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# STUDIES IN THE RIO CORREDOR BASIN

## BULLETIN 2

REPORT OF WORK

1988 TO 1991

**NATIONAL SPELEOLOGICAL SOCIETY**

**COSTA RICA PROJECT**


**EDITED BY:**
**NORMA DEE PEACOCK**
**AND**
**JOHN C. HEMPEL CPG**

# STUDIES IN THE RIO CORREDOR BASIN

## 1988 TO 1991

**A JOINT PROJECT
OF THE
NATIONAL SPELEOLOGICAL SOCIETY
AND
ASOCIACIÓN ESPELEOLOGICA COSTARICENSE**

# STUDIES IN THE RIO CORREDOR BASIN



**EDITED BY :** NORMA DEE PEACOCK
AND
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**GRAPHICS TEAM:**
HOPE AND JEFF UHL
TISHA SPRINGER

# DEDICATED TO JAMES WELBORN STOREY

NSS 5309 RLF 1935 - 1992

The Costa Rica project lost a close friend and fellow researcher in January of 1992. James (Jim) Storey, a team member in 1990, passed into unexplored territory while asleep at his home on January 11th. His untimely death shocked us all. At his death Jim was working with the editors to produce this report and was planning for the 1992 field season. Jim did everything he could to make our project a success. He would do any job, good or bad, to help the project, and his wit kept us all smiling through the hard days. We will miss his jokes and his smiling face at base camp.

To Jim
we dedicate this report.

**STUDIES IN THE RIO CORREDOR BASIN**
**BULLETIN 2**
**NSS COSTA RICA PROJECT**



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# TABLE OF CONTENTS

## TABLE OF CONTENTS CONTINUED

# SECTION 1

## BACKGROUND AND HISTORY

The National Speleological Society (NSS) first became involved in Costa Rica in 1973. In that year the Costa Rican National Park Service asked the Cave Research Foundation to assist in evaluating a potential cave park location.

Since then the NSS has remained active in Costa Rican Speleological research. In 1981 members of the Pittsburgh Chapter NSS petitioned the NSS for Expedition Status and began a three year project at Barra Honda National Park in northwest Costa Rica. In 1988 this expedition status was changed to "Project Status" and research activities moved to the Ciudad Neily area in southwest Costa Rica.

Reconnaissance during the 1982 field season had identified the Corredor River area as containing caves, and in 1988 the Asociacón Espeleologica Costarricense (AEC) invited Douglas Dotson, Bruce Bannerman, and John C. Hempel to join them on a two week expedition to several caves in the area. AEC proposed a series of jointly sponsored trips over a 5-year period to define the karst resources in the Neily area.

The Costa Rican government Institute Costarricenese de Turismo and the Department of Mines, Energy and Natural Resources pledged their support for the research, and project planning was begun. Meetings with government agencies quickly determined the areas of study that were most needed. Based on the needs of the people of Costa Rica and our own interests in the caves of Costa Rica, several areas of investigation were established.

The 1988-1990 expeditions attempted to describe the Corredor River Basin and to study the karstic sections located during field work. It was determined that detailed studies of geology, hydrology, biology, and speleology would be undertaken by future expeditions. In addition to basic scientific investigations the project would seek to document the natural resources of the area photographically. Caves studied at this time would be surveyed and maps prepared for use with further scientific investigations.

During the 1989 field season several members of the expedition team were stricken with blastomycosis (a respiratory disease). Because of this problem a new field of study, mycology, was undertaken in 1990. Efforts were made to define the caves infected with this potentially fatal fungus.

The expedition was asked to undertake several non-scientific goals in order to help the people of Costa Rica understand and appreciate their natural resources. To this end a series of public meetings was held in Cuidad Neily, and slide presentations were given to area residents. Articles on the expedition were printed in local papers and radio reports made all residents a part of the project. Local school children were treated to field trips led by expedition teachers and in-camp "teach ins" helped educate the children.

Many of the expedition team members were certified rescue instructors, and, at the request of the local fire rescue agencies and the Red Cross, three rescue classes were taught. These classes introduced rescue teams in Ciudad Neily and San Jose to modern rescue methods and operations.

All of the goals and services undertaken by the project were designed to maximize the knowledge obtained by the project while minimizing the cost.

### THE PARTICIPANTS

**1988**

In 1988 Douglas Dotson, Bruce Bannerman, and Chuck Hempel visited Ciudad Neily and reviewed the site for the 1989 expedition. During this trip Carlos Goicochea and Fernando Tristan lead the team on a reconnaissance of the study area. After two weeks of work it was determined that significant cave and karst potential existed just northeast of Neily and that an expedition would be required to complete a thorough study.

**1989**

In January of 1989, 28 researchers converged on the study area. Included in this group, and acting as science team coordinators were; Dr. Horton Hobbs III of Wittenberg University, John Hempel of EEI Geo Consultants, Norma Dee Peacock from the Jenison School District, Dean (Scott) Jones from the Pennsylvania Department of Environmental Resources. Cave survey responsibilities went to Jeff and Hope Uhl, a professional surveyor and a cartographer from Pennsylvania.

Medical needs of the expedition were taken care of by Doctor Ann Harman from Florida and Robert Barlow, a paramedic from Virginia.

Ethel Barlow, the trip's "senior" member, supervised camp activities. She also became the director of children's activities when Norma was away from camp.

Gordon McCracken served as photo historian and surveyor. Gordon took hours of videotape to document all project activities.

Our Costa Rican team leader was Carlos Goicochea. Carlos spent many hours in the bush looking for caves and days of work finding the many items we required at base camp.

In addition to Carlos, several other Costa Ricans joined the team in Ciudad Neily. Christian Lesko, Henry Molino, Tocho Obando, Either (Hector) Mora, and Allan Campos comprised the Costa Rican Team.

**1990**

The 1990 expedition went back to the Neily area to continue the work in the Rio Corredor Basin. Large insurgences had been discovered in blind valleys on the north and south sides of the river during the 1989 trip. These caves and sink were to be studied during the 1990 trip. Two camps were manned for two weeks by the 40 cavers and scientists joining the project for 1990's field activities.

Many of the 1989 team returned to continue work but about 15 new people were added. Several new science team personnel were included in this trip. Gary Storrick and Cindy Venn from the Geology department at the University of Pittsburgh joined the Geology team. Patrick Shaw took over duties as Biological Field Supervisor. Charles Kronk assumed duties of video historian while Gordon McCracken went exploring.

Medical duties fell to Barry Little, a doctor from Kentucky, and Keith Barnes, a paramedic from North Carolina.

All of our Costa Rican friends returned to help with the 1990 expedition. In addition Juan Carlos Crespo from AEC joined us and provided a truck to facilitate getting to more remote areas of the basin.

**1991**

We returned to the Ciudad Neily with a small group in 1991. This team of 10 completed some unfinished surveys and investigated the Alto Nubes area.

The group included most of the science team leaders active in preparing this report and undertook only those activities needed to complete this study.

After a week and a half in Neily the group proceeded north to the town of Venado where a new study area had been selected. This area will be the subject of future reports.

**POST 1991**

Since 1991 Carlos Goicochea led a small team of Swiss cavers to the Alto Nubes area and bottomed the cave found and descended by Ann Harman in 1991. The Pozo de Caño Seco became the deepest cave in Costa Rica on this trip.

# SECTION 2

## INTRODUCTION

### PROJECT DESCRIPTION

The rapid development of the earth's remaining natural areas has forced scientists to intensify the rate at which we seek to unlock the mystery of our remaining rain forests. The very diversity of life that we wish to preserve and study, make the job of a forest researcher almost impossible. The tropical rain forest also offers a unique laboratory for the speleologist but, studies in this area are very new and extremely difficult to undertake. As with many studies, each secret we unlock points the way to more mystery.

The field of speleological science began only a few decades ago when man began to appreciate the cave environment. For thousands of years man was housed in and provided refuge by the caves we now study. Since the 1900's many things have been learned about the fragile environment within the underground wilderness. As the development of limestone areas has increased we have discovered that seemingly benign actions undertaken by man often had adverse effects on the environment and living conditions of animals and others around him. Pollutants entering the vast limestone aquifer systems from farming and development often spread so widely and so quickly that much damage is done to the regional balance of nature before the problem is detected. In the highly developed countries remedial measures now try to correct the problems that already exist. It is the purpose of this study to help prevent a repeat of our earlier mistakes by examining the wilderness karst areas of Costa Rica and helping the country protect and preserve their underground wilderness.

The Costa Rica Project goals were developed through close consultation with many scientists both inside and out of Costa Rica and from meetings between the project leaders, AEC, the Costa Rican government and several local administrators near the proposed study area. These meetings led to the formulation of the following project objectives and a phased implementation plan. The project was designed to last five years including four field seasons and work in seven areas; geology, survey and exploration, hydrology, biology, mycology, speleology, education, and rescue training. The project contained 8 phases, each interdependent on work in other phases. These phases were:

1. **PHASE ONE** The first objective was to conduct a thorough and complete cave resource reconnaissance of the Rio Corredor River Basin. During this study all known caves would be located and surveyed using the latest location techniques available. Since much of the area of investigation is within tropical rain forests, this involved chopping trails to hundreds of sinkholes and caves. After the exploration phase of this task was completed, transit surveys would be done to each location.

2. **PHASE TWO** As soon as the exploration teams of phase 1 completed their work, survey teams began work on phase 2 of the project. Phase 2 called for the preparation of detailed cave maps and the exploration of all caves. Forty people and 10,000 man hours were dedicated to this task over the three field seasons of the study.

3. **PHASE THREE** From the information gathered in phase one and two of the study, work on phase 3 would begin. The third goal was to create a detailed geology map for use in understanding the effects of tectonics and volcanism on the area. Five project geologists were assigned 1200 hours for this task. From data collected a project geology map would be produced.

4. **PHASE FOUR** Once basic geology was delineated and caves located, work began on the hydrology of the area. It had been indicated that one of the most important tasks of the project (from the local officials point of view) would be the mapping and location of the large springs and their source areas. The data collected by the project hydrologists should include water chemistry, flow rates, underground pathway mapping, and dye tracing information. This task involved 20 people and 4 project hydrologists and took 2200 hours to complete.

5. **PHASE FIVE** The quality of the water as determined by phase 4 studies would be used by the project biologists to determine why certain animal life collected during their investigations existed in the caves. Phase 5 was a biological task which involved 3 biologists and two assistants and required 1479 hours to complete. The biologists were asked to prepare a complete reconnaissance of the cave life in the basin and to look for rare, new, or endangered life forms.

6. **PHASE SIX** This task evolved as an add-on, in response to several of the expedition members contracting a respiratory disease. Task six was the mycological study of the caves and water sources in the basin. Samples of many organisms were cultured and studied during this 500 man-hour task.

7. **PHASE SEVEN** Tasks were added to the expedition's goals at the request of local government leaders. Phase seven

was an educational task. The goal of the project was to help educate the children and local residents about the caves in the hills and to teach sound conservation practices to whomever would listen. This task was undertaken by our project teachers and administrators.

8. **PHASE EIGHT** Another pressing need of the community was the training of rescue personnel in the latest lifesaving methods used in fire rescue. The project had 5 rescue training personnel that conducted 7 days of training for the local Red Cross, two fire departments, and the national mountain rescue team.

## PROJECT DIRECTION

The project was directed by an international steering committee made up of Costa Rican cavers, AEC leaders, and the National Speleological Society's project leaders. The five committee members planned and directed all project activities. They were assisted in the day-to-day operations by task team leaders from each field of study. These individuals are described in detail in Chapter 3 of this report.

## PROJECT OPERATION

The project was organized much like a military expedition. Team leaders were appointed and areas of responsibility assigned. Sponsors (detailed in Appendix A) provided many of the materials required to undertake the tasks described in earlier sections of this report. The project's activities were divided into several sections: transportation, operations, logistics, and documentation. Each of these areas required massive amounts of support and planning.

### AIR TRANSPORTATION

The expedition supported four field seasons. Three of the years involved the movement of thousands of pounds of materials and as many as 40 personnel from the United States to Costa Rica. Approximately 6,000 pounds of laboratory and scientific equipment was flown by our transportation sponsors, LACSA Airlines. Reduced air fares were also obtained for expedition personnel from LACSA and Pan American Airlines.

### CUSTOMS

Like most international travelers the expeditions personnel had to pass through customs into countries. Preliminary work by the project leaders and help from both governments reduced the time involved in clearing customs to a minimum. The Costa Rican government was also very helpful in this area.

### GROUND TRANSPORTATION

The project was fortunate to receive complete support from the Costa Rican government who provided trucks and a bus to move equipment to the study area from San Jose. In addition, support from the Coca Cola Bottling Company,


PHOTO 2 A Equipment at the airport

providing trucks and other support, made ground transportation go smoothly. Juan Carlos Crespo of AEC loaned the project his personal 4-wheel drive truck so that travel time to remote sites from base camp was reduced.

## LOGISTICAL SUPPORT

The local communities, mainly Barrio San Rafael provided massive amounts of logistical support in the form of food discounts at stores and the use of public buildings for our headquarters. The support of local residents played a large part in the success of this project.

In addition to the local support US companies such as Duracell, H.J.Heinz and Zenith Corporation helped with material support. A large amount of the technical support for this project came from the "speleo-venders" detailed in Appendix A of this report.


Photo 2-B LACSA transport for teams

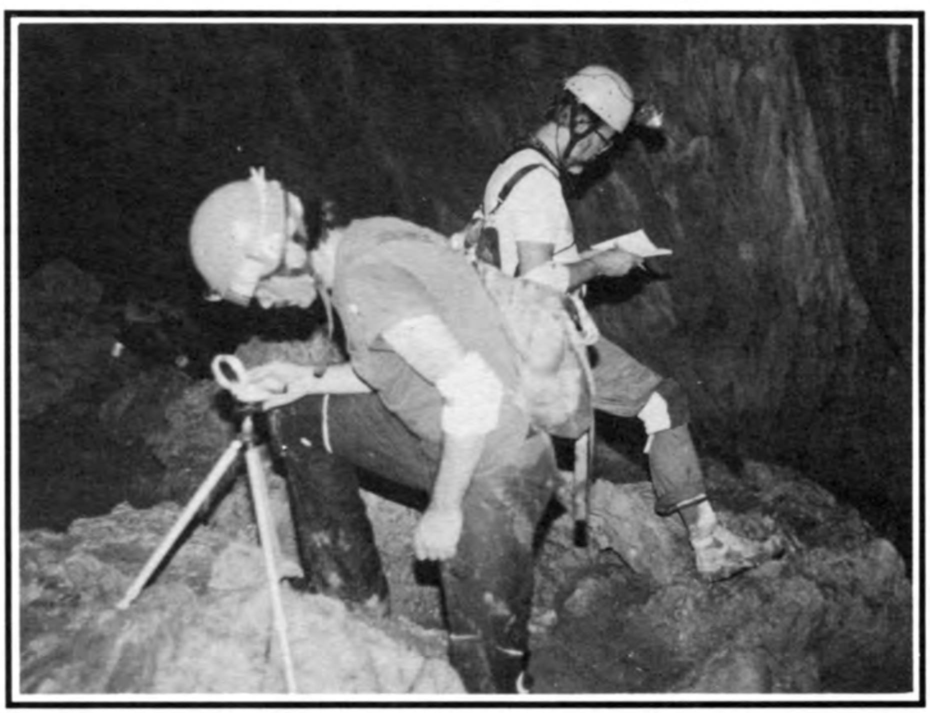


Photo 2-C Survey party in Corredor Cave

# SECTION 3

# PROJECT LEADERS

## PROJECT PERSONNEL

### 1987-88 FIELD SEASON

During the 1987-88 Christmas holiday Doug Dotson, Frostburg, MD, John C. Hempel, Dillner, PA, and Bruce Bannerman, Culloden, WV joined Carlos Goicochea C. and Fernando Tristan of San Jose, Costa Rica to undertake the field reconnaissance of the proposed study area near Ciudad Neily.

### 1988-1989 FIELD SEASON

December, 1988 and January, 1989 saw the first organized expedition to the southern karst of Costa Rica.

Leaders of the team were Douglas Dotson, John C. Hempel, and Norma Dee Peacock.

Each member of the expedition was assigned multiple duties. However, each team member is listed on the enclosed summary under the primary task that they performed.

**Biology**

Dr. Horton H. Hobbs III - Springfield, OH
Fred Grady - Arlington, VA

**Cartography**

Hope Uhl - North Hampton, PA
Jeff Uhl - North Hampton, PA

**Documentation**

Jim Powers - Denver, CO

**Geology**

John C. Hempel - Dilliner, PA
Bill MacDonald - Calgary, Alberta, Canada
Tom Wilkinson - State College, PA
Dr. Chas Yonge - Calgary, Alberta, Canada

**Hydrology**

D. Scott Jones - Acme, PA

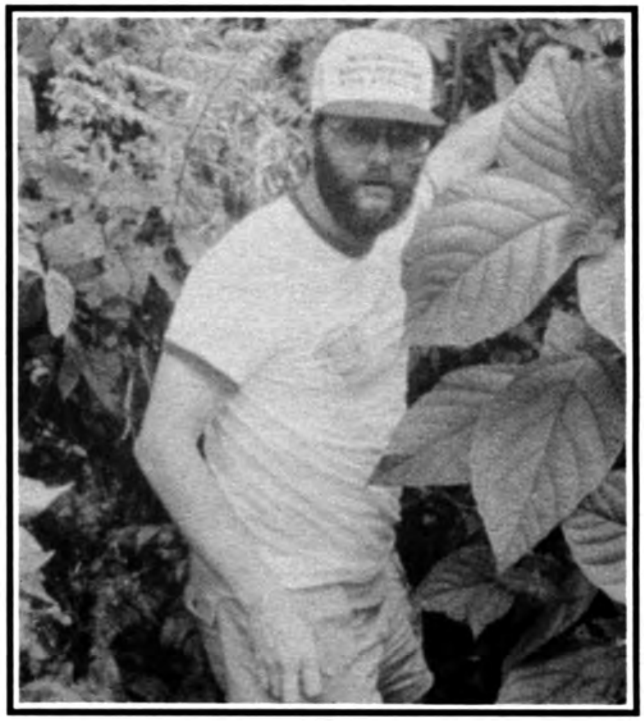


Photo 3-A Douglas Dotson 1987 - 88

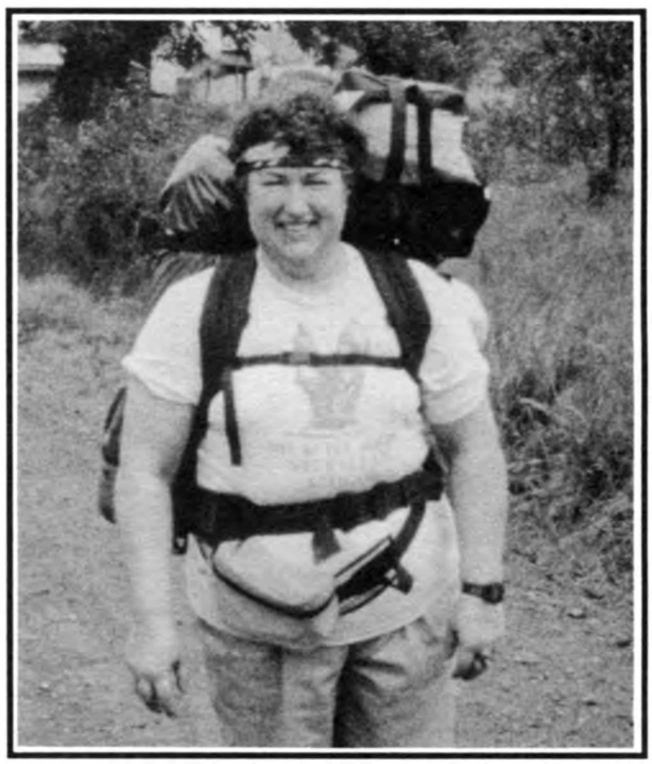


Photo 3-B Norma Dee Peacock 1988 - 92

**Interpreter and guide**

Carlos Goicochea C. - San Jose, Costa Rica

**Logistics**

Ethel Barlow - Roanoke, VA
Norma Dee Peacock - Jenison, MI

**Medical**

Dr. Ann Harmon - Tampa, FL

**Photography**

Robert Thrun - Adelphi, MD

**Rescue**

Robert Barlow - Marion, VA
A. Richard Fogle - Pittsburgh, PA

**Survey/exploration**

Miles Drake - Upper Marlboro, MD
Cindy Duncan - Ironton, OH
Robert Duncan - Ironton, OH
Scott Fee - Indianapolis, IN
Beth Gervase - Silver Spring, MD
Gordon McCracken - Reston, VA
Alan Martin - Morgantown, WV
Walt Pirie - Blacksburg, VA
Doug Rhodes - Albuquerque, NM
Jean Simonds - Blacksburg, VA
Bob Simonds - Blacksburg, VA
Jo Ann Smith - Upper Marlboro, MD

**Local Participants**

Henry Molino - Cuidad Neily, Costa Rica
Alan Campos - Cuidad Neily, Costa Rica
Either "Hector" Mora - Cuidad Neily, Costa Rica

Tocho Obando - Cuidad Neily, Costa Rica
David Bolaños - Alajuela, Costa Rica
Don Carlos Miranda, Cuidad Neily, Costa Rica

**1990 FIELD SEASON**

March, 1990 the expedition grew in size. Leaders for this trip were John C. Hempel, Norma Dee Peacock, Jeff Uhl, Carlos Goicochea C. and Juan Carlos Crespo. The group was divided into study and work teams as follows:

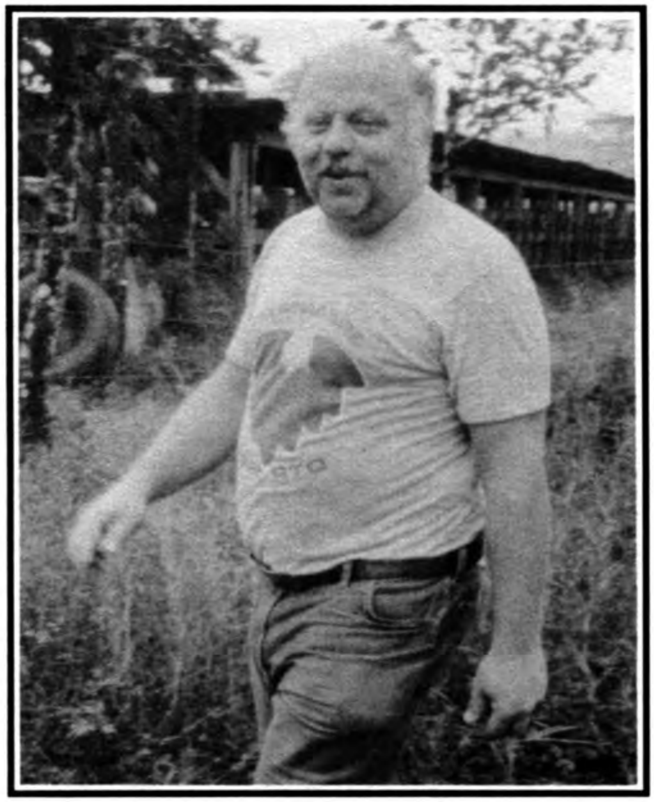


Photo 3-C John C. Hempel 1987 - 92

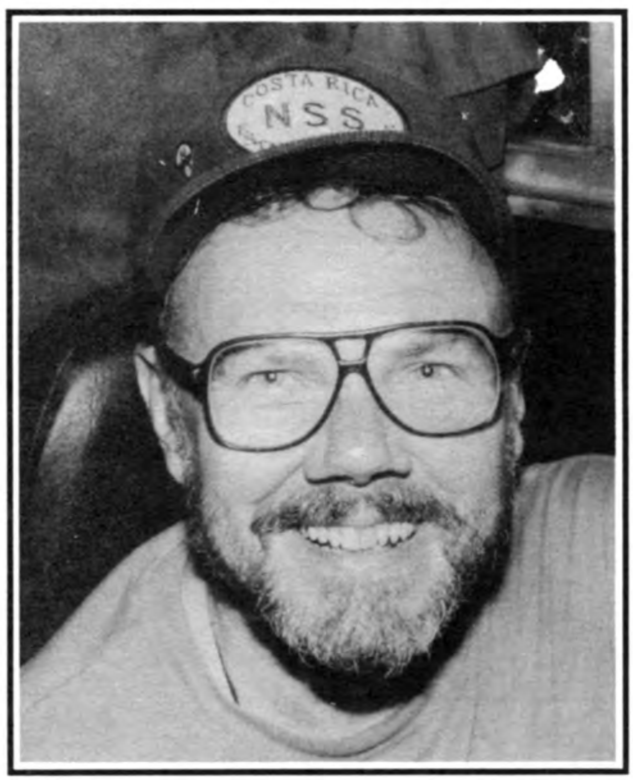



Photo 3-D Horton Hobbs 1992

**Biology**

Patrick Shaw - Saskatoon, Saskatchewan, Canada
Bill Stitzel - Springfield, OH
Charlie Kronk - Springfield, OH

**Cartography**

Hope Uhl - Green Lake, PA

**Documentation**

Larry Clauser - Birdsboro, PA

**Geology**

John C. Hempel - Dilliner, PA
Gary Storrick - Trafford, PA
Cindy Venn - Trafford, PA

**Hydrology**

Tim Glover - Tallahassee, FL
Bill MacDonald - Calgary, Alberta, Canada
Dr. Chas Yonge - Calgary, Alberta, Canada

**Interpreters**

Luis Arisso - Ann Arbor, MI
Carlos Goicochea C. - San Jose, Costa Rica

**Logistics**

Ray Fasciano - Westover, VA
Norma Dee Peacock - Jenison, MI
Don Shofstall - Evansville, IN
Jim Storey - Decatur, GA

**Medical**

Barry Little, MD - Morehead, KY
Keith Barnes, paramedic - Chapel Hill, NC

**Microbiology**

Pete Febbriorello - Torrington, CT

**Photography**

Bruce Bannerman - Culloden, WV

**Rescue**

Robert Barlow - Marion, VA

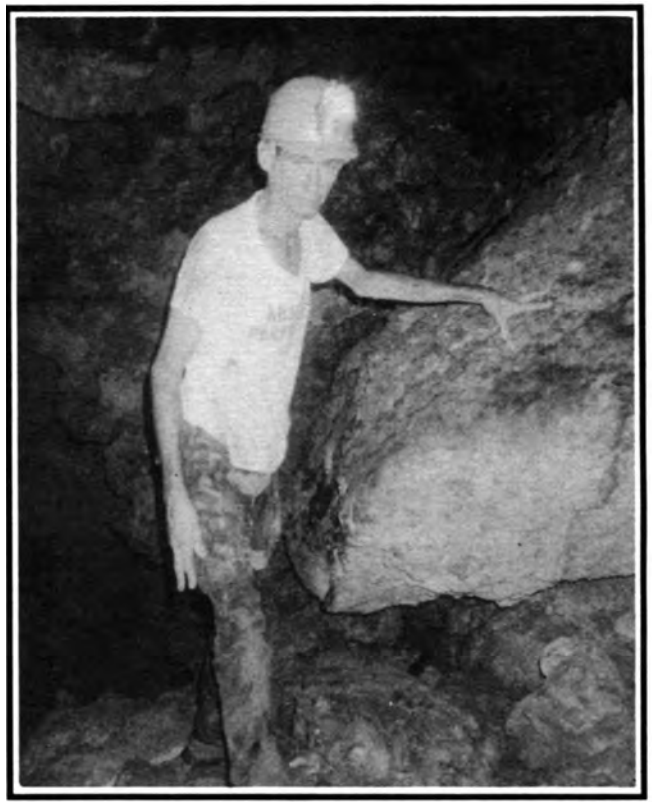


Photo 3-E Carlos Goicochea C. 1987 - 91

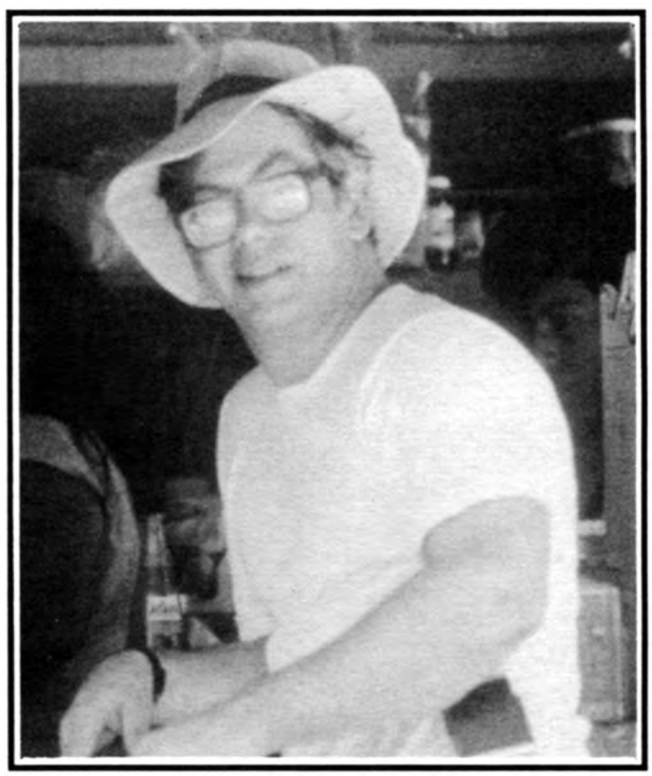


Photo 3-F Bruce Bannerman 1987 -89-92

**Survey/exploration**

Team Leader - Jeff Uhl - Green Lake, PA
George Cebulka - Pittsburgh, PA
Marshall Fausold - Pittsburgh, PA
Walt Hamm - Pittsburgh, PA
Ed Kehs - Quakertown, PA
Bill Klimak - Harve DeGrace, MD
Mike Kuga - Anbridge, PA
Gordon McCracken - Reston, VA
Alice Manko - Pittsburgh, PA
Alan Martin - Morgantown, WV
Walt Pirie - Blacksburg, VA
Bob Simonds - Blacksburg, VA
Jean Simonds - Blacksburg, VA
Bob Thrun - Adelphi, MD
Jake Turin - Socorro, NM
Pam Yonge - Calgary, Alberta, Canada

**Local Participants**

Henri Molino - Cuidad Neily
David Bolaños - Alujela, Costa Rica
Juan Carlos Crespo - San Jose, Costa Rica
Guillermo Cortez - San Jose, Costa Rica
José Villareal - San Jose, Costa Rica
"Cartago" - San Jose, Costa Rica

**1990-91 FIELD SEASON**

During Christmas, 1990 the project's field teams returned to the Ciudad Neily area to finish several remaining surveys and visit remaining leads. This was a much smaller group composed of the former expeditions members. Completing this activity the group proceeded north to the town of Venado. Since this was a reconnaissance trip, the work was not broken down into teams.

The participants for this year included:

**Leaders**: Bruce Bannerman - Culloden, WV
John C. Hempel - Dilliner, PA
Norma Dee Peacock - Jenison, MI
Carlos Goicochea - San Jose, CR

**Team members**

Dr. Ann Harmon - Tampa, FL
Dr. Horton H. Hobbs III - Springfield, OH
Mike Kuga - Anbridge, PA
Charlie Kronk - Springfield, OH
Howard Kronk - Springfield, OH
Bill Stitzel - Springfield, OH

Photo 3-G Jeff Uhl 1989

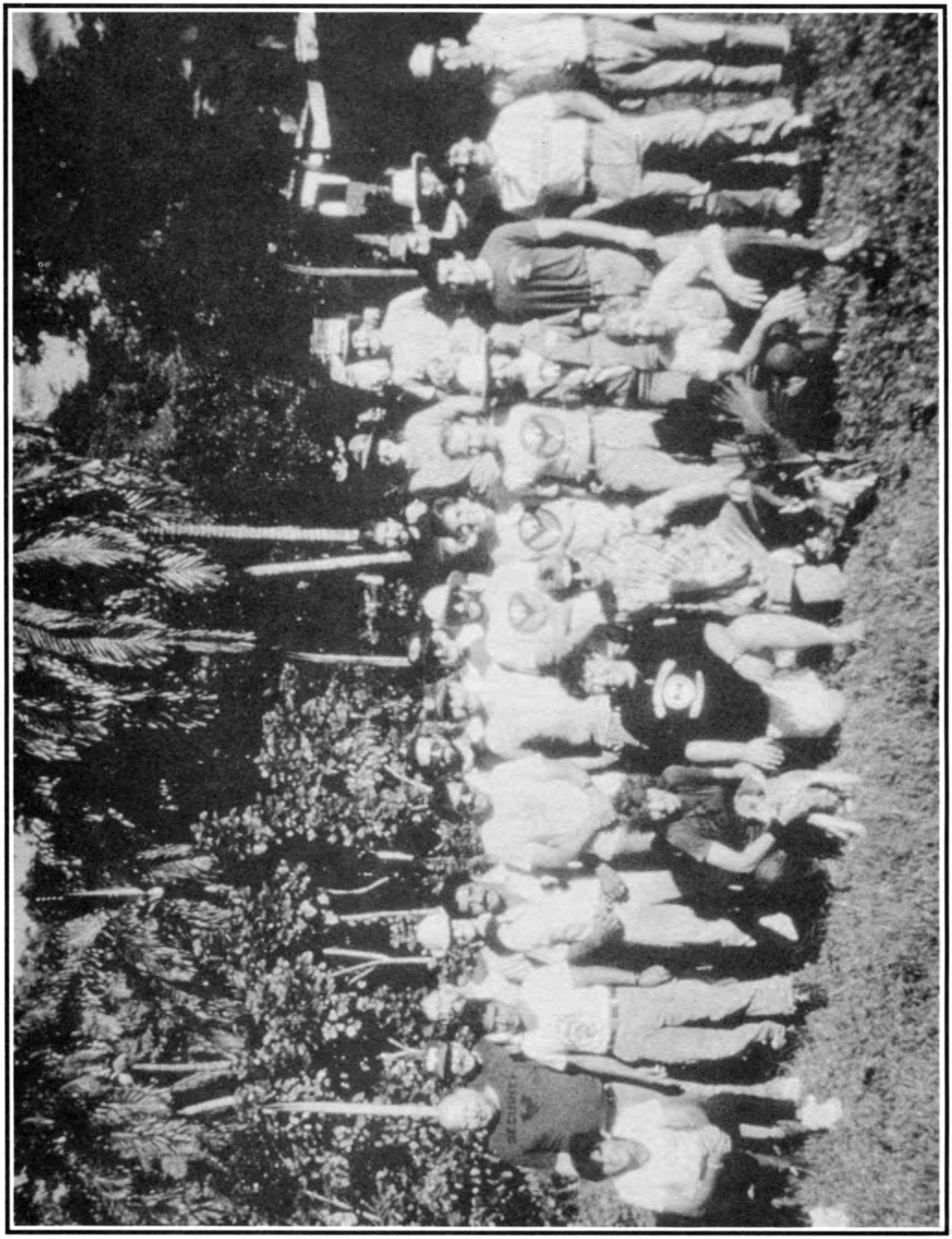


Photo 3-H Team photo 1988-89

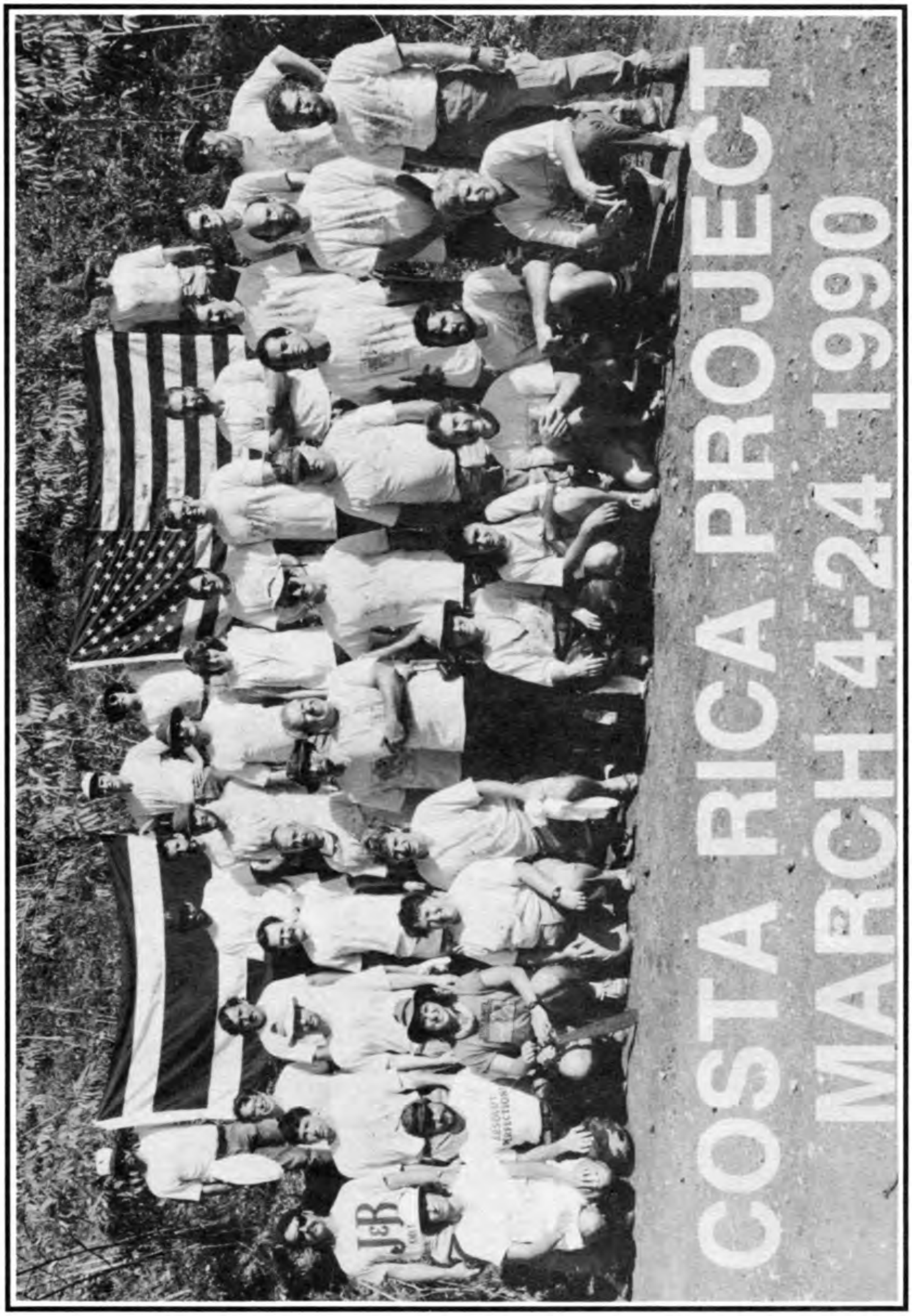



Photo 3-I Team photo 1990

# SECTION 4

## LOCATION OF THE STUDY AREA

Costa Rica is located near the center of the Central American Isthmus. It is situated just north of Panama and just south of Nicaragua.

The study area is reached via airplane from San Jose, Costa Rica's capital, or by a 6-hour bus ride to Ciudad Neily along the Inter-American Highway. Neily is the largest southern city on the Pacific coast of Costa Rica and is positioned on the edge of a linear limestone belt that includes the study area (Figure 4.1).

Major roadways connect the Rio Corredor karst area and the Rio Claro (Culerba) karst area 17 kilometers north of Neily. Both areas were the subject of intensive study by the project.

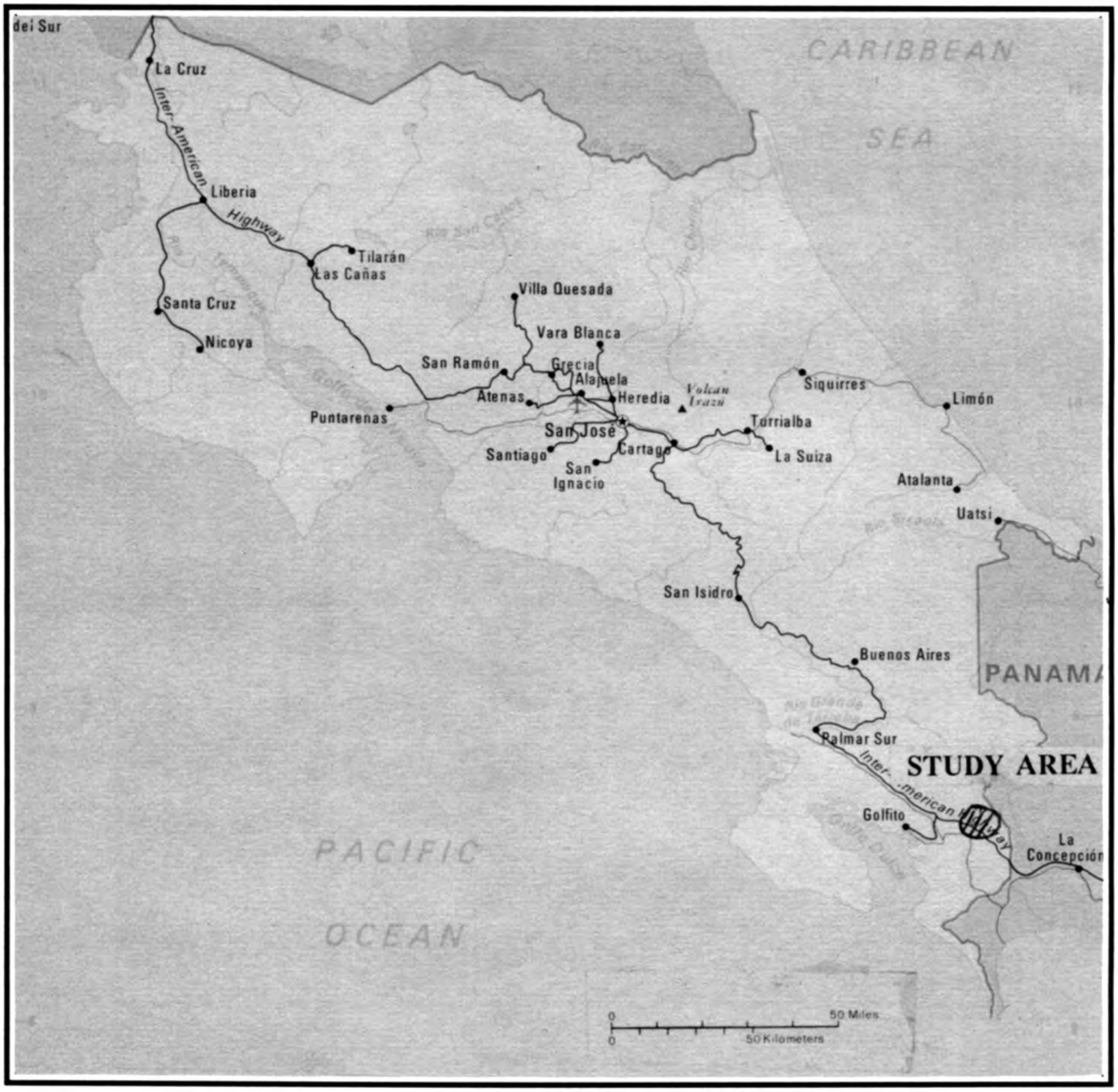



Figure 4.1 Location map

# SECTION 5

## KARST GEOLOGY OF THE CORREDOR RIVER BASIN

### GENERAL SETTING

The Rio Corredor is located in southwest Costa Rica. The area has been profoundly affected by tectonic forces and volcanism during the last 50 million years. Uplift and heavy tropical rains have created a jungle karst landscape in the study area.

During the last 10 years geologic investigators researching limestone caves have located approximately 16 isolated karst areas.These areas are distributed all around the country (Figure 5.1).

Detailed reconnaissance of these karst areas has been undertaken by the National Speleological Society and others, but detailed investagations have been limited to the Barra Honda, Dumas, Venado, Cajon and Neily areas. Other areas have been visited but no extensive studies have been undertaken.

The Rio Corredor karst area, near Neily, is the southern most karst area in Costa Rica. It is located along the Panama border on the Pacific coast of Costa Rica near Ciudad Neily (see Figure 5.2).

### BACKGROUND

The study of karst features in Costa Rica began at Barra Honda National Park. From 1973 to 1982 the Barra Honda Karst was studied by Associacion Espeleologica Costarricense (AEC), The National Speleological Society (NSS), the Cave Research Foundation (CRF), and Dr. Sergio Mora C.

The Rio Corredor karst area was selected for geologic

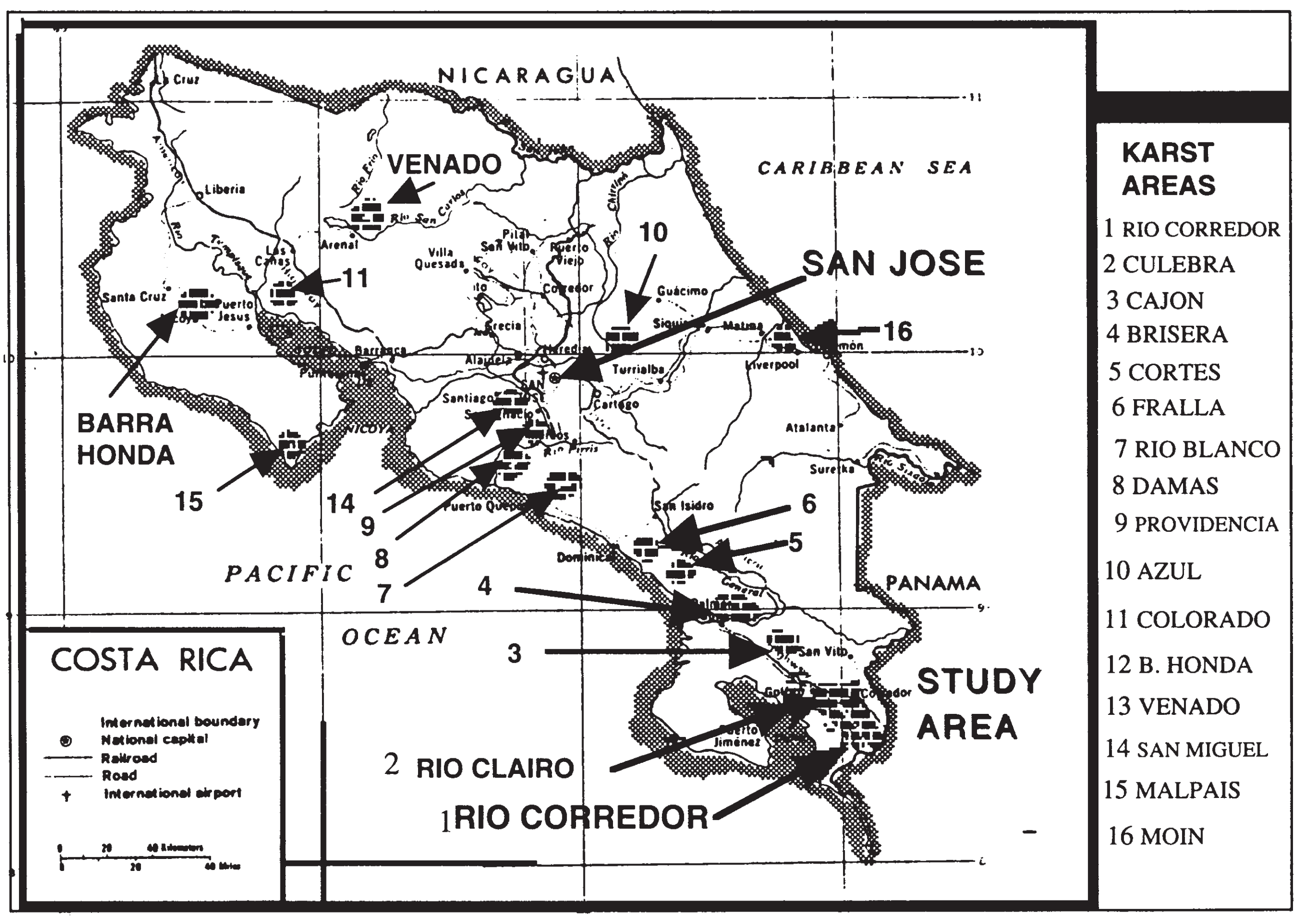



Figure 5.1 Karst Areas of Costa Rica

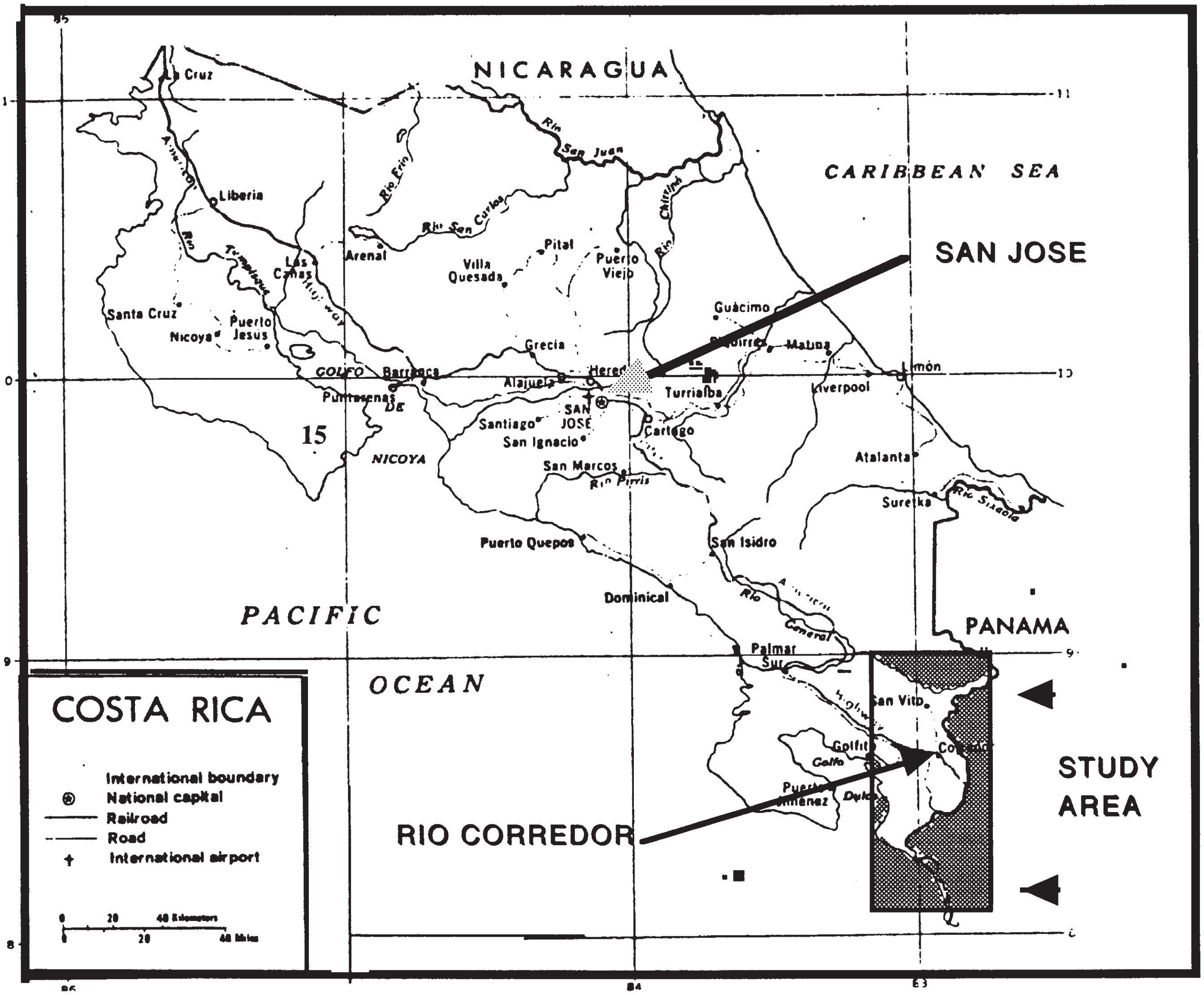



FIGURE 5.2 LOCATION MAP

study due to its abundance of caves and location. This southern tropical karst area was also selected because of its tectonic geology and tropical environment. It was felt that studies in this area, when compared with the Barra Honda data, would provide large amounts of comparable data to aid in understanding karst development in tectonically similar but climatologically different areas of Costa Rica.

The Neily area was first visited by the NSS 1982 Expedition as a possible additional study area. Reconnaissance by Charles Plantz, Bru Randall and Barb Shomer determined that a karst area existed and that further speleological investigations were warranted.

Carlos Goicochea C. and the members of the Associacion Espeleologica Costarricense began visiting the Neily area soon after the 1982 expedition and discovered a 10-square mile (25 sq. km) karst area comprising 4,000 acres of the Rio Corredor Basin.

## KARST GEOLOGY
## GENERAL SETTING

The karstic limestones of the Corredor Karst Basin were formed in a shallow marine environment (Corrigan et al., 1990). Reef development and near shore sediments can be found within or in close proximity to all major limestone units. Iron-rich Eocene /lower Miocene sand and shale units act as cap rock and perimeter boundaries. These units stratigraphically represent the Tèrrabo Formation and are located directly above the Corredor Limestone of the Brito Formation. Conflicting age determinations for the Tèrrabo formation have been published previously by Corrigan (1990) and others. It is this author's belief based on limited fossil evidence that this unit represents the upper Eocene period in units below the Turritellid bed (Ets) and basal Miocene above this bed.

The Tèrrabo is a sandy red shale that weathers to a red mud containing concretions. This unit acts as a resistant bed on which all surface water is concentrated during its downward travel toward the faulted valley floors. The contact of the Tèrrabo Formation and the Brito Formation often occurs at fault lines located in the perimeter valleys. All surface water disappears into sinks or headwalls along the limestone contact in the base of the valleys or flows down valley to a point where the first fault trace is encountered.

Karst features are well developed in the basin but are relatively young in age and maturity. Based on the age of uplift occurrences in the area (1.6 m.y.bp.) (Corrigan et al., 1990) it is unlikely any karst features or caves predate one million years of age.

The predominant karst-forming unit in the basin is a white to buff-colored foraminiferal limestone of Upper Eocene age (Wyle, 1980). The Corredor Limestone is described and named in a later section of this report. The Corredor unit appears to represent a reef or near shore deposit that has been uplifted and faulted extensively. Many overthrust blocks have been mapped in the study area and a tentative stratigraphic column developed. (see Stratigraphy Section Fig 5.11) This extensive thrusting makes it difficult to determine the exact thickness of units within this column.

Two other units have been mapped and determined to be calcareous. These units are referred to in this report as the Fila de Cal Limestone and the Turritellid Siltstone. Neither of these units exhibit karst features within the basin but the lack of features in the Fila de Cal unit may be more a function of limited outcrop area than inherent resistance to geomorphic processes. The Turritellid bed is heavily fossiliferous but contains mainly a shale matrix. No karst was noted in this unit.

## KARST DEVELOPMENT
## AND
## GEOLOGIC PROCESS

Almost all water reaching the limestone basins is first directed downward, over and across the Tèrrabo clastic sediments until a fault zone or limestone contact area exhibiting increased permeability is encountered.

Near the edges of the Brito Formation, thrust faults are found along the contact of the overlying ironstone and the Corredor Limestone. This is typified by the development in the Quebrada Seca River Valley. The eastern side of the valley is almost entirely composed of clastic red, iron-rich, sediments. The west valley wall and most of the floor is composed of Corredor Limestone. At the center of the valley a large fault, Quebrada Seca Fault (see Figure 5.3) is mapped.This fault is shown on the enclosed map and has been identified as a thrust trending northwest from south of the Corredor River to at least 8 km north of it.This fault trend has been identified as one of several parallel regionally dominant trends. No limestone has been mapped east of this fault.

In those areas west of the Quebrada Seca Fault and north of the river, additional thrust faults within the Fila de Cal ridge cause areas of duplicated strata. In almost every case, these thrust faults are found in the floor of the valleys and exhibit a parallel orientation to the Quebrada Seca Fault. The presence of these faults often enhances the development of karst features in the valley and is the direct cause of advanced stream piracy.

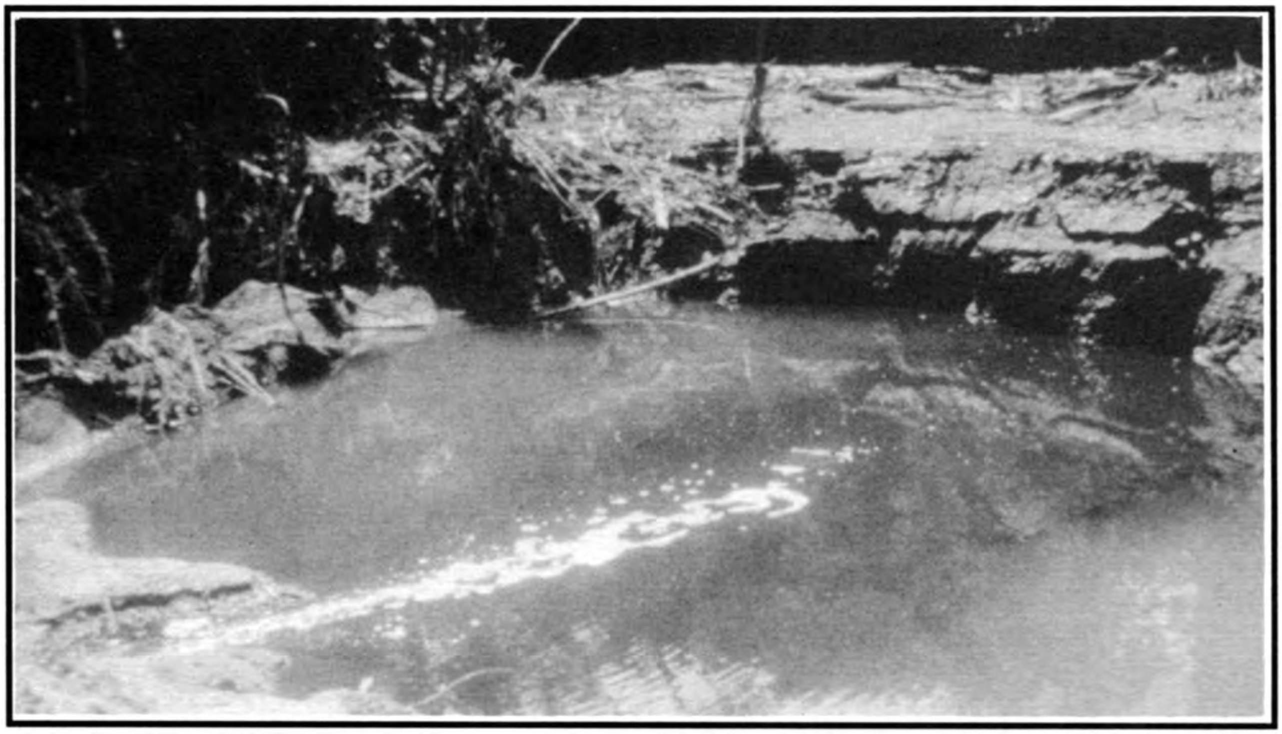


Photo 5-A Quebrada Seca Insurgence

**KARST FEATURES**

Karst development in the study area is typical of tropical areas. Caves and dolines are found capturing streams as they encounter the limestone. Large insurgences occur at contacts with clastic rocks or at the intersections of fault traces (Photo 5-A).

Insurgences occur at elevations of 300+ meters and resurge at the nearby rivers 100-200 meters lower. Underground water courses, developed along faults and fractures, conduct almost all surface water underground toward the Caño Seco or Rio Corredor rivers, which act as local base level for the area. Large resurgences occur all along Rio Corredor from San Rafael to the intersection of the La Bruja Valley about 4 km upstream (Photo 5-C).

Blind valleys, sinking streams, dolines and pseudo-cockpits can be found hidden in the jungle above the river. In areas of forest clear-cutting, tropical karst features abound. Grikes and Spitz Karen are common (see Photo 5-E).

The most prominent karst features in the study area are found in the Quebrada Seca Valley near Cueva Bananal. Two eroded towers rise out of the jungle above the cave. The most prominent tower covers an area of 10 acres and rises 50m or more above the valley floor. This feature was named the "Hershey Tower" because of its resemblance to a Hershey Kiss candy. Large dolines fill the valleys beneath the towers (Photo 5-B).

The most pronounced influences on karst development in this area are tectonic uplift and rainfall amounts.The study area is contained within a tropical rain forest environment receiving 304 cm or more of rain per year. This rainfall and the abundance of vegetative matter creates an ideal setting for the formation of carbonic acid and the development of caves and karst features. Combine this abundance of chemically aggressive water with widespread faulting and fracturing caused by active uplifting, and the potential for large cave systems is clearly seen.

In high valleys where major water flows are not available to erode large cave passages, small expanded joints and dead bottom pits provide primary infiltration routes for rain water falling on the study area. This results in the formation of very pronounced jungle karst forms of up to 2m in height. These features resemble giant spitzkarren and are razor sharp. Walking near or rigging ropes around pits becomes very dangerous for this reason. In the Alto Nubes area precipitation has been collected by small sinks and several deep pits have been explored. The largest pit is located on the west side of the Caño Seco River and descends 142m to an end. This is the deepest cave in Costa Rica.

Photo 5-B Typical karst valley

Photo 5-D Fault and vertical bedding along Rio Corredor at Brito/Terrabo contact

In low valleys or where clastic sediments concentrate run off, large dolines over 100m in diameter are often found. Most of the larger caves mapped in this study are located under these sinkhole valleys or nearby ridges.

## TECTONIC GEOLOGY

Tectonic activity in this area became intense about 1.6 million years ago and remains very active. Large earthquakes (6-7 r) strike the study area on a thirty-year cycle (Mora personal communication). This activity has had a marked effect on cave development.

Earthquakes registering high on the Richter scale are not uncommon in the study area. A majority of these quakes are centered at a 29 km depth (Corrigan et al., 1990). This depth seems to coincide with the position of the Cocos and Caribbean Plate subduction zone. Evidence of this activity is common in the caves under study. New fractures and collapses are seen each year or after major earthquakes.

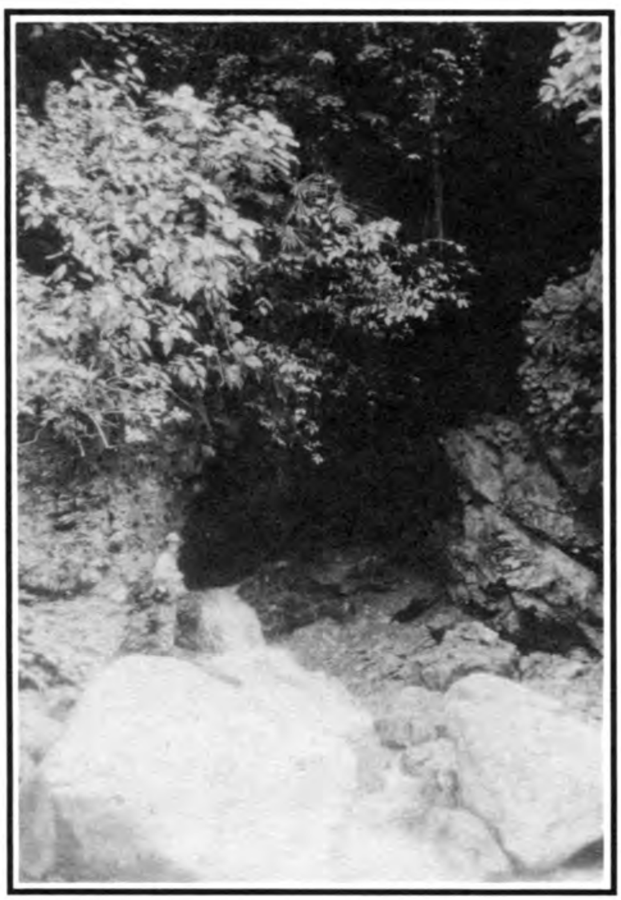


Photo 5-C Cave resurgence

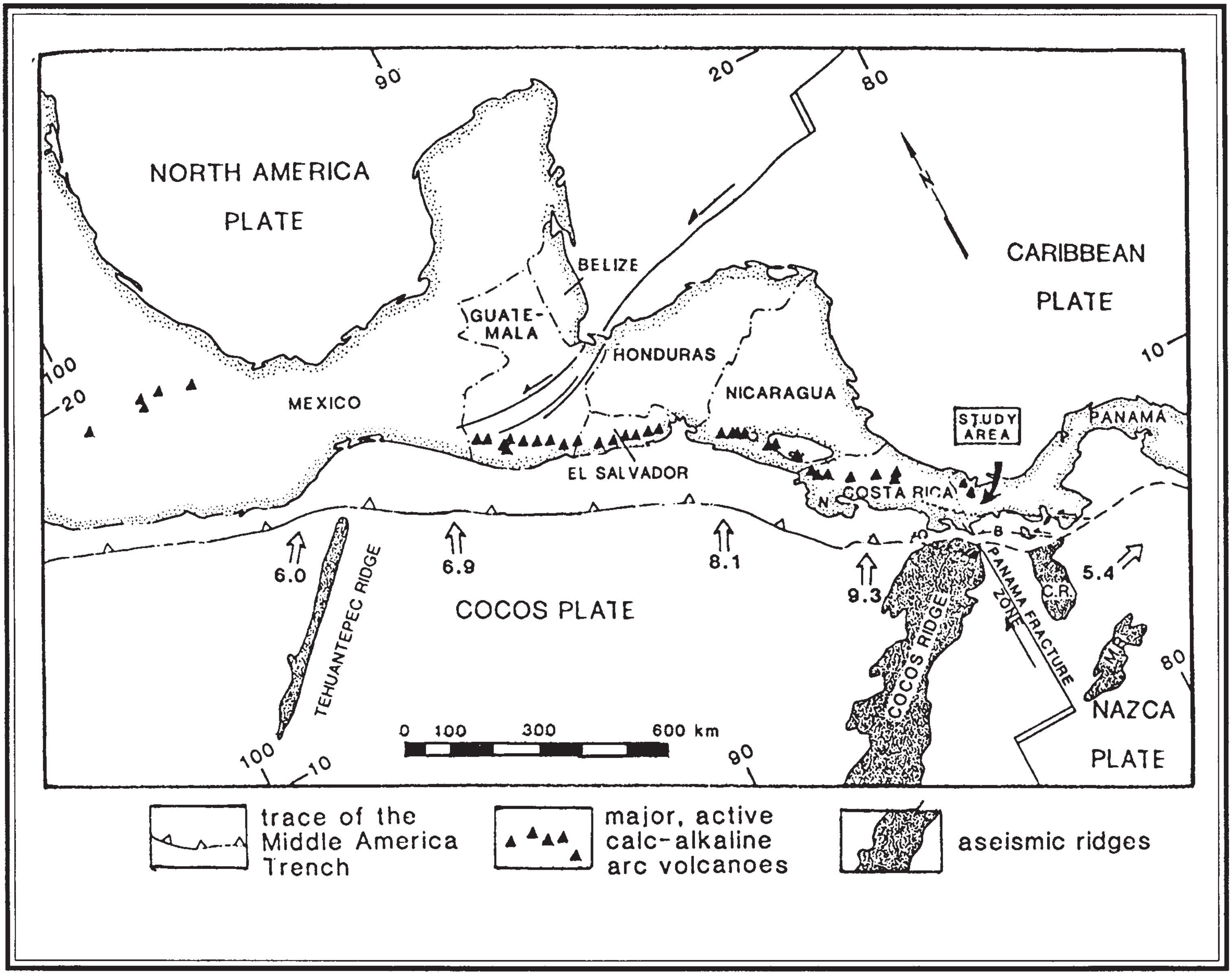
"The study area is located on the western edge of the Caribbean Plate (Wilkinson 1989)." At the western border of the Caribbean plate is the Middle America Trench. This trench marks the subduction contact of the northeast moving Cocos Plate as it encounters the Caribbean Plate (see Figure 5.4). This is a very active plate boundary and is located about 45 km west of the study area. Mora (1986) postulated that uplift began in this area during the Eocene period and has continued to the present. This rate of uplift varies with time but appears to be currently averaging about 1 mm a year (Corrigan et al., 1990). Sediments deposited during the Eocene contain considerable volcanic fragments, confirming an earlier start of volcanism in the area.

As the Cocos Plate was subducted, force was applied to strata above, lifting the Mafic Basement rocks. Pronounced regional flexure ensued, causing the end of Miocene deposition in the study area (see Figure 5.5). Only small areas associated with the Osa Peninsula appear to have received significant deposition after the Miocene. However fluctuation in ocean levels during the Pleistocene may have deposited some of the coastal plain material between Neily and Golfito.

The rate of subduction along the Mid America Trench also varies but averages 8 centimeters per year (Monger, 1987). Due to the rapid subduction of the Cocos Plate (containing the Cocos Ridge) large scale uplifting increased in intensity about 2 mybp. Folding and block faulting of the strata along the western boundary of Costa Rica ensued.

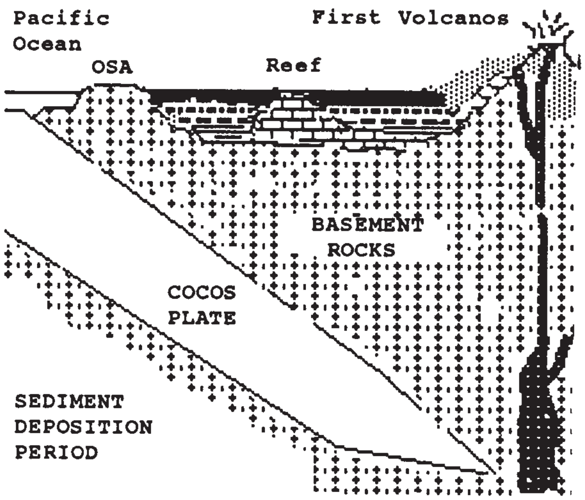
During the Pleistocene period arcward tilting of the Eocene and Miocene sediments began (Corrigan et al., 1990). In conjunction with this tilting, the thicker crustal material of the Cocos Ridge began undergoing subduction (see Figure 5.6). It is postulated that approximately two million years ago the subduction effects of the Cocos Plate, moving beneath the Caribbean Plate, underwent a significant change in character. This change can be attributed to the interaction of the thicker Cocos Ridge impacting the continental crust margin near the study area. A pronounced sub-horizontal shortening of the Eocene strata was caused by the compressive forces exerted by this impact. This shortening has resulted in the formation of large northeast/southwest trending anticlines and eventually reverse faults (see Figure 5.7). Volcanic activity east of the study area began as a by-product of this subduction and was well underway by the time the Eocene reefs were building.

Tectonic history of the study area has been made more complicated by the close proximity of the juncture of a third plate, the Nazca. The Nazca Plate interacts with the two plates discussed above along their southwest boundary. The Nazca northern boundary forms the edge of the Panama Fracture Zone.




After Corrigan, Man, and Ingle—GSA Bulletin,vol 102 (1990)

Figure 5.4 Location of tectonic plates



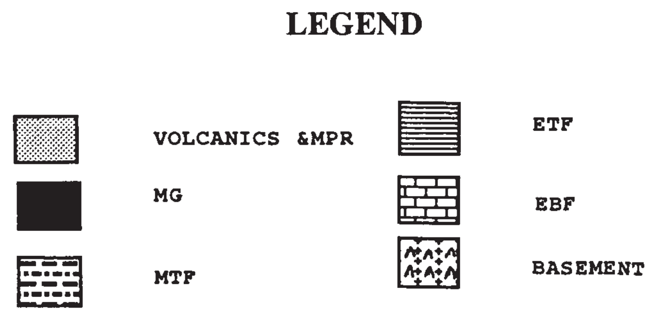




FIGURE 5.5 Depositon of sediments. Shallow seas cover study area and collect sediments from eroded volcanic slopes. Reef limestones and reef sediments dominate Eocene. Gentle uplift begins causing shallowing of the seas and a gradual transition to Miocene type deposits.

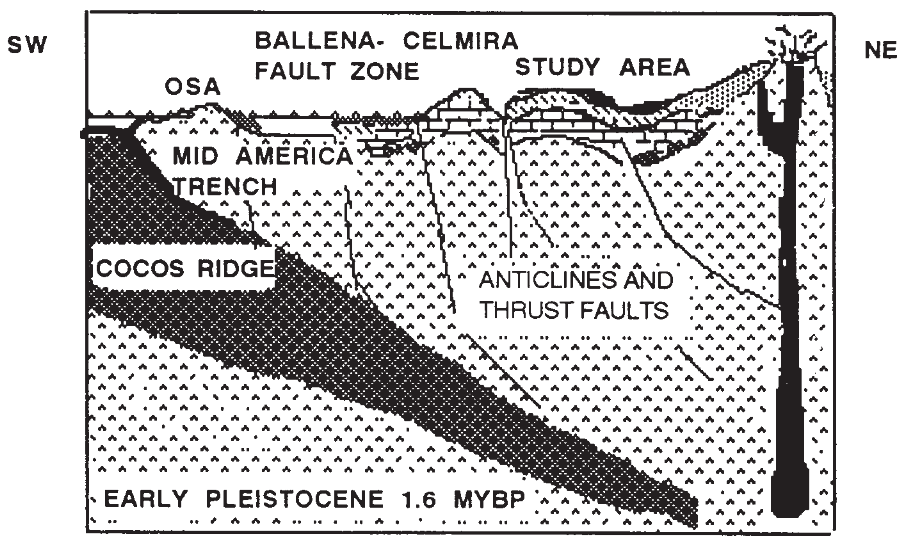



FIGURE 5.6 First deformation of sediments. Regional Anticlines form. Cocos Ridge subduction increases rate of shortening and uplift.

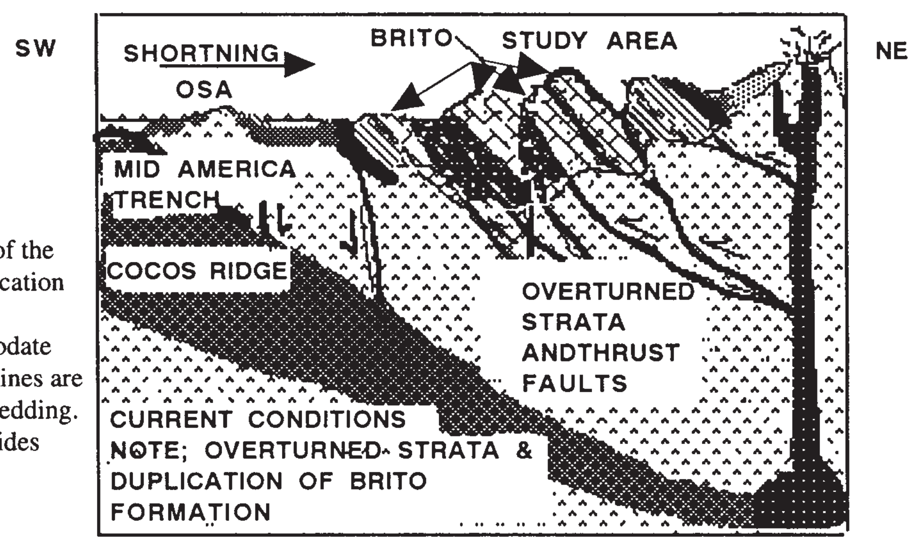



FIGURE 5.7 Present day conditions. Shortening of the strata becomes extreme causing faulting and duplication of units. Thrust faults occur at unit contacts and in fractured areas. Strike slip faults form to accommodate twisting caused by tri-plate juncture forces. Anticlines are overturned on the western flank causing vertical bedding. Uplift rates increase as the thicker Cocos Ridge slides under study area.

Photo 5-E Karst forms on a deforested ridge

This triplate convergence places the study area within a zone of complex tectonic activity where many directional forces interact. Predominant forces of compression are exerted from the west by the interaction of the Cocos Ridge and Caribbean plates, but significant structural effects can be attributed to the relative movement of the Nazca Plate at its juncture with the other two plates. This additional force has caused a "twisting" action to be exerted on strata in the study area. The bending of the northeast/southwest ridges has caused the formation of strike slip faults trending east/west across the older reverse faults, formed by the compression of the Eocene strata. It is postulated that this strike slip faulting occurred after the Pleistocene rapid uplift period and after the anticline structures had been faulted along their axis. These fault trends clearly transect the older thrusts and displace strata eastward (see Figure 5.3).

Earthquake activity is highest near Ciudad Neily and some volcanism is noted just outside the Corredor Basin in Panama. The presence of these volcanos can possibly be correlated with the pre Eocene/Miocene period but were certainly present in later periods.

It is felt that by late Santonian age (1 my bp) the Mid American Trench (located at the plate contact) was well established as a convergent margin (Auboin et al., 1979). However, evidence of uplift during the Paleocene and Eocene Epochs (36-63 my bp) and the start of ărc andesitic volcanism related to subduction of the Cocos plate (Mora, 1988) indicates early tectonic activity in the area.

## CHRONOLOGY OF DEFORMATION

During the Eocene this area was subjected to a period of gentle uplift that allowed the formation of shallow marine reef and platform limestones. These limestones appear to have been deposited on areas of basement rocks or on sandy marine sediments.

As uplift continued into the Miocene, sediment deposition ended in the area. These Eocene age sediments were gradually tilted and deformed creating pronounced structural features. Because of the compression of bedrock strata near the Caribbean/Cocos plate boundary, regional anticlinal features were first formed about 1mybp. These ancient anticlines paralleled the coast, forming basins and ridges. With this folding, several block faults occurred, forming basins and bays. Kesel (1983) suggested that uplift in the study area postdated the middle Pliocene and was probably Pleistocene to Holocene in age. The author agrees with this interpretation.

The rate of uplift quickly exceeded the ability of the limestones to deform plastically, causing the formation of thrust faults parallel to the original anticlinal axes.These thrusts were eventually transformed into reverse faults as blocks were tilted and fault angles increased.

Since compression was not always uniform or unidirectional, from the west, additional forces acting on the area from the south caused large strike slip faults to be formed perpendicular to the thrust and normal fault axes. This new faulting may have begun 500 thousand years before present, but information is lacking in this area. The blocks of fractured strata then moved eastward at slightly different rates creating the stair step outcrop pattern shown on Figure 5.3.

Based on cave passage formational characteristics, it is postulated that at least one period of rapid uplift has occurred since the formation of the major caves in the area. Large cave passages generally occur at two distinct elevations. These two levels are at elevations 25m apart. Evidence of increased regional down cutting and rapid lowering of cave water elevation supports the hypothesis of an increased uplift rate occurring after cave formation.

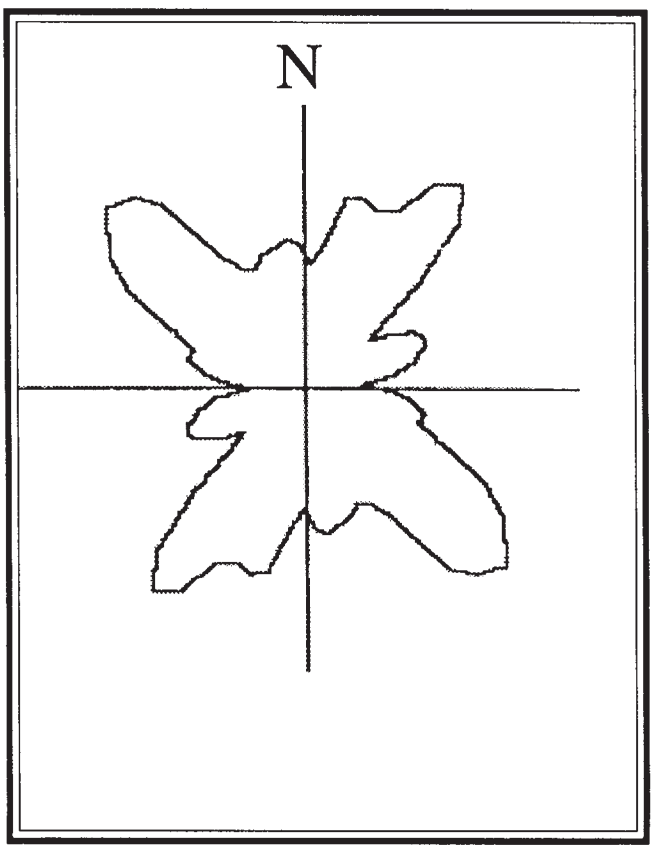



Figure 5.8 Lineament trends in area

## DATA COLLECTION

Geologic mapping in the Corredor Basin identified limestone contacts, fracture and fault trends, and lineaments. The major fault and fracture trends were grouped as follows:

> Large Normal and Reverse Faults trend N 40-50 W. These are transected by Strike Slip Faults trending N 45 E, N 65 E and N 35 E.

Linear feature mapping from air photos show major fracture trends as depicted on a Rose diagram (Fig. 5.8).

The Eocene limestones were broken into blocks and uplifted by the processes described above. The faults transect the Rio Corredor Basin and intersect the river. As a result of the thrust faulting, uplifted and tilted limestone ridges like Fila de Cal (Ridge of Lime) have become prominent local features. Thrust block fault dip angles increase to the west creating near vertical bedding in the city of Neily. Fault planes dip at an average of 59° NE near Bajos Indios and 81° NE near Neily. Down thrown blocks and normal faults occasionally exhibit dips to the southwest.

Mapping located many springs (detailed in the Hydrology section) and insurgences. The area between stream insurgences and their resurgence at regional base level was normally densely occupied by dolines and open pits that were found to be closely associated to fractures. Water enters the river in the limestone areas only from underground sources. The location of these springs was surveyed and mapped in relation to fault and fracture intersections along the river.

Maximum movement along east-west strike slip faults forming the north and south boundary of the study area has been estimated at 1/2 kilometer based on field mapping of contacts and air photo analysis. However, it has proven more difficult to determine the amount of over thrusting that has occurred in the Fila de Cal area thrust blocks. Based on the data collected it is postulated that the study area has experienced duplication of strata in the Brito Formation and over thrusting in the other units. There is evidence of overturned strata near Neily and strike and dip measurements indicate near vertical bedding along the river at Neily. This anticlinal folding has caused Miocene and younger sediments to appear in both the headwaters and lower sections of Rio Corredor.

## CAVE DEVELOPMENT

As discussed in previous sections, most of the 50 caves visited during the field portion of this study were located on or in close proximity to the major fault and fracture trends transecting the area. Many larger caves found by the project are "fault controlled" systems, these include the Cueva de Cerro Corredor system and Carma Cave.

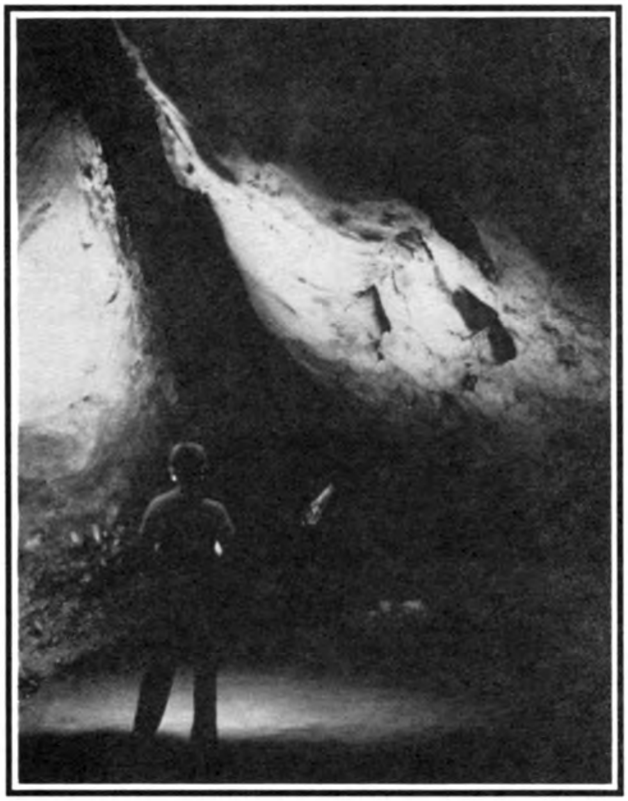


Photo 5-F Fault passage in Corredor Cave

The larger cave entrances are often located at either the insurgence or resurgence of larger streams. These entrances occur mainly at the intersections of fracture zones and stream beds.

The Corredor Cave stream passage is a prime example of fault controlled passage development. The water from the La Bruja Basin is captured by an extension of the Quebrada Seca Fault zone and channeled via the cave to the current regional base level, Rio Corredor. This water reappears along the southeast bank of the Rio Corredor at spring R6. Along its entire length it follows along a dominant fault that can be seen on the cave maps and in Photo 5-D.

All the larger caves in the basin are active stream caves containing one or more higher (dry) paleo-stream levels located 25m above the current stream.

Water flowing from the ridge above the La Bruja Valley traverses the iron rich clastic sediments and flows across the Corredor Limestone to a point where it is pirated downward along the Quebrada Seca Fault. This insurgence is the most recent infiltration area, but evidence in the form of old abandoned insurgence points give testimony to ongoing stream piracy by this fault. Analysis of sinkhole development in the valley indicates a steady up-valley migration of the La Bruja Creek insurgence. This migration, in reponse to normal geomorphic process has been a significant factor in the development of the Cerro Corredor Cave System. The composite map (Figure 7.4) of the system clearly shows the relationship of all caves and insurgences to the Corredor Cave Resurgence.

Insurgence points along the La Bruja Creek have continued to develop further upstream as regional uplift and down cutting of the Rio Corredor have progressed. Currently the insurgence is 1.7 km from its original outflow at the river. As this piracy has occurred, new underground stream courses have developed along major fractures.

A large offset in this fault controlled cave system is noted near the junction of Corredor Cave and Tururun Cave. It is theorized that the continued movement of the strike slip fault intersecting the caves at this point has caused this interruption in passage trend.

Abandoned paleo-stream courses are found in the higher levels of Corredor Cave.They tend to occur about 25m higher than the current stream level and resurgence. The same relationship of paleo-stream passages to the active streams are noted in the Quebrada Seca Valley caves and in Emus Cave.

Grand Gallery and parts of Bananal are paleo-remnants of higher water courses. Mapping indicates that these paleo-levels tend to occur at or near the same relative level as those in Corredor Cave across the river. This seems to indicate that the position of these abandoned levels is regionally interrelated or that the same tectonic occurrence caused their formation.

Similar paleo-levels have been documented in Emus Cave on Rio Claro, 17 km to the north. This further confirms the regional nature of the phenomena. It is therefore postulated that the larger abandoned passages found 17 to 35m above the current cave stream levels developed during a somewhat stable tectonic period when uplift remained constant at about 1 to 2 mm a year. This caused stream resurgences to remain at a constant elevation for years (hence the large entrances). As uplift intensified during the Recent Epoch (to perhaps 8 mm a year), the cave stream flowing along the fault became more aggressive in down-cutting and a period of rapid passage elevation change occurred. While this was occurring, the Rio Corredor was cutting down through the Fila de Cal Ridge at a rate equal to or greater than that of the cave streams. Further down-cutting caused the old upper levels to be abandoned quickly as streams were pirated downward along faults to the new base level. A slowing of this uplift has again caused enlargement of current stream passages.

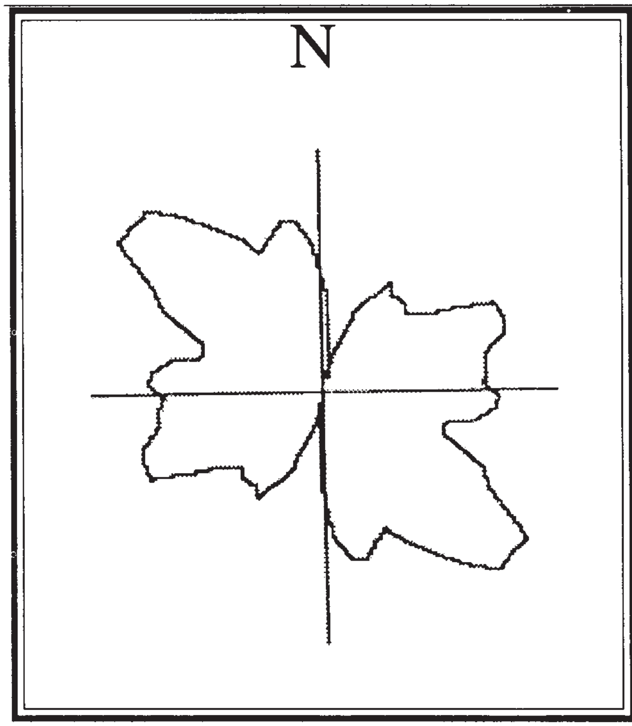



Figure 5.9 Passage trends in Corredor Cave

The main passage trend within each cave generally matched the trends associated with the thrust faulting in the area. Rose diagrams of both Carma and Corredor caves were prepared and compared to Figure 5-8. The similarity in passage trends and lineament trends confirmed the apparent connection.

In Figures 5.9 and 5.10 the predominant passage trend at N 50 W is identified as the Quebrada Seca Thrust Fault trace. The main passages in the La Bruja Valley caves are developed along this trend. The same trend is found in Carma Cave and represents a parallel fault. Photo 5-E shows a typical cross-section of the Corredor Cave stream passage. (Note the fault block face in the photo.)

## STRATIGRAPHY

The stratigraphy of the study area is complex and difficult to map. Faulting makes it nearly impossible to accurately measure units that are massive and uniform in appearance.

The study area is underlain by sediments ranging in age from Paleocene to Eocene.The shallow-water carbonate rocks containing the caves is part of the Brito Formation. Above the Brito Formation, the Tèrrabo Formation (Eocene/ Miocene age) is encountered (see Figure 5.11). Above this shale, on the highest ridges, are units of the Paso Real and Gatún Formations. These Miocene fossil sediments are found in the area adjacent to Neily where faults cause the strata to nearly overturn.

Below the Brito, the Nicoya Complex and basement rocks are found. These rocks outcrop near the western coast around Golfito.

Mapping of outcrops was done during three field seasons and encompassed an area of 150 square kilometers. From field descriptions the following units were identified (listed stratigraphically top to bottom).

## DESCRIPTION OF UNITS

The following description of units is based both on field observations, hand samples, and thin-sections prepared from some of the collected samples. Many of the macrofossils have been identified, but identification of species of foraminifera, vertebrate fossils, and some of the smaller mollusks is still in progress. Samples were collected from the following areas (Fig. 5.12): along Rio Abrojo (RA), both upstream and downstream from the tapped resurgence; along

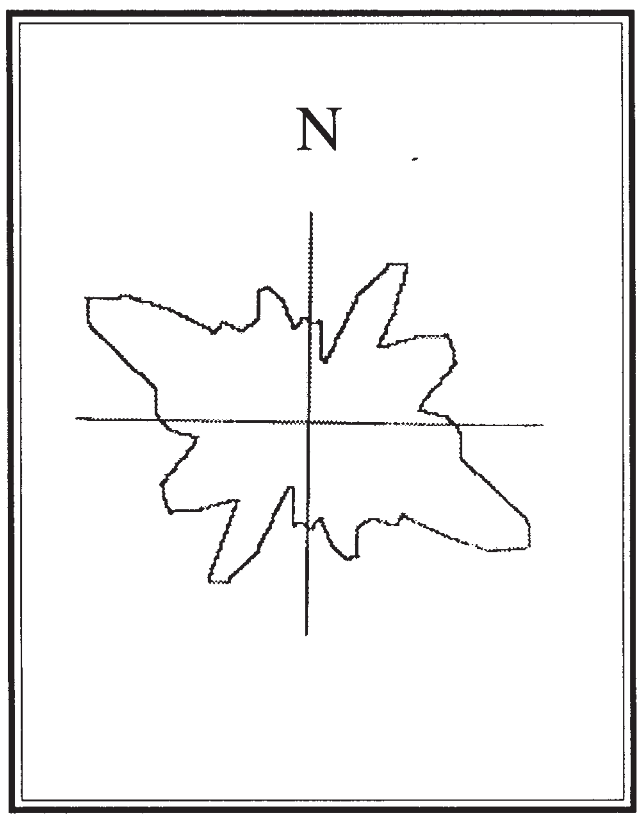
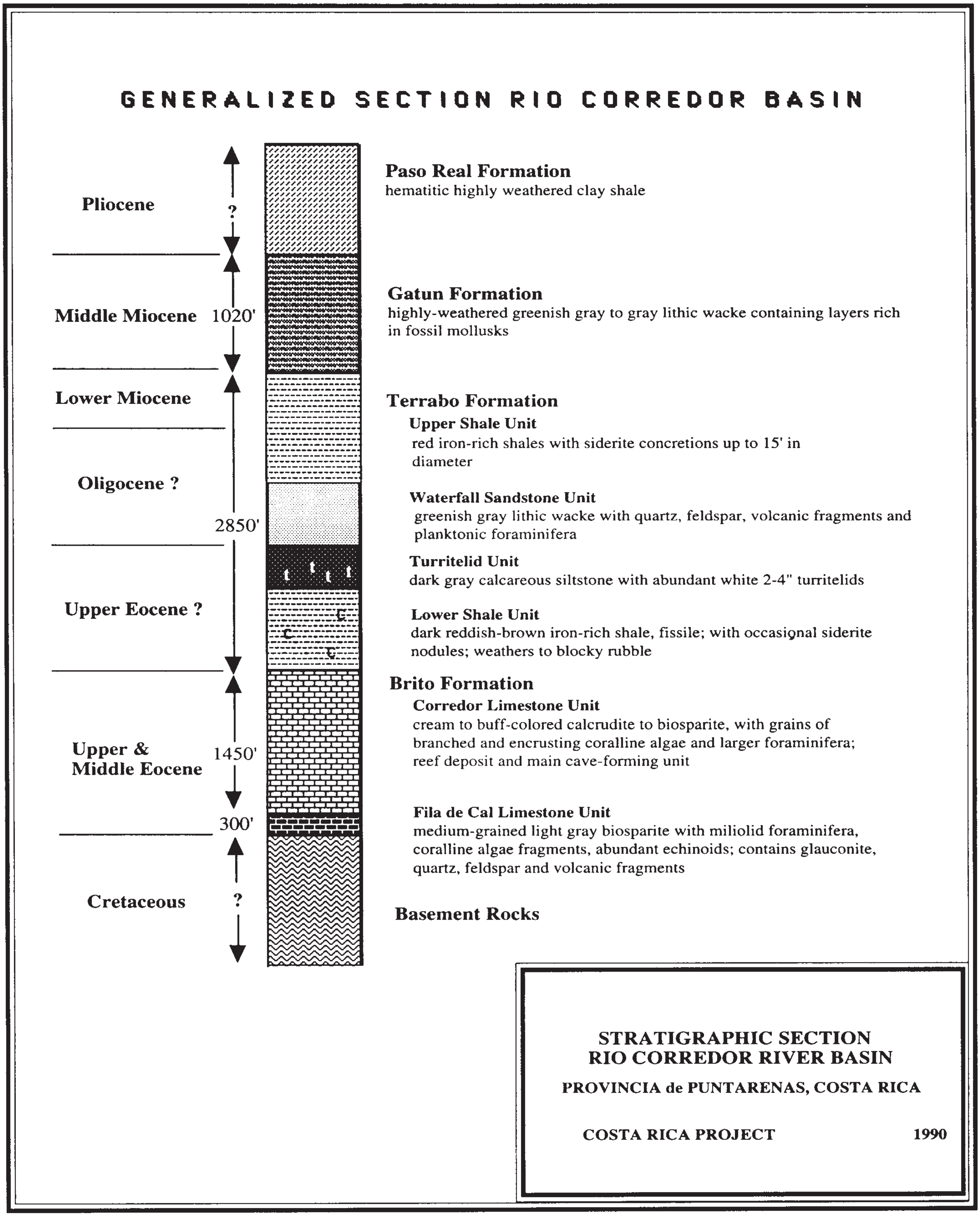



Figure 5.10 Passage trends in Carma Cave


GENERALIZED SECTION RIO CORREDOR BASIN
Pliocene
?
Middle Miocene
1020'
Lower Miocene
Oligocene ?
2850'
Upper Eocene ?
Upper & Middle Eocene
1450'
300'
Cretaceous
?
Paso Real Formation
hematitic highly weathered clay shale
Gatun Formation
highly-weathered greenish gray to gray lithic wacke containing layers rich in fossil mollusks
Terrabo Formation
Upper Shale Unit
red iron-rich shales with siderite concretions up to 15' in diameter
Waterfall Sandstone Unit
greenish gray lithic wacke with quartz, feldspar, volcanic fragments and planktonic foraminifera
Turritelid Unit
dark gray calcareous siltstone with abundant white 2-4" turritelids
Lower Shale Unit
dark reddish-brown iron-rich shale, fissile; with occasional siderite nodules; weathers to blocky rubble
Brito Formation
Corredor Limestone Unit
cream to buff-colored calcrudite to biosparite, with grains of branched and encrusting coralline algae and larger foraminifera; reef deposit and main cave-forming unit
Fila de Cal Limestone Unit
medium-grained light gray biosparite with miliolid foraminifera, coralline algae fragments, abundant echinoids; contains glauconite, quartz, feldspar and volcanic fragments
Basement Rocks
STRATIGRAPHIC SECTION
RIO CORREDOR RIVER BASIN
PROVINCIA de PUNTARENAS, COSTA RICA
COSTA RICA PROJECT
1990

Rio Corredor (RC); along Highway 16 on Fila de Cal (FC); and along the smaller road that connects Highway 16 with Florida (FR). Pictures of representative fossils and thin sections are included in Plates 1-7.

**THE PASO REAL FORMATION**

This unit is the highest strata investigated in this study. It occupies many of the highest hilltops around the Rio Corredor. Where found it weathers bright red or orange and forms a clay soil.

**GATÚN FORMATION - Middle Miocene**

This unit, exposed on the banks of Rio Corredor adjacent to Ciudad Neily, is a highly weathered greenish-gray to gray lithic wacke, containing occasional highly fossiliferous layers rich in fossil mollusks. Sand-sized grains include mollusk and echinoderm fragments, some foraminiferans, glauconite, angular quartz (some subhedral to euhedral), euhedral to subhedral plagioclase, opaques and volcanic rock fragments. Using fossil mollusks, we have correlated this unit with the Gatùn Formation of Panama (Woodring, 1957, 1964 , 1970, 1973, 1982) and of northern Costa Rica (Olsson, 1922). Mollusks identified in this unit are listed below and pictured in Plates 1-3.

**Bivalvia**

*Harvella elegans elegans (Sowerby, 1825)*
*Anadara (Potiarca) chavezi (Engerrand and Urbina, 1910)*
*Anadara sp. 1*
*Anadara sp. 2*
*Venericardia (Glyptoactis) ?aversa? Pilsbry and Johnson*
*Caryocorbula orosi Olsson*
*Varicorbula sp.*

**Gastropoda**

*Stigmaulax guppiana (Toula)*
*Mitra (tiara) dariensis Brown and Pilsbry*
*Cancellaria nancellaria Woodring 1970*
*Cancellaria sp. 1*
*Cancellaria sp. 2*
*Conus musaensis Olsson*
*Dolostoma sp.*
*Strioterebrum spiriferum (Dall)*
*Turritella abrupta Spieker*
*Turritella sp. (fragments)*

**Vertebrata**

*fish jaw (shark?) with teeth*
*shark tooth*

Microfossil identifications are still in progress.

**THE TÈRRABO FORMATION UPPER SHALES**

This unit is found on the higher peaks near the towns of Florida and Coppa Bueno. Typically it is seen outcropping on high ridge tops or directly in contact with the Corredor Limestone along faults. This unit is Hematitic and weathers to a bright rust red colored mud. It breaks down to soil readily when exposed to the elements. There is some gradational change noted across the study area. The most obvious of these changes is the gradational loss of the three contact units shown in the Rio Corredor section and their replacement with Iron Shales in the Caño Seco section.

One of the most prominent features of this unit is the abundance of Siderite concretions within the iron rich layers. These concretions range from a few centimeters in diameter to five meters or more. In weathered outcrops they look like cannon balls littering the surface. Most of the concretions are dark brown or black in color and appear to resist weathering.

This unit is the source bed of the large black "boulders" found in many of the caves. Apparently high velocity water flows have rolled these "balls" downstream and into the caves. No fossils were identified in this zone and its total thickness is about 1000 meters.

**THE WATERFALL SANDSTONE (Térrabo Form.)**

This unit is best seen along the road to Florida from Campo Dos or in the river bed near Bajos Indios. This silty sandstone is very fine grained with a large percentage of silt size particles within its matrix. In outcrop it is medium gray or greenish gray and is more resistant than the shale layers nearby.

Geomorphicly it usually forms rapids or waterfalls where rivers cross it. The bed is massive with a few shell fossils and Turritellids are found scattered throughout the unit. At the base of the unit is a gradational zone containing increased numbers of Turritellid fossils. The unit is approximately 220 meters thick in the Rio Corredor Valley but thins to the northwest.

**THE TURRITELLID BEDS (Térrabo Formation)**

Some of the most prominent fossil debris seen in the alluvium sediments of the Rio Corredor finds its source in the Turritellid beds. The predominant black matrix combined with the white fossils makes this unit easy to find and identify. The extent of this unit's distribution is unknown and it may may be localized in the Rio Corredor area since efforts to locate it in other rivers north and south of the described section were not successful. The outcrop is located near Bajos Indios, near the La Bruja trail crossing. The unit is a fine grained siltstone containing hundreds of fossils on each square meter of exposed surface. Like the siltstone described above, it forms rapids in river outcrops.

The unit is very resistant to erosion but is brittle and breaks into boulders that are often transported down river 6 km or more.

**LOWER TÉRRABO SHALES - Eocene / Miocene ?**

Below the Turritellid beds the clastic iron rich Terrabo shale is again found in outcrop. These shales and interbedded fine grained sandstones are found in outcrop at the mouth of the La Bruja valley. Geomorphicly they are responsible for the formation of the broad flat river bed found above the Corredor Canyon.

This unit is similar in appearance to the upper Térrabo shales except that the Siderite concretions rarely exceed 10 cm. The age of this unit may be Eocene or early Miocene.

**THE BRITO FORMATION - Eocene**

This massive Eocene Formiferal limestone is the predominant cave forming unit in the study area. The unit is a tan to buff colored reef limestone that was deposited in shallow marine environments. The unit in outcrop is characterized by expansive karst topography. Dolines and karst are found in both the Rio Corredor and Rio Abrojo Basins. Some facies differences are noted in the two areas but the formation was identifiable as two units described in this study. The upper section, referred to as the Corredor Limestone in this report, and the lower section, named the Fila de Cal Limestone can be identified in all sections under study.

**BRITO FORMATION IN RIO ABROJO**

Samples from the east side of the river consist of medium-to fine-grained, light gray to tannish-gray micritic limestone, with angular quartz, feldspar, some hornblende and volcanic rock fragments. All samples are rich in planktonic foraminifera (Globigerina and Globorotalia, particularly). Many samples have some iron staining and dark reddish brown patches of micrite (possibly of fecal pellet origin). The abundance of planktonic foraminifera and the presence of fine grained matrix indicate that these rocks were formed in a deep marine setting away from excessive volcaniclastic input.

On the opposite side of the river near the tapped resurgence are dark gray lithic wackes with no obvious fossils and little calcareous material. The juxtaposition of these rocks with the micritic limestone is most likely the result of movement along a fault through the Rio Abrojo Valley. We were unable to determine the amount of throw on the fault based on our field observations but both units are identified as Eocene age and the limestone is clearly the Brito Formation.

**BRITO FORMATION IN RIO CORREDOR AND RIO CAÑO SECO**

**CORREDOR LIMESTONE - Eocene**

This unit is a cream to buff-colored calcrudite (in places a boundstone according to the Dunham classification), composed of large fragments of coralline algae (both branching and encrusting forms) and larger foraminifera (Discocyclina? and others). The voids in this unit are mostly filled with sparry calcite. Samples from the top of Fila de Cal are almost completely composed of coralline algae, indicating that the unit is a reef front facies grading into a reef and lagoonal facies, with higher concentrations of larger foraminifera and broken pieces of coral.

This unit is the most extensive karstic unit in outcrop and forms several notable limestone features. The most dominant features formed by the Corredor Limestone are the Fila de Cal Ridge and the Corredor River Canyon. The Fila De Cal extends for several kilometers in a northwest direction from the Corredor River. The ridge is formed by the upthrusting of limestone block adjacent to the Quebrada Seca Fault.

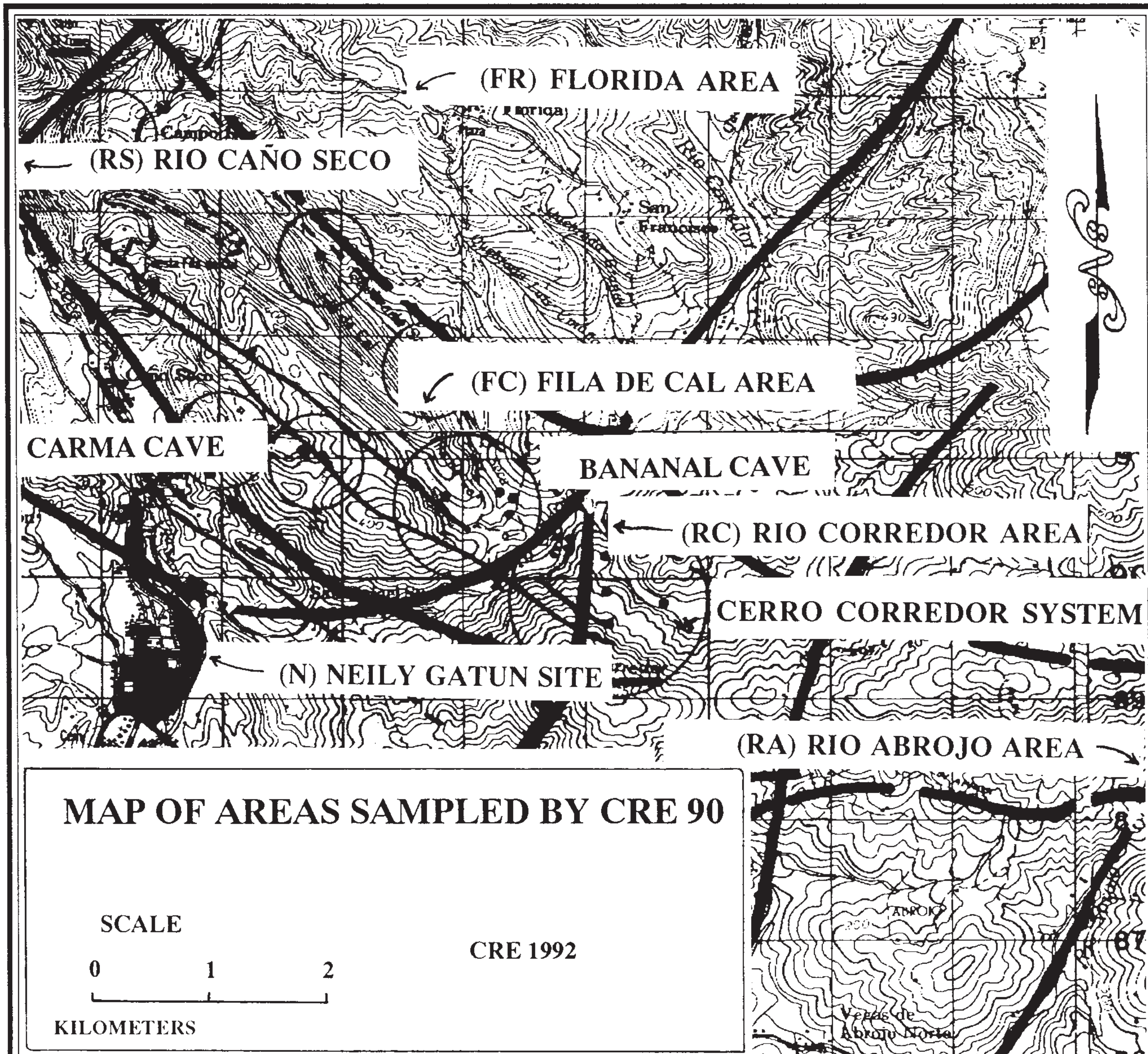
This Corredor Limestone is massive and uniform over much of its thickness. This uniformity makes it very difficult to determine the extent of duplication of strata associated with individual thrust faults. Only where the basal grey zone (Fila de Cal Limestone) or the upper Tèrrabo shale contact zone is exposed can accurate thickness measurements be obtained.

Much of the unit is a buff colored forminiferial limestone but as one descends the section, a zone of light grey "blobs" is encountered. These "blobs" weather grey against the buff-tan matrix and due to their 0.5m+ size are easily seen in outcrop. About 10m below this zone the unit becomes almost entirely grey and the largest fossils of the area are found. This area was determined to be a gradational zone between reef and near-reef limestones. The grey basal unit was named the Fila de Cal Limestone for its location within the study area.

**FILA DE CAL LIMESTONE - Eocene**

This unit is the basal protion of the Brito Formation in the study area. It is a grey biosparite with some volcaniclastic inclusions ( plagioclase and volcanic rock fragments). This unit represents sediments that were deposited near the reef margins. Numerous well preserved echinoids ranging in size from 3cm to 8cm were collected from this unit.

Biogenic components of the Filia de Cal unit vary in proportions based on proximity to the reef, and include milodid and uniserial foraminiferans, echinoids, ostracods, small gastrapods, and coralline algae. The same units identified in the Rio Abrojo Basin appear to represent a more offshore facies of this sediment.




Analysis of hand samples and thin sections resolved the area sampled into the units shown in the Stratigraphic Column in Figure 5-11. Samples from locations indicated on the map opposite grouped as follows: I. Gatun Formation (Sites 1-4); II. Terraba Formation - Upper Shale Unit (Sites 5-10, 24, 25), Waterfall Sandstone Unit (Sites 11, 12, 26, 28, 29), Turritellid Unit (Site 27), Lower Shale Unit (Sites 13-15, 30-32); III. Brito Formation - Corredor Limestone Unit (Sites 19-23), Fila da Cal Limestone Unit (Sites 16-18). The correlation of samples from Sites 33-37 is problematical. All are micritic limestone with numerous planktonic foraminiferans and may be a deep water unit equivalent to the Waterfall Sandstone Unit , simply further away from the volcanic source. The micritic limestone may, on the other hand, be an entirely different unit than those in the western part, moved into place along the valley fault. Further sampling in to the east and in Panama is necessary if this question is to be resolved. Representative thin sections of each of these units are pictured in Plates 5-7.

Figure 5.12 Stratigraphic sample sites

# FOSSIL PLATES

## PLATE 1

### Gastropod Fossils of the Gatun Formation

1–3. *Dolostoma* sp.; aperture views of 3 specimens

4,5. *Stigmaulax guppiana* (Toula); 2 specimens

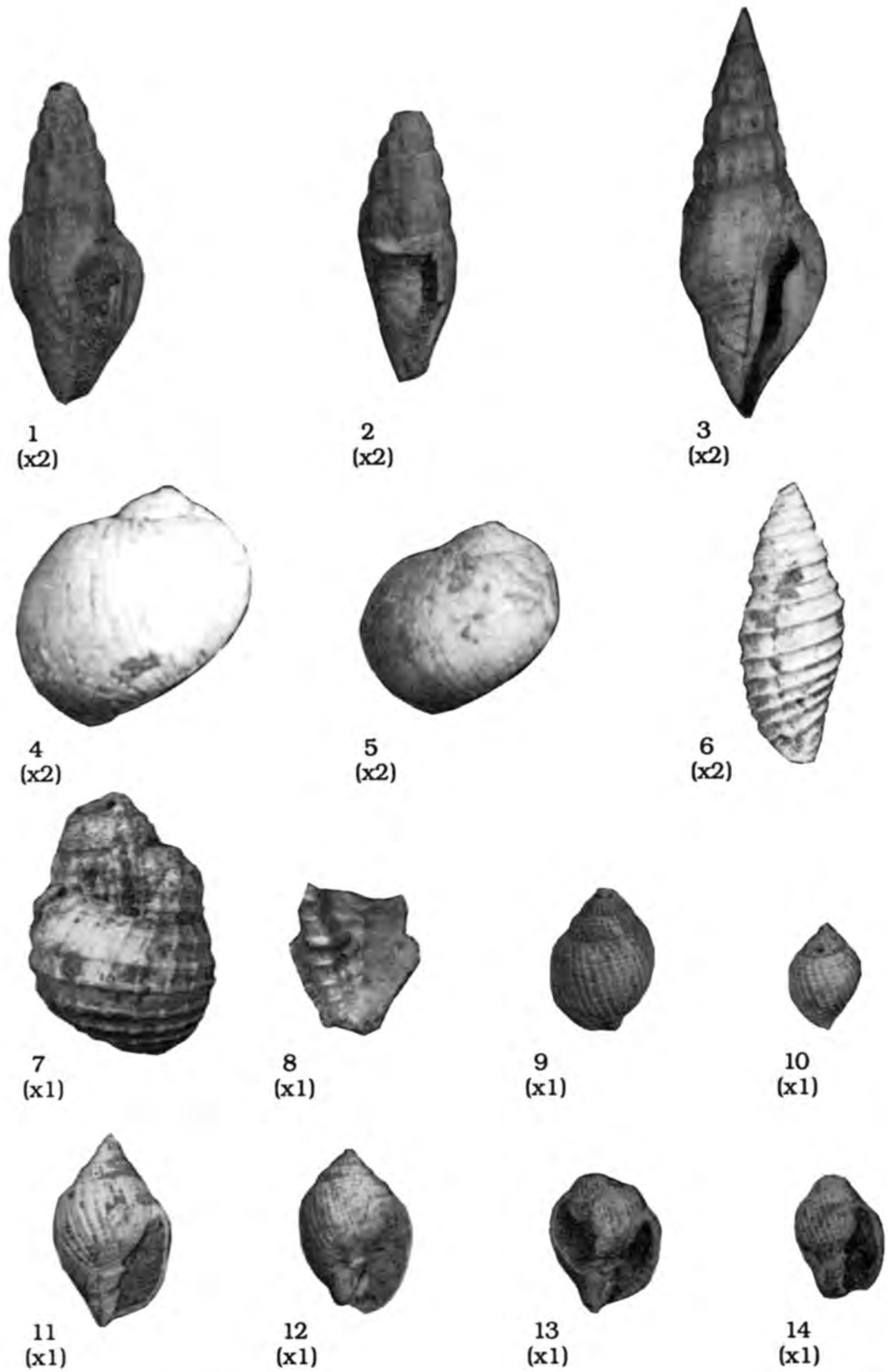
6. *Mitra (Tiara) dariensis* Brown and Pilsbry

7. *Cancellaria* sp. 1, fragment from apertural area

8. *Cancellaria* sp. 1; note aberrant shell growth pattern, probably due to injury during growth

9–14. *Cancellaria* sp. 2; six different specimens.

Plate 1



## PLATE 2

Gastropod Fossils of the Gatun Formation

1–3. *Turritella* sp. 1; 3 fragments, too incomplete for species identification

4. *Conus* sp., broken shell

5. *Conus musaensis* Olsson

6. Family Muricidae, *Nucella*?

7. Family Turridae

8. *Terebra* sp.

# Plate 2

1
(x2)

2
(x2)

3
(x2)

4
(x2)

5
(x2)

6
(x2)

7
(x2)

8
(x2)

PLATE 3

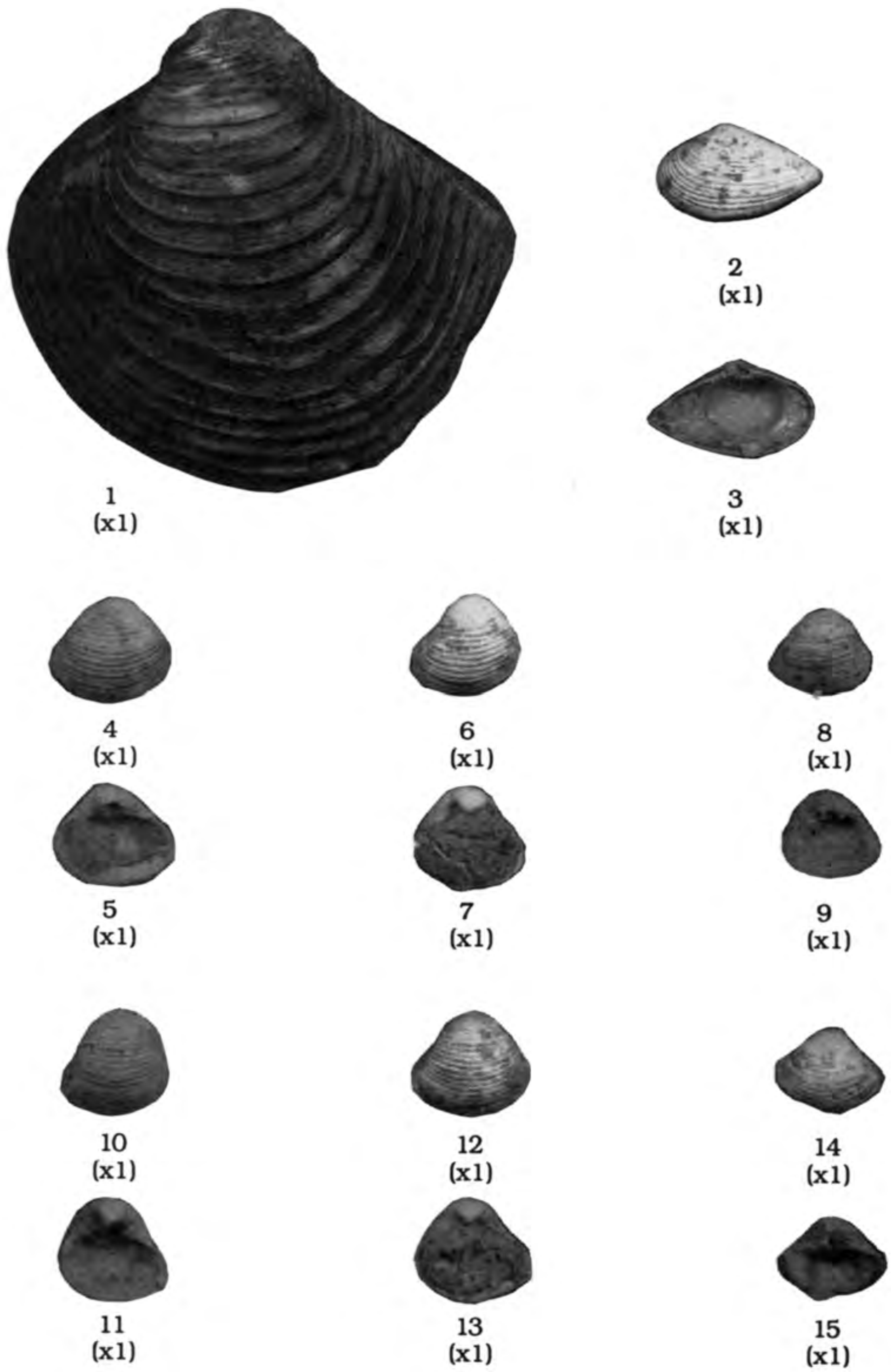
Bivalve Fossils of the Gatun Formation

1. *Harvella elegans*

2, 3. *Caryocorbula orosi* Olsson; exterior view and interior views, respectively.

4–15. *Varicorbula* sp., 6 specimens with exterior and interior views of each; pairs of views for each specimen are 4&5, 6&7, 8&9, 10&11, 12&13, 14&15

## Plate 3


1
(x1)
2
(x1)
3
(x1)
4
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5
(x1)
6
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7
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8
(x1)
9
(x1)
10
(x1)
11
(x1)
12
(x1)
13
(x1)
14
(x1)
15
(x1)

# PLATE 4

## Bivalve Fossils of the Gatun Formation

1–3. *Anadara (Potiarca) chavezi* (Engerrand and Urbina)
  1. left valve
  2. right valve
  3. articulated specimen

4,5. *Anadara (Potiarca) chavezi* (Engerrand and Urbina)?; exterior and interior views of a single specimen (right valve)

6–9. *Anadara* sp. 1, left valves
  6,7. exterior and interior views of single specimen
  8,9. exterior and interior views of a second specimen

10, 11. *Anadara* sp. 2, left valve; exterior and interior views

12, 13. *Venericardia (Glyptoactis)? aversa ?* Pilsbry and Brown; left valve, exterior and interior views

Plate 4

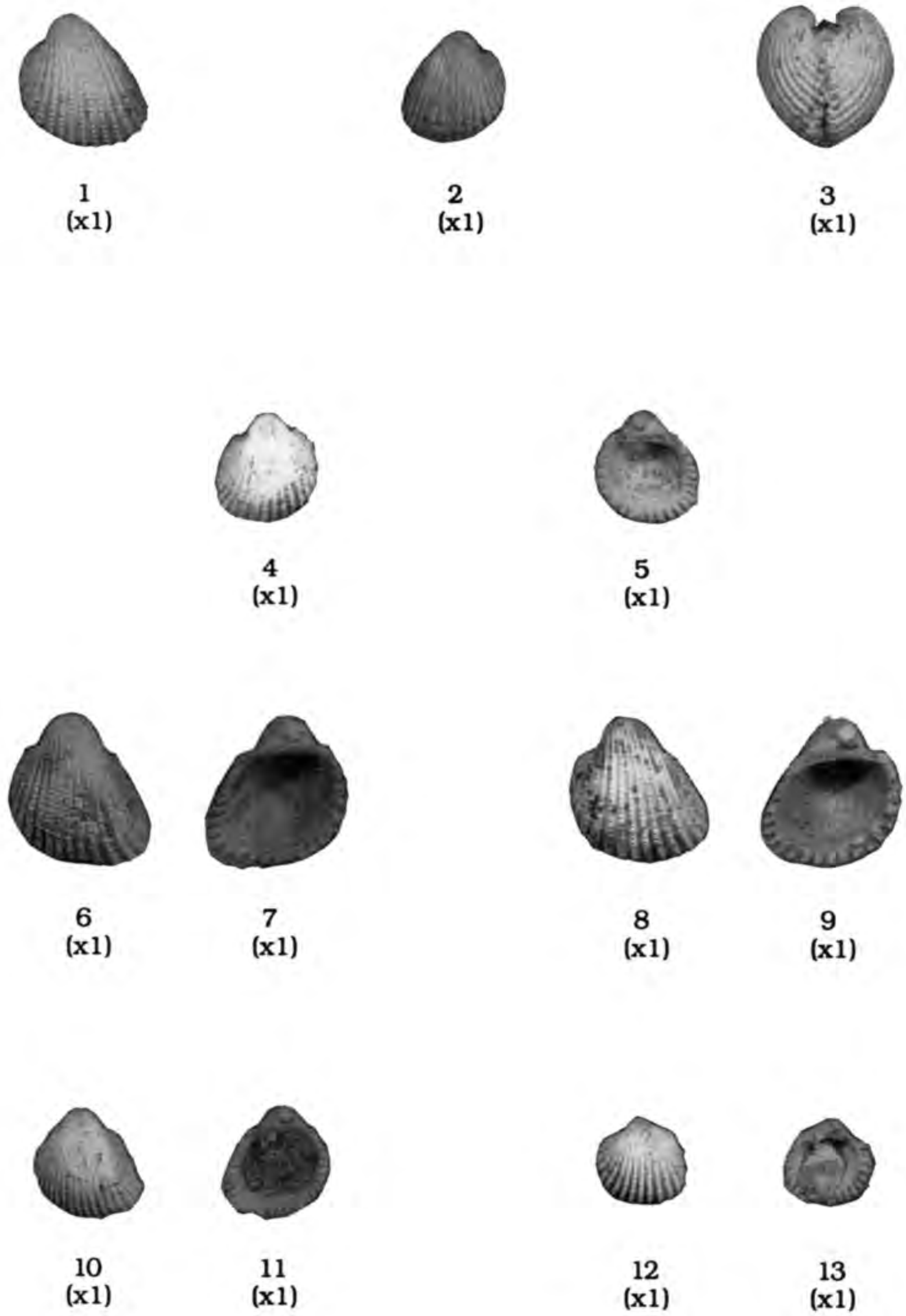


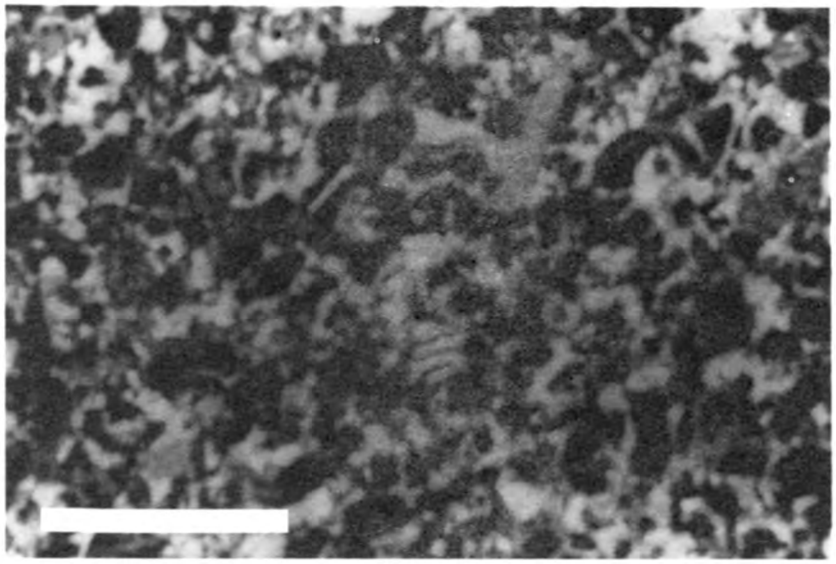
PLATE 5

1. Photomicrograph of a thin section of the Upper Shale Unit of the Terraba Formation, taken under crossed Nicols. Bar represents 1 mm. The sample is a calcite cemented lithic arenite, containing volcanic fragments, potassium feldspar, small laths of plagioclase, and some clinopyroxene. The sample pictured was from Site 10 on the map in Fig. 5.12.

2. Photomicrograph of a thin section of the Waterfall Sandstone Unit of the Terraba Formation, taken under plane polarized light. Bar represents 1 mm. Numerous globigerinids and other planktonic foraminiferans are evident in a fine felsic-rich groundmass. The sample pictured was from Site 28 on the map in Fig. 5.12. Samples of the same unit from Site 26 contained fewer planktonic foraminiferans and a higher percentage of fine felsic groundmass.

3. Photomicrograph of a thin section of a sample from Site 33 in Fig. 5.12, taken under crossed Nicols. Bar represents 1 mm. This sample, as well as samples from Sites 34–37, are somewhat problematical. They contain abundant planktonic foraminifera (center of image) in a micritic groundmass, and may be an offshore unit that correlates with the Waterfall Sandstone Unit of the Terraba Formation or may be a different unit altogether. Numerous faults in the Rio Abrojo Valley indicate possibly extensive transport.

1.



2.

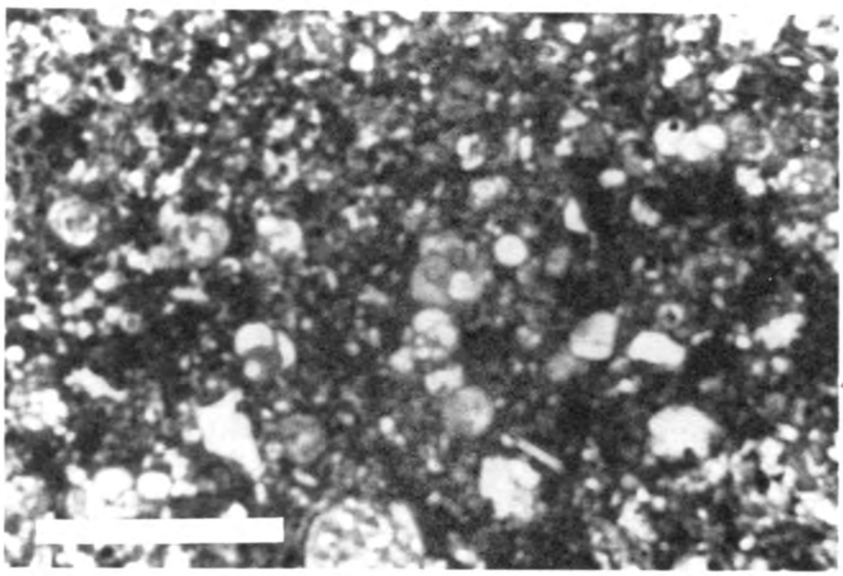


Plate 5

3.

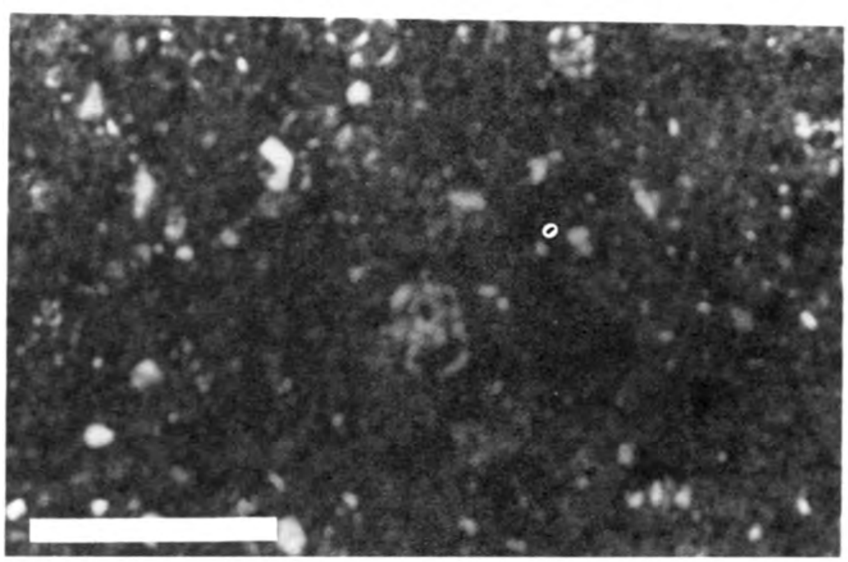


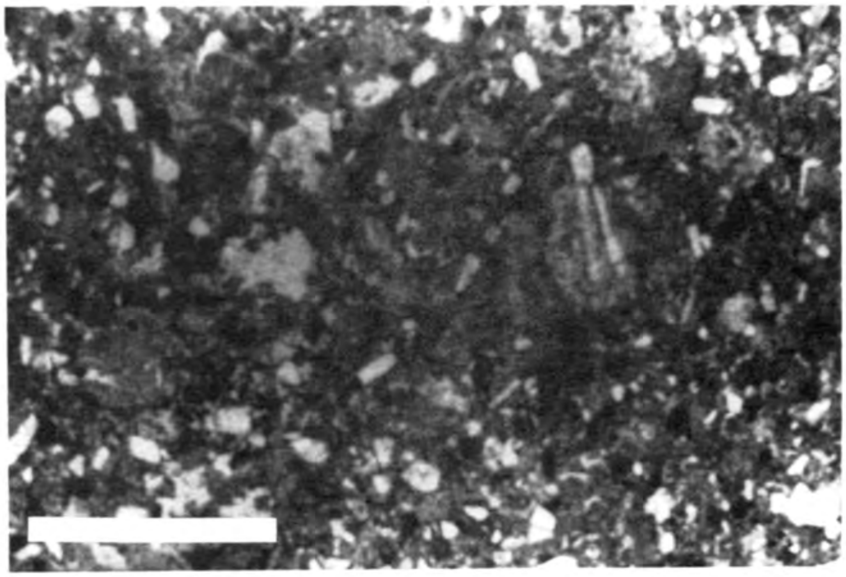
PLATE 6

1. Photomicrograph of a thin section of the Turritellid Unit of the Terraba Formation, taken in plane polarized light. Bar represents 1 mm. Sample is a calcite-cemented feldspathic litharenite, containing many fossil turritellids (as yet unidentified). No turritellids are evident in the photomicrograph.

2. Photomicrograph of a thin section of the Lower Shale Unit of the Terraba Formation, taken under crossed Nicols. Bar represents 1 mm. Subhedral to euhedral grains of plagioclase are evident and are probably of volcanic origin. The groundmass is rich in quarts and feldspar and contains few if any fossils. The sample pictured was from Site 15 on the map in Fig. 5.12.

Plate 6

1.



2.

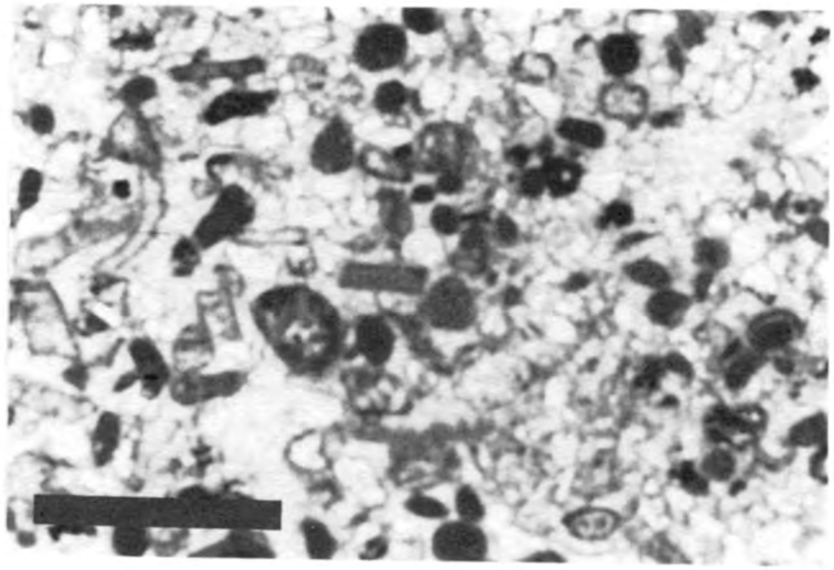
PLATE 7

1. Photomicrograph of a thin section of the Fila de Cal Limestone Unit of the Brito Formation, taken in plane polarized light. Bar represents 1 mm. Numerous small benthic foraminifera, including many miliolids, are present along with fragments of coralline algae and micritized pellets, all in a sparry calcite matrix. The sample pictured was from Site 17 on the map in Fig. 5.12.

2. Photomicrograph of a thin section of the Corredor Limestone Unit of the Brito Formation, taken under crossed Nicols. Bar represents 1 mm. Pictured is one of the larger foraminifera (probably *Discocyclina*) adjacent to a gastropod (with rounded light patches) and encrusting coralline algae (dark patches at bottom). This sample pictured was from Site 20 on the map in Fig. 5.12 and is typical of those rocks found along the ridge of Fila de Cal. The abundant large foraminiferans and red algae indicate a top reef or fore reef environment of formation.

3. Photomicrograph of a thin section of the Corredor Limestone Unit of the Brito Formation, taken under plane polarized light. Bar represents 1 mm. Several larger foraminiferans (*Discocyclina?*) and pieces of red algae are evident. The site of sampling for this specimen is not indicated in Fig. 5.12. The picture is included here as representing a typical specimen of the cave-forming unit in the Rio Corredor Valley.

1.



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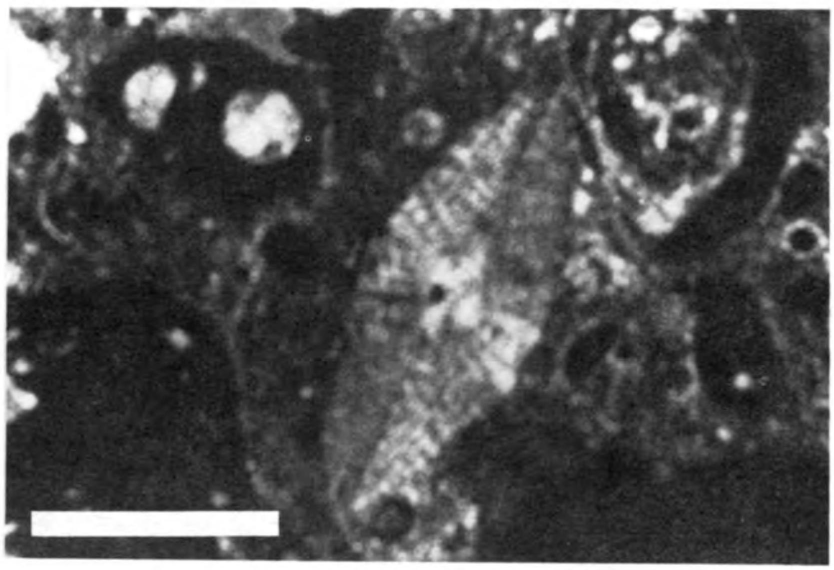

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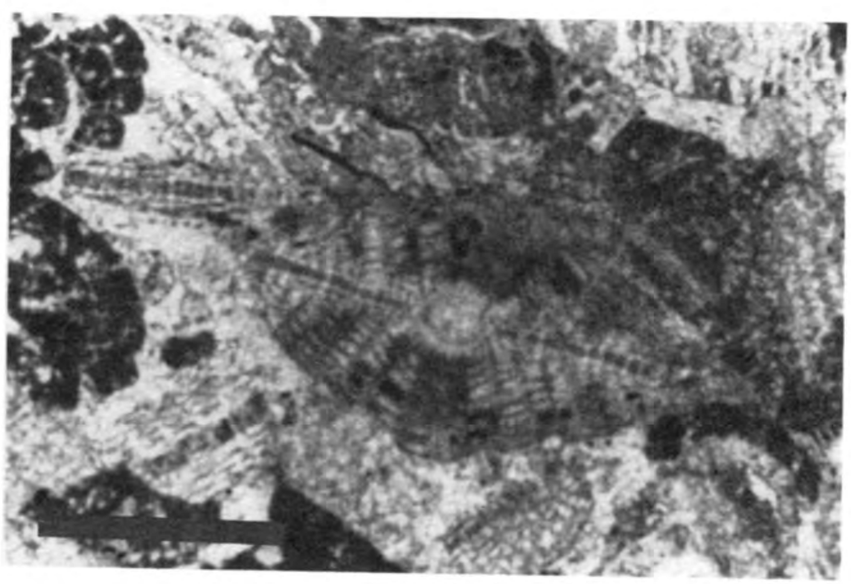


# SECTION 6

## HYDROLOGY OF THE RIO CORREDOR BASIN

The Rio Corredor Basin is a very large drainage encompassing over 10,000 acres. Part of the basin is underlain by Eocene limestone and exhibits typical karst features. In this area several karstic sub-basins have developed.

The La Bruja Basin and the Quebrada Seca Basin were studied by this project. This section of the report will describe the hydrology of the region and link the results of geological research and speleological investigation to the regional hydrologic conditions.

Water is very important to the local residents in Ciudad Neily since a large part of the town relies on the aqueous resources of the study area for potable water. The effects of deforestation and pollution within the recharge areas may have long-term effects on the domestic water supply.

No identification of recharge areas had been undertaken prior to this study. Therefore the first task of this project was to locate and map all insurgences and resurgences within the study area. This work was completed during the 1989 field season with minor additions made in 1990.

The second task of the hydrology team consisted of documenting the underground water courses and determining recharge area boundaries from topographic maps, cave maps, and air photos.

The third and most tedious task consisted of sampling all springs and caves to determine water quality.

### LOCATION OF HYDROLOGIC FEATURES

There are a number of features within the study area that were identified during the field reconnaissance portion of our research. These features are located on the enclosed map (Fig. 6.1).

During the course of our investigations the following features were described and sampled:

**LA BRUJA SECTION**

| | |
|---|---|
| Alma | Alma cave on north side of river near Corredor Cave |
| REC 1 | Sample in Calgary Hall, Rectangle Cave. |
| REC 2 | Sample from first sump in Rectangle Cave. |
| REC 3 | Sample in Bill's Passage, Rectangle Cave. |
| RECT. | Rectangle Cave, unknown site |
| RC1 | Spring with travertine near road trail entry to river on north wall of canyon. |
| RC2 | Spring emitting from an unnamed cave on north wall of canyon. |
| RC2a | Pool inside RC2 cave. |
| RC3 | Spring on north wall halfway to Corredor Cave. |
| RC4 | Spring located on north canyon wall below Corredor Cave. |
| RC5 | Spring across from Corredor Cave on northwest side of canyon. |
| RC6 | Resurgence of Corredor Cave at river. |
| RC6a | Corredor Cave stream 30 meters in cave wet entrance resurgence. |
| RC6b | Corredor Cave sump |
| RC7 | Small spring 5m west of cave entrance trail. |
| RC7a | Small spring 5m west of cave entrance trail next to RC7. |
| CC1 | In cave sample of Guyami River passage in Corredor Cave. |
| L1 | La Bruja stream (surface) |
| L 2 | La Bruja stream at junction of Rio Corredor |
| LB1 | Sample from La Bruja Cave lower sump. |
| C1 | Upstream Corredor River 200m above cave. |
| C2 | Corredor River at Don Carlos Miranda farm near swimming bridge. |

S1 San Rafael water supply resurgence on south side of canyon across from RC1.

**QUEBRADA SECA SECTION**

Q 1 Año Nuevo insurgence.

Q 2 Quebrada Seca insurgence. (surface)

Q 3 Bananal Sump.

**CARMA SECTION**

CA1 Sump in Carma Cave (Umbrella room).

CS1 Caño Seco public water supply near town of Vedo.

**RIO CLARO SECTION**

E 1 Emus resurgence

E 3 Emus Cave stream in cave at sta. 32.

## CONFIRMED HYDROLOGIC CONNECTIONS

During the course of this study stream tracing using fluorescein dye was undertaken in each sub basin. On the south side of the river, positive connections were established between La Bruja, Rectangle and Corredor Cave.

On the north side, the Quebrada Seca insurgence was connected to the Bananal sump and then to the spring at RC5.

In Rio Claro, Emus Cave was connected to its resurgence along the river. This was a short trace and no insurgence has been located.

At Carma an unsuccessful attempt was made to connect the cave to the spring CS1 at Vedo.

## GEOLOGIC FACTORS AFFECTING DRAINAGE

Based on the dye tests and geologic mapping the correlation of geologic faults and hydrology was established.

It appears that tectonic features such as faults and fracture zones act as the primary hydrologic control within the study area. Cave passages form more readily along these broken zones of increased permeability. Dye connections indicate almost straight line flow along faults from insurgences to resurgences in the study area. Only slight variations in flow direction occur when cross trend fractures are encountered.

The influence of dip and other factors plays a minimal role in controlling flow direction underground. Conversely the effects of uplift and river down-cutting have caused classic regressive stream piracy to occur.

Old insurgence points can be found in both the La Bruja and Quebrada Seca sections. These paleo-insurgences have been replaced by new swallow holes located higher up the valleys. The old trunk passages they fed have been abandoned for lower stream canyons.

From examination of the current stream levels and paleo-stream levels it appears that a period of rapid uplift or down-cutting occurred (perhaps during the last ice age) across the entire 400 square kilometer study area. Large paleo-stream levels in the Quebrada Seca, Corredor, and Emus caves seem to interrelate to their respective stream levels in a similar fashion. From pendants, scallops and other evidence, it may be concluded that the paleolevels in Emus and Corredor Caves were formed under phreatic conditions and abandoned for lower level water courses rather quickly.

There is almost no in-cave evidence to indicate the development of intermediate stream levels during the lowering of the regional base level and almost no mid-level horizontal passage development is seen. In general passages connecting the paleo and current stream levels are sloping breakdown covered walkways or pits between the upper dry and the lower wet levels.

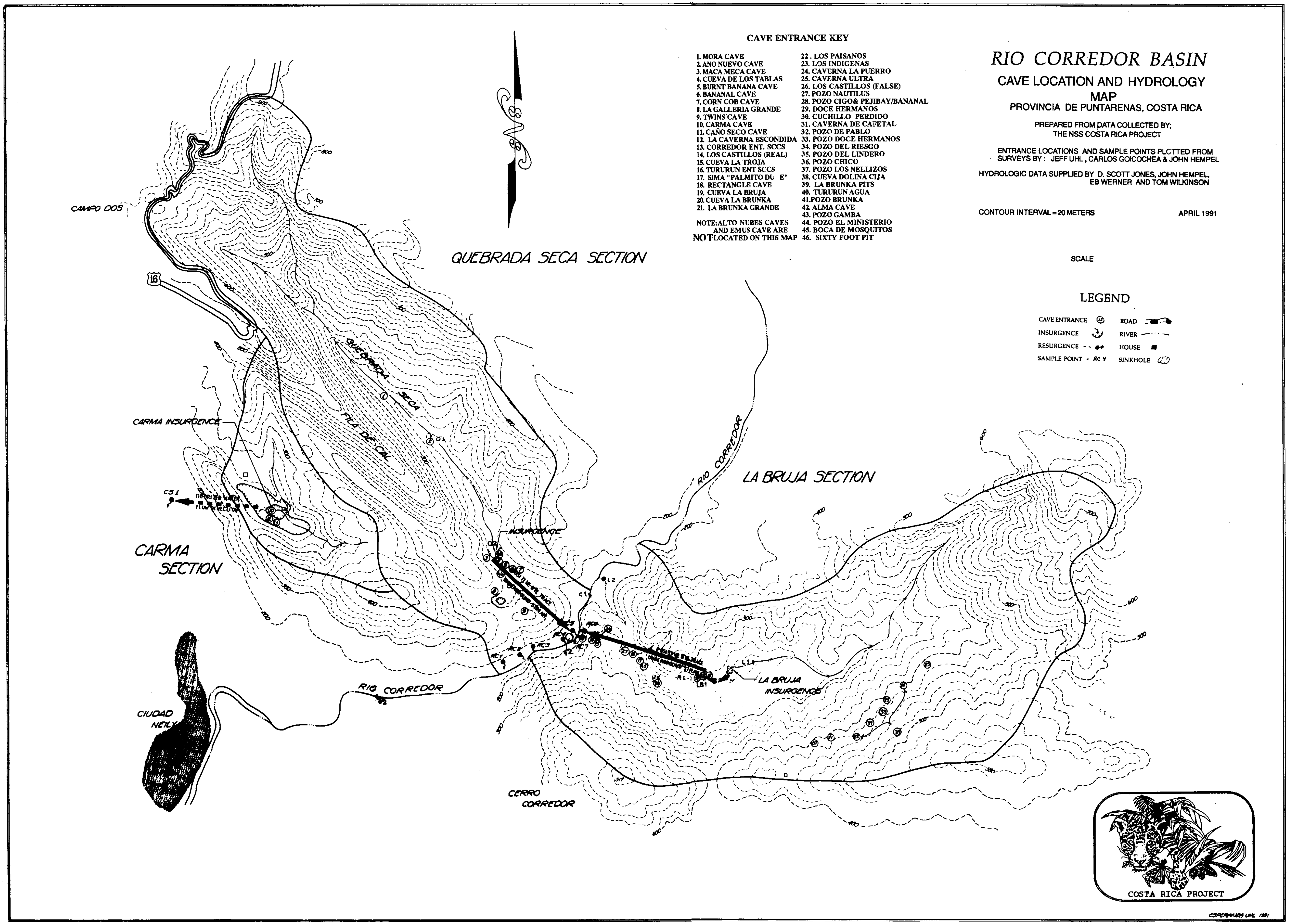
Based on the established connections and on the relationship of paleo-trunk passages in the caves connected, we may conclude that the La Bruja and Quebrada Seca basins in the Rio Corredor drainage have acted as sub-basins for much of the geologic life of the region and that at least one period of increased uplift occurred, profoundly affecting regional base levels and cave formation.

## DETERMINATION OF RECHARGE AREAS

From the data collected; including the cave maps and dye tracing studies, the recharge area of the Rio Corredor karst was determined (see Fig 6.1).

A majority of both karst sub-basins are covered with jungle, but agriculture is fast encroaching. The farming of beans and corn has become popular on the north side of the river, and massive clear cutting evident in air photos is being done to support this activity. This deforestation appears to be the direct cause of the massive sediment loads found in the Quebrada Seca caves.

Fertilizer and chemical by-products are beginning to be detected in water samples from the resurgences in the area.



CAVE ENTRANCE KEY
1. MORA CAVE
2. ANO NUEVO CAVE
3. MACA MECA CAVE
4. CUEVA DE LOS TABLAS
5. BURNT BANANA CAVE
6. BANANAL CAVE
7. CORN COB CAVE
8. LA GALLERIA GRANDE
9. TWINS CAVE
10. CARMA CAVE
11. CAÑO SECO CAVE
12. LA CAVERNA ESCONDIDA
13. CORREDOR ENT. SCCS
14. LOS CASTILLOS (REAL)
15. CUEVA LA TROJA
16. TURURUN ENT SCCS
17. SIMA "PALMITO DU E"
18. RECTANGLE CAVE
19. CUEVA LA BRUJA
20. CUEVA LA BRUNKA
21. LA BRUNKA GRANDE
22. LOS PAISANOS
23. LOS INDIGENAS
24. CAVERNA LA PUERRO
25. CAVERNA ULTRA
26. LOS CASTILLOS (FALSE)
27. POZO NAUTILUS
28. POZO CIGO& PEJIBAY/BANANAL
29. DOCE HERMANOS
30. CUCHILLO PERDIDO
31. CAVERNA DE CAFETAL
32. POZO DE PABLO
33. POZO DOCE HERMANOS
34. POZO DEL RIESGO
35. POZO DEL LINDERO
36. POZO CHICO
37. POZO LOS NELLIZOS
38. CUEVA DOLINA CIJA
39. LA BRUNKA PITS
40. TURURUN AGUA
41. POZO BRUNKA
42. ALMA CAVE
43. POZO GAMBA
44. POZO EL MINISTERIO
45. BOCA DE MOSQUITOS
46. SIXTY FOOT PIT
NOTE: ALTO NUBES CAVES AND EMUS CAVE ARE NOT LOCATED ON THIS MAP
RIO CORREDOR BASIN
CAVE LOCATION AND HYDROLOGY MAP
PROVINCIA DE PUNTARENAS, COSTA RICA
PREPARED FROM DATA COLLECTED BY; THE NSS COSTA RICA PROJECT
ENTRANCE LOCATIONS AND SAMPLE POINTS PLOTTED FROM SURVEYS BY : JEFF UHL , CARLOS GOICOCHEA & JOHN HEMPEL
HYDROLOGIC DATA SUPPLIED BY D. SCOTT JONES, JOHN HEMPEL, EB WERNER AND TOM WILKINSON
CONTOUR INTERVAL = 20 METERS
APRIL 1991
SCALE
LEGEND
CAVE ENTRANCE
ROAD
INSURGENCE
RIVER
RESURGENCE
HOUSE
SAMPLE POINT - RC 1
SINKHOLE
CAMPO DOS
16
QUEBRADA SECA SECTION
QUEBRADA SECA
FILA DE CAL
CARMA INSURGENCE
CARMA SECTION
INSURGENCE
LA BRUJA SECTION
RIO CORREDOR
LA BRUJA INSURGENCE
RIO CORREDOR
CIUDAD NEILY
CERRO CORREDOR
COSTA RICA PROJECT

**LA BRUJA SECTION**

On the south side of the river the La Bruja Basin area was found to contain 2010 acres. The basin is less farmed than Quebrada Seca but logging is occurring and trunks of trees may be found plugging cave passages.

La Bruja Creek sinks 1500 meters before it intersects the Corredor River and winds its way through several caves to the Corredor Cave resurgence at river base level.

**QUEBRADA SECA SECTION**

The north side of the river is unique in that two karst valleys drain about 2100 acres. One valley contains an active stream for most of its length and the other has no surface stream of any sort.

The "Chuck's Pit" Valley runs from the Carma Section to the entrance of Grand Gallery Cave. All rain falling in this valley quickly sinks into the many small sinkholes in the valley floor and flows underground to the RC 3 or 4 resurgences. No enterable caves exist in this valley.

The Quebrada Seca Valley is located on a fault line where clastic sediments and limestone contact. Water falling in this basin quickly flows to the valley floor and enters the underground Quebrada Seca River seen in Bananal Cave. One thousand meters before the valley reaches the Rio Corredor River, all water sinks into a large headwall near Maca Meca Cave. Water from this valley emerges at RC5 across from the Corredor Cave entrance.

Analysis of the topography of the valley indicates that Corn Cob Cave and the Grand Gallery headwall once were insurgence points for this valley but stream piracy has occurred allowing water to abandon these sinks. Water from the portion of the valley left isolated by this regression now sinks into Bananal Cave.

Figure 6A Quebrada Seca Valley

## CARMA SECTION

The Carma Basin, though poorly defined, is the least affected by farming due to its remoteness. Little sediment loading has been seen in the caves of this area. It is hypothesized that the two surface streams sinking into Carma Cave emerge as spring CS1. This is based more on the negative results obtained on a test run to the Corredor resurgences than on any conclusive results obtained at CS1. Traps placed during dye tracing disappeared and were not recovered at several sites. From maps and surveys prepared by the cartography team, basin boundaries have been established. Total drainage area appears to be about 300 acres.

Originally water sank into the Escondida Cave and the Caño Seco Cave systems but lowering of the local base level and down-cutting has left both caves high and dry. Currently all water is captured by Carma Cave.

## CAÑO SECO SECTION

The caves of the Caño Seco Basin are all pit types or small horizontal drains that take water in the wet season. Reconnaissance of the river (local base level) found no large resurgences entering from the Caño Seco Section area. Because of this it is theorized that the drainage area of the Caño Seco Basin is very small, possibly only the Alto Nubes Point area. Cave development is relatively young in this area and the lack of water further contributes to the minimal passage development found in this section.

## RIO CLARO SECTION

The Emus Cave drainage area is very large and may encompass thousands of acres but no descriptive work was completed in this project. Field teams confirmed large expanses of karst above the resurgence that need to be mapped in future expeditions. Limited water sampling was done in this basin and data from the caves are included in this report. Other resurgences or insurgences were not mapped or located.

## GEOCHEMISTRY OF THE WATERS OF THE RIO CORREDOR BASIN

Water samples were collected from streams and springs within the basin during the 1989 and 1990 field expeditions. The sample locations are listed in the section on hydrogeology in this volume. D. Scott Jones collected and analyzed 11 samples in the field in 1989 (shown as Set 4 in Table 1), and submitted two acidified samples for laboratory analysis (Set 3 in Table 1). The results from these samples are shown in Table 1. Although these data are indicative of the variability of the waters within the basin, there are not enough measurements for further hydrochemical interpretations.

| Sta. | Set | pH | T | SpC | Ca | Mg | Na | NO3 | SO4 | Cl | SiO2 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| C1 | 3 | | | | 33 | 2.4 | 16.0 | | 17 | 8.5 | 45.5 |
| E1 | 3 | | | | 75 | <0.1 | 6.9 | | <1 | 8.5 | 14.7 |
| CA1 | 4 | 8.7 | 27 | 231 | 70 | 4 | | 9.0 | 25 | | |
| CS1 | 4 | 8.5 | 26 | 276 | 64 | 1 | | 4.0 | 8 | | |
| E3 | 4 | 8.8 | 26 | 309 | 82 | 8 | | 3.7 | 0 | | |
| L2 | 4 | 7.9 | 16 | | 30 | 1 | | 4.5 | 12 | | |
| RC4 | 4 | 7.6 | 26 | 694 | 80 | 7 | | 3.3 | <1 | | |
| RC5 | 4 | 7.75 | 26 | 706 | 88 | 14 | | 4.0 | 23 | | |
| RC6 | 4 | 7.4 | 26 | 257 | 40 | 7 | | 4.4 | 0 | | |
| RC6a | 4 | 7.35 | 26 | 307 | 64 | 5 | | 2.7 | 0 | | |
| RC6b | 4 | 7.55 | 26 | 313 | 64 | 5 | | 3.3 | 0 | | |
| S1 | 4 | 7.7 | 16 | | 60 | 10 | | 4.0 | 9 | | |
| XX | 4 | 7.8 | 16 | | 68 | 2 | | 4.0 | <1 | | |

Table I Data from the samples collected in January, 1989

An additional 24 samples from 19 locations were collected during the 1990 season; half of these were partially analyzed in the field and partially in the laboratory in the U. S. (Set 2 in Table 2), and the remainder were analyzed entirely in the laboratory (Set 1). The samples were analyzed as completely as possible with facilities available. The procedures were not ideal in that field analysis techniques used may not have produced very precise results, and more time elapsed between sampling and laboratory analyses than the prescribed holding times for many of the constituents. A check was made for precipitation of calcite by analyzing the unacidified samples for calcium and then repeating the analysis after acidification; there was no significant or systematic difference between the two sets of analyses. For those samples for which sufficient data were available, calculations were

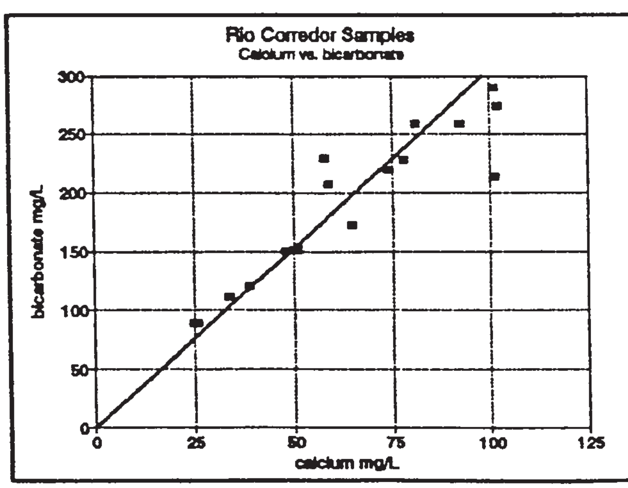



Figure 6.2 Plot of calcium vs. bicarbonate for all 1990 samples that were analyzed. Line indicated pure calcium bicarbonate.

Table 2 Results from analysis of samples collected during the March, 1990 NSS expedition

| Station | Set | pH | T | SpC | $Ca^{+2}$ | $Mg^{+2}$ | $Na^{+}$ | $K^{+}$ | $HCO_3^-$ | $NO_3^-$ | $SO_4^{-2}$ | $Cl^-$ | $SiO_2$ | $Al^{+3}$ | $SI_C$ | $SI_d$ | $pCO_2$ | Ca/Mg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | °C | µS/cm | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L | µg/L | | | | |
| *Samples from the Rio Corredor* | | | | | | | | | | | | | | | | | | |
| C1 | 1 | 7.61 | 29 | 255 | 34 | 2.4 | 7.3 | 1.3 | 111.3 | 0.4 | 25 | 1.3 | 35.5 | 175 | -0.13 | -0.55 | -2.53 | 8.5 |
| C1 | 2 | 8.8 | 29 | 210 | | | | | 60.7 | 2.4 | | | | | | | | |
| C2 | 1 | 7.75 | 26 | 540 | 65 | 3.0 | 24.2 | 2.0 | 172.8 | 0.4 | 19 | 72.5 | 25.8 | 470 | 0.39 | -0.14 | -2.51 | 13.0 |
| C2 | 2 | 8.6 | 26 | 530 | | | | | 137.7 | 2.7 | | | | | | | | |
| *Samples from the Cueva de Cerro Corredor system* | | | | | | | | | | | | | | | | | | |
| LB1 | 1 | 7.44 | 23 | 300 | 51 | 2.4 | 3.6 | 4.1 | 153.7 | 1.8 | 15 | 4.5 | 17.5 | 225 | -0.09 | -0.63 | -2.26 | 12.8 |
| REC1 | 1 | 7.42 | 24 | 290 | 51 | 1.8 | 3.0 | 1.6 | 151.3 | 1.8 | 15 | 2.5 | 15.5 | 25 | -0.10 | -0.70 | -2.24 | 17.0 |
| REC2 | 1 | 7.38 | 24 | 290 | 50 | 2.4 | 2.1 | 1.8 | 151.5 | 1.8 | 15 | 2.5 | 16.5 | 110 | -0.15 | -0.68 | -2.20 | 12.5 |
| REC3 | 1 | 7.35 | 24 | 290 | 51 | 2.4 | 2.3 | 0.7 | 152.0 | 1.8 | 16 | 1.3 | 16.8 | 5 | -0.17 | -0.70 | -2.17 | 12.8 |
| RC6 | 1 | 7.34 | 23 | 280 | 48 | 3.0 | 3.1 | 1.2 | 150.5 | 0.9 | 13 | 1.3 | 18.5 | 100 | -0.22 | -0.70 | -2.17 | 9.6 |
| RC6 | 2 | 8.6 | 23 | 260 | | | | | 167.2 | 3.0 | | | | | | | | |
| R2 | 1 | 7.40 | 24 | 350 | 59 | 3.6 | 7.0 | 0.9 | 207.9 | 1.3 | 12 | 2.5 | 43.5 | 25 | 0.07 | -0.41 | -2.09 | 9.8 |
| Rect | 1 | 7.75 | 23 | 390 | 78 | 3.0 | 3.0 | 0.4 | 228.1 | 1.3 | 21 | 1.3 | 27.0 | 125 | 0.55 | -0.04 | -2.41 | 15.6 |
| *Samples from Quebrada Seca (Bananal)* | | | | | | | | | | | | | | | | | | |
| Q1 | 2 | 8.1 | 23 | 190 | | | | | 60.7 | 2.4 | | | | | | | | |
| Q1 | 1 | 7.15 | 23 | 210 | 26 | 2.4 | 6.1 | 2.0 | 89.1 | 0.9 | 21 | 1.3 | 36.0 | 150 | -0.88 | -1.28 | -2.20 | 6.5 |
| Q2 | 2 | 7.5 | 26 | 260 | 39 | 3.6 | 3.1 | | 121.3 | 2.8 | 20 | 1.3 | 24.5 | | -0.19 | -0.57 | -2.40 | 6.5 |
| RC5 | 2 | 7.5 | 24 | 420 | 53 | 3.9 | | | 91.8 | | 21 | 49.0 | 23.0 | | -0.23 | -0.67 | -2.54 | 8.2 |
| *Samples from springs with high brine levels* | | | | | | | | | | | | | | | | | | |
| RC2 | 2 | 7.1 | 23 | 870 | 101 | 6.1 | 96 | | 290.2 | | 14 | 135 | 16.7 | | 0.08 | -0.41 | -1.66 | 9.9 |
| RC2A | 2 | 7.1 | 23 | 820 | 92 | 8.5 | 101 | | 259.0 | | 14 | 140 | 16.5 | | 0.00 | -0.40 | -1.71 | 6.5 |
| RC4 | 2 | 7.1 | 23 | 880 | 102 | 6.1 | 120 | | 273.8 | | 14 | 118 | 16.8 | | 0.06 | -0.43 | -1.68 | 10.0 |
| RC7 | 2 | 7.2 | 23 | 720 | 81 | 5.1 | 73 | | 259.0 | | 20 | 119 | 18.7 | | 0.05 | -0.43 | -1.81 | 9.5 |
| RC7A | 2 | 7.5 | 23 | 450 | 58 | 9.7 | 12 | | 229.5 | | 10 | 50 | 17.5 | | 0.17 | -0.09 | -2.15 | 3.6 |
| Alma | 2 | 7.2 | 23 | 880 | 101 | 6.1 | 97 | | 213.7 | | 14 | 130 | 18.1 | | 0.05 | -0.43 | -1.89 | 9.9 |
| *Emus Cave samples* | | | | | | | | | | | | | | | | | | |
| E1 | 1 | 7.56 | 26 | 350 | 74 | 0.6 | 1.6 | 1.2 | 219.3 | 1.3 | <1 | 1.3 | 7.6 | 180 | 0.38 | -0.53 | -2.21 | 74.0 |
| E1 | 2 | | | | | | | | 183.6 | 3.8 | | | | | | | | |

performed with a modified version of the Jacobson program (Jacobson and Langmuir, 1972) to derive the saturation indices with respect to calcite (SIc) and dolomite (SId), the equilibrium carbon dioxide partial pressure ($pCO_2$), and the calcium/magnesium ratio (Ca/Mg); these results are also reported in Table 2. Compound ions were not considered in these calculations. The first three of these derived values are strongly dependent on accurate pH measurements and bicarbonate determinations, both of which are difficult to perform under field conditions and which also tend to be unstable for samples stored for some time. For Set 1, these values reflect the characteristics of the water in the sample bottle and may not be accurate for the field locations; for Set 2, some of these values may be inaccurate because of the difficulties encountered under field conditions. The conclusions given below must be considered within the limitations of the analysis data.

The waters in the area are principally calcium bicarbonate waters, as shown by a slope reflective of the ratio of the weights of the two ions in the plot of calcium against bicarbonate (Figure 6.2). However, the scatter about the theoretical line shows that some other ions are important at some of the locations.

The Ca/Mg ratio of 10 or so for most of the samples is in the general range of water which is dissolving normal limestones; these ratios are approximately consistent with low magnesium calcites. An exception is in the samples from the Emus Cave stream (E1), which are anomalously low in magnesium within the available population of water samples from this area. Emus Cave is some distance from the rest of the sample stations, and a somewhat different bedrock there may explain the difference.

The calculated values indicate that these waters are near saturation with respect to calcite, except for a few samples, and undersaturated with respect to dolomite (Figure 6.3). This pattern is comparable to that of sample sets from limestone karst terrains elsewhere, and does not present an unusual situation. The only samples decidedly undersaturated with respect to calcite are the insurgences in Quebrada Seca.

Calculated equilibrium carbon dioxide partial pressures are higher than expected for temperate terrains, but by less than an order of magnitude. In most of the samples, these values overlap the high normal range of temperate zone values; the higher production and decay rates of organic material in the tropical climate is certainly sufficient to explain the difference. Except for a few, the values are consistent with results reported by others working in tropical areas (e.g., Troester and White 1986). For those samples with unusually high values, it appears that these have significant contributions from deep circulation sources, as explained further below.

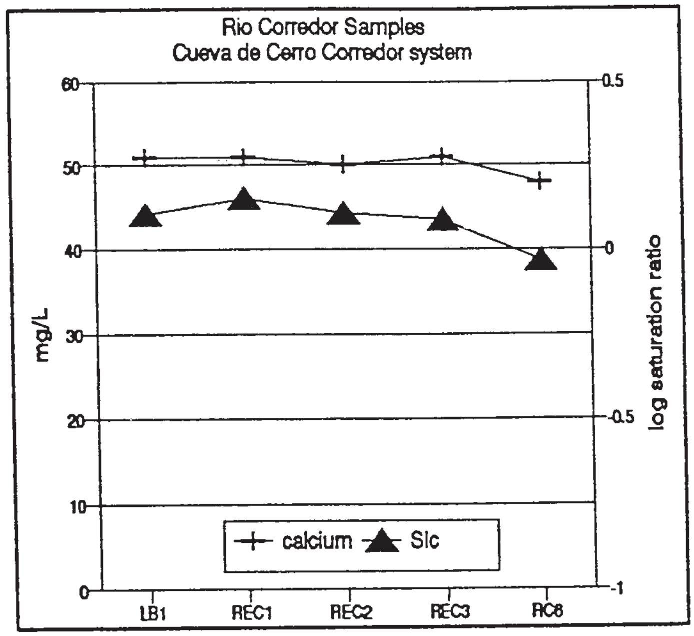



Figure 6.4 Evolution of waters flowing through the Cueva Cerro Corredor system.

## EVOLUTION OF WATERS

Table 2 groups water samples in flow paths to the extent that that is possible. Two sampling stations along the Rio Corredor indicate that there is a significant addition of material in solution as the river traverses the karst area. C1 is upstream and C2 is downstream of the karst area. Limestone dissolution products nearly double, and there is a considerable amount of sodium chloride added. Several springs along the banks of the river contribute to both of these substances; this is further discussed below. Also, water flowing through two large cave systems and into the river affects the river's water chemistry.

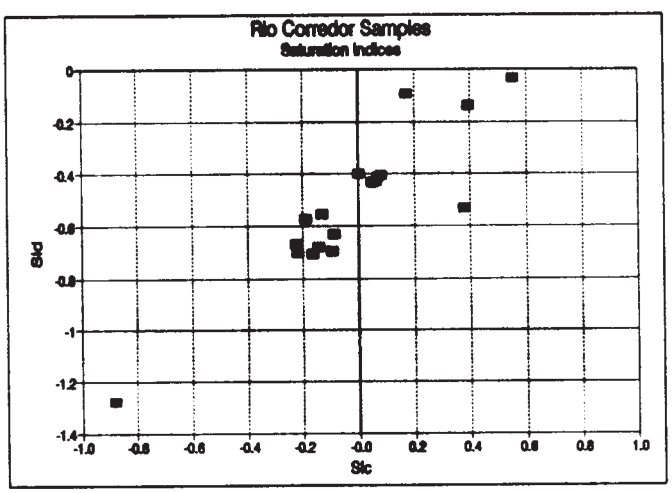



Figure 6.3 Calculated values of calcite and dolomite saturation plotted against each other.

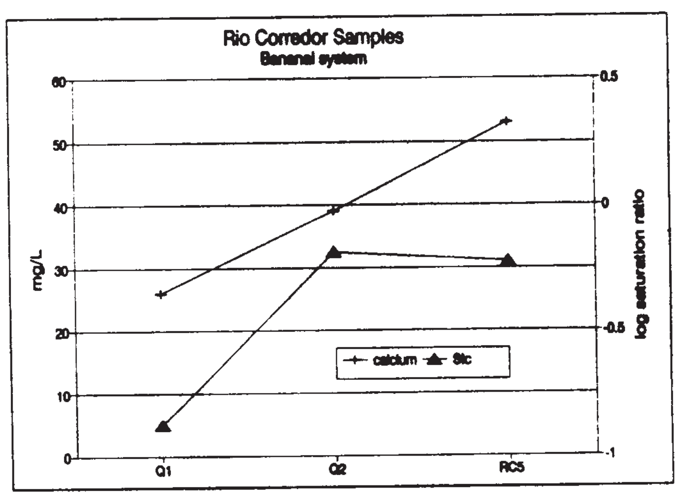



Figure 6.5 Evolution of waters flowing through Quebrada Seca /Bananal Cave

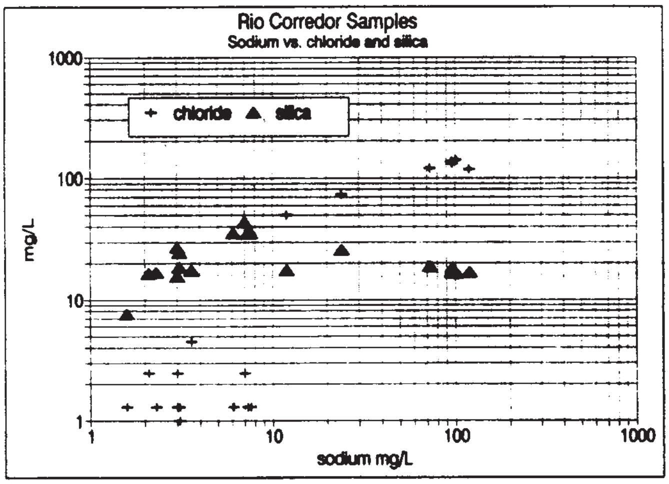



Figure 6.6 Plot of sodium against silica and chloride for all samples for which all three analyses were available. NOTE - use of Logarithmic scale.

Evolution of the water within the two cave systems is very different. Water flowing through the Cueva de Cerro Corredor changes relatively little along the path (Figure 6.4). Inspection of Table 2 shows that this water is slightly supersaturated with respect to calcite when it sinks (sample LB1). As it passes through the cave (REC1, REC2, REC3) it appears to pick up some carbon dioxide from the cave air and slowly decreases in saturation, falling below saturation at the resurgence (RC6), possibly with the help of some additional, aggressive water. The variation in dissolved calcium indicates possible precipitation within the cave, although it may not be significant.

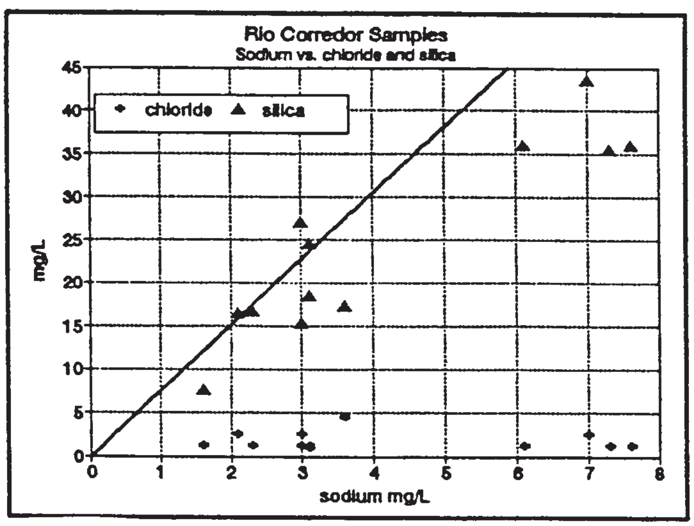



Figure 6.7 Plot of sodium against chloride and silica for samples with low sodiumand calacite concentrations. Line shows expected result from the decomposition and solution of albite.

Water flowing through the Bananal system, on the other hand, does change significantly (Figure 6.5). This water sinks at two points in Quebrada Seca (Q1 and Q2) in a highly undersaturated state, although it does add a significant amount of calcium and approaches saturation between the two sink points. This water then passes through the cave system, apparently picking up calcium cloride brine, and resurges at a slightly lower saturation rate(RC5).

**Sodium, chloride, and silica.** On examining the results of analyses for ions not usually associated with karst waters, some unusual aspects are apparent. Many of the springs in the Rio Corredor valley exhibit high levels of sodium and chloride, and the Rio Corredor acquires a significant increase between sample stations C1 and C2 (see Table 1). There is also an increase in sodium. The two insurgences

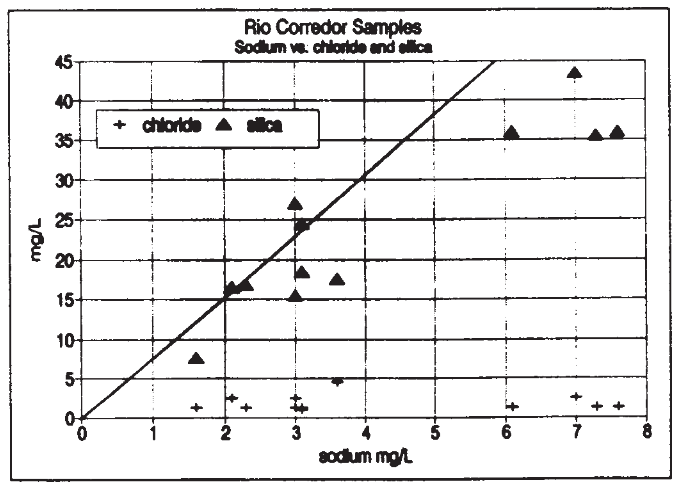



Figure 6.8 Plot of sodium against chloride and silica for those samples with high concentrations of sodium and chloride. Line shows a pure sodium chloride water.

in the Quebrada Seca Valley and the La Bruja stream are clearly not the contributors. Another unusual aspect of the water chemistry is the high level of dissolved silica in some of the samples. The relationship among these three components are shown in Figure 6.6. It is clear from this figure that the relationship involves at least two separate populations and, therefore, two probable sources for the waters.

To more clearly illustrate the relationship among sodium, chloride, and silica in the water samples, the data were divided into two sets and replotted separately in Figures 6.7 and 6.8. For those samples with sodium concentrations below 10 mg/L, there is a good linear correlation between sodium and silica, and no correlation between sodium and chloride (Figure 6.7). Costa Rica is in an active volcanic belt

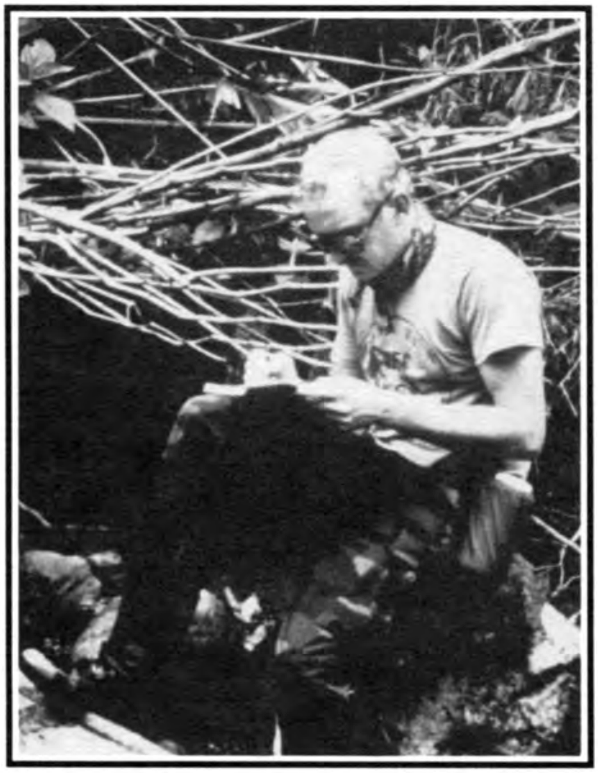


Photo 6-B Scott Jones sampling

and relatively young, and therefore fresh, igneous rocks of andesitic composition occur nearby. Rocks of this composition, especially when glassy or very fine-grained, weather relatively easily in the humid tropical climate and contribute the sodium ions and silica. Note that the weathering of albite would provide a reasonable approximation of the ratio of silica to sodium found in the low chloride samples (7.8:1 in albite, ~6-8:1 in water). A loss of a small amount of silica would serve to explain the discrepancy. However, it is likely that the weathering rocks are less sodic (typical andesite feldspar is a more calcic labradorite, and the other silica minerals are likely to be equally low in sodium), and that more silica is lost from the water than may at first appear, or that there are other sodium sources.

## SPRING LOCATIONS WITH SIGNIFICANT BRINE COMPONENTS

In a number of springs, there is clearly a linear relationship between sodium and chloride, and little or no relationship between sodium and silica (Figure 6.8). On further examining the data, we see also that these samples are the same ones with unusually high $pCO_2$ content, and also with high saturation indices. The geologic map for the area (see section on geology in this publication) indicates that the springs which yielded these samples especially high in sodium chloride (RC2, RC2A, RC4, RC7, and Alma [Cave] )all are located close together on the banks of the Rio Corredor, at places where significant thrust faults exist. Thus, these springs presumably have a large contribution from deeper water circulation, with connate brines from the marine sediments being expelled along the fault zones. Two other springs (RC5 and RC7A) nearby also exhibit high sodium chloride values, although only about half as high as the other five. These are probably more diluted by water from the resurging nearby cave streams. Estimates of discharges from springs RC4 and RC5 by D. Scott Jones of greater than 500 gallons per minute of water of the composition found indicates that only approximately 5 gallons per minute of typical young connate brine (equal to normal sea water) would be sufficient to provide all the sodium chloride present.

## ENVIRONMENTAL CONSIDERATIONS

The normal concerns with regard to chemical quality of water supply from karst aquifers apply to this area. It is apparent that the streams that sink eventually re-emerge at various resurgences on the river. These underground "rivers" also supply water to the public water supply springs. Because these are essentially free-surface streams flowing into groundwater, there is no filtration occurring such as would happen if the water infiltrated through soils. Consequently, substances which would be dependably removed or at least reduced by passing through soils such as bacteria and chemical substances, especially organic chemicals such as pesticides and herbicides, will be introduced into the ground water system at the same level as the entering streams. With development of the recharge area to agriculture, care must be taken to prevent the introduction of, or at least monitor for the presence of, agricultural chemicals in the sinking streams and water supply springs.

In the matter of the high sodium chloride levels in some of the springs, these are not of health concern except for individuals who may require an extremely low-sodium diet. Normal water quality standards allow at least twice the concentration found in this study. It is possible that if flow in the river or in the shallow fresh groundwater zone is reduced, that the sodium chloride levels may increase to levels which are of concern, but this is easily detected by taste. There may be some cause for concern in relation to corrosion of pipes and boilers or other containers if this water were to be piped or used for steam generation. The relatively high silica levels may also cause problems if the water were used in steam-driven turbines or other industrial applications.

In the event that wells are to be drilled for water supply, the locations would need to be carefully considered, because the groundwater with the high dissolved solids content associated with the high chloride springs might be encountered. This problem is likely to be encountered if any of the high-angle faults are intercepted.

**Summary.** The waters in this terrain are very like those of most limestone karst terrains and not especially remarkable, except for the high-chloride springs, and the higher silica levels (correlated with sodium) from weathering of rock from the local volcanic source. This elevated sodium chloride level is unlikely to be of health concern.

Photo 6-C Rio Corredor

# SECTION 7

## CAVE DESCRIPTIONS

Many new caves were found in the Corredor River Basin during project field work. An effort was made to explore completely and map each cave as it was found. In addition a description of each cave was prepared for use by other researchers. The exact locations of these caves are shown on location maps accompanying this section. Passage trends, geologic features, and scientific sampling points are indicated on individual cave maps and discussed in the descriptions provided.

The study area is divided into three geographic regions; the Rio Corredor Basin (Quebrada Seca & La Bruja sections), the Fila de Cal area (Carma & Caño Seco sections) and the Rio Claro Basin. The caves of each area are described under the appropriate heading. Figure 5.1 locates each of the three areas and sections within the study area.

### RIO CORREDOR BASIN

This area is located just north of Ciudad Neily on the Pan American Highway 10 kilometers north of Panama. The study area comprises two sections of karstic terrain. The first is located east of the Rio Corredor along a side tributary locally known as La Bruja or The Witch Creek area. Caves are numerous and quite large. The area is a semi-closed karst system from which almost no surface water escapes. The caves all show the effects of heavy water flows during the rainy season and most appear to flood.

The second section located along Rio Corredor is the Quebrada Seca section. This area is located directly across the river from La Bruja and is a completely closed karst valley system. No surface water leaves the blind valleys and sinkhole plains. All caves appear to be related to one large system but sediment derived from the slash-and-burn method of farming upstream from the cave divide it into many small passages.

## THE LA BRUJA SECTION

The La Bruja Section is composed of the entire drainage basin of the La Bruja Creek. Included are the caves known as System Cerro Corredor (see Fig. 7.1).

### CAVERNA DEL CAFETAL

This 40 meter long cave was found during the 1989 field season. It is essentially one large passage with a breakdown floor.

### THE TURURUN ENTRANCE TO CUEVA DE CERRO CORREDOR SYSTEM

This cave first appeared to be little more than a small sink in a valley on Don Tilo's farm, but on closer examination the original report on the size of the cave was found to be in error. The inconspicuous entrance pit is in the bottom of a small sinkhole. Two streams flow into the entrance in wet weather. The Italian cavers that had visited the cave a year earlier had reported a pit and little passage at the bottom. Twenty meters south of the main entrance along a bearing of 057 degrees (mag) is a second entrance which connects to the main cave. This fissure leads inward via an almost vertical slope to a circular room about 8.3m in diameter. From here a sloping passage drops 10m farther to a 6m breakdown choked pit. This pit provides entrance to the "Black Bean Room." This room measures 13.4 x 16.7m and can also be entered from the entrance pit via an easier vertical route. The pit entrance leads down the 6m entrance drop to an area of winding and twisting passage emerging in a small room, 1.3m high, 7m long and 2.5m wide. From the southwest side of the room a slope leads to a 18m deep drop to the Black Bean Room.

The Black Bean Room is named for the abundance of .5 to 3 m black (bean-like) (siderite?) concretions found on its floor and wedged in cracks and fissures. These black boulders contrast with the white/buff limestone forming the walls. The room slopes steeply to its center.

From the southern end of this room a slippery climb and guano covered passage (Histo Street) leads back to the fissure entrance. At the northeast end of the room a sloping floor leads to a steeply descending clean walled passage that drops 15.8 m as a 4m wide walkway to a large 26m high dome. Water enters from all sides of this dome.

The passage exits this room by cutting back under itself in a southwest direction. Wind in this connection area is very intense. Five meters beyond the dome a 15m vertical pit is encountered. A rope is required to descend the drop. After the drop a mid level area leads downward over unstable breakdown to another 7m pit.

The lower part of the drop is choked with breakdown and black boulders and is unstable. Because of this the pit is dangerous and must be descended carefully to avoid danger.

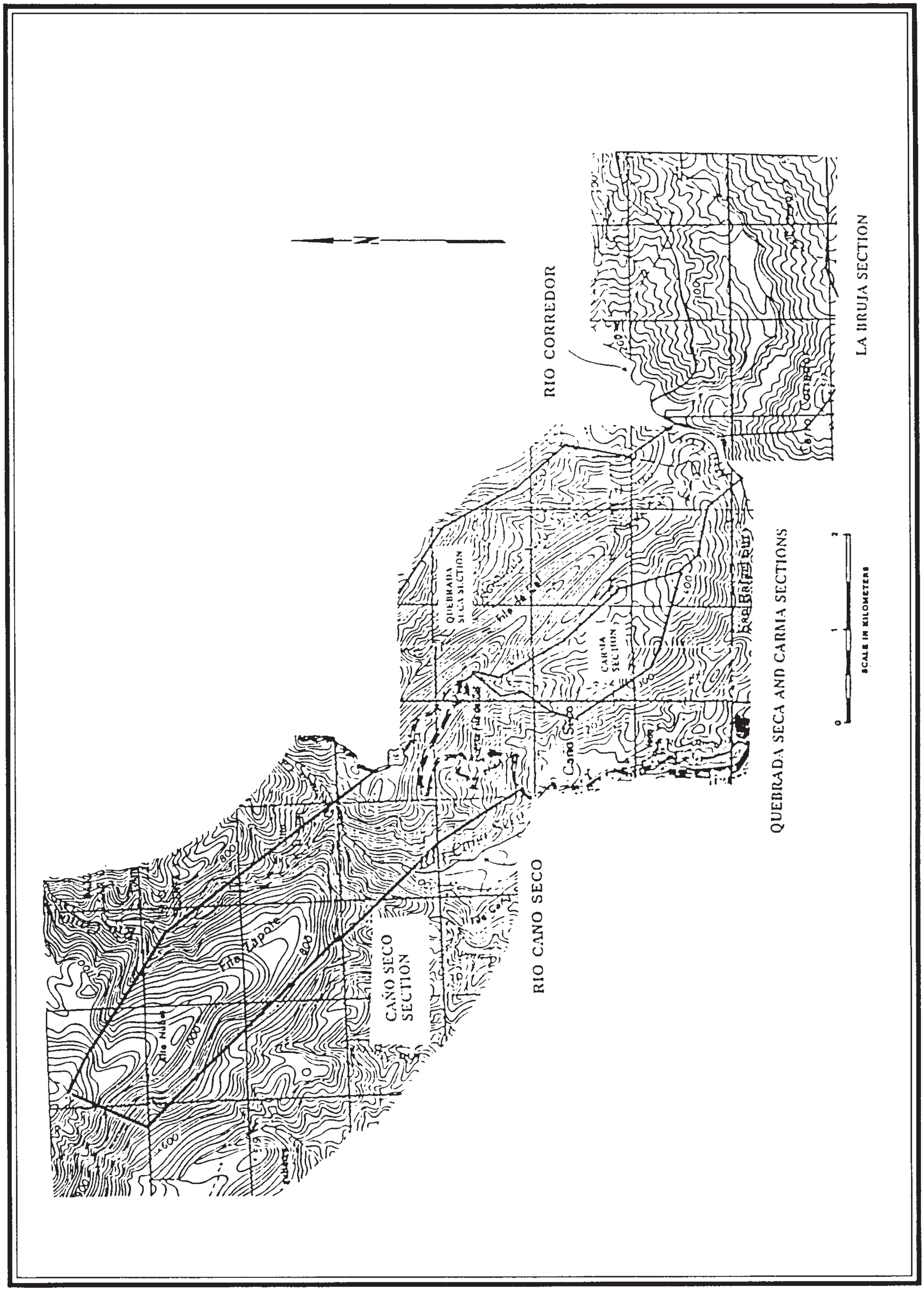



Figure 7.1 Section Location Map

Passage at the base leads quickly to the main stream in the cave and via this stream to the Corredor entrance.

## CORREDOR CAVE ENTRANCE TO THE CUEVA DE CERRO CORREDOR SYSTEM

The Corredor Cave is perhaps the best known cave in the area. It has two entrances visible from the Rio Corredor plus two skylight entrances above the river. The first entrance seen at river level is the water entrance. About 50 m higher is the Main entrance. The skylights are undetectable in the forest growth. A fifth path of entry is possible via the Tururun Cave located in the La Bruja valley one kilometer above the river entrance.

The lower entrance is the water resurgence entrance and is seldom used for entry due to a waterfall and sump. The entrance passage is 10 meters high and 6.7m wide and leads about 25m to a 4m high waterfall with a small passage to the left upstream.

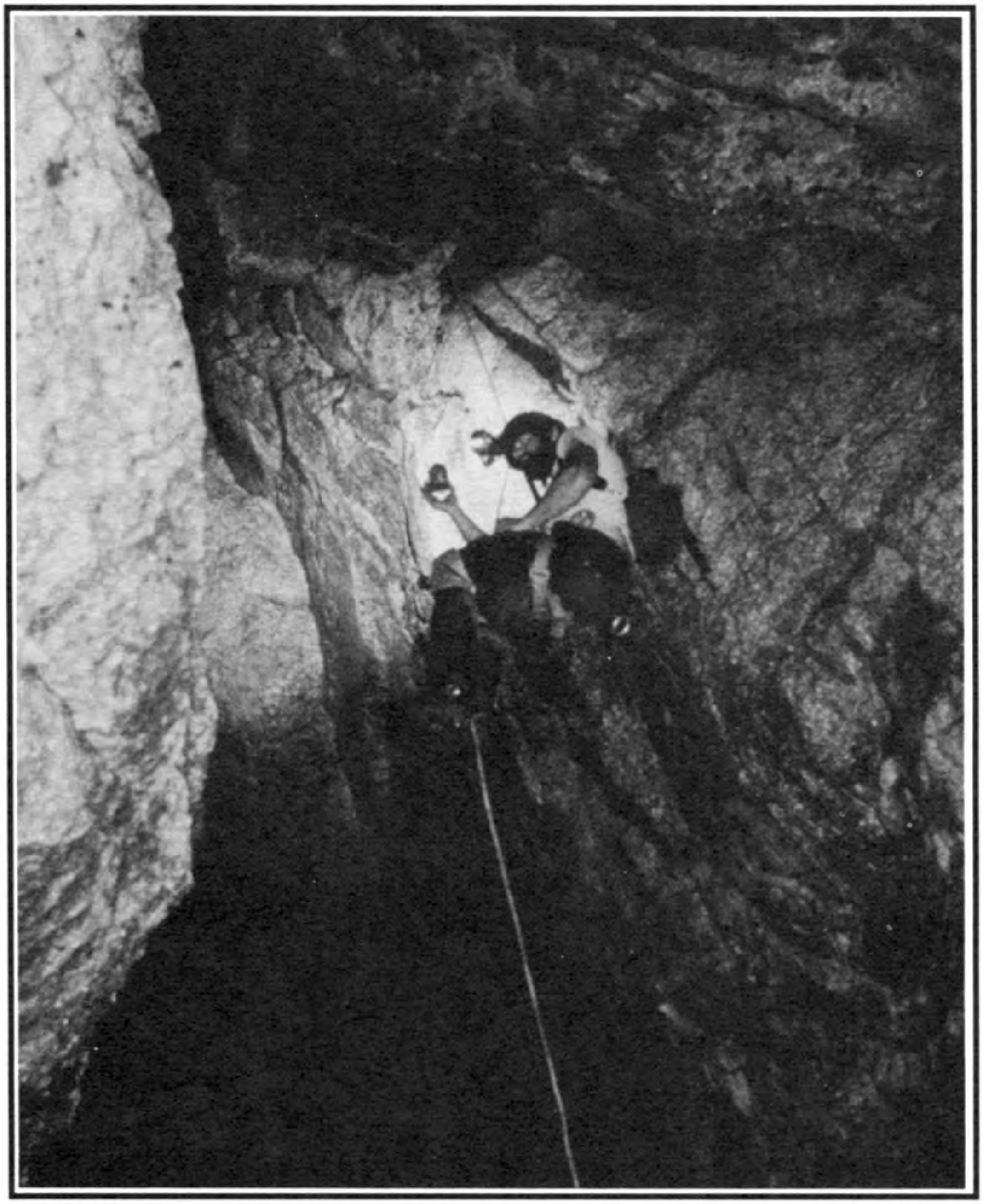


Photo 7-A Descent into Tururun pit, Cerro Corredor System

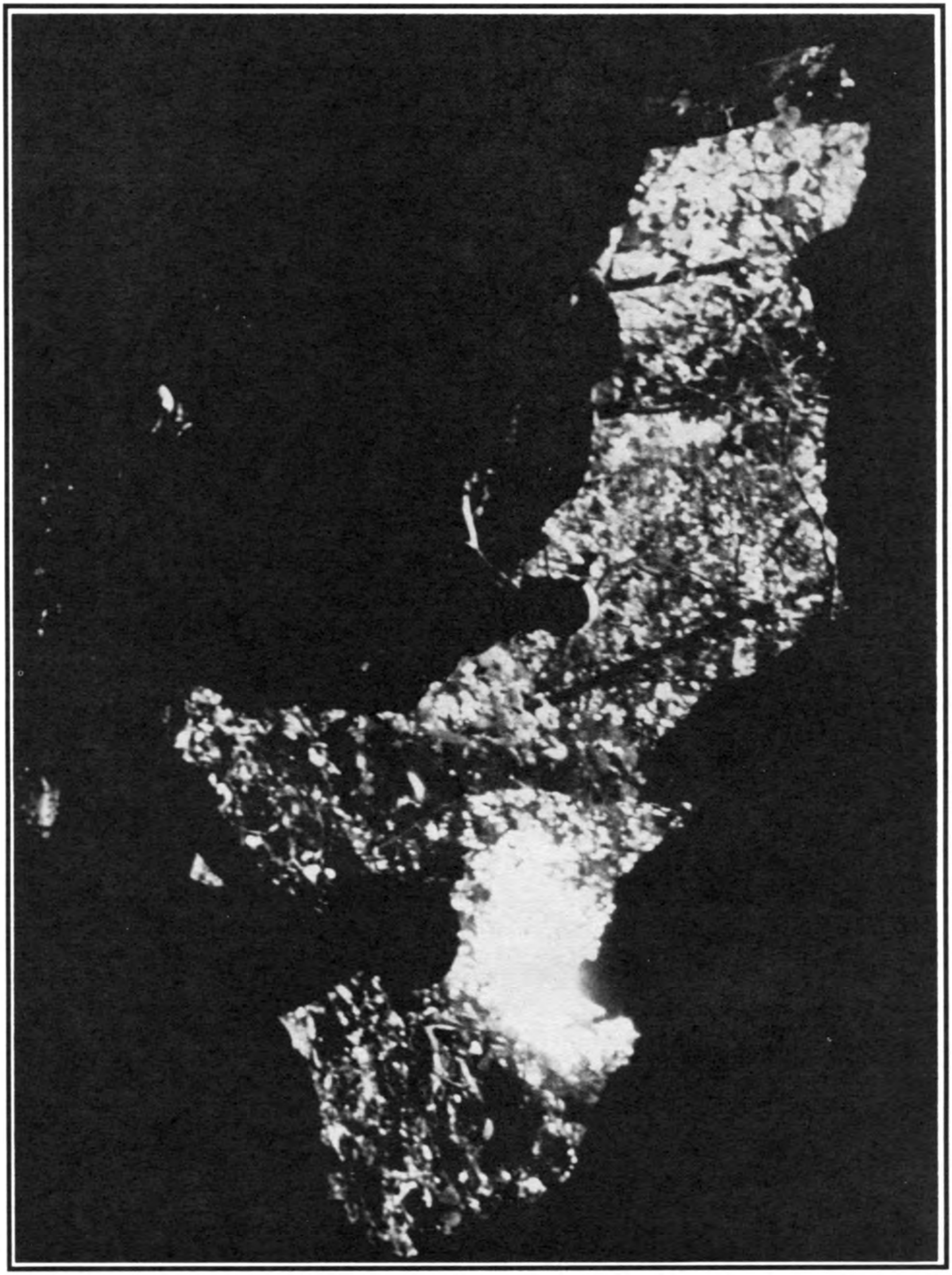


PHOTO 7-B Main Entrance, Cerro Corredor System

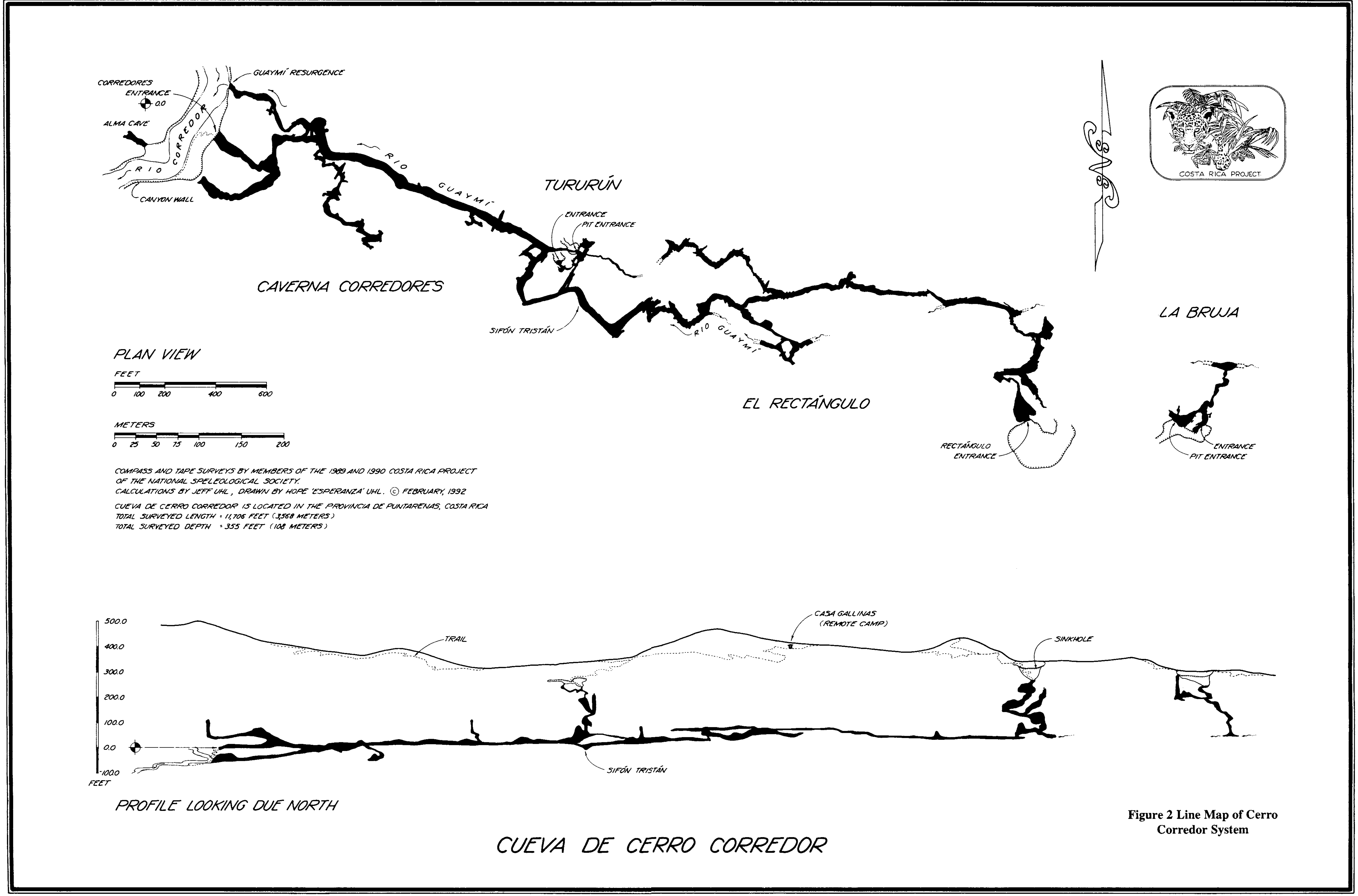
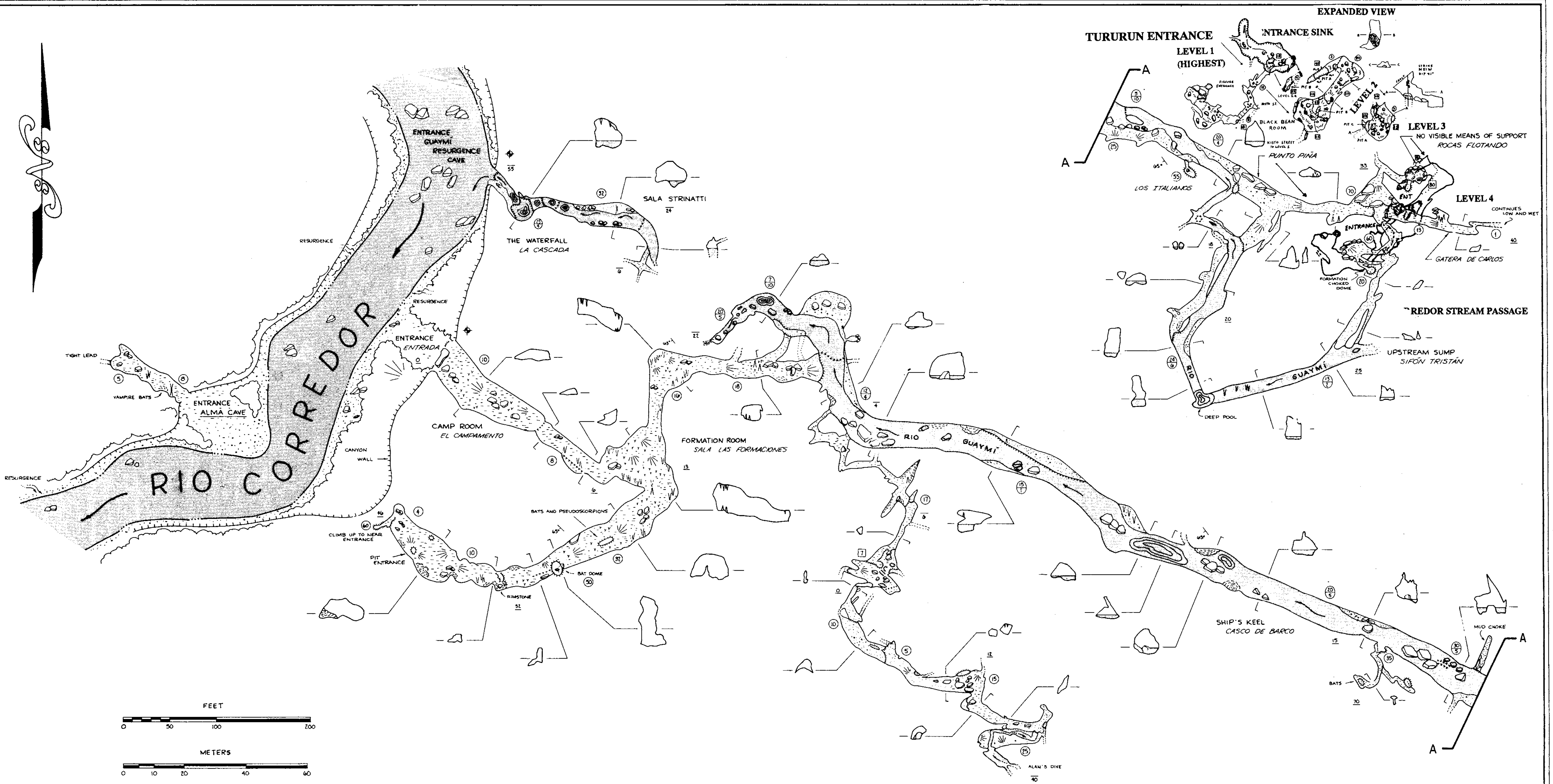



**Figure 2 Line Map of Cerro Corredor System**




## LEGEND

| | | | |
|---|---|---|---|
| SURVEYED PASSAGE | | CEILING DROP (HATCHERS POINT TOWARD LOW SIDE) | |
| UNDERLYING PASSAGE | | STREAM | |
| UPPER LEVEL PASSAGE | | STREAM (INTERMITTENT) | |
| SKETCHED PASSAGE | | FLOWSTONE | |
| CEILING HEIGHT | | RIMSTONE POOLS | |
| HEIGHT ABOVE / BELOW WATER | | STALACTITE, STALAGMITE | |
| DROP WITH DEPTH | | COLUMN | |
| SLOPE (LINES DIVERGE DOWN) | | BREAKDOWN | |
| PIT | | MUD OR CLAY | |
| DOME | | GUANO | |
| PASSAGE WITH WATER | | SILT, SAND W/COBBLE | |


# CAVERNA CORREDORES

## PROVINCIA DE PUNTARENAS, COSTA RICA

| GRID COORDINATES | FEET | METERS |
|---|---|---|
| LAMBERT PROJECTION | N 295,860 | N 90,178 |
| CANOAS QUAD | E 271,888 | E 82,872 |
| ELEVATION MSL | 750.69 | 228.81 |
| TOTAL SURVEYED LENGTH | 5,329.79 | 1,624.52 |
| TOTAL SURVEYED DEPTH | -46.63 | -14.21 |

COMPASS AND TAPE SURVEY BY MEMBERS OF THE 1989 COSTA RICA PROJECT OF THE NATIONAL SPELEOLOGICAL SOCIETY
ALL DIMENSIONS ARE IN FEET
CROSS-SECTIONS ARE TO SCALE
ALL ELEVATIONS ARE ABOVE OR BELOW CORREDOR ENTRANCE
CAVES DRAWN TO TRUE NORTH (DETERMINED BY ASTRONOMICAL OBSERVATION; JANUARY 19, 1989)
CALCULATIONS BY JEFF UHL
DRAWN BY HOPE E. UHL ©1989

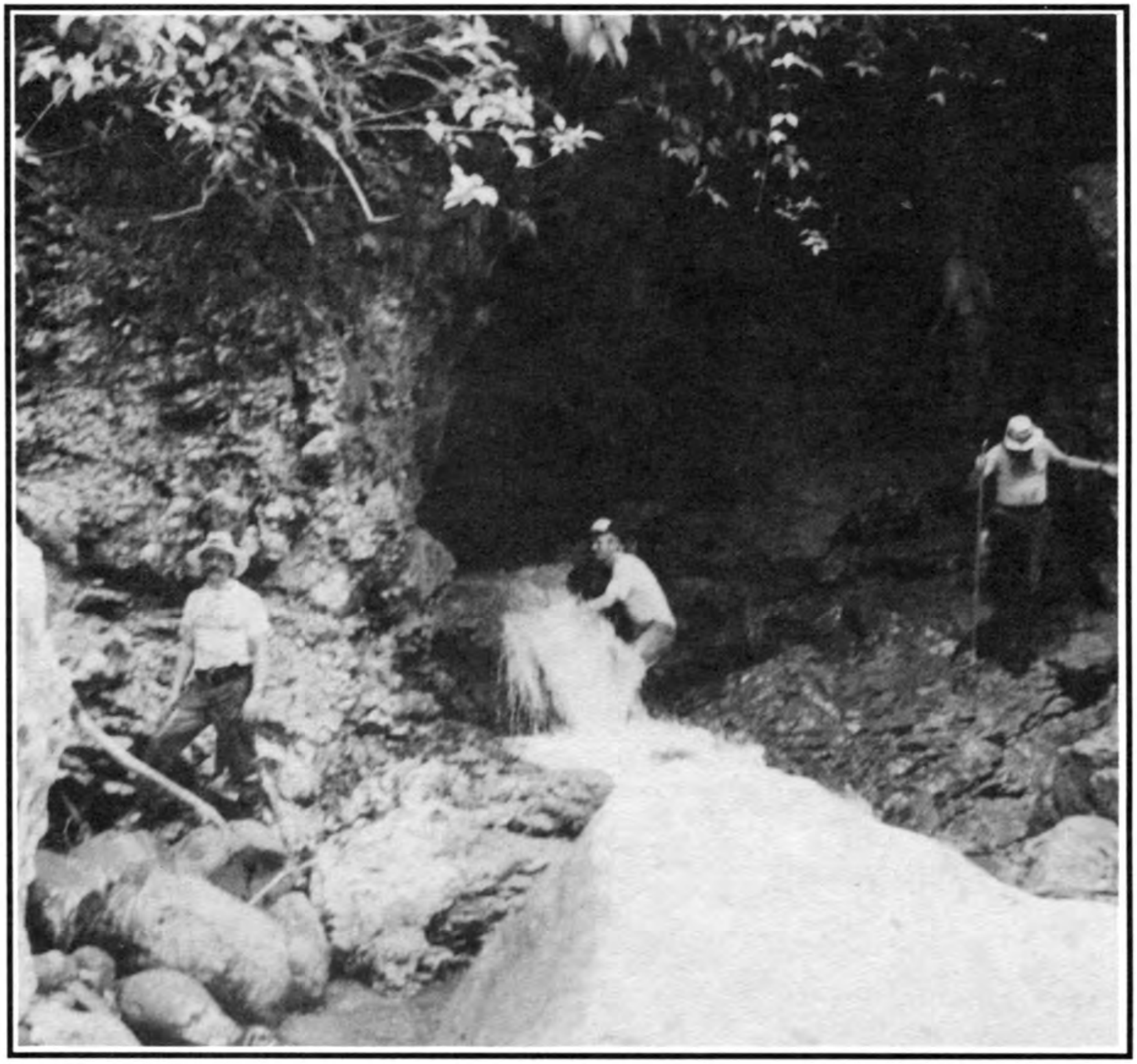


PHOTO 7-C Water Entrance, Cerro Corredor System

Thirty-five meters above the river, a rock escarpment can be seen. In this cliff a 2m high, 8m wide entrance is hidden. This entrance leads to a large paleo-stream passage trending S 50 E into the hillside. This trunk passage is covered with pendants cut when the cave stream flowed through the passage.

The Formation Room is dominated by a large formation slope on the right wall and a passage on the left. When climbed, the formation slope leads to a higher, dry passage, 6.6 x 6.6 m in size. This passage trends back toward the cliff for almost 100 m. The passage is a mud floored walking passage, containing "mud funnels." The mud funnels are circular funnel like depressions that have formed in the thick sediment. They appear to take water from the skylight passages but this was not observed. About 67m into the passage a bat dome is found housing vampire bats. Farther along, the passage crosses rimstone pools and encounters a skylight entrance. Fifteen meters farther a passage leading to the second skylight climb is located. Here also the passage ends abruptly.

The left passage in the Formation Room leads to the main stream. From the room a muddy walking passage extends across guano to a breakdown climbdown. At this climb a small crawl leads to the left, over guano, for ten meters to a drop into the main stream just above the sump pool. A rope is needed to descend to the main passage.

Climbing down the breakdown in the main passage allows easy access to the same stream about 30m upstream from the crawl. At the point where the stream is first encountered a large fault trace is noticed. The main stream occupies this fault zone for most of its length.

Gnats are a hazard in the Junction Room area since they number in the millions and there is evidence of possible Blastomycosis infestation in this area (Febbroriello 1992). Downstream (to the left) the upper end of the stream entrance sump is encountered about 66m below the Junction Room. The upstream part of the cave winds along a breakdown covered floor forming pools and waterfalls until it reaches the main fault passage 60m upstream. At the upper edge of the Junction Room a side passage may be entered to the right. This passage leads to extensive tight fissures and climbs but ends after about 266 meters. Several hundred feet upstream the cave passage widens and forms a triangle-shaped cross-section with the floor covered by a pool .3 to .7m deep.

After about 365m of linear stream passage, a larger room is entered. Side passages are again encountered exiting this room. Also at this point the main stream enters the passage via a large side passage and the main passage continues along the fault. This divergence causes the formation of a loop and leads via the stream passage to a sump. The other direction of the loop leads to a crawl and the Tururun connection passage described earlier. The cave is about three kilometers long, one of the longest in Costa Rica.

**CUEVA DOLINA CIJA**

After a 5m down-climbable pit a low tight passage heading northeast is encountered at the pit's base. This passage leads 5m to a climb down of 6m into a collapsed dome. Cave rats were nesting in the dome.

**"DOCE HERMANOS"**

This is one of 56 small caves found by Carlos Goicochea during field work. It was mapped to show its location geologically.

**LA BRUJA CAVE**

The La Bruja entrances are located along a well traveled trail. The main entrance is in a steep walled sinkhole located about one kilometer from Don Tilo's chicken house. A second entrance is a pit located on the other side of the trail. The cave may be entered by either of the two entrances. The cave is formed along a bedding plane that dips 35° downward from the entrances.

From the main entrance the passage descends along the bedding plane as a 2 to 4m high and 5 to 10m wide walkway. About 50m into the cave the passage widens and a side passage to the left is encountered. This side passage forms one branch of the **Y** shaped cave and leads to a second entrance pit.

The side passage beyond this fork becomes less uniform in size. Passage height and width vary from 1 to 7m in cross-section.

Throughout this section it is often difficult to distinguish passages from breakdown separations. In this area several small side passages exit the main cave but all end quickly. Formations are present near the entrance pit area.

The main passage below the split changes character quickly. A short section of 1.3m high passage leads to a 1x1 m window. The floor of the cave is littered throughout with breakdown and rock debris. Beyond the window, floors are clean and devoid of debris. The window leads to a dome room. The main passage turns left and crosses a small natural bridge. The next 33m of passage traverses the "Chute," a clean water worn canyon sloping steeply downward to a sandy floor. On the right is a dome penetrating the ceiling 8 m and opening as a window to the inside drop. Through this window an optical illusion causes the sloping cave pit to appear vertical. In fact this pit is a corkscrew slope ascending at 45 degrees. On the right wall is the "Chocolate Yogurt" formation.

The final steep slope leads downward to the cave stream and a small room. On each side of the room is a pool. The stream rises from the right hand pool and flows to the left where it sumps. Hydrologically this cave is connected to Cerro Corredor Cave System 100+ meters below. This was confirmed by dye tracing in 1991.

**LA BRUNKA PITS**

These six pits including Pozo Brunka and Caverna La Puerro are all dead bottom with an average depth of 16m. These pits are located on the east side of the La Bruja Valley high on the ridge.

**LA BRUNKA GRANDE**

The entrance is a 5 x 3m pit that is 23m deep on the high side and is 12m deep on the low side. This pit leads to a small room and a passage 4m up its wall. The passage was explored to the northeast and leads to a small chamber 6 x 3m. No air movement was noted in this area.

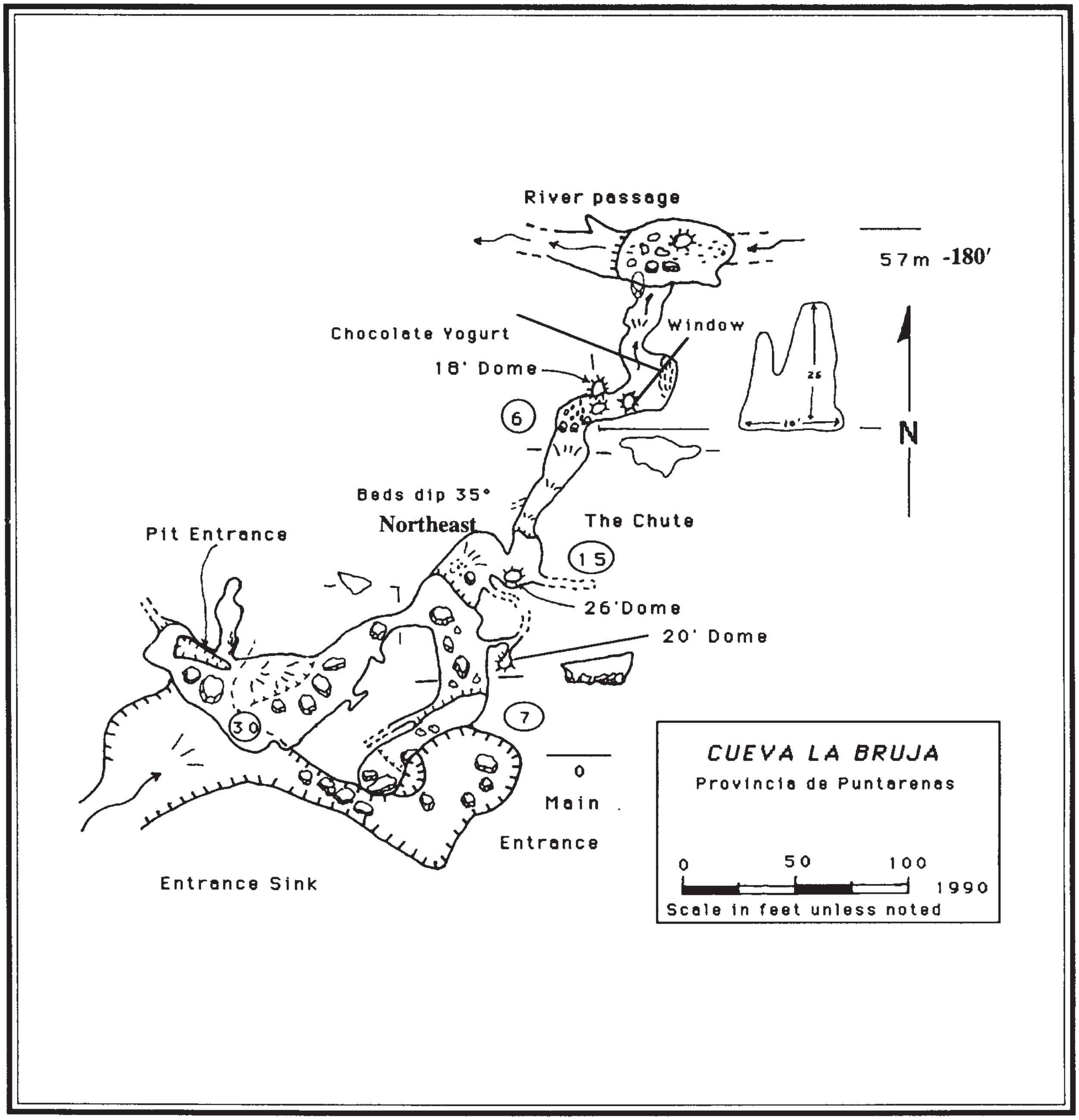



Figure 7. 3 Map of La Bruja

**LA TROJA**

This cave is located near Los Castillos cave in a steep walled 13 x 10m sinkhole. This sinkhole is 13m deep with the entrance near its base. The entrance leads to a large walking passage filled with numerous "dead" formations.

This passage is occupied by many bats and leads to a small constriction. Beyond this tight point a final dome room is encountered which houses a large bat colony. All passages exiting the room end in flowstone. The main passage and dome are located under the large sinkhole between the La Troja and Los Castillos entrances.

**LOS CASTILLOS** (REAL)

This cave lies in a shallow sinkhole in the La Bruja Valley. The sink hole contains 4 horizontal entrances and one vertical shaft. This shaft may be descended 7m by climbing and scrambling and provides access to the other entrances. At the low point of this passage another pit is climbable for 7m to a large room called Kings Quarters. Small crawls exit this room directly below the horizontal entrances but soon end.

The cave is inhabited by many fruit bats and, most passage floors are composed of guano covered breakdown and black concretions derived from the shale above the limestone.

**LOS CASTILLOS** (FALSE)

This shelter cave is located in the southeast end of an elongated sinkhole. The cave slopes steeply downward from its walk-in entrance. The cave has 27m of passage. Bats and "dead" formations were noted on the ceiling.

**LOS INDIGENAS**

This pozo is a twin drop cave leading to two small choked leads. The entrance is located 33m left of a small creek and measures 3.3 x 6m. The first drop is 25m to a tiny landing sloping downward to a 3m pit.

**LOS PAISANOS**

A 3 x 7m pit leads downward 16m to small passage heading north.

**PEJIBAYE / BANANAL**

This cave is little more than a tight fissure that pinches out quickly.

**POZO BRUNCA**

This is the largest of the La Bruja pits. Its entrance is larger than the other pits and takes a lot of water but is plugged after 5 meters.

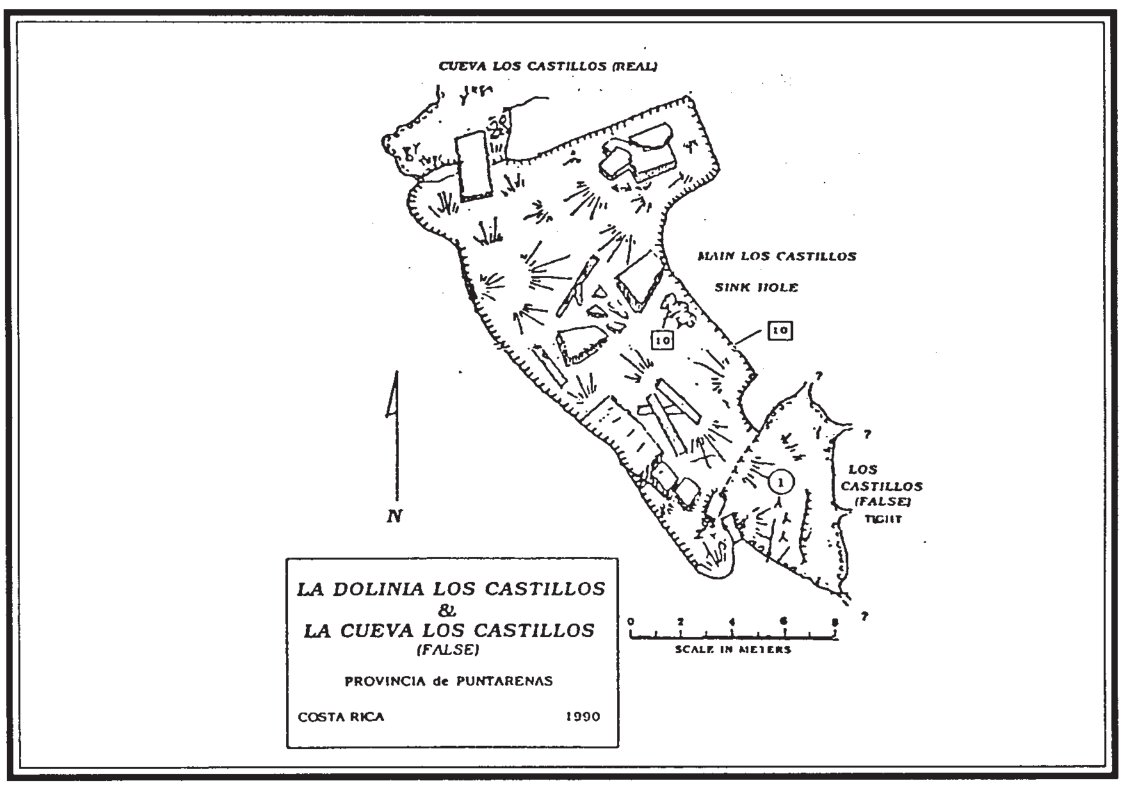



Figure 7.4 Map of Los Castillos Sinkhole and caves

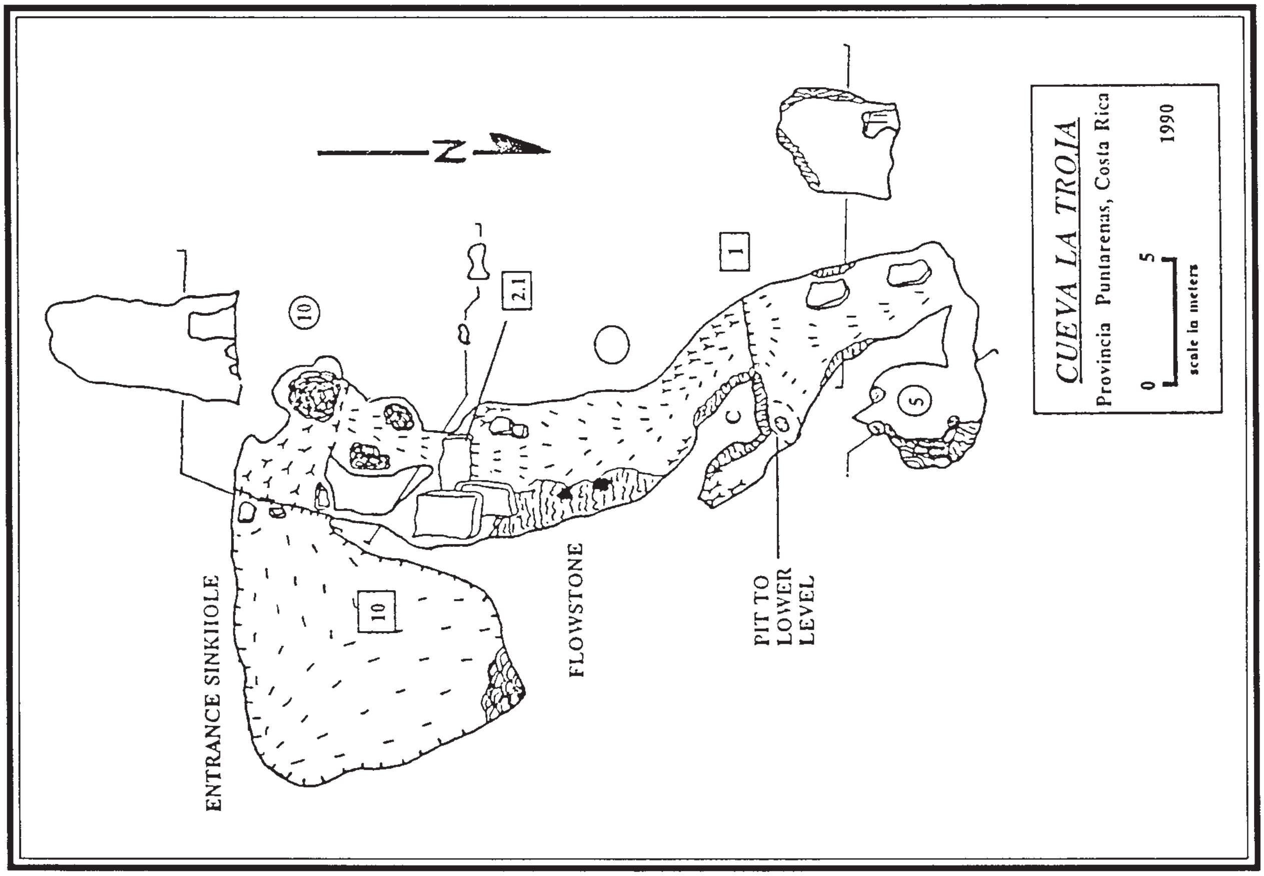



Figure 7. 6 La Troja map

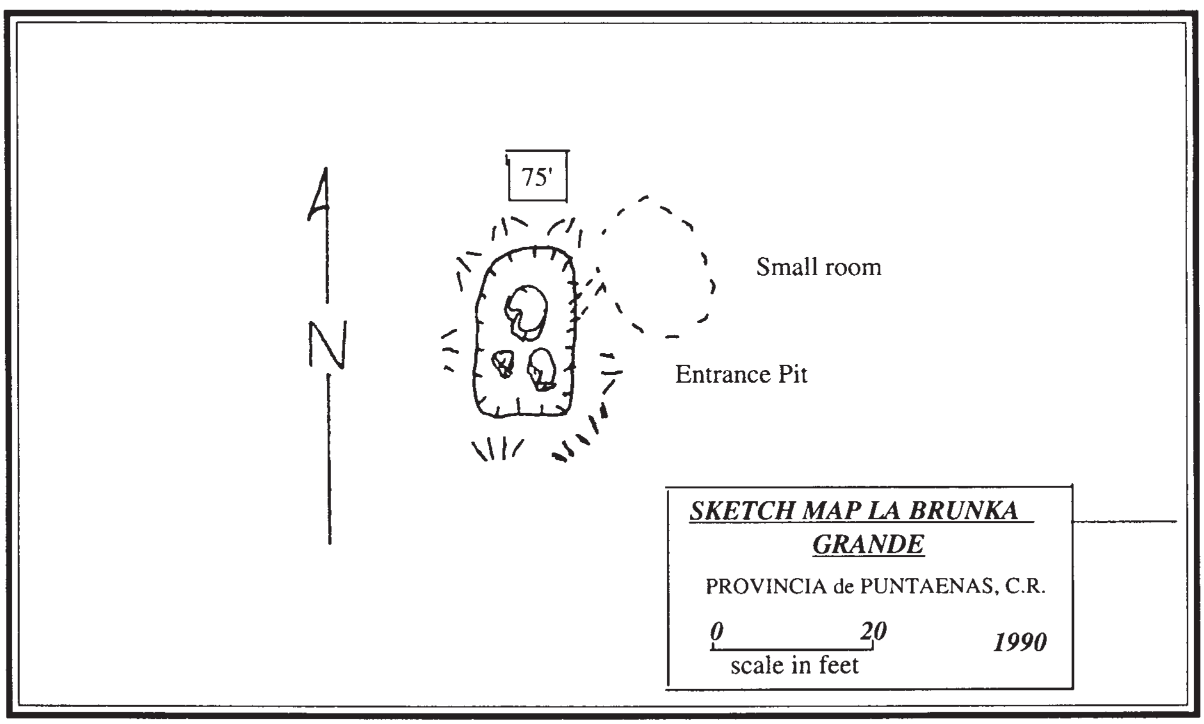



Figure7.5 Map of La Brunka Grande

**POZO CHICO**

This is another tight pit in the La Bruja basin.

**POZO CIGO**

This is a large entrance room with no passage.

**POZO "CUCHILLO PERDIDO"**

This is another small pit in the La Bruja area and is 13 meters deep. This pit has a 2 x1.57m entrance that splits into two shafts that rejoin with depth.

**POZO DE PABLO**

This pit drops 5m to a platform then slopes down at 25 degrees as a 2 x 2m passage bearing 126° toward another sink hole.

**POZO DEL LINDERO**

This is a small pit with a lead at the base.

**POZO DEL RIESGO**

This is a small cave that was mapped by Carlos Goicochea. A pit entrance drops 8 meters to a sloping floor and leads to a terminal dome under an adjacent sink.

**POZO DOCE HERMANOS**

This is one of the largest entrance sinks in the basin. The entrance is 7.5m x 4.5m and drops 13 meters to a 20m x 35m room. A smaller pozo 4m southwest of the main pit seems related.

**POZO EL MINISTERIO**

The entrance is located in a large sinkhole near the La Bruja Pits. The pit is a sloping, floored sink about 9 meters deep.

**POZO GAMBA**

This pit appears to contain some passage but wasps living in the entrance prevented exploration.

**POZO LOS NELLIZOS**

Another small pit and small passage.

**POZO NAUTILUS**

The entrance is found in a dark sinkhole west northwest of the Tururun entrance of Corredor Cave. It is about 3.3m high by 8m wide with a sloping floor leading downward over broken rock debris. The entrance room is large and well decorated. In the center of this 13 x 20m room is a large rock. Beneath this rock is a low, tight crawl leading downward. It opens into a small room inhabited by many bats. Evidence of cave rat nesting was also noted in this room.

From this point a 2m drop leads to a short walkway which quickly decreases in size. A final climb leads to a low, tight, unstable passage that is not passable. The cave has about 20m of passage past the entrance room.

**RECTANGLE CAVE**

This cave was found during the 1988 field season and is located on the farm of Don Tilo. The cave is entered via a rectangle-shaped hole for which the cave was named. This small entrance leads to a short climb ending in a large breakdown chamber.

Exiting this chamber is a 6m high, narrow, sinuous canyon named "La Serpentia." This passage carries storm water toward the main stream in wet weather and extends a short distance to where it intersects a major thrust fault where a large chamber opens. The ceiling is a flat faulted limestone resting on brecciated limestone walls.

Additional passages lead southwest to a terminal sump located about 100m upstream from Corredor Cave sump. The stream has been connected hydrologically to both La Bruja and Corredor caves.

A fault causes the cave passage to turn at a right angle to the entrance passage. The large fault passage follows the cave stream down to a terminal sump. This sump abounds with catfish washed in from the surface.

A high lead was found just before the sump that allowed access to an overflow channel bypassing the sump. This passage leads to more stream passage complete with swims, duck unders and wading pools. This passage extends southwest for more than 2 km, making this one of the best caves in southern Costa Rica.

### SIMA "PALMITO DULCE"

This small cave is one of several found below Don Tilo's house near Tururun Cave. The entrance is a crack in the base of a sinkhole measuring .6 x 4m long. The cave is a pit 29m deep with one side crawl at 6 meters deep. Total surveyed passage is 48m.

### TURURUN AGUA

One hundred meters upstream of Tururun Cave is a pit on the creek. It takes water during most of the year but could not be entered.

### CAVERNA ULTRA

The 3m x 5m entrance pit drops 8m to where a

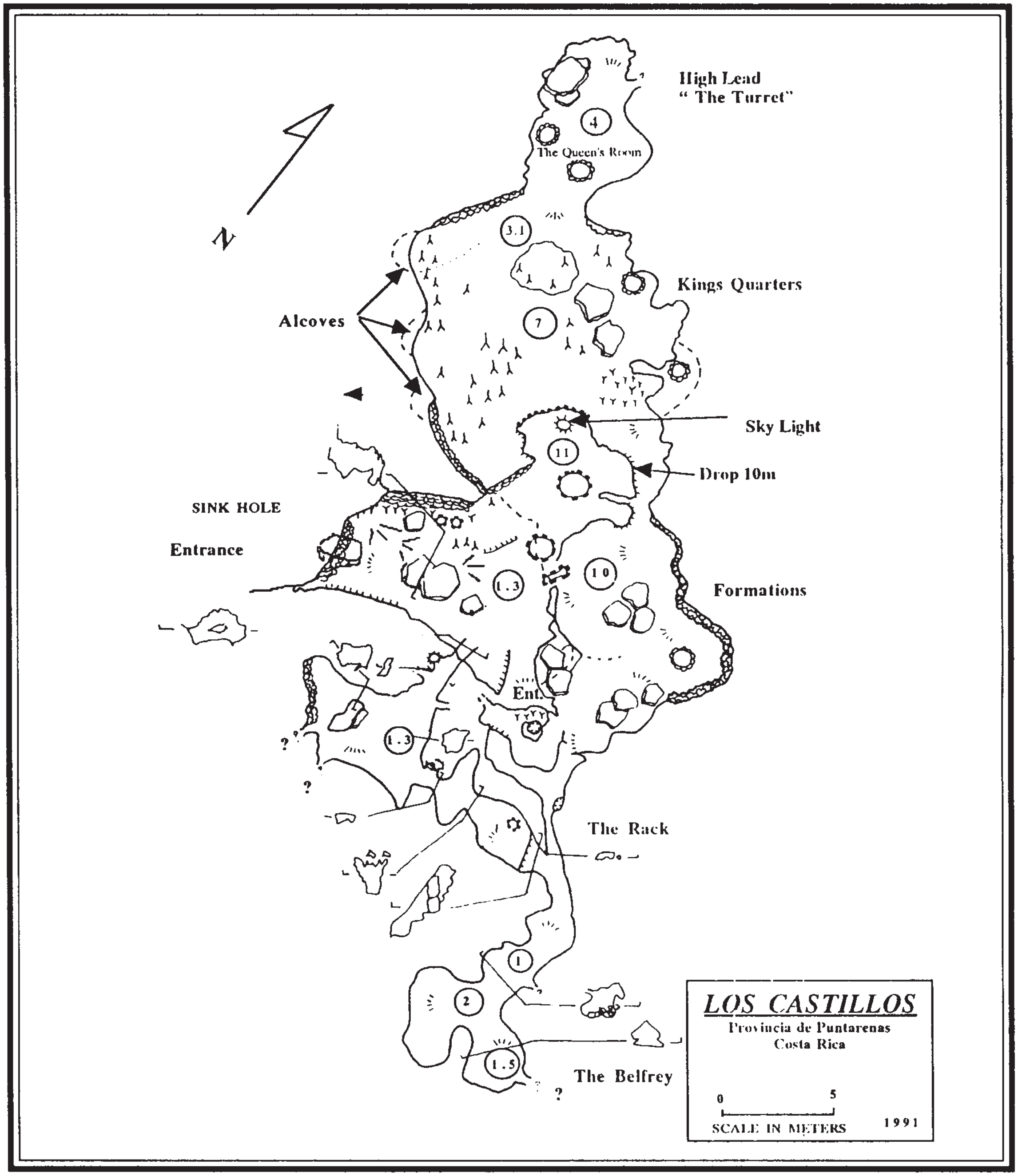



Figure 7.7 Map Los Castilos (REAL)

smaller 1 x 1.3m slot may be entered. This shaft descends 5m further to a dead bottom.

## THE QUEBRADA SECA SECTION

The Quebrada Seca Section is directly across the Rio Corredor from the La Bruja section. Extensions of the same thrust faults influence cave development in both sections.

The Quebrada Seca area differs from La Bruja in that it is a completely isolated blind valley system. All caves are formed along large valley complexes. Locations are shown on figure 6.1.

### ALMA CAVE

This cave is a small crawlway located across from the Corredor Cave entrance on the north bank of the Rio Corredor. The cave is about 10m long with pooled water on the floor.

### AÑO NUEVO CAVE

This cave, now plugged with sediment, is located on the west bank of the Quebrada Seca. It is situated about 1km upstream of the Quebrada Seca insurgence. The cave is entered via a small 1m x .7m entrance crawl that turns right to a 6m clean faced drop. A rope is needed at this drop. The passage at the base crosses some breakdown. From the breakdown area an obvious stream passage can be followed downward. The first room is called the Fin Room and contains bat guano in large amounts. The Fin Room is a steeply sloping downclimb of 5m highlighted by several rows of sharp rock "fins." Further down one encounters the "Pillar Climb." Black iron concretions are found at the base of this drop. Several additional climbs lead to a 5m smooth walled pit. At the base of this drop a clean smooth stream passage is encountered. This passage pinches out to a 14cm high crawl with larger passage visible beyond . A side lead at the top of the drop leads to a 5m down climb to the "Lions Den." This large room is muddy and has a low crawl exiting a short distance to a pinch. This is a young cave and is still developing.

### BANANAL CAVE

This cave is one of the largest caves in the area. It was located during field work in 1989 at the bottom of a small, Banana plant covered, sinkhole. The entrance is 1m high and .6m wide and leads to a small sinuous entrance passage. After a short traverse in twisting canyon passage a 7m drop is encountered. Here a handline is needed for descent to a small room with formations.

About 33m of sloping passage leads to the second drop of the entrance complex. This drop descends 6m to a ledge then 3.3m more to the floor and requires a rope to descend.

Five meters beyond the second drop another pit is encountered. Both the second and third drops are tight fissures. Below this drop the cave opens and descends more gently. Walls in this area are brecciated. Bats and insects inhabit this section. About 174m from the entrance several side leads are encountered. The first is a crawl which leads to two rooms of moderate size with ankle-deep mud. The walls are covered with white formations.

The second lead begins as a chute into a crawl which appears to flood in wet weather. The passage descends to a mud "sump" before ascending a flowstone mound to a side passage. A second lead exits the passage from about half way up the flowstone slope. The walking passage ends at a high (5m) climb up. This climb leads to decorated stoopway that eventually emerges mid-way up a 5m diameter waterfall dome. Slightly lower on the opposite wall a stoopway leads from the dome.

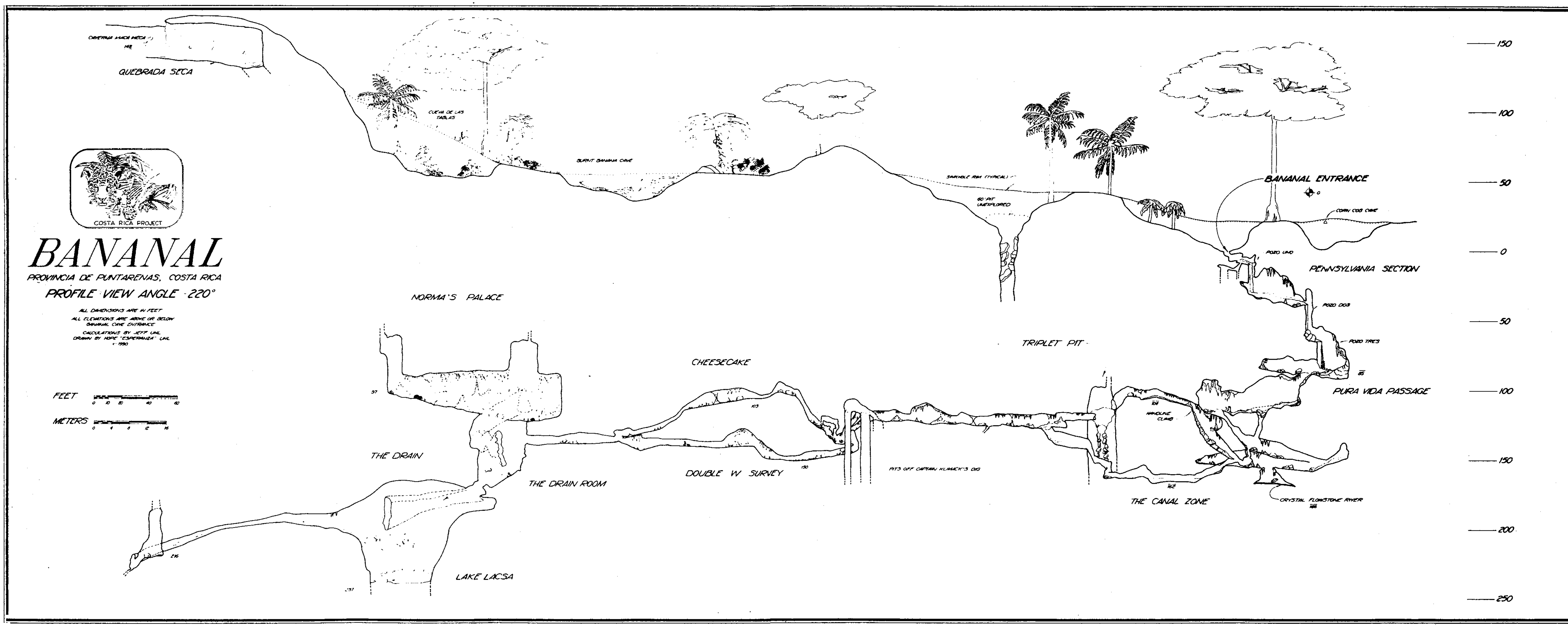
The lead partway up the flowstone is a hole that takes water. It leads to the "Canal," 33m of wet crawl, followed by 16m of mud crawl to a small dome. This section may be bypassed via a steep slope requiring a handline.

After this section the passage is mostly stoop or crawlway to an intersection. A passage to the left climbs a mud and rock bank and leads to a pit.

The entrance to the drop is constricted and too tight to enter. The pit was estimated to be 6.3 to 10m deep.

Another passage leaves the intersection to the right and may be followed downward to a mud crawl and another intersection. To the right is a small passage and a breakdown room. To the left 8m along and up sloping mud and breakdown crawl is another breakdown room. On the other side of this room is a dry crawl leading downward to a well decorated room. The crawl decreases in size through the formations but soon opens into a room full of white speleothems.

On the far side of this room the passage exits as a dropdown into a tight twisty crawl for 33 m and eventually intersects a walking passage. The right hand passage goes only 33m to a breakdown plug and is muddy. The left passage is mainly muddy walking passage and ends in the "Drain Room." This large room appears to act as a drain for water entering from several passages.


COSTA RICA PROJECT
BANANAL
PROVINCIA DE PUNTARENAS, COSTA RICA
PROFILE VIEW ANGLE 220°
ALL DIMENSIONS ARE IN FEET
ALL ELEVATIONS ARE ABOVE OR BELOW BANANAL CAVE ENTRANCE
CALCULATIONS BY JEFF UHL
DRAWN BY HOPE "ESPERANZA" UHL
© 1990
FEET
0 10 20 40 60
METERS
0 4 8 12 16
QUEBRADA SECA
CUEVA DE LAS TABLAS
BURNT BANANA CAVE
SINKHOLE RIM (TYPICAL)
60' PIT UNEXPLORED
BANANAL ENTRANCE
CORN COB CAVE
POZO UNO
PENNSYLVANIA SECTION
POZO DOS
POZO TRES
PURA VIDA PASSAGE
NORMA'S PALACE
TRIPLET PIT
CHEESECAKE
THE DRAIN
THE DRAIN ROOM
DOUBLE W SURVEY
PITS OFF CAPTAIN KLIMACK'S DIG
HANDLINE CLIMB
THE CANAL ZONE
CRYSTAL FLOWSTONE RIVER
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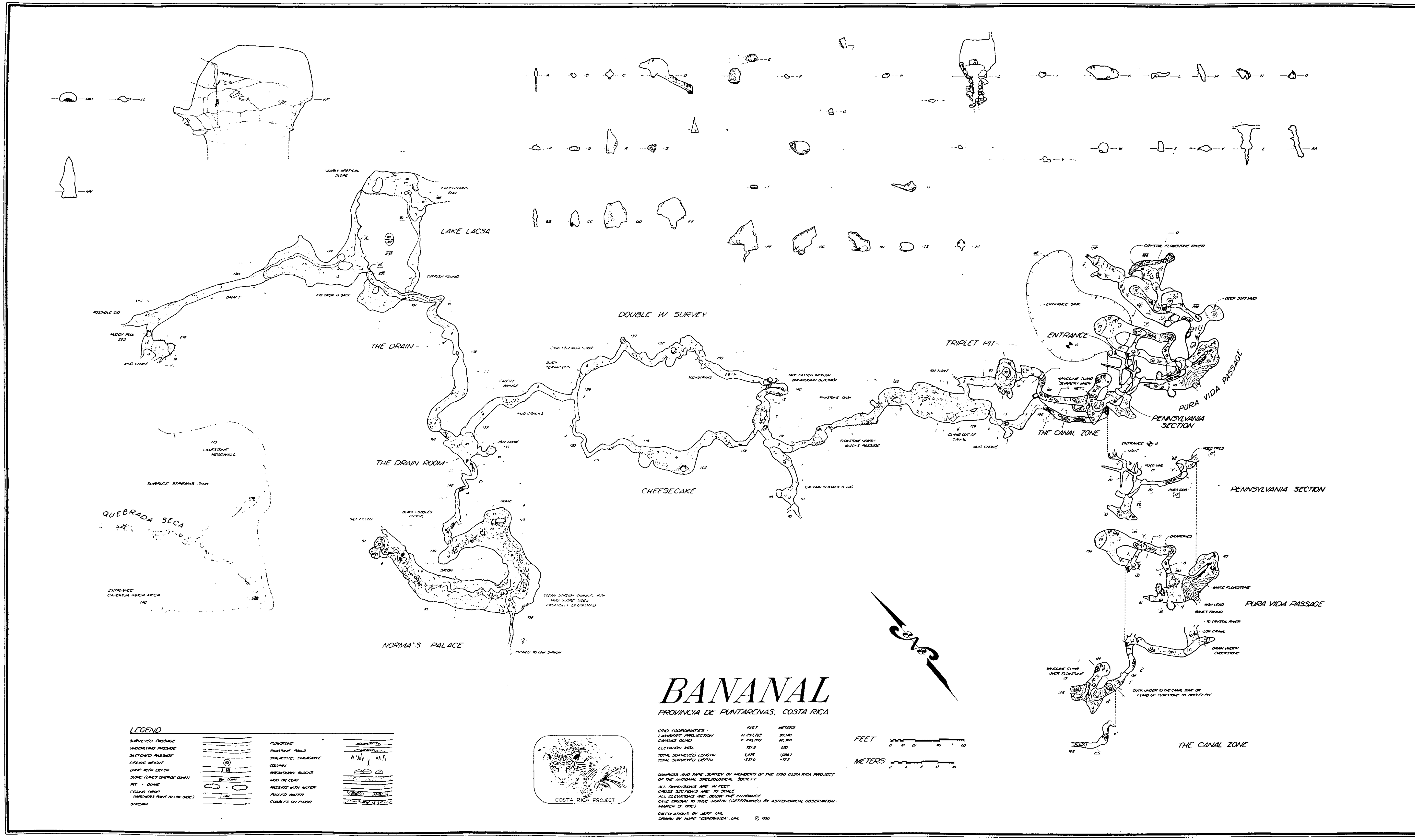


**Figure 7.8 B Map of Bananal Cave**

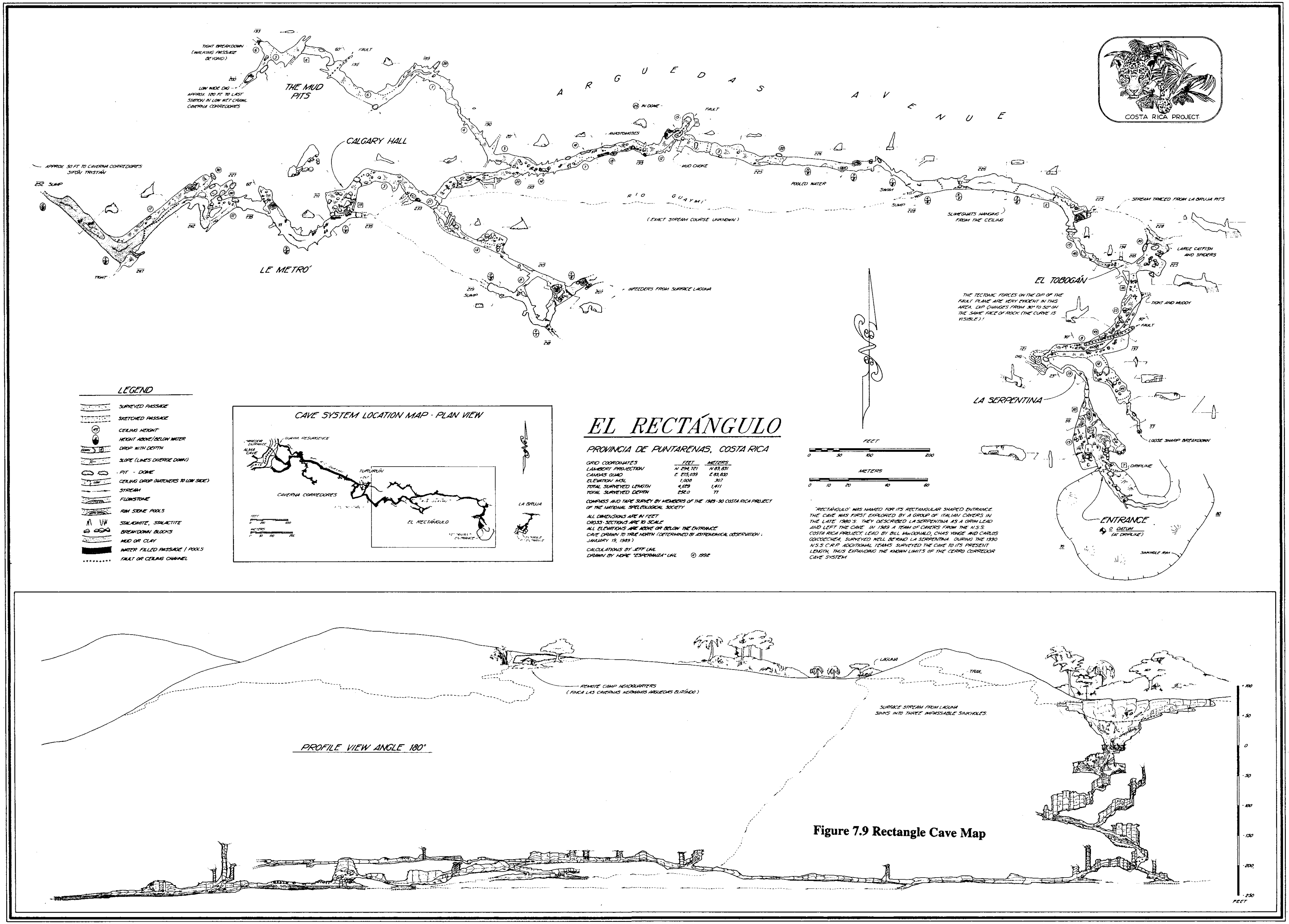


**Figure 7.9 Rectangle Cave Map**

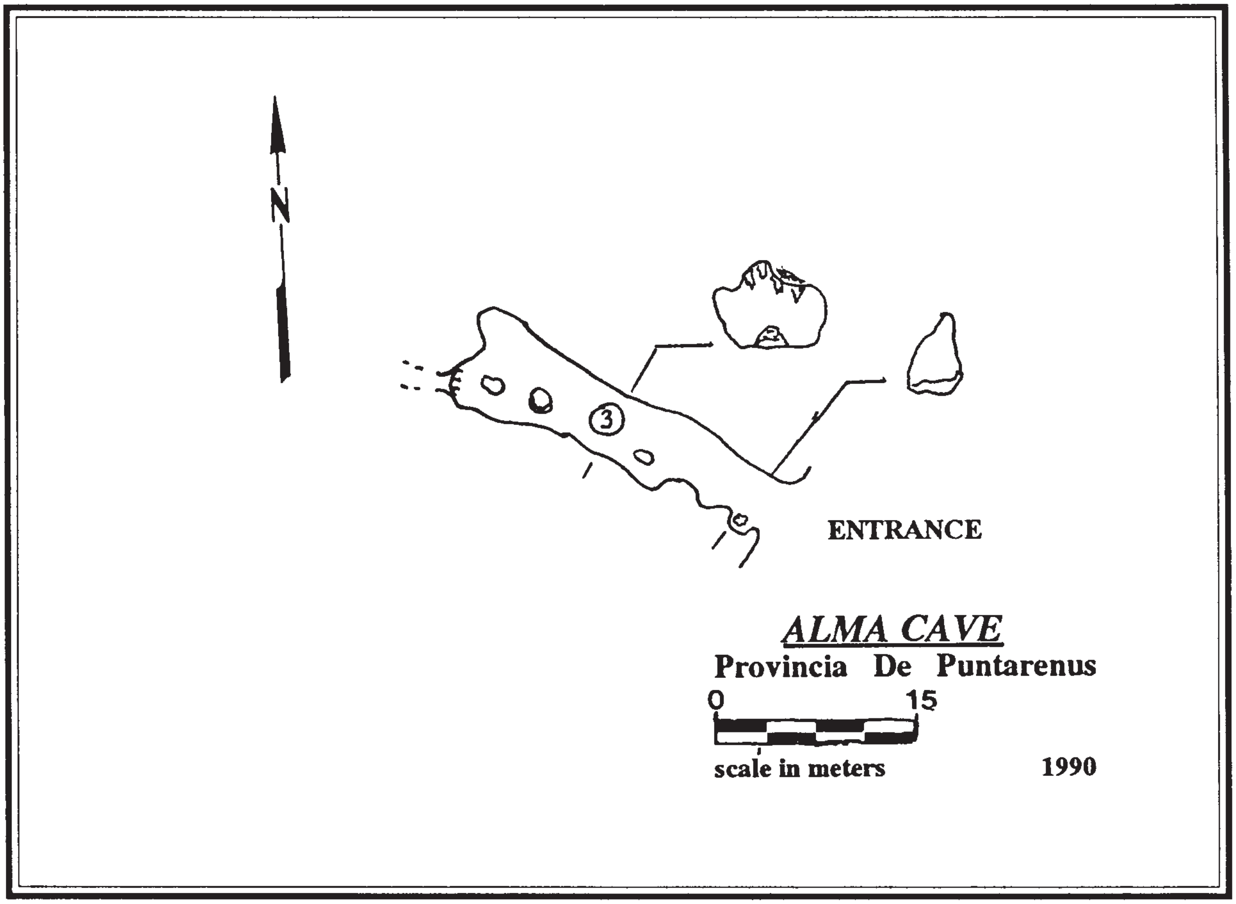


Figure 7.10 Map Alma Cave

The upper part of this room is mud covered while the lower portion is washed sand and black boulders 1m in diameter. On the opposite side of the room a clean washed passage enters. This leads upward to a large room. The walls and ceiling are completely covered with white (calcite deposits?). The passage is 8m high and 13m wide at this point. This room was called "Norma's Palace" in honor of the expedition's co-leader.

Another passage leaves the drain room leading upward to a dome of unknown height. Due to a dangerous climb this was not explored.

In the sand at the base of the room a choked crawl was dug open to allow entry into a walking passage. This passage was mud covered on the upper walls and clean rock on the lower portions. This leads to a ledge that overlooks the largest lake in the cave. This "Lake Room" was measured at 13m high and water was in excess of 10m deep.

A rope is required to descend into the room and, catfish can be seen swimming in the water below. A passage across the lake leads to the right but ends quickly. However to the left, a passage went a good distance to an upclimb which was not pushed. Additional trips were unable to enter this passage due to high water. This would be a good dry season climb.

The water in the lake was traced and found to be part of the underground Quebrada Seca River. The same sediment loading found at the insurgence is found in the Lake Room. Surface survey places this room and the insurgence in close proximity to each other.

**BOCA DE MOSQUITOS**

The entrance is located in breakdown on the flank of a large headwall. The entrance drops 2m to bedrock and enters a crawlway. Some air movement was noted but the passage was obstructed by debris. The cave was called Mosquito Cave due to the insects in it. It will require digging to explore.

**BURNT BANANA CAVE**

This cave was located only after the banana filled sink in which it is located was burned in 1989. The entrance is about half way up the rear of the sink in a small rock outcrop. The sink is just north of Bananal Cave along the same trail.The entrance lies in a straight line between Maca Meca and Bananal.

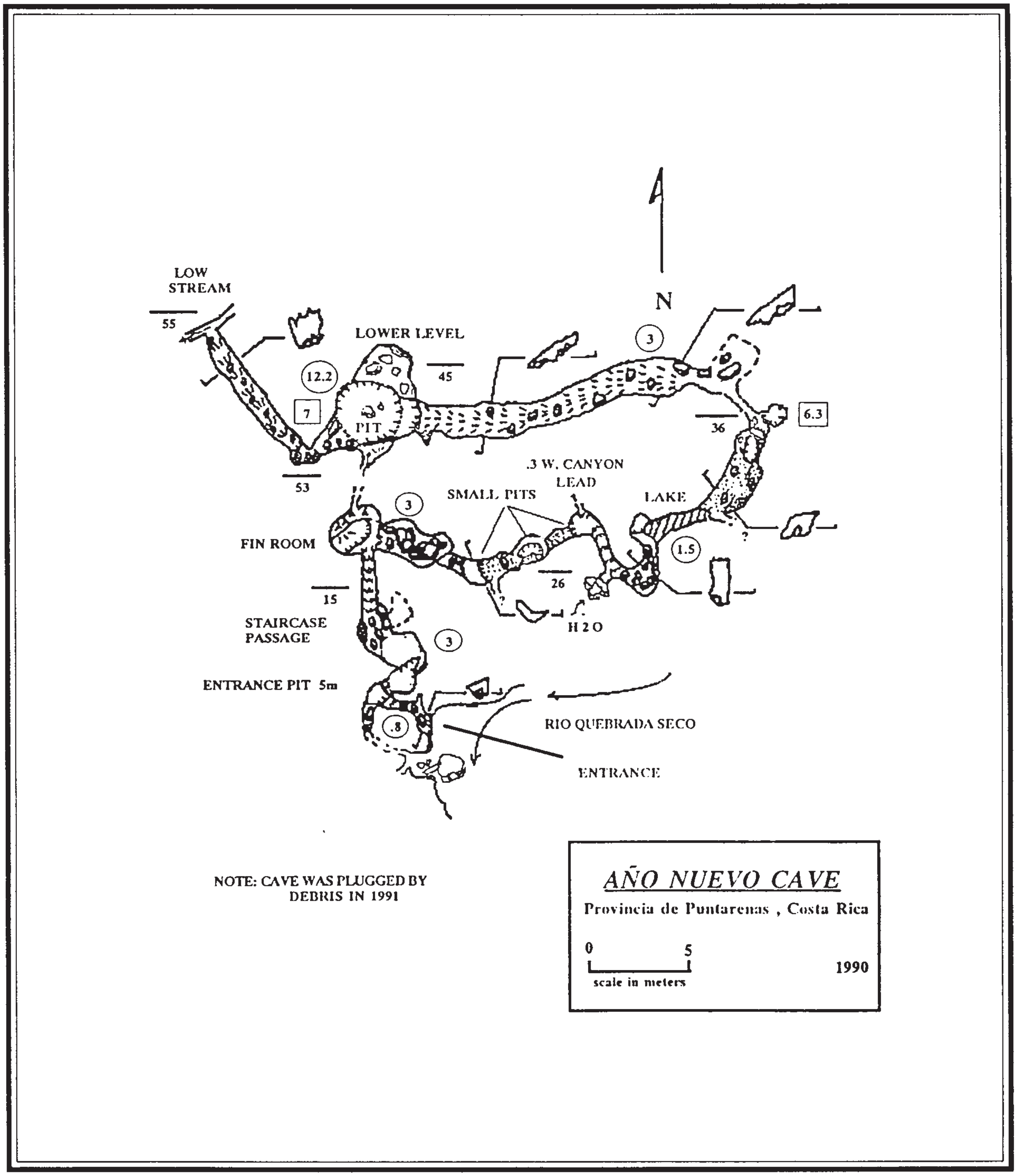


Figure 7.11 Año Nuevo Map

The 6.5 x 1.5m entrance room leads to a passage sloping 30° to a triangle shaped passage that ends at the top of an 8m pit. The pit may be climbed to a 3 x 10m room. The room is decorated with white formations and a small 2.5m to .3m canyon leads from the room toward the sink where it pinches. A small surface fissure in the base of the sink moves air and may connect to this lead.

### CORN COB CAVE

This cave is located directly across the trail from Bananal Cave. It is a large rock sided sink sloping to a large overhung entrance and a 3m drop to 16 m of 2 x 1.5m walking passage. The drop must be rigged. The passage slopes down over breakdown and ends in a plug for a total of 20m of surveyed passage.

### CUEVA DE LAS TABLAS

The entrance to this small cave is 2m high and 5m wide but is almost invisible in the vegetation. Upon entering, a crawl slopes downward 13m to a drop. This drop is climbable but tricky and should be rigged. At the bottom of the drop is a decorated room 6.5m wide by 10m long. Passages exit from right and left sides of the room but end in flowstone pinches. On the north side of the room is a 5m climb to a lead that was not explored. No air flow was noted but the cave is above passages in Bananal Cave.

### LA GALLERIA GRANDE

This cave is another large remnant of a paleocave system that is now truncated. The cave is located on the Fila de Cal Ridge between Chuck's Valley and Quebrada Seca. The entrance is a jungle-filled 66m+ x 100m+ sinkhole located behind La Casa de Bananal. At the base of a 26 m cliff is one of the largest entrances in the area. The entrance is 33m wide with two entrances located about 16m apart. The largest entrance slopes down over breakdown to a small formation room which is 8m wide and 5m high. A traverse on the left wall leads to a large trunk "room" or Galleria. The main passage is 17 x 13m on average and is very well decorated.

The second entrance is a slot in the wall at a wide spot near the middle of the Galleria.The cave extends 152m to a mud plug and a small side room on the right. This room is adjacent to the main passage and is entered via a crawl.

### MACA MECA CAVE

Maca Meca is a remnant cave located in the highwall at the insurgence of the Rio Quebrada Seca. The main entrance is about 7 meters above the fill and debris pile at the cliff face. This entrance is the lower of two entrances and is an overhang about 7 meters long and 1.5 meters deep. The entrance passage exits as a crawl from the left side of the overhang. This short crawl leads to a 25m **L** shaped room that has two leads and lots of vampire bats. The lower passage is a crawl that leads a short way from the room and becomes too tight to continue. The other branch leads up via a climb to the second entrance. A paca (large rodent) is reported living in this cave. Tracks and nasty growls were observed by researchers trying to confirm this report.

### MORA CAVE (WEYMER MORA CAVE)

This cave is located about 650m upstream of Año Nuevo and is on the west side of the river bank. As with all caves in this area it is positioned along a fault contact. The entrance to this cave is large and well known. The walking entrance leads to a large room and very little passage. The cave is small and was named for a Costa Rican member of the 1987 expedition who was killed in an auto accident.

### OTHER SMALL CAVES

There are many small caves in the area around Bananal and Grand Gallery. Two of these are worth recording.

### RIO CORREDOR CLIFF CAVES

Upstream of the Corredor Cave entrance the river becomes very narrow with vertical walls. In this gorge several small caves were located along small fractures. None of the caves was over 10m in length but most served as habitat area for bats.

### SIXTY FOOT PIT

This pit is located in a sink between and just behind the Burnt Banana and Bananal sinks. The entrance is a 20m pit. It has not been descended but appears to have a dead bottom.

### THE TWINS CAVE

This is a small cave located near the Casa Bananal road junction on the north side of the Florida road. It is essentially a two entrance sink with 16m or less of passage.

## THE FILA de CAL AREA

The Fila de Cal or Ridge of Lime is the most prominent geologic feature in the area. The ridge forming this feature is a thrust block composed of the Corredor Limestone. Along its length from the Rio Caño Seco to the Rio Corredor caves and pits can be found. On the north side of the Caño

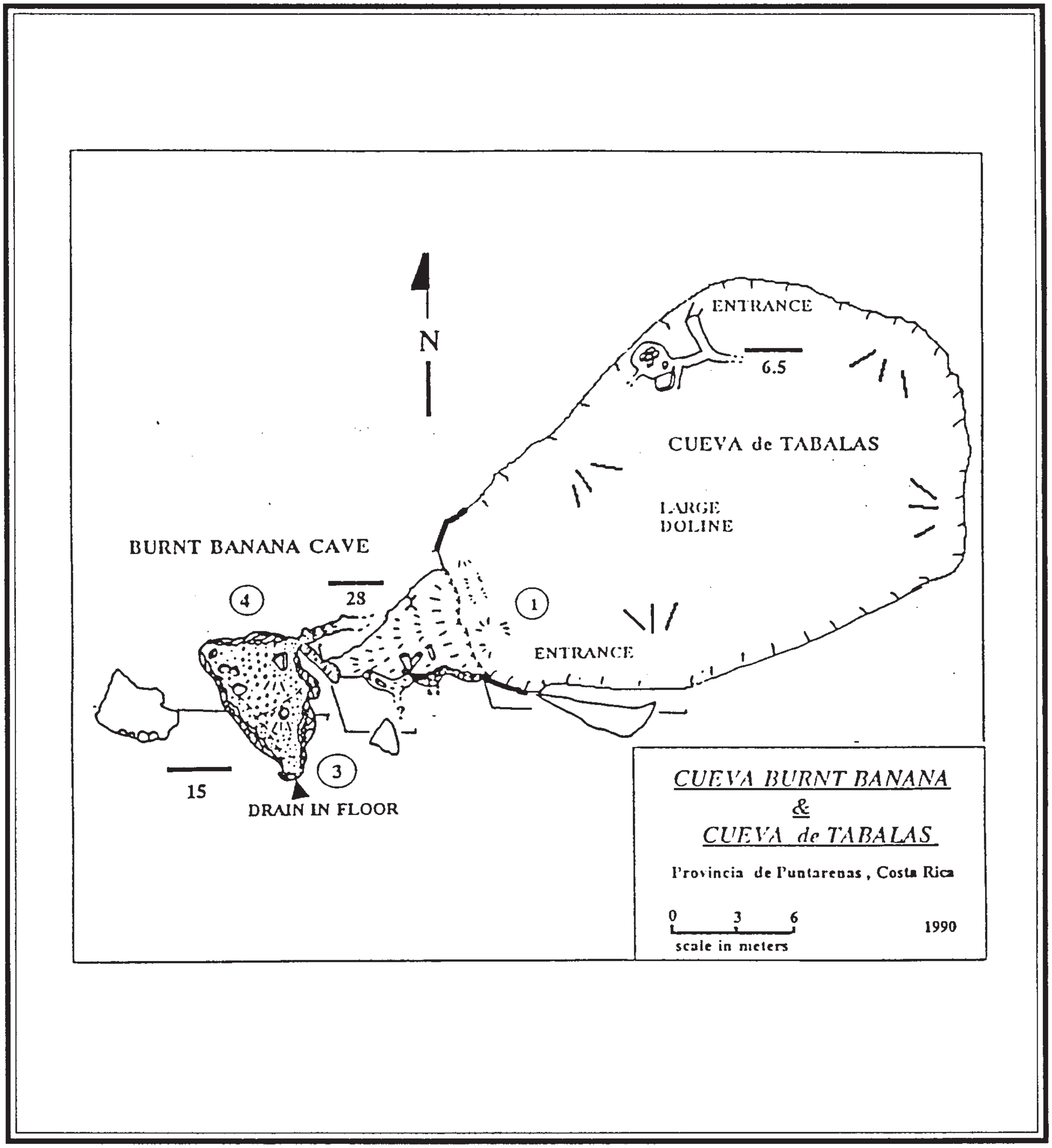


Figure 7.12 Map Burnt Banana Cave

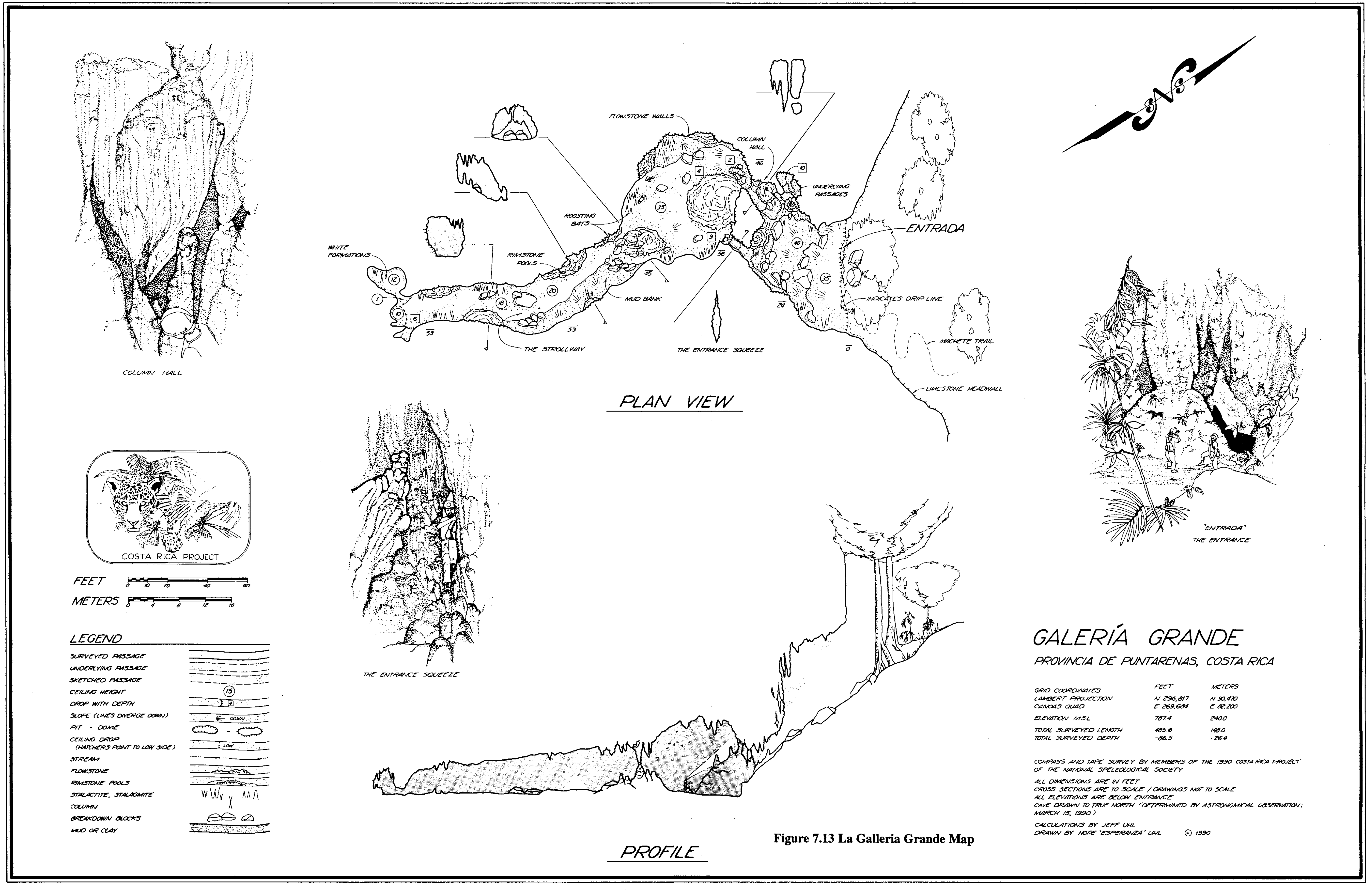


**Figure 7.13 La Galleria Grande Map**

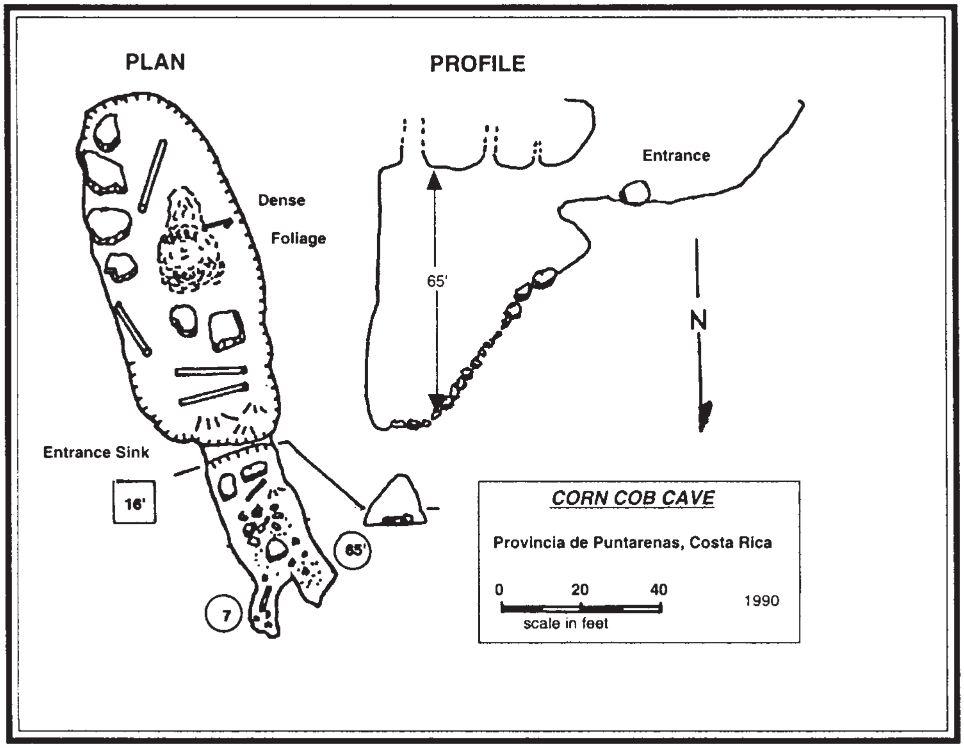


Figure 7.14 Corn Cob Cave Map

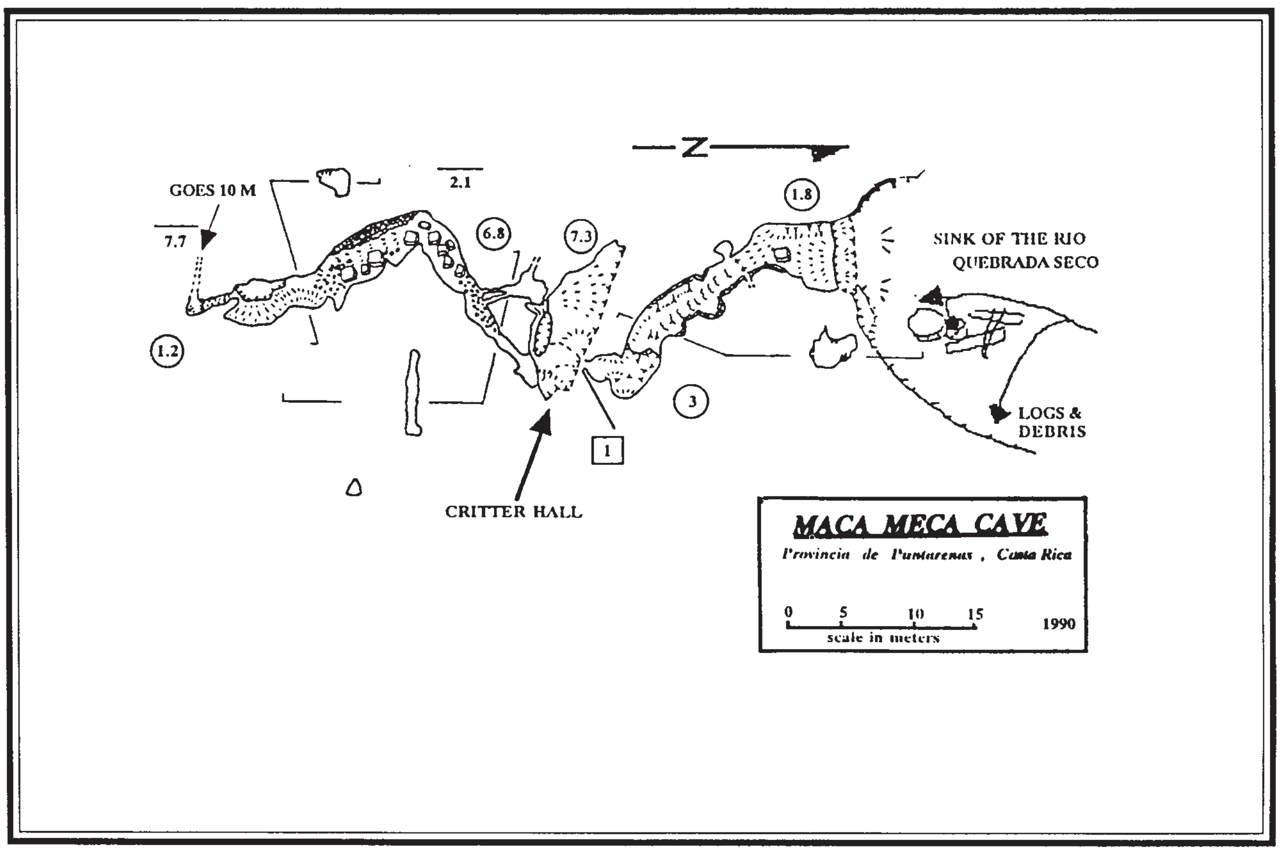


Figure 7.15 Maca Meca Cave

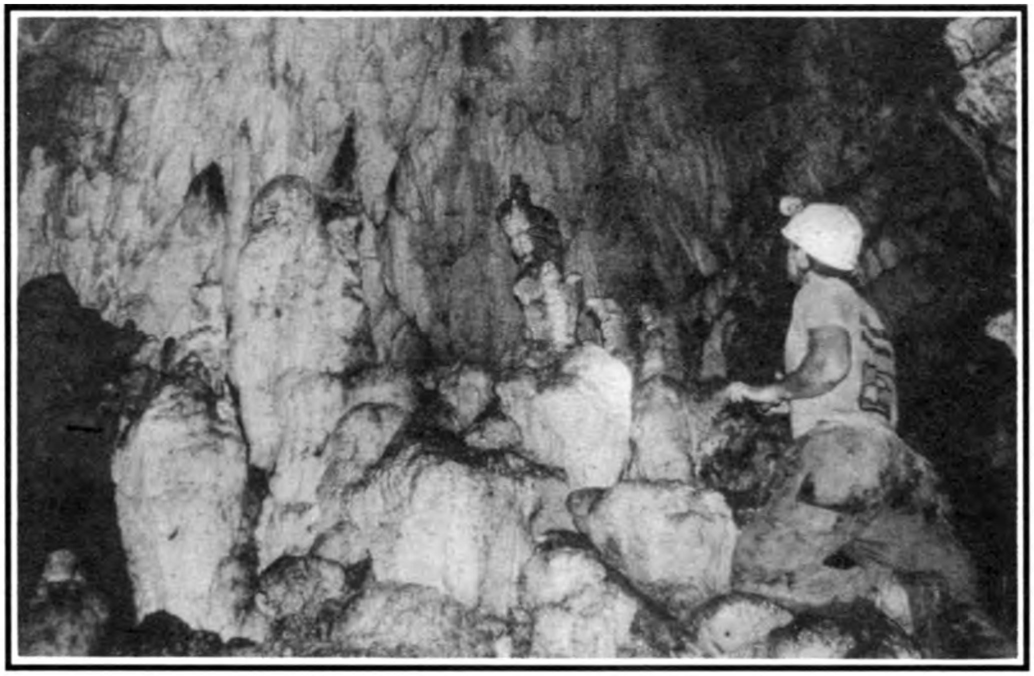

Photo 7-D Grand Gallery Cave

Seco the ridge continues and the deepest pits in the study area are found. For simplicity these sections are described separately.

## CAÑO SECO SECTION

This section is located between the Rio Caño Seco and the Rio Claro karst basin. The limestone is exposed for over 533 vertical meters from the river to the 1050m elevation. The caves are mainly pits and small crevices and are found in large sink holes that collect and concentrate water. No stream caves have been found in this area but work is incomplete.

### ALTO NUBES CAVE

This cave is located on a prominent point north of the Caño Seco River. The point is called Alto Nubes on topographic maps. The cave is located below the point in a small drainage below a coffee field. A small stream enters the cave via a sink near the entrance. Beyond the valley headwall in which the entrance is located, a line of sinkholes leads away from the cave. The cave entrance is small, 2m high and .7m wide. This entrance leads to a tight fissure passage leading toward the closest sink. The cave is not fully explored.

### COFFEE FARM PIT (Pozo Cafetal)

This pit is located near the summit of Alto Nubes on Fila Zapote (a limestone ridge). Entrance elevation is about 1060 m. The pit was found during the 1991 field season and, after some clearing of debris it was bottomed at 70m. No passage was found at the bottom.

### POZO DEL CAÑO SECO (SIMA GUAYABI)

The third cave in the area exhibits the greatest vertical extent. The entrance pit is located about 1 kilometer southeast of and 300m lower than the other Alto Nubes caves. It is reached from a farm road via a rough walk downhill toward the river over difficult karst. The 3 x 5m entrance is large and opens to a free drop of about 41m. One ledge is crossed in the descent to a sloping floor that leads downward 23m to a second drop believed to be at least 30m deep. This pit was descended as were several others to push this cave to a new Costa Rica depth record of 142m. Total length of the cave is 230m.

## THE CARMA SECTION

This section is located above the city of Neily and extends from the Rio Caño Seco to the Quebrada Seca section near Bananal Cave.

Caves form along faults transecting the limestone ridge. Where water is abundant and concentrated, larger caves have formed. Where water is minimal, pits and open joints have formed.

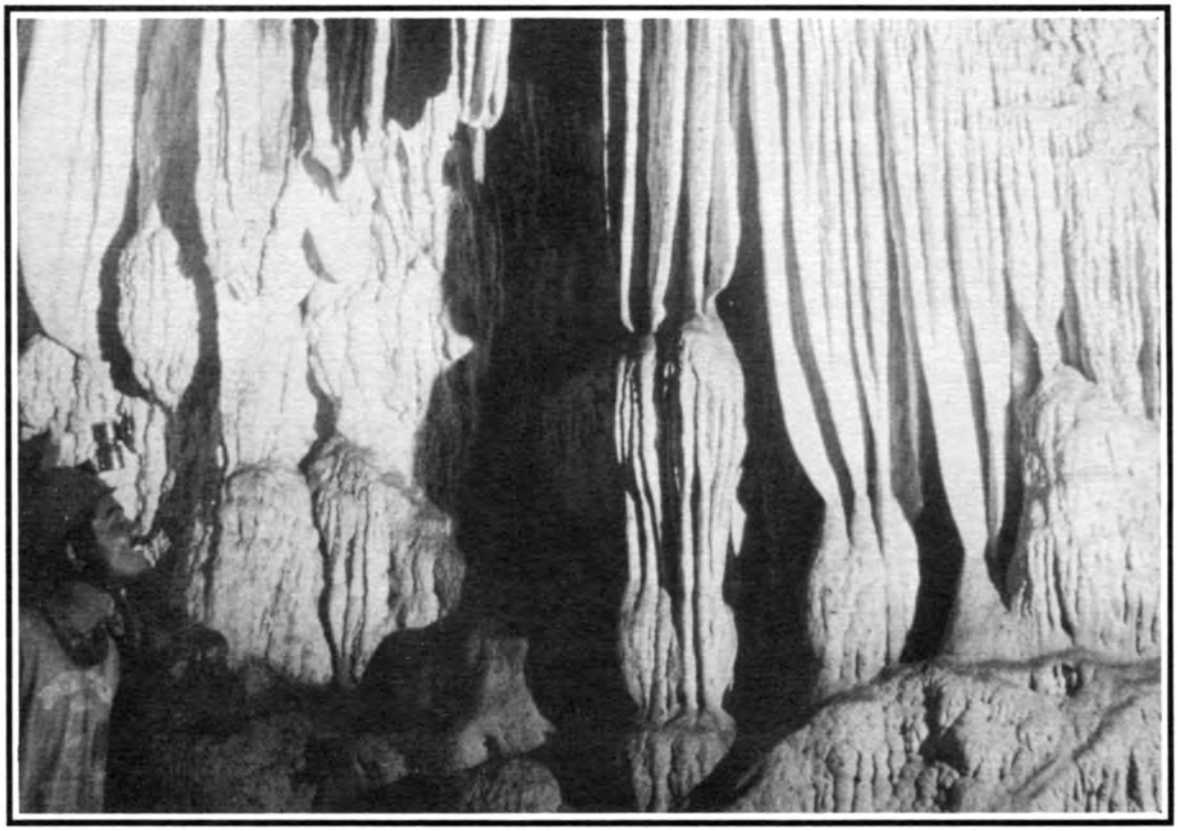

Photo 7-E Carma Cave

Photo 7-F Maca Meca Cave

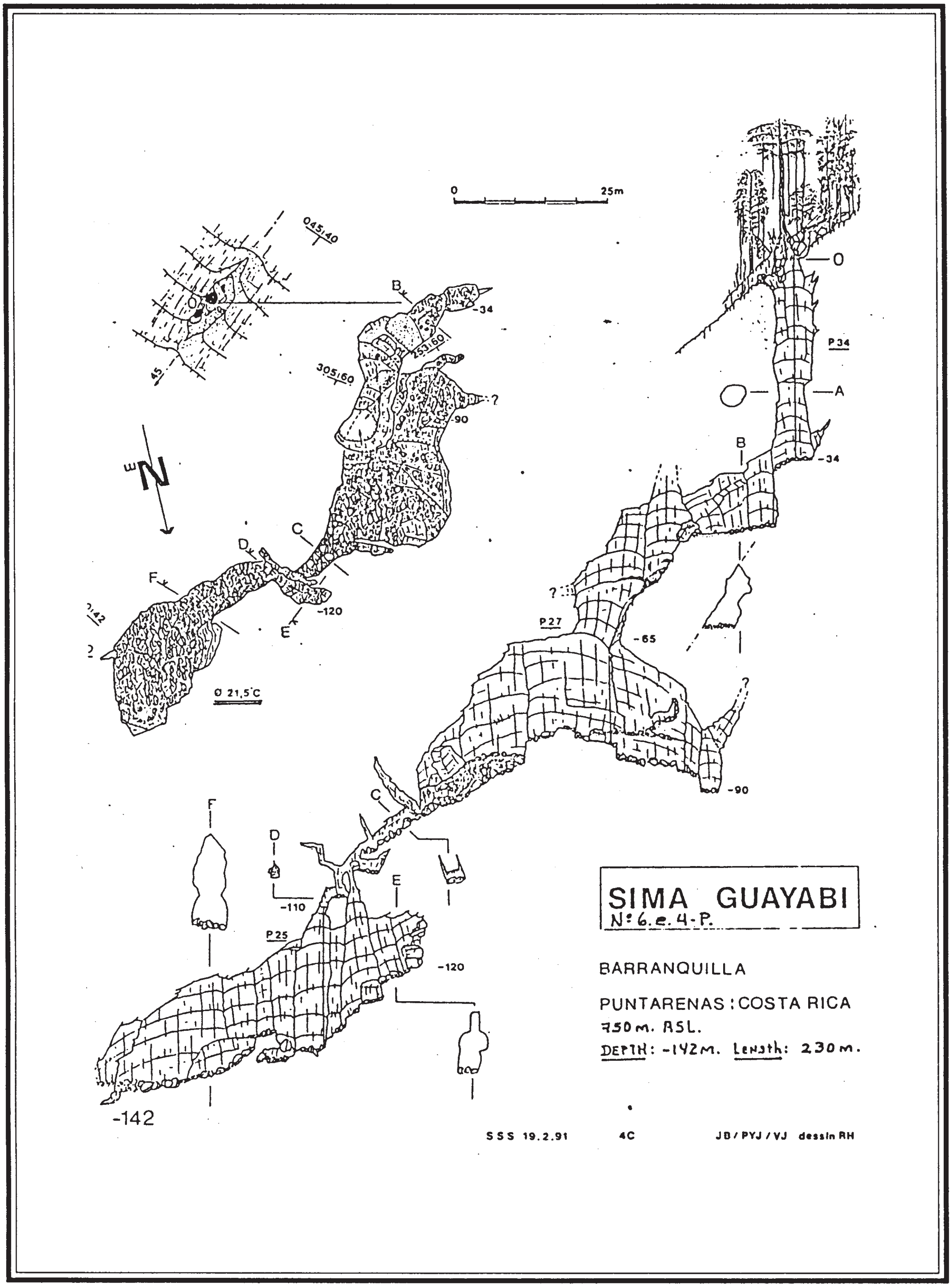


Figure 7.16 Pozo Del Caño Seco

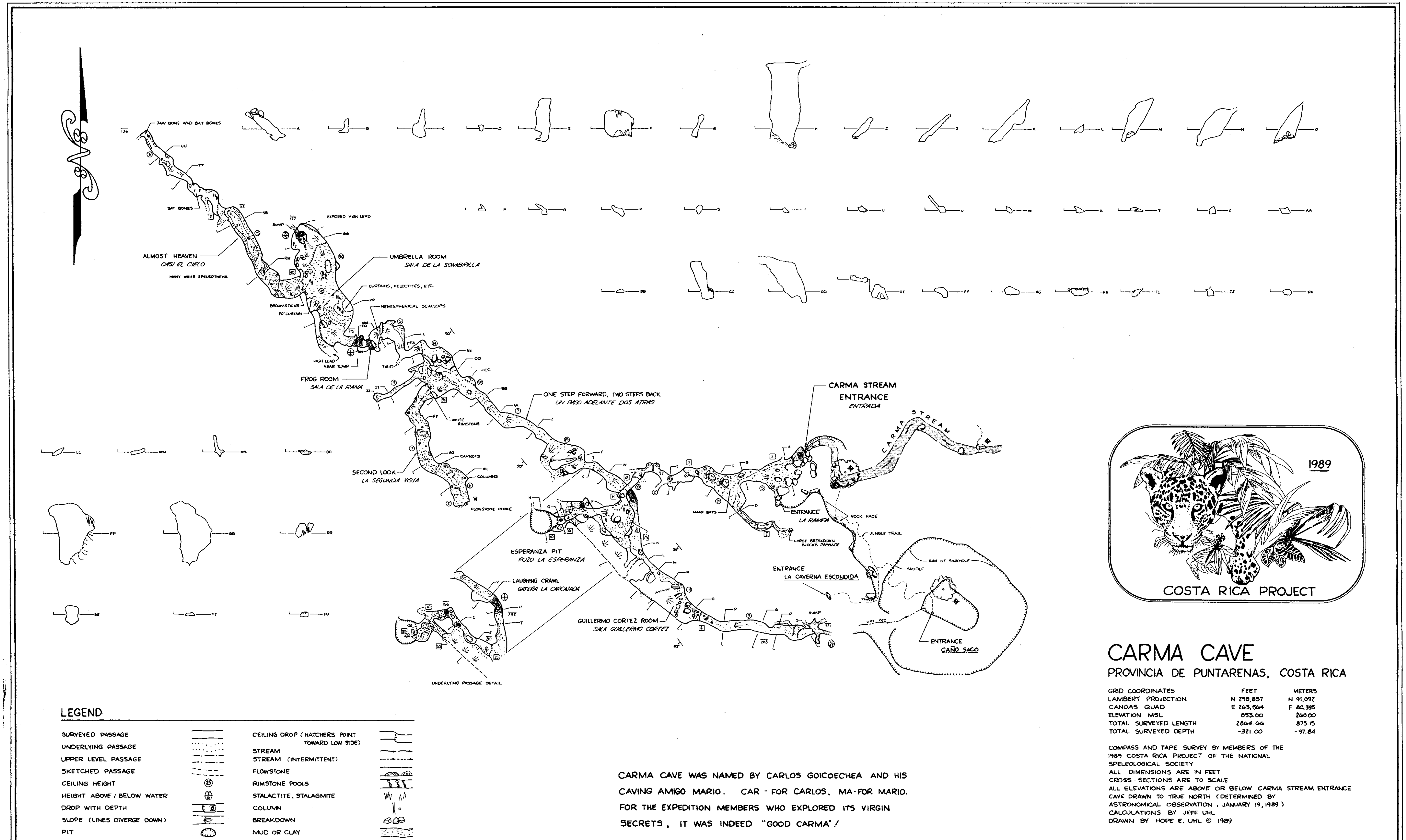


**Figure 7.17 Carma Cave Map**

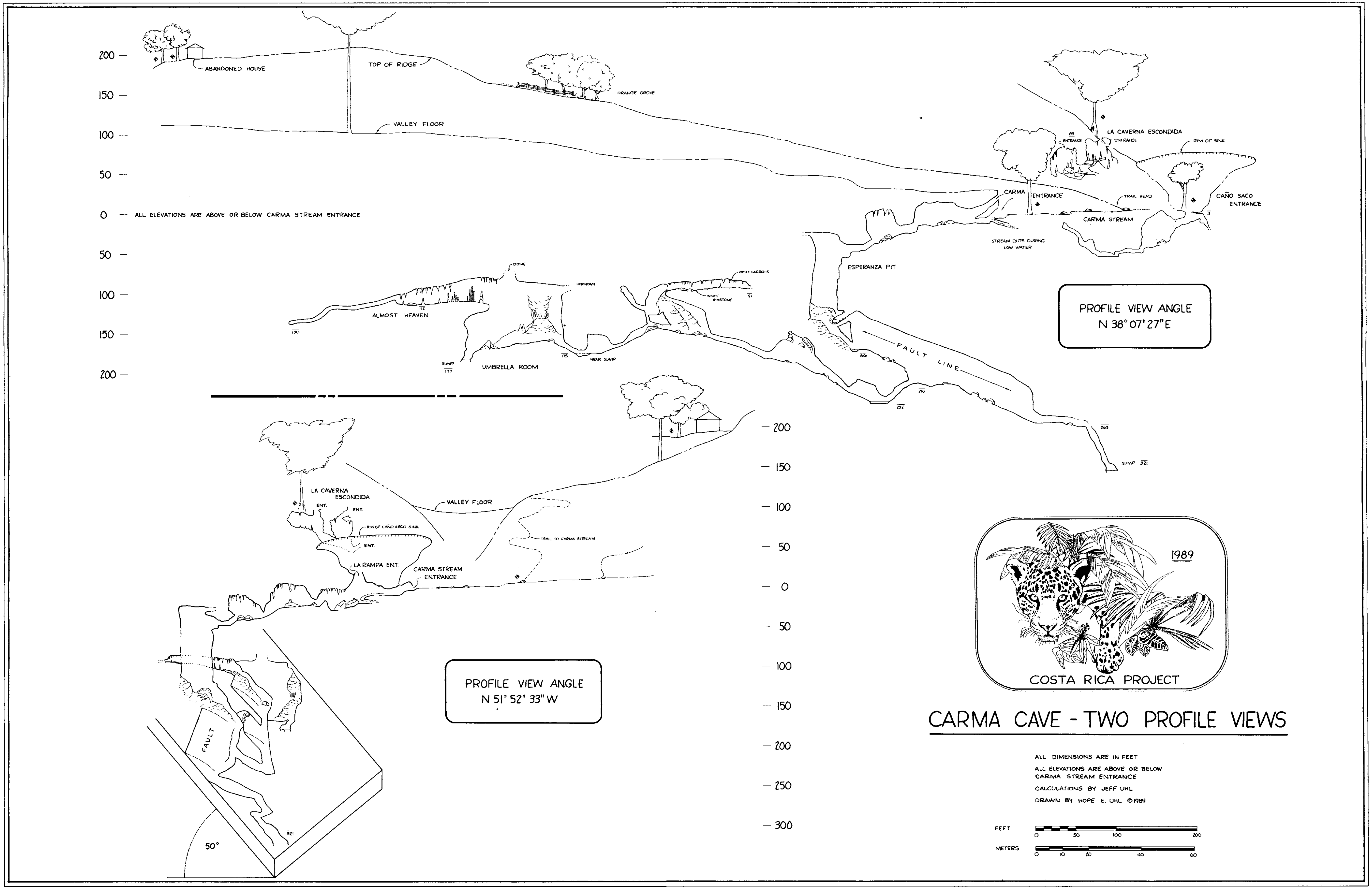


**Figure 7.18 Carma Cave profile**

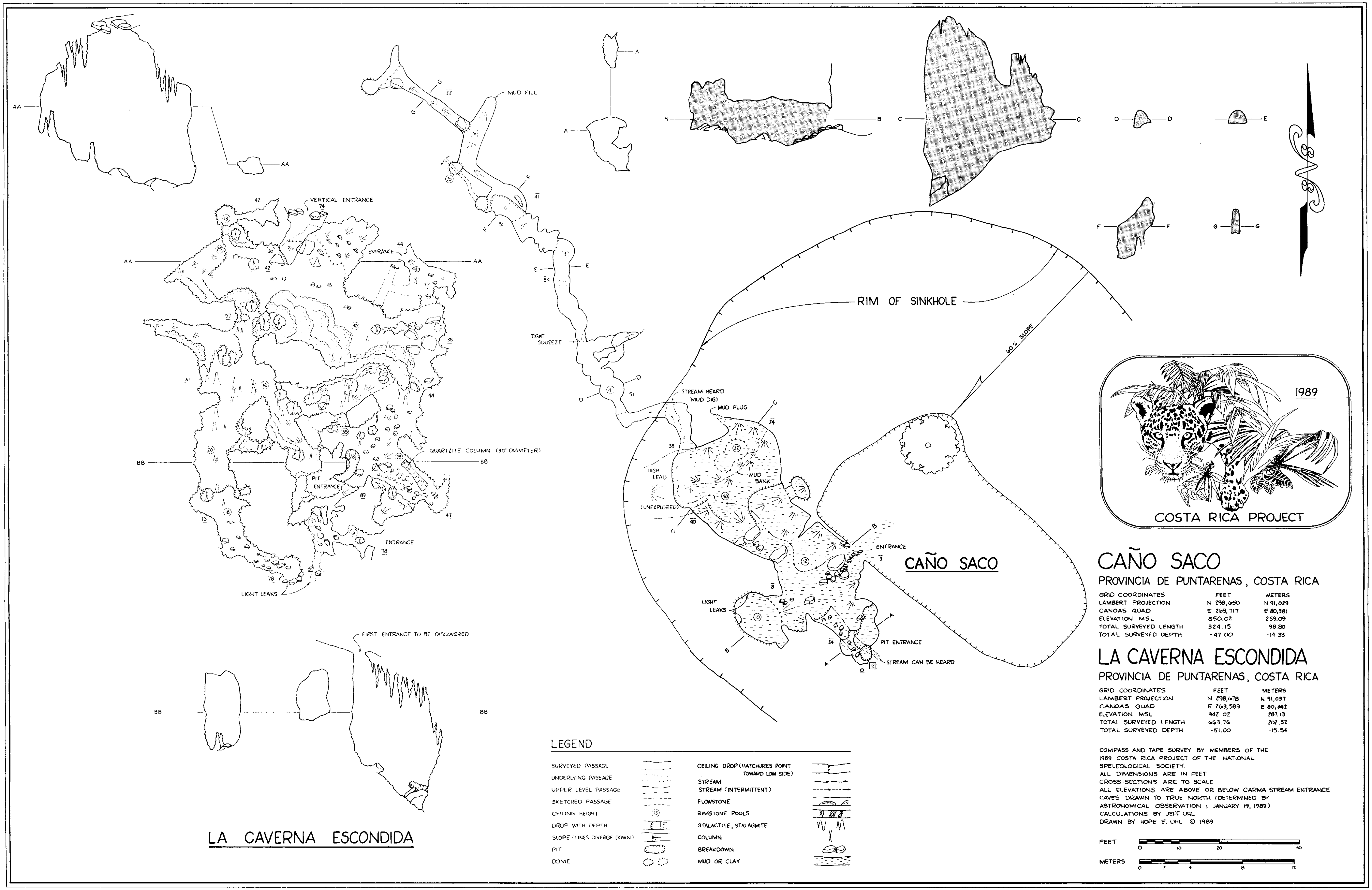


**Figure 7.19 Map of Cano Seco and Escondita Caves**

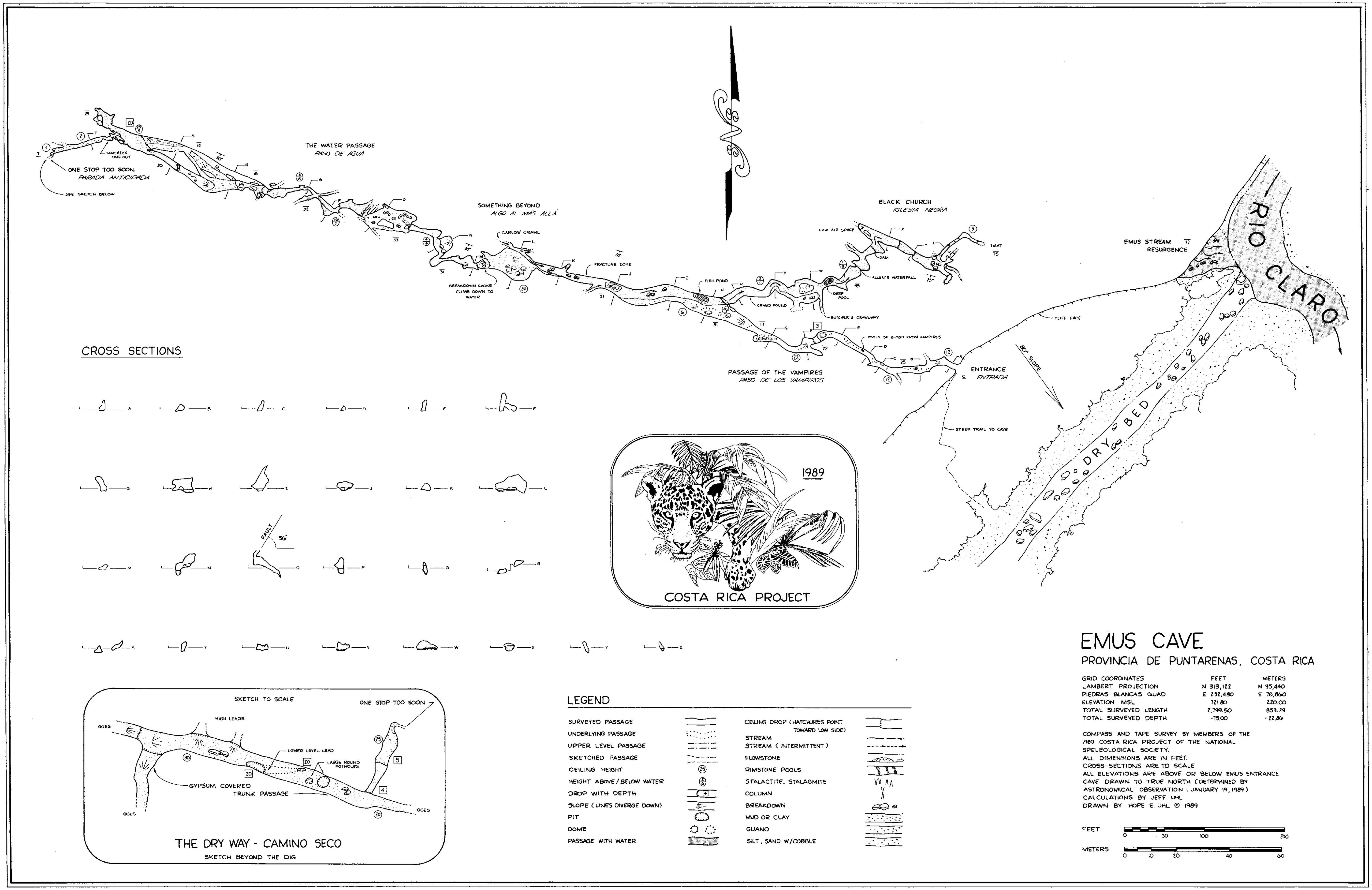


**Figure 7.20 Map of Emus Cave**

**THE BLUE PIT (Pozo Azul)**

Near Carma Cave about 1 km north of the old farm house is a large pit known to locals. This pit is reported to be 15m across and 4 to 5 seconds deep. The reports of this pit are numerous and one field team member reported seeing it on a hike. This needs to be relocated and visited.

**CAÑO SECO CAVE**

Located near the Carma entrance, this is another small cave that is probably related to Carma hydrologically. The entrance is in a large sink and is near its base. A short drop leads to a steeply sloping passage heading toward Carma.

**CARMA "EL POLOCO" CAVE**

This cave is the largest one in this section.The entrance is located at about 300m in elevation at the end of a large stream valley. Water enters the cave from the stream sink in most seasons. The entrance is 20m wide and 5m high and is situated in a large cliff headwall. The stream sinks along the right wall of the breakdown choked entrance. Next to the stream a walking passage leads down a slope to the main cave. The cave is also enterable via La Rampa entrance at the left wall. This sloping ramp entrance is entered through a 2 x 1.3m hole between breakdown blocks.

Both entrances lead to 133m of westerly trending passage that ranges from 7 to 16m high. This passage ends at Esperanza pit in a drop of 26m to underlying passages. The pit walls are highly brecciated indicating the presence of a large fault.

From the pit the cave runs both northwest and southeast along a fault. The southeast section of the cave trends 166m through two rooms to a sump near the Caño Seco Cave entrance. This passage slopes away from the pit and averages 3m in height . Large cup shaped wall scallops attest to the force at which water flows in this passage during the wet seasons.

To the northwest the passage climbs steeply up a cobble/sand passage to the upper trunk passages. Walking passages between the pit and the first room slope steeply upward and are hard to negotiate.

In the first room a walking passage to the left extends 63m to a flowstone plug. A second passage exits to the left but ends quickly after a 1m high stoop walk.

The largest room of the cave (the Umbrella Room) is located about 33m beyond the first room and is well decorated. A single passage exits this room to the left and is so highly decorated that it was named "Almost Heaven." A total of 933 meters of passage is mapped in this cave. Two other caves, Escondida and Caño Seco, seem related to this system but no connection has been made.

**LA CAVERNA ESCONDIDA**

This cave was apparently an upper level of the Carma Cave system that has been abandoned due to down-cutting of the entrance stream. The cave has multiple entrances, one of which is vertical and requires rigging. The entrances are located on a karst-covered hillside above Carma Cave. The cave is primarily a single room dissected by huge formations. The white formations give this room its name, "La Sala Blanca."

## THE RIO CLARO BASIN

This area is located near the town of Rio Claro, 17 kilometers north of the city of Neily. The area is reached via the Inter-American Highway and the Rio Claro Road. Geologically it is connected with the Fila de Cal area by 14 km of limestone hills called Fila Zapote.

Caves abound in this area but only one was fully explored by this project.

**CAVERNA EMUS**

Emus is perhaps the most challenging water cave in the country. The entrance of the cave is reached by a river road hike along an abandoned jeep trail and is located above a large resurgence at road level. The main entrance is 61m above the road in a near vertical cliff. To reach the entrance one must climb jungle vegetation to the entrance. The entrance is a vertical slot (like a doorway) leading to a walk-in passage measuring 3m wide by 3.5m high. It is the end of a dry paleo-stream passage that has been abandoned by the cave stream during down-cutting. The entrance passage trends west and is home to hundreds of vampire bats. The floor of this passage is partially covered with liquid vampire guano but otherwise is dry clay for the first 76m of walking. At this point the main cave stream intersects the main passage. This stream is habitat to a recently described species of crab (see section 8 of this report). The main stream can be found in and just below the main passage in this area. Sixty meters further along a small infeeder stream is encountered on the right. This crawl goes a short distance and becomes too tight to continue.

At this point the main stream is below the passage and a crawl down through breakdown found in 1988 and leads to the main stream passage. This crawl is on the left wall 15m beyond the side stream.

The main stream may be followed both up and down stream for a total of 536m. Much of the traverse is made by swimming and doing duck-unders. The up stream end of the cave ends 79m after it leaves the stream in a high trunk passage. It terminates in breakdown. The down stream end occurs at a sump below Allen's Waterfall. The cave has 1000m of surveyed passage. The stream was dye-traced to a nearby resurgence.

## REPORTS AND MAYBE'S

There are many caves reported in the Rio Claro drainage, and at least 5 pit caves are known between Emus and Alto Nubes. The area needs work in future trips.

Photo 7-G Bill Klimak mudding in Bananal Cave

# SECTION 8

## FAUNA OF SOUTHERN COSTA RICA CAVES

### INTRODUCTION

During the past two years (1989-1990) the efforts of the **Asociacion Espeleologica Costarricense/National Speleological Society Expedition** have resulted in the discovery of numerous caves in the Neily region of southern Costa Rica which is situated in the Province of Puntarenas and is part of the southwest Pacific lowlands and adjacent foothills area. These ongoing efforts have included not only exploration and survey of caves but have also entailed hydrological, geological, and biological studies of these karst features.

This preliminary report is a summary of the biological work undertaken and provides a list of the fauna observed and/or collected primarily from five caves, although limited data are presented for other caves. Much work remains, particularly with regard to species identification, and new species descriptions are in various stages of completion. A few specimens have yet to be assigned to any major group of organisms!

### METHODS AND MATERIALS

Because of the sensitivity of cave ecosystems globally and since very little was known about the fauna of Costa Rica

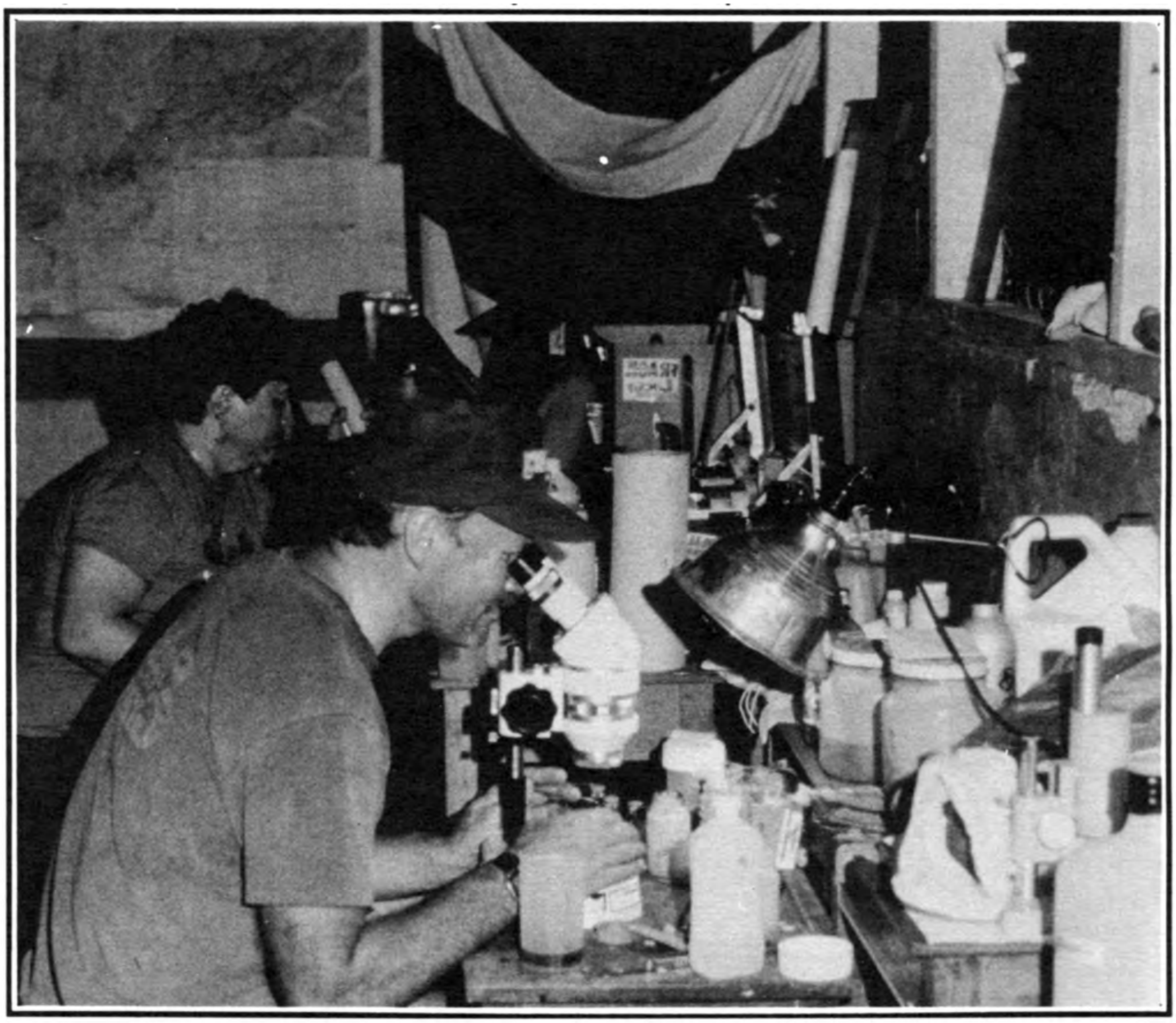

Photo 8-A Dr. Hobbs working in project lab caves (see National Speleological Society 1982; Strinati et al.,1987), only representative and very limited collections were made in caves explored. Still, comprehensive samples were taken in Carma, Corredor, and Emus caves during the 1989 Expedition and Corredor, La Bruja, and El Rectangulo caves were representatively collected during the 1990 Expedition. In addition, observations were made and very limited samples were taken from Año Nuevo, Bananal, Burnt Banana, Caño Seco, Corn Cob, New, and Tururun caves, and two small, unnamed caves in the vicinity of Corredor Cave.

A very large portion of the material collected in these caves was procured by simple search and capture. Use of aspirators, camelhair brushes, and hand-grabs were common techniques employed. Typically a "representative" portion of a chamber or section of passage was searched for a specific time (usually 30-45 minutes), a practice that would permit some measure of standard search effort. Animals collected were placed directly into 70% ethanol or 5% formalin and later transferred to 70% ethanol. No specimens of bats were taken.

Pitfall traps were set in Corredor, La Bruja, and El Rectangulo Caves for periods of 3-10 days. Pitfalls consisted of 355 ml (12 oz.) plastic cups buried to the lip in soil. Antifreeze was added to a depth of 1-2 cm and the traps baited with peanut butter. When collected, the trap contents were poured into 355 ml Whirl-Pac bags and transported from the cave. Collections were later strained from the antifreeze and preserved in 70% ethanol or 5% formalin.

Aquatic habitats varied from small, shallow, isolated pools, to deep, extensive pools, and from shallow or deep slowly moving or rapidly flowing streams. Hand collecting using screens and dipnets was effective for obtaining macroinvertebrates ( and one pimelodellid catfish). A Surber sampler was used in places where sufficient flow was confined and where the substrate consisted of cobbles and gravel. A net (330 microns) was placed against the substrate and held while the upstream bottom was disturbed. Particles dislodged and floated downstream where they were caught in the net. Wire minnow traps, baited with cat food, were used in deep pools and streams (lid and bottom punctured); these traps were left in the cave for up to 72 hours. All samples were preserved in 70% ethanol or 5% formalin.

## RESULTS

The following tables are summaries of the fauna observed or collected in the caves from 31 December 1988 to 21 January 1989 and from March 4 to 24, 1990. Although only representative collections were made, hopefully these data will aid in our understanding of the distribution, relative abundance, and ecology of the organisms inhabiting Costa Rica's caves. Five phyla, represented by at least 11 classes and 27 orders, are recognized; many taxa are awaiting specific identification by specialists.

**Table I.**
**PHYLOGENETIC LISTING OF FAUNA WITH ECOLOGICAL NOTES**

**Phylum Platyhelminthes**
- Class Turbellaria - A single planarian was collected from a room at the end of the dry series of passages in Corredor Cave

**Phylum Anellida**
- Class Oligochaeta
  - Order Haplotaxcida - "Earthworm" from Corredor Cave
- Class Polychaeta
  - Subclass Errantia
    - Family Nereidae
      - Subfamily Namanereidinae
        - Lycastopsis sp. - Very small, white polychaete worm from "organic pool" in Corredor Cave

**Phylum Arthropoda**
- Subphylum Chelicerata
  - Class Arachnida
    - Order Scorpionida - A single specimen was collected in the Serpentarium area of El Rectangulo Cave
    - Order Pseudoscorpionida - Several specimens from beneath small rocks on moderately dry substrates in Emus Cave
    - Order Amblypygida
      - Paraphrynus viridiceps - probably the species encountered in most caves. They are fairly abundant, particularly within 100m of the entrance in usually dry areas in Año Nuevo, La Bruja, Caño Seco, Carma, Corredor, Emus, and El Rectangulo caves
    - Order Araneae - Several species of spiders were observed in many caves

visited; collections from Año Nuevo, La Bruja, Burnt Banana, Corredor, Emus, New, and El Rectangulo caves. Most were observed in the environs of the entrance but many were seen in the deep portions of caves in dry to moist environments with or without organic debris. One small spider is of special note in that in addition to spinning a small web, it made a 3-4 mm square cube (egg case) that was suspended from the cave ceiling.

Order Opilionida

Family Phalangodidae - Harvestmen were collected from Año Nuevo, La Bruja, Corredor, and El Rectangulo caves. They were found near entrances as well as deep within caves and commonly were located on the walls of cave passages.

Order Acarina - Although undoubtedly abundant, mites were collected only in dried bat guano in Emus and El Rectangulo caves and aquatic mites were collected atop boulders in the entrance area of La Bruja Cave.

Subphylum Mandibulata

Class Crustacea

Subclass Copepoda - Copepods were found in small pools on boulders in the entrance room in La Bruja Cave. Cyclopoid and harpacticoid copepods are among the microcrustacean fauna being sorted and identified.

Subclass Malacostraca

Order Bathynellacea - A number of specimens of what may be bathynellids and would represent the first specimens recorded from Central America.

Order Isopoda - Terrestrial isopod (trichoniscid/oniscoid) from organic debris in dry sections of Corredor Cave.

Order Decapoda

Suborder Natantia

Family Palaemonidae

Macrobrachium carcinus - Shrimp collected in a trap from the stream in Corredor Cave and observed in pool in stream in Emus Cave; collected specimen from small silt-bottomed pool and observed shrimp in pool in upstream portion of La Bruja Cave; this species was seen in vicinity of Calgary Hall and in the Serpentarium sections of El Rectangulo Cave.

Suborder Reptantia

Family Pseudothelphusidae

Ptychophallus montanus - Crab from Carma Cave; observed in isolated pools (rimstone) in stream; large crab noted at bottom of short drop on sandy substrate not adjacent to any known water source; also collected in Año Nuevo Cave where stream first appears about 90 m from the entrance.

Pseudothelphusa puntarenas

Crab from cobble-bottom stream in Emus Cave.

Class Entognatha

Order Collembola - Springtails were noted in a variety of habitats, including bat guano and were collected in pitfall traps. They were collected from La Bruja, Corredor, and El Rectangulo caves.

Class Insecta

Order Odonota

Suborder Zygoptera - Probably a surface species - collected in Carma Cave.

Order Blattodea - Two species of roaches were collected in Carma and Emus caves; one on cave wall and other burrowing in dry soil. additional specimens were obtained from a pitfall trap in the bottom chamber of La Bruja Cave, from an area with rocks and dry mud in El Rectangulo Cave, and from the connection passage between Tururun & Corredor caves.

Order Dermaptera - Earwigs were collected from dried sediments in a rimstone pool, from bat guano pile, and from a wet section of cave (near "Ship's Keel") in Corredor Cave. Earwigs were also found in bat guano in the entrance of Emus Cave and in passages near the entrances of El Rectangulo and Corredor caves.

Order Orthoptera

Suborder Ensifera - Crickets were fairly common throughout La Bruja, Carma, Corredor, Emus, and El Rectangulo caves. They occupied a variety of habitats, and were particularly abundant on cave walls near entrances and in chambers and passages that were relatively dry; rarely were they observed in wet areas of caves. An unusual horned and eyed specimen with a very long ovipositor was collected from a pitfall in a small pit deep within Corredor Cave.

Order Hemiptera - A small hemipteran was collected from the entrance area of El Rectangulo and probably is a surface species.

Order Coleoptera - Various beetles from La Bruja, Carma, Corredor, Emus, and El Rectangulo caves were collected from wet and dry passages as well as from areas relatively close to entrances.

Order Diptera - Flies (larvae and adults) were collected from Carma and Emus caves where fly larvae populations were very dense in black, semi-liquid pools of vampire bat guano. Larvae and adults were collected in La Bruja Cave, and adults were obtained from Año Nuevo, Corredor, New, and El Rectangulo caves in both wet and dry passages. Mycetophilid larvae with webs were particularly abundant on the ceiling in wet portions of El Rectangulo Cave.

Order Lepidoptera - A small, adult moth was collected from a dry passage near the pit entrance to Corredor Cave.

Order Hymenoptera - An unidentified hymenopteran was collected from La Bruja Cave. A specimen was also collected in a dry passage near the pit entrance of Corredor Cave.

Family - Formicidae - Large ant within 100 m of entrance of Emus Cave was collected. Ants were obtained also from the entrance environs of La Bruja Cave.

Class Diplopoda - Two species of millipedes from Emus Cave were observed in bat guano deposits; millipedes were also collected from Año Nuevo, New, and El Rectangulo caves. None of these has been identified to species.

**Phylum Mollusca**

Class Gastropoda - Two species of snails from bat guano and shallow pools in Corredor Cave and shells (poor condition) of three species were found on the walls of the second large chamber in El Rectangulo Cave.

**Phylum Chordata**

Bones collected from Bananal and Emus caves await identification.

Class Osteichthyes - A pimelodelled catfish was collected from an upstream pool at the bottom of La Bruja Cave and this fish was common in the entrance-

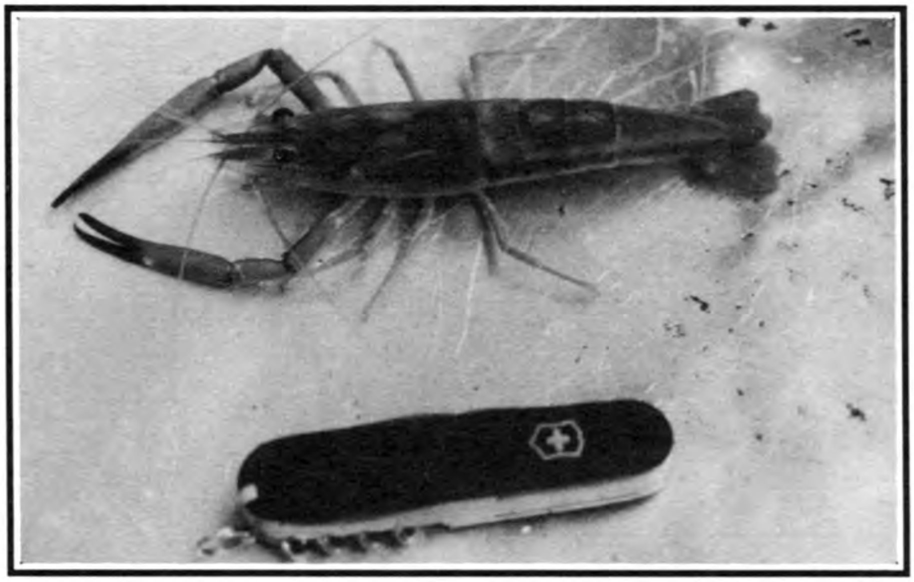

Photo 8-B

*Macrobrachium* shrimp

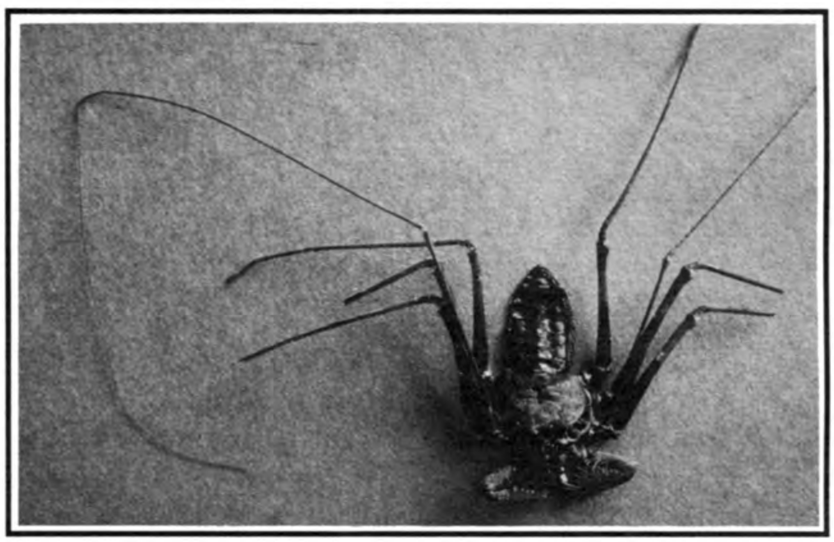

Photo 8-C

Amblypygida

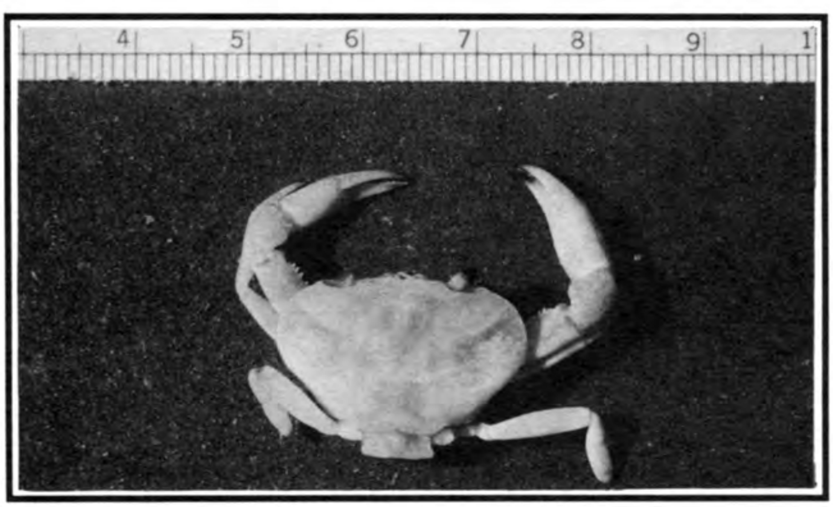

Photo 8-D

*Pseudothelphusa puntarenas* (NEW)

end of the pool section of El Rectangulo Cave; catfish were observed in the lake at the bottom of Bananal Cave. El Rectangulo floods sufficiently frequently that tiny cyprinid fishes were found in mud-bottomed pools up-cave of Calgary Hall.

Class Amphibia

Order Anura - Translucent, yet bright scarlet and lavender, tadpoles were collected from a gravel-bottomed pool in Carma Cave. Tadpoles were captured from pools in a dry passage near the pit entrance and from a small pool in mud above the stream in Corredor Cave. A frog was collected at the bottom of the entrance room of Corn Cob Cave and a small arrow frog was captured from the chamber beyond the entrance to Corredor Cave.

Class Mammalia

Order Chiroptera

Family Phyllostomatidae

Phyllostomus sp. - Large bats were observed high in the room south of the entrance to Corredor Cave - probably this genus.

Desmodus rotundus - Vampire bats were commonly observed in small domes or crevices in the ceiling of Emus Cave; they were in clusters of a few individuals to more than 50. The presence of this species in a cave can be determined immediately by the pungent odor of the cave as well as by the pools of black, semi-liquid to "greasy" guano beneath their roosts. These pools harbor a distinctive invertebrate fauna, including several families of flies and various beetles. This bat was also noted in a small cave opposite (Alma) and 50 m downstream from Corredor Cave and guano of this bat was observed in the entrance area and in the passage between the river and main access to the wet series in Corredor Cave.

Corollia perspicillata azteca - This short-tailed bat was observed near the entrance of Carma and Corredor caves; many individuals were noted hanging from the ceiling by one foot.

Micronycteris megalotis mexicana - This short-eared bat was observed in Corredor Cave and a very small cave at stream level directly below the entrance to Corredor Cave

**Table II. LIST OF FAUNAL OCCURRENCE BY CAVE**

| CAVE | ORGANISM |
|---|---|
| **Año Nuevo Cave** | Amblypygida |
| | Araneae |
| | Opilionida |
| | Ptychophallus montanus |
| | Diptera |
| | Diplopoda |
| **Bananal Cave** | Osteichthyes |
| **La Bruja Cave** | Amblypygida |
| | Araneae |
| | Opilionida |
| | Acarina |
| | Copepoda |

Macrobrachium carcinus
Collembola
Blattodea
Orthoptera
Coleoptera
Diptera
Hymenoptera
Osteichthyes

**Burnt Banana Cave**

Araneae

**Caño Seco Cave**

Amblypygida

**Carma Cave**

Ptychophallus montanus
Amblypygida
Zygoptera
Blattodea
Orthoptera
Coleoptera
Diptera
Anura
Corollia perspicillata azteca

**Corn Cob Cave**

Anura

**Corredor Cave**

Tubellaria
Haplotaxida
*Lycastopsis* sp.
Isopoda (terrestrial)
Macrobrachium carcinus
Amblypygida
Araneae
Opilionida
Collembola
Blattodea
Dermaptera
Orthoptera
Coleoptera
Diptera
Lepidoptera
Hymenoptera
Gastropoda
Anura
Phyllostomus sp
Desmodus rotundus
Corollia perspicillata azteca

Micronycteris megalotis mexicana

**Emus Cave**

Macrobrachium carcinus
Pseudothelphusa puntarenas
Pseudoscorpionida
Amblypygdia
Araneae
Acarina
Blattodea
Dermaptera
Orthoptera
Coleoptera
Diptera
Hymenoptera
Diplopoda
Desmodus rotundus

**New Cave**

Araneae
Diptera
Diplopoda

**El Rectangulo Cave**

Scorpioniida
Amblypygida
Araneae
Opilionid
Acrina
Macrobrachium carcinus
Collembola
Blattodea
Dermaptera
Orthoptera
Hemiptera
Coleoptera
Diptera
Diplopoda
Gastropoda
Osteichthyes -
Pimelodidae
Cyprinidae

**Tururun Cave**

Blattodea

**Small unnamed cave** at at stream level directly below Corredor Cave

Micronycteris megaloitis mexicana

**Alma Cave** opposite and 50m downstream from Corredor Cave — Desmodus rotundus

## DISCUSSION AND SUMMARY

Fourteen caves in the Province of Punterenas, southern Costa Rica, were sampled for biota during the 1989 and 1990 Asociacion Espeleologica Costarricense - National Speleological Society Expeditions. Although much work continues on the organisms collected during these expeditions, to date five phyla, represented by at least 11 classes and 27 orders, are recognized. The actual number of species observed/ collected in these caves has not yet been determined.

Sorting and identification of samples from the Costa Rican caves continues and will for some time in the future. Already, undescribed species have been discovered and the ranges of many organisms have been significantly changed; undoubtedly numerous new taxa will continue to appear as these samples are processed.

Because of our lack of knowledge and due to the sensitivity of cave ecosystems, members of future expeditions are encouraged to continue to make **limited** but **representative** collections of cave inhabitants (with appropriate data accompanying each collection). Not only will these data tell us what kinds of organisms live in what types of cave environments in tropical Costa Rica but it is anticipated that we can begin to understand **why what is where!** Based on the distribution of certain animals in particular caves, on cave/ springwater quality, and on dye tracing data, we are hopeful that biological data will support geological/hydrological data; that is, certain species may prove to be restricted to certain cave systems hydrologically isolated from others. Continued research over the next few expeditions should yield valuable data on all aspects of these scientific endeavors.

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Strinati, Pierre, Guillermo Cortes, and Carlos Goicochea. 1987. Quelques grottes du Costa Rica et leur faunae. Actes du 8th Congres national de la SSS, 1987: 23-32.

## ACKNOWLEDGMENTS

These lists result from the efforts of many individuals who were a part of the 1989 and 1990 expeditions, and all who aided in the biological investigations are thanked. D. Scott Jones, Fred Grady, and A. Fogle were most helpful during the 1989 Expedition. Appreciation is extended to Pat Shaw for overseeing the biological work during the 1990 Expedition and special thanks to Charles Kronk and Bill Stitzel for their tireless efforts during the 1990 trip. C. Glasby is acknowledged for his determination of the nereidid polychaete and appreciation is extended to Andy Grubb for his tentative identification of the amblypygids.

# PLATES AND NEW DISCOVERIES

## A NEW PSEUDOTHELPHUSID CRAB FROM A CAVE IN SOUTHERN COSTA RICA (DECOPODA:BRACHYURA)

H.H. Hobbs III

Since the publication of the monograph on the Pseudothelphusidae by Rodriguez (1982), only three new species of Pseudothelphusa have been described (Alverez 1987, 1989; Alvarez & Villalobos 1990), all from southern Mexico. During a joint Asociacion Espeleologica Costarricense - National Speleological Society Expedition to Costa Rica, a fourth species, described herein, was discovered from Emus Cave in Provincia de Puntarenas and represents the first cavernicolous pseudothelphusid known from Costa Rica. This species brings the total number of Central America (Mexico, Guatemala, Belize, and Costa Rica) cave pseudothelphusids to 16 (see also Reddell 1981; Rodriguez & Hobbs 1989a, 1989b). Information concerning other cavernicolous pseudothelphusids can be found in Rodriguez (1985, in press) and Rodriguez and Bosque (1990). Terminology follows that used by Rodriguez (1982). The following abbreviations are employed: USNM, United States National Museum (Smithsonian Institution), Washington, D.C.; IVIC, Centro de Ecologia, Instituto Venezolano de Investigaciones Cientificas, Caracas, Venezuela; CL, carapace length; CW, carapace width.

**Description.** — Superior frontal border of carapace (Fig 1A,C) generally smooth, divided medially by notch continuous with median groove. Inferior frontal border well defined, formed by small tubercles from which carapace rising steeply. Carapace surface (Fig. 1C) weakly convex with regions moderately well defined, gastric and branchial regions elevated; limits of epigastric regions rather obscure; broadly V-shaped cervical groove prominent, not reaching anterolateral margin. Anterolateral margin rather evenly rounded with 8-12 small denticles between orbit and cervical groove. Pterygostomian region densely setose (Fig. 1A). Third maxilliped (Fig. 1A, L) with exopod greater than half length of ischium; ischium/ecopod ratio varying from 53.4-64.3, average 59.3. Chelipeds unequal, right chela (Fig. 1B) generally more robust than left with mildly sinuous ventral margin; fingers of major chelae gaping, curved, and weakly punctuate; teeth on opposable cutting surfaces of finger of moderate size. Ventral view of body as in Fig. 1K. Eyes well developed, pigmented; carapace mottled with tan, brown, and reddish-brown pigmentation.

First male gonopod (Fig. 1D-G) with distal half arched laterally and with prominent triangular-shaped cephalic process; reniform mesial process well developed. Gonopod bearing short, stiff setae on middle part of mesial margin and few long setae on proximal half; apical cavity (Fig. 1J) elongated along caudo-cephalic axis, bearing setae over middle and cephalic end of cavity; terminal pore setae most densely distributed toward cephalomesial portion of cavity; borders of cavity of equal thickness with mesial one slightly elevated above lateral border; opening of sperm channel situated cephalically. Second male gonopod (Fig. 1H, I) extending to or slightly beyond apical end of gonopod; terminal part covered by numerous oblique rows of closely arranged spinules.

**Type material.** — Holotype: male, CL = 11.7 mm, CW = 18.3 mm, USNM 250555; paratypes: 3 males, CL = 9.7, 12.95, 8.3 mm, CW = 15.4, 21.5, 13.0 mm; 7 females, CL = 8.2, 10.5, 13.9, 15.9, 13.5, 11.2, 13.7 mm, CW = 12.9, 16.0, 22.6, 25.9, 22.1, 18.1, 22.1 mm, USNM; 1 male, IVIC

**Type locality.** — Small stream in Emus Cave, Provincia de Puntarenas, Costa Rica. The crabs were found approximately 120m from the entrance in pools and small riffle areas with rubble-cobble-gravel limestone substrates. The stream in Emus Cave on 1 January 1989 (temperature 24.3C) resurged about 23m in elevation below the entrance and flowed directly into the Rio Claro. A species of Macrobrachium (probably M. carcinus (Linnaeus)) was observed but not collected, as were individuals of an unidentified catfish.

**Etymology.** — This species is named for the Province, Puntarenas, where the cave is located in southwestern Costa Rica.

**Relationships.** — Although few external morphological characteristics have been demonstrated to have taxonomic value within the pseudothelphusids (Rodriguez, 1982), the gonopod however, has proven to be an important structure for distinguishing species. The distal part of the gonopod of the male of P. puntarenas shows similarities to that of P. leiophrys, Rodriguez & Smalley, 1969; P. galloi, Alvarez & Villalobos, 1990; P. granatensis, Rodriguez & Smalley, 1969; P. jouyi, Rathbun, 1893; P. parabelliana, Alvarez, 1989; and P. mexicana, Alvarez, 1987. The gonopods of all these species hav,e a well developed mesial process but in P. puntarenas, P. galloi, and P. leiophrys, the outer margin is smooth whereas it is serrate in the other species. The apex of the gonopod of P. mexicana, P. parabelliana, and P. granatensis has a well developed lateral lobe with three, two, and two projections, respectively, while P. puntarenas lacks a well developed lateral lobe. In general, the gonopod morphology of P. puntarenas is closer to that of P. leiophrys, but can easily be separated from it by the well developed cephalic process in P. puntarenas.

**Acknowledgments**

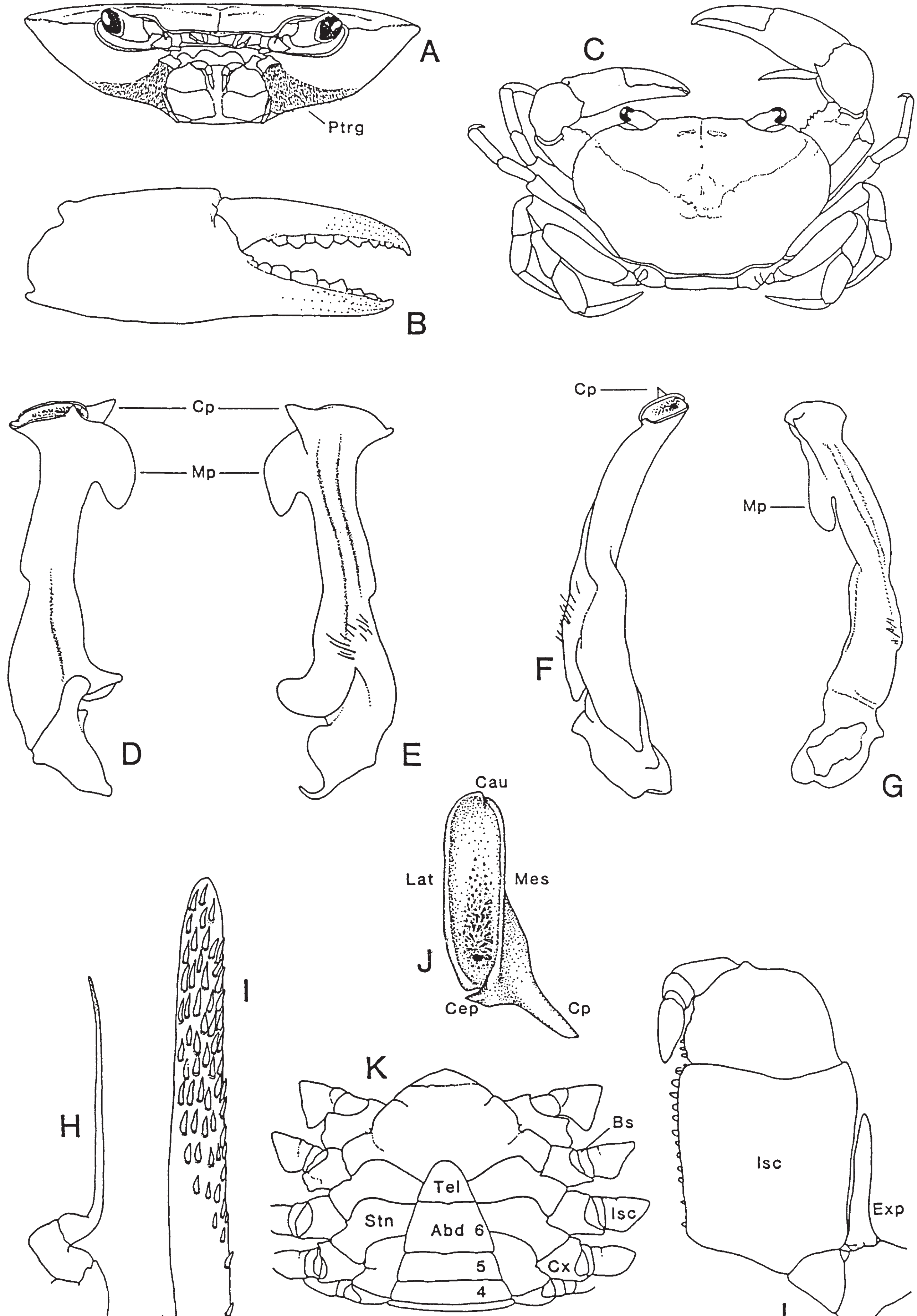
Appreciation is extended to the members of the 1989 Asociacion Espeleologica Costarricense - National Speleological Society Expedition for their Costa Rica and to F. Grady who helped collect the crab specimens. I am also grateful to H. H. Hobbs, Jr., and G. Rodriguez for their criticisms of the manuscript. This work was supported in part by grants received from the Faculty Research Fund Board and the Faculty Development Organization of Wittenberg University.

* Excerpts from the original description published 1991 in Proceedings of the Biology Society of Washington 104 (2:295)

**LEGEND FOR FIGURE**

Fig. 1 Pseudothelphusa puntarenas, new species **A,** frontal view of carapace, orbital and buccal region **B**, right chela **C**, dorsal view of crab **D**, lateral view of left first gonopod of male **E**, mesial view of same **F**, caudal view of same **G**, cephalic view of same **H**, caudal view of male second gonopod **I**, distal part of male second gonopod **J**, apical view of male left first gonopod **K**, sternum and abdomen, ventral view **L**, left third maxilliped (setae not shown)

Abbreviations: **Abd**, Abdomen **Bs**, Basis **Cau**, Caudal **Cep**, Cephalic **Cp**, Cephalic process **Cx**, Coxa **Esp**, Esopod **Isc**, Ischium **Lat**, Lateral **Mes**, Mesial **Mp**, Mesial process **Ptrg**, Pterygostomian region with setae **Stn**, Sternite **Tel**, Telson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# SECTION 9

## MYCOLOGY STUDIES IN THE RIO CORREDOR BASIN

### INTRODUCTION

During the 1989 field season several of the projects personnel were stricken with a respiratory illness later identified as Blastomycosis. This fungus was believed to have been encountered in the caves of the Corredor River Basin. As part of the study undertaken during the 1990 season limited mycologic investigations were begun. While much of the data is preliminary and inconclusive it is useful in understanding the ecologic processes occurring in the caves within the study area.

As a side study water samples were taken from most water sources utilized for domestic drinking water. The results of these studies are included herein.

Samples of water and soil from Carma Cave, Corn Cob, Emus Cave, Caverna La Troja, Caño Seco, Bananal, Galeria Grande, Rectangulo Cave, Burnt Banana Cave, Corredor Cave, Año Nuevo Cave, base and remote camp, and other drinking water supplies were collected and cultured in the field for total bacterial plate count, Coliform (water only) and mycological assay (soil and water).

Water samples from caves were less contaminated than drinking water at local commercial establishments. Predominant fungi in cave soils belong to Aspergillus, Penicillium, Blastomyces and Fusarium with several species and variants of each represented.

It was not possible to detect Histoplasma or Paracoccidioides in any of the samples.

### PURPOSE

Several members of a previous expedition to the study area contracted what was called "Blastomycosis." The correct nomenclature for this illness is Paracoccidioido-mycosis, and is produced by Paracoccidioides braziliensis. The condition is similar to Histoplasmosis with which it is often confused. On this expedition we would attempt to locate the source. In addition, the general condition of the local waters would be assayed, and simple microbiological studies of the caves and environs would be attempted to provide baseline data to assist the Costa Rican government in studies of rainforest clear cutting.

### METHODS

Samples of soil and water from caves in the study area were cultured on Plate Count agar (DIFCO 0479-01-1), and Sabaraud's Modified agar (DIFCO 0747-01-7) in the field, and then taken back to the lab for additional culturing and identification. One tenth of one milliliter of collected water samples were swirled into molten plate count agar at approximately 40 degrees Centigrade, which was then allowed to solidify.

After 24 hours, colonies were counted. Additionally, small aliquots of the same water samples were inoculated into inverted vials of E Coli Medium (DIFCO 0314-01-1) and incubated at ambient temperatures which remained very close to 37 degrees Centigrade. These were observed for gas production, presumptive evidence of Coliform bacteria.

Samples from water, soil, and other specimens were suspended in sterile distilled water. Small aliquots were then streaked or poured onto the surface of solid Sabaraud's agar and allowed to grow out for several days. Plates were examined with a low power stereo microscope and gross characteristics of each colony were noted. The specimens were sealed in plastic baggies and locked in a grommeted ammunition can for shipment. In this manner, specimens could be transported to the lab in relative safety, while information about the cultures would be preserved with the hope of later identification. It was not desired to open the culture plates to mount specimens due to the potential hazard. Lack of sterile isolation hoods and other security considerations led us to adapt this approach. Later, in the laboratory, the specimens were re-cultured in an identical manner and in many cases the same gross characteristics were noted. Agar block technique was then used to safely provide clear visualization of growth and sporulation characteristics for identification of genus and eventually, species.

### CAVE STUDIES

#### Corredor Cave

Corredor Cave was sampled for water, guano, and feces of a rat. Rio Guaymi samples yielded 6000 bacterial cultures per 100 cc, with no Coliforms.

The feces (4mm-1cm cylindrical - one end tapered -rodent?) appearing to have fungal growth (possibly sporulating) were found just past Los Italianos where a dry passage departs the stream bed to the south. The feces was found on the westernmost side of the beginning of the passage. Its appearance in situ was that of randomly scattered loose pellets.

Under low power were seen numerous scattered bulbous-white "fruiting bodies," with no mycelia visible.

Fruit bat guano from the area between the Pseudoscorpion Room and the Formation Room was cultured and examined under low power.

Tan-brown yeast or bacterial colonies appeared within 24 hours with mucus-like consistency. On Sabaraud's agar heavy bacterial growth took place similar to that found

**TABLE #1**

| CAVE | HIGHEST BACTERIA PER 100 CC | FUNGI OBSERVED | FAUNA |
|---|---|---|---|
| Año Nuevo | 220000 | at least 1type | bats, crab |
| Bananal | | | frog |
| Burnt Banana | | none seen yet | bats |
| Carma | | | |
| Caverna de Castillo | | | bats |
| Caverna de Troja | | | bats |
| Caverna Escondida | 1000 | at least 1 type | |
| Corn Cob | | Ascomyces ? | |
| Corredores | 18000 | Penicillium sp | frb, vpb, rat |
| Emus | | | lacking |
| Grand Gallery | | at least 1 type | bats |
| La Bruja | | | |
| Los Castillos Real | | | fruit bats |
| Maca Meca | | | vbp 41m |
| Pozo Nautilus | | | bats, rats |
| Rectangulo | 50000 | none seen yet | catfish |
| Three Hole Harry | | | bats |

Field cultures on Sabaraud's agar yielded bacterial colonies which were smeared in all directions, possibly by surface movement of amoebae. One week later, clusters of white mycelia appeared. Later lab cultures recovered this organism and it was identified as Penicillium sp.

Additional colonies seemed to represent more than one species of Penicillium; one with fluffy but low-growing white mycelia which darkens the agar while growing into it, another with surface mycelium which darkens the agar but with no subsurface activity, not yet identified.

From the same pellets grew a chocolate-spored variety with concentric growth rings, the mycelia not visible under heavy sporulation. Agar block culture on a microscope slide allowed identification of the genus as Blastomyces.

in water samples elsewhere. A fungus appeared one week later with large globular spore sacs. These are believed to be a species of Aspergillus. Lab cultures also yielded fibrous ropy synnematous, mostly flat, off-white growth. These "ropes" reach to the lid of the petri dish in single columns or sometimes anastomose midway. These are as yet unidentified.

Another culture yielded black spores with greenish specks suspended from webs of white mycelia, also unidentified.

Yet another lab culture grown at 37 degrees C. yielded foul smelling Actinomyces or Nocardia.

Found near Los Italianos was a 145mm x 2-3mm diameter stick of and unknown surface flora. Its surface was longitudinally striated and appeared to be covered with fungal growth. Under incandescent lighting there is a slight bluish color near one end. The passage is dry here, although flooding might be a means of entry. Field cultures on Sabaraud's yielded the usual bacterial overgrowth with fungi appearing about one week later.

One culture produced grey spores on white mycelia. A diluted specimen was cultured, but only bacteria appeared. Later lab cultures were unsuccessful in recovering this fungus. Also, bacterial analysis has not yet been attempted.

The cave had quite a few fruit eating bats. There were several small patches of guano everywhere with larger concentrations in roosting areas. Large foot long stalks were seen growing from chestnut sized seeds but only in a few places. Very large bat bones found in guano piles were not collected. One partly decomposed bat with a complete skull was observed but not collected. No vampire bats were seen directly, but a few scattered pools of tar-like material were observed and sampled. Formalin fixed material from one such puddle contained liver-fluke like organisms, fibers of bat hair, plant material or cellulose fibers, one short reddish solid strand resembling a vein, and one rather large "tube" with dark spots along its "spine." On close examination, these pools seemed to be boiling with life-forms.

**Año Nuevo Cave**

Survey teams carried sterile sample tubes into this cave and returned with several water and soil samples. This cave has by far the most varied and interesting fungi of all those collected.

None have yet been identified. Because this cave had an occluded entrance, the possibility of human contamination can almost be ruled out. Surface activity over this cave includes a coffee plantation and cattle grazing.

Below the Pillar Climb two soil samples were returned. One was from the upper soil layer and had a distinct brown tint while a deeper specimen was grey. Cultures were started on Sabaraud's containing 1/2 million units of Penicillin G per liter. The upper soil layer was diluted into distilled water and cultured. Within 24 hours a heavy fungus growth with white mycelia was found. The plates had a fruity odor, and contained additional colonies of yeast or Penicillin resistant bacteria. No other characteristics were noted at the time, and later lab work has failed to reproduce this culture.

Lab cultures from the same soil layer produced small colonies of mycelia which seemed to be able to reproduce by forcible discharge of spores over a distance of 1 cm or more.

Another lab culture yielded pale agar-colored thin-branched mycelia with many globules of clear exudate suspended on a very flat colony which quickly filled the plate. Other colonies were isolated which produced small fluffs of white mycelia having root-like processes. One of these had a mucus-like surface activity with reddish brown "rootlets" under the surface of the agar. Armilleriella mellea produces a similar growth pattern, but it is not believed to be the case here.

Some of these colonies appeared to spread on the agar surface like a slime mold with "fans" of growth projecting down into the agar reaching all the way through the gel. In one case crystals appeared in the agar proximally to these, both under the agar and on the surface.

One culture yielded a very interesting three-dimensional growth with processes growing all the way from agar surface to petri dish lid in one filament. The filament has globules of exudate suspended along its length.

One culture incubated at 37 degrees C produced a foul smelling organism which resembled Actinomyces or Nocardia.

Water samples from stalactite drips gave bacterial colony counts from 18800 to 50000 per 100cc. Samples from the stream gave counts of 13000 to 22000 per 100cc.

**Burnt Banana Cave**

Bat bones were collected by surveyors when they observed what appeared to be fungal hyphae attached to them. Cultures on Sabaraud's without Penicillin did not yield any fungal growth, but did have some spotty bacterial colonies, some of which were yellow in color.

At the bottom of the drop, specimens were collected which produced white lumpy mycelia that darken in center area with sparse vertical hyphae with green spores. Agar block cultures in the lab keyed out to Aspergillus sp.

Another culture from the same area produced white flattened mycelia with rare vertical spore bearing hyphae. The growth darkens the agar slightly on Sabaraud's with Penicillin and changes morphology on re-culture. Agar block cultures have not been successful.

**Rectangulo Cave**

Only water samples were brought back by survey teams. Twenty-four hour plate counts were done immediately. Sabaraud's pour plates were also prepared, but only one fungus appeared.

From separate pour pools in the fault chamber just downstream of La Serpentia samples gave counts of 1000-2000 colonies per 100cc.

Samples from a bat feces pool in La Serpentia gave very high bacteria counts and one fungus which produced dark mycelia but no spores. Here, counts are 10,000 - 50,000/100cc. The fungus was cultured on Sabaraud's.

Spot samples were taken from cave streams before survey teams contaminated them by swimming. Locations are: 1st sump end of "B" survey - 1000 colonies /100cc; Stream at station c-7 - 1000/100cc; 2nd stream insurgence south of station e17 - 5000 colonies/100cc.

### Bananal Cave

This cave became known for the "itch." Almost without exception, explorers would report an itching or burning sensation especially on the legs or behind the knees immediately upon exiting the cave. Small dark pellets, possibly of insect origin were collected in Norma's Palace on the mud slopes above the stream channel. Hairs or webs were clearly visible in the sample tube.

Culturing produced a mucus base with scant mycelia having a ropy appearance and buff color throughout. Agar darkens with age. Lab cultures were Fusarium sp.

Surface soil from the entrance sink was collected and cultured. Matted mycelia with very small greenish yellow spores and small white tufts of mycelia in concentric rings having distinct growth bands. This was identified as Blastomyces sp. from agar block culture. Bananal mud specimens gave white fluffy wet mycelia on malt agar. Eventually a heavy mat fills the dish. There is slightly less growth on Sabaraud's. No spores were produced in either case.

Bananal surface sink soil also produced dark brown rhizomorphic mycelia at agar surface with fluffy "top-hairs." Agar in this culture turned deep black.

Another culture from the surface soil produced a slime-mold like growth on malt agar with Penicillin added. Most of the growth was beneath the agar surface in the form of synnematous ropes radiating from a blob which appears on agar surface. The blob was flesh colored throughout, approximately 0.5cm in diameter and hollow. Construction appeared to be of individual cells. Some surface hyphae were re-cultured and identified as Fusarium sp.

Bananal surface sink soil cultures produced Fusarium sp. which darkens agar with subsurface runners radiating from the center and had white surface mycelia with numerous white spores.

### Carma Cave

At Carma Cave and locale we took three samples; one water at Carma Cave insurgence, one of soil in La Sala Blanca in La Caverna Escondida, and one aseptically collected dripwater. In spite of what appeared to be a large amount of bovine feces in the watershed, the water insurging into Carma cave only had 1000 colonies per 100cc. Fungi were also present and produced growth on Sabaraud's agar overnight.

Near a column in La Sala Blanca a small amount of soil was sampled and cultured. The Sabaraud's plates were quickly overrun with bacteria, some of which were pink colored and suggestive of Serratia. Nearby stalactite dripwater produced counts of 1000 colonies per 100 cc.

### Grande Galeria

On a stalactite in the southernmost reaches of this cave could be seen small fibers or strands of material which could be fungal hyphae. Cultures were started on Sabaraud's with Penicillin. Fine white filamentous mycelia with very small white spores borne directly on hyphae appear to be a species of Fusarium.

Another colony was isolated from the same specimen which yielded a mucus growth on agar, filaments extending to the cover of the petri dish in a column of "bundled" fibers. No visible spores have yet been produced.

The soil in this area of the cave does not seem to have been disturbed. Cultures were made on Sabaraud's with Penicillin which produced growth which was different from the stalactites directly above. White mycelia aging to pink-pores born on hyphae are buff colored. Folds form in older mycelia which darkens the agar. There is a mottled appearance to the surface of the mycelia and an exudate leaves depressions upon evaporation.

Another colony has white mycelia that leaves agar black. Numerous dark brown specks appear everywhere (spores?).

The presence of Fusarium in this cave is interesting in light of the fact that the surface plantation activity includes bananas, a Fusarium host. It cannot be determined whether the Fusarium present in the cave is a result of the banana plantation, or was present from the "beginning." Fruit-eating bats which inhabit the cave can be considered a vector for this fungus, the cave being a repository of Fusarium spores.

### Caño Seco

A strange spotted floral "stalk" from Caño Seco was cultured and produced two cultures: one, a kinky mat of old brownish mycelia with a white fluff evenly distributed. Creases develop in the agar peripherally. Agar block cultures in the lab indicate a species of Blastomyces.

The other culture also produced a kinky mat of brownish mycelia with an exudate which evaporates leaving depressions in the mat.

Gross characteristics are sufficiently similar to the first culture that it can be assumed also to be a Blastomyces, possibly a variant of the same species.

**Emus Cave**

Bat bones from this cave were cultured on Sabaraud's with Penicillin and yielded yeasts. Water from Emus Cave on the same media also grew yeast colonies.

**Caverna La Troja**

Caverna La Troja cultures produced a pink fungus with no spores on Malt agar with penicillin. Sabaraud's plates have yellowish growth rings.

**Corn Cob**

Bill Klimack brought in a black, oval growth he found growing on a washed-in log. They appeared to be saprophytic on decaying wood. Several more were in the back of the cave having long stalks and growing on soil. The cave is only about 60 feet long. All were growing in the twilight zone. Cultures made from the internal substance of this growth produced white cottony fluff with yellow spores and a liquid exudate. The growth darkens agar slightly. It is suspected to be an Ascomycete.

A sample from surface stream where trail and stream go down to Quebrada Seca gave plate counts of 13,000 per 100 cc and a white fungus on field cultures. Pink coloration of some of the bacterial cultures suggests presence of Serratia.

## DISCUSSION

Although no Paracoccidioides or Histoplasma were isolated, one member of the expedition was hospitalized for Histoplasmosis upon return to the U.S. Isolation of these fungi can be difficult under the best of conditions. Future attempts at isolation will probably involve animal inoculation with material retrieved from the field. Water samples from all areas were heavily laden with bacteria, and less so with fungi. From a health standpoint, one should always filter drinking water in remote regions and avoid water and ice, even though it may be commercially prepared.

Filter masks should be worn in any cave or dusty environment to help prevent respiratory infection by Histoplasma or Paracoccidioides. From a microbiological standpoint, cavers should avoid contaminating virgin cave with dirty coveralls from previous explorations. Trip leaders should be encouraged to take oil and water samples from virgin areas, as they are most likely to provide information on what organisms were there before human visitation. Analysis of all samples will continue until no new cultures appear. Old cultures will be compared with strains from the American Type Culture Collection and species identified will be listed in future NSS publications.

## NON SPELEOLOGICAL STUDIES

Norma Peacock brought back a water sample from remote camp where three explorers have come down with flu-like symptoms and diarrhea. The water sample was cultured on Sabaraud's without antibiotics and produced several bacterial colonies and possibly some yeasts. Total plate count was 2,000 colonies/100cc. This investigation led us to sample several unrelated water supplies used by the project. The results are discussed below.

### Water Sampling at Remote Camp

A water sample was collected from the remote camp water supply. This was done in response to three project members contracting flu-like symptoms and diarrhea. Symptoms indicated possible amoebic contamination of the water supply.

Sabaraud's cultures without antibiotics have mostly bacterial or yeast forms with a few myceliated entities. Plate count yielded 2,000 bacteria per 100cc. but amoebas were not reported.

### Sampling at La Moderna Restaurant

Plate counts gave heavy bacterial counts for the ice at the La Moderna Restaurant - 1,000,000 per 100cc. One plate had an area of inhibition indicating antibiotic activity against amoebic forms that were also visible on the plate.

### Rio Abrojo

Rio Abrojo water samples from cisterns and reservoirs were also heavily contaminated with bacteria. Counts averaged 100,000 per 100cc.

# APPENDIX A

# ACKNOWLEDGMENTS

A casual reading of the foregoing report will give a reasonable impression of the major commitment of time, energy, and just plain hard work required to undertake and complete a project the size of the Costa Rica Project. Work in the Corredor Basin has encompassed over 200 person weeks of field research, and an unrecorded amount of organization and preparation time in the United States and Canada by the various expedition leaders.

What may not be obvious from reading the report is the financial commitment required to do research in a tropical rain forest. For the most part, the field work was funded by personal contributions, the National Speleological Society, and the Costa Rican Government .

Many participants contributed to the project by paying their own travel expenses, and sharing some of the general expedition costs. The project's researchers supplied all their own equipment and often donated that equipment to the Costa Rican people before leaving the country.

Despite a great personal commitment by the members, the success of the project depended in many ways on the generous contributions of outside organizations. The leaders and members of the Costa Rica Project would like to express their gratitude to the following contributors without whom the project would not have succeeded.

Heading this list are a few major contributors that deserve special recognition:

## THE GOVERNMENT OF COSTA RICA

Several agencies of the government provided transportation, lodging and technical support for the project.

## ZENITH DATA SYSTEMS

Zenith donated a Turbosport 386 lap top computer which allowed daily plotting of cave maps and analysis of the thousands of bits of data collected by the science teams.

Planning and directing of each day's exploration and research was far more effective as a result.

## DURACELL USA

Without the thousands of alkaline batteries donated by this sponsor, the expedition could not have powered the cave lights, communications equipment, cameras, and all the other items for which we depend on batteries.

## HOUSTON INSTRUMENTS CORP.

Driven by the project's computers, a donated Houston flat-bed plotter, aided in the drafting of professional quality maps used in this report.

## BRUNTON INSTRUMENTS CORP.

Three Brunton compasses and tripods were supplied to the survey teams by this contributor. This equipment allowed our geologic and survey teams to complete several major goals of the project. Brunton compasses have set the standard for cave surveying and geologic field work for decades.

## LACSA AIRLINES

Getting to remote research areas is always difficult. LACSA, the airlines of Costa Rica, solved many of our logistical problems by offering special air fares, and the donation of transportation costs incurred in transporting thousands of kilos of equipment to and from Costa Rica.

## COCA COLA BOTTLING COMPANY OF COSTA RICA

Coca Cola is our longest participating sponsor, having supported every expedition since 1981. Each year they donate trucks, transportation, and products to the project.

## H.J. HEINZ CORPORATION

Heinz is another longtime sponsor of the project. Each year they donate the thousands of cans of food required to support project field teams.

In addition to our large corporate sponsors, our thanks go just as warmly to the following small companies and individuals. Each organization provided a part of the thousands of kilos of materials used by the project.

Urwiler & Walter, Inc.
Loisa Brothers Groceries of Neily, CR
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Juan Carlos Crespo
Wilderness Travel of Allentown
Cerveceria of Costa Rica
Pan Am Airlines
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Instituto Geografico

And finally, a very special list of U.S. outfitters, equipment dealers, manufacturers, and individuals within the caving community who have always strongly supported cave research. These people, many of them our personal friends as well as our favorite vendors, dug very deeply into their pockets to support the Costa Rica Project. Their contributions were instrumental in ensuring its successes.

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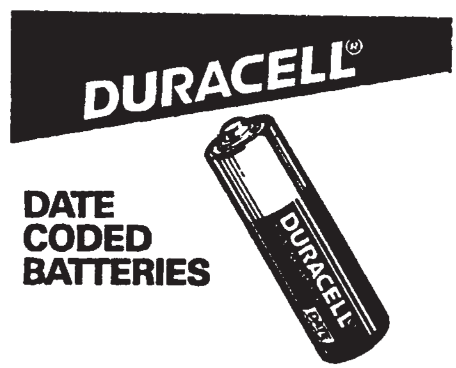

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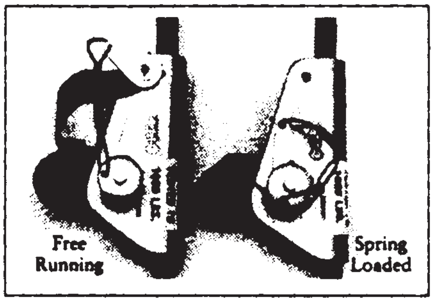


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# APPENDIX B

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## Guide To Authors

The *NSS Bulletin* is a multidisciplinary journal devoted to speleology, karst geomorphology, and karst hydrology. The *Bulletin* is seeking original, unpublished manuscripts concerning the scientific study of caves or other karst features. Authors need not be associated with the National Speleological Society.

Manuscripts must be in English with an abstract, conclusions, and references. An additional abstract in the author's native language (if other than English) is acceptable. Authors are encouraged to keep in mind that the readership of *The Bulletin* consists of both professional and amateur speleologists.

For general style refer to the present *Bulletin* and the following guides: "Suggestions to Authors" (U.S. Geological Survey), "Style Manual for Biological Journals" (American Institute of Biological Sciences), and "A Manual of Style" (The University of Chicago Press). For assistance in writing an abstract see "A Scrutiny of the Abstract" by K. Landes, Bulletin of the American Association of Petroleum Geologists, vol. 50 (1966), p. 1992. Because good figures are an essential part of any paper, authors are encouraged to see what bad figures look like in the editorial on figures by K. Rodolfo in the *Journal of Sedimentary Petrology,* vol. 49 (1979). p. 1053-60.

Each paper will contain a title with the author's names and address. This will be followed by an abstract and the text of the paper. Acknowledgements and references follow the text. References are alphabetical with senior author's last name first, followed by the date of publication, title, publisher, volume, and page numbers. See the current issue of *The Bulletin* for examples.

Authors should submit two copies of their manuscript (include only copies of the illustrations) to the appropriate specialty editor or the senior editor. The manuscript must be typed, double space on one side of the page. Authors submitting manuscripts longer than 15 typed pages may be asked to shorten them. All measurements will be in Système Internationale (metric). Other units will be allowed where necessary if placed in parentheses and following the SI units.

Figures and lettering must be neat and legible. Figure captions should be on a separate sheet of paper and not within the figure. Most figures will be reduced, hence the lettering should be large. Once the paper has been accepted for publication, the original drawings (with corrections where necessary) must be submitted to the editor. Black-and-white photographs must be sharp, high contrast, and printed on glossy paper. Color prints will be printed at author's expense only.

All submitted manuscripts are sent out to two specialists for review. Reviewed manuscripts are then returned to the author for consideration of the referee's remarks and revision (where necessary). Revised manuscripts are returned to the appropriate editor who then recommends acceptance or rejection. Upon acceptance, the author should submit all photographs and original drawings to the editor.

Once the paper has been typeset and laid-out, the senior author will be sent one set of proofs for review. Any corrections other than printer errors will be done at the author's expense. A reprint order form will be sent with the proofs. At this time all authors will be requested to contribute page charges of $25 per page to help defray the cost of publication. The actual cost to the society is about $100 per page. Acceptance of manuscripts for publication is not contingent upon payment of page charges.

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