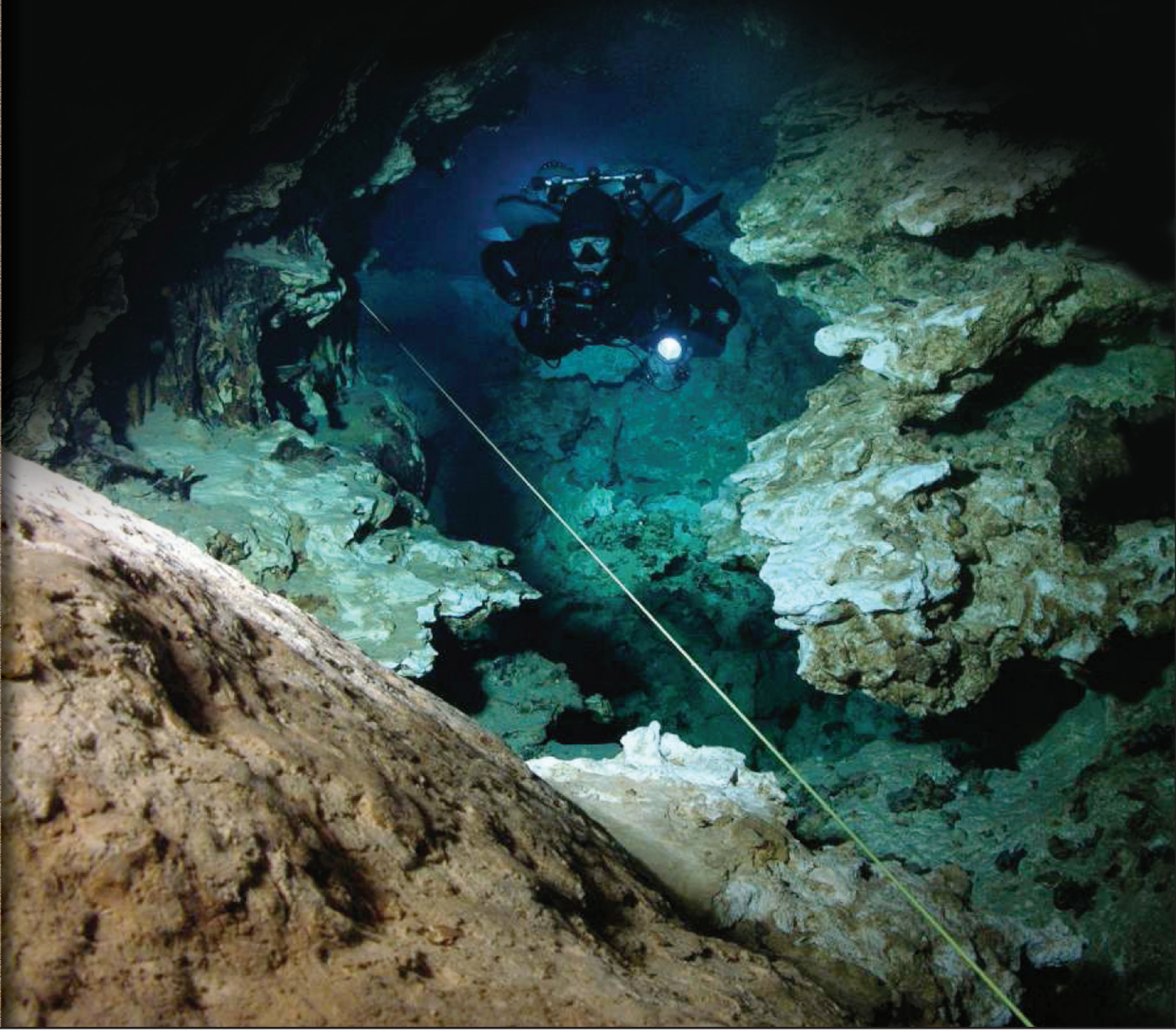




Mapping  
**Minotauro**

By Richard Wylde



## Understanding Minotauro

The shallow caves of the Yucatan are one of the wonders of the world. Formed during the ice ages in the recent Quaternary geological period, they are home to some of the longest underwater passages known to man.

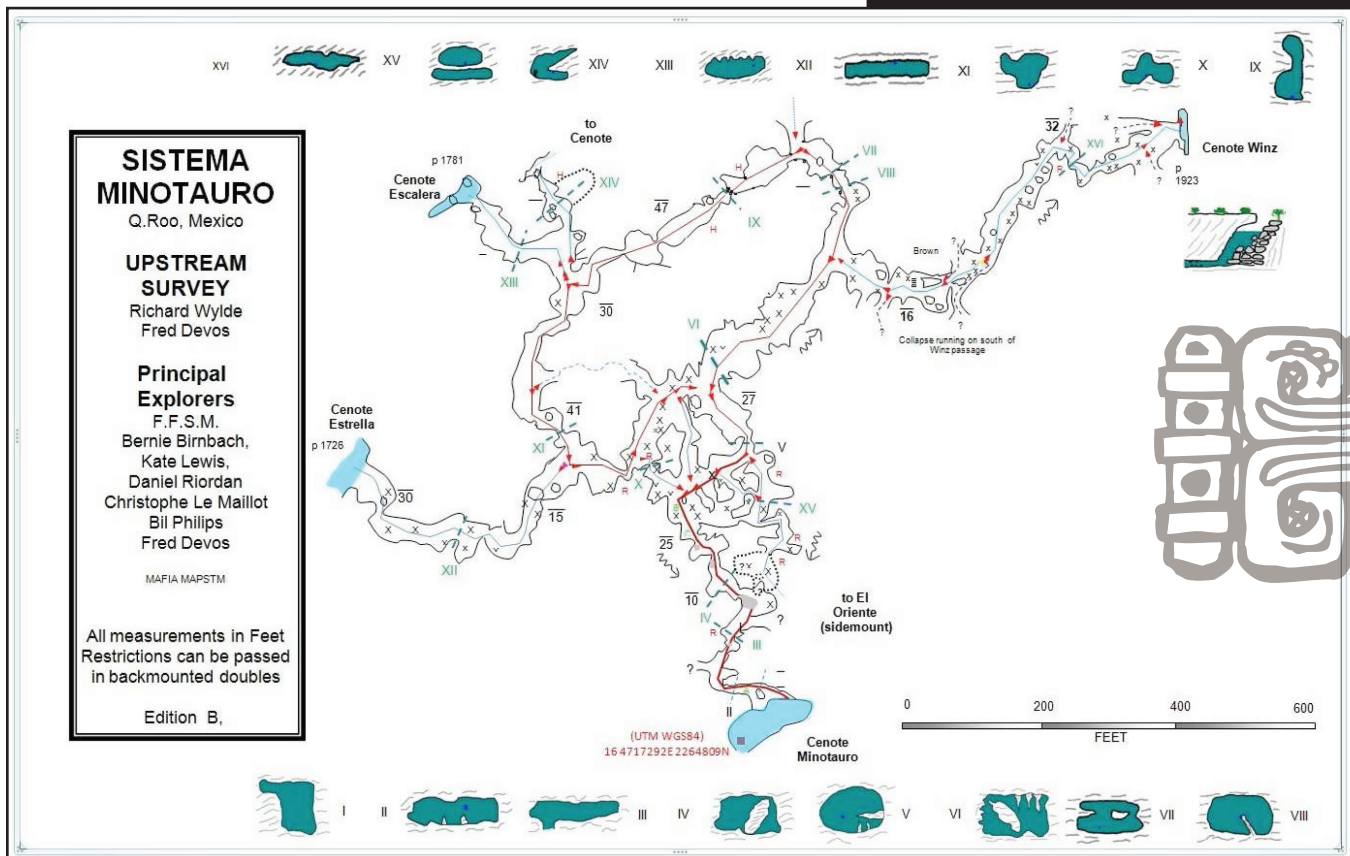
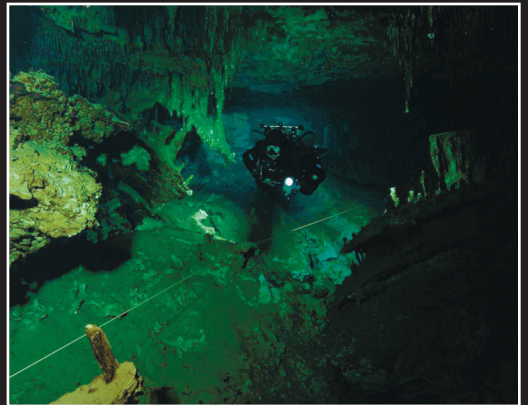
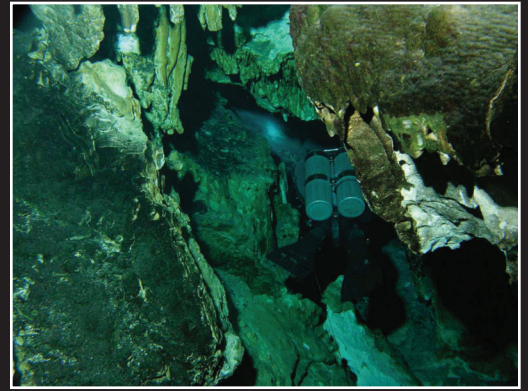
But after diving many of the sites over the years, I wanted to take my cave diving further and, ideally, give something back to the cave diving community. One might idly dream of exploring new cave – but realistically – for those of us with other responsibilities (wives, children, businesses to run, etc.) this is a bit of a pipe dream.

A much better task for the amateur cave diver (in contrast to professional permanent residents who often teach cave diving) is to map caves that have already been explored. Well, explored is perhaps the wrong word. Line will have been laid in them, with an aim of finding the end of the cave – the furthest distance of penetration – and some side passages may have been investigated. But that is a very long way from understanding the cave. Mapping a cave goes a long way toward that, and the maps can help others – cave divers and non-divers alike to appreciate and enjoy the cave. A map can be a work of art – I have many prepared by Jim Coke and his colleagues.

## Sistema Minotauro

Sistema Minotauros is situated some 5 kilometers South of Puerto Aventuras on land belonging to Don Inocencio, between Sistema Taj Mahal to the south and Sistema Actun Koh to the north.

Initial exploration was done by Bernie Birnbach, Kate Lewis, Daniel Riordan, Christophe Le Maillot, Bil Philips & Fred Devos in the mid 90's, when access was much harder than it is now: the road is much improved and building is underway in the area.



The mapping of the upstream part of Minotauro has taken from November 2006 to December 2008 and involved 5 trips to Mexico and a total of 33 dives in the system.

## Map accuracy

GPS information allows you to place the cave in a wider context. Displayed in UTM (Universal Transverse Mercator) co-ordinates, the start of our cave is at 16 471729E 2264809N.

These maps starts as “stick” diagrams – distance and azimuth (with small corrections for changes in depth). Working underwater is not easy, and accuracies in recording station-to-station distance to, say 2 ft in distance and 5 degrees in angle might be expected. Ignoring any systematic biases – the tendency to misread a compass in one direction or mechanical error (early on in the mapping, we discovered a bias in one of the Suunto compasses we used).

There are some 64 Stations to get the 1923 ft from Minotauro to, say, the Winz Cenote, so there is an average distance – call it L - of 30 ft between Stations. Simple statistics suggest that the error from distance miss-measurements should be at the level of  $\sqrt{L}$ , when L is the number of steps, times the error per step. Taking our expectation of measuring to, say, 2 ft accuracy, one might expect to be out by 16 ft by the time one got to Winz.

However, azimuth errors will also contribute, perhaps at the  $\sqrt{L} \sin N_f$  level, where f is the expected error in measuring azimuth. That gives an expected error of 20ft. In addition we have the error from the GPS measurement, which, if the WAAS augmentation works, might be at the 3M level – so 10ft at both Minotauro and the other Cenotes. As these errors should be statically independent, we can add the squares of them to give an expected error (one s-level, or 63% of the time)) of about 29ft.

What was actually achieved? We took a GPS with us with an extended antenna, packed into an empty light canister on the dives to the cenotes.. An often-risky climb out with a reel and compass providing the position above ground gave a GPS fix at the cenote. The GPS movement has been compared with the movement underwater and the difference displayed below.

Cenote in Minotauro System	Error in North Direction / ft	Error in East Direction / ft	Total radius error /ft
Estrella	24	1	24
Escalera	21	31	37
Winz	17	4	17

Well, we have two cenotes inside and one outside the ones level, which is plausible and validates our work to a level I am happy with.

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