Segundo día - 18 de noviembre. — OPCION "A": EXCURSION GEOLOGICO-MINERA A LA REGION DE BAILADORES-GUARAQUE, DISTRITO RIVAS DAVILA, ESTADO MERIDA, VENEZUELA

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PROGRAMA DE LA EXCURSION

ITINERARIO

Se saldrá de la población de Bailadores a las 8 a.m. hacia el suroeste, por la Carretera Trasandina; a los 3 km aproximadamente, seguiremos una pequeña vía hacia el sur, paralelamente a la quebrada Las Tapias que conduce hasta la mina De Lima II, ubicada a unos 8 km en esta dirección.

Al salir de Bailadores, hacia la parte norte del pueblo donde está el cementerio, observaremos una mancha blanquecina que corresponde a una pequeña intrusión riolítica en filitas micáceas de la Formación Mucuchachí. Esta roca está bastante meteorizada y su color blanco lechoso contrasta muy bien con el tono rojo intenso de meteorización de las filitas.

A los 2,5 km sobre la vía hacia el sur, en los cortes de carretera veremos afloramientos de la Formación Sierra Nevada del Grupo Iglesias (Precámbrico Superior), consistentes en granitos y ortogneises porfídicos, generalmente bastante meteorizados. A los 6 km. aproximadamente nos detendremos en el sitio denominado El Higuerón, para examinar un afloramiento donde se observa la discordancia entre el Grupo Iglesias y la Formación Mucuchachí (Paleozoico Superior) suprayacente; el difícil acceso hasta el sitio impide observarlo de cerca. Casi al final de la vía antes de llegar a De Lima II, veremos un "espejo de falla" de la falla de San Carlos, que corta aquí una pequeña masa de riodacita. Finalmente llegaremos a la zona mineralizada De Lima II, formada por una veta masiva principal (veta Nº 1) integrada por sulfuros metálicos de cobre, zinc y plomo mayormente, y de una zona de diseminación (veta Nº 2), separada de la primera por un espacio de 15 a 20 m, también integrada por sulfuros metálicos, principalmente calcopirita con menor porcentaje de blenda y galena. Estas mineralizaciones arman en una asociación de esquistos margaríticos, filitas cuarzo-cloríticas y/o micáceas, filitas sericíticas y rocas de origen volcánico. En esta zona hay además varias intrusiones, en forma de pequeñas masas o diques, de rocas sub-volcánicas de tipo riolítico, dacítico y andesítico.

Estación Nº 1 — 9:15 a.m. (10 minutos). Falla de San Carlos.

En este sitio se observa una superficie pulimentada de unos 4 m², con estrías de movimiento ("espejo" de falla) sobre una roca meta-ígnea ácida. Este espejo tiene una posición N 11° E, 63° NO y corresponde a la falla de San Carlos,

APPENDIX 1: RADIOCARBON SAMPLES AND DATES

Quebrada Mucubají series, Venezuela

Samples assoc. with postglacial features at Quebrada Mucubají (8°47′ N Lat, 70°49′ W Long), in tributary valley of Rio Santo Domingo, Venezuelan Andes. Coll. 1972 and subm. by Robert Giegengack, Univ. of Penna.

10,757 ± 165
SI-1228. 72-VA-CS-H 8625 B.C.

Clayey peat exposed in streamcut 2 m below base of modern soil. Saturated much of the year.

11,465 ± 110
SI-1246. 72-VA-CS-7 9515 B.C.

Peat exposed in streamcut 75 cm above stream surface, more than 4 m below base of modern soil. Saturated much of the year.

Quebrada Mucuchachí series, Venezuela

Samples assoc. with postglacial features at Quebrada Mucuchachí (8°45′ N Lat, 70°49′ W Long), in tributary valley of Rio Chama, Venezuelan Andes. Coll. 1972 and subm. by Robert Giegengack, Univ. of Penna.

1735 ± 45
SI-1223. 72-VA-CS-1 A.D. 215

Waterlogged wood exposed in streamcut 1 m below surface of depositional floodplain.

2815 ± 55
SI-1224. 72-VA-CS-2 865 B.C.

Wood from base of gravel stratum in streamcut, well above modern water level.

9755 ± 105
SI-1225. 72-VA-CS-13 7805 B.C.

Heavily organic clayey peat exposed in streamcut, more than 1 m below base of modern soil. Peat submerged much of the year.

12,700 ± 110
SI-1226. 72-VA-CS-14 10,750 B.C.

Heavily organic clayey peat exposed in streamcut, more than 1 m below base of modern soil. Peat submerged much of the year.

145 ± 35
SI-1227. 72-VA-CS-16 A.D. 1805

Stem of *Espeletia* sp. (id. by Giegengack) from 59 cm below top of organic-rich lake/stream sediment.

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3.—Glacier ice once covered a much greater area on the crest of the Andes than it does today. Irrefutable evidence of a least one complex, multiple glacial period, the Mucubají Period, exists. Strong evidence indicates the probability that at least two earlier glacial advances occurred; each of these may have been complex and extensive.

4.—Glaciers belonging to the Mucubají Period were in full retreat at least by 12,700 C^{14} years ago.

5.—The small glaciers whose termini lie above 4,600 m a.s.l. today are retreating rapidly; all indications suggest that they cannot long survive the present rate of net ablation.

6.—More geochronologic information is needed from sediments clearly related to the Mucubají advance before we can correlate climatic events in the Andes of Venezuela with those of others regions.

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TRAVERSE TO GLACIAR TIMONCITOS

A short, rocky trail, less than one kilometer long, leads from our position to the leading edge of the glacier. The trip should not be attempted by anyone unaccustomed to physical exertion at extremely high altitude.

The glacier terminus now lies at the north edge of a small lake, milky with rock flour, that has emerged from beneath the retreating glacier since 1961 (MICHEL LE BOULANGER DE GALARD, *personal communication,* 1972). In June 1972 it was possible to walk in under the ice at the north end of the lake, where rock particles of moraine could be seen protruding from the glassy ice that had recrystallized on the exposed lower surface of the glacier. At that time, the only evidence of glacier flow was the deformation of ice columns, composed of meltwater that had dripped from the lower surface of the glacier and had refrozen in a continuous column from rock floor to glacier sole, much as a stalactite and a stalagmite may grow to form a single column joining the floor and ceiling of a limestone cave. Several ice columns, presumably originally vertical, had been bent downslope near the base of the glacier.

It is possible to walk safely over the surface of the ice to see into a major crevasse near the back of the glacier and to examine a massive ice cliff that rises near its center. It is clear that the surface of the glacier, at least, has broken up into several large, rigid blocks, whose downslope movement is accomplished as much by basal sliding as by plastic deformation within the ice. We do not know if the glacier is thick enough anywhere to impose sufficient shear stress on ice at depth to bring about intragranular flow.

The leading edge of the glacier on Pico La Corona is similarly broken up into rigid slabs; it was possible in June 1972 to walk under the ice in many places along the glacier front on the north slope of Pico Bonpland. There was clear evidence at that time, however, that these slabs of glacier ice were moving downslope fairly rapidly; striations 2-3 m long were observed on the underside of the ice slabs downslope from rock protrusions on the valley floor. Apparently it is not safe to spend much time under the ice on Pico La Corona.

PART III — SUMMARY

In summary, we can make the following statements about the Late Cenozoic history of the Central Andes of Venezuela.

1.—The Boconó Fault zone has been an important tectonic feature of the range for a long time, long enough certainly to have exerted primary control on the gross topographic development of the Central Andes.

2.—Right-lateral strike-slip movement along the Boconó Fault occurred long before 12,700 C^{14} years ago and has occurred after, probably long after, 10,575 C^{14} years ago. A minimum of 250 m of such displacement has occurred since glacier ice of the Mucubají interval first reached its most downvalley position.

Throughout this stage, the cables of the Teleférico lie directly over the old path that leads from Mérida to Los Nevados, a village on the far side of the divide.

Fourth Stage.

From the Loma Redonda station a clear view is available of the massive headwall of the great cirque that lies between Pico Bolívar and Pico Espejo. A series of rock steps can be discerned below the headwall; the small basins between adjacent steps are filled with water or sediment; some the basins may be in part enclosed by ridges of end (recessional) moraine, but the closed basins would exist even in the total absence of glacial sediment.

The valley of Cañada Pico Espejo drops off abruptly below Loma Redonda into a large rock-cut basin, whose floor lies at ± 3,500 m a.s.l. It is not yet clear whether this feature was ever a true cirque; elsewhere along the range, however, the highest cirque in a given valley is no higher than 3,500 m.

The final stage of the Teleférico rises 720 m in a single swoop of 3,071 m between the only two towers; its route takes it across the floor of the huge cirque, enabling us to examine the erosional features on the floor of the upper valley as closely as we are likely to be able; the trip on foot into this part of the valley is a difficult one.

Small ridges of lateral moraine can be seen along the far margin of the highest rock bench below the headwall; the lip of the rock step itself is discontinuously veneered with moraine. This basin lies at ± 4,030 m altitude, higher than any dated samples from Quebrada Mucubají or Mucuchachí. Thus, we cannot estimate when the basin was last occupied by ice.

As the cable car inches up the face of the headwall below the final station, the view of the glaciers on the north and west faces of Pico Bolívar is dramatic. We will not visit either of these glaciers, as the path is difficult.

PICO ESPEJO

From the rock slope behind the terminal station the view is magnificent. The summit of Pico Bolívar is barely one kilometer to the northeast; the twin summits of La Corona (Pico Humboldt is the more distant, Pico Bonpland the nearer) rise 9 km to the east. The mass of Pico La Concha with its two small niche glaciers is hidden behind the bulk of Pico Bolívar. The Llanos are spread out to the south, and on very clear days, the snow-covered summits of la Sierra del Cocuy in Colombia are visible to the southwest.

The glacier cap that lies on Pico La Corona is the largest in Venezuela. We examined this glacier in June 1972 and established that it was retreating so rapidly that till was being spread more or less uniformly across a bedrock slope, rather than accumulating in the topographic form of an end moraine.

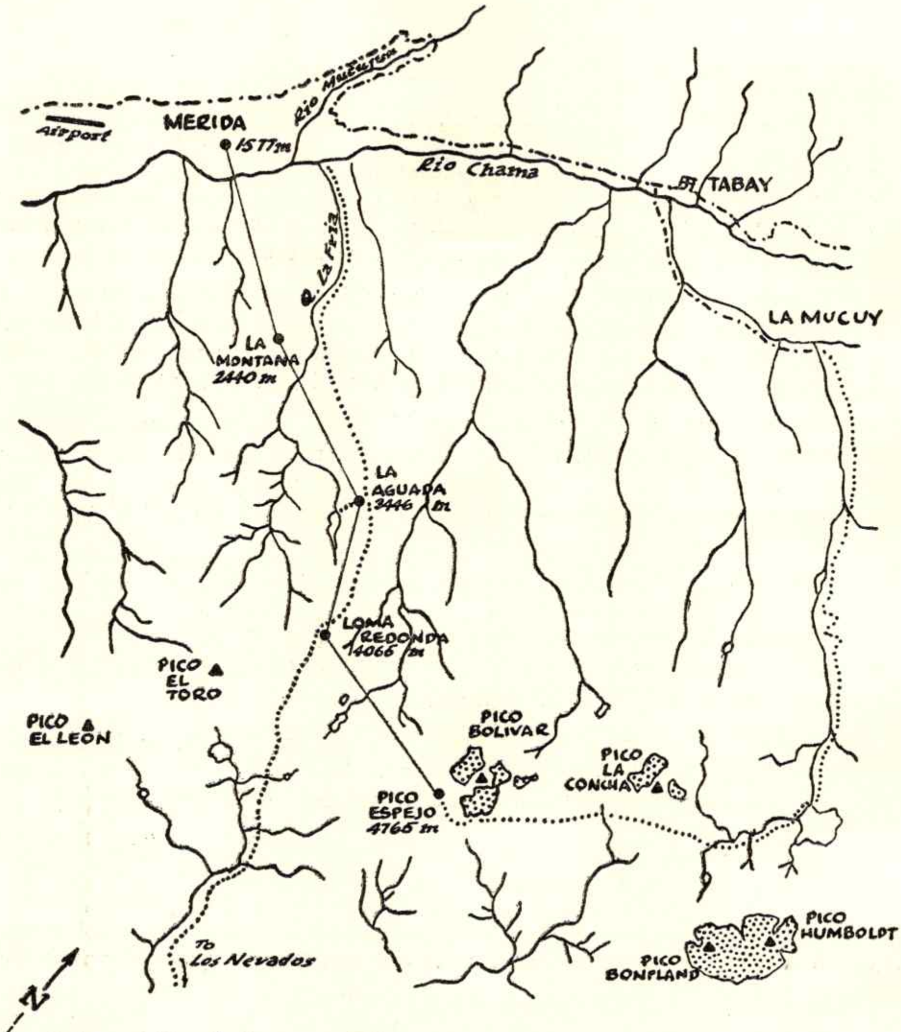


Fig. 13 MERIDA TELEFERICO 0 1 2 3 Km

CARRETERA TRASANDINA AND CONNECTING ROADS
FOOT TRAIL
TELEFERICO
GLACIER

BASE MAPS: 1:5000 TOPOGRAPHIC MAP OF TELEFERICO ROUTE; 1:50,000 DRAINAGE MAP
GLACIERS FROM 1959 AIR PHOTOS

Barinitas (1,577 m)	—	La Montaña	(2,442 m)
La Montaña	—	La Aguada	(3,452 m)
La Aguada	—	Loma Redonda	(4,045 m)
Loma Redonda	—	Pico Espejo	(4,765 m)

First stage

Most of the interesting geology to be seen on the first stage lies to the rear of the direction of travel. No description of the three-dimensional form of the surface on which the city of Mérida is built is a valid substitute for the gradual unfolding of the scale and mass of that feature as the cable car first drops away from the lip of the terrace, providing a brief but instructive view of the texture of the gravel deposit of which the terrace here is composed, and then silently rises up the opposite slope of the Chama valley.

With distance one's ability to resolve details of the terrace form diminishes, but one's ability to take in the sweep of the terrace and to appreciate the gross form of the upper surface grows. An appreciation both of the downvalley slope of the terrace surface and its slope toward the valley center should be gained early, however; by the time the cable car has risen a few hundred meters above the city one is more impressed by the planar aspect of the terrace.

Densely wooded, smoothly contoured slopes rise behind the city. The lower limit of glacial erosion can be identified where this topography gives way abruptly to rough, angular terrain of exposed bedrock that rises to the serrated crest of the Cordillera del Norte.

On the floor of the Chama valley between Mérida and Tabay lie several low, rounded hills, presumably underlain either by cataclastic rock or by wedges of non-resistant material dropped into the Chama graben.

During the first stage, the route of the Teleférico passes over luxuriant tropical forest; in places the cable car dips below an extension of the top of the canopy.

Second stage.

The city of Mérida and its terrace have diminished to insignificant size; we can no longer distinguish topographic features on the floor of the valley. The route of the Teleférico crosses the gorge of Quebrada La Fría, that drains the lake of the same name. Somewhere in the dense vegetation on the floor of the gorge must lie the lowest glacial sediment; we have not identified it on the ground.

During the second stage we can observe the transition from forest to páramo vegetation; La Aguada, at 3,452 m a.s.l., is only 108 m lower than the crest of the Santo Domingo-Chama divide.

Third Stage.

The route of the Teleférico is parallel to the major stream that drains the massive cirque between Pico Bolívar and Pico Espejo. Classic features of glacial erosion are now visible on the valley floor and on the mountain walls that rise precipitously on both sides; glaciers are visible both on Pico Bolívar and on the northwest face of Pico La Concha.

STOP 11: *Mucurubá east (Carretera Trasandina, 11.7 km west of Plaza Bolívar, Mucuchíes. Lat 8° 43′ N, Long. 70° 59′ W). View of Chama Valley.*

The valley is once again restricted; fresh bedrock is exposed in the stream bed just below the road. The mass of relatively fine-grained sediment exposed in the road cut is similar in lithology and texture to the type locality of the Mucuchíes Formation; its gentle dip, however, could be interpreted as initial dip; thus the sediment cannot be proven not to be a deposit of the modern Chama or one of its tributaries.

This is another locality where the Chama may lie close to one margin of its fault-controlled valley.

The village of Mucurubá is built on the steeply inclined surface of an alluvial fan derived from Quebrada Mucurubá. West of the town, sediments of an older alluvial cycle are preserved.

STOP 12: *Mucurubá West (Carretera Trasandina, 0.4 km west of Plaza Bolívar, Mucurubá. Lat. 8° 42′ N, Long. 71° 00′ W). Weathered alluvium.*

The prominent mesa that rises just west of Mucurubá we interpret as an erosional remnant of a complex alluvial fan much like the one that underlies the village of Mucuchíes. Good exposures of weathered alluvium appear along the narrow road that climbs the edge of the mesa from this stop.

Several small islands of deeply weathered cataclastic bedrock, more or less of granitic composition, protrude through the upper surface of the mesa.

The deeply weathered aspect of the sediment in this feature and the extent of erosional destruction of a presumed original alluvial fan morphology suggest that the feature is as old as or older than the Mucuchíes fan.

In a series of looping switchbacks, the road descends the steeply sloping surface of a younger alluvial fan that abuts against the feature just examined. At Escagüey, the road reaches the foot of the lower fan.

STOP 13: *Cacute East (Carretera Trasandina, 6.3 km west of Plaza Bolívar, Mucurubá. Lat. 8° 41′ N, Long. 71° 00′ W). Cataclastic rock.*

This road cut provides a good opportunity to examine a fairly accessible large surface of intensely altered bedrock.

STOP 14: *MERIDA TELEFERICO.*

The Mérida Teleférico was opened on Oct. 9, 1958; at that time it was the longest and highest cable car system in the world. It rises in 4 stages from Mérida (Estación Barinitas) at 1,577 m a.s.l. to Pico Espejo at 4,765 m in 12.5 km of horizontal travel. The four stages are the following (see also Fig. 13):

It seems likely that the whole lower end of the spur between Quebrada La Musuy and the Rio Chama consists of Mucuchíes Formation. The best interpretation of the nature, attitude, and position of this material is that it is a wedge of young sediment, probably of alluvial origin, that was incorporated into the tectonic graben and steeply tilted in the process. Its steep dip and its proximity to the river strongly suggest that it extends below the valley floor; thus it is improbable that the sediment represents a slump block that fell into the modern Chama valley.

STOP 10: *Quebrada La Carbonera (Carretera Trasandina 6.3 km west of Plaza Bolívar, Mucuchíes. Lat 8° 44′ N, Long. 70° 57′ W). View of Chama Valley.*

From the surface of the small fan at the mouth of Quebrada La Carbonera a better appreciation can be gained of the constriction in the Chama Valley just upstream. The long spur that separates the Chama from Quebrada La Musuy is composed entirely of cataclastic rock and Mucuchíes Formation.

The very old hacienda on the fan is the Casa Colonial de Moconoque, one of the oldest surviving structures in the valley. At the end of the 17th century, King Carlos III of Spain authorized don Vicente Pino, Vecino of the Province of Las Sierras Nevadas, whose seat of government was this hacienda, to import mountain dogs from Europa, possibly of the breed Grand Pyrenees, to be crossed with local dogs to produce the mountain dog known as Perro Mucuchíes. A representative of this breed, named Nevado, was presented by don Vicente Pino to Simón Bolívar when he was a visitor at Moconoque on June 10, 1813. Both Nevado and his keeper, the local (Mucuchisero) Indian Francisco Tinjaca, perished in the battle of Carabobo (CASTAÑÓN and NOGUERA, 1964).

The Plaza Bolívar in the center of Mucuchíes commemorates this legend with a statue of Nevado and Tinjaca at the foot of the bust of the Libertador; Mucuchíes may be the only village square in Venezuela where Bolívar shares the honors with a bronze dog.

A modern breeding facility for Perros Mucuchíes is in operation adjacent to the old hacienda. A very modern, highly productive trout hatchery (Truchicultura Moconoque), utilizing the excellent water of Quebrada La Carbonera, has been built above the hacienda.

Extensive ruins on the fan surface below the road may be the gardens and outbuildings of the old hacienda.

The bus will negotiate a series of steep hairpin turns as it descends the edge of a mass of sediment, largely granite boulders, that was dumped into the valley from Quebrada La Musuy and La Carbonera. This material lies directly on cataclastic rock, well exposed in the valley of Quebrada La Carbonera. Below this degraded fan, exposures of cataclastic rock are visible in several of the quebradas draining the valley.

to one of the widely recognized formations in the northern Andes; the folly of attempting to do so will be made more apparent at the next stop.

The cataclastic rock we will see here and elsewhere along the Boconó Fault zone offers less resistance to agents both of weathering and erosion than does the dense crystalline metamorphic rock that supports the massive walls of the Chama Valley. All along the axis of the valley we will see a distinct contrast between low, rounded hills on the valley floor and the steeper, more rugged topography of the mountain ranges on either side.

We cannot attribute the difference in morphology to the probable existence of more rigorous weathering conditions on the valley floor: the transition from weak cataclastic rock to durable unaltered rock is everywhere abrupt and is unrelated to altitude; islands of cataclastic rock are conspicuous from near the top of the Santo Domingo-Chama divide, at ± 3,500 m a.s.l., to the valley floor below Tabay, at ± 1,800 m.

The origin of these cataclastic wedges is at present uncertain. They may simply be fault-shattered block of Sierra Nevada Formation, or they may be wholly dissimilar rocks, in all probability considerably younger than the Sierra Nevada, that were dropped into a developing tectonic graben and sheared by the fault displacement occurring around them. That at least one of these features in the Chama valley owes its position to the latter mechanism will be demonstrated at the next stop.

STOP 9: *Quebrada La Musuy (Carretera Trasandina, 4.3 km west of Plaza Bolívar, Mucuchíes. Lat 8° 44′ N, Long. 70° 57′ W). Mucuchíes Formation.*

We have just traveled down a long spur that separates the valley of the Rio Chama from the valley of Quebrada La Musuy. The rock exposed in the almost continuous roadcut has all been cataclastic rock.

Just at the bend of the steepest switchback (this locality), sedimentary strata that dip back upvalley are exposed in the road cut.

The grain size of the sediment ranges from sand to coarse gravel. The attitude of strata is variable, but the section dips ± 25° east, not too steeply to be considered initial dip. On the far side of this spur a fresh outcrop of similar material is exposed in a slump scar on the valley wall. This sediment strikes E-W and dips north at 30°; too steep to be interpreted as initial dip in a sediment whose stratification is as regular as this. The base of the section is covered, but sediment is exposed not more than 2 m above the Chama and only 10 m distant.

Where the Chama rounds the spur just downstream from this exposure its valley is more restricted than it is anywhere else, and bedrock is exposed in the far bank, one of two places below Mucuchachí where bedrock can be seen in the river bed.

This sediment has been named the Mucuchíes Formation by GRAUCH (1971; GIEGENGACK and GRAUCH, 1972b). An age of Miocene-Pliocene has been tentatively assigned to this sediment on the basis of analysis of included pollen.

samples, collected from within the shallow cut incised by the modern stream through fine-grained sediments deposited in glacially-eroded bedrock basins. In neither case was it possible to determine the total thickness of sediment overlying bedrock, nor was it possible to estimate the length of time that may have elapsed between the time either point in the valley became ice-free and the time that the peat was deposited. These two dates are thus minimum ages of deglaciation: ice had retreated above 3,790 m a.s.l. in Quebrada Mucuchachí by 12,700 ± 110 C^{14} years B.P. (SI-1226).

As the road descends steeply beside the Rio Chama, the valley becomes more open. The village of Mucuchíes lies on top of a massive complex of alluvial sediment deposited in the valley by quebradas draining its north wall.

STOP 7: *Quebrada Misinta (Carretera Trasandina, 0.7 km east of Plaza Bolívar, Mucuchíes. Lat. 8° 45′ N, Long. 70° 55′ W). Mucuchíes Fan.*

The Mucuchíes Fan is a complex of sediment, largely if not wholly alluvial, from diverse sources, but primarily from quebradas draining the mountain range north of the village. We will not be able to examine all the different kinds of sediment in the fan; this one locality and adjacent road cuts will suffice, however, to demonstrate the following:

1. The dip of the sedimentary strata, if that dip is interpreted as initial, indicates derivation from the north wall of the valley.

2. Particles in the sediment are deeply weathered. They would never have survived stream transportation in their present state; hence, weathering must post-date deposition. The sediments thus are clearly older than alluvial sediments associated with glacial activity of the Mucubají interval.

3. The dimensions of the Chama valley at the time of deposition of the fan were not significantly smaller than those of the modern valley.

4. The fan at present is deeply incised, both by the Rio Chama itself and by tributary quebradas.

The trace of the recent displacement along the Boconó Fault can be identified where it crosses the upper part of the fan; primarily vertical motion has created a closed depression, now utilized as a common pasture, behind the village.

A linear trace of disturbed topography developed on bedrock adjacent to the Mucuchíes fan cannot be extended to connect with this sag pond. Minor displacement of alluvial fan morphology on the floor of the Chama valley, just upstream of this locality, similarly does not fall on the same line. Clearly, recent fault displacement occurred along a number of subparallel lines within the tectonic graben aproximately defined by the limits of occurrence of cataclastic rock.

STOP 8: *Mucuchíes west (Carretera Trasandina, 2.2 km west of Plaza Bolívar, Mucuchíes. Lat 8° 45′ N, Long. 70° 56′ W). Cataclastic rock.*

A series of cuts on the north side of the road exposes extremely shattered rock, now deeply weathered. It is not possible with confidence to assign this rock significant magnitude of right-lateral strike-slip displacement along a fault trace that lay just upvalley from the maximum extension of Mucubají ice in this valley. The stereopair of Fig. 11 and the geomorphic map of Fig. 12 show the morphology that is developed on a grand scale; the amplitude of relief, however, is so subtle that the details of the morphology are difficult to discern on the ground.

At least four distinct morainal loops can be identified south of the fault trace; north of the fault at least seven more are partially or wholly preserved.

The pattern of morainal morphology preserved north of the fault, as outlined schematically on Fig. 12, clearly shows an asymmetrical development: many lateral-moraine ridges, and at least three full terminal loops, are preserved on the east side of the modern stream; other than the single lateral ridge continuous with the westernmost loop, no morainal feature is represented on the west side. The modern stream, slightly deflected as it crosses the fault trace, now flows to the Rio Chama west of all but one of the moraines deposited by ice that occupied the valley. Furthermore, clasts of El Aguila phyllite, a lithology not exposed in the watershed of Quebrada Mucuchachí, are represented in the banks of the stream just above its confluence with the Chama.

It is clear that right-lateral strike-slip movement occurred either continuously or many times while moraines of the Mucubají interval were being built. After each successive fault movement, or after each successive minor glacier retreat, the lateral moraine on the right (east) side of the valley was moved far enough east to be protected from erosional destruction by the next advance of ice. The left-side moraine, however, was displaced toward the center of the Quebrada and was either destroyed or buried by the next glacier advance.

The Carretera Trasandina east of this stop is cut below the surface of till in the series of subparallel lateral moraines on the east side of Quebrada Mucuchachí. The serrated crest of road cut we have just passed is in effect a topographic profile across these features.

Thus, the right-lateral migration of the terrain north of the fault preserved the fine details of closely-spaced glacial events, much as the moving drum of a seismograph clearly separates individual earth tremors that would not be distinguished from one another had their vibrations been inscribed on a stationary tablet.

In the process of this fault movement, alluvial sediment containing clasts of El Aguila lithology has been imposed on the lower course of the modern stream.

Not only are ridges of Mucubají Till displaced by the fault, but the long ridge assigned to the Apartaderos Diamicton also terminates abruptly at the fault. Clearly, this ridge was once continuous with Mesa del Caballo; it must have been if the sediment in the depression to the east accumulated in a basin impounded by these two masses of Apartaderos sediment. So far we have been unable to find a continuation of the Mucuchachí ridge either in the morphology or lithology of Mesa del Caballo.

Several radiocarbon dates have been obtained from samples collected in upper Quebrada Mucuchachí (see Fig. 5). None of the samples was from an exposure as instructive as the one we have seen in Quebrada Mucubají; two were peat envision Mesa del Caballo covered with glacier ice at some time prior to the first advance of Mucubají ice.

We lack, however, two properties that would enable us confidently to assign a glacial origin to this material: a striated bedrock surface underlying the sediment, and preserved morainal morphology.

The low, rounded hill just across the Rio Chama from this locality is also discontinuously veneered with deeply weathered unconsolidated sediment. No exposure through a section of the material is available; a high proportion of the boulders and cobbles strewn across the hillsides are composed of granite, suggesting either derivation from the northwest range of the Andes or that weathering was so extensive as to preserve only granitic particles.

All these exposures have been assigned to the Apartaderos Diamicton, as has the long ridge on the east side of Quebrada Mucuchachí.

In the short, steep quebrada just north of the hill across the Chama a remnant of high-level stratified sediment adhering to the valley wall can be discerned. Too little of the sediment is preserved to permit confident assignment of age or specific mode of origin; the proximity of the sediment to the mass of Apartaderos Diamicton suggests that it was deposited in a context very similar to that of the sediment trapped in the basin now incised by Quebrada La Cañada.

The route of the field trip will now follow the upper Rio Chama and Motatán drainage. This route also abounds in glacial features, but we have been unable to find as clear a definition of the stratigraphic sequence as we discovered in the valleys of Rios Chama and Santo Domingo.

On the return trip from El Aguila we will turn at Apartaderos into the valley of Rio Chama; numerous road cuts in the first kilometer of this road are developed in intensely shattered cataclastic rock assigned by GRAUCH (1971) to the Sierra Nevada Formation, the Sierra Nevada Facies of the Iglesias Complex of SHAGAM (1972).

The road crosses to the north side of the Rio Chama and then back to the south. Almost immediately thereafter it is bordered by a continuous artificial cut through fresh moraine of the Mucubají interval, transported into the axis of the Chama valley by glaciers flowing in Quebrada Mucuchachí.

STOP 6: *Quebrada Mucuchachí (Carretera Trasandina 4.7 km west of the road intersection in Apartaderos. Lat. 8° 47′ N, Long. 70° EB′ W). Fault-displaced morainal morphology.*

This extensive road cut affords the best exposure we will examine of typical Mucubají Till, unobscured by the rich growth of vegetation that envelops every surface in the valley of Rio Santo Domingo. We have examined the entire exposure for organic material suitable for radiocarbon dating, but so far nothing has been found.

This quebrada is of special interest because of the large number of distinct morainal ridges that are preserved by virtue of the fortuitous coincidence of thus a minimum value for the southward tilting imposed on the north side of the basin as a consequence of displacement on the Boconó Fault.

At our feet we can see a well-preserved morainal loop emerging from beneath the main terminal feature of Quebrada Mucubají; a somewhat more degraded loop emerges from beneath it. These features have been assigned to the Mucubají interval, as has another smaller loop that is almost wholly buried by sediment that has accumulated in the basin behind the first. The breach in the lower moraine indicates that drainage of an earlier Quebrada Mucubají was also to the Chama system.

The arc of the moraine enclosing Laguna Mucubají is clearly a double ridge; thus we have identified five distinct terminal moraines related to greatest extent of ice in this valley during Mucubají time. This is far short, however, of the number identified in Quebrada del Venado.

An excellent section through typical Mucubají till can be examined in the large pit excavated in the floor of the old outlet through the most prominent moraine.

STOP 5: *Mesa del Caballo (Carretera Trasandina, 24.0 km west of Plaza Bolívar, Santo Domingo, to road intersection; 1 km to mesa rim. Lat. 8°48′ N, Long. 70°50′ W). Apartaderos Diamicton.*

In the wall of a recent slump scar we can examine an excellent exposure of unsorted, unstratified, clay-to-boulder diamicton whose individual clasts are so deeply weathered that it is impossible to remove a single clast from the outcrop-the sediment separates as readily through a cobble as it does along a cobble margin. The face of the slump scar itself represents a surface that cuts indiscriminately across cobble and matrix alike.

The texture of this sediment is reminiscent of the texture of the clearly glacial sediment of the Mucubají moraines. We cannot yet prove, however, that this material must have been transported to this locality by ice. Nowhere is the basal contact of the gravel with underlying bedrock clearly exposed; even if it were available for examination, it is unlikely that a rock as incohesive as this mass of cataclastic rock could preserve anything so delicate as a glacial striation, especially through an interval of weathering as intense as that which altered the overlying sediment.

The following lines of evidence support the probability that this sediment is a till:

1.—Its unstratified, unsorted texture.

2.—The presence of small enclosed ponds on the upper surface of the sediment; these may be artifacts of enclosed basins on typical morainal terrain, or may have formed as a result of subsurface solution and/or collapse under modern climatic conditions.

3.—The sediment lies at an altitude and in a location that has been extensively glaciated in the recent past it takes no great stretch of the imagination to

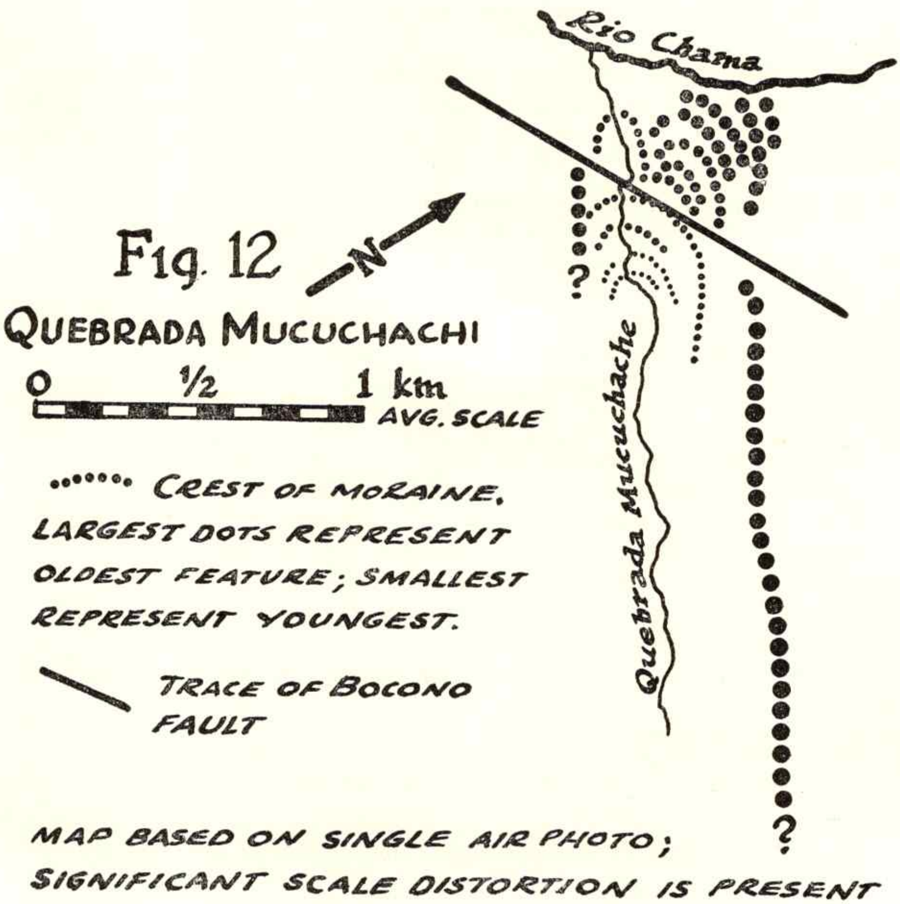


Fig. 12
N
QUEBRADA MUCUCHACHI
0 1/2 1 km
AVG. SCALE
CREST OF MORAINE. LARGEST DOTS REPRESENT OLDEST FEATURE; SMALLEST REPRESENT YOUNGEST.
TRACE OF BOCONO FAULT
Rio Chama
Quebrada Mucuchache
?
?
MAP BASED ON SINGLE AIR PHOTO; SIGNIFICANT SCALE DISTORTION IS PRESENT

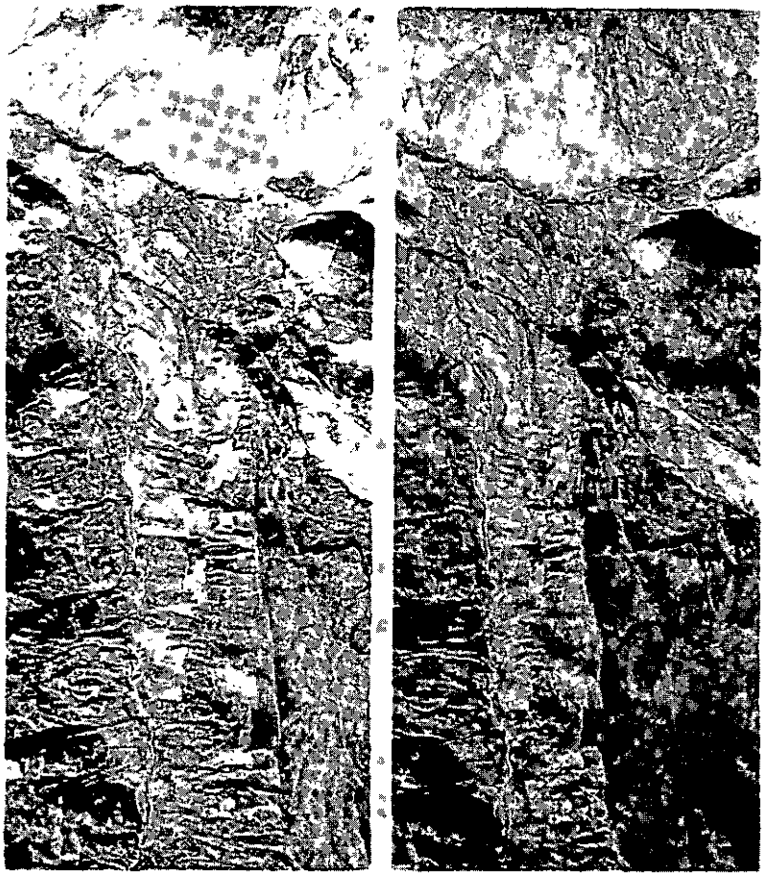


FIG. 11

Quebrada Mucuchache

0 1 km

avg. scale

N

tified as Apartaderos Diamicton. We will look at an exposure of this material at the next stop, but we will not again have the opportunity to view the spatial relationships of certain elements in the terrain before us.

The long, clearly defined ridge that slopes down from bedrock exposed at the head of Quebrada El Caballo is also composed of Apartaderos Diamicton, as deeply weathered as is the material exposed on the mesas below. The form of the ridge clearly suggests a lateral moraine along the east side of Quebrada Mucuchachí; examination of the west side of the ridge reveals no bedrock in the feature (see Figs. 10, 11, and 12). If this feature is a lateral moraine, it is not related to any Mucubají-interval morainal feature preserved in lower Quebrada Mucuchachí: it lacks the near-perfect preservation of morainal morphology characteristic of push till of that interval; the boulders of which it is composed are deeply weathered, and it lies far above the series of lateral moraines in Quebrada Mucuchachí that can be traced directly to terminal loops.

The ridge form of the feature may be the result of erosion by Quebrada Mucuchachí; if such is the case, both the absence of bedrock in the west wall of the ridge and its striking linear form are ambiguous.

The basin enclosed by this lateral ridge and the mass of Mesa del Caballo is filled with sediment. Right-lateral strike-slip movement along the Boconó Fault after (and possibly also during) deposition of this sediment eventually moved Mesa del Caballo far enough east to open a breach in the enclosing wall of the basin, through which the depression then drained via Quebrada La Cañada, eroding instructive cuts through the pile of basin sediments in the process.

Thus, it is clear that the ridge that flanks the east side of Quebrada Mucuchachí was once continuous with some part of Mesa del Caballo; we have not yet been able to trace the ridge directly (if, indeed, it was a ridge at that time) into the mass of sediment capping Mesa del Caballo. The diamicton capping Mesa de Julián contains cobbles of El Aguila phyllite, a lithology not exposed in the watershed of Quebrada Mucuchachí; hence we conclude it must have come down the valley of the Rio Chama. A small exposure in a ditch at the west end of Mesa de Julián suggests that part, at least, of its sediment cap is crudely bedded.

The well-preserved (hence Mucubají-interval) lateral moraine of Quebrada El Caballo clearly overlaps the alluvial sediment of the basin, which cannot be older than the masses of moraine-like sediment that define the basin; hence the moraine of Quebrada El Caballo is younger than the sediment of the mesas or of the ridge. This inference is further confirmed by the difference in extent of weathering of included cobbles and by the fact that significant bedrock erosion (such as was responsible for the incision of Quebrada Los Bijinos) has taken place since deposition of Apartaderos Diamicton, a conclusion incompatible with a Mucubají age for the Apartaderos Diamicton.

We have identified a broad, gentle syncline in the sediments that fill the basin between Quebrada El Caballo and Quebrada Mucuchachí (see Fig. 10). Most of the sediment comprising the basin fill must have been derived from the south, as the surface of Mesa del Caballo does not represent much of a source of sediment. The dip of sedimentary strata so derived must have been horizontal or inclined to the north; the dip of the north limb of the syncline (19°S) is

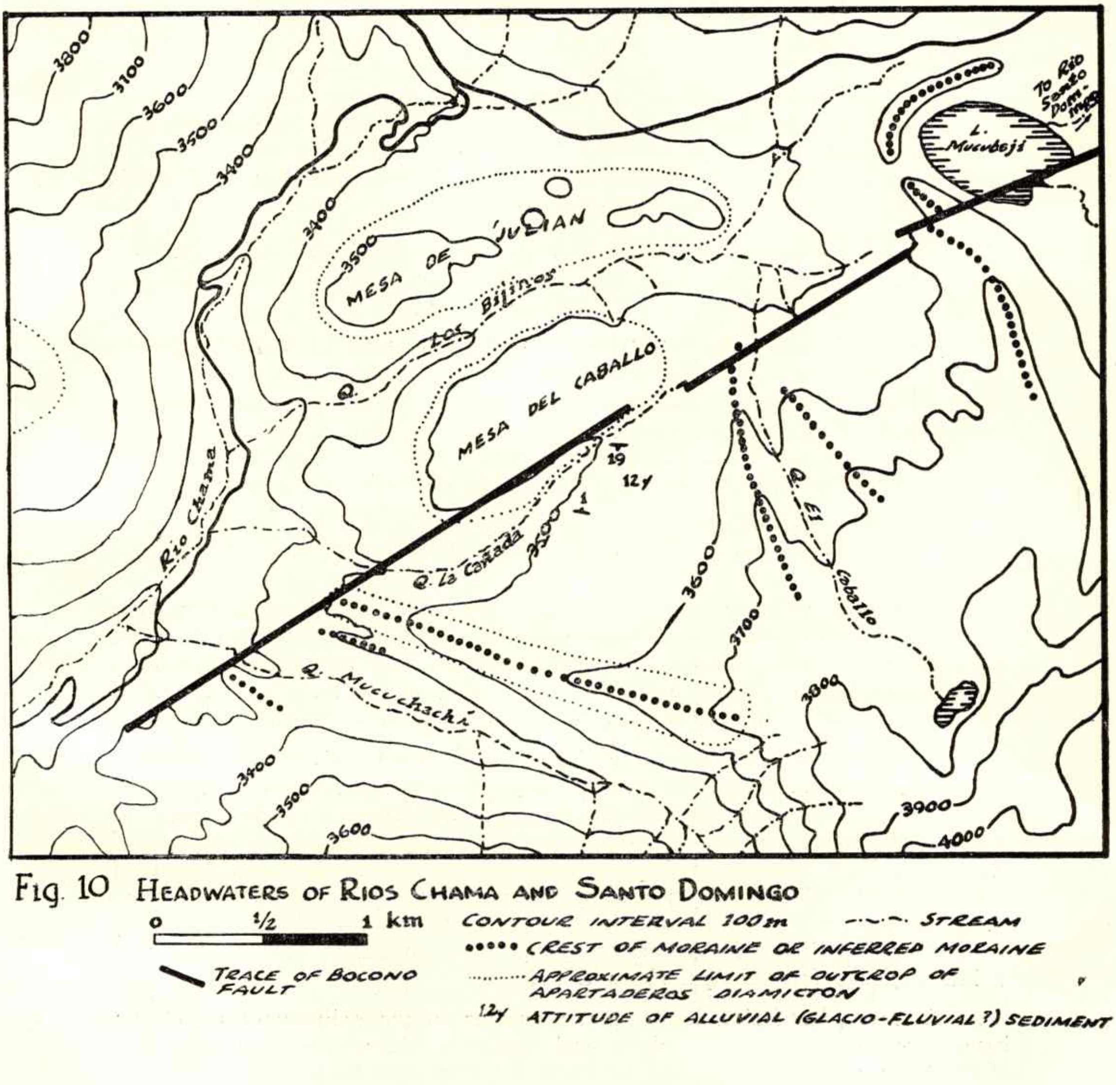


Fig. 10 HEADWATERS OF RIOS CHAMA AND SANTO DOMINGO

0 1/2 1 km

CONTOUR INTERVAL 100 m

STREAM

CREST OF MORAINE OR INFERRED MORAINE

TRACE OF BOCONO FAULT

APPROXIMATE LIMIT OF OUTCROP OF APARTADEROS DIAMICTON

12y ATTITUDE OF ALLUVIAL (GLACIO-FLUVIAL?) SEDIMENT

The sediment exposed at this locality was deposited in still water that supported an aquatic flora. The water body may have been impounded behind the small recessional moraine visible just downstream. The entire section of bedded sediment must have been deposited after this part of the valley was free of ice; consequently any radiocarbon date on peat in the section must be interpreted as a minimum age of the glacier terminus past this point. The lowest peat in the section, dated at 11,465 ± 110 C^{14} years B.P. (SI — 1246) thus represents the oldest minimum age; we are at a loss to estimate how much time might have elapsed after the glacier retreated past this point and before the lowest peat exposed in this section was deposited.

The slump event responsible for the scarp and ultimately for the thickness of exposed sediment in the stream bank must have occurred after deposition of the highest peat in the section. Consequently, the radiocarbon date of 10,575 ± 165 C^{14} years B.P. (SI — 1228) obtained for peat H represents a maximum age of the last faulting event (i.e.: at least *one* faulting event must postdate that time). Once again we cannot estimate how much time might have elapsed after deposition of the highest peat and before the fault event that produced the scarp; the freshness of the scarp and the excellent preservation of fault-disturbed topography along the trace of the Boconó throughout this region leads us to the suspicion that the last event occurred much later than 10,575 C^{14} years ago.

Peat samples from each of the units exposed here are being analyzed for their content of fossil pollen and spores.

Leaving this locality, we will return along the lateral moraine on the west side of Quebrada Mucubají. This feature is clearly multiple. One narrow ridge can be traced directly into the distinct recessional moraine just at the south end of Laguna Mucubají.

The trace of the Boconó Fault crosses the valley just downstream from the lowermost recessional moraine; in the center of the valley the trace passes through the lake itself, and we cannot establish the relative ages of the faulting event(s) and occupation of the recessional moraine (from evidence discussed at the last outcrop, it is clear that at least one faulting event occurred considerably later than occupation of the recessional moraine at the head of the lake).

From the crest of the Mucubají moraine where it is cut by the fault an instructive view along the fault trace in both directions is available. Where the fault trace emerges from the other side of the lake it is clearly defined by an alignment of shallow depressions —sag ponds in the summer— that passes directly south of Casa del MAC. To the west, the right-lateral displacement of the Mucubají morainal loop is apparent, and a series of aligned sag ponds can be traced across the till-covered terrain at the foot of the moraine. The fault trace is marked by a distinct scarp as it crosses the sediment-filled basin beween Quebrada Los Bijinos and Quebrada Mucuchachí; that basin presently is drained along the trace of the fault (see Fig. 10).

Two broad mesas, Mesa Julián and Mesa del Caballo, lie between the sediment-filled basin and the Rio Chama (see Fig. 10). These mesas are underlain by a thick mantle of deeply weathered, unsorted, unstratified sediment tentatively iden-

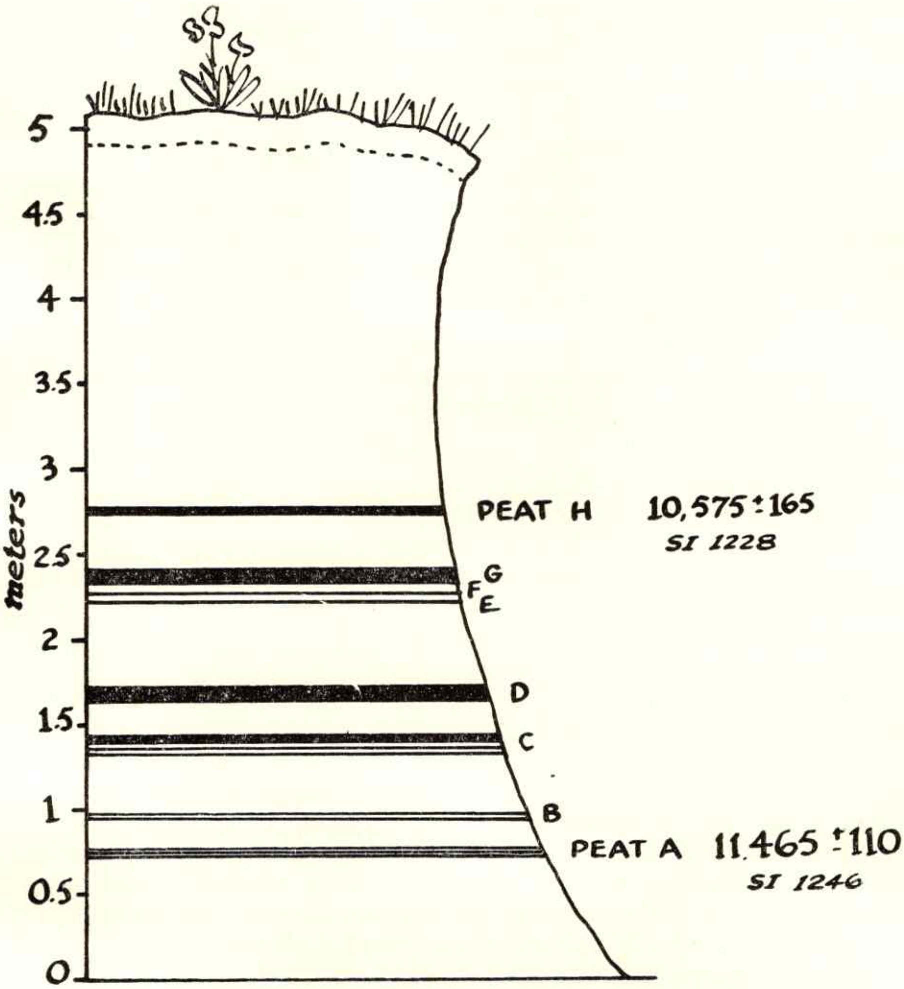


Fig. 9 SECTION OF ALLUVIAL SEDIMENT IN QUEBRADA MUCUBAJI

STOP 3: *Roadside Overlook (Carretera Trasandina 21,1 km west of Plaza Bolívar, Santo Domingo. Lat. 8° 45′ N, Long. 70° 48′ W.). Overview of faulted moraines.*

From this perspective a clear view of the three lowermost faulted moraines in the valley of Rio Santo Domingo emphasizes the persistence of the Boconó trace. From here it is also clear that there may be a considerable thickness of surficial sediment in the valley — the visible portions of the prominent moraines are those parts that stand above an overlapping fill of alluvium, some of it clearly fluvio-glacial. Furthermore, if the random distribution of bodies of till assigned to the Santo Domingo interval represents only those bodies of that sediment that have been exposed at the present ground surface by vertical movement along the Boconó Fault, there must be additional masses of the same sediment buried under younger material.

The road now approaches the crest of the divide between Santo Domingo and Chama drainage. Just on top of this divide (± 3,570 m) we turn off the Carretera Trasandina into the Parque Nacional de Sierra Nevada.

STOP 4: *Casa del M.A.C. (Quebrada Mucubají, Carretera Trasandina 23.0 km west of Plaza Bolívar, Santo Domingo, to road intersection, 1 km to Casa del M.A.C. Lat. 8° 48′ N, Long. 70° 49′ W). Mucubají Till.*

This is the type locality of the Mucubají Till; the long, uniform, curving morainal loop that encloses Laguna Mucubají is the best developed of all morainal features belonging to the latest major glacial advance.

From Casa del M.A.C. a gap can be discerned in the crest of the moraine on the far (west) side of the lake. During the early history of the lake, perhaps at a time when other routes were still blocked by ice, overflow from Laguna Mucubají escaped over the moraine to the west and joined the Chama watershed.

Sometime thereafter a lower outlet to the east became available, and the discharge of Quebrada Mucubají was incorporated into Santo Domingo drainage. The number of poorly defined morainal ridges and the probability, suggested by the absence of distinct lateral moraines on the east side of Quebrada Mucubají, that the glaciers in Quebradas La Victoria and Mucubají might at one time have coalesced, have thus far defeated our efforts to work out the detals of early post-glacial drainage diversions close to the divide.

We will walk a short distance up Quebrada Mucubají, past a series of well-defined recessional moraines, to visit a site from which samples of peat interbedded with finely layered clay were collected for radiocarbon dating.

A detailed section of this exposure is presented in Fig. 9. The total thickness of sediment exposed by incision of the quebrada is 5 m. A short distance downstream the banks are barely 1 m high; a distinct scarp, clearly visible on the air photos, runs across the valley just below this exposure and can be traced into the adjacent valley on either side. The upstream (south) side of the scarp is the upthrown side; erosion by Quebrada Mucubají since the scarp appeared has removed what must have been a very temporary knick in the stream profile; the waterfall visible just upstream from this locality is on bedrock.

initial morainal form has been much modified by erosion. The sediment differs from Mucubají till only in its content of particles of El Aguila phyllite. It was deposited by glaciers that advanced into the valley from the north wall, and presumably met glacier ice derived from the south wall somewhere near the axis of the valley. If the whole upper valley of the Rio Santo Domingo were buried in ice at this time, we should not be surprised that no classic morainal loop is preserved from these events. After ice retreated from the center of the valley, the sediment it had deposited was either buried by alluvium or modified by erosion (a system of now-abandoned drainage channels is preserved on the remnant of Santo Domingo Till directly opposite our position).

The Rio Santo Domingo does not follow what must have been the axis of the valley at the time of deposition of Santo Domingo Till; blocks of till which include El Aguila phyllite cobbles and boulders are now exposed south of the river where haphazard vertical movement accompanying activity on the Boconó Fault has placed them in juxtaposition to bodies of Mucubají Till that still retain near-perfect morainal form.

Our present impression is that Santo Domingo Till is older than Mucubají Till — morainal landforms as well preserved as those typical of established Mucubají features are represented on the north side of the Santo Domingo but lie far up short tributary valleys. We have assigned these features to the Mucubají interval; it follows that less well preserved moraines are older.

It is not clear why an earlier glacial advance should have been more extensive than the Mucubají event. If the climatic pattern that allowed the visibly asymmetric distribution of glacier tongues in the valley in Mucubají time prevailed also during Santo Domingo time, then we should expect to find till bodies of that age derived from the south side of the Santo Domingo Valley far downriver from the mouth of Quebrada del Venado. No such material has been identified; it may yet be discovered under the massive alluvial deposits in the valley of Rio Santo Domingo.

As the road continues up the Santo Domingo Valley, we will pass the mouth of Quebrada La Victoria 1 km beyond this stop. A spectacular morainal loop belonging to the Mucubají interval is preserved in this valley. Although the moraine is clearly cut by the fault, the fortuitous interaction of glacial and tectonic activity that provided the instructive morphology we observed in the two lower valleys did not occur here.

Quebrada La Victoria once contained a sizable lake within its morainal loop. Infilling by fluvio-glacial and alluvial sediments and erosion of the outlet has destroyed the natural lake; as part of the development of the Parque Nacional de Sierra Nevada the outlet has been dammed and the resulting small lake stocked with trout.

As the road continues up the west side of Quebrada El Gavilán, numerous exposures of probable till, as yet unassigned to any specific stratigraphic unit, appear in roadcuts.

Los Zerpas advanced more or less directly over the sediment deposited in the previous glacial event, obscuring older morphology.

After ice had retreated from the terminus in Quebrada Los Zerpas, a lake was impounded within the morainal loop. A more or less continuous section of sediment deposited within and adjacent to that lake can be examined in the cut produced when the quebrada was incised into the sediment after diversion of the outlet through the fault zone. Grain size of the sediment ranges from coarse boulder gravel exposed at the head of the incised portion of the stream to fine silty clay close to the terminal moraine. This latter sediment has been tilted from the horizontal as a result of recent movement along the fault zone; it now strikes N34° W and dips 8° NE. Except for its more nearly horizontal attitude, it is similar in all respects to the sediment exposed in the pit on top of the obstruction in Quebrada del Venado (Point A, Fig. 8).

Two sets of matched terraces, at 20-25 m and 6-10 m above the bed of Quebrada Los Zerpas (SCHUBERT and SIFONTES, 1970; GIEGENGACK and GRAUCH, 1972a) are well developed within the morainal loop. The nearly planar surface of the upper terrace is probably an original depositional surface; that the upper surface of the lower terrace is an erosional surface is clearly demonstrated by the continuity of sedimentary bedding through a section cut through both features on the east side of the valley.

We have interpreted the terrace morphology as follows (GIEGENGACK and GRAUCH, 1972a):

1. Fluvio-glacial sediment was deposited within the morainal loop up to the level of the higher terrace after ice had retreated from the terminal moraine.

2. Diversion of Quebrada Los Zerpas into the fault zone as a result of right-lateral strike-slip (and associated dip-slip) displacement caused incision of Quebrada Los Zerpas to the depth of the surface of the lower terrace; subsequent lateral erosion during a period of stability of the outlet produced the broad valley form cut below the initial depositional surface.

3. A second fault event caused additional diversion and incision of the outlet, ultimately to the level of the present stream. The outlet position has been relatively stable long enough to allow the innermost valley to be widened considerably.

The original outlet that developed across the terminal moraine can still be identified at the distal end of the morainal loop (SCHUBERT and SIFONTES, 1970; GIEGENGACK and GRAUCH, 1972a). This outlet was abandoned at the time of the earlier post-glacial faulting event, and has not since been occupied.

From the top of the hill just west of the abandoned outlet a good view of the morphology of the far side of the Santo Domingo valley can be obtained.

The hummocky topography, partly buried by the apron of coalesced alluvial fans, directly across the river from this vantage point, is underlain by till whose to develop. A shallow valley, now dry, breaches the crest of that terminal moraine; Quebrada del Venado does not follow it, however, but escapes from within the morainal loop along the Boconó Fault zone. Right-lateral displacement of the abandoned outlet with respect to the axis of the Quebrada south of the fault zone indicates a minimum of 100 m of movement along the fault after the last glacier to reach this altitude had retreated at least 400 m from its terminus.

The existence of two faintly preserved terraces within the morainal loop further suggests: 1) that the glacier had retreated far upvalley by the time this last fault displacement occurred, and 2) that two separate faulting events, each of which caused Quebrada del Venado to escape through the fault zone at a lower altitude, occurred, presumably in fairly rapid succession. The faulting that diverted the outlet of Quebrada del Venado also sheared across the array of lateral moraines on the west side of the quebrada, producing a narrow, linear, topographic trough of chaotic terrain. Two distinct slump blocks, each of which preserves the serrated aspect of a section through the array of lateral moraines, can be identified; additional elements of morainal form have been destroyed, presumably by the shear represented by ± 100 m of right-lateral strike-slip movement.

A view in either direction from the crest of the Venado moraine along the trace of the Boconó Fault will demonstrate the apparently random sense of dip-slip displacement that accompanied recent transcurrent movement along the fault. Just east of Quebrada del Venado, a slab of alluvial sediment on which initial morphology is preserved is uplifted and tilted; to the west the distal portion of the morainal loop of Quebrada Los Zerpas appears to have been displaced downward relative to the continuation of the morainal ridge south of the fault zone.

A view across the valley clearly shows that alluvial sediment, possibly in part fluvio-glacial outwash from the glaciers that constructed the terminal moraines visible high on the north wall of the valley, has flooded the valley, partially burying the hummocky topography of outliers of Santo Domingo Till. We will look at these features more closely at a later stop.

Aprons of alluvial sediment of fluvio-glacial origin overlap the margins of the distinct morainal landforms occupying both Quebrada del Venado and Quebrada Los Zerpas. These features have been distorted by recent movement along the fault.

STOP 2: *Quebrada Los Zerpas (Carretera Trasandina 14,7 km west of Plaza Bolívar, Santo Domingo. Lat. 8° 49′ N, Long. 70° 47′ W. Alluvial sediment within loop of faulted moraine of Mucubají Interval.*

Quebrada Los Zerpas is a short, steep valley similar to Quebrada del Venado. Excellent exposures of till can be examined around the terminal loop. This valley does not display the elaborate evidence of multiple glacial advance that we have just observed in Quebrada del Venado; apparently the accident of dip-slip movement that accompanied early movement along the fault was not such as to represent an obstacle to flow of subsequent glacier tongues. Each successive glacier in Quebrada

A pit (point A in Fig. 8) on the top of the prominent knob just east of the stop penetrates 1 m of coarse boulder gravel and then 4.5 m of fine-bedded silty clay that strikes N75° W and dips 45° S. Adjacent pits within a 25-m radius of pit A penetrate similar material; dip of the strata ranges from 20° S to 50° S, suggesting that the mass of sediment was not deformed as a rigid block. The fine sediment is interpreted as having been deposited in still water within a morainal loop; we will see a similar sediment still in contact with the walls of its basin in Quebrada Los Zerpas.

Quebrada del Venado preserves an array of spectacular lateral moraines, but the topographic form of the terminal moraine has been obscured as a result of young strike-slip right-lateral movement along the Boconó Fault; the distinct trace of most recent movement lies 400 m south of the road. The stereopair of Fig. 7 shows this morphology clearly; the sequence of events we have reconstructed (GIEGENGACK and GRAUCH, 1972b) can be followed in the field by reference to the stereopair and to Fig. 8.

1. Ice extended down Quebrada del Venado, depositing push till (end moraine) that overlaid or interfingered with Santo Domingo Till carried by ice that advanced from the north.

2. Retreat of the Venado ice tongue allowed finegrained sediment to be deposited within the morainal loop.

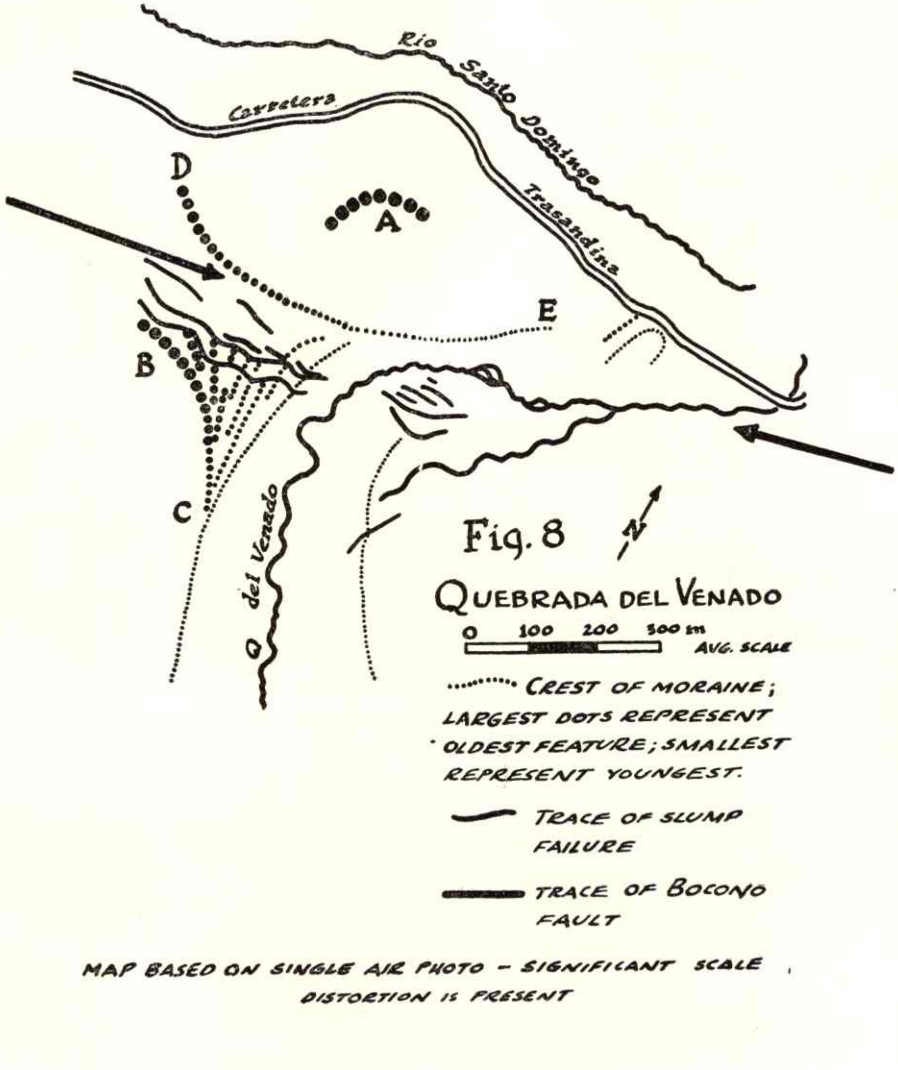
3. Predominantly vertical movement along the Boconó Fault uplifted the north side of the fault and with it this sequence of three sediment types, and tilted them ± 45° to the south; erosion subsequently obscured all suggestion of morainal form.

4. A glacier that later advanced down the valley was unable to override the uplifted mass of sediment plugging the valley mouth, and flowed around the obstruction to the west; the only evidence of this event that is preserved is the westernmost ridge of lateral moraine, indicated by B in Fig. 8.

5. Successive subsequent glacial events produced ice tongues, each of which passed somewhat east of the westernmost ridge of lateral moraine deposited by the previous glacier. Resulting topography is the array of linear ridges that radiates from point C in Fig. 8; depending on the minimum size of a ridge that one will accept as a lateral moraine, as few as 10 or as many as 17 separate glacial readvances are documented by this morphology. Because the total eastward displacement of successive ice tongues is the result of the position of the obstruction and not related directly to contemporary movement along the fault, it is not possible to reconstruct the sense of movement that might have occurred on the fault while these moraines were being built. Evidence to be documented in Quebrada Mucuchachí bears significantly on this problem.

6. Eventually the route to the west of the obstruction became so choked with glacial sediment that the ice escaped down valley east of the obstruction. The ridge D-E on Fig. 8 represents the slope built up of morainal material that cascaded down the front of the blocked glaciers as they occupied positions progressively farther east.

7. At least the last major glacial advance pushed ice all the way past the east flank of the obstruction, allowing a small terminal moraine of typical form


Rio Santo Domingo
Carretera Trasandina
D
A
E
B
C
Q. del Venado
N
Fig. 8
QUEBRADA DEL VENADO
0 100 200 300 m
AVG. SCALE
CREST OF MORAINE; LARGEST DOTS REPRESENT OLDEST FEATURE; SMALLEST REPRESENT YOUNGEST.
TRACE OF SLUMP FAILURE
TRACE OF BOCONO FAULT
MAP BASED ON SINGLE AIR PHOTO - SIGNIFICANT SCALE DISTORTION IS PRESENT

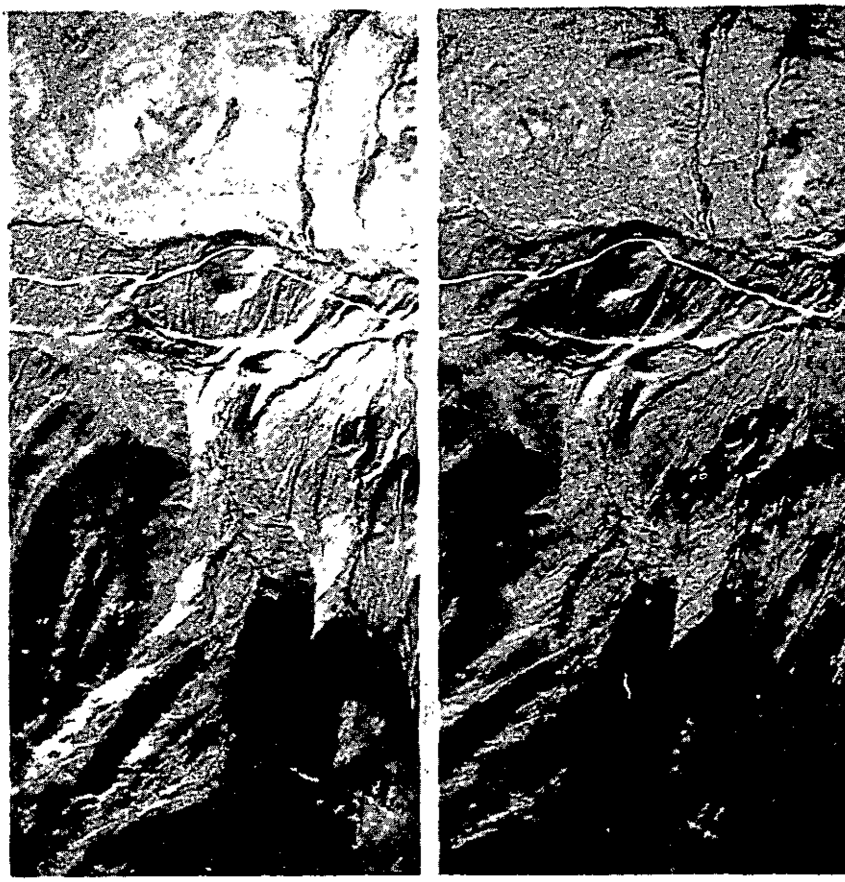


FIG. 7

Quebrada del Venado

0 1 km

avg. scale

N

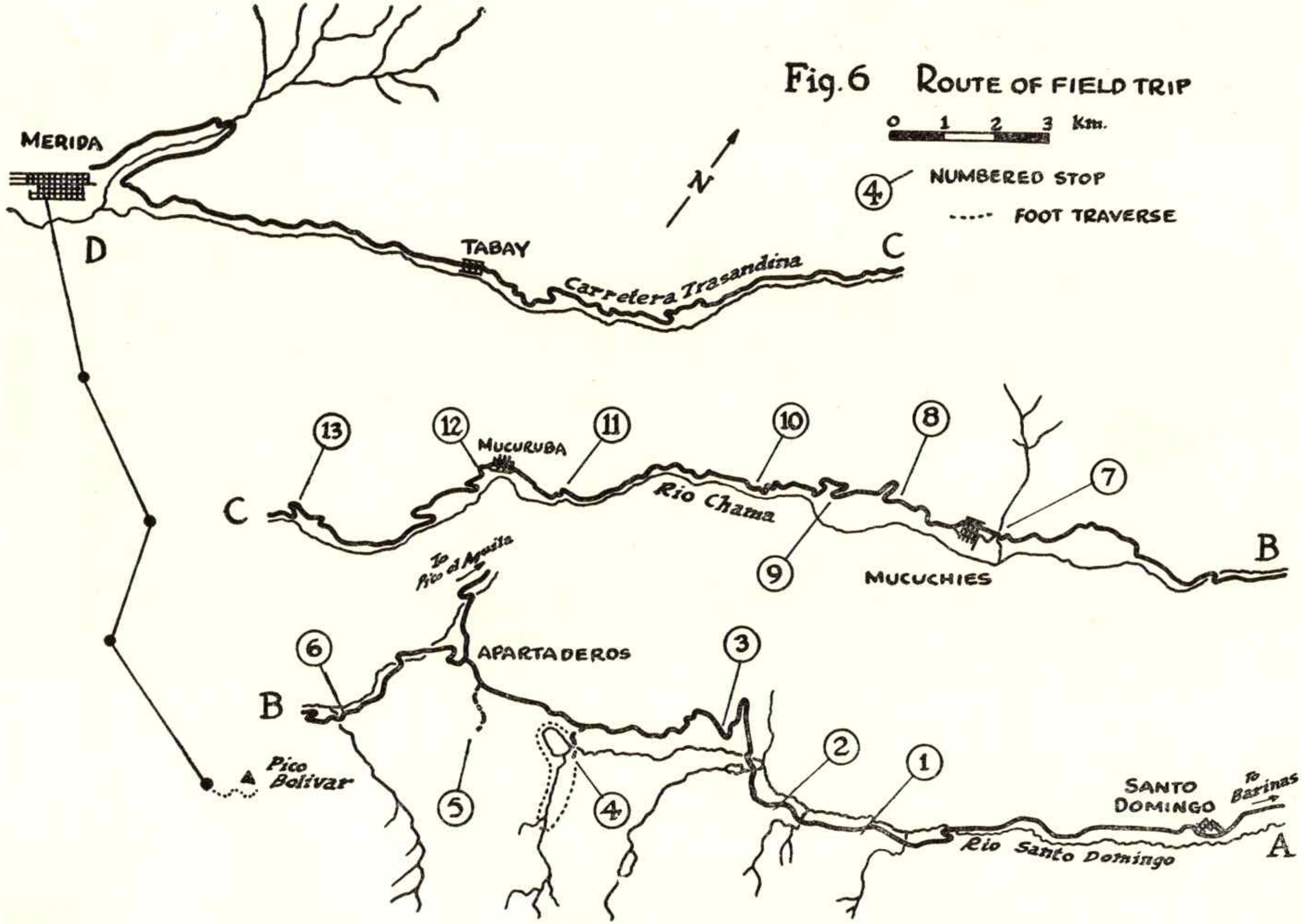


Fig. 6 Route of Field Trip

3. To outline the problems so far encountered in trying to date climatic events in the Andes.

4. To examine some of the more spectacular features of glacier erosion and deposition.

5. To demonstrate the magnitude and direction of fault displacement of depositional features belonging to the various stratigraphic units.

6. To view, from the Mérida Teleférico, contemporary glaciers and the dramatic examples of the effect of earlier, larger glacier tongues on páramo topography.

7. To examine terrace morphology in the Chama Valley and to consider the sedimentology of the materials comprising those landforms.

8. To study exposures of cataclastic rock in the Chama Valley, and to indicate the extent to which the topography of the valley is controlled by outcrop of such materials.

9. To demonstrate how the form of the Chama Valley, on all scales, is controlled by the geometry and history of the Boconó Fault zone.

The map in Fig. 6 shows part of the route of the field trip. Stops to examine Quaternary features are numbered.

PART II — LOG OF THE FIELD TRIP

Our commentary begins at the town of Santo Domingo. The village is constructed on the relatively smooth surface of aluvium deposited in the valley of the Rio Santo Domingo by quebradas draining the north wall of the valley. About 5½ km west of the town the valley becomes constricted and the alluvial fan morphology disappears as the Carretera Trasandina climbs steeply through a short series of switchbacks. The valley opens out again above this constriction. The lowest (2,880 m.a.s.l.) glacial till in the valley appears in a well-vegetated cut on the south side of the road about 2 km above the switchbacks. A series of glacial moraines can be seen extending down the south wall of the valley, whereas a broad alluvial apron mantles the north side.

STOP 1: *Quebrada del Venado (Carretera Trasandina 12,5 km west of Plaza Bolívar, Santo Domingo; Lat. 8° 49′ N, Long. 70° 46′ W).— Fault-displaced moraines of Mucubají interval.*

Quebrada del Venado is a short, steep valley; the highest cirque in the watershed, only 4 km south of the moraine, lies at 3,980 m.a.s.l., 1,040 m above the road at this point.

Sediment exposed in the road cut just east of the stop is Santo Domingo Till; cobbles of El Aguila phyllite can be observed in the section. A series of pits sunk in the slope above the road documents an abrupt disappearance of this lithology, without any other noticeable change; till higher in the slope is assigned to the Mucubají Formation.

Late-Cenozoic tectonic activity

Although many of the rock structures in the Venezuelan Andes are quite old, much evidence is available to demonstrate conclusively that the range is tectonically active. Most such evidence is in the form of the observed distribution of seismic activity and reports of displacement of young sedimentary rocks by movement along faults. The most persistent and best defined of such faults is the Boconó. Formally named by ROD (1956), the Boconó Fault is expressed by a continuous straight alignment of topographic features that extends from the Táchira Depression north of San Cristóbal to a point west of Puerto Cabello near the Caribbean. Much of its 450-km trace is defined by a prominent topographic depression; it is not clear at all localities whether this morphology is an artifact of initial fault displacement or has developed subsequently by preferential erosion of cataclastic rock.

In the high valleys of the Rios Chama and Santo Domingo, differential erosion of dissimilar rocks juxtaposed in tectonic events of unknown age clearly defines the fault trace; the landforms developed during subsequent erosion cannot be used to reconstruct the geometry of the tectonic events responsible for the topographic discontinuities. The involvement of rocks of the Mucuchíes Formation (GRAUCH, 1971) in the fault zone indicates that at least some of the earlier activity is Miocene or younger.

Displacement of glacial-deposition morphology and related alluvial landforms permits the sense and magnitude of very late, dominantly transcurrent, faulting to be determined directly from the displaced topography. Measurements in six glaciated valleys adjacent to the Santo Domingo-Chama divide indicate a minimum of 250 m of right-lateral strike-slip displacement along the Boconó Fault since the last major glacial advance first reached its terminal position; at least 120 m of right-lateral movement has occurred since ice retreated from contact with the most prominent terminal moraines.

The sense of dip-slip displacement is variable along the fault. The glacial sediment behaved as a series of distinct blocks, perhaps riding on bedrock blocks of similar dimensions; interference among such blocks in the course of net strike-slip movement resulted in an apparently random pattern of minor vertical displacement.

Fresh interest in the history and geometry of the Boconó Fault zone and related structural features in Venezuela has been stimulated by the recent general acceptance of the gross aspects of the new global tectonics.

Objectives of the Field Trip

The specific objectives of the Quaternary aspect of this excursion are the following:

1. To examine a representative example of each of the major sedimentary units.

2. To demonstrate the evidence for the sequence established for these units.

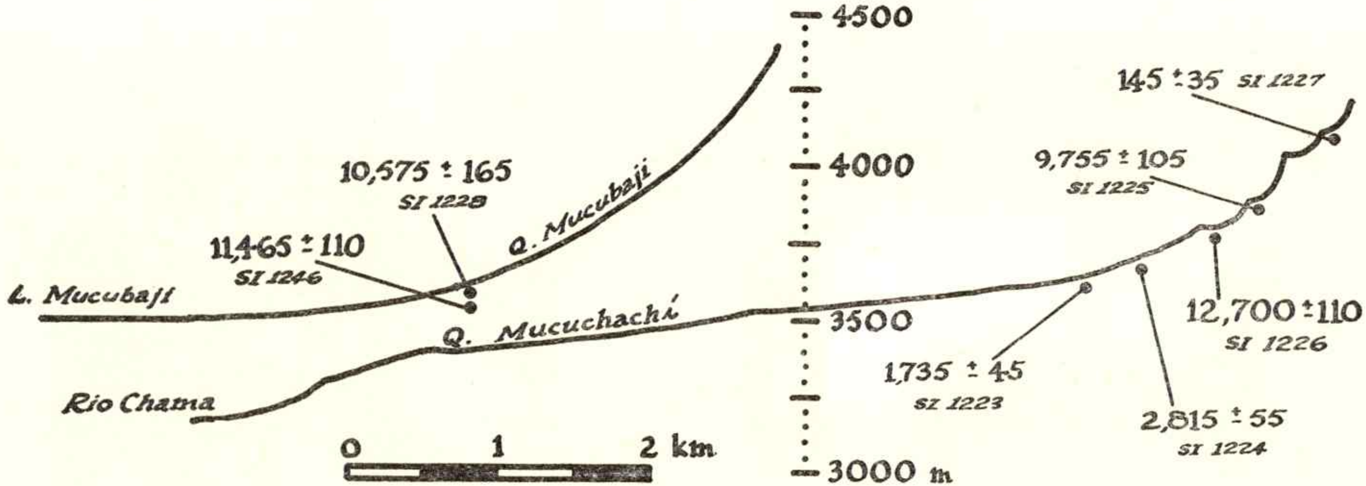


Fig. 5

RADIOCARBON DATES FROM QUEBRADAS MUCUBAJI AND MUCUCHACHI although more detailed work may indicate that such variation might have made a contribution to the present morphology.

Reconnaissance examination of the terrace morphology in the valley of the Rio Motatán has impressed us with the perfection and the spectacular scale of the terraces that flank the river; we are still too unfamiliar with both the bedrock and surficial geology of that valley to suggest a mode of origin of the terraces.

Chronology

The glacial sequence we have established for the upper Rio Santo Domingo and Chama is complex and may represent a long span of time. We have resisted the temptation to correlate elements of an inferred climatic sequence in the Venezuelan Andes with climatic chronologies established elsewhere for two reasons:

1.—There is no evidence that gross climatic variation at the latitude of the Venezuelan Andes need be in phase with climatic variation elsewhere.

2.—We have yet no absolute age of any unit in the stratigraphic sequence whose relationship to climatic history can be confidently demonstrated within sufficiently narrow limits to permit long-range correlation.

Assignment of relative ages to the various elements of the stratigraphic sequence has, of course, been implicit in the identification of that sequence. In addition, radiocarbon dates have been obtained for samples collected near the Santo Domingo-Chama divide, in Quebradas Mucubají and Mucuchachí (see Fig. 5 and App. 1).

Each of the 7 samples was recovered from alluvial or lacustrine sediment deposited on the valley floor after the glacier terminus had retreated upvalley past the point at which the sample was collected. In every case, there was a significant, unmeasurable thickness of non-glacial sediment under the sample and overlying the valley floor. Each date, therefore, represents a minimum age of the time when the floor of the valley at the point of the sample's location became ice-free. Since all dates are minimal we are not justified in interpreting a series of ages from a given valley as a chronology of glacier retreat; only the oldest date in each valley, which by coincidence comes from high in each valley, is significant.

Thus it is clear that the terminus of the glacier that occupied Quebrada Mucuchachí had retreated at least to 3.790 m in altitude by 12,700 $\pm$ 110 C^{14} years B.P. (SI-1226), and possibly much earlier, and that the glacier in Quebrada Mucubají had retreated at least to 3660 m by 11,465 $\pm$ 110 C^{14} years B.P. (SI-1226) and possibly much earlier.

These data are not incompatible with the interpretation that glacial events in the Venezuelan Andes were synchronous with those in say, the Alps or the Rocky Mountains of temperate North America, nor are they incompatible with the interpretation that glaciers reached maximum extension in the Andes far earlier than they did in those regions. Resolution of this fundamental problem (on which may depend the validity of many theoretical models of atmospheric circulation advanced in the last few years to explain the established variation in Pleistocene climates) must await the acquisition of more meaningful radiocarbon dates from more critical stratigraphic contexts.

ficulty, to one or more local quebradas. Below Mucurubá, however, the valley becomes wider and the alluvial features begin to coalesce, resulting ultimately in a continuous, more or less planar, alluvial surface whose general slope is in the same direction as that of the gradient of the Chama. The city of Mérida is built on one of the most spectacular such features in the valley. The fact that the runway of the Mérida airport and the main avenues (Avenidas) in the city slope downvalley at ± 4½% obscures in the minds of many the fact that the slope of the streets (Calles) toward the valley center is at least as steep. The slope of the Chama itself at Mérida is only ± 2½%; the terrace surface and the river profile would thus converge if the terrace surface were sufficiently extensive.

We have not progressed far in our study of the geomorphology and sedimentology of these alluvial features. We feel, however, that the more or less continuous terrace surface that is such a striking characteristic of the Chama Valley below Mucurubá is a composite surface of coalesced alluvial fans rather than remnants of a once-continuous valley fill, for the following reasons:

1.—The gravel in the terrace sediment is everywhere primarily of local lithology, implying lateral rather than axial derivation.

2.—The features slope as steeply toward the river as they do downvalley, a surface form unlikely to be achieved even by torrential deposition of coarse gravel on a riverine flood plain.

3.—Although the slope of the terrace surface is generally in the direction of the gradient of the Chama, the downvalley slope of the surface is more variable than is the gradient of the Chama, and the height of the terrace surface above the river varies through a wide range of values.

This lack of parallelism between the two surfaces can be interpreted either as: 1) differential tectonic deformation of a surface initially more uniform, or 2) random accumulation of a thick valley fill from contributions from tributary quebradas (in this case, sediment dumped into a semi-linear tectonic graben).

The first two lines of evidence advanced above strongly support the second of these hypotheses. The major contribution the Chama has made to this spectacular morphology has been to cut its present valley far below the surface of the coalesced fans.

(A useful comparison can be drawn between the Chama Valley and the valleys of Rios Burate, upper Boconó, and upper Guanare, which drain a portion of the Boconó Fault zone 60 km NE of Santo Domingo. In both regions, great quantities of alluvial sediment have been dumped into a tectonic trough, in each case a segment of the Boconó Fault zone. In the case of the Chama Valley a through-flowing stream, perhaps periodically swollen by glacial meltwater, fortuitously cuts a deep channel through the sedimentary pile; in the Boconó region no such trunk stream has been available, so the surface morphology of flanking alluvial fans has not been obscured).

We find no evidence to support the interpretation that the terrace morphology is a consequence of changes in Chama regimen related to climatic variation, of boulders exposed on till surfaces, thin weathered rinds, if any, on exposed boulders, and near-perfect preservation of morainal morphology.

With one exception (Laguna Mucubají), lakes impounded within morainal loops have been drained by erosion of their overflow outlets; in at least two cases (Quebradas del Venado and Los Zerpas) such draining was enhanced by erosion (and subsequent diversion of the outlet) along the trace of the Boconó Fault, which was clearly active before, during, and after occupation by ice of the most downvalley (and most prominent) terminal moraine.

In tributary valleys on the north side of the upper Rio Santo Domingo, terminal moraines bearing all the diagnostic characteristics of Mucubají Till are developed far upvalley from those much more eroded morainal features that have been assigned to the Santo Domingo interval.

That the Mucubají Till records a complex, multiple glaciation is shown by the abundance of well-developed recessional moraines in many of the valleys. In Quebradas del Venado and Mucuchachí, movement along the Boconó Fault during building of the most prominent morainal loop shows that construction of this feature was accomplished by a series of glacial advances, each achieving more or less equal extension. In other valleys sediment deposited by this succession of glaciers is incorporated into a single topographic feature.

Glacio-fluvial and alluvial sediments.

In addition to sediments deposited directly from ice, each of the major valleys contains a pile of sediment derived from glacial erosion, but ultimately deposited from running water. In the upper Santo Domingo Valley sediment of this type deposited late in the Mucubají interval can be shown to overlie earlier Mucubají moraines and nearly buried remnants of Santo Domingo moraines. The Rio Santo Domingo is now incised as much as 50 m into this alluvial sediment.

The topographic bench represented by the surface on top of this alluvium can accurately be described as a terrace, and since its elevation above the river is a result of river erosion it might be called a river terrace. This usage implies to many people that the river itself was the agent of deposition of the sediment, an interpretation to which we do not subscribe. In the discussion that follows, the term *terrace* is used in a wholly descriptive sense and should not carry any implication of mode of origin of the features to which it is applied.

Along the upper Rio Chama, prominent cliffs of alluvial sediment have been steeply undercut by erosion of the trunk stream, as at Mucuchíes, resulting in a nearly planar surface, dipping steeply toward the center of the valley, and terminating abruptly in a near-vertical cliff. Examination of the face of the cliff at Mucuchíes shows that the sediment is locally derived, some of it has been deeply weathered *after* deposition, and the pile of alluvial sediment represents but a few pages in a complex history of variation in regimen of the local quebradas. The sole contribution of the Rio Chama has been to provide the geologist with spectacular outcrops through the alluvium.

The upper Rio Chama is bordered by a series of such masses of young sediment, separated from one another; each is assignable, with more or less dif-

All are characterized by extensive deep weathering of both clasts and matrix. Where exposed in section, individual gneiss or granite cobbles can be cut with a knife; when strewn across a slope the surfaces of granite boulders are deeply etched where feldspar crystals have wholly weathered out, leaving a honeycombed quartz skeleton. The matrix of such bodies is almost wholly clay. The texture, diversity of included lithologies, range of grain sizes, and proximity to younger sediments of demonstrably glacial origin strongly support the interpretation that the Apartaderos Diamicton is in fact a till; the suggestion of morainal morphology in the long high ridge on the east side of Quebrada Mucuchachí further supports this inference.

The term *till* requires a specific mode of origin: *diamicton* is wholly descriptive and can be assigned to this sediment without carrying any connotation of agent of deposition.

A period of significant bedrock erosion occurred after deposition of elements of Apartaderos Diamicton and before deposition of later till bodies.

Santo Domingo Till.

Santo Domingo Till is a diamicton whose glacial origin is attested by a poorly preserved, but still recognizable, morainal form. This unit has been identified only in the upper Santo Domingo Valley, where it is distinguished from the overlying Mucubají Till primarily by its content of cobbles and boulders of phyllite from the El Aguila Formation; this rock type is not exposed on the south side of the Rio Santo Domingo watershed.

It is not clear at this time whether the Santo Domingo Till is a lateral equivalent of Mucubají Till or whether it is stratigraphically older. It is clear from demonstrable direct superposition that at least part of the Santo Domingo Till is older than part of the Mucubají Till; without the distinction provided by the presence of El Aguila phyllite in the Santo Domingo Till, it would be difficult, if not impossible, to distinguish the two. No systematic difference between thickness of weathered rinds in boulders in the two tills was observed. The stratigraphic distinction is made more difficult by the fact that the two bodies are directly associated only in the zone of most recently disturbed topography along the Boconó Fault.

The distinction between Santo Domingo Till and Mucubají Till has been made only in the upper Santo Domingo Valley. More detailed work, both here and in other valleys, is required to determine whether the two sedimentary units represent two distinct glacial periods. The stratigraphic distinction is valid and workable in the type area; we thus feel justified in establishing the two units as separate formations, despite our present uncertainty regarding their relative ages.

Mucubají Till.

The largest, most prominent terminal moraine loop in each major valley draining to the upper Rio Chama and Rio Santo Domingo has been assigned to the Mucubají Till. All till bodies so identified are characterized by an abundance

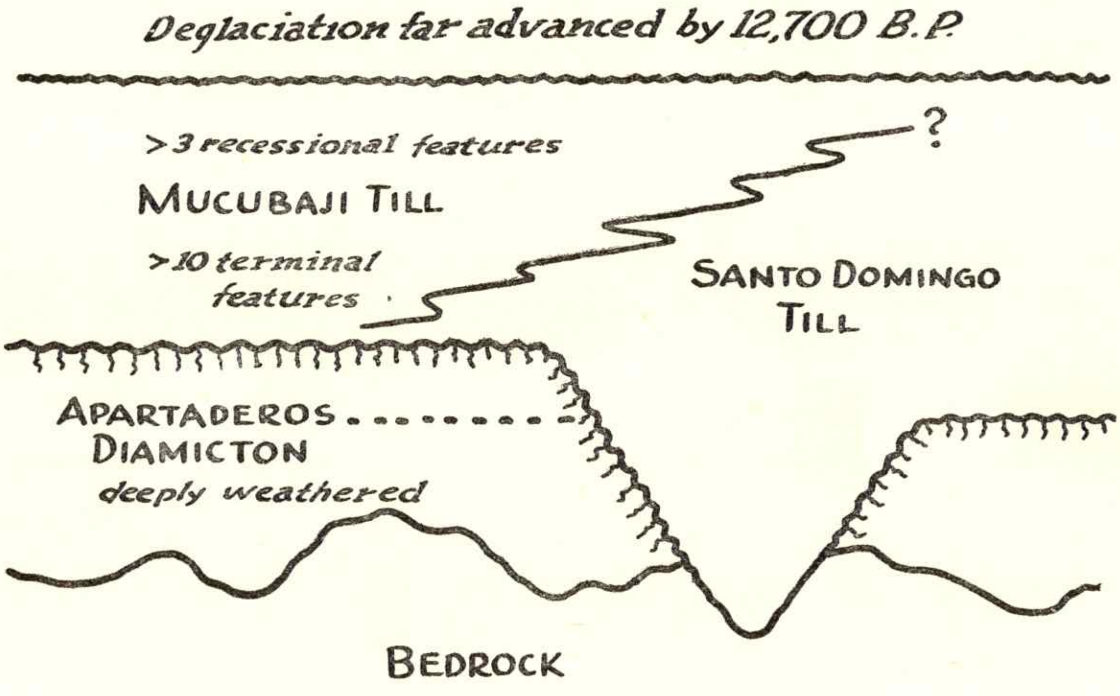


Fig. 4

SCHEMATIC STRATIGRAPHIC SECTION

Our intention has been to examine the record of glacier activity preserved in the high valleys of rios Santo Domingo, Chama, Motatán, and Mocotíes, and to erect local stratigraphic sequences of glacial and non-glacial events wherever possible. Correlation between adjacent valleys has confidently been established on the basis of qualitative considerations such as extent of destruction of morainal morphology and depth of weathering of boulders in the till; correlation from region to region and ultimately from continent to continent must await the acquisition of appropriate radiocarbon dates.

Our work to date has been concentrated in the high valleys of Rio Santo Domingo and Rio Chama and in the tributaries to these rivers.

Climatic stratigraphy

In delineating a sequence of stratigraphic units that represent climatic events in the valleys of the upper Rio Santo Domingo and Chama, we have analyzed both erosional features and depositional features and materials. The depositional features have been the more valuable: since the material of which they are composed is preserved and related to the process that formed them, they provide a positive, rather than negative record of what has transpired.

Two types of sedimentary deposits have received our greatest attention: till bodies, deposited directly from glacier ice, and fluvio-glacial sediments, deposited from glacial meltwater.

The former have been the more instructive, both because they offer incontrovertible evidence of the position of a glacier at the time the sediment was deposited, and because in many cases enough original morphology of the till body has been preserved to enable us to reconstruct the approximate size and shape of the glacier that produced it, the course the ice followed, and many details of the sequence of events as the glacier terminus retreated.

From observed superposition and morpho-stratigraphy of till bodies, from lithostratigraphy of the till itself, and from relative exposure ages of till bodies inferred from degree of preservation of morainal morphology, depth of soil developed on presumed original surfaces, and thickness of weathered rind on boulders included in the till, we have constructed a stratigraphic sequence of till units from which a complex, late-Pleistocene climatic sequence can be inferred.

The stratigraphic sequence is presented schematically in Fig. 4; the major objective of the Quaternary aspect of the field trip will be to offer examples of each unit represented there and to demonstrate the evidence that led to propose this sequence.

Apartaderos Diamicton.

A number of bodies of unsorted, unstratified, poorly consolidated cobble to boulder diamicton * have been identified near the Santo Domingo-Chama divide.

* *Diamicton:* Any nonsorted or poorly sorted terrigenous sediment that consists of sand and/or larger particles in a muddy matrix (FLINT *et al.,* 1960a,b).

Fig. 3 continued:

STATION	YEARS	SOURCE	NUMBER OF CROSSINGS OF 0° C						
				AMPLITUDE					
			0	-1° to +1°	-2° to +2°	-3° to +3°	-4° to +4°	-5° to +5°	-6° to +6°
Pico Espejo 4765 m	3	2	624	468	300	113	34	6	1
Loma Redonda 4065 m	3	2	90	26	6	0			
(La Aguada 3446 m)	3	2	0						

SOURCES: 1) Gonzalez V., P.E., 1971; 2) Computations from records in the Dep't. of Climatology, Escuela de Geografía, Universidad de Los Andes; 3) Schubert, Carlos, 1971.

Fig. 3: SELECTED CLIMATIC VARIABLES FOR PICO ESPEJO (4765 m) AND LOMA REDONDA (4065 m)

		YEARS	SOURCE	J	F	M	A	M	J	J	A	S	O	N	D	MEAN ANNUAL
PICO ESPEJO	Mean maximum	3	1,2	3.2	3.7	3.6	3.4	1.6	0.1	-0.3	0.0	0.7	1.4	3.6	3.0	2.0
	Mean	3	1,2	0.0	-0.4	0.0	0.2	-0.6	-1.1	-1.8	-1.6	-1.7	-1.0	0.6	0.2	-0.6
	Mean minimum	3	1,2	-2.6	-2.9	-2.4	-2.0	-2.1	-2.0	-2.8	-2.7	-3.1	-2.5	-1.6	-1.6	-2.4
	Absolute max.	2	3	8.0	8.7	6.8	8.9	4.5	5.8	6.0	2.4	3.7	3.7	6.3	7.1	
	Absolute min	2	3	-4.4	-5.4	-4.7	-4.6	-3.0	-6.0	-3.2	-4.0	-5.0	-10.8	-2.7	-3.5	
	Rel. humidity Mean, in %	2	1	68	70	75	77	92	94	94	96	94	90	-	84	MEAN TOTAL
	Precipitation Mean. in mm	3	1	55.3	6.1	12.1	60.1	132.3	130.1	129.3	170.8	147.7	211.9	154.4	49.1	1259.2
																MEAN ANNUAL
LOMA REDONDA	Mean maximum	3	1,2	6.0	6.5	6.5	5.9	6.7	5.6	5.0	4.6	5.3	5.3	5.2	5.5	5.2
	Mean	3	1,2	4.1	3.9	4.5	4.3	4.7	4.3	3.5	3.5	3.7	4.0	3.8	3.6	4.0
	Mean minimum	3	1,2	3.1	2.5	3.3	3.1	3.6	3.4	2.4	2.4	2.6	2.7	2.7	2.4	2.9
	Absolute max.	2	3	9.7	9.9	8.8	7.7	9.1	7.5	6.8	6.0	5.0	5.8	6.0	6.4	
	Absolute min.	2	3	-	0.1	-0.8	0.4	0.9	-1.0	-1.9	-2.5	-2.0	-1.0	-1.3	-1.6	
	Rel. humidity Mean, in %	3	1	73	75	73	86	85	85	86	89	86	88	83	76	MEAN TOTAL
	Precipitation Mean, in mm	3	1	25.1	29.8	21.7	217.3	148.7	170.3	161.8	148.8	142.5	204.5	138.2	61.1	1469.8

Fig. 3 is continued

the crest of the Sierra Nevada de Mérida just southeast of the city of Mérida. The climatic snowline now is at $\pm$ 4750 m; presumably it descends to the north and rises both to the south and west, the latter because of the rain shadow effect of the southeast range. No other peaks in the Andes rise high enough to intersect this inferred projection of the snowline, although the high mountains just south of the Santo Domingo-Chama divide were snow-covered throughout the year at the turn of the century, and were referred to as the Sierra Nevada de Santo Domingo, a name no longer appropriate.

The accumulation season for Andean glaciers falls in the summer, whereas the winter is a season of rapid ablation. That this is so is confirmed by consideration of the weather records for the meteorological station established in 1969 at Pico Espejo, the terminal station on the Merida Teleférico, and at 4765 m precisely on the modern snowline. Fig. 3 shows selected temperature and precipitation data for that station for the years 1969-71.

Summaries of early explorations and descriptions of the Sierra Nevada de Mérida, and summaries of conclusions drawn therefrom regarding the size and distribution of glaciers, have been presented by CHALBAUD CARDONA (1959) and SCHUBERT (1971). The conclusion is inescapable, as clearly pointed out by Schubert, that the glaciers on the Venezuelan Andes have been retreating rapidly at least since 1868. Since glaciers elsewhere in the world are also retreating, it is easy to draw the conclusion that all aspects of the climatic history of the Venezuelan Andes are synchronous with those of higher latitudes. However, 100 years of sporadic recorded observations are not sufficient to distinguish a long-term climatic trend from a small perturbation.

The question of synchrony of climatic change in Venezuela with similar changes at other latitudes will only be solved when radiocarbon dates, determined from samples taken from rigorously controlled stratigraphic contexts, are available for long-range correlation.

Previous studies

A handful of geologists and geographers have considered the evidence of once-greater extent of glaciers in the Andes of Venezuela (e.g. JAHN, 1912, 1925, 1931; ROYO y GÓMEZ, 1959; CÁRDENAS, 1962; TRICART, 1966; TRICART & MICHEL, 1965; TRICART & MILLES-LACROIX, 1962; SCHUBERT, 1970a, 1970b, 1971, 1972; and SCHUBERT and SIFONTES, 1970, 1972). Most reports have been largely descriptive; Tricart, however, assigned presumed glacial features near Mucuchíes to glacial periods correlated directly with those of western Europe. SCHUBERT (1970a) and SCHUBERT and SIFONTES (1970) obtained radiocarbon dates on material removed from sand and gravel of glacial origin in a valley fill in Quebrada la Victoria, a tributary of the upper Rio Santo Domingo, but were unable to assign any specific stratigraphic significance to the dated samples. The dates were compared, however, with the comprehensive climatic record recovered from a long core drilled in the floor of the Sabana de Bogotá by VAN DER HAMMEN and GONZÁLEZ (1960), and the chronology established by those workers was applied directly to the Andes.

Fig. 2 b:

STATION		YEARS	SOURCE	J	F	M	A	M	J	J	A	S	O	N	D	MEAN ANNUAL
Barinas-Socony	Mean maximum	2	1	31.1	32.0	33.0	33.1	31.4	30.4	29.9	30.4	30.7	28.8	31.3	30.9	31.1
	Mean minimum	2	1	20.1	20.3	21.5	21.3	20.7	20.4	20.5	20.2	20.4	21.2	21.3	20.3	21.5
Hotel Santo Domingo	Mean maximum	2½	2	16.8	18.5	18.3	17.7	18.0	16.9	17.9	18.3	18.6	18.4	19.0	18.9	18.1
	Mean	2½	2	14.0	14.5	14.7	15.0	15.0	14.1	14.8	15.0	15.2	15.2	15.5	14.4	14.8
	Mean minimum	2½	2	11.3	10.4	11.1	12.3	12.0	11.3	12.0	12.0	12.3	12.0	11.9	10.0	11.6
Mucubají	Mean maximum	2½	2	7.7	10.8	10.6	9.2	9.0	8.0	7.0	7.6	8.5	8.7	10.0	9.0	8.8
	Mean	2½	2	4.3	4.9	5.1	5.8	5.8	5.4	4.7	5.2	5.6	5.6	6.0	4.8	5.3
	Mean minimum	2½	2	0.7	-1.1	-0.3	2.4	2.5	2.7	2.3	2.4	2.9	2.6	2.0	0.5	1.6
Pico El Aguila	Mean maximum	½	3							4.6	4.6	5.5	5.6	6.3	6.2	
	Mean minimum	½	3							0.1	0.1	0.3	0.4	1.8	-1.0	
Mérida FAV	Mean maximum	7	1	23.7	24.0	24.7	24.1	24.4	24.3	24.2	24.5	24.7	24.1	23.2	23.4	24.1
	Mean	7	1	17.9	18.3	19.2	19.1	19.2	19.3	19.1	19.1	19.1	18.9	18.5	18.2	18.8
	Mean minimum	7	1	14.1	14.3	15.1	15.9	15.9	15.7	15.0	15.2	15.2	15.6	15.3	14.4	15.1
El Vigía	Mean maximum	1	1	-	29.9	30.0	30.3	31.1	30.8	31.5	31.8	32.2	31.3	31.0	30.3	30.9
	Mean minimum	1	1	-	21.2	22.0	22.4	22.8	22.7	22.6	22.3	22.4	22.2	22.2	22.0	22.2

SOURCES: 1 and 2 as in Fig 2a; 3) Boletín Climatología, Instituto de Geografía, Universidad de Los Andes, Facultad de Ciencias Forestales, Mérida, Venezuela, 1970.

STATION	YEARS OF RECORD	ALTITUDE	SOURCE	MEAN MONTHLY PRECIPITATION (mm) J	F	M	A	M	J	J	A	S	O	N	D	MEAN TOTAL
Barinas-Socony	23	185	1	10.8	6.7	24.2	112.0	279.3	226.9	212.6	188.5	169.5	181.6	112.4	23.1	1498.0
Barinas	18	185*	1	17.6	5.5	20.4	118.8	212.2	251.2	209.6	184.3	166.4	168.8	109.6	28.3	1492.6
Santo Domingo	14	2200*	1	6.3	21.6	29.9	113.8	213.5	205.4	166.8	178.2	129.9	105.1	54.4	21.2	1245.0
Hotel Sto. Domingo	2½	2110	2	5.9	12.6	28.6	133.2	141.7	302.8	250.7	165.6	172.0	93.0	61.9	26.2	1394.2
Mucubají	2½	3550	2	6.5	7.7	11.3	121.8	107.9	191.3	216.7	129.9	123.3	101.6	55.5	32.2	1105.7
Pico El Aguila	19	4090	1	8.6	7.8	17.4	68.1	103.4	124.4	127.7	97.9	83.4	86.5	54.6	16.3	795.9
Mucuchíes	19	2900*	1	5.6	6.1	13.2	71.0	87.8	68.3	66.1	64.2	71.3	78.0	34.3	9.9	575.9
Mucurubá	22	2300*	1	23.4	19.7	35.4	104.2	125.3	70.9	72.4	65.0	66.3	110.8	67.8	34.1	798.3
Mérida FAV	51	1479	1	38.9	37.6	71.7	258.1	229.3	195.3	124.0	143.4	175.3	299.9	229.2	106.2	1908.9
Páramo La Culata	11	3500#	1	35.7	27.5	44.5	180.3	162.2	101.5	75.7	109.3	118.0	173.4	129.0	34.7	1186.9
El Vigía	27	110*	1	136.6	120.2	107.5	211.0	173.3	123.2	88.5	106.8	93.8	179.7	262.8	204.5	1807.9

SOURCES: 1) Permanent Record, Ministerio de Obras Publicas (MOP); 2) Republica de Venezuela, C.A. de Administracion y Fomento Electrico O.D.H.L.A. (CADAFE), Seccion de Hidrometeorologia, Boletin Mensual Climatologico e Hidrologico.

* Altitude estimated from topographic maps # Altitude grossly estimated from approximate position of station on 1:100,000 topographic map.

As the spring advances, the ITC moves inexorably northward, passing over the Andes from south to north as the season progresses. The first heavy rains come earlier in the south than in the north. By midsummer the ITC lies across the northern part of the Andes; in some years the southern end of the range may experience a brief midsummer dry spell.

During the rainy season the winds are still from the NE in the northern Andes; the influence of the SE trades may be felt in the south, but airflow direction is much modified as the winds pass across the Amazon basin.

Close to the ITC the Trade Winds contain much moisture, which condenses from rising air and falls as rain over much of the range; significant snow fall is experienced on the Páramo. A typical day may begin with clear skies, but by late morning clouds have formed over the southeast range as rising, moisture-laden air is cooled. By noon precipitation has begun even on the top of the range, and may continue throughout the night. By early morning the circulation pattern may decay, but as soon as the Equatorial sun begins to warm the Llanos the pattern is quickly reestablished.

Since the airflow is predominantly from the east, much of the moisture is extracted from the Trade Winds as they pass over the southeast range; the range northwest of the central valley receives significantly less precipitation, and the diurnal rainy season circulation pattern typically does not develop until early afternoon. Some air may be drawn off Lake Maracaibo into the low-pressure zone over the Andes, causing local orographic rainfall, especially on the slopes of the northwest range that face the lake.

Air moving toward the Andes from the Llanos typically is funneled into major valleys draining the southeast range. Conditions in some such valleys may be significantly wetter than on adjacent slopes. The route of the field trip follows one such valley, that of the Rio Santo Domingo.

During the rainy season it is a common sight from the top of the Santo Domingo-Chama drainage divide to see a bank of cold wet clouds advancing systematically up the valley, spilling over into one tributary after another. An observer at the divide is first enveloped in a fine cold mist that changes rapidly to gentle rain and then into a heavy downpour. We have often watched tatters of clouds spill over the divide into the Chama valley and disappear as they warmed adiabatically by descending the few hundred meters to the valley floor. This circulation may persist for hours until sufficient moisture has been carried across the divide to bring about precipitation in the Chama valley as well.

Temperature variation is of lower amplitude during the rainy season than during the winter. Figure 2 shows pertinent climatologic data for selected stations along and adjacent to the route of the field trip. The climatic pattern described above is consistent with these data; analysis of records from these and many other stations is in progress, leading ultimately to a more precise model of the Andean climate.

Permanent snow persists today on only three peaks in the Venezuelan Andes: Pico Bolívar (5007 m), Pico La Concha (4992 m), and Pico La Corona, comprising the twin summits Humboldt (4942 m), and Bonpland (4893 m) at

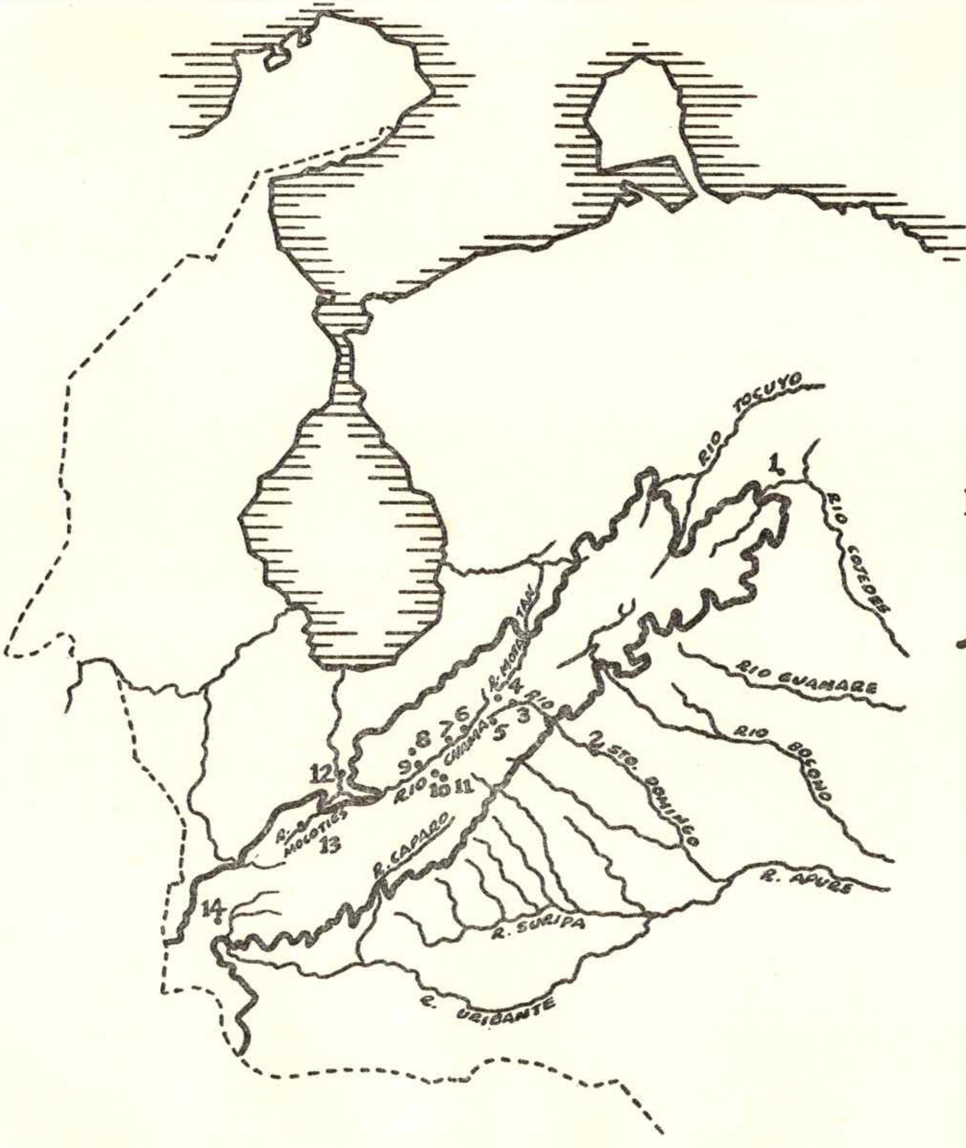


Fig. 1

VENEZUELAN ANDES

0 KM 100

800-m contour

LOCALITIES:

1 BARQUISIMETO
2 BARINAS
3 SANTO DOMINGO
4 EL AGUILA
5 MUCUBAJI
6 MUCUCHIES
7 MUCURUBA
8 PARAMO LA CULATA
9 MERIDA
10 LOMA REDONDA
11 PICO ESPEJO
12 EL VIGIA
13 BAILADORES
14 SAN CRISTOBAL