Preliminary notes on the karst of Sierra Mixteca-Zapoteca, south of Tehuacàn, Mexico

Notas preliminares sobre el fenómeno cárstico de la sierra Mixteca-Zapoteca al sur de Tehuacán, México

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Abstract

Since 2002, the Italian team "La Venta" is carrying on a research project that has the aim to investigate the karst systems in the area of Sierra Mixteca-Zapoteca, south of Tehuacàn. The Sierra consists mainly of Cretaceous limestone, covered by Upper Cretaceous marly limestones and Tertiary calcareous conglomerates. The most karstified area is the limestone plateau crossed by the Rio Juquila (or Xiquila) Canyon. Four missions, performed in the years 2002, 2003, 2004 and 2006, have allowed to discover more than 50 caves. Despite the good karst potential of the area, large underground systems have not been yet explored. The longest cave is located in the middle part of Juquila Canyon and consists of a large relict phreatic conduit more than one km long. The deepest caves are placed in the top area of Cerro Grande and in the southeast area, between the canyon and the village of Santa Maria di Ixcatlàn. Some of these vertical caves have deep pits, which are closed at bottom by debris and mud deposits carried in by runoff water. In the area just to northwest of S. Maria, some caves of thermal origin have been surveyed during the last mission. These caves display dissolution features due to underwater processes, which probably attained during the rise of thermal waters. Finally, many of the caves show ancient traces of human's frequentation, as graffiti, wall paintings and jars, usually close to ruins of pre-hispanic settlements.
Key words: relict karst, hydrothermal caves, Tehuacàn, México.

Resumen

La Asociación italiana La Venta lleva a cabo desde el 2002, un proyecto de investigación que tiene como objetivo la exploración de sistemas cársticos en la zona Sur de Tehuacán. La sierra es constituida por calizas de el Cretácico, cubiertas por calizas y lutitas de el Cretácico Superior y conglomerados calcáreos de el Terciario. La área mas carsificada es la mesa de caliza que está atravesada por el Cañón del Río Juquila o (Xiquila). Actualmente se han llevado acabo 4 expediciones, en el 2002, 2003, 2004 y 2006, estas han permitido identificar más de 50 cuevas. No obstante el notable potencial de la zona, no se han encontrado por el momento grandes sistemas subterráneos. La cueva más larga explorada se encuentra en el cañón Juquila y está constituida por una gran galería de más de 1km de desarrollo. En cambio las cuevas más profundas se encuentran en la zona más alta del Cerro Grande y al Sureste del mismo, entre el cañón y el pueblo de Santa María de Ixcatlán. Se trata de algunas cuevas de desarrollo vertical con pozos profundos, que se cierran al fondo por depósitos de detritos y fango portados por el agua. La Cueva de la Laguna Prieta, que se abre en una gran dolina de derrumbe a 2490 m de cota, presenta un pozo inicial de 210 m y alcanza una profundidad de 280 m. En la zona Noroeste de Santa Maria Ixcatlán, se exploraron algunas cuevas de origen hidrotermal. Estas cuevas presentan formas debida a los fenómenos de corrosión en ambientes sumergidos, los cuales son legados al la resalida de aguas termales ipogenicas. Cabe mencionar que se encontraron rastros de frecuentación humana, en forma de grafitos, pinturas murales y fragmentos de cerámica en diversas cuevas de la zona, unidamente a vestigios de asentamientos pre-hispánicos.
Palabras clave: carso relicto, cuevas hidrotermales, Tehuacàn, México.

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Introduction

The Tehuacán-Cuicatlán valley, in the northern section of the state of Oaxaca, is a NNW-SSE tectonic basin bordered by the Sierra Mixteca-Zapoteca on the western side and by the Sierra Mazateca, the Sierra de Juarez and the Sierra de Zongolica on the eastern side.

The eastern ridges are made up mainly by Jurassic-Cretaceous limestone and the karst is present with majestic underground systems. The Sierra Juarez-Mazateca hosts the deepest caves of the whole American continent, the Cheve System (-1484 m) and the Huautla System (-1475 m) with tens of kilometres of explored caves (Hose, 2000; Steele & Smith, 2004). In contrast, the western mountains do not display relevant karst landforms.

In order to investigate the sierra located west of Tehuacan, the “La Venta” Geographical Association performed four speleological expeditions from 2002 to 2006 (De Vivo, 2003a; Bernabei et al., 2003; Mecchia & Piccini, 2006) focused on the central area of the mountain chain. This part is a wide limestone plateau, with mountains passing 2600 m in altitude, crossed by the Rio Juquila (or Xiquila) from SW to NE. The river drains the waters of a wide highland area towards the Rio Salado, in the Cuicatlán valley, a river flowing into the Gulf of Mexico. Limestone crops out on a surface of about 450 km^2, but field investigation have revealed that karst forms are concentrated in a few limited areas. At present we discover just more than 50 caves, most of them are vadose relict caves, but we did not yet achieve to explore the deep active karst systems.

Geographical setting

The studied region is located at 18° 05’ and 17° 50’ latitude N and 97° 10’ and 97° 20’ longitude W and it is a small part of the whole karst area that develops for about 200 km from the west of Tehuacán (Puebla) in the north to the city of Oaxaca in the south (Fig. 1).

From an administration point of view, the region belongs to the communities of Tepelmeme de Morelos and Santa Maria Ixcatlán and is part of the protected semi-desert area of the Reserva de la Biosfera de Tehuacán -Cuicatlán, world known for its many endemic species of cactuses.

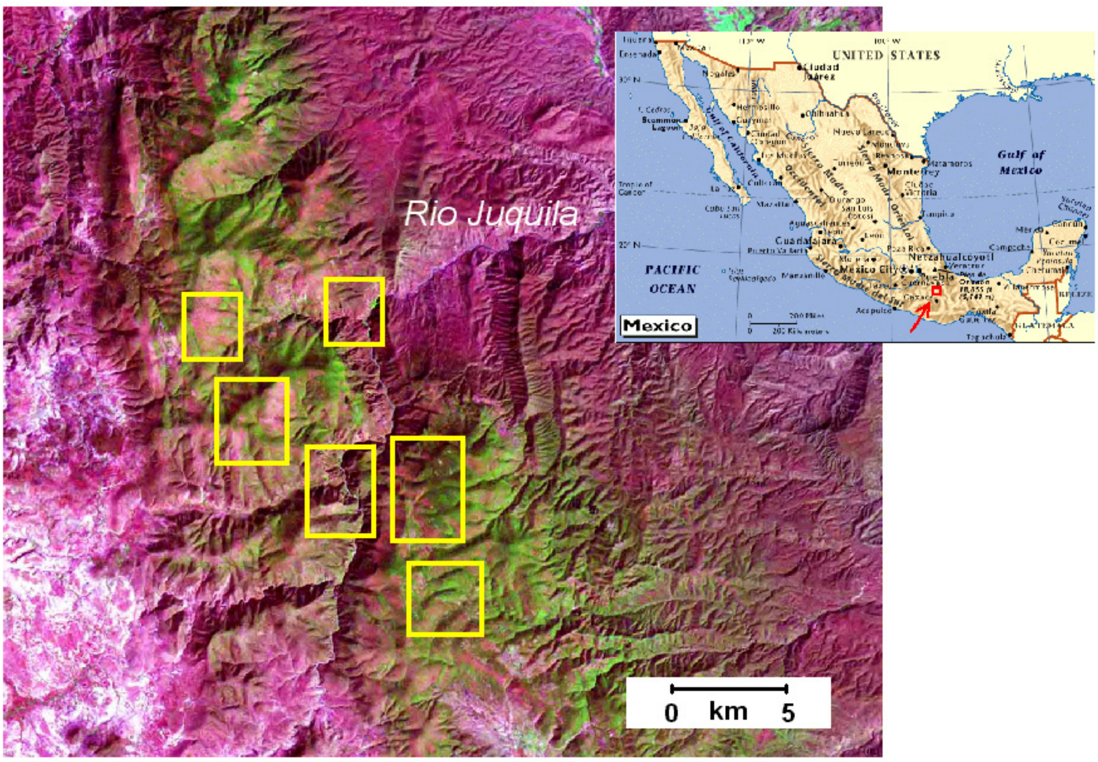


Fig. 1 – Location map and satellite image of Juquila Canyon. Yellow squares indicate investigated zones.

Geographic and climatic isolation of the valley contribute to a high level of endemism. Mountain ranges surrounding the valley reduce the influx of tropical maritime moisture. Just to east of the valley, slopes of the southern Sierra Madre facing the Gulf of Mexico (Sierra Mazateca), receive an annual average precipitation of more than 4000 mm and support tropical rainforest. In contrast, the ranges west of Tehuacán basin are characterized by a semi-arid climate, with rainfalls ranging from 250 to 500 mm, depending on the altitude, concentrated in the months from June to September season (Byers, 1967). Since there are no pluviometric stations, it is not possible to give a reliable evaluation of the rainfalls, but on the highland above 2000 m of altitude they could reach 500-600 mm per year.

Geological framework

Bibliographic sources on the geology of the area are quite scarce: only 1:250,000 Geological Map of Mexico (sheet E14-9 Oaxaca - southern sector - and E14-6 Orizaba - northern sector -) and some studies at regional scale (e.g. Mossman & Viniegra, 1976) may be consulted. A recent work by Nieto-Samaniego et al. (2006) describes the geological evolution of the limestone of the Mixteca-Zapoteca chain, and analyses the activity of the fault of Oaxaca, bordering the limestone range on its eastern side. Another very recent study is the doctorate thesis by Dávalos-Álvarez (2006) dedicated to the tectonic evolution, since the Cenozoic to the present time, of the Tehuacán valley, just north of the Juquila canyon. Lacking in specific geological studies, we can only attempt a general sketch on the recent geological and geomorphic evolution of the area of the Juquila canyon.

The geological maps do not show deposits of Late Cretaceous; such unconformity temporally encloses the activity of the Laramide orogenesis, which developed in a marine environment and ended up with the emersion of the region. The Laramide orogenesis, during which the area was thrust and moved eastward, produced the main tectonic compressive structures of the Mixteca-Zapoteca range, whereas the Oaxaca normal fault is the regional structure responsible of the neotectonic evolution. The latter is a complex deformation zone that consists of faults having mainly NW-SE directions in the northern segment (from Tehuacán, in the state of Puebla, to Teotitlán) and N-S directions in the southern one (from Teotitlán to the city of Oaxaca). The Mixteca-Zapoteca carbonate range lies west of the fault, which also forms the eastern edge of the Tehuacán valley.

At the end of the Paleocene – beginning of the Eocene an extension phase started, producing the longitudinal fragmentation of the range, the deepening of the Tehuacán valley and the uprising of the nearby *sierras*: the Sierra Mixteca-Zapoteca on the West and the Sierra Mazateca on the East. This distension phase was accompanied by volcanic activity of andesite type lasting until the Oligocene (Martiny et al., 2000). The tectonic phase produced by the activity of the Oaxaca fault, went on until the Quaternary with a series of "pulsations", recorded in the Cenozoic continental deposits of the Tehuacán valley. According to Dávalos-Álvarez (2006) the pulsations are testified by a series of three cycles of sediments and by four faulting events, which have led to the uplift of the *sierra* and the relative deepening of the Tehuacán valley.

In short, the present geologic framework can be summarized as follows.

The Sierra Mixteca-Zapoteca consists mainly of a Early Cretaceous calcareous sequence, about 1000 m thick, characterized by mainly detritic and bioclastic facies, which lies on Cretaceous marls and shales. In the canyon area, and particularly east of it, we found bioclastic calcarenites and calcirudites with decimetric to metric thick beds with megabreccias bodies and frequent horizons enriched with cherts nodules and rare interlayers of yellowish clay. In the west sector of the area we found well stratified limestones, with abundant cherts, often interlayered with marly and shaly beds. In the eastern sectors of this area Upper Cretaceous limestone crops out. A Tertiary (Paleocene – Oligocene) terrigenous sequence, consisting mainly of marls and sandstones, overlies calcareous formations in the southwestern sectors of the Juquila basin.

In many places, wide debris deposits due to the intense physical weathering cover the bedrock. This detrital deposits are responsible of the filling of inner basins. The slope debris forms well-cemented covers, typical of semi-arid mountain environments.

Structural setting is relatively simple. Beds are moderately westward dipping. The limestone massif is cut by several faults, prevalently NNW-SSE oriented, parallel to the master faults of Tehuacán basin. Other faults have orientation E-W. The river network is mainly developed along faults and it shows an angular pattern.

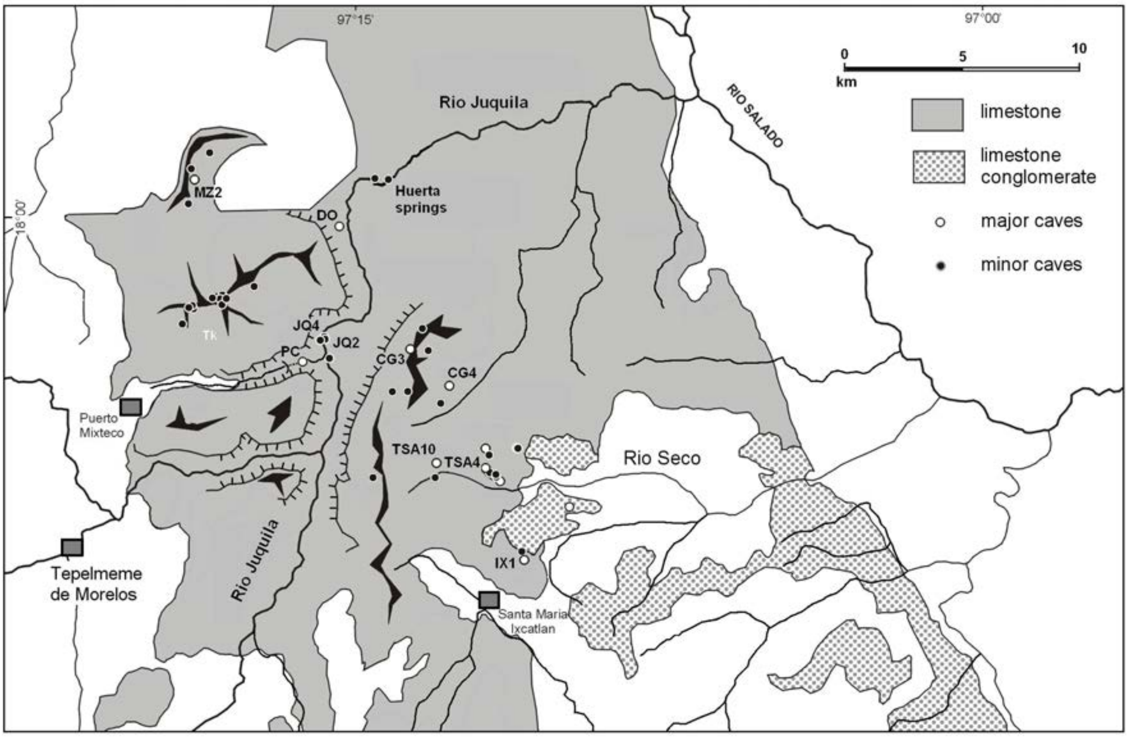


Fig 2 - Map of the Juquila karst area, showing the location of caves. Cave indexes as in Appendix (from: Geological Map of Mexico – INEGI).

Caves surveying results

The investigated area may be subdivided into three sectors: 1) Juquila canyon, 2) left hydrographical side highland, 3) right hydrographical side highland (Fig. 2).

The Juquila canyon

The Juquila canyon is one of the most impressive of the Sierra Mixteca-Zapateca. Both sides are steep, sometimes forming almost vertical walls up to 500 m high. During the dry season, that is winter, the river is a modest stream all the way down to La Huerta springs, located at an altitude of approximately 1200 m a.s.l.; the few tributaries, instead, are normally dry.

Several springs flow out from both sides of the riverbed at La Huerta. In this area, in fact, the canyon incision reaches a less permeable layer, which consists of limestone, marl and sandstone, underlying the strongly karstified limestone that forms the walls of the canyon and the plateau. The total discharge of the springs is not known, though it is enough relevant even in the driest periods. According to the available information, there is not much difference between the dry season flow and the wet season one. One of the spring-caves is located on the western side and may be accessed for about 70 m up to a final sump. During winter 2003 its water flow was some 30-40 litres per second.

All along the canyon, several cave entrances may be found either close to the riverbed or on its steep slopes. Upstream La Huerta, at altitudes between 1550 and 1580 m a.s.l., four caves have been explored. These are short segments of old phreatic tubes, up to 10 m in diameter, closed by fluvial deposits, flowstones or rock falls after a few dozens of meters of length (Fig. 3).

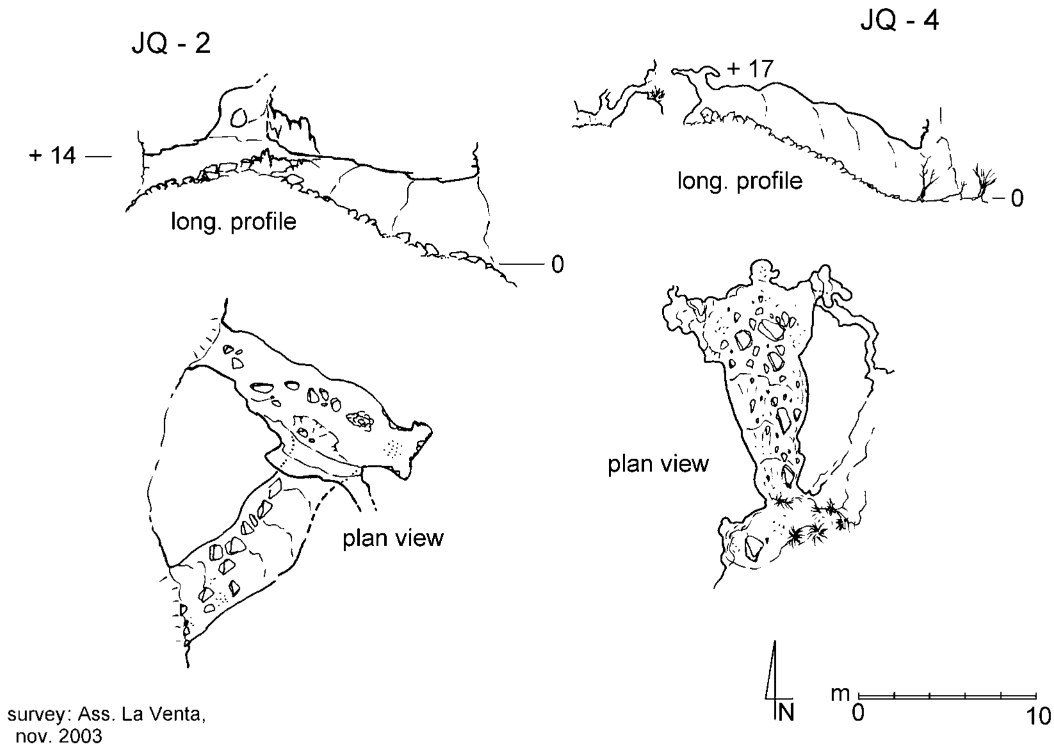


Fig. 3 – Plan views and longitudinal section of two paleo-phreatic caves located in the Juquila Canyon (survey: Ass. Geogr. La Venta).

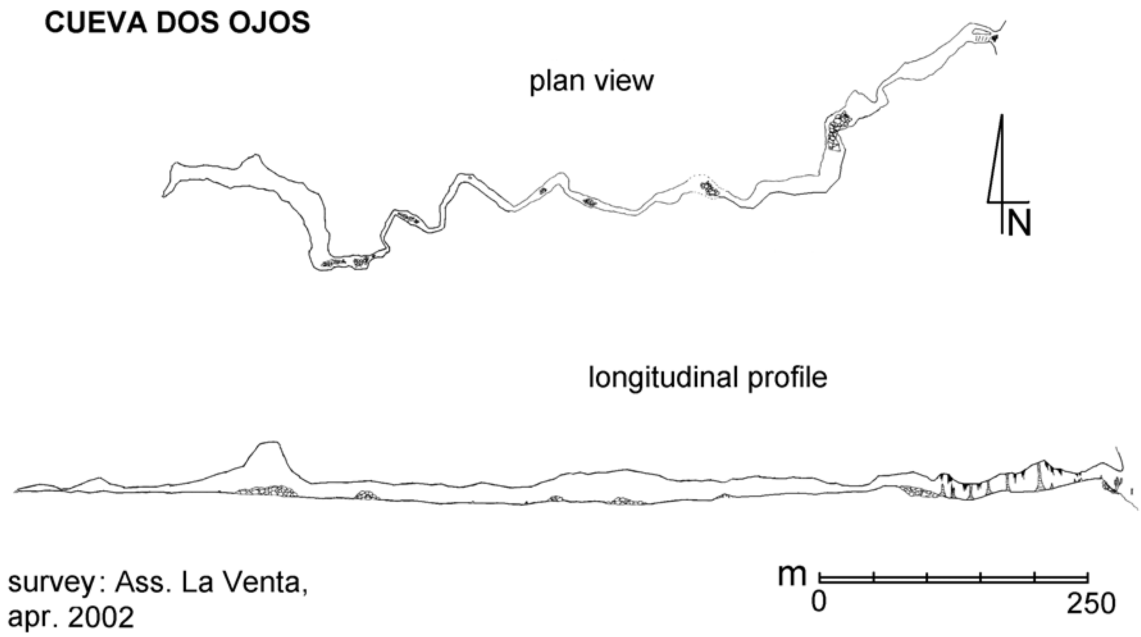


Fig. 4 - Plan views and longitudinal profile of Cueva Dos Ojos, Juquila Canyon (survey: Ass. Geogr. La Venta).

The longest cave is the Cueva Dos Ojos, located on the left side almost 300 m above the active springs. This is an almost straight dry gallery (Fig. 4), about 1 km long, which presents clear phreatic features (Fig. 5). The paleo-phreatic caves explored in the canyon are probably remnants of an ancient deep drainage network collecting the underground water of surrounding relieves.

A very interesting cave, well known since a very long time, is located in the tributary canyon Rio Grande that cuts down the limestone massif near the village of Puerto Mixteco. This cave is locally renown as Puente Colosal (PC), and consists of a natural 250 m long tunnel. The impressive gallery, located at the end of a blind valley, is up to 50 m high in the final part and never less than 15 m wide (Fig. 6 and 7). Nuiñe paintings and inscriptions are present on the gallery walls; the archaeological studies date them between 300 and 800 A.D. (Mautner, 1995, 2005; Urcid, 2004). Today the cave is completely dry, except than during strong floods, but in the past a big water stream evidently crossed it.

Left hydrographical highland

The western section of the limestone range consists of a 15 km long ridge connecting, from south to north, Cerro Tequelite, Cerro Pericon and Cerro Verde, the latter almost 3000 m of altitude. The range presents rounded crests covered by tree-like vegetation, particularly on the north facing sides. The slopes are covered with debris deposits, particularly thick and wide on the lower sides.

The 15 explored caves are concentrated in the upper areas, above the altitude of 2600 m, mostly on low gradient surfaces close to mountain crests. For the most part they are non-active vertical caves, beheaded by erosion and showing clear signs of senescence, as the altered stalactite and stalagmite deposits clearly demonstrate. The longest cave is MZ2, at an altitude of 2680 m on the southern crest of Cerro Pericon, close to the small village of Mahujzapan (MZ zone). This cave consists of some interconnected shafts with concretionary walls. In the isolated section south of the Puente Colosal canyon we explored the 20 m deep JQ5 pit, located close to the massif top, at the altitude of 2600 m.

Fig. 5 – The large phreatic tube of Cueva Dos Ojos (photo: Ass. Geogr. La Venta).

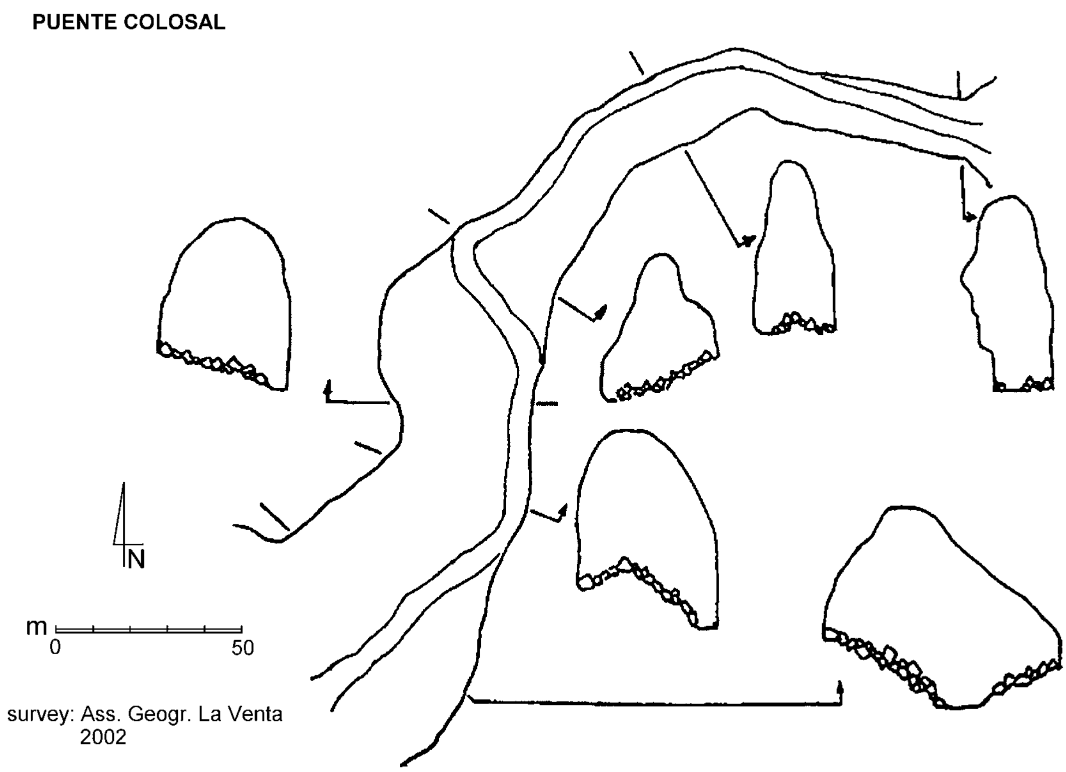


Fig. 6 – Plan view and cross-sections of Puente Colossal (survey: Ass. Geogr. La venta).

Fig. 7 – The Puente Colossal, a big karst tunnel partially filled with coarse fluvial deposits (photo: Ass. Geogr. La Venta)

Right hydrographical highland

The highland located east of Juquila canyon represents the widest karts area and is characterized by flat areas, differently from what may be found on the left hydrographical side, with several wide and shallow dolines and some collapse depression. 26 caves have been surveyed in this area, most of which presents a vertical development. Some occasionally active sinkholes are also present, but they may be followed only for short distances. The caves are concentrated in two areas: Cerro Grande, in the NW (CG zone), in the territory of Tepelmeme, surveyed in 2003, and Llano la Cumbre, in the SE (IX and TSA zone), in the territory of Santa Maria Ixcatlán, surveyed in 2006.

The longest and deepest cave is the Sotano de la Laguna Prieta (CG3) located near the top of Cerro Grande. The entrance consists of a wide collapse doline (Fig. 8) that opens on a 140 m deep shaft, formed by two joined parallel pits (Fig. 9). A hanging terrace made of rock blocks opens on a 40 m vertical drop that gives origin to a high, few metre wide, gorge descending SE. A further 35 m deep pit leads into a chamber with big blocks embedded among the walls. The bottom section is definitely stuck by mud and organic material.

The other relevant cave in Cerro Grande is the Pozo de la Vaca Ladra (CG4), not far from CG3; its entrance, also shaped as a collapse doline, leads into a 12 m deep pit. At its base a detritic slope leads on a 100 m vertical drop, which consists of a pit with 4 x 6 metres elliptic plan. A side narrow passage, along the generating fracture of the pit, leads into a 7 m drop, closed by mud at the bottom.

Fig. 8 – The entrance pit of the Pozo de la Laguna Prieta, Cerro Grande (photo: Ass. Geogr. La Venta).

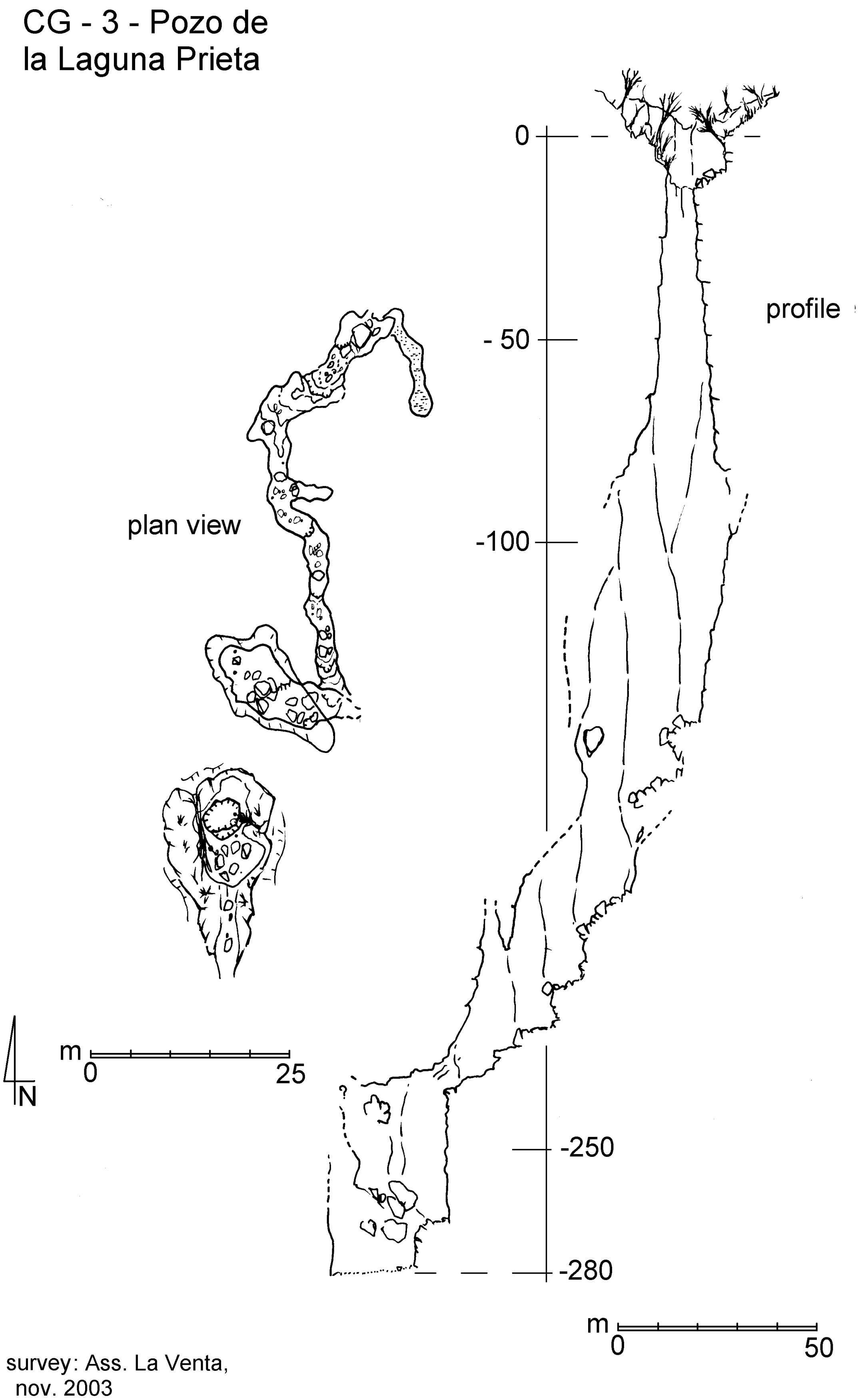


Fig. 9 - Plan views and longitudinal section of Pozo de la Laguna Prieta, Cerro Grande (survey: Ass. Geogr. La Venta).

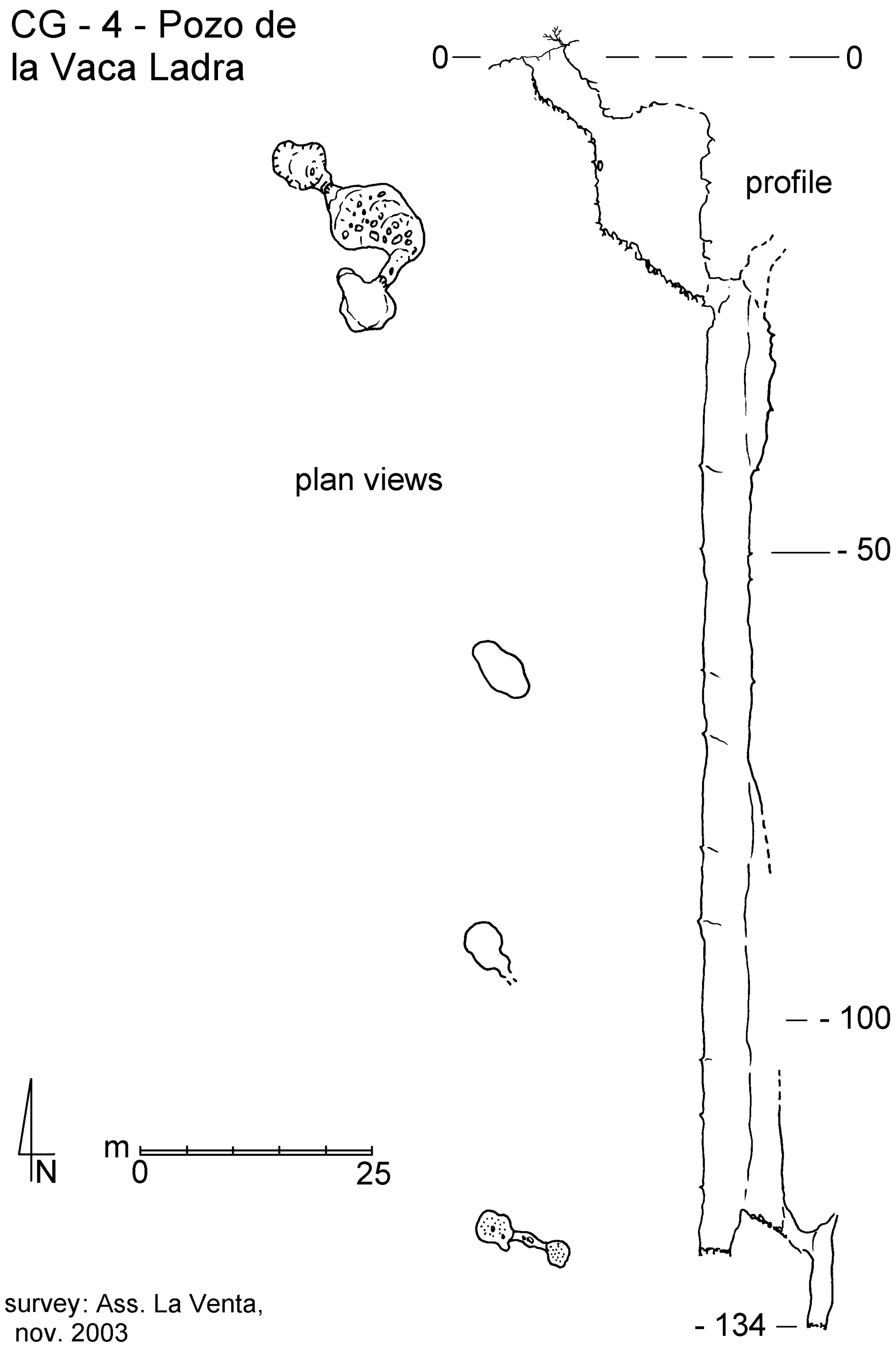


Fig. 10 - Plan views and longitudinal section of Pozo de la Vaca Ladra, Cerro Grande (survey: Ass. Geogr. La Venta).

Llano la Cumbre is a wide depression located NW of Santa Maria de Ixcatlàn, artificially dammed in order to form a water basin for livestock watering. The caves are found in the surrounding area. The largest cave is Sotano Rodeo (IX1); it opens SE of the water basin, in the woods, with a 10 m large sinkhole. The base of the wide entrance pit, almost 40 m deep, continues with a debris slope and a further 10 m deep drops, leading to the top of a 75 m deep large pit. Its bottom continues with a small meander, stuck by debris after about twenty metres at a depth of -135 m. For the main part, the other explored caves are in the small valleys of the

Terrero San Antonio, 2-3 km north of Llano la Cumbre. Among these caves, the deepest one is Sotano la Calabera (TSA6) consisting of a single 77 m deep shaft.

The main valley is now divided into small blind basins, lined in N-S direction and drained by sinking streams. Probably, before the waters were absorbed in the underground, they formed a single valley, left tributary of Rio Seco. At the present time, the runoff rills are active only in the wet season. Following the bottom of the ditches, two sinkholes were discovered and explored for a few tens of metres, Cueva Perfecto 3 (TSA15), upstream, and Sumidero San Antonio (TSA4), downstream. Cueva Perfecto 3 starts with a 20 m pit and continues in a gorge that after a dozen metres ends up in a chamber, where two different conduits may be covered for a maximum of 30 m both upstream and downstream. The latter shows a low gradient, meander-like course and ends up in a shallow water pool (-39 m).

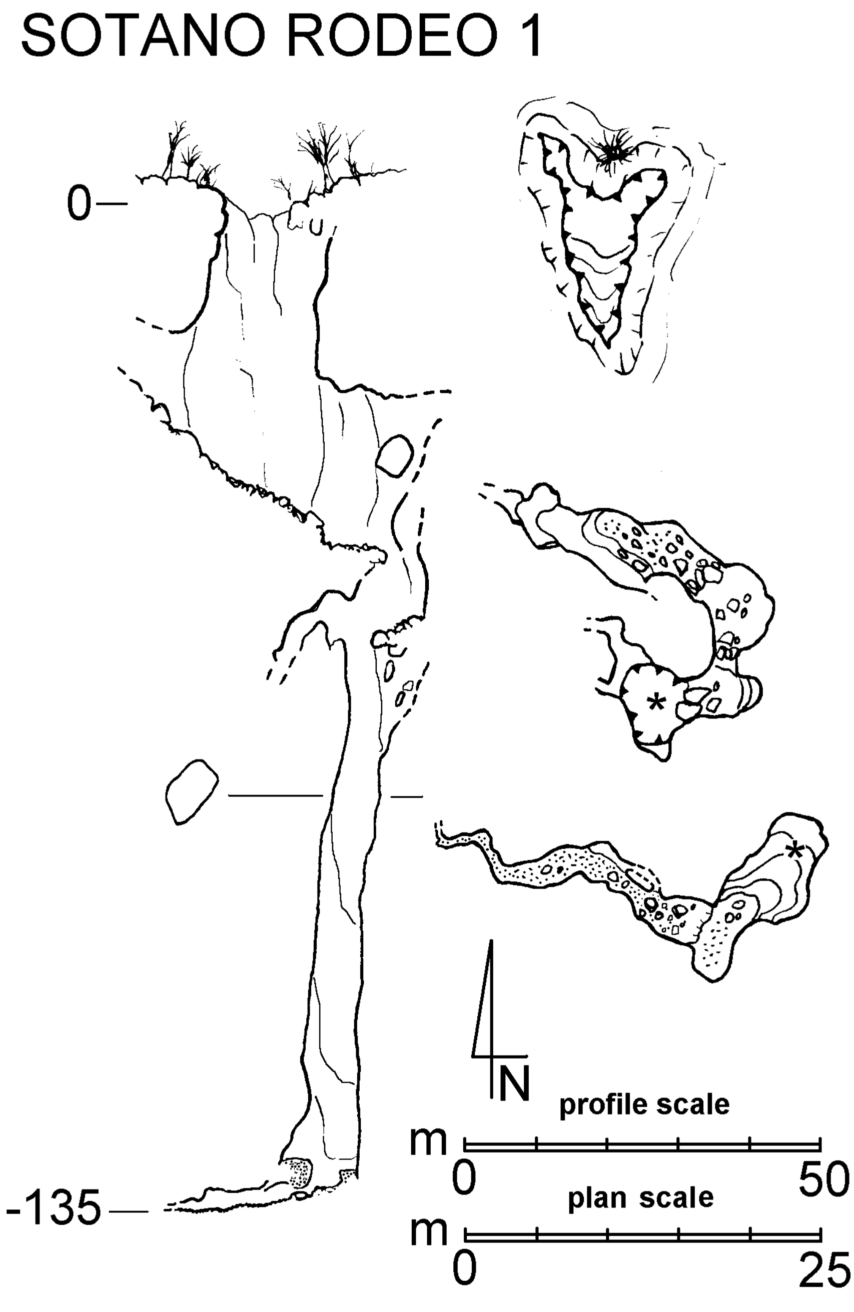


Fig. 11 - Plan views and longitudinal section of two caves in the Llano la Cumbre, S. Maria Ixcatlan (survey: Ass. Geogr. La Venta).

Along the same valley line, 700 m downstream TSA15, we find the second sinkhole, Sumidero San Antonio, 100 m long. This cave as well as Cueva el Calacote (TSA10), that opens 2 km further west, are particularly interesting for the understanding of the geological evolution of the area because these caves show solution forms typical of a convective circulation of thermal waters, with calcite crusts covering distinctive dome-shaped voids. This morphology might testify to an ancient phase of karstification produced by uprising hot water, and therefore the two caves might be among the oldest ones in the region. Presently, the surface erosion has exhumed the two caves and in Sumidero San Antonio the hydrothermal forms were locally remoulded by the flow of the rainwater stream sinking into it.

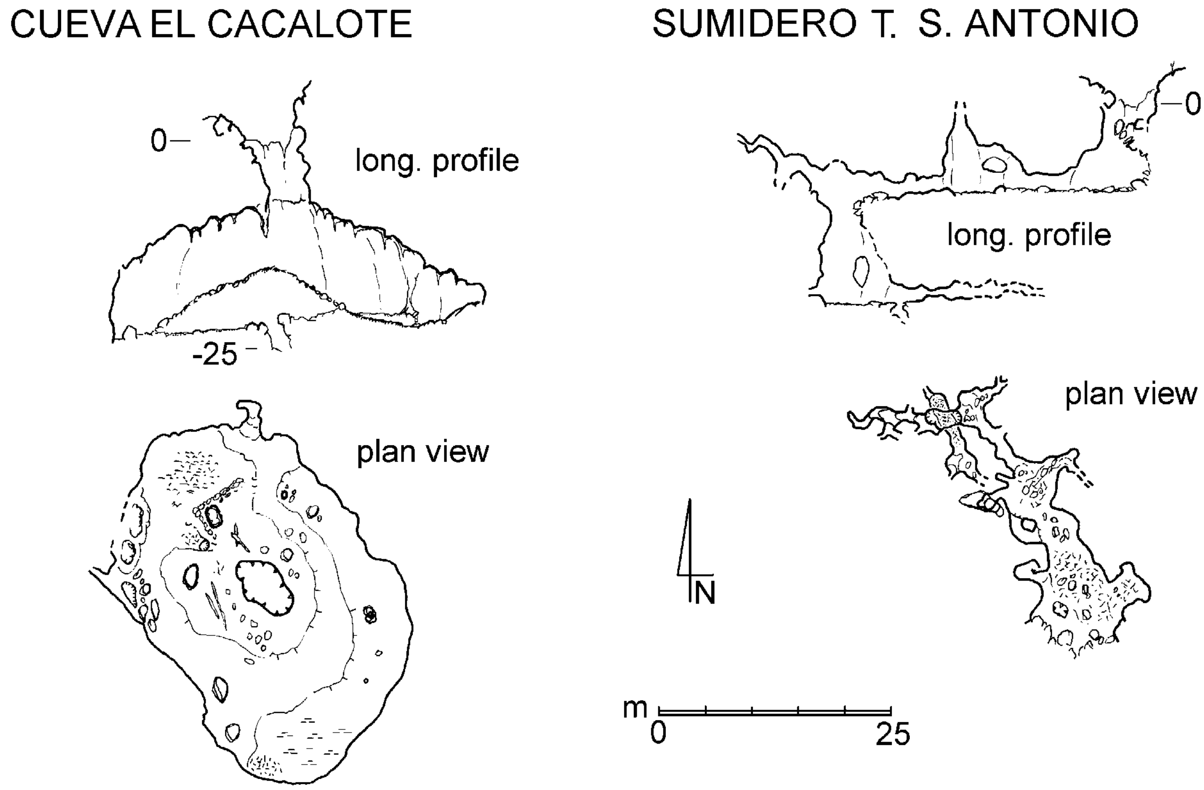


Fig. 12 - Plan views and longitudinal section of two hydrothermal caves in the Terrero San Antonio area, S. Maria Ixcatlan (survey Ass. Geogr. La Venta).

All the caves described up to now in this sector are dug into Cretaceous limestone, whereas the last cave to be described originated in Tertiary conglomerates. The now isolated strips of the original wide conglomerate plate, several tens of metres thick, are located on the eastern edge of the highland. The Cueva Loma del Muerto (IX3) was explored in the locally sub-horizontal beds located on top of the formation, consisting of limestone pebbles. The cave opens on a wall, with two big entrances, which gives origin to two not joined ascending galleries, completely closed after a few metres. Some chimneys opening on the gallery vault, 1-2 m wide and 3-4 m high, represent a peculiar feature of the cave.

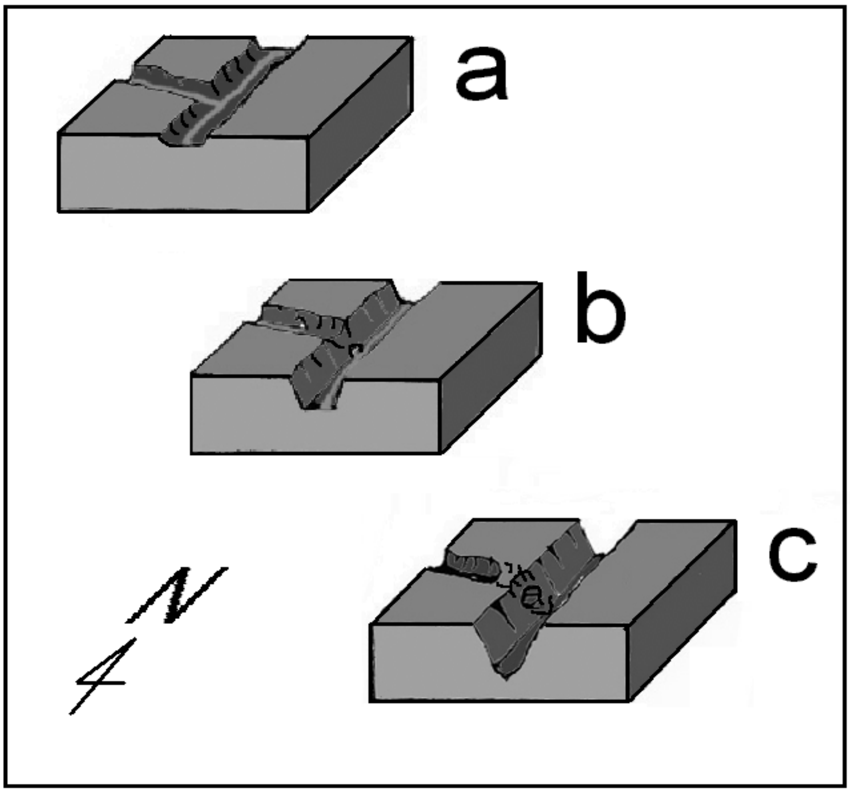
Conclusions

The evolution of caves and karts landforms in the area of Juquila Canyon is certainly related to the complex morphotectonic history of the Tehuacan basin. Today we have only few data concerning it, and here we present some preliminary hypotheses that need further investigations.

The present relief, cut by the canyon of Rio Juquila, represents what remains of an ancient levelled surface that might have formed in the late Cenozoic, during a period of relative tectonic quiescence. During the formation of this surface, that cut the tectonic structures, the karst should be not so developed in extension and depth. The above-described faulting events progressively raised the *sierras* and lowered the tectonic depressions of Tehuacán and Cuicatlán. The Rio Juquila and the main tributaries must have been active before the uplifting, in an initial phase during which the climate conditions were probably wetter than today, and the river erosion more effective. As a result, the watercourse progressively incised the canyon and the initial plain became a highland. This must have been the evolution set in which the karst began to develop. Probably, the large karst tunnel of Puente Colosal was formed during the first phase of drainage downcutting (Fig 13).

During a lapse of time, the length of which we do not know but that might have been of several million years, the underground waters formed a network of subterranean galleries along fractures and bed partings. The opening of new fractures during the faulting events and the deepening of the canyon helped the transfer of the flow through different and deeper levels, with the activation of springs located at lower altitudes. The change of the drainage network implied leaving old courses, activating new fractures and widening them to form new caves.

At the present time, we may find several generations of karst forms, the relative age of which is nevertheless difficult to infer. The most ancient generation seems to be that of hydrothermal caves, located in the southern section of the studied area, which are hypogenic caves re-elaborated by percolation waters and intercepted by surface erosion. Such caves might be related to the last phases of the Tertiary magmatic activity that affected the area, and therefore be very ancient (Miocene?). For sure their morphological features require a very different situation from the present one, preceding the deepening of the hydrographical network.



Frig. 13 – Hypothetical evolution steps of Puente Colosal (from: Livornese 2005)

Along with the development of the deep karst network, surface karst dissolution had a relevant role levelling the topographic surface. As a consequence, the present highland does not correspond to the original plain, and the first-phase karst forms have not survived, other than as relict and beheaded caves preserved in limited sectors. Trace of the progressive lowering of the base level may be found in the phreatic passages along the canyon walls, mainly between 1500 and 1600 m of altitude; they are segments of an ancient network that fed springs deactivated due to the following lowering of the base level.

Also the vertical caves explored on the highland (absorption points of rain water and transit conduits to the deeper zones) may belong to different generations and some of them are still rather active, despite the scarcity of rain feeding the underground network. At present, the decrease in the feeding of the karst network, due to the recent passage to a drier climate, has reduced the entity of karst dissolution and slowed down the development of the underground network. Furthermore, the progressive washing away of the soils present on the top plateau, together with the abundant vegetable material, is leading to the obstruction of the karst cavities.

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Appendix

CANYON JUQUILA

cave	UTM E (14) (NAD 1927)	UTM N (NAD 1927)	elevation m a.s.l.	depth m	lenght m
Puente Colosal (PC)	683060	1984840	1760	- 37	255
JQ – 1	684200	1984980	1580	- 4, + 10	15
JQ – 2	683950	1985850	1550	+ 10	30
JQ – 3	683900	1985900	1550	+ 2	23
JQ – 4	683780	1985800	1580	+ 16	75
Cueva Dos Ojos (DO)	684538	1990564	1495	-25, +30	1020

LEFT HYDROGRAPHICAL SIDE (Cerro Verde – Cerro Tequelite)

MZ-1	678160	1991470	2630	- 10	13
MZ-2	678393	1992460	2680	- 37	50
MZ-3	678980	1993585	2665	- 7	10
MZ -5	678240	1992885	2635	- 11	15
TK-1	678345	1987080	2665	- 5	9
TK-2	678375	1987100	2665	- 7	11
TK-3	678420	1987040	2660	- 13	20
TK-4	679620	1987220	2605	- 11	25
TK-5	679785	1987455	2735	- 21	25
TK-7	679560	1987615	2620	- 8	10
TK-8	679525	1987460	2625	- 19	25
TK-9	679200	1987439	2695	- 2	8
TK-10	677980	1986375	2515	- 6	15
JQ – 5	678200	1982350	2600	- 20	

RIGHT HYDROGRAPHICAL SIDE *(Cerro Granudo – Cerro Grande – Llano la Cumbre)*

Pozo de la Loma (CG-1)	686045	1980035	2420	- 10	13
Pozo Canada Pericon (CG-2)	686805	1983650	2300	- 6	10
Sotano de la Laguna Prieta (CG-3)	687555	1985460	2490	- 280	330
Pozo de la Vaca Ladra (CG-4)	688335	1985380	2455	- 134	180
Pozo de la Mosca Molesta (CG-4)	688070	1986344	2525	- 35	50
Pozo el Timbre (CG-6)	688825	1983195	2370	- 10	20
Pozo el Campamento (CG-7)	689270	1983925	2320	- 17	25
Pozo de la Cañada de la Cruz (CG-8)	687500	1983650	2405	- 7	10
Cueva el Cacalote (TSA10)	688775	1980663	2255	-25	60
Pozo de la Laguna Primera (TSA11)	688710	1980085	2230	-42	50
Pozo Terrero San Antonio 1 (TSA1)	690847	1980980	2256	-14	25
Pozo Terrero San Antonio 2 (TSA2)	690853	1980990	2255	-6	8
Pozo Terrero San Antonio 3 (TSA3)	690832	1980983	2255	-22	37
Sumidero San Antonio (TSA4)	690860	1980580	2190	-23	100
Pozo el Palmones (TSA5)	691058	1980343	2220	-18	30
Sotano la Calabera (TSA6)	691435	1980020	2260	-77	100
Cueva Destendido 1 (TSA7)	691273	1980168	2220	-52	60
Cueva Destendido 2 (TSA8)	691345	1980148	2227	-10	20
Cueva Destendido 3 (TSA9)	691273	1980165	2213	-6	18
Cueva Majada Vieja 1 (TSA12)	692097	1981328	2182	-4	7
Cueva Majada Vieja 2 (TSA13)	692100	1981340	2185	-8	12
Pozo C P3 (TSA14)	690955	1981120	2300	-28	52
Cueva Perfecto 3 (TSA15)	690775	1981275	2265	-39	172
Sotano Rodeo 1 (IX1)	692420	1976625	2200	-135	210
Sotano Rodeo 2 (IX2)	692414	1977000	2230	-15	18
Cueva de la Loma del Muerto (IX3)	694270	1978930	2130	+5	70