

A brief history of exploration in Lechuguilla Cave in New Mexico, USA

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ABSTRACT

Lechuguilla Cave, a complex three-dimensional cave with a single known entrance, is located in remote desert terrain in Carlsbad Caverns National Park, in southeastern New Mexico, USA. The Guadalupe Mountains there contain uplifted limestone and dolomite rock in the Permian-age Capitan Reef complex. Hundreds of caves have been found in this region, but Lechuguilla Cave greatly exceeds the size of all others known. It was only a small pit mined for bat guano in the early twentieth century. In the 1970s the Cave Research Foundation performed digs at the bottom, where profuse air movement had been noted in the debris. This work ceased but another team of cavers visited in 1984, hearing and feeling the significant air, and began a digging project approved by the Park. The cavers dug into continuing passage in 1986. It was explored in three major branches, generally trending west/southwest to east/northeast, parallel to the reef face, with north-south connections along deep rift features. Depositional and corrosional events during sulfuric-acid speleogenesis created remarkable speleothems and speleogenesis, and the cave has often been called "the Jewel of the Underground". The rapidly growing cave passed 80 km of surveyed length by 1990. Within the first ten years of exploration, 28 large-scale expeditions led to the cave reaching 113 km in length. From 1997 to 2013, 109 additional kilometers were mapped with smaller teams of up to 12 cavers per expedition. Exploration and mapping is now done in three to five expeditions per year, and recent work has focused on climbs and smaller leads such as tight crawls and fissures that were previously passed. Significant discoveries continue to be found using these techniques. The cave reaches a depth of 475 m and has been mapped to over 222 km in length. Exploration to the extreme ends is efficiently done with multi-day expeditions, using established camps in each branch. Cavers from the United States and dozens of other countries have been involved in this mapping project. The cave now has more than 35,000 survey stations, and the complexity of the maze of passages creates significant challenges for cartographers. Based on ever-present airflow and porosity of the bedrock, it is expected that this cave will continue to surprise and delight explorers and speleo-scientists in the future.

Key words: cave, exploration, limestone, New Mexico, Permian

Una historia abreviada de las exploraciones en la cueva Lechuguilla, Nuevo México, EE.UU.

RESUMEN

La cueva Lechuguilla, una cavidad tridimensional compleja con una sola entrada conocida, está ubicada en un remoto terreno desértico en el Carlsbad Caverns National Park, en el sureste de Nuevo México, Estados Unidos. En dicha zona, las Montañas de Guadalupe están formadas por calizas y dolomías levantadas tectónicamente en el complejo Capitan Reef de edad pérmica. En esta región se han encontrado cientos de cuevas, pero la cueva Lechuguilla supera con creces el tamaño de todas las conocidas. A comienzos del siglo veinte se trataba de una pequeña depresión que se laboreaba para obtener guano de murciélago. En la década de los setenta la Cave Research Foundation realizó excavaciones en el fondo, donde se había observado un movimiento de aire profuso en los escombros. Este trabajo cesó, pero otro equipo de espeleólogos visitó el lugar en 1984, y al oír y sentir la significativa corriente de aire comenzaron un proyecto

de excavación con la aprobación del Parque. Los espeleólogos llegaron a encontrar un pasaje continuo en 1986. Se exploró en tres ramas principales, generalmente con dirección de oeste/sudoeste a este/noreste, paralelo a la cara del arrecife, con conexiones norte-sur a lo largo de características profundas del arrecife. Los eventos deposicionales y de corrosión durante la espeleogénesis con ácido sulfúrico crearon notables espeleotemas y espeleogénesis, y la cueva se ha llamado a menudo como "la Joya Subterránea". El conocimiento de la cueva creció rápidamente y había pasado de 80 km de longitud en 1990. Dentro de los primeros diez años de exploración, 28 expediciones a gran escala llegaron a los 113 km de longitud. Desde 1997 hasta 2013, 109 kilómetros adicionales fueron topografiados con equipos más pequeños de hasta 12 espeleólogos por expedición. La exploración y la cartografía se realizan ahora por de tres a cinco expediciones anuales, y el trabajo más reciente se ha centrado en escaladas e investigación de pequeñas incógnitas por pasajes más pequeños tales como oquedades muy estrechas y fisuras que fueron previamente ignoradas. Utilizando esta estrategia se siguen haciendo importantes descubrimientos. La cueva alcanza una profundidad de 475 m y tiene más de 222 kilómetros de longitud cartografiada. La exploración a los extremos finales se realiza eficientemente en expediciones de varios días, utilizando los campos base establecidos en cada rama. Los espeleólogos de Estados Unidos, y decenas de otros países, han participado en este proyecto de cartografía. La cueva tiene ahora más de 35000 estaciones topográficas, y la complejidad del laberinto de pasajes crea desafíos significativos para los cartógrafos. Basados en el flujo de aire siempre presente y en la porosidad de la roca, se espera que esta cueva siga sorprendiendo y deleitando a exploradores y espelo-científicos en el futuro.

Palabras clave: caliza, cueva, exploración, Nuevo México, Pérmico.

VERSION ABREVIADA EN CASTELLANO

Introducción

La cueva Lechuguilla es un complejo tridimensional de cavidades con una única entrada conocida, a una altura de 1531 m en el remoto terreno desértico en el Carlsbad Caverns National Park, al sureste de Nuevo México, EE.UU. En dicho lugar, las Montañas de Guadalupe contienen calizas y dolomías, de edad pérmica, elevadas tectónicamente en el Complejo Capitan Reef. La cueva es considerada como una de las cavidades más bellas del mundo, debido a las grandes cantidades de yeso junto con espectaculares espeleotemas desarrollados a partir de la reacción de ácido sulfúrico con la roca caliza. Los primeros espeleólogos excavaron en un pasaje del tamaño de un hombre en 1986, y después del primer año con 11 km explorados, el trabajo se detuvo hasta que se firmó un acuerdo entre la administración del Parque y los exploradores de cuevas. Posteriormente, la cueva fue explorada y cartografiada en tres ramas principales, generalmente con orientación de oeste-suroeste a este-noreste, paralelo al frente del arrecife, con conexiones norte-sur a lo largo de rasgos profundos del arrecife. La exploración y la cartografía han continuado hasta nuestros días, ahora con sólo unas pocas expediciones por año. El trabajo reciente se centra en la mejora de la precisión de las topografías, así como a la exploración con escalada y pequeñas incógnitas que hay que seguir las gateando y que se habían ignorado previamente por los espeleólogos. Se siguen encontrando descubrimientos significativos siguiendo con esta estrategia.

Discusión

En el año del descubrimiento de la cueva, una característica alta y estrecha con orientación norte-sur llamada el Rift, había sido descubierta y explorada hasta una profundidad de 260 metros por debajo de la entrada. El año siguiente un equipo de espeleólogos descubrió una salida de la parte terminal sur del Rift hacia un pasaje accesible y con un movimiento notable de aire. Esto llevó ramales a tres rutas distintas, una hacia abajo a pozos importantes que conducen a una rama oriental y occidental, y otra que continúa horizontalmente durante una distancia moderada. Al el año siguiente, tuvo lugar el mayor número de exploraciones, durante las cuales los espeleólogos continuaron haciendo descubrimientos en las ramas este y oeste, y encontraron una rama sur adicional en el fondo de un paso estrecho al final del pasaje horizontal. Cinco expediciones incrementaron los 11 km de cueva conocida hasta el momento, mediante el añadido de 34.5 kilómetros adicionales. En la rama oeste, los equipos cartografiaron todo el camino hasta la zona del bello estanque Oasis y la sala Rainbow, que fue la parte terminal en esa dirección durante una década. Las dimensiones de los pasajes en este pozo occidental kilométrico fueron en muchos casos de 30 metros de ancho y la mitad de altura, y en partes estaban revestidas de yeso blanco que parece nieve. En el

camino se encontraron con varios lagos subterráneos y grandes pasajes que van de norte a sur. En el este, los equipos cartografiaron a través de un complejo de 160 m de profundidad con espectaculares pasajes, pasando un estanque azul celeste de 30 metros de profundidad, el Lake of the Blue Giants, para llegar a la sala Moby Dick. Las futuras exploraciones requerirán un esfuerzo importante de escalada. En la rama sur, se encontraron numerosos activos antes del descubrimiento de un segmento de un gran pasaje llamado Lebarge Borehole. Más allá, exploraron a través de un laberinto tridimensional para llegar a la sala Hoodoo Hall y la sala decorada Chandelier Ballroom, seguido por la enorme sala Prickly Ice Cube. Grandes pasajes que se dirigen hacia otras direcciones se mantuvieron sin explorar. Una ruta condujo a un gran complejo llamado el Vacío, que alcanzó el punto más profundo de la cueva (410 m) en ese momento, con numerosos depósitos de azufre y lagos. En 1989 llegaron equipos de expedición a gran escala al Parque, y se exploraron 26 kilómetros adicionales de la cueva. La atención se centró en las ramas sur y este, llegando a una formación terminal en el sur bajo un cañón superficial, y escalando los 65 m del Aragonitemare más allá de Moby Dick, para descubrir la región del Lejano Oriente. Esto permitió eventualmente alcanzar un gran cruce, con un lugar favorable para la ubicación del campamento cerca de un pequeño arroyo. Los niveles superiores se exploraron hasta una cascada de piedra carmesí con estanques y la terminación eventual del pasaje. Los niveles más bajos se alcanzaron a través de una serie de pozos con recubrimientos de residuos de ferromanganeso y laderas muy inclinadas que conducen a un ramal descendente hasta la Outback. Los espeleólogos exploraron una fisura profunda a lo largo del borde norte de la Outback que conducían hasta el nivel freático en el lago de las White Roses a -475 m por debajo de la entrada, el punto más profundo en la cueva hasta el momento. En 1990, la cueva ya había pasado de los 80 kilómetros de longitud cartografiados. Los próximos dos años de las exploraciones añadieron detalles a cada una de los tres ramas principales, y también se produjo el cese de la exploración hasta que el Parque y los espeleólogos llegaron a un nuevo acuerdo. El impacto físico a la cueva se hizo evidente, y se establecieron límites anuales sobre el número de exploradores que trabajarían en la cueva. Dentro de los primeros diez años de exploración, 28 expediciones a gran escala permitieron alcanzar los 113 kilómetros de longitud. De 1997 a 2013, fueron cartografiados 109 kilómetros más con equipos más pequeños de hasta 12 espeleólogos por expedición. Durante este período, varios descubrimientos importantes incrementaron la extensión a las ramas oriental y occidental: South Winds, Mother Lode (1994), Southern Climes (1995), Sanctuary (1997), Zanzibar (1999) and the Promised Land (2003) se descubrieron y cartografiaron en el este. Coral Sea (2005) and Nor'easter (2008) fueron descubiertas mediante el gateo a través de capas caóticas y destrozadas más allá del Outback en el este. Todos estos descubrimientos ampliaron significativamente la planta de la cueva. Irónicamente, incluso las incógnitas dentro de los límites conocidos de la cueva han contribuido significativamente a la cueva, como fue el descubrimiento de Emerald City. A este lugar se llegó a través de una gatera sin explorar en un laberinto completamente explorado, al norte del pozo occidental en 2007. Un domo de 125 m de altura al final de Emerald City resultó ser escalable por espeleólogos competentes en 2012, lo que condujo al descubrimiento de Oz, 150 m por encima de la cueva conocida y a unos 50 metros de la superficie. El inmenso tamaño y longitud del pasaje asombraron a los exploradores y espeleo-científicos, estando a una altura similar a la entrada de la cueva. Aproximadamente 3.2 kilómetros de pasajes decorados han sido descubiertos en este complejo hasta el momento.

Conclusión

La cueva Lechuguilla ha alcanzado una profundidad de 475 metros y se han cartografiado más de 222 kilómetros de longitud. La exploración a los extremos terminales se realiza de manera eficiente con expediciones de varios días y el uso de campamentos base establecidos en cada rama. Los espeleólogos de los Estados Unidos y docenas de otros países han participado en este proyecto de cartografía. La cueva tiene ahora más de 35 000 estaciones topográficas, y la complejidad del laberinto de pasajes crea desafíos significativos para los cartógrafos. Basado en el omnipresente flujo de aire y la porosidad de la roca encajante, se espera que la exploración de esta cueva siga premiando a los espeleólogos y espeleo-científicos en el futuro.

Introduction

The cave is located in southeastern New Mexico, USA, approximately 8 kilometers from Carlsbad Cavern, the namesake cave in Carlsbad Caverns National Park. The cave entrance is at 1531 meters above sea level. Lechuguilla Cave is often regarded

as one of the world's most beautiful caves. The reaction of sulfuric acid with limestone created massive amounts of gypsum, and the cave displays spectacular speleothems, including its signature selenite "chandeliers." Both authors have been extensively involved in the exploration and mapping of this cave.

As the cave penetrates deep into the Permian Capitan reef, exploration at the extreme ends is best done in multi-day explorations, using established camps in each branch. Climbs and tight crawls are physical obstacles that are often encountered, both having potential to lead to additional passage in this cave. Many were passed over in the early years of exploration, when great boreholes and walking passages seemed endless. Discoveries of significant new areas have continued in all three branches of the cave. Much work has been in the largest, the Western Branch. The western edge has been extended several times over the past two decades. Work inside the perimeter of the cave has found new connections and discovered large amounts of boneyard passage beneath the breakdown of established rooms and passages. Recent climbs have discovered significant upper level cave development, especially in the western and southern branches. Sizable chambers have been discovered in the blank spaces around known passages, by pushing tight leads and crawls. In the Eastern Branch, teams have found new areas deep in the Outback, extending the map in the northeast corner. Just when it seems that we understand the cave, a paradigm change can happen from a new discovery, leading to new understanding of the complexity of the passage development. The discovery of Coral Sea in the East and Oz in the West are both recent examples of this change.

For every team that explores the frontier, there are others checking and repairing blunders and re-sketching complex areas with better survey standards than those of two decades ago. New techniques are being implemented, such as multiple clothes changes, ultra-light camping, use of PDAs and ultra-small PCs in-cave, along with laser rangefinders. Efforts by dedicated volunteers continue to contribute to understanding of this complicated and exceptional cave.

We will now describe the activities that resulted in cave growth, by calendar year, since the main cave was first entered in 1986. We have avoided geological and biological discussions in order to present the story of exploration and cartography of this large cave. Many details of personnel and timing have been omitted for space. The references provide additional information.

1986

In the first trip in May, nine cavers explored approximately 1 km of mostly walking passage, first climbing down a wet flowstone cascade dropping to a pool. They proceeded to find continuation of their route

blocked by a 46-m free drop that was named Boulder Falls. Below this, passage gained dimensions and depth, leading to a spectacular gypsum mass called Glacier Bay. Deep, fluted vadose drill holes up to 2 m in diameter abounded here, and a route was found down to Rim City and Windy City, named for the movement of survey marker flagging from air movement. The team then explored through Sugarlands to the Rift, a north-south-trending deep fissure several meters wide, bridged by massive boulders and fill at the initial approach. Each direction dropped into deep chasms. The bridge across the Rift was ~200 m below the entrance. The next team that year continued downward in the Rift, pushing south where the air seemed strongest. They were eventually stopped when the wind diminished at a flowstone-cemented pool at a depth of 260 m below the entrance. A third small team returned to the cave in October.

Continuing exploration would require experienced climbers to go up at the south end of the Rift. In addition, there were organizational disagreements among the project leaders that needed sorting out. This led to a cessation of exploration as directed by the National Park, to work out an agreement for further exploration.

1987

The cavers organized Lechuguilla Cave Project (LCP) with the approval of the cave resource management at the Park. The organization was devoted to surveying and studying the cave, but it became a source of problems as will be discussed later. In August, after an exploration agreement was in place with the Park, the newly organized cavers returned with strong climbers, to find their way out of the south end of the Rift and reach a more convenient route. The Overpass traversed along the upper Rift and reached a major junction where E and F surveys continued. All travel to the deep branches now goes via this upper route, with a few safety lines installed along traverses. The right fork of the junction led 300 m through a white gypsum-coated passage to obscure leads. The left fork was the E survey, and passed a significant deep inclined pit before ending at another even deeper pit. The first was called the Great White Way and led to an immense trunk that begins the Western Branch of the cave. The second pit was named Apricot Pit. It led down a series of inclines to the beginning of the Eastern Branch of the cave.

The August expedition brought in 35 cavers and mapped just under 3 km of cave. Most of the work focused on descending the Great White Way to the Deep

Secrets corridor, strewn with giant breakdown as it descended westward through massive reef. Pools of water were found off to the sides of this route. At Fortress of Chaos a climb up led to Pellucidar, a 30 x 85 m room festooned with soda-straw stalactites and with the first discovery of subaqueous helictites in the cave. Another route downward and to the west came to Deep Seas, a large flat chamber with a floor of loose flakes of calcite rafts. Later it would become a prime camp location. Exploration stopped at the nearby White Christmas Tree room and Lake Louise, where drinking water could be collected. A beautiful golden and white waterline highlighted stunning mammillaries over the lake.

A few months later, 45 cavers returned to Lechuguilla Cave. One team climbed up a steep series of raft-covered slopes beyond the lake to reach a giant borehole with white gypsum 'snow.' Thus began the Western Borehole, from which many kilometers of future discoveries would be explored. This horizontal trunk headed west for over 1 km and was frequently at least 30 m wide and 15-20 m tall. Winterlands led to the Three Amigos, three remnants of drilled gypsum stalagmites standing alone. Farther west they came to the Leaning Tower, a spectacular leaning raft cone reminding them of the famous tower of Pisa. The western route continued big, but the team was unable to continue mapping due to consumption of all of their carbide for lamps. The two expeditions in 1987 brought the cave to about 11 km in length.

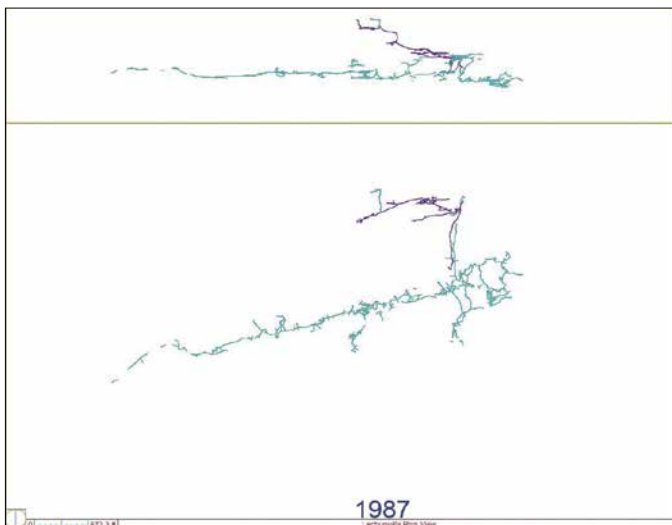


Figure 1: Entrance Series, Rift, Western Borehole and Eastern Maze.
Figura 1. Parte de la entrada al Sistema Rift, Western Borehole y Eastern Maze.

1988

The largest amount of exploration occurred in five expeditions in 1988 when 34.5 km was added to the length of Lechuguilla Cave. The number of caver visits was high, with 55 cavers participating in January on 39 survey trips into the cave. In the West, the borehole reached Hard Daze Night Hall, where large leads abounded. Side leads led to Jackpot and Mirage Room on the north and Chocolate Factory and Far Planetarium on the south side. Beyond this to the west was Huapache Highway, ending at the Oasis, a beautiful ancient pool basin decorated with exquisite dripping stalactites and vermilion-colored shelfstones and stalagmites. A northern branch of the Highway led to Keel Hall, Long Haul and finally terminated at Rainbow Room after passing through thick ferromanganese residue. Near the Three Amigos an upper level was discovered with massive gypsum stalagmites having drooping radial selenite arms. This was called the Chandelier Graveyard.

Back in the Eastern Branch, cavers found their way down Apricot Pit with five roped descents totaling 166 m, and reached another horizontal trunk heading east, beginning physically close to Deep Secrets in the Western Branch. A spectacularly decorated route through Nirvana came to another pool suitable for water collection. Beyond this, the route became more difficult, passing the iron-laden Rusticles (another future camp site) to reach the Orange Bowl and two significant lakes, Stud and Blue Giants (30 m deep). The eastern direction terminated at the Moby Dick room, named for a giant whale-like boulder. An airy popcorn- and aragonite-walled dome above this room excited explorers as to what might be ahead.

An upper-level area above the eastern maze was reached through a climb by caver Lyles Moss up Apricot Dome. This led to Hoot-n-Holler Hall, and Ghost Town, a large chamber with derelict stalagmites. Later a shorter route to this complex was found through the difficult S&M Crawl to reach this level from an intermediate pitch in Apricot Pit, saving hours of trip time.

Another push team returned to F Survey at the Overpass level, and found another inclined pit series, named Little White Bastard for its body-sized dimensions. This dropped down into the narrow pool area of the Gulf of California. Another team found a traverse over this to a series of large lakes including Lebarge and Chandelar. Another giant borehole led south and west, along the Yellow Brick Road, to a sparkly complex maze in gypsum, named Tinseltown. The Southern Branch was distinctly separate from the Eastern and Western branches. The first team found

Land of Awes and then Darktown, with 6-m-long hanging gypsum hairs. Beyond this they dropped down into Hoodoo Hall, floored with raft cones three to four meters tall. A subsequent team discovered a large chamber with rows of giant selenite stalactites, the Chandelier Ballroom. These enormous jagged crystals up to 5 m long became a landmark photo location in the cave. Beyond this the cave branched again, leading into a complex 3D maze and the giant Prickly Ice Cube Room (PICR). A climb out of PICR led up into Seesaw Canyon, where it dropped back down to the Chicken Little Room with an immense shaft above it, the Mother of Pearl Dome. Beyond this was the FLI room, at the base of an impressive popcorn-covered climb named High Hopes. In another finger of cave, a deep maze called the Void passed masses of sulfur and reached depths greater than 410 m at Sulfur Shores, the deepest point found in the Southern Branch. This discovery reinforced the role of sulfuric acid in the theory of development of Lechuguilla Cave.

1989

Exploration and survey yielded about 26 km of passage with 4 large plus one small expedition in 1989. The largest expedition ever had 103 cavers in January, with 39 trips in cave. The average distance surveyed per expedition was 6.4 km. Focus was on the new discoveries in the East and South, with little work in the Western Branch. Another survey team climbed into Underground Atlanta where the 68

m- deep Hotlanta Well was discovered to be the upper end of the Mother of Pearl dome. Higher up, cavers found Tower Place, spectacular with flowstones and 10-m stalagmites. Leads above Seesaw Canyon led to Lechy's Lair, an unpleasantly silty upper level of development with dangerous pits that dropped out into the ceiling of the underlying PICR. In another direction from the Chandelier Maze, exploration found Lake Margaret, and the Pearlsian Gulf was named for pools with exceptional cave pearls. Nearby a flat area was designated for camping, and named Big Sky Country. A route to Hoodoo Hall was discovered, where giant raft cones covered the floor of a giant chamber. Beyond Hoodoo Hall, cavers explored to find Deliverance, and the end of this finger of cave. The year ended with High Hopes getting climbed to discover a decorated region starting with Shangri-La. From this, a traverse across the edge of Conniption Pit reached a passage with mounds of gypsum hairs, named the Spinning Room. After this the passage led to Atlantis and Vesuvius, with large pools decorated with flowstone, lions' tails, pool fingers, tiered pool shelves, and the characteristic stalactites and stalagmites. Flowstone chokes formed the termination of the Southwest direction, as the cave was below a major canyon with surface drainage.

Ghost Town was pushed in the east. A bold series of climbs ascended the airy dome above Moby Dick room, first attempted by climbers Bryan Becker and Don Doucette in 1988, then completed by Lyle Moss, Dan Clardy and Don Kluever. They called it Aragonitemare. At the top of the 65-m dome the passage became horizontal again, going east in the Land of Enchantment and the China Shop with 2-m-tall aragonite bushes. This would become one of the more fragile trade routes in the cave, always requiring extra care when carrying camp packs. After following a slanted-floored trunk, cavers found an airy route through a narrow flowstone-coated fissure to a short but difficult low crawl. This opened up into another giant trunk leading to Grand Guadalupe Junction, with large horizontal walking passage going in several directions. A camp was established nearby with the only (slightly) flowing water known in the cave, named Lost Pecos River. This region of the cave was called the Far East, and has continued to challenge cavers to the present, as it continues to reveal new passages to persistent explorers. The highest levels had gypsum, while the lower levels were more barren and fractured. Near the camp a walking passage was explored to a series of pools in Boundary Waters. Beyond this cavers discovered La Morada Room, Crimson Falls, and Firefall Hall following a colorful flowstone cascade, and found a lake with a profusion of pearls, named Lake of the

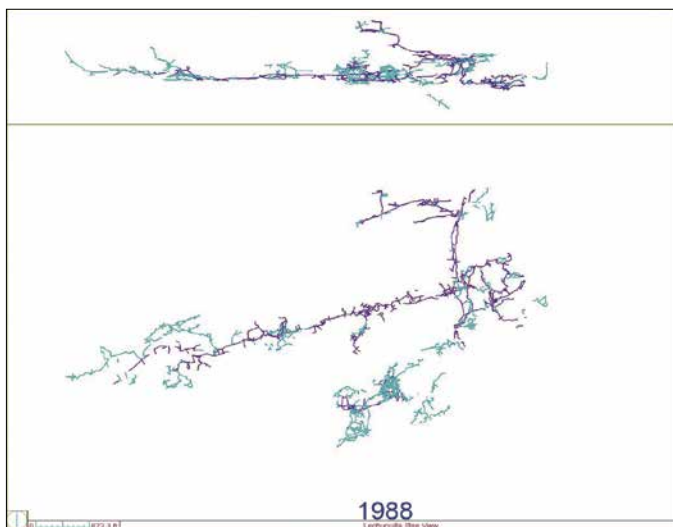


Figure 2: Addition of Keel Hall, Rainbow Room in the west and the Southern Branch.

Figura 2. Adición de Keel Hall, Rainbow Room, South Branch.

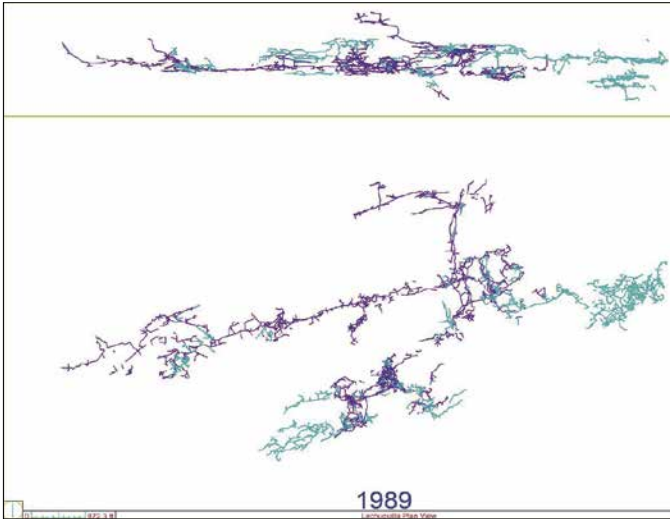


Figure 3: Addition of High Hopes, Deliverance, and Far East.
Figura 3. Adición de High Hopes, Deliverance, y Far East.

Lost Marbles. Crossing the water they reached Happy Hunting Grounds, the easternmost extent of the cave. High above Firefall Hall they discovered a decorated pool chamber named Quasimodo's Lair.

Back in the southeastern direction from Grand Guadalupe Junction, cavers found a dirty series of inclined pits and slopes called the Gorilla Pit, leading to a free-fall drop where they discovered the Ruby Chamber below. This large round chamber had an obvious route downward to the Wild Black Yonder. Beyond this, a long inclined trunk of immense dimensions entered the Outback. In the last expedition of 1989, cavers explored a deep fissure along the northern edge that led down to the true water table at Lake of the White Roses at -475 m below the entrance, at the time being the deepest point in a mainland United States cave. The Far East and the entire Eastern Branch proved to be complex additions to the outline of Lechuguilla Cave. By the end of the year, the cave was 70 km long.

1990

In 1990, exploration slowed down, and only three large expeditions were fielded. They surveyed 14.7 km of new passage, working in all three branches of the cave. Above the Overpass in the Rift, the Parallel Universe and Buck Rogers Dome were found by climbing crevices. In the West, a fissure was climbed above Chandelier Graveyard to find the Piled Higher and Deeper (PHD) room, measuring 40 x 55 m and reaching up into the backreef formation. Also in the

vicinity, cavers found a room named Jewel Box, for the sparkling calcite on the walls and a 1-m-long selenite chandelier that was exceptionally transparent.

Mapping in Ghost Town over the eastern maze led to the discovery of additional subaqueous helictites. Much of the work was in the Far East, where various galleries were discovered in the inclined "pancake" passages characteristic of the Outback. At the end of one, Flake Lake and Halloween Lakes were discovered, along with a colorful flowstone mass called the Purple People Eater. Also below the Ruby Chamber, cavers chimneyed down against the wall to find a new finger of cave leading to TNT pit and a route heading away from Ruby Chamber to the south.

1991

LCP led four expeditions of varying duration in the cave. In the Eastern Branch, Ghostriders Hall was explored off Ghost Town. In the west, climber Dave Jones ascended to an obvious hole above a northern alcove near the center of the Western Borehole; this tall sloping Northwest Passage headed off the map to reach Hudson Bay. The 50-m-wide x 105-m-long chamber had numerous pools and raft cones. Farther on, Spar City was explored, with some of the largest dog-tooth spar found in the cave. Beyond this, the Three O'clock Staircase led to Avenida Sombra.

The Red Seas was found in a climb starting only minutes from the Deep Seas campsite. This ascending chamber was marked with old orange-lined pool basins with little islands crowned by fantasy-castle aragonite spires. From there, a rappel dropped back down to the Dead Sea, an austere room about 75 by 50 meters, lined with mammillary calcite and going to the lowest point in the Western Branch. During the same expedition, a major rescue of an injured caver in the West brought national media coverage to the cave. The impact of the rescue effort was high. To add to the media exposure, a long-awaited photographic report on Lechuguilla Cave was published in the March issue of the National Geographic magazine.

1992

1992 was a low point for exploration of Lechuguilla Cave. The management of LCP had disagreements with the Park management over ownership of original survey sketches, and all caving was halted until a solution was worked out. A new organization, the Lechuguilla Exploration and Research Network (LEARN), was formed by some of the former LCP

cavers, with a more "democratic" organization. This allowed more cavers to apply to survey in the cave. Independent expeditions were now allowed as well. With this came new regulations on expedition sizes, down to 32 persons, to better protect the resource from human impact. One special project during the year was a scuba dive at the Lake of the White Roses in the Far East. No continuation was found under water, but the cave depth was extended to 490 meters.

1993

When the cave was reopened in 1993, LEARN fielded six expeditions; six private teams also surveyed. Twelve kilometers were added to the cave's length. A LEARN team pushed beyond Spar City in the Northwest Passage to Here Be Dragons. At the time this was the highest passage besides the entrance series. Another team found the magnificent Neverland trend above Red Seas, with a very large, steeply-ascending gallery that led up multiple flowstone-coated technical climbs, separated by level balconies with spectacular pool basins containing pool fingers and bizarre variants of subaqueous helictites. The ascents culminated in a dome several hundred feet above the starting point. The Needle Park Maze, and Blanca Navidad were also found above Red Seas. Although only a few hundred feet from the Neverland tube, Blanca Navidad was very different. Instead of flowstone, it was floored mostly by one of the best-preserved gypsum "glaciers" in the cave, with a remarkable igloo-like gypsum-rimmed vent in the center, and overlapping splash rings etched into its slope. In alcoves below and along its perimeter were numerous pools, having the greatest concentration of subaqueous helictites in any small area of the cave. Around Blanca Navidad there were other strange mineralizations: chunks of elemental sulfur; dark-green stains that were later identified as the phosphate mineral fluorapatite; and the most bizarre "Gripping Hand" stalactite/drapery group. Yellowish, flattened, twisting and branching repeatedly for several meters, they resembled inverted moose antlers.

In order to find cave trending North towards a small blowing cave nearby known as Manhole Cave, expeditions also worked in the North Rift. This was in response to the concerns that gas well operations outside the Park might unknowingly perforate the grand cave or its tributaries. Proof of the concern would be to find major cave going north. To date, the North Rift has resisted trending far to the north.

1994

LEARN led four expeditions in 1994 while independent teams led three. There were fewer teams in the Southwest and East that year. Just as it was thought that the West was completely mapped, cavers discovered the Wild West and South Winds, yielding many kilometers of passage. Both were found via obscure leads on the south side of the Western Borehole: an independent expedition focused on an impressive breakdown zone that went up to an indefinite height south of Hard Daze Night Hall. Teams surveyed to a balcony traversing along the top edge of the Far Planetarium room. A rising tube left the breakdown zone into a corroded virgin fissure that was followed to a room. This was called the Wild Wild West. A few months later a LEARN team followed the lead and broke into a 33- by 15-m breccia-walled room, the Outpost, from which holes went in several directions. One alcove dropped into a hole opening into a inclined flowstone pit that was descended to a deep green lake. Beyond this pool, a path led up to eventually cut back over itself into a large ascending room named Boomtown. There, they free-climbed a windy chimney that opened to a magnificent dome-chamber with flowstone, pools and terraced dripstone, and a giant stalagmite. This was called Trail's End Dome.

Meanwhile, while checking a mislabeled lead, Donald Davis crawled into a new trend, where his team found a dark, high chamber, Black and White Hall. Dave Jones free-climbed up to a hole on one wall, leading to a two meter-diameter round passage with very noticeable wind. This opened into a high, slanted room where they climbed up to a horizontal ledge along a great slope. The new trend was called South Winds. This was new passage on a scale that hadn't been experienced since the Far East discovery. The downward trend from this Southern Cross fissure leveled off back near Western Borehole elevation in a series of large, aragonite-decorated rooms with climbing leads going out. The upward trend just kept sloping up. Teams pushed upward, ascending into a region of intimidating shattered breakdown in high-angle crevices. High in the rubble they found a massive broken section of ancient stalagmite--a tantalizing clue that some sizable room was above.

The April and July expeditions yielded over 8.5 km of passage, with 30 and 32 cavers. In October a team pushed upwards into High Aim and eventually came up into a giant cupola dome with a huge echo. This was the source of the stray stalagmite, and the flowstone slope led up to standing 10-meter "totem" stalagmites with fallen stalactites that were cemented to the floor with flowstone. The 100-m-diameter

chamber was named the Mother Lode, and the ceiling ascended up into the backreef level, from where formations had fallen 60 meters. A dark fissure led down on the opposite side of the Mother Lode. Later in the week several thin cavers descended this to connect back to a route near the Far Planetarium. This completed a long loop closure linking South Winds with the near end of the Wild West route. The Mother Lode was that topmost void at the apex of the great breakdown zone south of Hard Daze Night Hall. Airflow spins in a great convection cell up from there, condensing corrosive moisture in the dark fissure, then across through the Mother Lode, and back down through South Winds, where it evaporates moisture and makes gypsum and hydromagnesite grow. At the end of 1994 Lechuguilla Cave was 115 km long, and the new discoveries in the west left plenty of exploration potential for the coming year.

1995

In 1995, four private teams worked in the cave, and LEARN led 3 expeditions. Much work went into mop-up, connecting loops, surveying in boneyard, pushing climbs, and other more difficult or mundane work. Over one kilometer of passage continued to be found and mapped on each expedition. Altogether, 6.7 km of passage was discovered and mapped. Southern Climes was discovered from a major climb far above South Winds. Once they ascended ~90 m of vertical fissure/tube, cavers followed a left-trending, ascending passage several hundred feet into the Rock 'n Rillen Room, a heavily-corroded chamber sitting like a bubble at the top of Southern Climes. Back at the main route, a large boneyard maze intersected various large fissures and tubes. The biggest went to the Wahoo Pit, a gaping, free-climbable descent into the Romper Room. Mango Pit bottomed in the same chamber via a roped descent. Beyond these the slanted main trend lead to a series of giant empty pool basins with ochre-colored shelfstone in Magnolia Bayou. Along the route, elongated gypsum flowers nearly one meter in length were documented. Beyond this, passage broke into a segment of trunk with Lake Okeechobee at one end. Preservation of cave microbiology had become a concern at the Park, and regulations now prevented crossing pools, leaving Okeechobee and a pool-filled lead in Trail's End Dome of the Wild West closed to further exploration. The extreme end of Southern Climes plotted within 100 meters of Deliverance in the Southern Branch. In December K2 was discovered by climbing above Deliverance. This still did

not come close enough to connect to the Southern Climes termination. These two branches of the cave have never been joined in this region.

The park closed the cave to survey expeditions in 1996, as impact from the previous years was evident. Something had to be done to reduce damage to the cave from exploration. Cavers took on major restoration projects, and science continued to bring more questions than answers from Lechuguilla Cave. The management at the Park made decisions that would again change the way that future exploration teams were composed. A limit of 12 cavers per expedition was established.

1997

Five expeditions were fielded in 1997, two from LEARN, and the rest led by individuals. In July of 1997, a team of LEARN cavers was mopping up surveys in a rift-like passage trending north of the Leaning Tower in the Western Branch. While surveying in tight but airy boneyard near Jackpot, they broke into virgin passage again. The Oregon Trail was named, and a route was surveyed to a chamber called the Menagerie, and then a climb went up to a larger chamber named the Sanctuary that was 35 x 65 m in size. It was bearing parallel to the Northwest Passage, but to the west where no passage existed. This area and mop-up work above the Chandelier Graveyard kept the teams busy. By October a selection of climbs

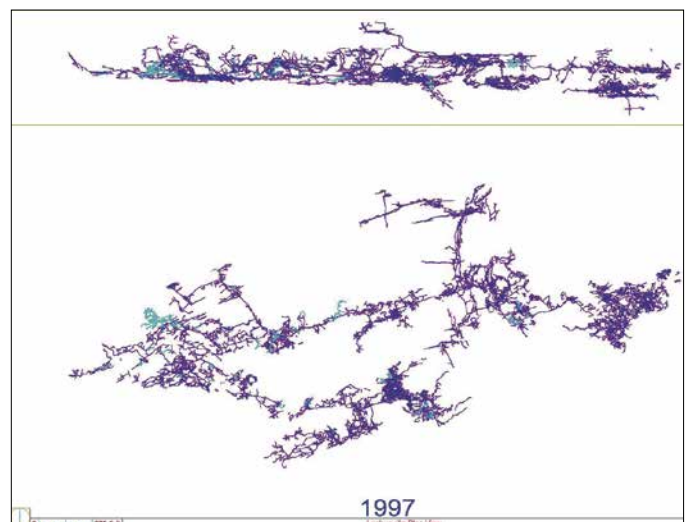


Figure 4: Addition of NW Passage, Sanctuary, Southern Climes, Mother Lode, Wild Wild West.

Figura 4. Adición del NW Passage, Sanctuary, Southern Climes, Mother Lode, Wild Wild West.

was checked at Sanctuary, including Tetanus Town, Spartacus, and the Topless Room. None offered passage continuation. One connection was made back to an old survey in the 1988 Room above Jackpot, making a significant survey loop. The Sanctuary complex is not highly decorated, but has interesting macro-crystalline "trays" or coralloid planes, and some of the best Permian fossils exposed in the cave. At the end of the year Lechuguilla Cave stood at 167 km of mapped passage.

1998

LEARN led three expeditions and private individuals led three in 1998. The year started off with work in the Near East by the April LEARN expedition. The Coal Mine was a dirty area found from Snowfall Hall to Tag Hall. Another Spartacus was named, this time Spartacus Chamber above Tag Hall. In June, a nicely decorated area (Frost Works) was found in a lower level through boneyard and breakdown beneath Hard Daze Night Hall and to the south. One caver named the combination "breakyard," which was added to the cave vernacular. Eventually an extensive network of passages was discovered and two additional entrances to the maze were found beside the Western Borehole trail. An old lead near the Adobe Room, south of the Western Borehole, led to Crinoid Loud, Mental Breakdown Maze, and the discovery of a green stalactite (later found to be barite). LEARN cavers discovered Amaze 'n Mammillaries, Hypophobia, and Golden Gripper Grotto. In October, LEARN continued working in this area, and the Pom Pom Puncture Palace was named. In December, survey concentrated in the Far East and Southwest, with no work in the west for the first time in over a year. A climb yielded rooms such as Balcony Room, Attic, El Nido del Lobo, Century Hall, and the East West room. Century Hall was so designated because the cave reached 100 miles (160 km) of length during that end-of-year expedition.

1999

An independent expedition in March focused on correcting sketches and quads in the North Rift, Chandelier Graveyard, Near West and the Southwest. In May, more mop-up was accomplished in Frost Works and the Chandelier Graveyard. In June, an expedition worked above Red Seas in Needle Park Maze, and below in Dead Seas to find the Sea of Resurrection. Below Fubar (near the beginning of

the Western Borehole) excellent fossils were found in Clam Bake. In July, Kachina Lakes was found by climbing up the dirty fissure above Gorilla Pit in the Eastern Branch. A climb was pushed at Temple of Dagon near the Pearlsian Gulf, to Delilah's Spiral Staircase in the Southern Branch. Exploration began in the Western Branch again in August when a LEARN expedition had a breakout in a airy tight crawl that John Lyles was checking against the northeast wall of Keel Haul. This led to lengthy passage that continually improved in quality and location, named Northern Exposure. Two teams spent the entire week surveying this trend, reached by a 75-minute brisk hike through the borehole from Deep Seas camp followed by another 45 minutes of crawling, climbing and walking. A series of distinct chambers were named Teardrop Basin Room, Birthday Present, Zanzibar, Christmas in August, and Nativity Chamber. Zanzibar measured 25 x 83 m, and the lower part was blanketed with tall thick aragonite "bushes." The Northern Exposure discovery was the first breakthrough to extend the Western Borehole to the northwest past the long standing Rainbow Room. Nativity Chamber had passage potential to continue, as there was evidence of air and corrosion over the entry hole. It did not get pushed on the last day, as it was highly decorated with flowstone and stalagmites, and the team was not prepared to continue without a plan for conservation. It would be four years before it was finally explored and surveyed.

In the Far East, the high-elevation Kachina Lake area was pushed to Baby Alien Chamber, and Redemption Room. In September, more work in these areas provided some new survey for LEARN. Outback, La Morada Maze, and Grand Guadalupe Junction continued to provide mop-up work for the teams. In October LEARN teams again pushed in the Far West and the Far East. Lost Cargo was found under the opposite side of Keel Haul from Northern Exposure. Continued survey in leads off the Northern Exposure route kept teams busy.

In 2000, exploration in the cave stopped again, as the Park executed a costly and difficult project to replace the simple pipe and cap entrance gate with a airlock-portal made from welded stainless-steel sheeting and tubing. Volunteers spent time hauling materials across the desert to the cave and helping with assembly, while a helicopter brought cement and massive items. The new airlock sealed the cave properly from the outside environment, to the extent that Windy City no longer was breezy. Further in, the cave air movement was still evident, from giant convective loops due to the vertical extent and temperature gradient, plus hundreds of tight connections and voids in the reef.

2001

LEARN continued to run exploration and survey expeditions in this period, but the experiment of a completely democratic organization had not ensured having the best surveyors and explorers on teams together. Thus a new series of private expeditions began to focus on the work of individual cartographers in specific areas of the cave. Lechuguilla Cave has always been explored through the work of many volunteers, and the cave map is broken into quad sheets, which are assigned to individuals responsible for their cartography. This approach breaks the complex cave into more manageable pieces, but requires uniform cartography standards that are followed by all cavers involved. The private-expedition model began to replace LEARN as a way to bring experienced surveyors and explorers into the cave to produce the best maps for the National Park.

Only two expeditions entered late in the year, one by LEARN and one private. The LEARN team resurveyed and improved the quality of sketches in the Southern and Eastern Branches, and mopped-up various leads, with very little new passage found. A private group of cavers led by Peter Bosted and Ray Keeler concentrated on checking the edges of the Far West near Keel Hall, Long Haul, Rainbow Room, Birthday Present and Zanzibar. The continuation of exploration beyond Nativity Chamber was not going to be considered without first exhaustively searching for a parallel route or bypass around the pristine flowstone. This route was never found, but much new survey was recorded as many holes and crawls were explored. Additional exploration and survey in Frost Works and the Mother Lode area was productive as well. A short but exciting discovery just off the central Western Borehole led to Weasels Ripped My Flesh, a vertical boneyard that ended too tight, not far from Black and White Hall in South Winds. One team explored a high fissure over the borehole, named Prickly Overlook Boneyard, for 305 m. By the end of 2001, Lechuguilla Cave had reached approximately 170 km of surveyed length.

2002

Five camp expeditions were fielded in 2002, and two shorter projects near the Rift were accomplished. Two of the expeditions were led by LEARN personnel and worked in all three branches of the cave. In August, Scott Linn's team pushed down under the breakdown west of Hard Daze Night Hall, and found virgin boneyard (breakyard) 15 - 20 m below, that

continued in several directions. This new area was named Paris Texas (PT), and would continue to be explored on future expeditions. Like Frost Works, it was overlain by well-explored passage and reconnected in several locations to the Western Borehole trail. Another expedition continued to explore PT, and found a major trend going west under the borehole to the Huapache Highway where the trail turned north to Keel Hall. Work also continued in the Mother Lode. The expedition had an international contingent, with cavers from France and Australia involved. Over 7 km was surveyed in 2002, 1/3 of this being new discovery, and the rest was resurvey.

2003

In January of 2003, six cavers worked in the Far East correcting survey blunders, improving sketches, and pushing leads. In May, a team of cavers worked on the Chandelier Graveyard quads in the west. In June a team of four cavers entered Nativity Chamber for the first time since its discovery in 1999. This was a laborious trip due to alternating ferromanganese residue and clean areas that required clothes/boots changes. With these changes it required a 3-hour trek from camp each way to the frontier. 860 meters of new passage were discovered and surveyed, and the trend was named Promised Land. Individual galleries were often exquisitely decorated with flowstone cascades, pool fingers, large stalagmites, aragonite, and

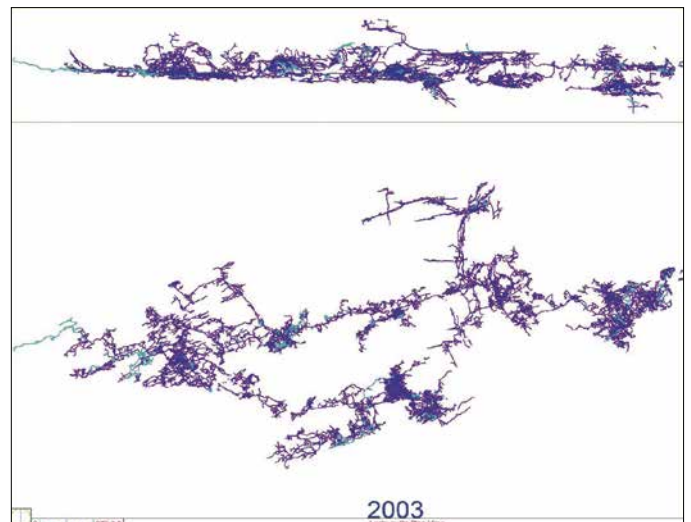


Figure 5: Addition of Northern Exposure (Zanzibar) and Promised Land.

Figura 5. Adición del Northern Exposure (Zanzibar) y de Promised Land.

profuse soda straw stalactites: Nativity Chamber (23 x 60 m), Eden, Billiard Parlor (15 x 50 m), Tulip Garden (24 x 75 m), Sparadise (25 x 75 m) and Congo (23 x 212 m); altogether a very impressive discovery that had been waiting for exploration approval for four years. This region extended the westernmost boundary of the cave by 243 meters. In August, LEARN cavers surveyed in the Southern, Eastern and Western Branches. In October, LEARN cavers surveyed in the Far East in La Morada, Boundary Waters and Ruby Chamber, and in the southwest near Lechy's Lair. In November, another team worked in the Western Branch adding sketches, resurveying blundered loops, and pushing leads in going project areas. Additional entrances were found to the Paris Texas breakyard complex under the borehole at Huapache Highway. On the last day, a radioactive tyuyamunite-spotted crawl, named Transuranic Way, led to a white-raft room, along the south boundary of the Western Borehole. No further passage was found to continue this trend. 8.1 km of cave were surveyed in 2003, and a little over half of this was new discovery.

2004

Resurvey in the Western Branch continued to improve the Chandelier Graveyard/Manifest Destiny Quads. Paris Texas continued to meander in horrendous breakyard and boneyard under the Huapache Highway, with more discoveries of tyuyamunite mineralization. The Mother Lode continued to be scoured for new discoveries. One lead, under a breakdown block, reached a fissure (called Another Lode) that required a return trip with rope. Thirty meters of rope was not enough and loose rocks rumbled and rolled for 10 seconds below. At the extreme edge of the cave, teams continued to explore the new Promised Land in another laborious expedition. Because of the distance from the camp in Deep Seas, they stayed in Promised Land surveying for longer periods, and "days" began to extend to 30 hours. In the Northern Exposure route, at the southwest edge of Zanzibar, John Lyles climbed a very tight chimney to discover Zombie Zoo, and ihop (International House of Pain). These pushed the western edge of the Northern Exposure trend closer to but not connected to Rainbow Room; Promised Land still stretched out further to the northwest. In the Southern Branch, a high quality resketch was made of the Chandelier Ballroom. In the Eastern Branch, one expedition team resketched La Morada room, and surveyed new passage in Cochise Stronghold, and in other locations in the Outback. In the Rift, two teams explored both the

North and South Rift in numerous day trips. Some of these areas hadn't been looked since the 1980's.

2005

Exploration continued in all branches of Lechuguilla Cave in 2005. This was the first year that LEARN did not receive permits to explore in the cave. The dissolution of the LEARN organization was imminent, as it was no longer the preferred method of recruiting cavers for the mapping effort. Independent cavers and cartographers wrote proposals for the National Park, and seven teams obtained permits to organize expeditions to specific areas. They researched existing quads for areas needing improved sketches, better loop closures, or having quantities of unfinished leads. 3.7 kilometers of new cave were explored and surveyed, bringing the cave up to 186 km in length. Climbs and tight crawls were often encountered, both having potential to lead to additional passage in this cave. Many were passed over in the early years of exploration, when great boreholes and walking passages seemed endless. Others had only just been discovered, in places that were thought to be "finished." Along with the change in organization and permits came a change in techniques to explore this monster cave. No longer was it sufficient to come in with just a strong survey team, but there also needed to be cavers willing to endure painful tight crawls, and rock climbers willing to extend routes upward despite unknown rock quality and risks.

In April, a team of six cavers mopped up leads and surveyed in the Southwest. In May a team of nine cave-women worked in the Western Branch doing the same. In June nine cavers worked in the East doing mop-up. A major breakout was made off the eastern edge of the upper Outback by Rich Sundquist, Gary Dunkley and Ron Miller. It was found by pushing an old marked lead through a popcorn-lined fissure behind a strange flowstone formation known as the Purple People Eater. It revealed an area of popcorn and wet flowstone rooms and passages, very uncharacteristic of the bleak Outback. There were large-diameter coralloid formations and multicolored flowstones in shades of purple, ochre, brown, orange and golden. The area contained many cave pearls and pools, and required multiple clothes changes. Having pioneered such techniques in the Promised Land, Miller's team was well aware of how to protect their discovery from careless hands and footsteps. Coral Sea was the name chosen for the area, and the first major chamber was Hall of the Dancing Bears. Over 550 m of new passage were surveyed in Coral Sea,

and many leads remained for return trips. This new area was extraordinary in that it changed character from the pancake-layered fractured dry Outback, to decorated chambers with flowstone, aragonite, large popcorn, dripstone and pools. The discovery was an important step, as it re-established the Far East as a place where major discoveries were still possible, after years of diminishing results.

A team of 11 cavers worked in the Far West in November, including returning to Mother Lode, Sanctuary, South Winds, and Magnolia Bayou. Some of these areas hadn't been visited in at least 8 years. In Mother Lode, the "Another Lode" fissure found in 2004 was descended with 50 m of ropes and connected to a marked lead at a ceiling slot in a passage near Far Planetarium. Another long survey loop was completed. Nine cavers worked in the Far East in November. Another team of 4 cavers did the same in December to continue resurveys and checking off leads. During this expedition, while a climb was being done in the tall fissure above the descending route to Lake of the White Roses, John Lyles crawled into a hole near the trail and found a corroded jagged passage, leading in multiple directions, that was named El Malpais. A new survey began, but time ran out to continue further. Four day-trips occurred in the year to continue surveys in the North Rift.

2006

Private expeditions were fielded in the massive Western Branch. In one memorable week, a long-sought connection was found from Mirage Room to Jackpot by John Lyles' team, following air through crawls in spar-coated boneyard. The route was named Spah Haabah, and it created a large survey loop (~1.4 km) in the computer that was useful to check the quality of the many survey lines included, some going back to 1988. The expedition managed to discover over 2 km of virgin passage, an exceptional result for a mop-up expedition.

In the Southern Branch, several large inspiring domes were finally climbed. In Fluted Hall, one lead marked in 1988 had been ignored for 18 years. Andy Armstrong organized and led an expedition to climb it. Leading upwards for 60 m, Anvil Cloud Dome was the key to the discovery of 800 meters of cave called Flatlands. Most of Flatlands was remarkably flat, with survey inclinations near zero degrees. It featured bat skeletons, large crinoid fossils, water-washed silt deposits and severely corroded bedrock. Flatlands crossed over the top of the PICR, with several exposed holes looking 20 to 30 m downward through the

ceiling below. New rooms or passages were named Anvil Room, Acid Rain, Acid Reflux, Dew Point Drop, Powder River and Poo Holler. Another climbing expedition started ascending Trepidation Dome in the ceiling of PICR, without completion this year. Another climb nearby, called Crazy Tasty Town, led to almost 400 m of new passage before it ended.

In the Eastern Branch, an expedition worked between Giant Chiclets and Lake of the Blue Giants and found more surveyable passage. Two separate expeditions explored in the newly-discovered Coral Sea area, which extended the Outback level east. 892 meters of new passage were found. A large pool named Lake Aloha was found, with exquisite flowstone, popcorn and aragonite nearby. Two new galleries, Independence Hall (9 x 24 m) and the New Guinea Room were discovered, adding to the complexity of the Coral Sea region. New survey also continued deep along the route down to Lake of the White Roses, in the recently-discovered El Malpais level at a depth of -410 m below the entrance elevation. One passage was named Rust Never Sleeps for fascinating "Rusty Wire" (rusticle) formations and iron-rich stalactites and crusts. The Rusty Wires are nearly-vertical meter-long tubular strands that branch with interconnected loops. It was speculated that these were of microbial origin.

Day trips continued to work near the central Rift, closer to the entrance. A week of day trips also worked in the Ghost Town area, reached via S&M Crawl off of Apricot Pit. They found and surveyed additional passage as well as correcting old errors in the survey data. Lechuguilla Cave (193.8 km) passed Switzerland's Hoelloch (193.6 km) in length in 2006.

2007

After 21 years, 30,234 survey stations had been placed in Lechuguilla Cave. Expeditions were again led to all three branches of the cave, plus the North Rift area. In March, seven cavers added 658 m and completed exploration of Flatlands above the PICR. One exceptional lead remained in a crawl in Acid Reflux, headed into the blank region of the map between the Southern and Western Branches of the cave. It was blocked by an obstruction to human passage. An expected connection was made to an old pit lead in Lechy's Lair, and several new climbs were made. In May a team of 12 cavers added 690 m and resurveyed a larger amount in the Chandelier Graveyard and Deep Seas camp area. In June, a team of cavers camped near the Rusticles in the Near East and concentrated on blunder corrections and re-sketches. A

team of eight cavers camped in the Far East and added 1.3 km of new cave to the ongoing Coral Sea trend in the Outback. They discovered two large adjacent chambers via a lead half way down a pit: Wasp's Nest (30 x 60 m, 30 m tall) and Anglican Basement (15 x 50 m). Wasp Nest was floored with mounds of well-developed rillenkarren, often coated in glistening flowstone. A shortcut back to base camp was found, eliminating ropes and travel through the arduous Coral Sea discovery route. It was astounding how close this area was to a known travel route, an indication of the confusing complexity of the Outback. A survey was established up a flowstone climb above Anglican Basement, but passage ended too tight, close to the Lost Pecos River water source near camp. This was likely a water source for the active lower area. Coral Sea had now added approximately 1 km to Lechuguilla Cave, and more than 100 pools had been discovered. This changed the known character of the Outback level of the Far East considerably.

In August a small team finished the Trepidation Dome climb over PCR, to find it ended without additional passage. In September, an expedition of 12 cavers from the United States, France and Australia worked over a broad area of the Western Branch. They completed survey in a maze (Hahd Coah) beneath Rock'n Rillen Room in Southern Climes, and had success pushing into holes under breakdown in Jackpot, that were passed over in prior years. They named this discovery Crinoid Casino, and it led to additional virgin passage to explore. A team went to Wild Wild West for the first visit in over a decade, and began working off leads in this remote area. Meanwhile, an exciting new development opened from a small tight crawl in the Spinning Room, not far from the the Leaning Tower, before the Jackpot and the route to Sanctuary. Green crystals were discovered in a wall, and a tight spot in a small alcove perplexed John Lyles, as air was disappearing into this same wall, in a small room above. After squeezing through a low restriction for a few meters, he stood up and was in a walking trunk passage. Inside this new area additional green deposits and coatings were observed, along with fantastic gypsum beards and needles. Emerald City filled in a blank region of the map between Hudson Bay, the Northwest Passage, the Jackpot and the Western Borehole. Survey of the easiest horizontal passage was completed in ~120 m, while at least four attractive climbing leads remained. The 10 x 10 m main trunk ascended to a sloping chamber with gypsum blocks and 23-m ceiling height. At the last survey station they needed a climber and rope, as the talus slope was too steep to ascend easily. They returned with James Hunter and completed surveying up the

slope for 77 m to a wall ending the trunk. Two adjacent domes rose in the ceiling, one measuring ~ 80 m to a top (maybe a rock, or ceiling) using a Disto laser rangefinder. This dome was adjacent to the predominantly vertical Dire Straits passage off Hudson Bay.

Additional work was done by team leader Steve Reames, completing all known leads in the North Rift after six years of working there. It was another excellent year for the cave, where expeditions often brought out more new leads than they started with.

2008

Two survey expeditions took place in the massive Western Branch, in locations such as the Chandelier Graveyard, Widowmaker, Adobe Room, Jackpot, Crinoid Casino, Northwest Passage, Mother Lode, and Far Planetarium. The new Emerald City discovery of 2007 continued to be pushed, with a climb in Lions Lair leading to a passage that almost intersected the NW passage, but not quite! A very tight crawl led to gigantic spar in the Mutant Baby Birth Canal. Reconnaissance trips to Dire Straits, Paradox Dome and Here be Dragons found degraded old rigging and ropes, and leads to be pursued and mapped. On May 29, an international survey team of 12 cavers celebrated reaching 200 kilometers, a milestone in Lechuguilla Cave. In the Southern Branch, a July climb team continued above Chandelier Maze, with an unfortunate fall causing a compound arm fracture. A self-rescue was accomplished by the expedition team, getting the injured caver out to waiting emergency personnel on the surface within 24 hours. In the Eastern Branch, an expedition worked in the Near East area, fixing sketches, adding detail and correcting blunders.

Another expedition continued day trips to the upper levels near Apricot Pit in the Near East. Three expeditions explored in the Outback area of the Far East, in Coral Sea and a new discovery. A diligent mop-up survey team led by John Lyles pushed through tight, difficult belly crawls to a small room, ZZ Bottom, with a 50-degree inclined fissure in the ceiling. Named Mount Vernon, this low airy pancake crawl went upward for 20m to reach La Grange Hall. Popcorn and frostwork along with scoured ceilings indicated that this was a major airflow route. Larger chambers named Hooterville and Tushka were explored and surveyed, and the Nor'easter Passage took off from here with a walking-sized ascending tube leading northeast. A colorful silt dike in the ceiling guided the surveyors up this passage northward off the known map. Spectacular gypsum flowers

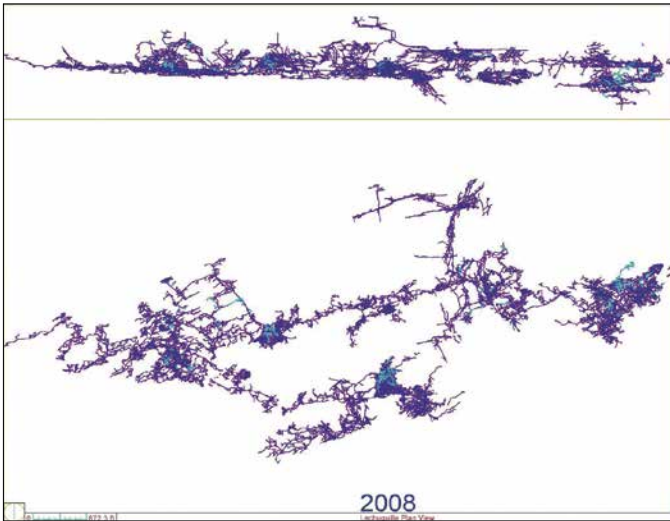


Figure 6: Emerald City, Coral Sea and Northeast Corridor.
Figura 6. Emerald City, Coral Sea y Northeast Corridor.

grew from the floor and walls. After the team had surveyed about 230 m of easy passage, the walls and ceiling receded further and the passage became 15 m in diameter. Soon the floors were covered in long, ropelike flowers and chandeliers hung from the walls and ceilings, the first chandeliers of this magnitude discovered in the Far East. A large side chamber named Northern Lights included at least 20 clear and other chandeliers, masses of angel hair, and large needles. A short lead climb up a gypsum-crust spongework wall led the cavers to the base of Mt. Washington, a large room. Mt. Washington was 35 m in diameter and over 50m high with a taunting dome lead in the ceiling. Reaching this high lead would require another major climbing effort. The Northeast Corridor, as the trend was named, projected northward into blank territory, heading towards an area of the Guadalupe Anticline with no known cave passage. New survey also continued deep along the route down to Lake of the White Roses, in El Malpais. One expedition team resketched along the main Outback borehole and picked up additional new survey in the area. Lechuguilla Cave continued to astound cavers with exciting new discoveries after two decades of exploration, but the work and time to reach them increased manifold.

2009

Five private expeditions were fielded in 2009, to all three branches of the cave. One team worked in the Far East and mopped up leads in Outback and the

upper camp level. They continued working in the Northeast Corridor trend, and three climbers spent six days on the wall of Mt. Washington, finally reaching the top in 46 meters, with a combination of aid and freeclimbing. Removable bolts were used in many spots. At the top, a large gypsum rim indicated air movement, and a chamber named Vernal Equinox was entered. There was no time to survey with a team, since it was the last hour of the last day in the cave, so it would need to wait until 2010 for exploration. A 9-mm free-hanging rope was left rigged.

In the south, an expedition went in to re-sketch many areas to be able to produce an accurate quad map, resurveying over 2.9 km of passage. This was in areas such as Lebarge Borehole and Void, which were hastily surveyed 21 years before, during the great rush to rapidly discover length and depth. Another team worked in the south and checked off leads in the Chandelier Maze area.

A smaller team worked in the Far West, with plenty of rework without new discoveries. Another team of 10 worked in the west in Emerald City, Jackpot, Dire Straits, Southern Climes, Chandelier Graveyard and other familiar places. John Lyles tested a new device he called Rockcaster, a combination fishing line casting reel and slingshot. The idea was to shoot a projectile, such as a steel nut, up and over the bridge, pulling up the heavy monofilament. Then this line would pull up a 2-mm cord, which would pull up an 11-mm static caving rope. This was not the first time such a device was used in the cave. The wall was of poor quality for bolts and aid, so this device was being used to attempt to reach the first bridge across a dome above the end of Emerald City, 23 m above the floor. It was successful in crossing over the bridge, but the fishing line was not strong enough to survive pulling it over against sharp edges. They would have to wait another year for better technology to be brought back into the cave.

2010

Five private expeditions were scheduled: two to the Southern Branch, two to the Western Branch, and one to the Eastern Branch. In the Southern Branch two smaller teams improved survey quality working in known problem areas such as the Void, above the former deep point of the cave. Another group fixed 35 blunders found in surveys that originated before accuracy-enhancing backsights were required. They worked in the Void, the Chandelier Maze, Chandelier Ballroom area, Seesaw Canyon, and in Deliverance Passage,

In the Western Branch several expeditions followed up on leads and continued to add footage in multiple areas. A first bridge in the dome at the end of Emerald City was finally ascended with help from a commercial line-throwing device. The wall above this was no better in quality, with unnerving loose flakes of rock. The climbers backed down with the hope for a stronger team to return in the future. They named this dome Kansas Twister, as it could be seen twisting and changing direction above, like the tornado funnel cloud in the old movie, Wizard of Oz. Other areas of focus included finding a new route connecting the north side of the Mother Lode to the Widowmaker below, following a tight chimney lead from a prior year.

A second western expedition worked extensively in South Winds, Southern Cross, Southern Climes and Magnolia Bayou under the leadership of a new cartographer for that quad. The team was composed of German, UK and US cavers. They resurveyed the Southern Cross slope down to the bottom of the Southern Climes rope. Short but worthwhile discoveries were found and surveyed in Wahoo Pit, Magnolia Bayou and Lake Okeechobee. They attempted to find a route around the wall-to-wall lake to the lead beyond, but it did not go the direction they wanted. The longest gypsum flower (95 cm) and needle (79 cm) in the cave were found in Magnolia Bayou area.

In the Far East, the Vernal Equinox at the top of Mt. Washington (Northeast Corridor) was explored when two teams climbed the 9 mm rope that had been anchored at the top in 2009. Unfortunately, no further human-sized passage could be found after an hour of short surveying by both teams. The air coming up the pit was disappearing into small cracks and gaps in corroded spar ceilings. The best trend going off the map in the Far East had shut down. It was the best location for a route to Manhole Cave, a small blowing cave to the northeast of Lechuguilla Cave. But this was not to be the way for cavers to go. This outcome was often the outcome of difficult climbs in Lechuguilla Cave. Fortunately, luck would improve for the same team in the near future. At the end of 2010, the cave was just under 208 km in surveyed length.

2011

Eight private expeditions were scheduled: one near the entrance in day trips, two to the Southern Branch, two to the Western Branch, and three to the Eastern Branch. In the Southern Branch, teams improved survey quality working in known problem areas such as the Void, above the former deep point of the cave.

Over 2.1 km of survey, 80% of it being resurvey, was completed by 2 separate expeditions.

In the Western Branch two expeditions followed up on leads and continued to add footage in multiple areas. New passage was found within a half hour of Deep Seas camp, by checking old leads and areas. Tedious climbs up into Neverland (also near camp) were checked without finding appreciable discoveries. Climbing continued in the heights of Dire Straits without much passage gain. In the other expedition, the first return to Promised Land since 2004 yielded new passages in Congo that were missed earlier. Teams returned to Zanzibar, Rainbow Room, Long Haul, Keel Hall, and Oasis to complete resurveys of areas whose original data was unusable to create a final quad map.

The new quad for this region was completed, but a few leads still need to be checked in the future. 2.24 km of new passage were mapped in the West.

In the Eastern Branch, three expeditions were fielded. One was in the Near East based at Rusticles camp. This rarely-used base camp can sleep no more than 6 cavers. They worked on resurveys and mapped 437 m of new passage. In the Far East, one expedition team mopped up leads in Wasp Nest, Anglican Basement, Independence Hall and New Guinea Room in the Coral Sea, including completing several unproductive climbs. Their tally was 706 m of new passage. The cavers found a very interesting dripping stalactite that had a slimy film, known as a snottite. It was believed to be of biological origin. The last expedition worked on the eastern edge up at camp level, in Firefall Hall, Burning Lakes and Quasimodo's Lair, making new detailed sketches to replace the more primitive 1989 work. Restoration of soiled flowstone was a prime objective, while new sketches of this impressive flowstone area were finished. 2011 expeditions added approximately 4 km to the length of the cave.

2012

Only three camping expeditions were approved in 2012, one to the Far East and two to the Far West. In the Eastern Branch cavers found 1.43 km of new passage to add to the length of the cave, Most of the Happy Hunting Grounds beyond Lake of the Lost Marbles was resurveyed with new sketches. Survey was done in the Outback, in Cochise Stronghold, near Flake Lake, and above the fissure leading to Lake of the White Roses. Several climbs were accomplished. Additional work was accomplished in the upper level near Grand Guadalupe Junction.

In May, an independent expedition team of ten cavers mapped 2.02 km of new passage along with accomplishing considerable resurvey and improving sketches in the Western Branch. The formidable dome climb called Kansas Twister, at the northeast end of Emerald City, had been partially climbed in 2009 and 2010, using a slingshot and fishing casting reel to shoot a projectile to pull up the line. Derek Bristol and James Hunter continued from here and led a laborious climb up this shaft, using all the tools of the trade that were hauled in. The laser-measured height of 75 m was about half of the actual elevation that they climbed for 5 days, as the shaft corkscrewed upward into the unknown. The route was slow, as only hand drilling is allowed in the designated wilderness, and the rock quality was marginal much of the time. Finally, they topped out in the main shaft and crawled up a silty slope into breakdown. Following air, they crawled along a low wall in loose rubble and broke out into a giant borehole. Realizing the significance of their discovery so high up in the cave, they alerted everyone in camp to be prepared for a long last day mapping the enormous passage. Two teams headed up the four ropes for 125 m, passing three rebelay bolts and two large ledges, transitioning from massive Capitan Formation to bedded backreef, which is close to the surface. The first laser measurement into the large passage indicated 70 m to the ceiling above. The name Oz was immediately chosen for the new discovery. One team carefully traversed across an exposed silty slope into a giant tubular passage named Munchkinland, while the other team worked on several significant side leads.

They found several outstanding large pits and domes that needed additional ropes to continue. One dome/pit was noted to have considerable airflow, and a sizable upper lead could be seen. The large passage eventually transitioned from a breakdown debris floor to snowy gypsum crusts, passing scattered deposits of ferromanganese deposits, blue endellite and fluffy rock flour. Eventually they reached an outstandingly beautiful pool area replete with a 4-m soda straw, giant stalagmite mounds, dark shelfstone, amber flowstone, columns, and passages going off in three directions. Taking the easiest route, they continued surveying until after midnight when they ran low on water, food, batteries and survey paper, and headed back to camp exhausted but fueled by adrenaline. They had surveyed a trend that started northeast and then turned southeast and headed towards the Western Borehole, but ~215 m above it. This survey continued on the same bearing for nearly 300 m before stopping. Several high ceiling shots were within 60 m from the elevation of

the cave entrance. Oz is the highest passage development known, besides the entrance series above Boulder Falls. In September an additional with Derek Bristol, James Hunter, John Lyles and Stan Allison of the Park yielded additional survey, and accomplished needed tasks including replacing some ropes with new ones, improving rigging at rebelays, and adding additional trail flagging. Kansas Twister is now the longest known vertical shaft in Lechuguilla Cave at 125 m to the bottom of the rope upslope in Emerald City. There is another 38 m to the bottom of the breakdown slope. It is interesting to note that this entire complex was discovered after one small hole was found into Emerald City, in the middle of a block of cavernous bedrock having surveyed passages to the north, south, east and west sides. Like the two recent discoveries in the Far East, Northeast Corridor and Coral Sea, there is still room for discovery in Lechuguilla Cave if one looks in the right places.

A second international team in the Far West returned to Southern Cross, Southern Climes, and South Winds as in 2010. They resurveyed Romper Room and as before, were able to find three new passages to survey, the longest being 110 m.

2013

In 2013, four expedition teams worked in the cave, one in the South and three in the Western Branch. These added 4.5 km of new passage to the length of the cave. In the Southern Branch, six cavers continued to work near the Void (former deep area) to help the cartographer complete quad maps. They discovered 738 m of new passage and resurveyed 976 m.

A 12-person team worked in the Far West, to work in Oz as well as secondary objectives in Northern Exposure, Sanctuary, Mirage Room and under Keel Hall. They also reconnoitered several potential climbs in Mother Lode that have not been checked. In Oz, they surveyed many of the remaining leads, including pits and several climbs, and surveyed across the decorated pool area. Munchkinland (40 x 235 m) is one of the larger chambers in the cave. An airy pit series called Wizards Elevator took three days to rig and survey, descending down a wide fissure. Along the way down there was green staining on massive gypsum banks. In the final pitch, the cavers descended through grooves of giant rillenkarren. It bottomed out 150 m below, with a dead end, coming very close to the nearby base level of Northwest Passage. All passages north of the pool area are more active, with dripstone, long soda-straw stalactites, stalagmites, columns, drapery, flowstone, pool spar, shelfstone,

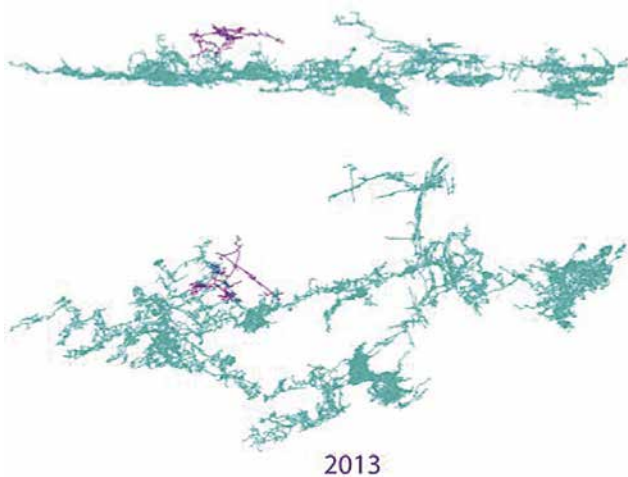


Figure 7: Current line plot of entire cave. Oz highlighted.
Figura 7. Topografía actual de la cueva. Se ha destacado Oz.

and other beautiful speleothems. The northeast gallery was called Hall of the Flying Monkeys (25 x 110 m). A crossover passage was named Ozmatorium (25 x 70 m) and contained large quantities of hanging draperies and stalactites. 3.1 km of virgin cave passage were explored and mapped on this expedition. This was the largest amount that has been surveyed in a single expedition in over 20 years, since the Far East was discovered when Aragonitemare was climbed.

A third expedition went west with a smaller team, and worked on an aid climb above Neverland, not far from base camp at Deep Seas. They also spent one day on leads off Kansas Twister. They added 635 m of new passage to the cave's length. A final expedition in 2013 with 10 cavers continued to mop up in the Far West, and took high quality photographs of Oz.

Procedure for Surveying in Lechuguilla Cave

The current method of getting surveys and exploration done is for a trip leader to request a permit by submitting a detailed proposal to the cave resource management at Carlsbad Caverns National Park. All proposals to work within a calendar year are submitted at the end of the previous year. Significant research is involved in planning these expeditions as the Park expects a high level of detail in the proposals. Each year two to four expeditions are awarded permits, with some of them involving a week of camping underground in one of the established base camps to reduce impact. Camping in the cave allows

for a favorable ratio of survey work versus travel time. Exploration has involved cavers from all over the United States and from many other countries.

Conclusions

In the first years of exploration, until 1995, the surveyed cave length grew to 112 km. After a year-long closure, surveying began again, and after 15 more years of survey (with closure for new airlock), the length has nearly doubled to 221 km. While it appears that new discoveries of passages are dwindling, there have been a surprising number of reasonable breakouts in the past seven years to indicate that the cave is not fully discovered.

Initially, exploration projects were organized by a small group of cavers in an organization (LCP) with a leader and a board of directors, in general agreement with the management of the National Park. Many US and international cave explorers were given the opportunity to join the project and survey the cave. As the cave grew, the organization changed and eventually came to differences of opinion as to how to best manage the survey information of a big cave. As the leaders of LCP lost focus on the objectives of the Park, they were rejected from continuing the survey, and LCP dissolved rapidly. A second organization formed from the remaining board (LEARN) with a principle of having a democratic process to select cavers for expeditions. It allowed a board of directors to be made up of elected cavers from all of the regions of the United States. Eventually this organization, too, didn't work as well with the goals of the cave managers at the Park. What was lacking was a way to ensure that quad maps were being completed. With a cave as complex as this, it is easy to see how maps are difficult to complete. Independent expeditions began to be awarded permits, and the application process refined until it now favors cartographers who are generating quad maps to select their expedition teams and goals. This system appears to be working, although it restricts the number of cavers who can explore and survey in Lechuguilla Cave to those who know or are known by a cartographer of the cave map. As many of the original cavers are older and retiring from the project, there are several generations of younger cavers who have joined the project and contributed to adding to the understanding of this complex cave.

With all of the organizations, failures, and changes by the cave management for resource protection and conservation, exploration in Lechuguilla Cave remains a dynamic and exciting project. There is

great personal satisfaction with being a part of the discovery of the nature of this cave. But the most awarding aspect of it is the human thrill of discovering passages and galleries that have been hidden to mankind, to explore into this unknown and to see the "Jewels" firsthand. It is indeed the Jewel of the Underground.

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Recibido: febrero 2015

Revisado: marzo 2015

Aceptado: abril 2015

Publicado: marzo 2016