Trump and Salvador, 1964, p. 5), and on this basis the formation is assigned to the early and middle Albian when it was deposited under

! very shallow marine conditions. i
; The Aguardiente is recognized .also in western Venezuela where it
:5~ is the middle member of the Cogollo Group (Sutton, 1946, p. 1630). Westward from the Colombian-Venezuelan border area, sandstone of the Aguardiente very gradually phases into shales, and in the Middle
Magdalena Valley the lower part of the Simiti is the lateral equivalent
of the Aguardiente.
The Aguardiente yields oil in the Tibu, Socuavo, and Petrolea
, ^~
> North Dome fields of the Barco Concession (Notestein et al, 1944,
, P. 1177).

r?
/

Capacho Formation
The narae for this formation dates back to
1888 when Wilheln Sievers first used it for limestone exposures near
the village of Capacho Viejo in western Tachira, Venezuela. The
village has since been re-named Libertad. The Capacho is the upper
s- formation of the Cogollo Group in Venezuela which includes the Apon
^

at the base and the Aguardiente in the middle (Sutton, 1946, p. 1630).
A fourth formation is now recognized in western Venezuela, the Maraca,
^

1 between the Aguardiente and the Capacho (Trump and Salvador, 1964,
p, 5). It is only a few meters thick in some places and has not been
lj - found in the area of this report.
In their report on the Barco Concession of northeastern Colombia, Notestein et al (1944) apparently thought that their, Cogollo Formation was the equivalent of the undivided Cogollo in the type locality. It
has since been established that the Cogollo Formation of the Barco
s ~ Concession is equivalent to only the Capacho Formation of the type
*s

locality of the Cogollo Group (Trump and Salvador, 1964, p. 4).
In the area of the Barco Concession, two divisions and sometimes
three are recognizable in the Capacho according to Notestein et al
(1944, p. 1179):
Guayacan Member - Limestone, brownish-gray, abundantly
, fossiliferous, in massive beds with interbedded, non-calcareous, partly silty and micaceous, dark-gray to black shale.
Middle Member - shale, dark-gray to black, non-calcareous, with
few beds of siltstone and argillaceous, fossiliferous gray
limestone.

Lower Member - shale, black, thin-bedded, very calcareous,
organic, bituminous, foraminiferal, and forarainiferal dark
gray limestone.
: The limestones of the Guayacan Member are not widespread, and the
b " uppermost part of the Capacho is usually shale. Thickness of the formation ranges from 175-435 meters, increasing from north to south,
x

Along the highway and Rio Pamplonita east of Pamplona, in
3 quadrangle H-13, the Capacho Formation is well exposed, and a section measured there is described below. Beds in the lower part of the
'°~ section are overturned, as are those of the underlying Aguardiente.
A regional strike fault apparently passes through the Capacho in this area, so that the accuracy of the measured thickness of 475 meters is open to question. Limestone is most abundant near the middle of the section.
The base and top of the Capacho are conformable and usually
r

well-defined with the underlying Aguardiente and overlying La Luna Formations, and the unit tends to form a belt of lower topography
between the two more resistant formations,
Late Albian fossils have been found in the sandy limestone of the underlying Maraca Formation in western Venezuela, and rare ammonites

T i / " in the Guayacan Member of the Capacho (Trump and Salvador, 1964,

I p. 5, 6), Based on this evidence, the age of the Capacho probably
* i
, ranges from Cenomanian to late Turonian. According to these same authors (ibid., p. 4), the Capacho grades laterally northward into the
' lower part of the L0. Luna Formation in the foothills of the central
! part of the Serrania dc Perl jo"!

277

- Stratigraphic section of the Capacho Formation
<M along the highway east of Pamplona (planchita 110 II-C,
C-10). Municipality of Pamplona« Department of North Santarrder.. (Measured and described by F. Montero, October, 1968)

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La Lima Formation (lover beds only):
Chert, black to gray, hard, brittle, calcareous, in
plane uniform beds It-20 cm thick, with numerous
beds of micaceous, laminar black shale up to 2.6 m thick near the base .... Capacho Formation:
Shale, black and dark-gray, brittle to fissile, mica-ceous, with few interbeds of hard, crystalline, fossiliferous, bluish- to dark-gray limestone
1.1-1.It m thick, N. 5° E., vertical .... Limestone, bluish- and dark-gray, hard, crystalline, fossiliferous, in beds 10-80 cm thick, with thin interbeds of brittle to fissile, black and dark-
gray shale, N. 7° E»> vertical .... Shale, black and dark-gray, brittle to fissile, mica-

ceous ....

Limestone, bluish- and dark-gray, hard, crystalline, fossiliferous, with thin interbeds of black shale . . Shale, black and dark-gray, brittle and fissile, micaceous ..----------

Meters !

178.0:

6.0

26.0

U.O

30.0

270

5-

Meters

Limestone, bluish- and dark-gray, hard, crystalline, fossiliferous, in beds 10-60 cm thick, with thin
interbeds of brittle to fissile, dark-gray to black
shale 31-5

Shale, black and dark-gray, brittle to fissile, mica-
ceous id.2
Limestone, bluish- and dark-gray, hard, crystalline, fossiliferous, in beds 10-60 cm thick/ with thin
interbeds of brittle to fissile, black and dark-
gray shale, N. 10° E., h$° NW. 58.0
Shale, black, brittle to fissile, micaceous, with
scattered interbeds of hard, crystalline, fossili- ;

i ferous, bluish- to dark-gray limestone in beds !

10-30 cm thick 117.0

i Limestone, bluish-gray, very hard, massive, nodular i i
i at the base, highly fossiliferous, with veinlets

of calcite perpendicular to the bedding, N. 9° E.,
5° NW. 11.7

Sandstone, yellowish-gray, friable, very fine grained,
argillaceous 0.9
Shale, black,' brittle to fissile, micaceous,

i N. 10° K., 36° NH. ....

279

Meters

5-

Sandstone, brownish-gray, hard, fine- to i&edium-grained, argillaceous, micaceous, with carbon fragments and grains of pyrite .... Shale, black, brittle to fissile, micaceous, with interbeds of fine-grained, highly glauconitic, micaceous, brownish- to yellowish-gray sandstone, partly conglomeratic with pebbles of quartz; two 15-cm beds of hard conglomerate .... Total thickness of Capacho Formation
Aguardiente Formation (upper beds only):
Sandstone, yellowish-white ,to light-yellowish-gray, hard, fine- to medium-grained, feldspathic, mica-ceous, glauconitic, in beds 1.2-2.6 m thick,
N. 21° E., U8° HW. ' ....

k.O i

6.0

22.0

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'5-

The Capacho correlates with the upper part of the Simiti
Formation of the middle Magdalena Valley section and is similar to the Siraiti in the predominance of dark gray shales.
Oil is produced from all three members of the Capacho on the Petrolea anticline of the Barco Concession and is controlled by fracturing (Notestein et al, 1944, p. 1181 and fig. 5). The beds contain much organic material, and the oil could well have originated within the formation. ~
La Luna Formation
The formation is named for Quebrada La Luna

x x

in the eastern foothills of Serrania de Perija, about 16 kilometers northwest of La Villa del Rosario, Zulia, Venezuela (Notestein et al,

<s ' 1944, p. 1182). There the formation contains hard, dark-gray to black,
carbonaceous and bituminous limestone in plane, uniform beds up to 20 centimeters thick with interbedded black calcareous shale (Sutton,
x

1946, p. 1648). Hard, fine-grained, dark-gray calcareous sandstone and seams and nodules of chert are present in subordinate amounts. Discoidal concretions of hard, black limestone from a few centimeters to more than one meter in diameter are characteristic of the formation. Megafossils, including ammonites, are common in these concretions, surfaces of the limestone generally have a gassy odor.

Southward from the type locality, and in the eastern part of the present report area, the La Luna assumes a two-member character with chert or porcelanite as the main constituent of the upper part and limestone and calcareous shale with concretions in the lower part. A
!

iwell-exposed section that clearly shows these members was measured north of the report area near Lourdes in quadrangle G-13 by J. Abozaglo
(see belov?) . The main phosphorite beds are near the middle
of the upper member which is 63 meters thick. The lower member is 37 meters thick. The terra porcelanite is an oversimplified description of the beds which contain also true chert and siliceous shale.
Another section of the La Luna exposed along the highway southeast
of Pamplona in quadrangle H-13 follows. This section contains
black chert with interbedded black shale near the base and top, but
,no section of limestone and calcareous shale with concretions is present. Thin beds of phosphatic black sandstone are present near the base of the formation.

20 2

Stratigraphic section of the La Luna Formation
..in Quebrada &1 Portigo (planchita 87 Ilf-B. H~2 NW). 'Municipality or Lourdes, Department of North Santand.er*. (Measured and described by J. Abozaglo, 1968)

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Colon Formation (lower beds only):
Sandstone, gray, thick-bedded, hard, fine-grained, calcareous; at the base are abundant phosphatic black grains and nodules up to 25 nan in diameter
and a few grains of glauconite; weathered surface contains small cavities .... Phosphorite, dark-brown, hard, granular, calcareous, in uniform bed with abundant phosphatic black

grains and nodules up to 15 mm in diameter;i weathers with rough, earthy texture ...... Shale, gray to dark-brown, soft, finely laminated, calcareous, with few phosphatic grains; basal
sandy calcareous phosphorite in irregular bed up
to k cm thick contains lenses of fine-crystal, line gray limestone up to 8 cm thick ......
- - - - - - - - - - - unconformity- --------
La Luna Formation (strike N. 10° E., dip 26° NW,): Porcelanite Member:
Porcelanlte, dark-gray, hard, calcareous, in beds 5-8 cm thick, with velnlets of calcite . .

Meters

3-00

0.20

0.35

3-00

* ! l\

203

5-

Meters.

i i
Limestone, gray, hard, fine-crystalline, !

i

lenticular .... o .... 0*35 j
Porcelanite, dark-gray, hard, calcareous, in beds
5-8 cm thick with interbeds of yellowish-brown
claystone up to 3 cm thick; 5-cabed of hard,
dark-gray limestone at the base contains phos-
]
phatic grains and fish scales .... 1.30 j
j
Shale, dark-gray, hard, calcareous, with phosphatic i
i i
grains near the base and top .... 0.15 i
i
Limestone, gray, hard, argillaceous, with scattered !
black phosphatic grains and nodules up to 2 nm in :
!

diameter, and weathered yellowish-brown claystone j
i
at the base .... 0.25 i
Porcelanite, dark-gray, hard, calcareous, with vein- j

| lets of calcite, in irregular to lenticular thin
beds; hard, lenticular, dark-gray, limestone near
the middle, up to 30 cm thick, contains scattered
foraminifers 7-00
Limestone, gray, hard, fine-crystalline, lenticular
grades laterally to porcelanite containing poorly
preserved foraminifers 0.50

2 0 4

Meters,
i
Porcelanite, dark-gray, hard, calcareous, In j
1

irregular "beds 7-10 en thick with calcite j
veinlets and poorly preserved foraminifers . . . 2.30
Limestone, gray, hard, fine-crystalline, grading |
' i
laterally to dark-gray porcelanite -with poorly j
i

preserved foraminifers ....*... 0.30;i i
Porcelanite, dark-gray, hard, calcareous, in irregular j
i i
to lenticular "beds with section of hard, lenticular I
dark-gray limestone above the middle 0.85
Limestone, gray, hard, fine-crystalline, lenticular . . 0.55
Porcelanite, dark-gray, hard, calcareous, in irregular ;
thin beds ....;.. 2.00; i
Limestone, gray, hard, fine-crystalline, lenticular . 0.20,
Porcelanite, dark-gray, hard, calcareous, in irregular !
i
thin to thick "beds 0.30
Limestone, gray, hard, fine-crystalline, lenticular . . 0.20
Porcelanite, dark-gray, hard, calcareous, in irregular ,
_ thin beds that change laterally to dark-gray limestone; contains detrital quartz grains and abundant siliceous-calcareous black lenses distributed at random 2.60

205

5-

10-

15-

Heters

Limestone, gray, hard, fine-crystalline, in thin
beds containing grains of quartz and apatite;
soft, dark-brownish-gray calcareous shale at the j I

base contains abundant pnosphatic grains . . . . . 0.25 ! i i
Phosphorite, dark-brown to black, hard, granular,
calcareous, in a uniform bed with black phosphatic
grains; 19.08 percent PpOc in channel sample ... O.U-5 Limestone, gray, hard, fine-crystalline, with
phosphatic black grains and small nodules; 1.73
percent P 0K in channel sasmle «« *» 0*20 Phosphorite, dark-brown to black, hard, granular, calcareous, in a uniform thick bed with smooth,
ovoid, phosphatic black grains; siliceous-calcareous
lenses near the base are up to 6 cm thick and con-
tain phosphatic grains; weathers dark-brown with
rough earthy texture, N.-S., 35° W.; 19»23 percent
?20c in channel sample .... 1.70 Porcelanite, dark-gray, hard, calcareous, in irregular
thin beds with siliceous-calcareous black lenses and lenticular beds of fine-crystalline gray limestone
up to 50 cm thick above the base and near the top . .1.30

Meters

15-

Limestone, gray, hard, fine-crystalline, with
veinlets of calcite and phosphatic grains; siliceous-calcareous black lenses up to 10 cm
thick near the middle; 10.27 percent P20«- in
channel sample .... 0.50 Porcelanite, dark-gray, hard, calcareous, in irregular
thin beds with phosphatic grains near the top ... 0.35 Limestone, gray, hard, medium-crystal line, with
calcite veinlets, in irregular thin beds with
few phosphatic grains near the top; gray,
calcareous concretions near the base are up to
30 cm in diameter 0.55
Porcelanite, dark-gray, hard, calcareous, in
irregular thin beds .... 1.00 Limestone, gray, hard, fine-crystal line,

lenticular .... O.UO i i
Porcelanite, dark-gray, hard, calcareous, in irregular
i
thin beds .... 0.?5
Limestone, gray, hard, fine-crystalline, lenticular, siliceous near the top .... 0.^5 Porcelanite, dark-gray, hard, calcareous, in irregular
to lenticular thin beds 2.60

207

5-

Meters

Porcelanite, dark-gray, hard, calcareous, with
8-cm beds of dark-brown limestone at the top
and base containing abundant phosphatic grains
and bone fragments .... 1.00 Porcelanite, dark-gray, hard, calcareous, in
irregular to lenticular thin beds, with lenticular
beds of hard, fine-crystalline, gray limestone
20-UO cm thick at the middle and top ...... 2.80 Porcelanite, dark-gray, hard, calcareous, with inter-
beds 1-15 cm thick of soft, plastic, yellowish-
- brown to light-greenish-gray claystone and one
20-cm bed of hard, fine-crystal line gray limestone
in the upper half .... 2.^5
Limestone, gray to black, hard, fine-crystalline,
siliceous, in thin to thick beds with interbedded
soft, plastic, light-greenish-gray claystone up
to *K) cm thick and few beds of hard calcareous
dark-gray porcelanite 2.80
Porcelanite, dark-gray, hard, calcareous, in thin beds with veinlets of calcite; calcareous concretions
near the middle are up to 35 cm in diameter; fine-crystalline, lenticular, gray limestone up to 50 cm
thick near base 5*50

280

Meters

i i Limestone, gray, hard, somewhat lenticular, vith i
few phosphatic grains 0.20
Procelanite, dark-gray, hard, calcareous, in i

irregular to lenticular beds .... 2.00 i
Limestone, gray, hard, fine-crystalline, lenticular 0.^5 I

Porcelanite, dark-gray, hard, calcareous, in -' |
!

irregular to lenticular thin beds; calcareous j
concretions up to 25 cm in diameter in a zone i
70 cm above the base 3.60
Porcelanite, dark-gray, hard, calcareous, with thin
zones of soft, plastic, yellowish-brown clay stone
and gray, calcareous concretions up to 37 cm in' !

I
I

diameter at the base and top .... 3»55

i Porcelanite, dark-gray, hard, -calcareous, in j

i
irregular beds with zones of gray calcareous con- j
cretions up to 25 cm in diameter near the top and
up to 1.1 m in diameter near the base IK00
Covered 2.00
Total thickness of Porcelanite Member 62.70

20!)

5-

10-

Meters s

Limestone Member: ' |
ii
Limestone, dark-gray, hard, in alternating thin and j

thick beds, with abundant scattered gray calcareous ;i
concretions up to 20 cm in diameter 5-50;

i Limestone, gray, hard, fine-crystalline, in alter- j
|
nating, irregular to lenticular, thin and thick j
beds with laminar-bedded, dark-gray to light- j

i
brown calcareous shale; abundant scattered gray !
i
calcareous concretions up to 80 cm in diameter;
2-cn bed of -weathered, soft, yellowish-brown
claystone 8.1 m above the base .... 19«60 Shale, dark-gray, hard, calcareous, in laminar beds
with lenticular, fine-crystalline limestone up to
5 cm thick in the upper part and a zone of gray
calcareous concretions up to ^5 cm in diameter
60 cm above the base .... 1.80 Limestone, gray, hard, fine-crystalline, in single
thick bed with soft, yellowish-gray weathered
claystone at base « .... 0.^5

290

Meters

Shale, dark-gray, hard, calcareous, in lamirar
beds with hard lenticular beds of fine-crystalline
gray limestone up to 50 cm thick near the base and
middle and gray calcareous concretions up to 30 cm
in diameter near the top .... 2.60 Limestone, gray, hard, fine-crystalline, in irregular
to lenticular beds with abundant scattered gray
calcareous concretions up to 50 cm in diameter . Ij-.OO Covered .... 1*30 Porcelanite, dark-gray, hard, calcareous, with inter-
beds of soft, yellowish-brown weathered claystone . 0.95 Limestone, gray, hard, fine-crystalline, in irregular
thin beds with interbeds of soft, yellowish-brown weathered claystone .... 0.75 Limestone, gray, hard, in irregular to lenticular
beds with scattered phosphatic grains and
nodules .... 0.^4-5
Total thickness of Limestone Member 37*^0
Total thickness of La Luna Formation 100.10
Capacho Formation (upper beds only): | Siltstone, dark-gray, soft, fissile, calcareous, with
small crystals of gypsum on bedding planes; 15-cm
bed of hard, argillaceous, gray limestone near the
middle contains fev scattered phosphatic grains ... U.15

291

5-

Liuiestone, gray, hard, fine- to coarse-textured,
in massive beds with abundant fossil pelecypods . Silt stone, dark-gray, soft, slightly calcareous . .

Meters !

3-50

10-

29

Strati graphic section of the La Luna Formation along
the Pain pi ona-Cftit^ga highway (planchita llO^l'l^Q , D-10, and D-ll), Municipality of Pamplona, Department of North Santander, (Measured and described by F. Montero, October * 1968)

Meters

Colo'n Formation (lover beds only):
Shale, dark-gray, brittle to fissile, with thin
beds of yellowish-brown ironstone up to 10 cm
thick; interbeds of hard, very fine grained, argillaceous, partly glauconitic, dark-gray
sandstone in beds 0.9-1.5 m thick ....
. . . . -unconformity- ---------
La Luna Formation:
Chert, black, dark-gray, and white, highly fractured and folded, with interbeds of black shale, N. 23° W., 26° ME. .... Covered .... Chert, black, dark-gray and gray, hard, brittle, calcareous, in uniform plane beds from U-20 cm thick; numerous interbeds of micaceous, siliceous, laminar black shale up to 2.6 m thick near the base, and a few beds 5-10 cm thick of black pkosphatic sandstone,
H. 26° W., U6° ME.

39.0
26.6

Total thickness of La Luna Formation

,178.0
2^3.0

293

Meters

Capacho Formation (upper beds only):
Shale, black and dark-gray, brittle to fissile, micaceous, with fev interbeds of hard, crystalline, fossiliferous, bluish- to dark-gray limestone
l.l-l.U m thick, N. 5° E., vertical ......

291

The La Luna shows large variations in thickness. From 200 meters
/
at the type section, it thins southward to 43-56 meters in the Tibu area of the Barco Concession of quadrangle F-13 (Notestein et al f
' /
1944, p. 1182). Southward from Tibu, it thickens no 100 meters near Lourdes in quadrangle G-13 and to 243 meters at Pamplona
A study of the La Luna Formation by E. K. Maughan and
others (written cornmun.) made in connection with the formation's
»>

phosphorite resources, has indicated probable erosional periods between the members and at the top of the formation which apparently account for the large variations in thickness, In places where the section is thickest, it forms a characteristically sharp topographic ridge between the less resistant, shaly Capacho and Colon and Mito Juan Formations. But where the La Luna Formation is thin, the ridge is seldom well defined. '
Abundant fossils in the La Luna include numerous ammonites,
pelecypods, pelagic foraminifers and fish remains. At the type locality, early and late Turonian and early Coniacian fossils have been identified (Button, 1946, p. 1650).

20 f

The lower, concretionary limestone-shale member correlatss with
the Salada and Pujamana Members of the La Luna in the middle Msgdalena Valley, whereas the upper chert member correlates with the Galembo Member. In western Venezuela, the upper chert member is called the
x '
Tachira Chert (Trump and Salvador, 1964, p. 6), but the lower, concretionary limestone-shale section is unnamed,
Oil is produced from shallow wells that penetrate fractured beds
of the La Luna near the crest of the Petrolea North Dome of the Barco
*"

Concession (Notestein et al, 1944, p. 1182). The bituminous nature and abundant organic remains in the La Luna are considered by Hedberg
X
(1931) to indicate sources of petroleum.

2<J o

,_______________ _________ _ . __ Co Ton "and-Mi to Juan Formations --
Because of the similarities in
lithology and weathering characteristics, the boundary between these formations cannot be mapped with certainty, and they have therefore
* been mapped as a single unit. The type section of the Colon is in the 5 ~., District of Ayacucho north of the town of Colon in western Tachira,
6 Venezuela. There the formation consists almost entirely of dark-gray to black, hard, locally pyritic, conchoidal- to irregular-fracturing
* x
shale (Sutton, 1946, p. 1651), A few very thin beds of gray, hard,
dense limestone are present in the upper part in some places.
Foraminifers are abundant. In the Barco Concession area of north-

.!

eastern Colombia (quadrangle F-13), the formation consists of gray to dark-gray, slightly calcareous, fissile, moderately foraminiferal shale with thin nodules and lenses of brown clay-ironstone (Notestein et al,
.4 ^

1944, p, 1183). At the base, overlying the La Luna, is a zone of
several meters of sandy glauconite, re-worked foraminifers, abundant
fish remains and nodules and pellets of phosphorite.
The Mito Juan Formation is named for Quebrada Mito Juan on the
east flank of the Petrolea North Dome in the Barco Concession,
quadrangle F-13, where it consists of greenish-gray shales, with silty
to sandy shales increasing upward to siltstone and very fine-grained
s

sandstone near the top (Notestein et al, 1944, p. 1184). Thin lenses
and small nodular masses of brown clay-ironstone are common, A few

thin beds of glauconitic, sandy, fossiliferous, ferruginous limestone (
j °ccur in the upper part of the formation.

2 ill

The Catatumbo Formation, which overlies the Mito Juan Formation in
the Rio Catatumbo area of the northern part of the Barco Concession
' (quadrangle F-13), is composed predominantly of dark-gray shales and
4 claystones that are commonly somewhat carbonaceous and contain small
w'
5 ~ nodules and thin lenses of brown clay-ironstone (Kotestein et al, 1944, 6 'p. 1186). Interbedded and interlarainated dark-gray, argillaceous, very
7 fine- to fine-grained sandstones that are present in the type locality
3 are less common farther south, and the formation cannot be mapped as a
9 unit distinct from the Colon-Mito Juan section. In western Tachira,
:C the Catatumbo is mappable only locally and is therefore regarded as a
s

member of the Mito Juan Formation (Trump and Salvador, 1964, p. 7). In the area of this report, the Cataturabo is not a distinct unit betveen
the underlying Mito Juan and the overlying Barco Formation and is therefore regarded as a member of the former (fig. 9).
15-'

> Although structural discordance has not been reported between the Colon and La Luna Formations, a break in sedimentation occurred during all or part of the Santonian stage according to Sutton (1946, p. 1652)
;or an erosional interval occurred according to Maughan et al (written commun.)* The Colon-Mito Juan boundary is conformable and gradational lithologically but is more sharply defined in foraminiferal izones. According to Notestein et al (1944, p. 1189), the Catatumbo is ;apparently conformable with the underlying Mito Juan and the overlying Barco Formations, but Sutton (1946, p, 1656) expresses doubt about this because of thinning of the Catatumbo and Barco Formations over anticlines and thickening in synciines.

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The Colon Formation at the type location is 90O meters thick. On
the Barco Concession it varies from 215 to 460 meters (Notestein et al, 19^4, p. 1183). The Mito Juan is 275 to 420 meters thick in the type locality, and the Catatumbo from 106 to 208 meters thick. In the area
of this report, no section has been found well enough exposed for measurement and description, but estimates of thickness of the Colon and Mito Juan together, based on average dips and width of outcrop belt, range from 325 to 600 meters.
/
According to Trump and Salvador (1964, p, 7), the Colon-Mito Juan

_ s

sequence contains the most prolific microfauna known in Tachira. It ranges from Santonian to Maestrichtian. The carbonaceous beds of the Catatumbo Member contain Paleccene pollen which extends the age range of the sequence above the Cretaceous-Tertiary boundary.
In the Barco Concession area of northeastern Colombia, Notestein
/
et al (1944, p. 1184) report a Carapanian-Maestrichtian age for the Colon Formation based on microfossil studies by Cushman and Hedberg
y
(1941). Ammonites and pelecypods have also been reported from this area. The Mito Juan is assigned to the Maestrichtian, likewise on the basis of microfossils, ammonites, and pelecypods. On the basis of pelecypods and the upward extension of a foraminiferal zone from the
; Mito Juan into the Catatumbo, the age of the latter is at least Maestrichtian and possibly younger. The upper part of the Catatumbo
is of brackish-water to non-marine origin, and fossils are lacking. Pollen studies are not reported for this area.

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The Colon-Mito Juan sequence correlates well with the Umir Formation of the middle Magdalena Valley section (fig. 9), and the uppermost part probably is equivalent to' the lowermost part of the Lisama Formation. The correlation with the Urair applies to the lithology and topographic expression as well as to the age.
In the Rio de Oro anticline in the northern part of the Barco Concession, a thin sandstone near the top of the Mito Juan produces
/
oil (Notestein et al, 1944, p. 1185). The main production is from
the sandstones of the Catatumbo which are also productive on the Sardinata anticline.

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Tertiary and Quaternary, Middle Magdalsna Valley section
In the western part of the report area, the Tertiary sedimentary
' rocks have been mapped in accordance with the standard nomenclature ;adopted by representatives of the Colombian petroleum industry (Morales

j et a! 9 1958, p. 647). In the eastern part, the nomenclature of the

Maracaibo Basin of northeastern Colombia and western Venezuela are

j
used (Notestein et al, 1944; Trump and Salvador, 1964). The nomen-clature of the two regions is shown in figure 9.
!

! Marine deposition came to an end near the close of the Cretaceous i

. Period as the Cordillera Oriental began to rise and became a source of (Tertiary continental sediments deposited along its flanks. Along the !west flank, these sediments isay exceed 8000 meters in thickness acccrd-i v^
ling to Morales et al (1958, fig. 7). They vary greatly in thickness and lithologic character. Much coarser material was deposited in the ;upper half of the Tertiary than in the lower half.
Compared with the marine Cretaceous section, the Tertiary
jFormations have few fossils. Age determinations are based on fresh
!

!water pelecypods and gastropods, pollen grains, planty and vertebrate ;remains.

301

The thickness of 1090 meters (see section) compares with a maximum
of 1225 reported by Morales et al (1958, p. 657).. In the de Mares Concession of quadrangle H-ll, Taborda (1965, p, 11) reports a maximum
I of 1100 meters, and states that the formation is often missing due to erosion during post-Lisama uplift.
Palynological studies indicate a Paleocene age for the Lisama
I according to Taborda (1965, p. 11). The lithologic character suggests
1 deposltional conditions ranging from lagoonal to deltaic.

Chorro Group
Wheeler first used the name "Chorro series" (Pilsbry and Olsson,
1935) for beds now recognized as the La Paz and Esmeraldas Forma-
tions (Morales et al, 1958, p. 658) in the Chorro Group.

La Paz Formation .--The prominent La Paz ridge in the
tV" western part of quadrangle H-12, between the Rios Lebrija and Sogamoso, is the source of the name for this formation. It was originally used
s ^

in the Rio Sogamoso area of the de Mares Concession (Taborda, 1965,
P» 11). The unit consists principally of massive, cross-bedded, light-gray conglomeratic sandstones. In the lower part and near the
top are interbeds of rather soft gray claystone. A section measured
\

Along the new Bucaramanga-Barrancabermeja highway along the north
8 lope of the canyon of Rio Sogamoso follows:

30.1

- trati graplilc section of the the**Tiew BucararaanKa-Barrrancaberins.la highway (pi arcMta 120 I-B-, g-2, D-2 and D-l) . Municipality of Giron^ Department of Santander^ ' ' . (Measured and described by F. Montero, September, 1968)
i
| Meters
La Paz Formation (lower beds only) : ;
Sandstone, gray, hard, fine-grained, conglomeratic i
vith quartz pebbles, in beds 0.8-2.0 m thick;
interbeds of soft gray claystone 10-1*0 cm thick. . n.?
- - - - - - .__ -unconformity- ----..-..
Lisama Formation: :
i
daystoae, brovn, soft, with interbeds of brovn,
fine-grained, hard, micaceous sandstone
Sandstone, gray, fine-grained, micaceous, slightly argillaceous, medium-hard, crossbedded
Claystone, violet-gray, soft, micaceous ...... Sandstone, greenish-gray to violet, hard, very fine grained, micaceous, crossbedded, in beds 0.9-2.1 m thick ....
Claystone, violet, soft, micaceous ....
- Sandstone, violet, hard, very fine-grained, micaceous, feldspathic, argillaceous, crossbedded ...... Claystone, violet, sandy, soft .... Sandstone, brown and violet, very fine grained, argillaceous, medium-hard
Claystone, gray and violet, micaceous, soft, in beds 1.0-3.2 m thick ....

60

k.6
3.8

12.1
8.2

6.5
3.5

9.5

28.0

304

Meters
Covered .... 370.^
Claystone, brown, soft, with numerous thin beds of
white gypsum 2-8 mm thick, N. 25° E., ^5° NW. . . . 1.7 Claystone, brown, soft, with thin beds of coal,
N. 26° E., 52° NW. 3.b
Claystone, brown, soft, with thin beds of white
gypsum .....1. .... 1.2
Covered 230.0
Sandstone, greenish-gray, very fine grained, hard,
conglomeratic,'crossbedded .... ^.2
Claystone, gray, soft, slightly micaceous ..... 6.8 Sandstone, greenish-gray, very fine grained, " ' i i
conglomeratic, crossbedded, very hard; interbedded
with hard, argillaceous, micaceous, slightly cal- I careous, dark-gray sandstone, H. 25° E., hQ° NW. . . 22.5
Covered 151*2
Sandstone, greenish-gray, very fine grained, hard,
micaceous, crossbedded in some parts; interbeds of
soft, micaceous, gray and black claystone 0.8-^.0 m
thick, and fine-grained, medium-hard, micaceous,
argillaceous, gray and brown sandstone in beds
1.2-U.5 m thick, H. kQ° E., 80° NW. ...... 7^5

305

5-.

Meters

Covered .... kQ.Q
Sandstone, dark- and light-gray, very fine grained,
hard, argillaceous and micaceous, with interbeds |

of gray, green, and black claystone ...... 8.0 i
Claystone, violet-gray, black, and yellow, hard to j
soft, micaceous, slightly sandy in parts 58.8
Claystone, gray, shaly, slightly concretionary; !

i
interbeds of fine-grained, slightly hard, argilla-
ceous gray sandstone 20-75 cm thick .... 3^.5
Total thickness of Lisama Formation 1039.7
Unir Formation (upper beds only):
Shale, dark-gray, brittle, micaceous, with thin beds ;

i
i

and lenses of brown clay ironstone and thin seams
of coal .... 1^2.0
Sandstone, light-gray, fine-grained, hard, micaceous 5.0
Shale, dark-gray, brittle, micaceous, with thin beds
and lenses of brown clay ironstone 151.0

306

Type stratjgraphic section of the La Paz Formtlon
along the new Bucaramq^ga-Barrancaberme.1a highway en ths north side of t'-ne canyon of the Rio Spgamoso (planchitas 120 I-A. :-.'- C-15 and 120 I-B, C-l and D-l). Municipality of Giron. Department of Sant^nder.
"(Measured and described by P. Montero, September, 1968)
j Meters Esmeraldas Formation (lower beds only):
Sandstone, light-brown, fine-grained, very hard,
slightly micaceous, in four beds of about 1.1 m
each, with interbedded light-gray to reddish-
gray soft claystone, N. kk° E., 2T° NW. ..... 14-.8 ;
Conglomerate, light-gray, with pebbles of white
quartz and sandy claystone up to 5 cm in diameter
in matrix of light-gray clay 1.1
Claystone, greenish- and violet-gray, soft >..... 67.0
Sandstone, light-gray, fine-grained, hard 3.2
Sandstone, light-gray, fine-grained, hard, conglom-
eratic with pebbles of white quartz and chert up
to 2 cm in diameter 1.3
Sandstone, gray and violet, fine-grained, argillaceous, slightly hard, N. 75° E., 32° KW. .... - 2.8 Claystone, greenish- and violet-gray, soft, with
sandy claystone concretions and lenses of
argillaceous, fine-grained sandstone at the base . . 15.!}.

1

ty 07

Meters
La Paz Formation:
Sandstone, very light yellowish gray, fine-grained,
hard, conglomeratic with quartz pebbles up to
k cm in diameter 12.k
Claystone, greenish- and violet-gray, soft . . . . . 6.7 Sandstone, brown, fine-grained, hard, in beds up to
10 cm thick, interbedded with slightly hard, brown
claystone in beds up to Ik cm thick 3.6
Sandstone, very light yellowish gray, hard, conglom-

eratic .with quartz pebbles .... 2.3 i
days tone, dark-gray, soft, nodular .... 16.8 Sandstone, greenish-gray, fine-grained, hard, micaceous
and argillaceous 1.9
Claystone, greenish- and dark-gray, soft, micaceous,

conglomeratic, with interbedded greenish-gray, fine- i
grained sandstone 1.1
Sandstone, very light gray, fine-grained, hard, argil- j
i
laceous, reddish on weathered surface; contains |
abundant dark grains 17*6
Sandstone, light-gray, hard, argillaceous, conglom- . ;
i
eratic with quarts pebbles up to 3 cm in diameter, . j
. N. 1*0° E., 32° NW. 5-8

300

Meters

Sandstone, light-gray, hard, argillaceous, conglom-eratic, with fev interbeds of dark-gray, soft, carbon-aceous clay stone up to 1.2 m thick in the upper part; contains carbonized plant remains, N. 35 E.,
32° NW.

Sandstone, very light yellowish gray, fine-grained, very hard, micaceous, crossbedded, in beds up to
80 cm thick; scattered conglomeratic beds up to
2.6 m thick and claystone beds are more numerous at the base and top, ». 25° B., **0° NW. ...... Sandstone, very light yellowish gray, fine-grained, very hard, micaceous, crossbedded, conglomeratic
and argillaceous at the top, middle, and base ... Sandstone, brown to pink, fine-grained, slightly hard, crossbedded, with interbedded greenish-gray, soft, nodular claystone .... Sandstone, pink and greenish- and yellowish-gray, very fine grained, hard, micaceous, crossbedded,
N. 1*2° E., 32° EW. .... Sandstone, light-gray, fine-grained, slightly hard, micaceous, carbonaceous, interbedded with soft, dark-
gray claystone in beds up to 10 cm thick ....

1*2.0

202.0

3^-0

3-2

39-5

3.6

300

S5-

Claystone, dark-gray, soft, slightly micaceous ... Sandstone, light-gray, fine-grained, slightly hard, micaceous, carbonaceous, interbedded with soft, dark-gray claystone .... Sandstone, greenish-gray, fine-grained, hard, micaceous, carbonaceous, N. 30° E., U6° HW. ... Covered .... Sandstone, gray, fine-grained, hard, micaceous; carbonaceous, in beds up to 1.8 m thick, inter-bedded with micaceous, soft, gray claystone in
beds up to 1.1 m thick .... Sandstone, greenish- and yellowish-gray, very fine grained, very hard, silty, micaceous, carbonaceous, conglomeratic with pebbles up to 3 cm in diameter Claystone, violet-gray, micaceous, slightly hard . Sandstone, greenish- and yellowish-gray, very fine grained, very hard, silty, micaceous, carbonaceous, conglomeratic with pebbles up to 3 cm in diameter Claystone, reddish-brown, slightly hard, micaceous Sandstone, greenish- and yellowish-gray, very hard, very fine grained, silty, micaceous, carbonaceous, crossbedded, conglomeratic with pebbles up to 3 cm in diameter, H. 27° E.,

Meters
16.0

39*0

120.0

7.6

10.0
2.0

11.0

21.7

310

5-

Heters

Claystone, violet-gray, soft, micaceous .... 3^.k Sandstone, gray, fine-grained, very porous, con-
glomeratic with pebbles up to k cm in diameter . « . 2,1 Claystone, light-gray and greenish-gray, soft,
micaceous .... « 1?«3 Sandstone, gray, fine-grained, very porous, con-
glomeratic, with pebbles up to k cm in diameter . * 4.8 Conglomerate, gray, very hard, with pebbles of quartz
and nodules of pink and gray sandy claystone up to
6 en in diameter in fine sandy matrix .... 4.6 Sandstone, gray, fine-graced, conglomeratic with
pebbles up to k cm in diameter 2.0
Conglomerate, gray, hard, with pebbles of quartz, j
i
feldspar, flint, and agate up to 6 cm in diameter 7«1 Claystone, gray, soft 3.8
Sandstone, gray, fine-grained, hard, slightly con- !
glomeratic .... 5*1 Claystone, gray and violet, soft .... 9-2 Sandstone, gray, fine-grained, hard, conglomeratic, in
beds up to 2 ni thick, with interbeds of soft, gray \
claystone up to kO cm thick 11.7
Total thickness of La Paz Formation 1102.k
. . . . -unconformity- ---------

313

2 I Meters

Lisama Formation (upper beds only):
daystone, brovn, soft, with interbeds of hard,
micaceous, fine-grained, brown sandstone 6.3

31!:

*-

The La Paz attains its maximum thickness in the Rio Sogamoso area. Taborda (1965, p. 12) mentions 1280 meters measured along
the river, but only 460 meters in Quebrada Putana about 14 kilometers
to the southwest. Farther to the west, in oil fields of quadrangle H-ll, the La Paz is only 170-210 meters thick.
At the base of the La Paz in some places, a hard, dense, grayish-
pfhk to cream-colored shale about 30 meters thick was originally referred to as the "altered shale" but is now termed the "Toro Member" I s

(Taborda, 1965, p. 12).
i
: The lower boundary of the La Paz is one of regional unconformity

| and angular discordance. This is less apparent in the outcrops of the i j western part of quadrangle H-12 than in the subsurface in quadrangle (H-ll where, in the La Cira oil field, it overlies the truncated edges

| of all the Cretaceous formations and' part of the Giron Formation i' ^
: (Taborda, 1965, fig. 7). The contact with the overlying Esmeraldas i
; Format ion is conformable. The formation yields oil in some of the
i
\ smaller fields of the middle Magdalena Valley.
!

j No fossils have been found with which to date the continental La

!

paz, but its position with respect to dated formations above and below ^indicates an Eocene age.

Esmeralrias Formation .--This upper formation of the Chorro

5-

X

Group was naraed for the hamlet of La Esmeralda on.Rio Sogaraoso where the type section is exposed in the western part of quadrangle H-12.
A description of this section was published by Wheeler (Pilsbry and
/
Olsson, 1935). The formation consists of light gray to greenish-gray, i thin-bedded to laminated, fine-grained sandstone and siltstone with
i
interbedded dark-gray shale locally mottled brown, red, and purple. Scattered seams of lignite are present. The formation is conformable with the underlying La Paz Formation but is unconformable with the overlying Mugrosa Formation. It generally forms very low topography. The lower beds of the Esmeraldas Formation in the area of the type section are described with the La Paz Formation. A section measured along the Rio Lebrija about 27 kilometers north northeast of the type section is shown below. The thickness of 575 meters is less than half the 1200 meters reported at the type section. The formation is thin-ner also to the south and west of the type section.
Brackish- to fresh-water gastropods and pelecypods from the Los
Corros fossil horizon, which occurs locally at the top of the formation,

v/

have oeen identified as late Eocene forms (Pilsbry and Olsson, 1935). Studies of pollen also indicate a late Eocene age on the basis of correlation with pollen of the late Eocene (lower part of the Carbonera
: /
Formation) of the Maracaibo Basin (Morales et al, 1958, p. 659). A ,deltaic and lagoonal origin is indicated for the formation.

31

section of the Ssmeraldas Forn^tion
along the Bucar^rr.anga*Puerto ^ilches railroad on the south f.side of the Rio Lebrija. (planchita 109 I-D. H-8 and H-7).

i . . Municipality of Lebri.la, Department .of Santander^
(Measured and described by A. Castro, September* 1968)
Meters

Mugrosa Formation (lower beds only)
5 _ Sandstone, light-gray, fine- to medium-grained,
argillaceous, micaceous, in beds 0.5-1.0 m thick;
interbedded yellowish-gray claystone in the
upper part .... 19*7 Covered 92.0
- - ..... -. -unconformity- ----------
Esmeraldas Formation:
Claystone (60 percent), gray, soft, laminar, with yellowish-gray, medium-grained, crossbedded, crumbly sandstone (ho percent) at the base and middle,
N. 3° E., 62° »W. .... 27.6 Covered .... 10.7 Sandstone (50 percent), yellowish-gray, medium-grained, crumbly, micaceous, crossbedded, thin-bedded to
laminar; interbedded with gray claystone (50 percent) ^5-7 Covered .... 91.8 Sandstone (80 percent), yellowish-gray, medium-grained, crumbly, micaceous, crossbedded, thin-bedded to
massive in the middle; contains abundant dark grains; interbedded with gray claystone (20 percent) in the
upper half, N. k° W., 56° SW. U6.0

97«-/ JL

Covered ....
Sandstone (70 percent), yellowish-brown, medium- to coarse-grained, crumbly, argillaceous, micaceous, crossbedded and thin-bedded; contains abundant
dark grains; interbedded with laminar gray clay-stone (30 percent) in the upper part, N. 6° W.,
49° SW. ....
Covered ....
Sandstone (60 percent), yellowish-brown to yellowish-gray, fine-grained in lower part, medium-grained in
. upper part, crumbly, argillaceous, micaceous, cross-bedded, in beds 0.2-0.8 m thick; interbedded with yellowish-gray clay stone (1*0 percent) ...... Total thickness of Esmeraldas Formation
La Paz Formation (upper beds only):
Sandstone, light-gray, medium- to very coarse
grained, hard, micaceous, argillaceous; contains small clay nodules and carbonaceous films on
bedding planes, N. 5° W., 6k° SM. ......

Meters
127.6

27.8
117-5

80.6
575.3

316

iChuspas Group i
i ' The beds above the Los Corros fossil horizon and below

the coarse clastic strata of the Real Formation were originally called
t

3 | the Chuspas Formation. The section was later divided into the Mugrosa i. ' -x
* | and Colorado Formations by Wheeler (Pilsbry and Olsson, 1935) on the
i
5 ~ ; basis of the Mugrosa fossil horizon at the top of the Mugrosa
i
6 j Formation.
!i
7 ! '

8 1 -

Mugrosa Formation_____ __.--The type section is in the

jI Quebrada Mugrosa in the area of the Mugrosa anticline in quadrangle

9 i

H-ll. In this general area, the lower part consists of. gray to grayish-
10- t

green, fine- to medium-grained, rarely coarse and pebbly sandstone with
I

iinterbedded gray and blue shale (Taborda, 1965, p. 13). The middle 12 |
1 part contains dull blue and brown, massive, mottled shales with few

13 i

;thin interbeds of fine-grained sandstone and light green sandy shales.
ii
'The upper part includes gray, fine- to coarse-grained, rarely pebbly

sandstone with minor interbeds of green and mottled shale. The
i
, proportion of sand to shale increases eastward in the lower part (Tomi),

. ;whereas in the upper part (Toms) the proportion of shale to sand
j S
increases (Morales et al, 1958, p. 660). A little oolitic glauconite

. , is present. The formation weathers to low topographic relief.

I The boundary with the underlying Esmeraldas Is one of regional

' "

Unconformity according to Morales et al (1958, p. 660), but Taborda
IS -

i(l965, p. 13) states that the unconformity has not been found in the
! /
4 jRio Soganoso area and oil fields of quadrangle H-ll. It is conformable
i
)t , with the overlying Colorado Formation.

317

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10-

A partially exposed section of the Hugrosa in quebradas south of
/ '
the Rio Lebriia and Bucararaanga-Puerto Wilches railroad is described V^p below. The thickness of this section, 843 meters, is similar to
the 820 meters in the Colorado oil field about 10 kilometers north of
the type section. Southward from the described section the
formation thickens and may reach 2000 meters,
I

; The Mugrosa fossil horizon that occurs locally at the top of the formation contains fresh-water gastropods, a few fish bones and plates
i
of turtles. On the basis of these fossils the age of the formation ranges from Early to Middle Oligocene. Oil is produced from the
; Mugrosa in the fields of quadrangle H-ll. :

Colorado Formation .--This formation receives its name from
;Rio Colorado in quadrangle H-ll where the type section is located.
i
There the lower boundary is the top of the fossiliferous zone at the top of the Mugrosa Formation. The formation consists of tough, massive,

X"

;light-gray, purple and red mottled shales with interbeds of fine- to
I

|coarse-grained, white, gray and yellowish-brown cross-bedded sandstone (Morales et al, 1958, p. 660). The shales are more reddish in color
and the sandstones are coarser and more conglomeratic than those of the Mugrosa Formation. The La Cira fossil zone marks the top of the
j Colorado which is unconformable with the overlying Real Group. Total
i
thickness at the type section is 1250 meters. Elsewhere it ranges up
!to 2500 meters. ;

318

5-

c section of the-Mucrrosa Formation so:i
of the BucararaanKa-Pueyfco Wllches railroad in the area of (foebradas Arenosa and Vega de Pato (ftlarrchita 109 I-D. H-JZ and H-6). Municipality of Lebri.la. Department of. Santander.i (Measured fcnd described by A. Castro, September, 1968)
j Meters Colorado Formation (lower beds only):
Conglomerate, yellowish-gray, hard, well-cemented,
slightly calcareous, in beds 0.8-1.2 m thick; '
pebbles up to 12 cm in diameter of sandstone,
limestone, quartz, and very few of metamorphic
and igneous rocks, N. 3° E., 62° NW. .... 73.8 Covered ....

Mugrosa Formation (upper member):
Claystone, yellowish-brown, medium-hard; in upper
" part are a few beds of coarse- to very coarse
grained, argillaceous, feldspathic, conglomeratic
sandstone In beds 20-^0 cm thick .... Sandstone, yellowish-brown, medium-hard, very coarse grained, slightly conglomeratic with rounded pebbles up to 2 cm in diameter, in beds 0.7-1.0 m thick; interbeds of yelloyish-gray argillaceous
_-_ sandstone at the base and pinkish-gray claystone near the top, N. 3° E., 56° NW.
Covered

172.6

30.0

32.0
22.0

0] <) », / i " j

5-

Meters

Conglomerate, poorly consolidated, with subangular j
pebbles of quartz and feldspar up to k cm in :
diameter, fewer smaller pebbles of metamorphic j
!
rock; interbeds of coarse-grained, argillaceous
, i
sandstone, N. ^° E., 614-° NW. 33.0
Claystone, greenish- to violet-gray, 8 m at the base
and 6 m at the top, separated by coarse-grained, I
argillaceous, feldspathic, yellowish-gray sand- :
stone in beds up to 2 m thick 17.0
Covered 28.0
Sandstone (50 percent), yellowish-gray, coarse- to
very coarse grained, argillaceous, with few beds' !

i of conglomerate containing pebbles of quartz and j

i
feldspar up to 2 cm in diameter; interbedded with i
yellowish-gray claystone (50 percent), N.-S., i
60° W. 30.0
Covered 8.0
Claystone, yellowish-pink, with interbedded argilla-
ceous conglomeratic, coarse-grained, yellowish-
gray sandstone 12.0
Covered 11.0

r

Meters

Mugrosa Formation (lower member, Tmi)

A

Covered 82.0
Siltstone, yellowish-gray, medium-hard, with few beds
of argillaceous, micaceous, yellowish-white sand-
stone in beds 20-50 cm thick h6.0
Covered 36.0
Silt stone, greenish- to violet-gray, medium-hard, with
few beds of argillaceous, yellowish-white sandstone
in beds 5-10 cm thick 60.0
Sandstone, yellc^ish-^yhite, poorly consolidated, argillaceous, micaceous, with interbedded yellowish-
gray siltstone, N.-S., 51° W. 42.0
Covered 96.0
Sandstone, yellowish-white, poorly consolidated, argillaceous, micaceous, with interbedded violet-
green siltstone, N. h° E., 66° NW. .... 36.0 Siltstone, yellowish-green to yellowish-gray, medium-
hard, with few interbeds 15-20 cm thick of medium-
grained, argillaceous, micaceous, crumbly, yellowish-
red sandstone 63.3
Covered 50.0

991 «y fc-i J

5-

Meters

Sandstone, light-gray, crumbly, fine- to medium-
grained, argillaceous, micaceous, in beds 0.5-1.0 m
thick, with interbeds of yellowish-gray clays tone
near the top 19.7
Covered 92.0
Total thickness of the Mugrosa Formation 8^3.0
- - - - - - - - - - unconformity- ---------
Esmeraldas Formation (upper beds only):
daystone (60 percent), gray, soft, laminar, with yellovish-gray, medium-grained, crossbedded,
crumbly sandstone (^0,percent) at the base and
middle, N. 3° E., 62° NW. 27-6

909 <J L, »M

s-

A section of the Colorado Formation exposed along and near the Bucaramanga-Puerto Wilches railroad is described below. The formation there is 1379 meters thick and is composed mostly of coarse conglomerates with abundant pebbles and boulders of sandstone and limestone, fewer of quartz, chert, and metamorphic and igneous rocks,
in a coarse-grained, sandy, calcareous matrix. Pebbles, cobbles, and boulders range up to 45 cm in diameter, but most are less than 12 cm. The beds in the lower part of the formation are hard and form a prominent ridge in contrast to the low topography over the Hugrosa Formation. The upper beds of the Colorado are poorly consolidated and do not form prominent topography.
In the La Cira shale zone at the top of the Colorado, a fresn-
water gastropod, genus Hemisinus, is the most characteristic fossil y
(Taborda, 1965, p. 14). Other fossils include lignitic material, fish scales and teeth, vertebrae, bone fragments, and small pelecypods.
i^
The latter were described by Pilsbry and Olsson (1935). On the basis
of these fossils and those in the fossiliferous zone at the top of the Mugrosa, the Colorado is placed in the Late Oligocene and Early Miocene and is of continental origin. It is an important oil reservoir in some of the oil fields in quadrangle H-ll.

32:)

Stratjgraphic section of the Colorado Formgt.ip_n_alcn£
the Bucararcanga-Puerto Wilches railroad (planch!ta 109 I-D«
' C-5) and in Quebrada Kilometro 72, west of
rogd (plinchita 109 I-Dt F-6 . J» Munlei pal 1 ty of
: Lebri.la, Department of Santander,
Treasured and described by A. Castro, September, 1968)
Meters

Real Formation (lower beds only) :
Conglomerate, sandstone, and claystone, inter-
bedded ....
Covered ....
- - - - - - . - -unconformity- -------..
Colorado Formation (measured along the railroad from post number km 67/10-68/5):
Conglomerate, yellowish-gray, poorly consolidated, in beds 1.5-2.5 m thick, with interbeds of purplish-
gray, sandy claystone up. to 1.0 m thick and yellowish-gray, medium-grained, argillaceous, lenticular sand-stone beds up to 1.5 m thick. Pebbles and boulders
in the conglomerate range up to 25 cm in diameter,
most are from 6-12 cm, and include fine- to medium-grained, yellowish-gray, hard sandstone, argillaceous
and micaceous friable sandstone, and few scattered
pebbles of chert and metair.orphic rocks, N. 9° E.,

101.3

59° NW.

Covered (railroad tunnel) 79.1

324

I

Meters

Conglomerate, similar to that described above,
with pebbles up to 16 cm in diameter, in beds
3-4 m thick; interbeds of purplish-gray, sandy claystone, N. 6° 1IE., 56° NW. ....
Covered .. .. Conglomerate, yellowish-gray, poorly consolidated, in beds 1.5-2.5 m thick, with interbeds of purplish-gray siltstone and lenticular beds of argillaceous, fine- to medium-grained, crumbly, yellowish-purple sandstone up to 1.5 m thick. Pebbles are of hard
to friable, yellowish-gray sandstone up to 10 cm
in diameter and a few are of chert and metamorphic
rocks ....*.. Covered ....

75-9

60.

0 o

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15-

Meters

Sandstone, yellowish-purple, coarse- to very coarse grained, argillaceous, conglomeratic with pebbles of quartz and sandstone up to 6 mm in diameter.
At the base these beds have scattered pebbles of quartz, sandstone, and chert up to 10 cm in diameter, mostly 2-5 cm, and alternate with beds-
of purplish-gray claystone. In the middle part,
the beds are more conglomeratic and pebbles are
larger. In the upper part, pebbles and cobbles
up to 13 cm in diameter are mostly of sandstone,
some are of quartz, few are of chert. Thin inter-
beds are of claystone and. lenticular sandstone . . . 2U6.2 (Measured in Quebrada Kllometro 72, west of the railroad) Covered .. ....*........ ... 82.k Conglomerate, hard, calcareous, with pebbles 3-12 cm
in diameter, in beds up to 1.0 m thick; pebbles are
mostly of sandstone, others are of quartz, limestone,
_ chert, and few are of metamorphic and igneous rocks,
N. 2° E., 62° HW. 7lf.5

32f>

Meters

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Conglomerate, yellowish-gray, with rounded pebbles of limestone and sandstone 6-18 cm in diameter,
few smaller ones of chert; calcareous matrix of coarse- to very coarse grained sand; at the top, pebbles are mostly medium-grained, micaceous,
hard, yellowish-gray sandstone l*-22 cm in dia-meter, N.-S., 63° W. .... Sandstone, brownish-gray, coarse-grained, hard, calcareous, conglomeratic, with interbeds of conglomerate, with pebbles of limestone and yellowish- to pinkish-gray sandstone, N. 2° E.,
62° NW. ....'........'.. Conglomerate, gray, hard, with pebbles 12-2^4- cm in diameter of limestone, sandstone, quartz, few of chert and very few of metamorphic rocks in sandy, calcareous matrix; pebbles decrease in size to 6-10
mm in diameter at the top and beds are thinner . .

109.6

66.0

327

Meters

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Conglomerate, gray, iiard, with pebbles of limestone and sandstone in sandy, calcareous matrix; the lower beds have mostly limestone pebbles up to
15 cm in diameter and few sandstone pebbles 5-8 cm;
at the top, sandstone and light- and dark-gray limestone pebbles are about equal in numbers, mostly 10-15 cm in diameter with some boulders 30-1^5 cm, N. k° E., 58° NW. .... Covered .... Conglomerate, gray, hard, in beds 0.8-1.2 m thick, with pebbles up to 12 cm in diameter of sandstone, limestone, quartz, very few of metamorphic and igneous rocks, in slightly calcareous, coarse- to very coarse grained sandy matrix ....
Covered ....

80.6

. . . . 73 «8
. . . . 172.6
Total thickness of Colorado Formation 1378.7
Mugrosa Formation (upper beds only):
Claystone, yellowish-brown, medium hard; in upper part
are a few beds of coarse- to very coarse grained, argillaceous, feldspathic, conglomeratic sandstone
in beds 20-^0 cm thick 30.0

320

!~ Real Group
The type section of the Real is in
*' quadrangle I-11 on the north side of Rio Opon and two kilometers west
3 of Quebrada Real. A description of these rocks as the "Real Series"
> /
* | was first published by Wheeler (Pilsbry and Olsson, 1935). Attempts i
5 ~ { to divide the thick section into units have been successful only

! ' * j locally according to Taborda (1965, p. 14). In quadrangle H-12, it is
i
; divided into three unnamed units, lower (Tmri), Middle (Tmrra), and
a upper (Trars). The contacts with the underlying Colorado Formation and
overlying Mesa Group are unconforrnable.
10 ~ At the type section along the Rio Opon, the following description

^ S

, of the Real is given by Taborda (1965, p. 14) and Morales et al (1958,
:? '. p. 661):
! Mesa"Group
_ ... --..----.--unconformity-------------
Real Group . M Sandstone, blue-gray, hard, fine- to coarse-grained
with interbeds of laminated dark-gray shale 747
Shale, gray, with few thin interbeds of coarse-
grained, friable, grayish-white sandstone 457
Conglomerate, massive, with pebbles of brown and
black chert, clay ironstone and quartz, and ;
fragments of coal; interbeds of massive, coarse-
grained sandstone with thin shale partings 1067

i Shale, gray with red mottling, with scattered I
* . interbeds of fine- to coarse-grained sandstone 1295
Q 9

Sandstone, massive, cross-bedded, friable to hard,
with streaks of blue clay and small coal fragments 453
Conglomerate, massive, with pebbles of brown and
black chert, clay ironstone and quartz, and
5 ~ fragments of coal 35 Total thickness 4054
- - - - - - - - - - - - - unconformity-------------
1 j Colorado Formation

A partly exposed section of the Real Group along the Bucaramanga-
Puerto Wilches railroad follows, below. Only the lower and middle divisions are present, and the 1732 meters measured is less than
half the thickness of the type section.
I

< Vertebrate fossils ranging from Late Oligocene to Late Miocene,
* i
I

and plant leaves and gastropods of Miocene age have been reported from the Real (Morales et al, 1958, p. 661) and indicate a continental
origin.
I Mesa Group
i _- -
i

In the Magdalena Valley, all beds above the
. Late Miocene are included in the Mesa Group (Morales et al, 1958,
(? 662). Earlier, the name Mesa Formation was used by Weiske (1926)
and by Butler (1942) for beds in the lower part of the group in the
* t
I Honda area in the upper Magdalena Valley. Various names have been used
i
j locally by different oil companies in the middle Magdalena Valley, some
i
recognizing two members, others a single unit. The Mesa is unconform-
jable over the Real Group.

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Covered .... Sandstone, white to light-gray, medium- to coarse-grained, feldspathic, friable, in massive beds up to 2 m thick, with conglomeratic zones and inter-beds of sandy, grayish-green claystone up to lj-0 cm thick; coarser grained and more conglomeratic at the top vhere interbeds are fine- to medium-grained, dark-green argillaceous sandstone,
N. 9° E., 14-5° m. .... Sandstone, white to light-gray, medium- to coarse-grained, feldspathic, friable, in beds up to 2 m thick, with alternate beds of sandy, greenish-
gray claystone up to k. 5 m thick. Poorly consoli-dated basal conglomerate 1.2 m thick contains
pebbles of quartz and sandstone up to k cm in
diameter, N. 12° E., 38° NW. ....
. . . . . -.. -unconformity- ---------
Real Group (lower part):
Sandstone (poorly exposed), yellowish-gray, coarse- to
very coarse grained, crumbly, feldspathic, conglom-
eratic, with interbedded conglomerate and greenish-
gray, sandy to conglomeratic claystone; claystone predominant in upper part, N» 11 E.,
NW. ....

Meters
121.1

115.6

37-8

331

Meters

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15-

Covered .... Conglomerate (poorly exposed), yellowish-gray, crumbly, with pebbles of sandstone and metamorphic and igneous rocks 10-15 cm In diameter ...... Sandstone (poorly exposed), light-yellowish-gray, coarse-grained, alternating with conglomerate
with pebbles of sandstone and metamorphic and igneous rocks up to 15 on in diameter and dark-violet-green, sandy to conglomeratic claystone; sandstones predominate in middle part, N.(9° E.,

282.

58° NW.

Conglomerate, coarse, crumbly, with pebbles of sandstone, siltstone, metamorphic and igneous rocks, few of chert and very few of volcanic rocks up to 18 cm in diameter, in beds up to 2 m thick, with lenticular sandstone beds,
H. 10° E., 56° NW. .... Sandstone, yellowish-gray, coarse-grained to conglomeratic, crumbly, highly feldspathic, in beds up to 1,5 m thick, alternating with coarse conglomerate beds up to 2 m thick and violet-gray sandy claystone ....

20.0

87.7

27.0

57-7

r

'5-

Covered

Meters
101.3

Total thickness of Real Group 1731.9
- - - - - - - - - - unconformity- --------- Colorado Formation (upper beds only):
Conglomerate, yellowish-gray, poorly consolidated,
with pebbles of fine- to medium-grained, hard,
yellowish-gray sandstone, argillaceous and
micaceous friable sandstone, and few of chert
and metamorphic rock up to 25 en in diameter,
in "beds up to 2.5 21 thick .... kk.O

334

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At the type locality, Alto de Gigante northwest of Honda, the lower part of the Mesa consists of well-bedded sands and andesitic tuffs which contain beds of coarse-grained sandstone, grits,
i
| agglomerates } clay, silt, conglomerates and pyroclastics. In the
i pyroclastics are fragments of andesite, dacite, pumice and ash and
|
j small fragments of quartz and flakes of phyllite. The upper part
i
i contains gravel, boulders, sandstone and interbedded silts. The group i
: ranges up to 575 meters in thickness.
In the de Mares Concession (quadrangle H-ll and I-I1), where the Capote and Magdalena Formations are recognized, the Mesa consists of
, massive black shales, friable sandstones, poorly consolidated
^

s conglomerates, arid terrace gravels and sands (Taborda, 1965, p. 15). I Some of the sandstones contain abundant carbonized plant material.
j The dark bluish-gray conglomerates contain pebbles of quartz, chert and igneous rocks. In the uppermost part are unconsolidated, poorly bedded gravels in sandy matrix, with local interbeds of yellowish- to reddish-gray clayey sand and sandy clay. The thickness ranges up to
! 250 meters.

In the northwest corner of quadrangle H-12, the Mesa occurs over
a wide area. Exposures occur along the Bucaramanga-Puerto Wilches
; railroad between kilometers 53 and 64 from Puerto Wilches. The section consists of alternating sandstones and thinner claystones and a few
| beds of conglomerate. The following descriptions list the lithologies
in order of abundance:

3.'! r>

No fossils have been reported on which to base an age determina-

tion for the Mesa Group. The lower part was considered to be of
/
Pliocene age by Wheeler (Pilsbry and Olsson, 1935). On this assumption,

the upper part is placed in the Pleistocene.

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Upper part ..'- -thickness ?
Sandstone, yellowish-gray to reddish-brown, very coarse-
to fine-grained, poorly consolidated; conglomeratic in some beds with pebbles of quartz and sandstone and few of
5 ~ metaraorphic rocks up to 5 cm in diameter Claystone, reddish-gray, soft, sandy
Lower part -estimated thickness 1100 meters
Sandstone, light yellowish-gray to yellowish-gray, coarse-
to very coarse-grained, poorly consolidated, cross-bedded, conglomeratic in most beds with pebbles of sandstone and
quartz and few of igneous, metamorphic, and volcanic rocks
up to 5 cm in diameter, mostly 1-2 cm
Claystone, light yellox^ish- to greenish-gray, sandy and conglomeratic !
i
Conglomerate, light yellowish- to brownish-gray, poorly
consolidated, in scattered beds and lenses with pebbles of
quartz and sandstone and few of igneous, raetamorphic and
volcanic rocks up to 15 cm in diameter

Because of the low dips of the beds and the intermittent nature of
the exposures, accurate measurements of thickness of individual exposures could not be made. An estimate has been made of the thick-
ness of the lower member based on an average dip of 12°. In the upper member, dips are only a few degrees to horizontal and no estimate of thickness has been made.

3:t7

Tertiary and Quaternary, Ma.racaibo. Basin, Colombia Barco Formation

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The type section for this formation is the
prominent East Barco Ridge of the Petroiea anticline on the Barco
/ l
Concession, quadrangle F-13 (Notestein et al, 1944, p. 1190 and fig.
8). There the formation is composed of 215 meters of interbedded sandstone, shale, and claystone. The sandstone, which commonly
I

i comprises one-half to two-thirds of the section, is in beds ranging

i i - > i from 0.3-20 meters thick and is mostly gray, argillaceous, very fine-
i
, to medium-grained, well-sorted, cross-bedded, with locally abundant
t

i micaceous-carbonaceous partings and shale laminae. Secondary growth

| of quartz on sand grains is a common occurrence, and the resulting ii .
| crystal faces produce the "sparkling sandstones" of the Barco. The Interbedded shales and claystones are gray to dark-gray, partly silty, micaceous, and carbonaceous. Thin lenses and small nodules of brown
i

iclay-ironstone are common, and one or more thin beds of coal are

!| usually present in the upper part of the formation. '

In the eastern part of quadrangle H-13 of this report, the Barco
1 is very similar in character to that of the type locality and is conformable with the underlying Mito Juan Formation. Estimates of the thickness in various places vary from 160-275 meters. This is similar
to the range of 150-278 meters found in outcrops in the Barco Concession area (Notestein et al, 1944, p. 1191). In wells of that area, the
thickness ranges from 76-198 meters. (

«.* / * >

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A few non-diagnostic arenaceous foraminifers have been found in
*

j the Barco Formation (Trump and Salvador, 1964, p. 8), but an early

! S \ Paleocene age is assigned to it on the basis of Paleocene pollen
;
! described by Van der Hammen (1958, p. 94). A fluviatile to brackish-

I water origin is indicated for the unit. It correlates with the lower 1 . i part of the Lisaraa Formation of the middle Magdalena Valley (fig. 9)

1 and with the lower parts of the Angostura, Marcelina, and Trujillo
^ \
Formations of Venezuela (Sutton, 1946, p. 1630). . j
i
Oil is produced from sandstones of the Barco in the Petrolea and

Tibu-Socuavo fields of the Barco Concession (Notestein et al, 1944,

p. 1191), and it contains gas on the Sardinata anticline. Production

is mainly from the "sparkling sandstones." i

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-Los- Cuervos Forma tion-

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The type section of this formation is in
/
Quebrada Los Cuervos that drains into Rio Catatumbo in the northern
^

part of the Barco Concession, quadrangle F-13 (Notestein et al, 1944,

p. 1192). There the formation is mostly claystone and shale with

scattered sandstone beds. The lower 75 meters contain dark-gray

carbonaceous shale and claystone interbedded with micaceous,

carbonaceous siltstone, fine-grained sandstone and coal. There are

usually 8 to 10 coal beds ranging from 0.1 to 2.5 meters thick. Above! i
the coal-bearing section, the Los Cuervos is mostly gray and greenish-

gray, partly silty, usually sideritic claystone with scattered beds

of argillaceous sandstone. The lower part of the section contains ;

dark-gray carbonaceous shales, and the claystones are slightly mottled e
i ,
Mottling is more pronounced in the upper half of the formation, with
!

colors of red, yellow, and purple. The Los Cuervos is conformable ji

with the underlying Barco Formation.

The Los Cuervos is part of the Tertiary section that crops out j
!

in the eastern part of quadrangle H-13 of this report. It is quite < i
similar to the section in the type locality. It tends .to weather as

a slight valley between the more resistant Barco and Mirador |
t

Formations. Coal beds in the lower part of the section are mined on ,

a small scale in various places. The estimated thickness varies from

265 to 420 meters as compared to 245 to 490 in outcrops in the area of
i
the type locality. In wells of the type locality the Los Cuervos j
varies from 249 to 426 meters (Notestein et al, 1944, p. 1192). In western Tachira, Venezuela, Trump and Salvador (19"64, p, 8 and fig. 6)
report thicknesses varying 'from 320 to 500 meters. i

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i The only fauna reported from the Los Cuervos includes a few
i

j marine or brackish-water pelecypods from a thin black shale near the
i
base of the formation in the type locality (Notestein et al, 1944, !
p. 1194). Their age is Cretaceous or Tertiary. Paleocene pollen
reported from carbonaceous beds in western Tachira (Trump and i

. !

Salvador, 1964, p. 8) dates the formation more closely. According to Van der Haramen (1958, p. 94) the age range indicated by pollen is from middle Paleocene to early Eocene. The presence of coal indicates a
paludal environment. I
The Los Cuervos correlates with the upper part of the Lisama Formation of the middle Magdalena Valley section (fig. 9), and with | the upper parts of the 'Angostura, Marcelina, and Trujillo Formations
of Venezuela (Sutton, 1946, p. 1630). '
Oil is produced from two sandstones of the Los Cuervos in the Carbonera field of the Barco Concession and in the Tarra field of Venezuela (Notestein et al, 1944, p. 1192, 1194). The oil is presumed
to have migrated from lower source beds along faults to the present reservoirs where permeability is controlled by fracturing.

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This formation is name! for Cerro Mirador on

i x ; |the Tarra anticline of the Colon district in southwestern Zulia,
\ ' \
|Venezuela (Sutton, 1946, p. 1669). It is predominantly light colored, clean, massive, fine- to coarse-grained sandstone with conglomeratic
beds containing quartz pebbles. In the lower p^rt, the sandstone is less clean and thinner bedded. Cross-bedding aixi ripple-marks are
| common. Interbeds of purplish-gray shale and siltstone are few and f

i
thin. A persistent shale break occurs near the middle of the formation in some areas, but has not been .found in the area of this report where the Mirador is limited to the southeastern part of quadrangle" H-13. Topographically, the Mirador forms a persistent ridge that is similar to but somewhat moi'e prominent than that of the 3arco Formaticn. The contact with the underlying Los Cuervos is unconformable, at least
j locally, in the area north of quadrangle H-13 (Kotestein et al, 1944,
i :
p. 1195), but no unconformity has been noted in the area of this |

i
i
: report. \
> I

In the eastern part of quadrangle H-13, several estimates of the
\
thickness of the Mirador range from 210 to 235 meters. Notestein et : s al (1944, p. 1195) report 160-400 meters in surface sections of. the
i Barco Concession in quadrangle F-13, and 251-4^8 meters in wells of that area. Thicknesses of 80-190 meters are reported from Xv*estern
/ ^ t
Tachira, Venezuela (Trump and Salvador, 1964, p. 9). j

Diagnostic fossils are lacking, and rare pollen remains are not ; conclusive as to the age of the Mirador according- to Trump and \

i
Salvador (1964, p. 9). According to Van der Hammen (1958, p. 94, 95), palynological evidence indicates an early Eocene age for most of the ; formation and a middle Eocene age for the upper part. ; The Mirador correlates with the La Paz Formation of the middle
i
Magdalena Valley section (fig. 9). In western Venezuela, it has been traced around the southern end of the Maracaibo Basin into, the Misoa Formation on the eastern side (Sutton, 1946, p. 1669).
Oil seeps have been found in outcrops of the Mirador, but no oil
has been produced from this formation in Colombia. However, it has important producing zones in the Tarra field in western Venezuela (Notestein et al, 1944, p. 1195).

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CarTsoriefa -Fdrrhat'ion ~j
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The formation name is taken from the
Quebrada La Carbonera on the eastern flank of the.Petrolea anticline
in the Barco Concession in quadrangle F-13 (Notestein et al, 1944,
p. 1196 and fig. 10). There the formation is a thick series of gray to greenish-gray and brown claystone and associated sandstone with ; i
lignitic coals in the lower and upper parts. A few thin limestone beds occur in the coal-bearing intervals and rare glauconitic zones > i
of limited lateral extent have been found in various parts of the
i
section. In western Tachira, the section is described by Trump and Salvador (1964, p. 9) as an alternating sequence of sandstones, siltstones, claystones, shales and coals with occasional fossiliferous sandy limestones. The fine- to medium-grained brown sandstone contains carbonaceous laminae, and carbonized plant.remains are common throughout the section, although coal beds are limited to the lower two-thirds. Sandstone is more abundant in the lower part of the section, and beds are more massive than" in the upper part where shale
i
is more abundant. Sections of the Carbonera in the Barco Concession
and western Tachira range from 410 to 560 meters thick. The contact
with the underlying Mirador is conformable and gradational.

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The Carbonera is the youngest Tertiary formation of the Maracaibo Basin section in the area of this report where it crops out in the southeastern part of quadrangle H-13. The upper part and all younger Tertiary beds have been eroded away. The part of the Carbonera that remains is not well exposed, and its maximum thickness is estimated
at 375 meters in planchita 121 II-C, C-8 and C-9. The coal beds are thinner and of poorer quality than those of the Los Cuervos Formation, and no instance of mining development of the coals of the Carbonera is known.
i Although the widespread occurrence of coal beds and plant fossils

:i indicate a generally non-marine origin for the Carbonera, marine beds
j
I are present from which molluscan faunas have been collected and

s

reported from the type locality and from north and west of Cucuta in Colombia (Notestein et al, 1944, p. 1199) and from southeast of San
| Antonio in western Tachira, Venezuela (Trump and Salvador, 1964, p. 9), i The collections from Colombia have been dated as late Eocene and
i ^
\ middle'Oligocene, and those from Tachira as late Eocene. On the basis i . I V
\ of palynological studies, Van der Hammen (1958, p. 95)'assigns the
i
I lower part of the Carbonera to the late Eocene and the upper part to
i | I the early Oligocene.
The Carbonera may be correlated with the Esmeraldas Formation
and the lower part of the iMugrosa Formation of the middle iMagdalena Valley section (fig. 9).

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Surf i c ia1 d e posits
Glacial deposits >

i

Deposits of bouldery till are present on the flanks and floors of
some of the valleys above 3200 meters altitude in the northern, central, and southeastern parts of quadrangle H-13. These deposits are typically linear to crescentic in form- and occur as lateral moraines along the sides of valleys or as lateral and terminal moraines which flank and cross the valleys. In some places glaciofluvial valley-train deposits cover the floors of the valleys. In many places the terminal moraines have been partly to wholly removed by glaciofluvial or modern streams and only the lateral moraines remain. However, well-formed terminal moraines are preserved in some places as in Quebrada El Salado north of Vetas (H-13, a-2 SE.) and in Quebrada
/ x
Rarairez east of Cachiri (H-13, a-1 1C.). Moraine deposits are well

X

displayed and readily accessible north of Berlin on the road to Vetas. Another extensive but less accessible morainal deposit lies about 7

i
kilometers north of El Portillo (H-13, b-5 NW.). A large deposit of till and valley-train sediments is located south of Presidente and north of Paramo de Almorzadero (H-13, c-6 NW.).

/7lk. *

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The glacial deposits were formed by cirque glaciers which

formerly occupied favorably situated valley heads. The moraines rarely

reach below 3200 meters altitude. Above this altitude glacial erosion

is common, and extensive areas of fresh rock stripped of weathered

material are exposed, particularly above 3600 meters, as on Morro ;

Nevado (H-13, b-2 NW.). Tarn lakes are common throughout much of the
j
high country. j
i
The glacial deposits are simple and as far as can be determined
!

| are of only one age. Four successive parallel moraines, each j
; i

j representing a stage in the retreat of the terminus of a glacier that

formerly occupied the site, project into the valley of Quebrada Los
! >

S Salados where it makes a right-angle bend southeast of Morro Nevado
i . ;
(H-13, b-2 SW.). Nowhere else were multiple moraines seen. j

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Valley-train glaciofluvial deposits downstream from the former
sites of the glaciers are common. These deposits -can be recognized by their association with moraines, and that close to their heads the deposits contain boulders far larger than those being moved by the
present streams. The valley-train deposits appear to be graded to
terrace deposits farther down the valleys. This was noted in Quebrada
x x

Ramirez east of Cachiri, and in Quebradas Honda and Los Salados west of Mutiscua. Large terraces in the valleys north of El Portillo in ;

X ; the headwaters of the Rio Mataperros (H-13, b-5 W.) appear to be

deposits of meltwater streams that issued from former nearby glaciers.
Terrace deposits over much of the area are discontinuous and ;
fragmentary owing to steep gradients of the narrow valleys of some of the mountain streams. However, it is reasonable to infer that most,
if not all, the terraces in the larger stream valleys in the high ;
country were deposited concomitantly with glaciation. The glaciation ; was probably accompanied by increased precipitation (Van der Hamraen
X

and Gonzalez, 1963) which resulted in increased erosion and transpor- ;
j tation by streams in the high country. This appears to have been
I ;
I accompanied by aggradation at somewhat lower altitudes. ;
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Terrace and alluvial fan feposits Terrace and alluvial fan deposits are widely distributed in the southern half of che report area. Many of the larger stream valleys have terraces or terrace remnants with surfaces well above the modern
flood-plain surface. The terraces tend to be widest, most extensive,
and least dissected in the upper reaches of valleys. Examples can be

s ' S seen at Mogotes, on the paramo near Berlin and in the valleys of Rio ;

Guaca and Perchiquez. Downstream, particularly in the deeper canyons, the terrace deposits are dissected and quite fragmentary. They appear to be remnants of more extensive alluvial deposits that once may have filled most of the large valleys in the zone but are now undergoing
| erosion. In places, one or two smaller and lower fragmentary terraces are present with surfaces not far above the modern flood plain. These
s . / '
were noted in places along the Rio Chicamocha near Cepita and in the

s

Bucaramanga area along the Rio de Oro and its tributaries. j
i
Extensive coalescing alluvial fans- at and south of Bucaramanga
i
partly fill the basin west of the mountain front. These deposits are
/ :
being dissected by the modern drainage. Near Bucaramanga the Rio de / /
Oro flows about 150 meters and the Rio Surata flows about 350 meters below the surface of the fans. South toward Floridablanca and Piedecuesta, the coalescing fans are less dissected and form a fairly continuous, westward-sloping surface. The apex of each fan coincides with, but lies at a considerably higher elevation than, the mouth of a modern stream valley issuing from the mountain front.

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The Bucaramanga terrace, on which the city of Rucaramanga is
s

located, has been described by de Forta (1959, p. 5-13) and Julivert
j
(1963, p. 41-59). The lower part of the terrace is composed of fluvial gravel, sand, silt, and minor clayey beds. The upper part is composed of unsorted bouldery materials interpreted by us as colluvial deposits,
The colluvial deposits thin away from the mountain front, have a !
greater surface gradient than that of the underlying stream deposits,
and are restricted to a zone along the valley sides. i
i
The gradient of the upper surface of the fluvial deposits appears
to be more gentle than that of the surface of the terrace on the
overlying colluvial deposits. The top of the stream deposits on the

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edge of the Bucaramanga terrace overlooking the gorge of the Rio Surata
is at about 700 meters. To the north, the top of the stream deposits

lies at about 825 meters. Towards Giron, flat surfaces on -remnants of i
the dissected terrace lie at about 850 to 825 meters. The surface :

i x - . i
may have been graded to a divide to the -Rio Sogamoso at about 900 '
meters elevation on the west side of Mesa de Los Santos. However, the present axis along the lowest part of the surface of the deposits seems to plunge northward rather than southward in the direction of the
i

present drainage. The terrace deposits appear to have completely filled the valley of Bucaramanga and Giron for they abut against the west wall of the valley near Giron where they are tilted up at the
/ '
Suarez fault (Julivert, 1963, figs. 6, 7, laminas II, III). Here landslide debris from slopes to the west unconformably cover the upturned terrace deposit, r. here. _ __ ... _ _ ....

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The lower fluvial deposits appear to be derived chiefly from
2 | Jurassic and Cretaceous sandstones. This is particularly true south
x *' '
of Giron and suggests a source in that direction. Julivert (1958,
p. 34-36) proposed that the deposits were laid down by the ancestral
Rio Chicainocha-Sogamoso before capture from the west by streams north
of Zapatoca. :
Remnants of terraces, apparently formerly continuous with the ,
fluvial deposits of the Bucaramanga terrace, flank the sides of the

x x ' Rios Surata and Tona in the mountains east of Bucaramanga. i
, i
10 ~ i The wedge of colluvium at the top of the Bucararaanga terrace has
i
11 j a somewhat uneven surface. Features such as the Lagos de Florida and 12 the Lagos del Cacique south of Bucaramanga may be natural depressions on an irregular initial surface. The boulders in the material range
from hard quartzite (Tarabor Formation) through white to purple, soft,
|
15-1 crumbly arkosic sandstone (Giron Formation) to very soft, punky, almost , 6 !
saprolitic feldspathic gneiss (Bucaramanga G,neiss) and quartz monzonite
; (La Corcova Quartz Monzonite). The color of the matrix is a deep red
j i
18 'I in most places, but in others it is brown or even yellow gray. The
I

19 ' latter material seems to be derived,entirely from areas underlain by La Corcova Quartz Monzonite, as can be seen in a road cut on the high-
way near Floridablanca. The material making up the colluvial deposits
must have been derived from deeply weathered parent material, such as
is found today on the mountains east of Bucaramnnga. In some places materials of unlike color and texture are in sharp contact with one another. This relationship suggests r.hat the colluvial deposits arc t'-'C individual deposits act- derived fro;:i a broad ran-o of
source ni.itorial.

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Colluvial deposits \
Areas of thick landslide, talus, mud flow, and other colluvial
deposits have been combined in a single unit on the geologic maps.
i
Landslide deposits are most common on steep slopes, particularly where
a more resistant rock overlies a less resistant rock. The age of these deposits, as suggested in the previous section, probably ranges from
| Pleistocene to Holocene. Landsliding is an active process throughout
i
the zone. ~ . j
i i
Landslides form a larger part of this map unit in the eastern part
of quadrangle H-13 than they do elsewhere. In c-4-W., an area of '

1 4 to 5 square kilometers of sandstone of the Aguardiente Formation has i

i crumbled and slid down-dip southeastward toward Rio Chitaga. In
i
j &-7-E., landslides in a cirquelike basin in the Aguardiente and Capacho i Formations are funneling down through the narrow Quebrada Agua Sucio
: toward Rio Servita. In c-7-SE. , a large slide has occurred in the !
Barco, Colon, and Mito Juan Formations which has moved northeastward
1 toward Quebrada El Oso. On the surfaces of these slides, features can
, be seen on aerial photographs which are similar to those seen on the
: surfaces of glaciers, including crevasses and pressure ridges (
| " i
I transverse to the direction of movement.

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Alluvium

2 i; The most extensive areas of alluvium flank major streams, such 3 ; as the Rios s Lebrija and Sogamoso, where they flow on the floor of the 4 i Magdalena Valley in the western part of quadrangle H-12.
5 ~ In the mountainous areas alluvial deposits are sparse. Some of 6 the deposits mapped as alluvium in the high paramo are possibly in
7 !\ part or entirely correlative with the terrace and fan deposits and
8 j are possibly Pleistocene.

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METAMORPHISM

Regional dynamothermal metamorphism i i
i The pattern of regional metamorphism in the southern half of I

: Zone III is complicated by post-metarcorphic batholiths, by the
! presence of at least two periods of regional metamorphism, and by i
extensive faulting that has juxtaposed at the present level of exposure huge blocks of the massif which were metamorphosed at different depths in the crust. Accordingly, raetamorphic isograds commonly follow stratigraphic boundaries, the contacts of intrusive masses, or faults. Where isograds follow faults or stratigraphic boundaries, the rock units themselves act as raetamorphic zones
i
, delimited by the faults or stratigraphic contacts. The isograds drawn indicate the first appearance of certain index minerals that formed at the peak of regional met amor phi sen.
Isograds in the Bucararaanga Gneiss and the Silgara Formation
appear to form a single simple pattern even though it is likely that roore than one period of metamorphism has affected the older rocks.
The distribution of the isograds is not influenced by the Jurassic-

Triassic batholiths of the Santander Plutonic Group. i

Isograds in the Floresta Formation do not coincide with those in
the underlying rocks. Except locally for the Diamante Formation, rock Ur>its younger than the Floresta Formation are not metamorphosed. How-
ever, the Diamante Formation of Permian-Carboniferous age is noticeably Crystaliized in areas where the Floresta Formation shows the most

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Bucaramanga Gneiss j
The Bucaramanga Gneiss is composed of rocks of high metamorphic
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grade, entirely within the sillimanite isograd, tliat belong to the
upper amphibolite facies. Mineral assemblages indicate metamorphisa
of the Bosost type because of the complete lack of kyanite, the !
general lack of garnet, and the prevalence of andalusite and ;
I

cordierite (Winkler, 1967, table 7). Typical assemblages are shown '
in table 3 . |

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The gneiss has undergone varying degrees of retrograde meta-
mor.phism in which aluminum silicates have been sericitized and ;

i
cordierite has been pinitized. Because of the difficulty in ;
distinguishing primary from secondary muscovite in the field. only the first sillimanite isograd marking the beginning of the sillimanite-
cordierite-muscovite-(alraandine) subfacies of the cordierite- \
\s :
amphibolite facies (Winkler, 1967, p. 121-122) has been shown. An examination of the mineral assemblages (table 3) shows that the sillimanite-cordierite-orthoclase-(almandine) subfacies has also been

! reached. Rocks of this subfacies are in fact fairly widespread. The

presence of andalusite and sillimanite in one assemblage should be noted. Discussion of this association will be deferred to the section /
on the Silgara Formation.

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In the belt of Bucaramanga Gneiss east of Bucararaanga, garnet is extremely rare; a trace of garnet was seen in only one specimen. The
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composition of this garnet is unknown. Aluminum silicates are
andalusite and sillimanite with cordierite, indicating low pressure-
high temperature assemblages. No orthopyroxenes have been observed and biotite is universally present indicating that none of the rocks

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belong to the granulite fades. No wollastonite was found in ;

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calcareous rocks. j

| The same assemblages prevail in the Bucaramanga Gneiss in the

Berlin-Vetas belt of Gneiss. A trace of garnet was noted in the Tona area, but it is typically lacking in the main part of this belt.

' ' S ' Only in paragneisses in the Rio Carab<i area northeast of Berlin near
the Silgara Formation is garnet abundant. Interestingly enough, some i
of the layers of granitic gneiss contain traces of garnet. " !
The Bucaramanga Gneiss in the Chitaga-Pamplona area has
assemblages similar to those observed elsewhere. East of Chitaga, the
bulk of the rocks appear to be in the sillimanite-cordierite-orthoclase (almandine) subfacies.

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These rocks were metamorphosed within the range of temperatures
at which raigmatitic gneiss forms through anatexis of rocks of
appropriate composition. The migmatitic character of much of the Bucaramanga Gneiss is in keeping with the degree of metamorphism Involved. As discussed under the description of the Bucararaanga
Gneiss, some layers are too thick and too obviously discordant in composition and structure to have formed by anatexis in situ. However, many of the small features of the migmatitic gneiss could well be of local anatectic origin. The fluidal structures in some of these
gneisses indicate extreme plasticity during deformation. Some layers
of meta-arenite are quite granitoid in appearance.

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Silgara Formation
The Silgara Formation is typically low or medium grade. Its
mineral assemblages are those of the greenschist or lower amphibolite facies, although locally assemblages diagnostic of the upper
amphibolite facies occur. Like the Bucaramanga Gneiss, the Silgara has been affected to varying degrees
by retrograde raetamorphism. j The range of facies series in which the Silgara Formation has undergone metamorphism is more apparent than in the Bucararaanga Gneiss. | In the northern part of the Quebrada Silgara belt, the rocks are within the greenschist facies, but to the south they pass into the amphibolite facies. Chloritoid, staurolite, and garnet, except for rare traces, are lacking. In the higher grade rocks to the south, pelitic rocks contain andalusite, cordierite, and sillimanite (table 3). These assemblages are typical of the Abukuma or Bosost-type facies series. In the Tona area garnet and staurolite are present although not in great abundance. In the remainder of the belts of the Silgara Formation, typical assemblages in the upper greenschist and lower amphibolite facies contain garnet and staurolite, and with increasing metamorphism they contain andalusite, cordierite, and sillimanite. The presence of garnet and staurolite in low- to middle-grade rocks in this area could be interpreted as evidence that the Silgara Formation may have metamorphosed in a somewhat higher pressure series than elsewhere. Chlorite persists into the amphibolite facies
in some rocks in the Silos and Pescadero areas probably due to an
. unusual bulk composition_pf these rocks. ... _ .__.. ._.

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Mineral paragencses in the Silgara Formation as well as those in
the Bucaramanga Gneiss suggest a complex metamorphic history. Early muscovite, chlorite, biotite, and sillimanite, particularly fibrolite,
are generally oriented parallel to the foliation or to a cleavage.
Long axes of andalusite and staurolite crystals tend to lie in the plane
of foliation, but tend to be randomly oriented within that plane. The orientation of these two minerals may be mimetic or controlled by narrow zones of'suitable composition. Garnet in some specimens shovs
a spiral structure. On the other hand, some biotite and chlorite porphyroblasts have grown athwart the foliation. Late muscovite

^ forms mats of fine flakes or groups of large poikiloblastic \ flakes without preferred orientation. These muscovites may be related to the widespread retrograde metamorphism. Many porphyroblasts of cordierite and some of andalusite contain needles of sillimanite whose long axes lie in the plane of foliation. This relationship suggests post-kinematic growth of the andalusite and cordierite and further demonstrates the non-contemporaneity of individual minerals in the reported assemblages (table 3). Metaraorphic crystallization, which may have been either continuous or have taken place in steps, occurred under changing conditions of pressure and temperature. Petrographic relationships described briefly above wera seen throughout the Bucaramanga Gneiss and Silgara Formations and suggest that an earlier phase of metamorphism with a strong dynamic element was followed by a

later more static phase. The apparent typomorphic minerals of the i
Abukuma facies series in these rocks may .be_ in. part, the .overprint of j
> t H'i. I '»

11 static-thermal conditions of metamorphism on an earlier assemblage possibly formed in a different facies series. The change from
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3 crystallization under dynamic conditions to crystallization under ', static conditions could have occurred during a single continuous period
of metamorphism. !

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Floresta Formation '
The Floresta Formation locally has been metamorphosed within the greenschist facies to form argillitic slates to phyllites. Quartz, chlorite, and muscovite constitute the usual mineral assemblage. Porphyroblasts of garnet, chloritoid, and biotite are present only in
the area south of Berlin at the north end of the Covarachia-Silos belt of the Floresta Formation, but some of these rocks may actually belong to the Silgara Formation.
Structures and minerals of the rocks of the Floresta Formation
are products of dynamothermal metamorphism. In the Mogotes area, for example, three sets of S planes can be distinguished readily
bedding - Sj, primary foliation - S^, and a slip cleavage - S^. Metamorphic minerals are oriented parallel to 82 which is not every-where coincident with S, , and some reorientation and recrys"tallization
of minerals accompanied the development of Sg.
porphyrobiasts have been observed in this area.

No late postkinematic

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Orthogneiss
Mineral assemblages of the different types of orthogneiss are
5 stable over a wide range of middle- to high-grade metaraorphic
I conditions. However, where the metaraorphic grade of the enclosing rocks is low (greenschist facies), the orthogneiss contains more chlorite and epidote, has more thoroughly altered plagioclase, and
shows less annealing of cataclastic texture than orthogneiss enclosed
in rocks of higher metamorphic grade. These features are well dis-
| played in the orthogneiss around Coverachia and Capitanejo where the '°~ surrounding recks are of low metamorphic grade as contrasted with orthogneiss in rocks of high raetamorphic grade north of Berlin.
The concordance of foliation and lineation in the orthogneiss
with these structures in adjacent rocks of the Bucaramanga Gneiss and Silgara Formation are interpreted as indicating that all th'ree rocks
] have undergone the same dynamothermal inetaraorphism. Whether the
j orthogneiss was eraplaced as magma during metaraorphism, or is plutonic
. i

1 rock emplaced and solidified prior to metamorphisin is not certain.

Radiometric age determinations (table 2) and the observation
in many parts of the world that emplacement of batholiths and
regional high-grade metamorphism are spatially related form the
basis for believing that the orthogneiss was emplaced more or less synchronously with the regional progressive metamorphism of the
Bucaramanga Gneiss and Silgara Formation. Details of the internal textures and structures of the orthogneiss have been given earlier

in the section on the description of the unit. : - 36-5

Retrograde metamorpbisrn
Many features indicating a widespread retrograde metaraorphisra
have been mentioned in the preceding sections. These features are most pronounced in the Bucararaanga Gneiss and in certain areas of the Silgara Formation. The Floresta Formation does not show retrograde effects.
In the Bucaramanga Gneiss the most prominent retrograde features
are pinitized cordierite, saussuritized plagioclase, and sericitized sillimanite and andalusite. Potassium feldspar is generally
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I0 ~i unaffected, although it may be kaolinized or sericitized in some
i places. Hornblende is little affected, although clusters of epidote,
: biotite, and chlorite with sphene and iron oxide in some rocks may be j relics of the complete alteration of hornblende. Widespread and
i pervasive muscovitization is characteristic of much of the 'retrograde
: metamorphism. In places it is difficult to distinguish this
; muscovitization from that caused by dynamic metaraorphisra produced by
| local shearing and faulting. In some rocks the muscovitization has
I

I produced only mats of sericite; in other places the sericite appears | to have coalesced to form large, nonoriented, commonly poikiloblastic j Muscovite flakes that have replaced aluminum silicates or cordierite. fibrolite is pseudomorphed by rauscovite in many rocks, but in other rocks oriented sillimanite needles are preserved in rauscovite porphyroblasts. In some rocks coupled reactions have taken place in which biotite altered to chlorite providing potassium for the

sericitizntion of aluminum silicates, .._.. __.._ . . ..

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Retrograclc metemorphisra in the Silgara Formation, particularly
in rocks in the greenschist facies, is less evident than that in the Bucaramanga Gneiss. This is because these low-grade mineral
assemblages were more or less stable under the conditions of the retrograde metamorphism. In rocks in the lower amphibolite facies, particularly in the Pescadero-Aratoca belt, garnet has in part been chloritized and staurolite has been to some extent altered to sericite i
and chlorite. Otherwise reactions are similar to those in the :
Bucaramanga Gneiss. Retrograde chlorite can be distinguished from prograde chlorite by the usually anomalous interference colors of the former and by its inclusions of exsolved iron oxide : and in some
cases leucoxene. ;
In the orthogneiss similar retrograde effects are observed. ;
However the restricted mineral assemblages of these rocks limit the

e minerals ! erfectEdAto biotite and plagioclase, which may be partly chloritized

\ . i
and saussuritized, respectively. j
The retrograde metairorphism was accompanied by appreciable i
I

activity of water and potassium. Temperatures were apparently those of the greenschist facies. The time of this raetarnorphism in relation to the prograde metamorphisms, beyond that it is younger than the netaraorphism of the Silgara Formation, is unknown.

Cent act metamorph ism
Contact metamorphic effects of the batholiths of the Santander
i i
Plutonic Group are minor. No hornfels has been observed. The only
! effect noticed in the field was a coarsening of grain size of i
muscovite in certain rocks of the Silgara Formation at their contacts with the intrusives. For example, large round plates of poikiloblastic muscovite are prominent near the contact with the Pescadero Granite south of the bridge over Rio Chicamocha at Pescadero. Probably,
however, more effects took place in the wall rocks than has been ;
i
, noticed. i
i Contaraination of the plutonic rocks by the meta-sediments,
i i

however, is usually more prominent. Muscovite and garnet are common
| in granite and quartz monzonite near contacts with meta-sediments.
I * I
j This was noticed along the east side of the Rio Negro batholith and
i j
; in some of the La Corcova Quartz Monzonite. The Durania Granite is]
liberally contaminated by the schists it intrudes. The Santa ;

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/ ; i Barbara Quartz Monzonite is in places more biotitic and contains
hornblende adjacent to hornblendic rocks. !

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and discussion

j The regional dynamothermal met^rorphism of the Bucaramanga Gneiss and the Silgara Formation is of the Eosost type facies series in the
i belt of metamorphic rocks on the west side of the massif, east of the I

! Bucararaanga fault and possibly of the Eastern Pyrenees-type facies
I ' x
I series along the east side of the massif and in the Silgara Formation west of the Bucararaanga fault south of Bucaramanga. These facies series may be considered variants of the Abukuma-type facies series.
On the basis of the mineral assemblages, it is estimated that the maximum temperatures of the metaraorphism were at 600 to 700 C. and
, the maximum depths of burial were about 10 km for the rocks on the east side of the massif and perhaps 15 km for those on the western side of the massif.
; However it should be pointed out that the rocks on the eastern side of the massif that show evidence of belonging to a somewhat
higher pressure facies series than those to the west are restricted to the middle- and low-grade zones of the Silgara Formation. It is possible that whereas the temperature-pressure curve of Abukuma-type ntetamorphisra was relatively straight in the western belt, the curve was concave in the eastern belt with lower than normal temperatures at ! the shallow depths and standard temperatures for this type of metamorphism at greater depth. It is the Silgara Formation that shows more clearly the difference in metamorphic facies series from place to
\ place and not the Bucaramanga Gneiss. This could be interpreted as
I having result-.ii from the Bucaramanga Gneiss having been metarv.orphosed
.; under different conditions and at an earlier tin* than the Si.rara '-formation. However there is no concrete evidence for such interpretati on

«> i it

A static phase of thermal recryctallization appears to have
followed an earlier dynamic phase in both the Eucaramanga Gneiss and Silgara Formation.
The major regional dynamotherir.ai mttornorphism occurred prior to
1 the deposition of the Floresta Formation4 which rests unconforraably and with metaraorphic discontinuity on rocks of the Silgara Formation and
on orthogneiss. Radioraetric Rb-Sr whole rock determination on orthogneiss and raeta-diorite indicates an upper Ordovician age for the metamorphism of these rocks. Because Precambrian gneisses of high meta-morphic grade are involved, however, a period of Precambrian metamorphism may have occurred prior to the Ordovician event. An alternative explanation is that the Ordovician ages are actually, Precambrian ages partially made younger during the post-Devonian metamorphism. This would be possible if the Silgara Formation were Precambrian also and
not Cambro-Ordovician as believed. Radiometric dates that support the Ordovician age of the orthogneiss are found in the nearby Cordillera de Merida of Venezuela where Bass and Shagam (1960, p. 381) report Rb-Sr ages of 410 ± 40 and 420 ± 105 m.y. on muscovite from phyllite and whole rock (schist) respectively. To the south, in the Serrania de la Macarena, Pinson and others (1962, p. 907-960) report ages of about 436 and 484 ra.y. from pegmatites. These widely distributed radiometric ages suggest a regional plutonic-metamorphic event in northwestern South America during the lower Silurian-upper Ordovician.

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' The metamorphisni of the Floresta Formation is reqional prograde
| dynamothennal and everywhere of low grade. This metarnorphism also
; affected the Permo-Carboniferous Diamante Formation, but it predates
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|the deposition of the continental deposits of Bocas Formation of
s- Triassic age. A phyllite in the Silgara Formation between Sardinata iand Ocana in the north part of Zone III gives a K-Ar age of 221-8 m.y.

I ;; (table 2) or lower Triassic although this date may reflect some
!

resetting by the nearby Aguablanca batholith from which 196*7 m.y. ;
i - !

j (table 2) age was obtained. Radiometric dating of metamorphic rocks
i
: ~i in the nearby Cordillera de Merida of Venezuela has given similar ages i ranging from 230 to 280 m.y. (Bass and Shagam, I960, p. 381).
Retrograde metamorphism characterized by high water and potassium activity affected rocks of the Bucaramanga Gneiss and Silgara' Formation
i
i over most of Zone III. The time of this metamorphism is uncertain.
It could be related to the regional progressive low-grade metamorphism
of the Floresta Formation. The retrograde metamorphisra appears to be
too widespread to be related to the emplacement of the batholiths of
the Santander Plutonic Group, sll of which have negligible contact
- metamorphic effects but might be related to the initial rise of magma.

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STRUCTURE

Structural features of the metamorphic rocks

Primary minor structural features are well preserved in many of the metamorphic rocks, although they are frequently distorted. In the Floresta'and Silgara Formations, small-scale « feature? such as lamination, graded bedding , fine-scale cross-bedding, channeling,
and intraformational conglomerate are present in many rocks, particularly in meta-siltstones and meta-sandstones of the greenschist facies of metamorphism. In rocks of higher metamorphic grade these features are less evident. In the highest grade rocks, such as the Bucaramanga Gneiss, only gross compositional layering reflecting the original sedimentary bedding is preserved.
Foliation in the Bucaramanga Gneiss is in most places parallel to compositional layering, both on large and small scales, so that foliation symbols on the map normally indicate the attitude of the layering or relict bedding as well. In the Silgara and Floresta Formations, however, foliation and bedding are commonly discordant to one another; only in the more arenaceous thin-bedded rocks are they generally parallel. In some places foliation and bedding are grossly discordant, particularly in the axial zones of folds. This relation-
ship is best seen in the thicker pelitic beds. Foliation symbols in the Silgara and Floresta Formations therefore cannot be relied upon to depict the attitude of layering or bedding.

371

Slip cleavage is the most prominent structural feature in rocks
of the Floresta Formation in the Mogotes area and t:he Coverachia-San Andres belt. The slip cleavage generally is at a high angle to layering and foliation. Many of the foliation symbols in the Floresta Formation were actually measured on this cleavage and cannot be used /
to interpret attitudes of beds and foliation. In areas where cleavage and foliation were distinguished and cleavage symbols are present, the foliation and bedding symbols may be relied upon. Cleavage in the Silgara Formation parallels axial surfaces of crinkles, chevron, or drag folds in schist.
Attitudes of minor folds, the strike and dip of their axial sur-faces, and more commonly the strike and plunge of their axes, are indicated in some places. Although the mapping of these features was rather spotty, they help to interpret the gross structure of the rocks and the orientation of the stress field that prevailed during folding and metamorphisra. Where attitudes of fold axes range widely over small areas, folds of several generations have been measured, or faulting has disrupted the pattern. In the latter situation,attitudes within any one fault block should be consistent, but may be at variance with attitudes in adjacent blocks. ^Where folds of several generations
are present, axes with different orientations may be measured in single outcrops. This situation is not uncommon in the Santander Massif, and indicates a rather complex history of deformation.

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Two sets of folds ueem to be present. One set is characterized
by tight to isoclinal folds with foliation tending to be non-parallel
areas.

to bedding in the axial/ The other set is characterized by more open folding of both layering and foliation with the development of slip cleavage parallel to axial surfaces. The two types are not distinguished on the geologic maps.
Minor folds in the Bucararaanga Gneiss are less conspicuous,
although tight isoclinal folds are present. Broadly folded foliation
and layering are common. In the migmatitic rocks, folds tend to be disharrnonic and reflect the high degree of plasticity of the rocks during deformation.

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Structural trends and major; structural features

Structural attitudes measured in the snetaraorphic rocks are sufficient to indicate the general trend of these rocks but are insufficient to more than suggest locally their internal pattern of folding. The trends of foliation and orientation of folds are more or less similar in the Bucaramanga Gneiss, the Silgara Formation, the Floresta Formation, and the orthogneiss. Regionally, trends are north-south and parallel the grain of the Cordillera Oriental with only local departures. The continuity of the trends in the basement rocks of the massif is broken by the batholiths and where covered by sedimentary rocks.

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Bucaraisanga-311gara'-Cepita>> belt. The Bucaracianga Gneiss in the
"belt east of Bucaramanga has a general north to northwest trend, but
the rocks are so intensely folded and sheared that little can be said about overall structural patterns within the belt. Fold axes are subpara.ll el to or strike into the Bucaramarsga fault and are clearly
much older than it. There is a suggestion of a syncline in the
gneiss from the Bucaramanga area to the Piedecuesta area between the Bucaramanga fault and the La Corcova Quartz Monzonite, Tine axis plunges northwesterly. Axes of minor folds plunge fairly consistently to the northwest in the gneiss from Bucaramanga to the Tona" area. ij They bear more to the west than the strike of the Bucaramanga fault. I | Dips of foliation in the gneiss between the La Corcova pluton and the i Santa Barbara batholith in the Sevilla area and south to the Cepita^ Ifcrpala area are relatively gentle. Further south it is noteworthy
that dips in the gneiss are to the east on the east side of the Bucaramanga fault and to the west in the roof pendants in the Mogotes batholith west of the fault* In the Silgara7 Formation east of the
Rio Negro batholith the general trend of foliation is north-south.
The rocks are apparently highly folded to the north with no clear
^ pattern. Near the southern end of the Silgara belt, the Silgara' Formation appears to lie in a northward plunging syncline.
South of Matanzas and northwest of Tona, the Silgara' Formation
trends east-west and dips of layering and plunges of fold axes are to the northwest, off the underlying Bucarnmanga Gneiss. Here and near Tona^ and in the patches of Silgara' to the couth, the attitudes and '[outcrop pattern surest that the Silgara is fairly flat-lyirrj. . . ....

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PIedecuesta-Aratoca -_Moa:qtes belt. The metanorphic rocks in the i - - , belt from Piedecuesta to Mogotes all lie vest of the BucaraTr.aQ.ga

fault and, except for the roof pendants of Bucaramanga Gneiss in the i

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Mogotes batholith along the fault in 1-13, consist of the Silgara | Formation and, in the Mcgotes area, the Floresta Formation. In the j Pescadero-Aratoca area the trends are north to northwesterly. Axial planes of folds were measured only in one area south of Pescadero

where the attitudes suggest vergence of folding toward the northeast.;i Here, axes of minor folds plunge to the southwest . However, north of

I Pescadero plunges are to the northeast, and to the south in the
Aratoca area, plunges of folds are to the southeast. This distribu-tion of plunges is domical. Near Mogotes cleavage and foliation strike generally northerly whereas layering strikes generally east-
vest. The area of Silgara' Formation southeast of San Joaquin.and northwest of Onzaga is synclinal if the foliation and layering are parallel. Trends of planar features in the Floresta Formation in this area tend to follow trends in the older rocks. Slip cleavage is prominent in the Floresta here and strikes northerly.

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Ber1in-Vetas-Paramo Santurban area.--The most prominent structural feature in the Paramo de Santurban area is the incomplete dome in the

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Rio Caraba area. This dome plunges moderately southward near the Rio Caraba and gently northward in the Morro Nevado and Vetas areas. The
5- Silgara Formation dips off the doae on the east side and wraps around i the Bucaramanga Gneiss and orthogneiss on the south side. The map pattern of the orthogneiss and Silgara Formation west of Mutiscua suggests the presence of gently plunging isoclinal folds within the
major feature. The orthogneiss appears to represent the core of an anticline and the Silgara to the west a complementary syncline. These
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. folds must be refolded near the Rio Caraba. Further west, toward Vetas and California, the patterns are less clear. Trends are northward and foliation and layering, at least in the western part, dip west. Near Morro Nevado some outcrops show reverse drag folds with westward dipping axial planes indicating overturning to the east. Several large ; isoclinal folds can be seen in the excellent exposures of Bucaramanga Gneiss in this area. However observations are lacking elsewhere so that the complete fold pattern of this belt cannot be determined. East
of Cachiri, the distribution of rock types in the Bucaramanga Gneiss suggests either a westward dipping homoclinal or isoclinally folded
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frequence. South of this area toward California there is no clear
; Pattern.

377

Famplona-Chitaga area. --The metamorphic rocks near Parrsplona and
Chitaga lie in fault-bounded blocks and little can be said about their structural pattern. Trends of foliation and layering are generally northward as elsewhere. At Paciplona the orthogneiss is greatly sheared with vertical shear planes. The Silgara Formation in. the area southwest of Pamplona, near Morro Negro, appears to dip off the Bucaramanga Gneiss east of the intervening Durania Granite. The Bucararaanga Gneiss near Chitaga, on the other hand, dips gently to moderately eastward, but the Silgara Formation further east appears to be folded with assymetry to the west. Information is scanty in the southern part of this belt.
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Barava-Guaca-San Andres belt.--Trends in the metamorphic rocks of the belt east of the Santa Barbara batholith are also northerly. Westward-dipping cleavage and axial planes of minor folds suggest that minor folds in the Floresta Formation are assymetrically overturned to the
east. Plunges of minor fold axes near Baraya and Sari Andres are south-southeastward as in the Aratoca area. There is a general north-west trend to layering and foliation in the area from San Andres south. East-west trends are recorded in the Bucarananga Gneiss west of the Bucaramanga fault in this area.

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Summary. The prevailing structural trends in the metamorpliic
rocks of the southern half of Zone III are northerly vith north-northwest strikes somewhat predominant over north-south and north-northeast strikes* Complexity of deformation seems to decrease from the older to the younger rocks. Where the trends of later deforma-tions departed from those of earlier ones, the imprints of the earlier deformations are blurred. The complex folding seen in some outcrops of Bucaranianga Gneiss cannot be adequately depicted on the geologic maps. Retrograde features in the pre-Devonian metamorphic rocks, local shearing and mylonitization, and lineation in much of the orthogneiss, all attest to a history of repeated deformations, the chronology of which is somewhat obscure. It appears, however, that the orientations of the stress fields of the successive deformations were somewhat similar and that this resulted in folds, foliation, and lineation that trend roughly north-south in all the rocks.

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Limsaments
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Lineaments mapped on aerial photographs were interpreted as i
faults where this interpretation best fitted the map pattern. Else- j
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where the lineaments could be either faults or joints. Most of the lineaments shown in the Rio Negro batholith in northeastern H-12 are joints that reflect a regional fracture pattern in the uniform rock of the batholith. These joints probably formed in connection with ! movements on the Bucararaanga fault. Such lineaments are less evident
in the other batholiths. |
Drainage channels commonly develop along faults and joints ;
j
because of the fractured and generally weakened condition of the rocks in such places. As a consequence, many linear drainage channels are indicated as lineaments on the geologic maps even though little or no j
relative displacement can be detected. In flat-lying or nearly :
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horizontal beds, such as on the Mesa de Los Santos, numerous linear drainage channels are apparent on the aerial photographs, some with relative vertical displacement and others without.

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Zones of mylonite, phyllonite, mylonitic gneiss, and cataclasite
are encountered in many places. Many of these zones lie east of the Bucararaanga fault both near and several kilometers from it. They are not, however, clearly related to it. Dips of some of these zones are gentle in contrast with the apparent steep dip of the Bucaramanga
fault. Near Piedecuesta mylonite strikes into the fault, but it could be argued that raylonite, formed during early movements on the fault> could have been rotated by later movements on the fault. Northeast of Pescadero, near Umpala, mylonite dips gently away from the fault. Mylonite can be traced for about 10 kilometers northeast of Los Curos i
along the contact of the Bucararaanga Gneiss with the La Corcova Quartz Monzonite. This mylonite dips westward, in places gently, into the Bucaramanga fault. It is exposed along the road about a kilometer
I

east of Los Curos (120 IV-B, C-14 SE). Another narrow zone further
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i east within the La Corcova is vertical but also strikes northerly.

Even further east and exposed on this same road near the east contact
of the La Corcova with the Bucararaanga Gneiss is another mylonite zone within the Bucararaanga Gneiss that dips gently to moderately westward
Into the adjacent more steeply-dipping intrusive contact. l

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Sheared rock dipping gently west was encountered at places along
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the Rio Sevilla to the north, A very narrow zone, less than a meter
wide and dipping gently east, crops out at the contact of the Silgara Formation with Bucararaanga Gneiss and La Corcova Quartz Monzonite west of Alto El Picacho on the Bucaramanga-Paraplona highway. One or the other of these zones may connect with the zone on the east side of the La Corcova Quartz Monzonite on the Los Curos-Guaca road to the south. Narrow zones of mylonite crop out in the Bucaramanga Gneiss on
the Bucaramanga-Pamplona highway a few kilometers air-line east of Bucaramanga. On strike and further north, westward-dipping, mylonite
X /

and phyllonite crop out along the west side of the Rio Surata and in
x x

j places in the block of Bucararnanga Gneiss east of the Rio Surata where moderate dips both to the east and west are encountered. With more detailed work it might be possible to trace out zones of mylonite and to connect some of the outcrops described above. Zones of mylonite are not readily seen on aerial photographs because of the relatively competent character of the rock and/are often overlooked in rapid reconnaissance mapping in the field.
Elsewhere in the zone, mylonite crops out in dioritic orthogneiss southwest of Babega (110 IV-C, E-l NW). The orthogneiss near Pamplona
is markedly sheared. Mylonite dips westward in orthogneiss near the
' x- ' contact with the Floresta Formation south of Covarachia.

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Soma of the mylonite may be related to late high-angled fault5 *
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However such faults are generally more typically characterized by ;

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breccia with open voids and discrete surfaces with slickensides and in some cases by hydrotherraal alteration. The broad range of attitudes , i
of the raylonite and the commonly moderate or gentle dips, as well as its tight,-competent character indicate that it represents an older
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generation of faulting that took place deep in the crust. A detailed i
study of the mylonite zones and their distribution might reveal that
i
the Santander massif at one time underwent appreciable low-angle
I

thrusting. These zones, like some of the rock units, have been perhaps folded and dislocated by later faults. The antiquity of some mylonite is indicated by the presence of pebbles of raylonite in conglomerate of the Bocas Formation of Triassic age found north of Bucaramanga and
|
west of the Bucaramanga fault. The presence of these clasts of | ,mylonite indicated fault movements in Triassic or pre-Triassic time. Some mylonite could be as old as the proposed late Ordovician Orogeny

/ that metamorphosed the Silgara Formation. That some mylonite is related

to the Bucaramanga fault cannot be ruled out. Some mylonite zones
may mark local thrusts contemporaneocs with lateral movement on the Bucaramanga fault.

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Faults of pre-Cretaceous age
- - "A thrust fault
system older than the emplacement of the tonalite and granodiorite of Paranc Rico pluton has been postulated around the south end of the Rio Caraba dome as described in the section on northerly-trending faults below. | i
The outcrop pattern of the continental deposits of Triassic and Jurassic age suggests deposition in north-trending basins separated by positive areas or it suggests post-deposition differential uplift and erosion with north-south central in pre-Cretaceous time. In either case faulting may have played a part. Conglomerates in the Bocas Formation near the hydro-electric plant on the Rio Surata northeast of Bucaramanga (109 IV-D, G-2 SW).contain pebbles of mylonite and granite of a type present in the massif to the east.
This shows that part of the massif was exposed in Triassic time. Faulting may have contributed to the uplift.
Julivert and Tellez (1963, p. 9-15) have presented estimates that
the
Aratoca and Surata faults were active in pre-Cretaceous time and that the Surata fault had a sense of movement opposite to that which it has had since the Cretaceous.

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The structural control for the emplacement of the batholiths was discussed in an earlier section. The strong north-south control
evident in the distribution of the batholiths and in the linearity of
their eastern and western margins suggests prebatholith or pene-contemporaneous fault control. The age of these faults would be no
younger than early Triassic to Jurassic. They probably are younger than the marine deposits of Permian and Carboniferous age.

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BucatTvmanea fault

I The Eucaramanga fault dominates the fault pattern in the southern
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half of Zone III (fig. 11). Tt is a fault of regional extent that can

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be traced from near the southern end of the Santander massif to the Caribbean coast west of Santa Marta where it is called the Santa Marta fault. The name Santa Marta fault has been applied to the" fault in
the Bucaramanga area as well. We prefer to keep the name Bucararaanga fault for that part of the Santa Marta-Bucararcanga fault system in
Zone III, at least for that part south of Ocana, because the fault is not a single straight lineament but appears to be a system of some
i complexity (fig. 11). Clear topographic expression of the fault
s ^

system is limited to the area south of the Rio Cesar valley (all of i

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i fig. 11). To the north, the Santa Marta fault is expressed chiefly
in the sub-surface (Tschanz, written commun., 1968).

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I The most prominent feature of the Bucaramanga fault in the

Santander massif is its topographic expression, although there are

;some areas where this is obscure. Throughout most of its extent it
i
;presents a remarkably straight lineament expressed by aligned valleys i
1 and differences in rock units on either side, observations consistent I
i
with the view that the fault has a steep dip. The apparent steep dip

of the fault and the long distance through which the lineaments can

be traced suggest that the fault is a major wrench fault as discussed
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(by Raasveldt (1956) , Rod (1956), Young (1956), Alberding (1960),
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[Moody and Hill (1956), and Campbell (1965). Campbell calculates a
i
left lateral strike-slip displacement of 110 km for the fault. On

\ different evidence, Tschanz (oral commun.) calculates a similar strike-! -"" ^ '""

; slip displacement of about 100 km. Julivert (1958, 1961, 1970), however,

looking at the evidence in the Bucaramanga area, stresses the importance

i of the vertical component. He visualizes the Bucaramanga fault to be

; a bounding fault of an uplifted mountain block with primarily vertical

displacement. A full discussion of the Bucaramanga-Santa Marta fault

system and its relation to the tectonics of northern South America

is beyond the scope of this report and the following discussion
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will relate to the fault as it appears in the report area.

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In detail the Bucaramanga fault appears to be a zone of faulting
in which one particular fault carries the major displacement. Zones
of parallel faults have been observed in some places as near
Bucaramanga, and lineaments parv-llel to the main fault have been observed in other places, particularly north of Bucaramanga. There
is no great crush or breccia zone comparable to that reported by I
i
Feininger (1970, p. 1203) along the Palestina fault in i

eastern Antioquia, nor any widespread mylonitization. The fault zone :i
contains much fractured and locally sheared rock and numerous j
i
slickensided surfaces oriented in different directions. No systematic i
study has been made of orientations of slickensided surfaces or |
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striae. Individual fault surfaces that have formed during the latest i movement dip steeply. As mentioned in a previous section, mylonite
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zones, probably in part older than the Bucaramanga fault, dip |
moderately to gently into it or away from it. The mylonite zones are,
in some places, cut by the steeper faults.

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The Bu'caramanga fault has a fairly straight southeasterly trace with a few fault slices from the north edge of quadrangle H-12 (c-1)
to the Rio Manco near Los Curos (d-7 NE). This trace is interrupted only where the fault has been offset by northeast-striking faults.
The fault assumes a nearly south strike from Los Curos south to near Cepita (1-13, a-1 NW) where its strike once again is southeasterly
but less distinct. Although several lineaments exist in this sector, the rocks on either side of the fault are somewhat similar, and it is difficult to tell which lineament corresponds with the major fault, particularly near Capitanejo in quadrangle 1-13. Possibly the fault splays out in this area.
Julivert C1961a, b) shows the Bucaramanga fault as one of a series
of high-angle reverse faults with ,the east block upthrown that formed during the development of the present Magdalena Valley and the concomitant rise of the Santander massif. Present observations s^eia to support this interpretation. Lower Mesozoic and Upper Paleozoic strata are vertical to overturned in places near Bucaramanga fault on the west block in the Piedecuesta and Floridablanca areas (H-12, d-6, d-5) indicating that here relative movement of the east block was upward and westward. North of Bucaramanga the attitudes of beds near
the fault are inconsistent. Immediately north of Bucaramanga along the Rio Surata, a block of sedimentary rocks in normal sequence dips
into the fault. This is in an angle or reentrant where the Bucaramanga fault is offset and this block may have been rotated.

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From the north edge of the geologic map (pi. 1) to the Umpala-
Cepita area (H-13, a-8 KW; 1-13, a-1 NW), rocks are older and topography is higher northeast of the Bucaramanga fault than to the southwest. Southeast of Cepita the age relationships of the rocks on j the two cides of the Bucaramanga fault are reversed. The relatively older rocks are in the west block. In this sector the fault passes between the Mogotes and Santa Barbara batholiths, and lithologic contrast between the two blocks is lost. In this sector too^little difference in elevation exists between the two blocks.
Topography on either side of the fault is not a consistent indicator of throw on the fault, nor is age of bedrock in the two blocks a consistent criterion. The observations suggest that appreciable erosion has taken place since any major fault movements occurred and also suggest that movement along the fault is. primarily lateral.
Although Campbell (1965) showed illustrations indicating left-lateral displacement of streams flowing across the trace of the Bucaramanga fault in the Bucaramanga area, no apparent systematic offset of streams exists along the fault in the length from Bucaramanga to the northern edge of the zone. For example, Rio Santa Cruz is deflected southward along the fault before turning east to the
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Magdalena Valley, but Rio Cachira north of the map area is deflected northward.

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i Several features in the southern half of Zone III support the

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I interpretation that the Bucaramanga fault is a major wrench fault of
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; considerable displacement. The elongate, thin south end of the Rio
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Negro batholith could be interpreted as a "drag tail" along a fault

of left lateral displacement, as might the little mass of quartz

monzonite at Bucararaanga be a "drag slice." Equally as suggestive
is the similarity of the Rio Negro and Mogotes batholiths with their

j quartz monzonite phases and their granodiorite phases in similar

!

relative positions. However, geologic control on either side of the

i fault is not good enough to demonstrate convincingly the amount of

strike-slip movement, if any, that occurred on the Eucararaanga fault.

The linearity and length of the Bucaramanga fault suggest that
it is primarily a strike-slip fault of major proportions. The presence of features that could be interpreted as drag tails and drag slices would support this concept. It is also possible to match in a crude way displaced rock units on either side of the fault.
Yet near Bucaramanga, the fault clearly has vertical displacement with movement of the east block up and to the west and regionally it seems to be part of a system of faults involving the develoment of the Magdalena Valley and the rise of the Santander massif. It is quite possible that the Bucaramanga fault has been the locus of move ments of different styles and at different times. The latest move-ments appear to be those related to uplift of the massif. The Bucaramanga fault is probably a very old fault that has a long and complex history.

i Structural features east of the Bacaramanga fault
i
The Bucararsanga fault divides the report area into two large
structural provinces, the Stintander i.ir=sif to the east and the mesa-
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i plateau-basin region to the west.
! In the northern part of the Santander massif, sedimentary rocks which once covered the massif have been preserved in long belt-like remnants bounded on one side by north- or northwest-trending faults
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(pi. 1 and sections A-A!, B-B!). On the west flank of the massif, the uplifted blocks within the massif are on the west sides of the faults, whereas on the eastern flank the uplifted blocks are on the east sides. This gives the impression that during post-Cretaceous faulting the central part of the massif has collapsed or settled relative to the flank areas.

In the southern part of the Santander massif, north- and north-west-trending faults are prominent. Here two large areas of sedimentary rocks are preserved in what appear to be structural basins
or complexly faulted areas that subsided prior to elevation to their
i
present positions. |

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Western flank of the Santander massif !

Northeast-trending faults are prominent in the southern half of
Zone 111, particularly in the area immediately to the east of the Bucaramanga fault. They are younger or penecontemporaneous with the Bucaramanga fault, for where they intersect it they appear to offset it with a general right-lateral, and rarely left-lateral sense of horizontal displacement. Faults with right-lateral displacement 6.**e near El Playon (H-12, c-1 NW) and several small faults are to the south, one being at R£O Negro (H-12, c-3 SE). The largest offset, at least 750 meters, is along the Surata fault at Bucaramanga. Other northeast-trending faults with right-lateral displacement are near Piedecuesta (H-12, d-6 NE) and near Cepita on the Rio Perchiquez fault 1 - sense of
(H-13, a-8 SW). The/displacement is less certain at other places such as along the Rio Manco fault (H-12, d-7 NE) and the Rio Urapala fault (H-13, a-8 NW). Left-lateral movement of small displacement occurred on the Sevilla fault just north of Los Curos (H-12, d-7 NE). Left-lateral movement may also have occurred on two faults between Rio Negro and El Playon, but the presence of alluvial cover at the critical places renders this unproved. * i Vertical movement iB apparently also involved in some of these
faults. The fault north of Piedecuesta (H-12, d-6 NE) offsets the
La Corcova Quartz Monzonite in the opposite sense than it does the Bucaramanga fault.

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Surata fault:.--This fault, which extends northeastward from
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Bucararaanga approximately parallel to Rio Strata, is the largast of
the northeast-trending faults on tha east side of the Bucaramanga
fault. Near Surata CH-13, a-2 NW), where the Upper Cretaceous Umir Formation is in contact with the Silgara Formation of pre-Devonian age, the throw of the fault is estimated to be at least 2100 meters (assuming a thickness for the Cretaceous section of 1000 meters). ; Near the northern edge of H-13, where the fault has a northerly trend, the Giron Formation overlies the Silgara on the western side of the fault. The narrow belt of Cretaceous rocks ends about one kilometer north of the map boundary, but the fault continues to the north through a synclinal area containing recks of the Gircr, ar.d Eccas Formations.
In the Cretaceous rocks east of the fault, strike faults cause repetition of the lower part of the section as can be seen along the road from Surata to California. The faults appear to be concentrated in the shales of the Paja and Tablazo Formations. Higher in the section there is considerable small-scale folding and contortion of the beds that is difficult to recognize in the lower black shales but which is readily seen in the distinct thin beds of the La Luna Formation.

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One kilometer southwest of Surata is a small angular fault block
of Lower Cretaceous rocks adjacent to the Surata fault on the west and apparently in fault contact with the Umir shales on the north, south
and east. Inasmuch as the Cretaceous rocks are progressively younger
from the normal contact along the east margin of the belt toward the Surata fault on the wast, the only probable explanation for the anomalous presence of this block is that it somehow failed to undergo the full displacement that is indicated elsewhere along the fault.
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Julivert and Tellez (1963, p. 9-15) point out that the Surata
fault has a history of pre-Cretaceous as well as post-Cretaceous movement. To the southwest of the belt of Cretaceous rocks, pre-Cretaceous rocks of the Bocas, Jordan, and Giron Formations are present in blocks that are bounded by faults which separate them nearly everywhere from the Cretaceous rocks (H-12, d-3 E).. These blocks were apparently saved from pre-Cretaceous erosion by being downfaulted into the pre-Devonian metamprphic rocks.
The Surata fault splays out at its southern end where, as mentioned before, it offsets the Bucaramanga fault.

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Cristalina fault.--This fault of north-ncrthvest trend (H-13, a-2, a-3,
and a-4) places Lower to Upper Cretaceous o£diaent£.ry rocks on the
east in contact with pre-Devonian orthogneiss and the Silgara Forma-
tion on the west. About one-half kilometer west of Charta (a-3 NW),
the fault is exposed in a cut on the north side of the road where the Tablazo Formation is in contact with orthogneiss. At its southern end, the fault makes a broad curve toward the east and dies out in the
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orthogneiss west of Berlin (a-4 NO. It is apparently offset by cross faults in several places. North of Quebrada La Rinconada, where it is offset to the northeast by a northeast-trending fault along this quebrada (H-13, a-3 NW), the Cristalina fault apparently dies out in the Cretaceous sedimentary rocks east of the Surata fault. The maximum throw of the fault is estimated to be at least 140O meters.

Tona fault.--This fault extends from the Cristalina fault (H-13, a-3 SW) on a south to south-southwesterly trend through the town of Tona to the Sevilla fault north of Sevilla (H-12, d-6 NE). It extends through pre-Devonian metamorphic rocks except for a three-kilometer segment near the middle where the Giron and Tambor Formations of the Picacho syncline on the east are in contact with the Silgara Formation and quartz monzonite on the upthrown west side. The southern boundary of this block of sedimentary rocks is an east-trending fault which is upthrown on the south side. On the south side of this fault the Tona fault is displaced slightly toward the west. The estimated minimum throw of the Tona fault is 300 meters.

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! Plcncho svrcHne.--This indistinctly synclinal area which includes i
| sedimentary rocks of the Giron, Tambor and Rosa Blanca Formations i
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i (H-13, a-4 SW and a-5 fiW), is about 12 kilometers from north to south

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i and less than five kilometers in maximum width. Only a thin section of the Giron Formation is present in the northern and western parts
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where the underlying rocks are mostly pre-Devonian orthogneiss and Silgara Formation. In the east, where the Giron is absent, the Tambor;

overlies the Santa Barbara Quartz Monzonite. The normal contact of i
; sedimentary with metaraorphic rocks along most of the western boundary contrasts with the areas of sedimentary rocks to the north where the ! ' Surata and Charta faults mark the western boundaries of the belts of

\ sedimentary rocks. ,i
Picacho and Sevilla faults.--These parallel south-southwest;-trending
i
faults extend across the middle of the Picacho syncline from its '
i
northeastern boundary into the pre-Devonian "Silgara Formation and |
Bucaramanga Gneiss. The Picacho fault ends against the Tona fault

near the boundary between H-12 and H-13, whereas the Sevilla fault '{
i extends on to the Bucararnanga fault and produces a slight offset in
| that fault north of Los Curos (H-12, d-7 NE). The upthrown sides of both faults are to the west. Near Alto El Picacho (H-13, a-5 NW), where the Picacho fault is well-exposed on the Bucaramanga-Paraplona highway, the vertical displacement on this fault appears to be 400-500 meters. The displacement on the Sevilla fault may be even greater.

Rio Manco, Rio Urr.pala, and Rio Perch!;;;. i- _i .vjL_l_t_3. --These taults or northeast trend extend from tha Bucarr.,. .ir.£,a fault across the igneous
3 ' and raetamorphic rocks for lor-g distances in the southwestern part of H-13. Where they intersect the Bucaramcinga fault they produce right lateral displacements.

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Eastern flank of the Santander raassif

Major north-trending faults extend frora the northern edge of H-13

/ ' , in the Paraplona and Mutiscua areas south to the Soata area in 1-13

Most appear to be normal faults, sorae of which have
quite large displacements that bring rocks of Early Paleozoic or Precarabrian age against rocks as young as Tertiary. In places the faulting displays imbricate patterns with criss-crossing north- and northwest-trending segments. The pattern of the post-Cretaceous
/
faults in the Paraplona-Mutiscua area is to bring up older recks on the north and east sides. In the northern part of H-13, some of these faults are interpreted as thrusts. Pre-Cretaceous faulting occurred

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north of Mutiscua on the Mutiscua and Sulasquilla faults and southeast
of Chitaga on the Chitaga fault. On the Mutiscua and Chitaga faults,
the pre-Cretaceous movement was opposite to that on the post-Cretaceous faults, placing strata of Devonian and Permian to Carboniferous age on
the east side in contact with rocks of pre-Devonian age on the west.

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Mut iscua and Rio^_^i 1 a^cui 1 la f_au11 s . - -The presence of rocks of the Floresta and Diamante Formations between these two north-trending faults (H-13, b-1 E and b-2 E) suggests that the two formations occur in a graben and thereby escaped pre-Cretaceous erosion. The presence of a generally synclinal area of Cretaceous rocks overlying the Floresta in the northern part of the graben indicates that there was further movement on these faults in post-Cretaceous times. In the area of these Cretaceous rocks, vertical displacement by the post-Cretaceous faulting is estimated at a minimum of 10OO meters on the Mutiscua fault and 1500 meters on the Rio Sulasquilla fault. The amount of pre-Cretaceous displacement cannot be estimated.
The Mutiscua fault extends from the northern boundary of H-13
(b-1 NE) southward to Mutiscua near where it is offset by two cross faults (b-2 SE). It may continue southward from Mutiscua in the Silgara' Formation along Quebradas La Laguna (Rio La Plata) and La Honda to terminate at another fault northwest of Silos (b-4 NE), but
/
this is not clear. The continuation of Rio Sulasquilla fault is unclear also. It apparently dies out beneath the long belt of Cretaceous rocks that lie west of Morro Ne°;ro fault.

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I a-iuna f aul t. - -Thib fault trend3 south and south-southwest from east
i of Mutiscua (H-13, b-3 E) and has Cretaceous rocks on the east side in : contact with pre-Cretaceous rocks on the west. The fault dies out
south of the village of La Laguna (Montegrande on topographic maps) beyond which the Cretaceous rocks overlie the Silgara in depositional contact. The thick section of sandstone of the Aguardiente Formation
!

I forms a prominent high ridge in this block of Cretaceous rocks.
i . \ \ Spcota and Angosturas faults.--Except for the northern part of the
i

, Socota fault, these two generally south-trending parallel faults i
i define a narrow graben in which mostly Jurassic and Lower Cretaceous
! rocks are exposed (H-13, b-4 E and b-5 E). The Socota'fault on the

i (i
east extends frora its intersection with the Laguna fault southward along the western slope of Cuchilla Socota. South of Rio Caraba it crosses from the west side to the east side of the canyon of Rio Angosturas and continues parallel to that stream toward the central ridge of the massif. The north end of the Angosturas fault is east
of Silos frora where it extends southward at distances varying from 0.3-1.3 kilometers vest of Socota fault. The two faults may join and continue on into the southeastern part of H-13, but this is not clear. In b-5 E, where Rosa Blanca limestone of the graben is in contact with ^ i
Silgara Formation on the east side of Socota fault, the minimum vertical displacement of the fault is estimated at 1500 meters. On the Angosturas fault to the west, a throw of 1200 meters is estimated, based on the presence of an isolated remnant of the Tcnbor Formation lying on the Giron Formation in a synclinal area about two kilometers
- Vest of the- fault (b-5 Si:).

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"f '"*' '"^" ~i'*, - -',-^- ' .'"'" '* '" v?~ , '" ' J* ,'. " : x1"". --". ' '-.-' .'-. -'. " .' - J- ;'- '-B'^*"'

' YrtV '.-",v;.*'-.-i'*"

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Mqrro Negro f^ult aj^d^Carbonera^ s vncline .--This f au It t rac e s a broad
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arc from the northern boundary of H-13 southward to the Mutiscua area
and then southeastward to where it intersects and offsets the Chitaga fault (H-13, c-1 W to c-4 NW). The belt of sedimentary rocks on the west side of the fault contains Cretaceous and Tertiary formations, possibly including the Mirador. The outcrop of the Aguardiente Formation makes a prominent ridge in the northern and southern parts of the belt but is less prominent in the central part. The Tertiary rocks form the narrow, sharply-defined Carbonera syncline with its axis along Quebrada La Carbonera which parallels the fault about 400 meters to the west (c-3 W), '< Along the northern half of the fault, overthrusting is indicated
by the trace of the fault with respect to the topography. Where it was observed on a farm road west of the unfinished road from Pamplona to Cucutilla (110-II-A, J-2 SW), the fault dips eastward at a low angle. In the southeast-trending southern half of the fault, left lateral movement is indicated by an offset of about one kilometer in the Chitaga fault. However, the offset in the southeastward-dipping Cretaceous formations across the fault in this locality is the opposite of that in the Chitaga fault, suggesting that the Chitaga fault may dip to the northwest and that the offsets across the Korro Negro fault are mostly apparent offsets due to vertical displacement of dipping components rather than true offsets due to lateral displacement. The trace of the fault is generally well-defined by breaks an-1 irregular-
s in the topography than can be seen on aerial photographs exo.pt
n it crones the Durania Granite (c-3 S'.O.

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The belt of sedimentary rocks west of the Morro Negro fault ends abruptly against the north northeast-trending Babega fault (c-3 NW) which terminates at the Morro Negro fault where the vertical displace-ment on the latter is probably at a maximum. The minimum displacement on the Morro Negro fault is estimated to be 2300 meters.

Babega fault.--From its termination at the Morro Negro fault, the Babega fault extends south southwestward to Babega and beyond, and, as shown on plate 1, possibly continues to a termination at the Socota fault in Quebrada El Oso (H-13, c-3 SW to b-5 NE). Assuming that the fault is continuous as indicated, rotational movement has occurred about an axis normal to the fault in the central area where orthogneiss (pDo) on the southeast side of the fault is in contact with orthogneiss (pDod) on the northwest. Northeast of this axis, older rocks are on the southeastern side of the fault, whereas to the southwest the older rocks are on the northwestern side, and relative, displacement increases from zero at the axis to maxinums at the ends of the fault. Such an explanation of the present structure appears quite possible for the northeastern part of the fault but is not as applicable in the southwestern part. There the irregular trace of the fault on the eastern slope of Rio Angosturas indicates a strong east dip on the fault plane. The minimum vertical displacement at the northern end of the Babega fault equals the 2300 meters estimated for the Morro Negro fault in this locality where Tertiary rocks are in contact with pre-Devonian rocks and Durania Granite.

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Par: olona fault.--This fault extends into the report area from the
north and continues with south to south-southwest trend west of
Paisplona to terminate at the Morro Negro fault (H-13, c-1 W to c-3 W). Along most of its northern half, pre-Devonian orthogneiss on the east
is in contact with a narrow belt of Cretaceous rocks on the west, up
to and including the La Luna Formation. Sandstone of the Aguardiente Formation forms a prominent central ridge throughout the length of this belt. Beyond the southern end of the belt, the fault cuts across the pluton of Durania Granite and then becomes the boundary between this granite and the Silgara Formation to the west. South of a northwest-trending fault that offsets it slightly to the east (c-3 W), the Pamplona fault again cuts through Durania Granite to its termination at the Morro Negro fault.
Northwest of Paraplona, where the Tibu, Mercedes, Aguardiente, and

Capacho Formations are present west of the fault, the vertical i displacement is estimated to be 2000-2500 meters. Near the north boundary of H-13, where the La Luna Formation is present, the displacement may be even greater.

Chitaga fau11,--This is the largest and longest fault on the eastern flank of the Santander massif in the report area. From a southerly trend in the northeastern part of H-13 (c-1 and c-2), it curves south-
, ' s
i westward to Rio Chitaga and follows the broad arc of that river around
a wide area of pre-Devonian arid Devonian rocks in the eastern part of
the quadrangle (H-13, c-3 to c-6).

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In the area east and northeast of Pair.plor.a, the Pamplonita
sync line borders the fault on the west, and thrust faults are included
in the highly complex fault pattern of that area. Giron Formation
rocks have been thrust westward over Cretaceous and Tertiary rocks,
and the Bocas Formation in turn has been thrust westward over the
Giron. The section of Bocas shales, orthoquartzites, and feldspathic sandstones is estimated to be 2700 meters thick. Southwest of ; Pamplona, a small pluton of quartz monzonite (eg) appears to be thrust westward locally over Cretaceous and Tertiary rocks (c-2 E), although this is not clearly evident in the field. ; South of the Pamplonita syncline, the trace of the Chitaga fault
is much more regular where Bucaramanga gneiss has be,en brought up on the eastern side for a long distance. About 4 kilometers south of
the offset caused by the intersecting Morro Negro fault (c-4),. another intersecting fault that causes approximately equal displacement, but of opposite direction, restores the fault trace to its original course. South of Chitaga the fault changes trend to southeasterly and
follows Quebradas Sorotaraa and El Queraado where the Floresta Formation is on the upthrown northeast side. In Quebrada El Queinado and south-eastward to the boundary of the quadrangle, Bucararaanga Gneiss is on the southwestern side of the fault, indicating that pre-Cretaceous movement occurred on the fault opposite in direction to that of the post-Cretaceous faulting.

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Central area of the Santander massif '

In this area where altitudes range from 3,000-4,500 meters,
extending across H-13 from northwest to southeast, rocks are less weathered and better exposed, and as a consequence the structure is better defined in most places than in the flank areas. 1 In the northern part of the massif, where pre-Devonian raeta-
morphic rocks predominate, fault trends vary from northeast to north-west, with north-northeast trends somewhat more common than others.
In the southern half, an area with mostly sedimentary rocks ranging from Devonian to Tertiary, strikes of folds and most major faults fall within a narrow range of north to north-northeast. Short cross faults of northeast to east trend are numerous in the eastern part of this area but do not represent major movements.

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Rio Cucutilla fault,--The Rio Cucutilla fault forms a marked lineament more prominent north of the map area than within it. It enters the

: map area in north-central H-13 (b-1 NW), but immediately becomes
indistinct and branches. What appears to be the main branch trends
' /
southward to cross Rio Vetas and Paramo Rico where it intersects the Charta fault (H-13, a-2 E, a-3 E). A branch of the fault may connect
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with a probable fault along Rio Eaja. The mineralisation in the Rio
Baja area may have some connection with the Rio Cucutilla fault, if not directly on the fault itself, then in satellitic faults at an angle
to the main fault. Displacement on the fault is undetermined for the rocks on either side are ..similar and no displacement is evident, .

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I Rio Charta f?.ult.--A remarkable arc-like northwest- to west-trending fault southeast and east of Charta (H-13, a-3) chows little apparent vertical displacement but appreciable left-lateral horizontal displacement. This fault extends from the Charta area across the southern part of the Paramo de Santurban to Rio Caraba. East of the Berlln-Vetas road this fault is no more than a lineament, but in Rio
/
Caraba it appears to cut the nose of the Rio Caraba dome and postulated / '
thrust faults between orthogneiss and the Silgara Formation in the Rio Caraba area.

Ventanas fauIt,--The west contact of the mass of orthogneiss west of Mutiscua (H-13, b-3 C) that passes near Morro de Ventanas north of the /
Rio Caraba is shown as a fault which has placed the orthogneiss over the Silgara Formation. The inference is that this mass of orthogneiss is an anticline with the west limb overturned and faulted. Near Rio

Caraba two faults are indicated. One with gentle dip has been offset f , .^ .
by the other which has a steeper dip (pi. 1, sec.B-B 1), The gently-dipping fault is interpreted as a thrust on the quadrangle map of H-13 (pi. -1) and is shown as having been cut by the normal fault along the
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Rio Caraba, The continuation of the postulated thrust on the block

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south of Rio Caraba is drawn in the area between Volcan Amarillo and Cerro El Albedri north of Berlin (H-13, a-35E). This thrust predates the intrusion of the tonalite and grenodiorite of the Paramo
Rico pluton, A discordance in attitudes in the gneisses on either side of this thrust is not matched by any possibly related feature in
the adjacent tonalite and granodiorite.

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Servita fault.--Frcm its termination at the Babega fault, the Servita fault trends southward with slight deviations and becomes the boundary between the Malaga structural basin to the x^est and the Cerrito structural basin to the east (H-13, c-4 W to c-8 W). The Giron
Formation is exposed along most of the western side of the fault in
H-13 where it is in contact with mostly Upper Cretaceous and Paleocene rocks on the east. The largest vertical displacement is in the northern part (c-5 W) where the Servita and Chitaga faults define a short graben-like area about four kilometers wide that appears to be a northern extension of the Delgadito syncline. Inasmuch as the older Tertiary beds on the west limb of the syncline are overturned and dip westward, an asymmetrical syncline probably lies at depth, and the vertical displacement of the fault may exceed 3000 meters. The fault dies out rapidly to the north where orthcgneiss occurs on both sides at the north end. Displacement decreases gradually to the south, and the fault splays out in the Cretaceous formations in the southern part
of H-13. :

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Malaga structural hasin.--This portion of the central region of the massif is a roughly elliptical synclinal area with long axis trending north-south. It is defined on the west by the boundary of the ; Floresta Formation with pre-Devonian metamorphic rocks and the Santa Barbara batholith and on the east by the Servita fault. It extends from the central part of H-13 southward into 1-13. Within this large area the sharply defined Angosturas sync line is the dominant feature
of the eastern part of the basin, whereas north- to northeast-trending faults are dominant in the west. Pre-Devonian rocks crop out only in a small area in the northeast (H-13, b-5 SE) where they have been raised on the eastern side of the Socota fault. Santa Barbara Quartz Monzonite is present in the same area and in a small outcrop about five kilometers to the southwest.A fev masses of basic igneous rock intruded /
the Giron Formation of which the most notable is a sill of andesite about 75 meters thick that was found near the Giron-Tarnbor contact
about 10 kilometers east northeast of Guaca (121 III-B, E-10 W).
Similar rock, possibly the same sill but thinner, was found in similar
st ratigraphic position one and one-half kilometers to the northeast
(D -11 SE).

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Although the basin appears to result from tectonic rather than depositional activity, the thick sections of coarse sediments of the Jordan and Giron Formation suggest that it was also the site of a
! rather narrowly defined depositional besin during Jurassic time, complementary to the thick deposition west of the Bucaramanga fault
and derived from the intervening Santa Barbara bathoiith and the older rocks that originally covered it and that flank it on the east and
west. The Cretaceous rocks, of which the youngest is the small area
I of La Luna Formation a few kilometers southeast of Guaca (H-13, b-7 SW), i i
i are quite similar in character and thickness to the Cretaceous else-
1

| where in the region of the massif, and they do not suggest that there
j was any localized basin of deposition in this area during Cretaceous

i time. Isolated remnants of Tambor, sandstone at the base of the ii
Cretaceous section, lying on pre-Cretaceous rocks of various ages, are

; indicative of the continuous and uniform nature of the Cretaceous I

deposition. The lithologic variation of the pre-Cretaceous surface is j strikingly revealed in the western half of the basin. Along the

I; western limb, Cretaceous rocks lie directly over beds of Devonian

whereas a few kilometers to the east a thick section of the Bocas, Jordan, and Giron Formations is exposed along the east sides of the faults. Possibly some of these rocks were saved from pre-
Cretaceous erosion as down-faulted blocks that have since been raised by reverse movements.

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_3araya_faul.L.--This north-trending fault on the west side of the basin has brought pre-Cretacsous rocks up on 'the east side of the fault into contact with Cretaceous rocks on the west (H-13, b-6 W to b-8 W).
South of the Rio Listara fault, it is offset one-half kilometer to the east, beyond which it continues southward into 1-13. East of Guaca, where rocks as old as the Floresta Formation are in contact with the Upper Cretaceous La Luna, the minimum displacement is estimated to be not less than 2000 meters. Locally in this area the fault plane has a low angle of dip to the east where the Bocas Formation has been thrust westward over the La Luna. Northward from this area the displacement decreases gradually and the fault splays out north of Baraya in the El Portillo area.

. Alto de Guaca fault.--This north-trending fault is approximately parallel to the Baraya fault and 2 to 4 kilometers to the east (H-13, c-6 to c-8). In the ridge east of Alto de Guaca (c-7 SO and on the slope southward to Rio Listara, the fault is well-exposed, with gray shales of the Bocas Formation on the east in contact with Jordan red beds to the west. Elsewhere also, older recks are exposed on the east side of the fault except for a downfaulted anticlinal block of the Giron a short distance north of Alto de Guaca.

There is no clear extension of the fault south of the Rio Listara
, fault. In its northern part, it is. offset to the east by an inter-secting northeast-trending fault, and it then swings toward the
i northeast and dies out near the Angosturas fault. Vertical displace-
!
s- raent across the fault cannot be estimated, but considering the
smaller differences in rock ages on the opposite sides as compared
| with the Baraya fault, the displacement must be considerably less

I ' than that of the Baraya fault.
i
Morro Las Fenas fault.--This north-trending fault is approximately parallel to the Baraya and Alto de Guaca faults and about A kilometers east of the latter (H-13, b-6 E to b-8 E). It has similar relative displacement, with older rocks upthrown on the east side. From its
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termination at the Rio Listara fault, it extends northward on the east side of Morro Las Penas (b-7 SE) with Giron rocks on the east in contact with Cretaceous rocks on the west. -Farther north it continues as a well-defined lineament through the thick Giron section and possibly extends to the junction of the Angosturas and Socota faults (H-13, b-6 NE), although this is not clear.
Maximum vertical displacement along the Morro Las Penas fault
occurs northeast of Morro Las Penas where Aguardiente sandstone is
in contact with Giron beds. The displacement there is estimated to be 1,600 meters.

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In the southern part of H-13, the sync line loses its symmetrical appearance rather abruptly south of an east-trending cross fault on
the east limb (c-7 SW). The Giron is no longer exposed on the east
limb which is obscured by local folding, and the main axis is shifted toward the west. . ;
i

Cerrito structural basin.--This large feature, bounded by the Servita fault on the west and the Chitaga fault on the east, is somewhat similar in shape to the Malaga structural basin but with axial trend of north-northwest (H-13, c-5 to c-8). The contrast in stratigraphy-is very great however. The Tertiary and Upper Cretaceous rocks that are the most commonly exposed in the Cerrito basin are absent in the Malaga basin, whereas the Giron and older rocks that are the most widespread in the Malaga basin are not exposed anywhere in the Cerrito basin. The structures of the area are well displayed on aerial
!

photographs by the outcrops of the thick sandstone sections of the
i
Barco and Mirador Formations. j

Although faults are numerous, folding is the more striking
structural feature. The Delgadito sync line is the largest and longest in the basin, and its axis corresponds to the long axis of the basin, trending N. 15 -20 W. and extending northward, beyond a highly

/ / faulted area, into the graben between the Servita and Chitaga faults.

To the southwest of and parallel to the Delgadito syncline are the Vado Ancho anticline, La Arena syncline, and Pescaditos anticline, of which the axis of the last named corresponds to the long, curving Pescaditos fault. West of the Pescaditos fault is the Almorzadero syncline with axis trending south-southwest and changing to south-southeast. This axis, if projected on to the southeast, nearly coincides with the axis of the El Coronal syncline southeast of
Cerrito (c-8 W). :

Westward from the Delgadito syncline, folding is progressively i i
| sharper until the limbs are nearly parallel in the Almorzadero syncline. The coal in beds near the base of the Los Cuervos Formation is very hard and has apparently been compressed to about half the

I :: thickness that is found in mines 20 kilometers to the north.

Numerous cross faults offset the axes of the synclines and
anticlines. The trend of these faults varies from east to northeast,

, and in the northern part of the basin (c-6 W) there are also short i

!

! cross faults of northwest trend.

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In the eastern part of the basin, where a full section of
?

i ! Cretaceous rocks is exposed above Bucaramanga Gneiss, folding and I faulting complicate the structure of the Upper Cretaceous formations
as revealed in the outcrop pattern of the La Luna Formation. A strike
5- fault in the northern part of this area (c-6 SE, c-7 NE) has raised
the southwestern side, resulting in repetition there of the Upper Cretaceous section that is exposed northeast of the fault.

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Structural features west of the Bucg-ran-anga faul^t

This part of the report area is divided into three areas with
! differences in structural character. The Suarez fault separates the topographically lower mesa area south of Buccramanga from a higher plateau belt to the west. Westward fro^ the plateau belt, all formations ranging from the Girbn to those of the Tertiary and
I Quaternary dip westward into the geosynclinal area of the middle
i

i Magdalena basin.

x

I Suarez fault
I

! This fault extends into quadrangle H-13 from near the middle
j of its southern boundary and traces a rather sinuous course northward
!

to its termination at the Bucaramanga fault north of Bucaramanga. In the southern part of H-12 it is closely parallel to the course of Rio Sogamoso and 2 to 3 kilometers to the west. Where the river changes course from north to northwest, the fault changes trend to northeast and crosses the river at right angles. Other faults are present in this area that complicate the structural pattern, and the net effect suggests an offset to the northeast, beyond which the fault continues its northward trend.

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ln the southern part; of H-12, where the fault is west of Rio
Sogamoso, red beds of the Giron Formation on the west side are in ! contact with Cretaceous formations up to and including the Paja on the east. Estimates of vertical displacement of the Tambor-Rosa Blanca contact across the fault in this area range from 1700 to 2300 maters, with displacement decreasing toward the north. North of the offset area and about 10 kilometers south of the town of Giron, the vertical displacement of the Tambor-Giron contact across the fault is estimated to be LOCO meters. In this area and continuing to the north, the trace of the fault is covered by Quaternary beds. : West of Giron and continuing to the north, an eroded fault scarp
i
lies west of the fault, and older Quaternary beds of the Bucaramanga terrace have been dragged up to a vertical position on the east side /
of the fault by later Quaternary movements (Julivert, 1963, fig. 7 and pis. II and III), These beds are well exposed where the highway from Giron to Lebrija crosses the fault (120 II-A, F-9). Beds of the Giron Formation underlie the terrace deposits, and a few small exposures of
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them lie east of Rio de Oro along the road from Giron to the rail-road terminus at Cafe Madrid. Inasmuch as Giron rocks U- e on both sides of the fault in this area, a good estimate of the vertical displacement cannot be made. However, the height of the fault scarp to the west makes a throw of 400-500 meters quite possible.

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\ Near its termination at the Bucaramanga fault, the Suarez fault

!

cuts Devonian and Permian-Carboniferous beds of the Fioresta and
i
i Diamante Formations in a narrow belt of these recks that parallels the t

Bucaramanga fault on the west side. The structure in this area is

complicated by other faults, but apparently the vertical displacement

along the Suarez fault is not very large.

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Mesa area

The wedge-shaped fault block between the Bucaramanga and Suarez faults is down-dropped and tilted slightly toward the west. It is the site of the present mesas of Barichara (1-12 NE) and Los Santos and Ruitoque (H-12 SE). Mesa areas in the middle of this block are capped by sandstone of the Tambor Formation where it has not been eroded to expose older beds of the Giron and Jordan Formations. To the south, Mesa Barichara and part of Mesa Los Santos retain a cover of younger Cretaceous rocks up to the Tablazo and possibly higher (Tellez, 1964, p. 17). Pre-Devonian rocks of the Silgara Formation crop out on the eastern slopes of these mesas below the cap rocks.
The present surface of the fault block is lowest at the northern
end, reached not in a uniform gradient from south to north but probably in steps related to northeast-trending faults along fhe northern edges of Mesas Los Santos and Ruitoque. At the narrow north end of the block, the thick Quaternary deposits of the Bucarawanga terrace accumulated in the basin between the Suarez and Bucararoanga faults. In his morphotectonic study of the mesa area, Jullvert (1958, p. 37 and fig. 13) postulates that the stream-derived lower beds of the terrace were deposited when Rio Sogamoso earlier flowed northward along the Suarez fault to Rio Lebrija before it was captured by a northwestward-flowing stream that is the present channel of the river.

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On Mesa Los Santos a network of faults is indicated by the
lineaments that can be seen in the drainage pattern on aerial photo-graphs. They apparently have little vertical displacement. The Los Santos fault, which trends northwestward along Quebrada Los Santos
from the southern slope of the mesa, dies out northwest of the village of Los Santos. It probably has greater displacement than any other fault in the mesa surface, but near Los Santos this is probably not more than 100 meters. The flexure with which this fault is associated probably results from a fault in the pre-Cretaceous rocks and extends on to the northwest beyond the end of the fault. Northeast of this
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fault, sandstone of the Tambor Formation which caps the mesa dips gently southwestvard toward the fault, with dip increasing rather-abrupt ly near the fault. The southwest side is downthrown, and there the Rosa Blanca Formation overlies the Tambor, with the Paja and Tablazo Formations also present farther to the southwest. The ! combined and reinforcing effects of the fault, the flexure, and the regional dip make the mesa area to the southwest of the fault 400-500 meters lower than that to the northeast.
If projected toward the southeast, the Los Santos fault coincides
with the Aratoca fault that extends northwestward from Aratoca along Quebrada La PIaya to Rio Chicamocha. However, landslides and colluvium on the lower slopes of Mesa Los Santos in this locality make this extension of the Los Santos fault unclear.

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Plateau area west of the S.:?.rez fault

This area includes a belt lying west of the Suarez fault that
narrows gradually northward from the south central part of H-12 and terminates at the Bucaramanga fault. It differs from the lower mesa area to the east in that gentle folding has resulted in an uneven surface as compared to the gentle and regular westward slopes of the mesas. Cretaceous rocks up to and including the Tablazo Formation overlie the thick Giron Formation in the Zapatoca sync line" (H-12, b-8, c-7, c-8), and Tamhor Formation sandstone is present north of Rio Sogamoso, but the northern half of the plateau area has only Giron Formation exposed. Compared with the Zapatoca sync line that trends parallel to the belt, all other anticlinal and synclinal structures
are minor in extent and rather variable in trend. i Lineaments traced on aerial photographs generally show a rather
random orientation. A long, winding lineament has bean traced in the Giron Formation west of the Suarez fault (c-7, c-8) that corresponds
to a sharp change in strike and dip of beds as seen on aerial photographs The absence of indicated lineaments and fold axes in the southv/estern part of the plateau belt (b-5 E, b-6 E and b-7 E) is due to lack of
full photo coverage rather than to absence of these features in the rocks.
The western boundary of the plateau belt is not sharply defined
located
but Is/ where the undulations of the beds of the Giron are succeeded by strong and sustained dips toward the yos't. JuiJvert (1958, p. 16) has called this the "flexion del Chuc uri."

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El Espino fault.--This north-trending fault lies west of and roughly parallel to the Bucararaanga fault from the western slope of Quebrada
El Espino in the south nearly to La Ceiba in the north (H-12, c-1 to
. c-4). Along most of this distance, from Bocas northward to
; Portachuelo, the trace of the fault is along the upper west slope of
I X -

Rio Negro. The position of the fault in eastward-draining quebradas and on adjacent ridges indicates a. west dip in the fault plane. Dips in the Bocas Formation east of the fault are mostly toward the east. Those in the Giron Formation on the west are toward the west.
At Portachuelo El Espino fault is only a few meters east, of the Bucararaanga fault. To the north it is exposed in several places on

' the lower west slope of Quebrada San Francisco. It terminates at a

northeast-trending fault that intersects and offsets the Bucaramanga fault at La Ceiba (c-1 S).

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La Plata and Rio "e?ro faults.--These cwo relatively short, north-trending faults lie between the Bucararr.anga and El Espino faults west and east of the town of Rionegro (H-12, c-3). They are the boundaries of a narrow downfaultec! block of reddish-brown siltstone

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and sandstone of the Jordan Formation. West of Rionegro, fractured light-colored quartzites of the Bocas Formation are west of the La Plata fault. North of an offsetting cross fault, dips in the Jordan are toward the west; those in the Bocas are toward the east. Similar to the El Espino fault, the La Plata fault lies along the slope west
x-

of Rio Negro, but in this case fault positions in eastward-draining quebradas and on adjacent ridges indicate an eastward dip in the fault plane. The fault terminates at El Espino fault to the south and apparently terminates at a small spur fault west of the Bucaramanga fault to the north. j
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The Rio Negro fault extends northeastward from near the
confluence of Rio Negro and Rio Lebrija- and then curves northward to a position tangent to the Bucaramanga fault north of the town of

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Rionegro. The fault is exposed in a road cut along the highway to

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Rionegro (109 IV-A, 1-13 NE). North of this exposure, beds of the Bocas Formation are highly fractured in the narrow belt between the Rio Negro and Bucaramanga faults.

Middle Maedalena basin

West of the plateau area, approximately half of quadrangle H-12
lies on the eastern side of the middle Magdalena basin. The belt of
I westward-dipping Jurassic and Cretaceous formations display more
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j complicated structure than does the Nuevo Mundo syncline with its
| Tertiary rocks to the west. The western boundary of this syncline is

ij the La Salina fault.

Pre-Tertiary belt,--From a north-northeast trend in the southwestern
part of H-12, this belt changes rather abruptly to a northwest trend near the northern boundary in an area of rather complex folding and faulting. The Cretaceous rocks of the belt are only a few kilometers west of the Bucaramanga fault at this change of trend. The broad area of Giron Formation exposed in the plateau area ends here and is succeeded to the north by a rapidly widening area where the Bocas : Formation is exposed. This latter area is somewhat similar ' structurally to the plateau area, at least in the western part. In the eastern part, faults are prominent features and dips of beds are steep to vertical, possibly as a result of the intrusion of a long body of rhyolite which trends parallel to the Bucaramanga fault.

Solferinri fault.--In the north central part of K-12, the Giron Formation has apparently been thrust slightly westward over Cretaceous formations over a distance of 5 or 6 kilometers along this fault
(pi. 1, sec. A-A' 1). West of the fault, the Cretaceous beds have responded to the deformation by gradually reaching an overturned position from their normal westward dips to the north and south. An intersecting fault of northwest trend causes offset in the Solferino fault near the place of maximum thrust. - > The Solferino fault dies out rapidly toward the south as a
strike fault. Northeastward its oblique truncation of the Cretaceous formations dies out gradually. A lineament on aerial photographs indicates that the fault continues northward in the Bocas Formation with trend curving to the north and northwest where it parallels the
west boundary of the long rhyolite intrusion. It terminates at the

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Rio Cachira fault. Another lineament branches to the left and extends approximately parallel to the Giron-Bocas boundary. :

' '

Sardina fault.--This fault is closely parallel to I.he eastern boundary /
of the rhyolite intrusion in the Bocas Forr.aticn south of the Rio Cachira fault (H-12, c-1 SW, c-2 NW). It terminates at the Solferino fault in the south and at the Rio Cachira fault in the north. Beds of the Giron and Tambor Formations are on the east side of the fault over most of its length. A thick zone of cemented coarse fault breccia is exposed in several places in Quebrada Sardina and in tributary quebradas to the east. Blocks of breccia have been found also in the

s

quebrada that marks the course of the fault south of Rio Salanianga.
The narrow, curving fault block between the Solferino and
Sardina faults suggests that the rhyolite intrusion has pushed this block upward.

t ^^ ^ ^

I _Rio Cachira fault.--Along the valley of Rio Cachira, this fault cuts almost directly across the structural trend and strike of formations in the north central part of H-12 (c-1 W, c-2 NW). Right lateral movement has apparently occurred to cause the large offsets across
the fault. The rhyolite intrusion is displaced about 2.5 kilometers and the Giron Formation about 1.5 kilometers. The fault is thought
to curve northwestward to a position parallel to the Bucararnanga fault near the northern boundary of H-12. A northeast-trending branch, or possibly a different fault, continues the northeast trend and inter-sects and offsets the Bucarananga fault with right late-ral displace-ment of less than 500 meters.

~-s structural e-'-a'm5nt, --This area of northeast- to northwest-

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striking Cretaceous and pre-Cretaceous formations is bounded on the
east by the Solferino fault and on the west by the Lebrija fault
(H-12, b-1 E, b-2 E, c-1 W, c-2 W). The embayment appears to result
from the movements on the Solferino fault and uplift to the north
where the Bocas Formation is widely exposed and is intruded by a long body of rhyolite that has probably been a factor in the uplift.
| Numerous faults and folds cross the enibayraent with trends varying from northwest to northeast. They extend into the Umir Formation in
. the southern part of the embayraent where they are covered by widespread

j Quaternary deposits or die out in the Umir Formation shales. Undoubt- i
|
I edly some of them continue south of the embayment because the thickness i ' | of the Umir is much less than the width of the outcrop belt seems to indicate (see section A-A 1 ' of pi, 1). \ i
i
Vane ga s an t i c 1 in e . - -T he somewhat winding and gently plunging axis of
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this structure can be traced for about 14 kilometers from the Giron
I

i Formation in the north to the La Luna Formation in the south (H-12,
I

b-1 SE, b-2 E). In view of this length and persistence, the anticline i

| probably continues southward in the Urair Formation (see section A-A 11, pi. 1), although this is not clear.

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Vanegas syncline an^ CupsjLarica^ Jiau.lt:._. --The eastern limb of the
I Vanegas anticline adjoins the Vanegas syncline which plunges gently
J ! southward and disappears under the alluvium of Rio Lebrija. The

j synclinal axis is well-defined northward to the Cuestarica fault,

which then traces the approximate axis of the syncline to the north-west. In the Bocas Formation near the northern boundary of H-12, dips and strikes of beds indicate a syncline of northwest trend that is in approximate alignment with the Vanegas syncline, but there is no clear I continuity. In its northwestern part, the Cuestarica fault intersects i
, the Lebrija fault and offsets it slightly to the northwest. Beyond
i
this offset it dies out in Tertiary beds west of the Lebrija fault,
I A vertical displacement of 400 meters is estimated in the Tambor-Giron

!i
contact across the fault where the Vanegas anticline is sharply defined in the Giron Formation (H-12, B-l SE) .

. Arevalo syncline.--This sharp, north northeast-trending syncline near i
j the eastern side of the Vanegas structural erabayraent is the best defined of several folds that occur east of the Rio Cachira fault.
i
I All of them plunge gently southward and disappear under Quaternary deposits. :

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Rio Sucio anticline and Naranio svncline.--These features lie within
I the wide outcrop belt of the Umir Formation southwest of the Vanegas j . structural embayment (H-12, b-4). Two elongate areas of the Lisama
I ' Formation containing thick sandstone beds overlie the Umir Formation
| x
5 ~ east of the axis of the Rio Sucio anticline and are isolated from the main westward-dipping outcrop of the Lisama along the west limb of the
i
| anticline. In its southern part, the anticlinal axis is represented
' I by a fault with the eastern side downthrown.
The northern isolated area of the Lisaraa Formation, and part of
the southern one, lie in the trough of the Naranjo syncline. The syncline is in a downfaulted position between parallel strike faults
, to the east and west.

! San Viccnte faulted and folded area.--Folding and faulting that are
j
i confined mostly to the Urair Formation south of the Vanegas structural embayment extend into some of the older Cretaceous rocks in the San

Vicente area (H-12, a-6 SE, a-7 E, b-6 W, b-7 W). The Giron, Tarnbor, i
and Rosa Elanca Formations remain relatively unaffected.
The £an Vicente syncline (not labeled on pi. 1) plunges very gently northward along the east side of the distrubed area and apparently terminates at both ends against the San Vicente fault. This fault is downthrown on the west side and cuts obliquely across the section
from the Uniir Formation at the north end to the Paja Formation in
the south.

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West of the San Vicente fault, several strike faults with down-
f 2 I thrown sides on the east result in repetition of t.he section that is
!

| j X

j 3 ! well-shown in the La Luna Formation. The Chucuri anticline is a well- i !
defined, narrow structure in the La Luna that plunges northward and is bounded by strike faults.
6 The Tertiary rocks to the west of the San Vicente area of faulting
7 land folding are relatively unaffected.

Nuevo Mundo syncline and La Salina fault.--This large synclinal area
that covers most of the western part of H-12 is only the small, easternmost part of a much larger geosynclinal area that has been
referred to structurally as a "half-ramp1 ' because of the extensive faulting near and parallel to the eastern margin. The Tertiary section (and probably also the Cretaceous) reaches its greatest thickness along this side of the geosyncline and may exceed 6000 meters in the Nuevo Mundo syncline (Morales et al, 1958, fig. 7>.
The north-trending La Salina fault, which is immediately to the
west of the boundary of H-12 with H-ll, forms the western boundary of
the Nuevo Mundo syncline in its southern part. The fault extends
j briefly into H-12 (a-7 W) and dies out farther north in the northeast-ward plunge of Las Monas anticline (a-3 W). It is an eastward-dipping, high-angle reverse fault along which the eastern side is thrust up and westward, bringing the Umir Formation on the east side into contact with

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rocks as young as the Real Formation on the west. The fault is present
in the subsurface at the woct end of section A-A 1 ' of pla'ce 1. A throw
of about 1200 meters is indicated in the Unir-Li sarra contact in this
. localHy.

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; At the surface, the axis of the Nuevo Mundo syncline is close to

j the west limb, probably as a result of the strong uplift along the i
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1 east side of La Salina fault. In the subsurface the axis probably
moves eastward as depth increases (see section A-A 1 ' of pi. 1).. In
the southwestern part of H-12, the axis of the syncline in the Urnir Formation corresponds to the northeast-trending Putana fault. This
fault extends from La Salina fault in H-ll and produces a large offset
in the Umir-Lisama contact. North of this offset, the axis of the
/ '
syncline diverges northward from the Putana fault. North of Rio ;
Sogamoso, the axis of the syncline is offset 4 to 5 kilometers to the west of its position south of the river. A similar offset occurs in the La Salina fault. The offsets suggest that a fault of west-northwest trend, and with strong left lateral displacement, is present along the course of Rio Sogamoso beneath the cover of alluvium.
The position of the axis of the Mundo Nuevo syncline becomes
j unclear in the northwestern part of H-12 where the youngest Tertiary
beds are nearly horizontal. i

, i Id? __. !L Ji^n a ._..__ 5. c- r^: ASlif16 "This nose-like feature plunges to the northeast J beyond the end of La Salina fault and possibly reflects the dying out of the fault at depth.

Proyincla fault.--This fault diverges northward from the axis of the Nuevo Mundo syncline and corresponds to the western boundary of the Provinciu oil field at its south end. There is slight uplift on the
- eastern sido.. ._ .._ _

1 Provincia anticline.--In outcrops, the axis of this structure diverges
2 |northeastward from the trend at the producing level of the Provincia
3 |oil field. In the southern part of the field, there is no well-defined
4 jposition of the axis at the surface, although the field is bordered on 5-jthe east by the Mundo Nuevo syncline and on the west by a sharp syncline in the Mesa Formation.

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GEOLOGIC HISTORY

The geologic history of the southern half of Zone III and by
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extension the Santander massif is.s^vmerized in table 4. Discussion
of age and correlation already presented at the end of the description
of each unit are here summarized, and additional remarks intended to clarify or amplify specific events or to show areas of uncertainty are also given. The geologic history is presented belov; in 18 events whose numbering corresponds to that on table 4.
1) The Bucararaanga Gneiss became part of the Precambrian Guayana shield probably in late Precarabrian time, about 950 m.y. ago. The 945 m.y. age from, the Santander massif, the oldest reported from the

Cordillera Oriental, is supported by a 940 rn.y. age from the Sierra *TSTitten dcCTiun., J &
Nevada de Santa Marta (Tschanz,/1969). The 680 m.y. age from the Santander massif is interpreted as retrograded. Older ages of 1300 to 1400 m.y. are reported by Tschanz from the Sierra Nevada^and ages of 1200 to 1300 m.y. are reported by Pinson and others (1962) to the east of the Cordillera Oriental in the Guayana Shield in the Rio Guaviare region, and by Kalliokoski (1965) in central Venezuela. These ages apparently date an older orogeny to the east of that in the Santar.der massif. The rocks that give the 1300 to 140O m.y. ages in
the Sierra Nevada de Santa Karta are granulite facies rocks, whereas
the Eucaramanga Gneiss is no higher grade than the upper amphibolite facies.

' 3 7

The thickness of the Silgara' is uncertain. The Silgara in the Pescadero-Aratoca area may be 3700 deters thick and there is probably a similar amount, if not greater thickness, in the Quebrada Silgara area. Hubach (l957> P« 162) notes that the equivcJLet Guejar series thickens appreciably in the Cordillera Oriental westward from the Serrania de la Macarena. Eenz reports 2000 meters of the Gue'jar on the trail to Uribe. C. J. Campbell (l9£> 5> enclosure 1 and p. ll) calculates the Quetazne Group east of Bogota and correlative 'of the
11 , -S

Guejar series is 2750 meters thick. Christ (1927, p. kok) estimates the total thickness of the possibly correlative Bella Vista and Caparo Formations in the Cordillera de Merida as 3000 meters.
No evidence has been seen that the Precambrian rocks in the
Santander massif were exposed during the time of deposition of the Silgara^Formation. The source area for the thin-bedded fine-grained primarily siliceous sediments may be the Guayana shield to the east. The thickness of the formation in different areas and Its degree of
metamorphism give some clue as to the limits of the Ordovician- j
" / S ' Cambrian Basin. The Ordovician-Carabrlan Guejar Group in the Serrania
de la Macarena is thin, very lightly metamorphosed, and contains ;
i

appreciable amounts of quartz sandstone (HvJbach, 1957, P. l6l-l62). .'
Further north, the Caparo Formation of Ordovician age between the !
Cordillera de Merida and the Barinas Basin to the south is 700 meters : thick and little metamorphosed. The nonfoosiliferous Bella Vista Formation which crops out in the same area and Is of pr
Cambrian age is more str^v/ly metamorphosed

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and much thicker. The two formations cppear to be separated by a
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major fault (Pierce, 1960, p. 220), and the Bella-Vista may represent metamorphosed deposits of a de2p-?r part of the geosyncline than the Caparo Formation. The Macar^na area and the Barinas basin area may
be near the limits of the Ordovician-Cambrian basin. In the Serrania de Perija, the Ordovician and Cambrian strata also appear to be thin
*x

and little metamorphosed. Hea and Whitman (1960, p. 354) indicate about 1000 meters thickness in northwest Venezuela for their revised /
definition of the Perija Series, which they consider to be Ordovician
v~

and Cambrian rather than Lower Devonian. Trumpy (1943, p. 1292) indicates about 70O meters of thickness for pre-Devonian beds south of San Isabel in the southwestern Perija and these are little metamor-phosed. Possibly the Serrania de Perija represents the site of the western or northern margin of the Early Paleozoic geosyncline. No rocks of Ordovician-Carabrian age are known from the Sierra Nevada de Santa Marta (Tschanz, written conmun., 1969).

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3) The degree and extent cf the Late Crdovician-Early Silurian raetaraorphism and plutonism is somewhat uncertain, and without a better knowledge of the stratigraphic boundary between the Bucararaanga Gneiss and the Silgara Formation no definite statement can be made. Some of
the coarse-grained mica schists and the meta-wackes assigned to the Silgara Formation may actually be less metamorphosed Bucararaanga Gneiss. The true base of the OrdovicianC?) and CambrianC?) rocks may be somewhat higher than we have indicated on our map. The principal evidence for an Ordovician-Silurian orogeny lies in the fact that metamorphosed rocks with radioraetric ages of 450 m.y. and 410 m.y. are unconformably overlain by unrnetamorphosed rocks of Devonian age. Similar ages have been obtained elsewhere in eastern) Colombia and western Venezuela (table 4). It is unlikely that these closely-spaced ages are retrograded Precambrian ages. The Ordovician-Silurian raetamorphisra however was too weak to entirely eradicate radiometric evidence for the Precambrian age of the Bucararaanga Gneiss, It is puzzling, however, that the distribution of isograds and orthogneiss in the Silgara Formation and Bucaramanga Gneiss suggest but a single

metamorphic-plutonic event rather than the two events indicated by thei
radiometric ages. A more detailed study of the stratigraphic relation
of the Silgara Formation to the Bucaramanga Gneiss and of the spatial relations of the rocks mapped as orthogneiss in the Santanclor massif is needed.

': -'t 1!

f A) No fossil or other evidence exists for the presence of strata of Silurian and lower Devonian in the Santander massif; presumably
this was a time of uplift and erosion. However, Mencher (1963) cites Boucot as stating that fossils in the Cordillera de Merida of
- Venezuela previously thought to be Devonian are in reality Silurian in i
age, implying the presence of Silurian strata in that region.

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5) The basin of deposition of the Florasta formation and other
1 /
I Devonian recks in the Cordillera Oriental and Cordillera de Merida
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iwas apparently a widespread shallow sea. In most places the Devonian

1 section is thin and unraetamorphoscd or only slightly metamorphosed.
/ / x
The Cachiri Group of the eastern flank of the Serrania de Perija is about 2600 meters thick (Sutton, 1946, p.1635) and is considered to
be the maximum thickness for the Devonian system in Venezuela. Pierce (1960, p. 223-225) indicates a thickness of 1800 meters for. two formations of the Mucachuchi Group of Devonian age in the Cordillera de Merida. At Floresta, the thickness of the type Florasta Formation iis 600 to 700 meters (Botero, 1950, p. 259). Patches of completely ;unmetamorphosed Devonian strata occur in the Acuavio, Medina, and
i
Villariconcio quadrangles in central Colombia, east of Bogota, Accord-ing to Campbell (1965, enclosure 1 and p. 11) these strata are about 600 meters thick. Near Bucaramanga, the thickness of the Floresta is

I estimated also to be 600 to 700 meters by us. Near the center of the i
ISantander massif, where the Devonian rocks are more metamorphosed than I elsewhere, the section appears to be thicker, but folding makes accurate measurement of the section impossible. This area may be coincident with the axis of the Devonian miogeosyncline. As with the Ordovician-Carabrian geosyncline, the probable site of the axis of the Igeosyncline and the most intense metamorphisrn are nearly coincident vith the axis of the Cordillera Oriental where are now exposed the oldest and most, metamorphosed rocks.

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6) The metarnorphisra of the Floresta Formation in the Santander
jmassif may have taken place between che Middle Devonian and the Middle ipennsylvanian, a span in which no fossil or sedimentary record is known j
tto be preserved. However, no appreciable angular discordance between the Floresta Formation and the overlying Carboniferous beds is evi-. dent in most places, nor are there any radiometric ages within this

t < time span. We also observed in the Berlin and Mutiscua areas that the
i

I Diamante Formation of Middle Pennsylvanian to Permian age was affected i
i

; by the metaraorphism of the Floresta Formation. Although the recrystal-lization of the limestone of the Diamante could be attributed"to thermal metamorphism related to emplacement of the Jurassic-Triassic batholithc, the phyllitic rocks associated with the recrystallized limestone in the Mutiscua area are not the product of simple thermal metamorphism. Either the limestone and associated phyllite-are not
j Diamante, but possibly Floresta Formation, or the metamorphism of the Devonian and Pennsylvanian rocks occurred later, in Late Permian to Early Triassic time (see event 9).
7-8) From the Late Permian event (8) to the Late Triassic event
(11) was apparently a time of progressively increasing orogenic activity whose initial pulse is registered in the mild discordance between the Diamante Formation and the overlying Tiburon Formation.

9) The metarnorphisra of the Floresta Formation in the Sant-crxler
massif is most intense in the east centra] part of the cassif and,
i * \

'except for the Mogotes area, is confined to a rather restricted belt ; from Capitanejo to the Mutiscua area. Metamorphosed Devonian rocks
are present in the Cordillera de Merida, but Devonian beds are not . metamorphosed in the Serrania de Perija nor in the Convencion region
of the Department of Norte de Santander. The axis of most intense jmetamorphism of the Devonian rocks thus appears to lie on the east flank of the Santander massif and to swing off northeastward into the Cordillera de Merida of Venezuela.
The existence of radiometric ages ranging from Latest Permsylvanian
to Ea rly Triassic in the Cordillera de Merida, Sierra Nevada, and
i
Santander massif (table 4), and the presence of metamorphosed Pennsylvanian rocks in the Santander massif support the interpretation

! of a plutonic-metaraorphic event during Late Permian to Triassic time.
Radiometric ages in this time span have also been reported from the Cordillera Central. This event appears to have been marked in most Places mainly by plutonic intrusion without attendant regional raeta-except in the Santander massif and the Cordillera de Merida.
the spread in the radiometric ages is apparently the combined
fe sult of different methods of dating and the effect of heating during ^e major episode of batholithic intrusion in the Jurassic and Late Ar iassic in the Cordillera Oriental and Sierra Nevada de Santa Marta.

10) For the first time there is definite evidence that the massif
vas once a positive area. The evidence is that the Bocas Formation
contains detritus derived from older rocks of the. massif. The deposition of the continental sediments of the Bocas Formation followed the Late
Permian -Early Triassic orogeny and marks the beginning of a new phase
in the history of the massif.

11) The Late Paleozoic-Early Mesozoic orogenesis and uplift
culminated in widespread postkinematic emplacement of calc-alkaline
batholiths in the Santander massif (the Santander Plutonic Group), the

written commun./ Sierra Nevada de Santa Marta (Tscnanz ,/1969) , and procaoly in the

Merida Andes. The oldest batholiths were emplaced near the Jurassic -
Triassic boundary in the Santander massif. The nearby Palmar Granite
of northwest Venezuela, however, appears to be somewhat oldar (Mencher,
! 1963, p. 75). Emplacement of the batholiths continued well into the
Jurassic period both in the Sierra Nevada de Santa Marta (Tschanz, written comr 1969) and in the Santander massif. ' '

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11-12) Continental and marine red beds containing volcanic debris
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i interlayerad with volcanic rocks are widely distributed in the Santander i

! massif, Cordillera de Merida, xxxSerrania de Perija and Sierra Nevada de
i Santa Marta, and on the east flank of the Cordillera Central. Their i

| age ranges from Triassic through Jurassic and in some places even into

X

the Early Cretaceous. In the Santander massif, the Jordan Formation
X*

contains less igneous material than do equivalent beds in the Perija

I x x

I and Sierra Nevada de Santa Marta and Cordillera de Merida. The Jordan !

is quite variable in thickness, in part due to later differential !uplift and erosion and probably also due to original deposition in
basins of limited width and depth. I
i 13) Renewed orogenesis in Late Jurassic time is t recorded by the
!

:angular unconformity between the Jordan and Giron Formations. The

/

present distribution and thicknesses of the Giron also suggest ^ ;
deposition in rather limited basins. Clasts derived from the Triassic-Jurassic batholiths show that these were de-roofed by the time of
deposition of the Giron Formation. j
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14) Deposition of the Giron Formation was followed by a period of
. Iquiescense and marine transgression during the Cretaceous. On the west flank of the Santander massif, marine deposition began in tu2 Ea^lv Cretaceous, but on the east flank it did not begin until the Middle Cretaceous. The Giron Formation on the east side of the massif may be in part of Early Cretaceous age, equivalent to the Rio Negro Formation
of western Venezuela. ,

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I Porphyry dikes that cut Lower Cretaceous rocks northeast of
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j Bucaramanga as well as rhyciite in the Gcar.a area north of the area
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of the geologic maps with a radiometric age of 127 ra.y. show that
igneous activity in the Santander massif continued into the Early Cretaceous. Radioraetric ages of 129 and 131 m.y. have been obtained from rhyolite ignimbrite and granodiorite respectively in the Sierra Nevada de Santa Marta (Tschanz, written commun., 1963). A period of mineralization affecting rocks of Middle Cretaceous age in the ' Santander massif occurred at some later date. . j
15) In the Late Cretaceous, marine deposition continued in the
j area of the Santander massif but was interrupted by three periods of mild uplift and erosion of varying extent (Maughan , personal commun.). These uplifts occurred prior to, during, and following
the black shale-chert-phosphorite deposition of the La Luna Formation which covered a very large area of Colombia and western Venezuela.
In the last and most far-reaching of these periods, much of the La Luna was eroded in some places, including the main phosphorite beds. A thin but widespread conglomeratic and glauconitic sandstone at the base of the overlying Umir Formation contains varying amounts of phosphatic
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pellets and nodules derived from the eroded beds of the La Luna. Seas became gradually shallower during the deposition of the shales of the Umir, and of the Colon and Mito Juan Formations.

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16) By the end of Cretaceous time, s^as bad withdrawn to the
extent that sedimentation was taking on a continental character, with coal beds in the upper Umir and in the Paleocene Lisama Formations.
The Santander massif in the area of the present report probably became
^

again a positive area during this period (see also Young et al, 1956, fig. 6).
17) The Tertiary period was one of continued uplift and , diastrophisra. In the absence of any remnants of Tertiary formations in the large area between the western part of H-12 and the eastern part of H-13, it is difficult to estimate the original extent of the Tertiary deposition in most of the area of the massif as well as in the mesa and plateau area west of the Eucaramanga. fault. The deposition was undoubtedly of continental nature end similar to that which is present in the western and eastern areas at the present time. /
According to Morales et al (1958, p. 664), the sedimentary record in the middle Magdalena Valley gives evidence of uplifts there at the end of the Paleocene, at the end of the Eocene, at the close of the Oligocene, in the Middle Miocene, and during the Pliocene. There may have been two other uplifts, although the evidence is less clear

s ' (Julivert, 196lb, p. Al). During the Oligocene, the middle Kagdalena
Valley was flooded by the most widespread transgression of the Tertiary, but deposition remained essentially continental in
/
character (Morales et al, 1958, p. 664).

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The discordances in the section of the middle Magdalena Valley are known in the oil-producing area west of the La Salina fault where the
| Tertiary section is probably only half as thick as that in the Nuevo Mundo sync line to the east of the fault. The thicker section in the
sync line represents a more nearly continuous accumulation of sediments derived from the rising area to the east that included not only the massif but the mesa and plateau area west of the Bucaramanga fault as well. The increasing coarseness of the material deposited
: during the Oligocene and Miocene reflects the increase in the rate of
! '
i uplift as the Tertiary period progressed. i

I ! On the eastern flank of the massif, remnants of Tertiary
i ;
j formations that are present in fault blocks and in the Cerrito structural basin are limited to the Paleocene, Eocene, and lower Oligocene. These rocks are mostly similar in lithology to those of > ! the sane age in the middle Magdalena Valley but are only about half as i
thick, indicating a slower rate of deposition or possibly less i
i
deposition to the east of the massif during this part of the Tertiary.
18) The deposits in the vicinity of Bucaramanga record the latest
i events in the geologic history of the area. No fossils have been
!

found with which to fix the age of these deposits, but they are

s ' generally regarded as of Quaternary age. Juliyert (1903) has
recognized four stages which we have modified somewhat: I

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1. Very coarse to fine fluvial materials of the present Bucaramanga terrace were deposited in a sinking block
between the Suarez and Bucaramanga faults to a depth of 250-300 meters. The sinking was further localized
x X*

south of a connecting fault along Rio Surata (de Porta,
1959, fig. 2). ' !

2. During a period of regional uplift that followed, unsorted colluvial material derived from deeply weathered rock
was deposited over much of the terrace. .Similar colluvial deposits in the mesa area and throughout the Cordillera Oriental are thought to have been formed at
the same time. ;

3. Locally in the highest parts of the Bucarananga terrace, a sequence of interbedded gray silts and peaty material
up to five or six. meters thick accumulated over the
i
colluvial deposits.

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4. Small terraces . below the level of the Bucaramanga terrace do not have its cover of colluvial material. These terraces are therefore of more recent origin, and indicate stages in the dissection of the
i
valley fill.

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The Suarez and probably the Bucaramanga faults were active during
the accumulation of the sediments of the presant Bucaramanga terrace
but probably not since that time. Remnants of the colluvial material that overlies the Suarez fault have not been disturbed by any later
. X

movements on the fault (Julivert, 1963, fig. 7). ;
The alpine glaciation that occurred in the highest parts of the Santander massif probably developed during one of the major glacial

~ ~~ ! periods of the Pleistocene _ __ The '

surfaces of glacio-fluvial deposits seem to be graded to the surfaces of terraced remnants of valley fill such as the Bucaramanga terrace.

Diastrophism and uplift in the Cordillera Oriental continue
actively at the present time. Within the report area, erosion is
proceeding In the massif at elevations up to 4,500 meters while :
material is being deposited in the northern part of the Nuevo Mundo syncline at elevations of less than 100-meters. Erosion processes can.

i ^ x-

I be observed very strikingly in such areas as that of Rio Umpala where
it cuts the Santa Barbara batholith. Here the deeply weathered rock '
i
! crumbles and slides dov/n long steep slopes to the river which carries
the material away like a conveyor belt.

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