Revista Mexicana de Ciencias Geológicas, volumen 12, número 1, 1995, p. 108-111
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WORLD'S DEEPEST KARST HYDROLOGIC SYSTEM DOCUMENTED IN SIERRA JUÁREZ, OAXACA

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INTRODUCTION

Mexico is rapidly being recognized as possessing some of the most spectacular and deepest caves in the world. Six of the 46 cave systems in the world that have been explored to depths greater than 1,000 m are in Mexico (Minton, 1994). Two of the world's 10 deepest explored caves are in Oaxaca. Mexico's second deepest explored cave, Sistema Cheve, is in the Sierra Juárez in northeastern Oaxaca (Figure 1). Its present explored depth is 1,386 m, the eighth deepest in the world. The surveyed length of the cave is 23.3 km and exploration continues each year during the dry season (Figure 2). The deepest explored cave system in Mexico, Sistema Huautla, is in the Sierra Mazateca, near the town of Huautla de Jiménez. A recent multi-national expedition pushed its explored limits to -1,475 m. The waters from both Sistema Cheve and Sistema Huautla reappear at karst springs—resurgences—in the Cañón Santo Domingo, approximately 1,400 m apart but on opposite sides of the Río Grande (Figure 3).

The greatest proven relief of a karst hydrologic system previously reported was 2,355 m for the Napra cave system in the Caucasus (Kazharsky, 1993). The Iljukhina system, also in the Caucasus, has a depth of 2,350 m (Klimchouk, 1993). The deepest cave exploration in the world has been to a depth of -1,602 m in Reseau Jean-Bernard in France.

Figure 1.- Location map for the Sistema Cheve. The darkened area on the large map represents the State of Oaxaca. The inset map shows the location of Sistema Cheve within the State of Oaxaca.

METHODOLOGY

The highest point in the multi-entrance Sistema Cheve is the entrance to Cueva Escondida. Cueva Cheve, however, is the largest and most accessible entrance to the system. A physical connection between the two caves has been traversed and the connecting passages have been surveyed. Fluorescein, a non-toxic dye, was placed in a stream flowing into the main entrance to the system—Cueva Cheve—in the spring of 1990 (Smith, 1991). Eight days after the dye was injected into the system, bright green water emerged 18 km north of the Cueva Cheve entrance at Agua Fría de Santa Ana, a karst spring on the southern side of the Río Grande in the Cañón Santo Domingo.

To determine the precise, relative positions of the Escondida and Agua Fría entrances, a double differential Global Positioning System (GPS) was utilized. The absolute elevation was determined to a point near the Escondida entrance using two NAVPRO 5000 receivers. A second series of tests determined the precise relative locations and elevation change from this control point to two sites near Agua Fría de Santa Ana. Precision overland surveys were made to connect the control site and the two remote, GPS stations to the two cave entrances—Escondida and Agua Fría. The final depth of the system also incorporates the depth reached by a 1984 scuba dive of the spring.

RESULTS OF THE SURVEY

The highest entrance to the system—Cueva Escondida—is at an elevation of 2,798 m a.s.l. The Cueva Cheve entrance is at 2,654 m a.s.l. The spring where the water from the system resurfaces—Agua Fría de Santa Ana—is at an elevation of 291 m. This resurgence cave had been previously explored by scuba divers to a depth of 18 m—273 m a.s.l.—in 1984 (Stone, 1988), prior to the discovery and exploration of the insurgence area. Thus, the total vertical extent of the hydrologic system is 2,525 m a.s.l. (Figure 4). The vertical extent of the subterranean dye trace, the deepest ever successfully completed, was 2,363 m a.s.l.

Cueva del Mano, a dry cave connected to Agua Fría, has an explored length of over seven kilometers of maze passages that extend about one kilometer towards Cueva Cheve. The

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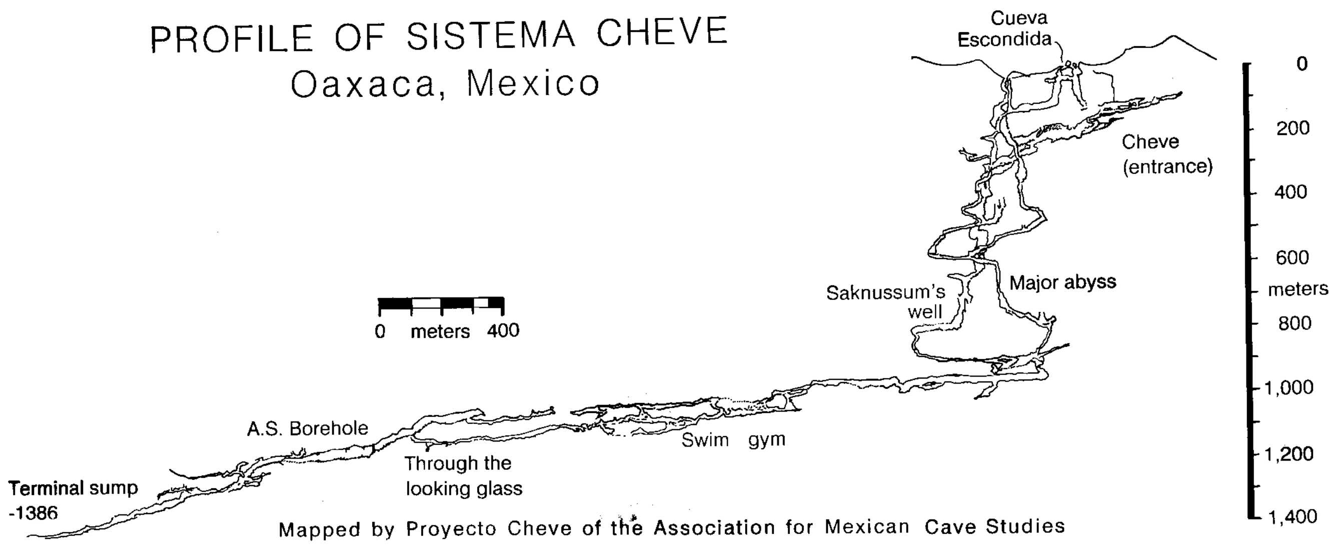

Figure 2.- Cross-section of the explored portions of the upper part of Sistema Cheve hydrologic system. Surveying and mapping of the cave is a continuing effort by the multinational Proyecto Cheve (after Vesely, 1993).

cave is not fully explored and exploration continues. The deepest passage in the upper, explored part of the Cheve system, is filled with water and will require an ambitious scuba diving effort to explore. One attempt using scuba was made in 1991, but it ended in water filled passage (Hose, 1992a). It is likely that exploration will eventually connect the lower and upper parts of the system, which are now approximately 13 km apart.

GEOLOGIC SETTING

The Sistema Cheve is formed within an approximately four kilometer wide, north-northwest-trending band of Cretaceous carbonates. The cave walls and surface comprise a melange of rudist-bearing limestone, laminated micrite, fore-reef breccia, thick-to-massive bedded dolomite, thin-bedded limestone and chert, thin-bedded limestone, laminated back-reef limestone, and mylonitic marble (Hose, 1991). An hypabyssal andesitic dike cross-cuts the carbonate terrain and is exposed in the upper part of the cave. On the surface, the carbonate terrain is surrounded to the west, south, and east by cataclastic rocks of the Cuicateco Metamorphic Complex, including talcose and scaly serpentinite, sandstone, shale, volcanic rocks, and chert-mica schist (Figure 3). These rocks were severely tectonized during Late Cretaceous-Paleogene (Laramide) thrusting events. Foliation (approximately N20°W 60°W-90°) is sub-parallel with the trend of the fault that divides the two terrains.

The entrances and passages are just east of the tectonized terrain. Most of the cave is east of and under the hanging wall of an east-verging, Laramide thrust fault, that trends approximately N20°W 60°W (Figure 5) in mostly east-dipping beds. The hanging wall is made up of insoluble, cataclastic rocks which are not exposed in the explored passages of the system. Most of the known passages are linear and developed along joints. The joints are parallel to the trend of the fault and probably represent the axial cleavage of an east-verging-syncline (Hose, 1992b).

Exploration in the upper portion of the hydrologic system—Cueva Cheve—has not penetrated beyond the Aguacate lineament, which is expressed by east-northeast-trending cliffs on the surface. Near the end of the cave, a large—approximately 15 m wide x 25 m high—passage abruptly changes to a maze of smaller passages, most of which are filled with boulders that have collapsed from the ceiling. The lowest explored passage in Cueva Cheve is a water-filled tube in mylonitic marble, presently referred to as the Terminal Sump. The only exploratory scuba dive in the sump failed to penetrate to air-filled passage.

The lowest part of the hydrologic system—Agua Fría and Cueva del Mano—are also formed in mylonitic marble within the foot wall—eastern side—of the major north-northwest-trending thrust fault (Figure 3). Passages are linear and have formed along joints that are parallel to the trend of the fault.

All of the known input sites—*i. e.*, cave entrances—to the hydrologic systems of Sistema Cheve and its neighbor, Sistema Huautla, are in carbonate outcrops immediately adjacent to insoluble rocks. Surface streams that traverse across insoluble rocks sink into the cave systems within a few tens of meters. Thus, the karst above and east of Sistema Cheve lacks permanent streams.

DISCUSSION

A hydrologic system in which water flows 19 km and drops 2,525 m in eight days through subterranean conduits demonstrates the vulnerability of high-relief karst terrains to

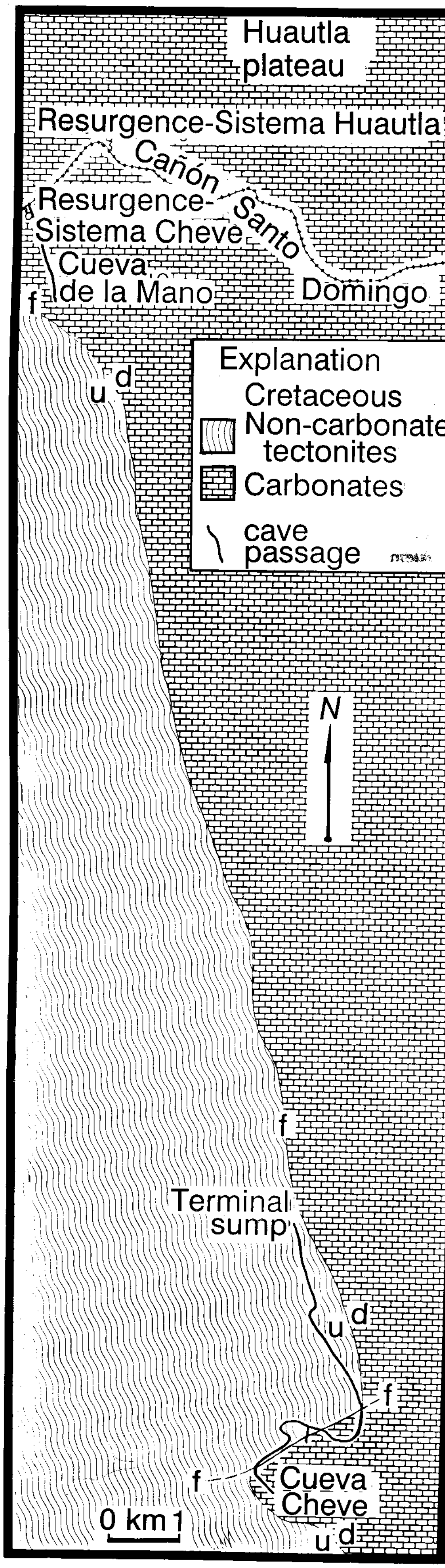

Figure 3.- Simplified geologic map of the Sistema Cheve area.

widespread groundwater contamination. Such systems are more similar to surface drainage systems than they are to clastic aquifers. Yet, the drainage patterns and input areas of most karst springs in Mexico are completely unknown.

Extensive, high-relief karst is present in many regions in Mexico, including the states of Chiapas, Guanajuato, Guerrero, Nuevo León, Oaxaca, Puebla, Querétaro, San Luis Potosí, Tamaulipas, and Veracruz (Espinasa-Pereña, 1990a, 1990b). New roads are entering many of the mountainous input areas that were previously remote and inaccessible to motorized vehicles. Greater impact on the environment, including the groundwater, commonly accompanies the improved accessibility. The necessity of understanding karst better, particularly high-relief systems, is becoming increasingly important in Mexico.

ACKNOWLEDGMENTS

A grant from the National Geographic Society Committee for Field Exploration and Research funded this study. UNAVCO and Magellan Systems provided the global positioning system receivers and technical support. Dr. Germán Cruz-Martínez, director of Unidad Estatal de Protección Civil in Oaxaca, provided valuable assistance to the project. Proyecto Cheve, a multinational group of cave explorers, provided the subsurface survey data, performed the dye tracing test, and assisted with all phases of this study. Arturo Gómez-Caballero gave a useful and appreciated review of this paper. Luis Fernando Guinea-Larrazábal helped with drafting most of the figures. The author wishes to thank each of these contributors.

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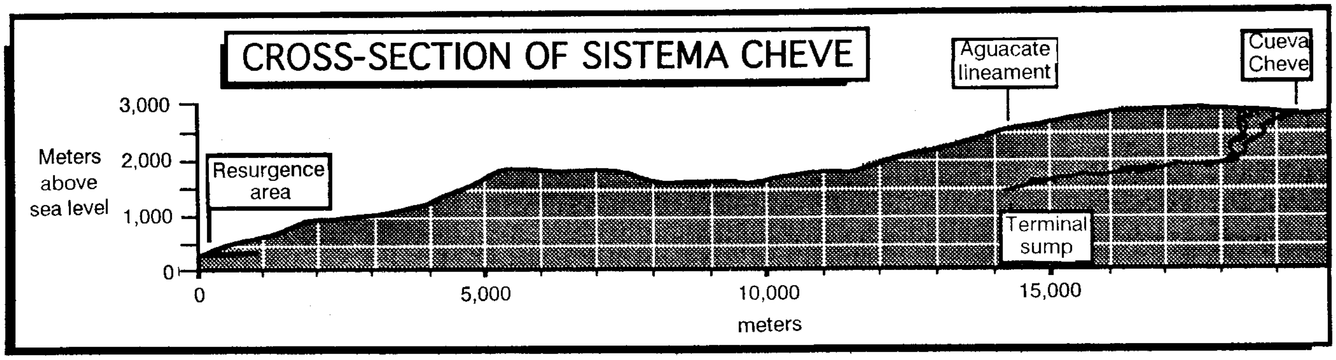

Figure 4.- North-south-trending cross-section of the explored portions of the Sistema Cheve hydrologic system including the upper part, commonly called Cueva Cheve, and the resurgence area, Agua Fría de Santa Ana and Cueva del Mano.

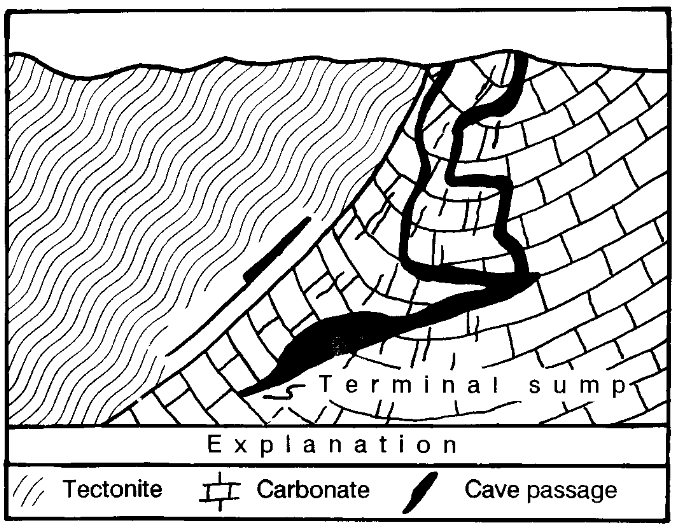

Figure 5.- East-west-trending, schematic cross-section of the upper portion of the Sistema Cheve hydrologic system.

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Manuscript received: December 14, 1993.
Corrected manuscript received: November 28, 1994.
Manuscript accepted: December 6, 1994.