Surveying & Maps


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An important element of our project was making maps of each cave we explored. We surveyed each cave and then rendered stick maps, cartographic maps, and other representations, such as 3D models.

The bread and butter of cave exploration is the *stick map.* This is a map that can be produced by measuring *azimuth* (compass heading), distance, and water depth, at each of a series of *stations* that are formed by *tie-offs* or *placements* to cave formations as our line passes through the cave. We make a tie-off or placement each time the line changes direction or depth, so if we survey the line, we end up with a cave map that has a series of jagged straight lines representing the path of the stations through the cave, rather than the cave walls themselves. This path is called the *transect.* A complete cave map is made up of one or more transects, each bisecting the other where the lines meet.

Stick maps are very useful and are probably the most convenient way to show the cave to other divers. If the stick map data is supplemented with just a single GPS coordinate at the start of a transect, satellite images can be overlaid on the stick map, showing where the cave passes under the surface of the earth that most of us see normally. This can create important uses of stick maps for land planners and civilians. Caves can pass below anything—jungle, buildings, highways, even bodies of water and the ocean.

We made stick maps of Burrodromo, Ma' Áayin, Ak K'U', Guadalupe, and Senderos, all included in this book.

Historically, stick maps were drawn by writing a set of compass, distance (counting knotted line), and depth (measured by manometer) measurements in a diver's wet-notes, and then producing the map by hand from this data. Later, software allowed maps to be drawn by a computer after data entry.

But recently, this has all become faster with a new device called the *MNemo,* produced by Sebastien Kister, a cave diver in Playa del Carmen, Mexico, near where we conducted this project. Our exploration team uses a couple of MNemos, together with Sebastien's software called *Ariane's Line,* which integrates with the MNemo to dramatically streamline the survey and mapping process. While lacking the polish of a consumer device (the market is obviously too small), the MNemo can more rapidly capture compass, depth, and distance measurements and store them automatically, simply by running it along our cave lines and pausing and pressing a few buttons to let it take measurements at each survey station.

Moving beyond the basic stick map, we can augment our compass direction, distance, and depth data with a cross-section measurement at each survey station. To take a simple cross-section, we can measure left, right, up, and down (LRUD) from where the line crosses each station by using a very large tape measure.

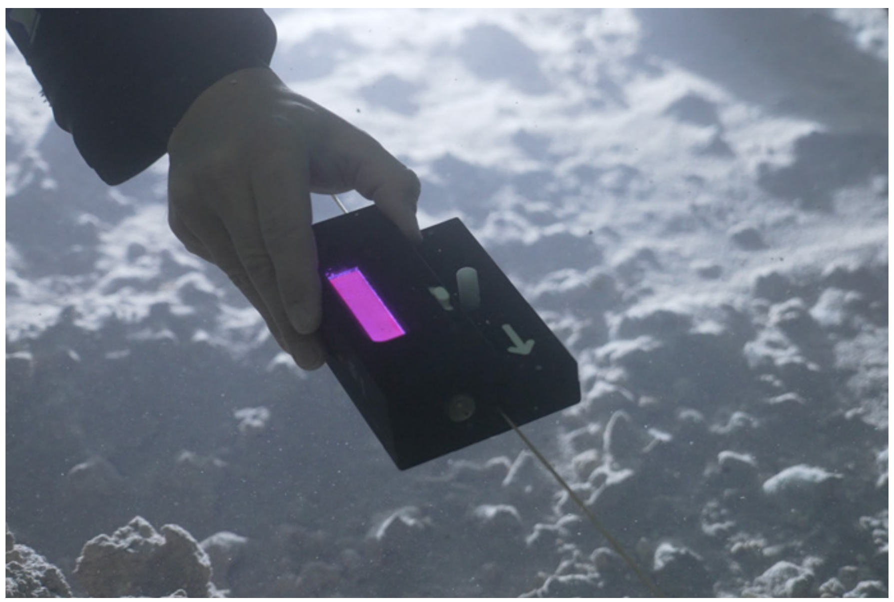
We might also note the shapes of the cross sections so that we can render an accurate profile, rather than just a basic cylinder.

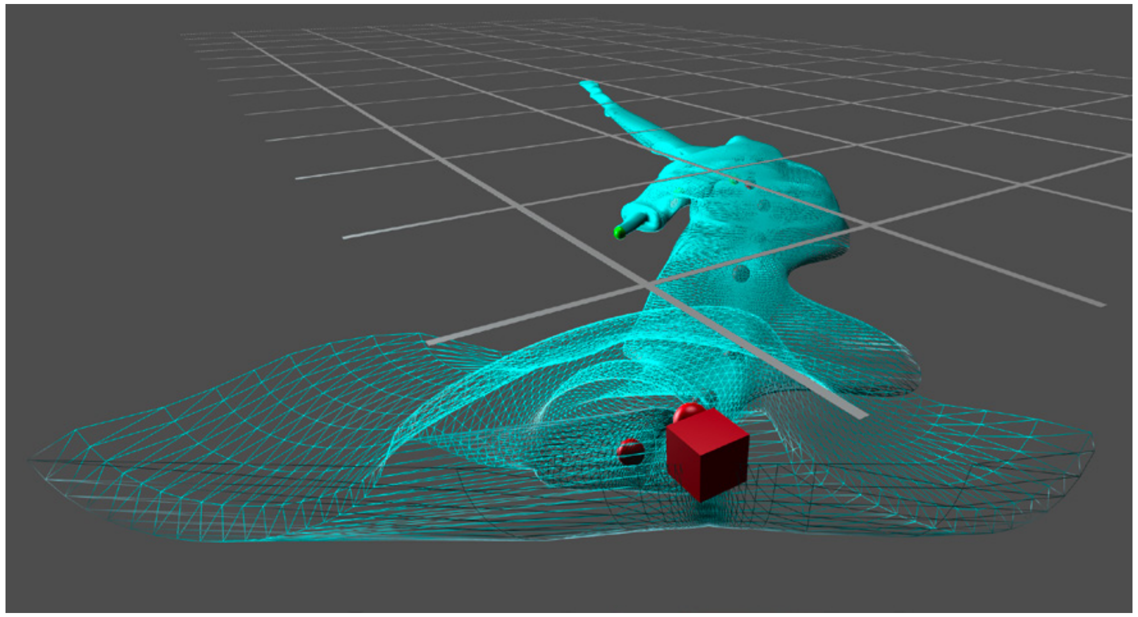
A stick map plus cross-sections allows us to produce a three-dimensional cave map. This can be manipulated in Ariane's Line or exported for representation in VR or 3D graphic engines like Blender or Maya. Three-dimensional maps are fun to play with and give a better sense of what the volume of the cave feels like as one swims through it.

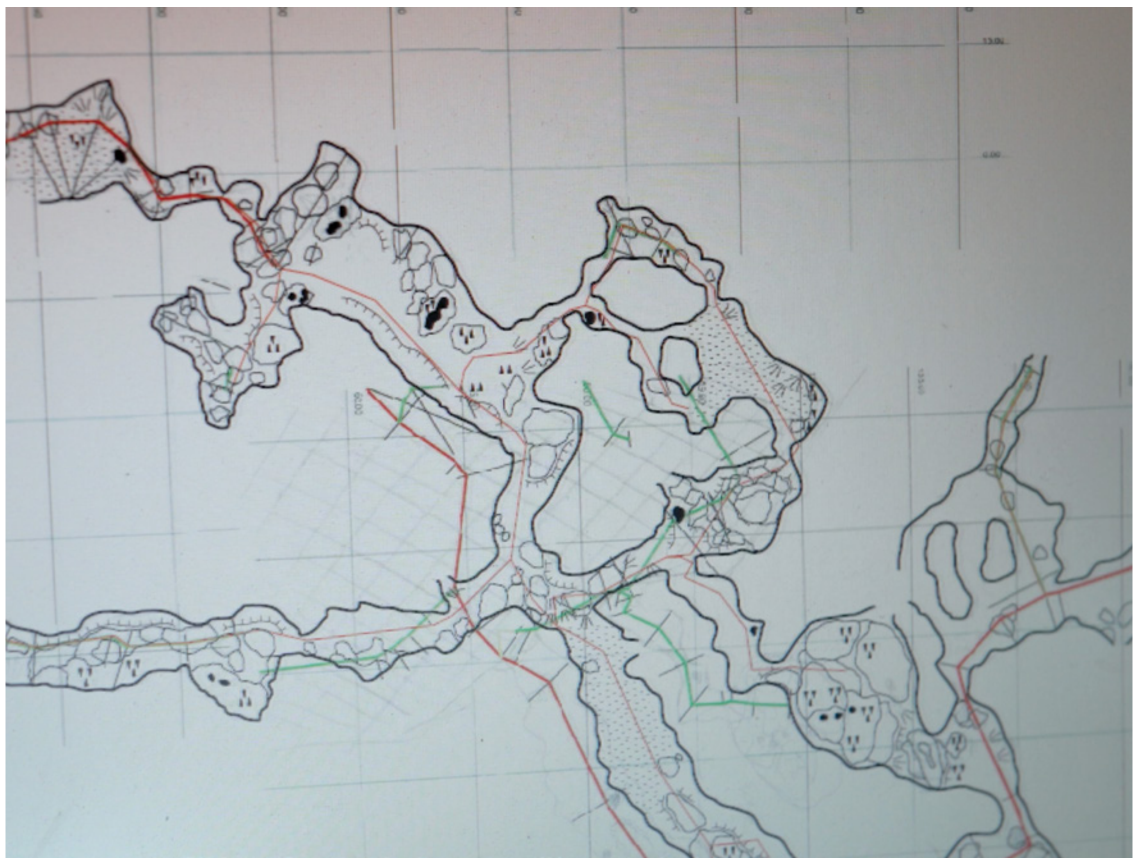
We captured LRUD data for Guadalupe, Burrodromo, and Senderos and made models of the caves.

Page 125: Ivo and Matt surveying in Ma' Áayin. We run lines through the contours of the cave and then glide the Mnemo device along the line to capture compass direction, distance, and depth to make cave maps.

Left and right: Matt surveying in Burrodromo, with the Mnemo device which has rapidly sped up the process of capturing the data we need to make maps.







Left: Matt and Ivo reviewing the map of Burrodromo. Due to the painstaking work involved, this is one of the few full cartographic maps ever made in the northern part of the Yucatán Peninsula.

Top: By adding cross-section measurements to our cave survey, we were able to build a three-dimensional model of Cenote Senderos.

Bottom: A section of the Burrodromo cartographic map. The black lines indicate cave walls and features, while the red lines indicate the surveyed line we've run into the cave.

Page 130: The full cartographic map of Burrodromo.

Traditionally, the apex of cave survey is the full cartographic map. These maps are meticulously created from careful measurements and detailed sketches of each significant feature in the cave. Full cartography of even a moderately-sized cave can take years, and just one or two beautiful maps could be the work of a lifetime for someone sufficiently dedicated to it.

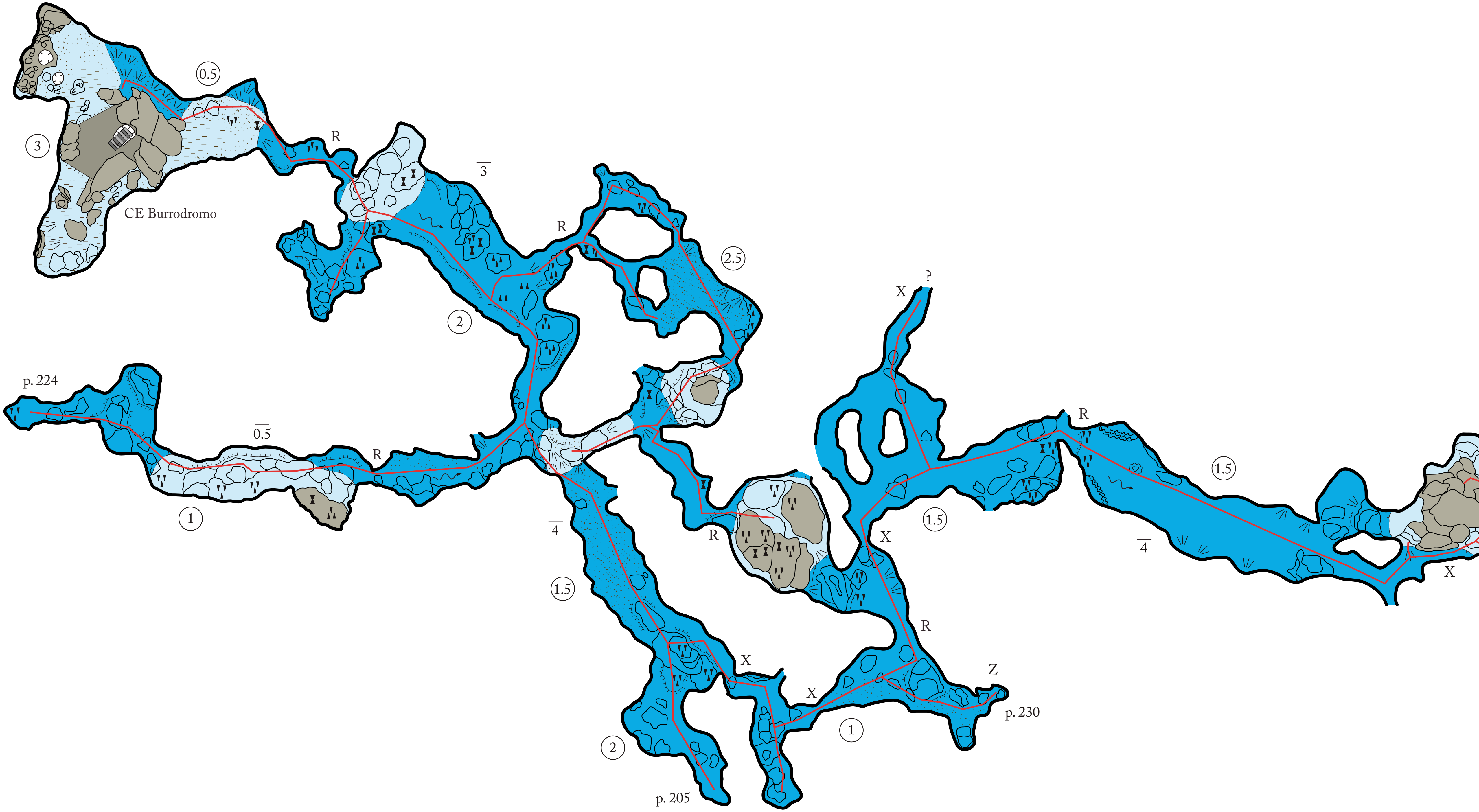
A very fine example of full cartographic mapping is David Mayor's current *Taj Mahal Cartography Project,* which can be found online at www.cenotetajmahalcartographyproject.com.

Midway through our project, we decided to make a full cartographic map of Burrodromo. Even for a cave of relatively modest size, it took about ten dives just to gather data, and then countless hours to draw the map, which Ivo did lovingly in his evening hours over the course of about a year. The cartographic map is included in the book.

Photogrammetry is perhaps the current frontier of cave mapping. In this technique, a series of overlapping photographs are processed by photogrammetric software to generate a high-resolution three-dimensional model of the cave. This technique has the potential to speed the creation of high-resolution cartography and interactive models or even virtual reality experiences.

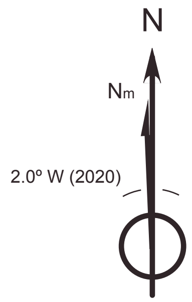
We experimented with photogrammetry to make some models of Guadalupe but decided that the task was better served with our traditional techniques.

Photogrammetry does have some significant challenges, and there isn't yet a consensus on the best techniques for cave cartography. But more practitioners are now pushing this technology to see what it can do, and it already is a best practice for making models of smaller volumes such as shipwrecks and archeological sites. Right now, it seems that a primary limitation is computer processing time. This limitation will disappear quickly, and we're excited to use more photogrammetry techniques in our projects in the future. ✦



SISTEMA BURRODROMO

Playa del Carmen, Quintana Roo
N 20.692387 W 87.032954



1988 Original explorers: Wes Skiles, Jim Coke, Tom Morris, and Pete Butt

2020-2022 Resurvey, exploration & photography: Proyecto Mayakoba Team
Matt Scantland, Henry Frawley-Fulcher, Ivo Chiarino, SJ Alice Bennett
Map drafted by Ivo Chiarino (August 2022)

All ceiling heights and depths in meters
Surveyed Length of Burrodromo Cave: 1313.8 m (November 2020)
Maximum Depth on Map: 6.5 m
Average Depth on Map: 3.1 m