Pumacocha 2004

Expedition Report

Produced in November 2004 by expedition members
Cover photo: Martin Holroyd

Pumacocha 2004 Expedition Report

1. Introduction

Between September 5 and September 25, 2004, an international team of fourteen experienced cavers continued the work begun by previous expeditions in 2001 and 2002 in the Yauyos District of Central Peru. This report summarizes the achievements of the 2004 expedition.

Copies of this report are presented to the expedition's sponsors along with our thanks for their support. Additionally, it is our hope that the information contained herein may be of assistance to other cavers intent on working in the Andes.

2. Background

The Andes Mountains are the longest mountain chain on earth, extending almost 9000 kilometres down the west side of South America. They are also the second highest mountain range on earth. Although the majority of Andean rock is volcanic in origin, many of the high peaks and ridges are limestone.

Cavers have long been interested in very high limestone mountains because they make possible the existence of very deep cave systems. Explorations have generally been disappointing however, giving rise to speculation that high-altitude karsts are incapable of major cave development. Certainly investigations in the Andes over the past thirty-five years have had modest results, with the deepest known cave prior to our expeditions being the 407m deep Millpu de Kaukiran (aka Sima de Millpu or Racas Marca), surveyed in 1972. As well, Peru's difficult political history and the limited number of local cavers have slowed investigations.

In 1999 Les Oldham, a British exploration geologist and former caver living in Lima, came across a sinking stream and highly favourable geology at Pumacocha ('mountain lion lake' in the local Quechua language); classic conditions for cave development. His friend and fellow geologist/caver Nick Hawkes tried unsuccessfully to locate local cavers, and then attempted to generate interest amongst caving companions worldwide, but it was not until 2001 that a small team of cavers from overseas were convinced to travel to the Yauyos district of central Peru. The success of that expedition gave rise to two further expeditions in 2002 and 2004, both of which included Peruvian cavers from the Centro de Exploraciones Subterraneas del Peru.

It should be noted that our three expeditions are only a small part of Andes cave exploration. There has been long-standing and ongoing interest in Peru from French, Brazilian, American and other caving teams, each of whom have made new discoveries and contributed towards our knowledge of Andean caves. The establishment of a new continental depth record in Sima Pumacocha may refocus attention to the high Andes karsts, and future expedition reports from local and visiting cavers can be expected.

3. Expedition Objectives and History

Pumacocha 2004 was the final of three expeditions focused on the exploration of caves in the Yauyos District of central Peru. The principal objective of the 2004 expedition was the further exploration of Sima Pumacocha, the deepest cave in South America, first explored in 2001 and 2002 by core members of the 2004 team. Secondary objectives included tying up some loose ends from previous explorations, including Qaqa Mach'ay and Tragadero Puyo, neither of which had been explored to any great extent, and reconnaissance of the Puyo valley. A tertiary objective was to add to the stock of photographs taken during the two previous expeditions.

The 2001 Expedition

Our first expedition consisted of five cavers intending to investigate the sinking stream at Pumacocha during two weeks in June 2001. Altitude acclimatization consisted of a circuitous drive from Lima over a 4818m pass through La Oroya to an overnight in Huancayo, and thence a drive back over the 4825m pass at Yauricocha to base camp at the Llapay power station. Investigation of the stream sink at Pumacocha soon followed. After confirming that SP1 was too wet to enter and that SP3 was choked (though draughting) at -120m, exploration and survey commenced down the dry SP2 entrance of Sima Pumacocha. We attempted to reduce abrasion on our 9mm rope by rebelaying off bolts and, where feasible, natural anchors. The most notable features of the cave were its persistently vertical nature, the 113m fossiliferous Ammonite Shaft, and the dramatic entry of the main (SP1) stream at about -300m (The Shining Path). The presence of significant falling water now slowed exploration, and the team began to run out of time at a cascade at -370m. A probe across the stream and partway down the next pitch was achieved with the last piece of the expedition's 500 metres of rope. The estimated explored depth of just over 400m made Sima Pumacocha the deepest cave in the Andes.

The 2002 Expedition

This was a slightly larger affair, consisting of nine cavers and 1000m of rope, and occurred over a two-week period in September. As the cave was known to be 'going', rigging was a little more thorough. Exploration and survey continued down the cascading streamway, down wet pitches as deep as 75m and past a very impressive and noisy column of water entering thru the ceiling of the passage (Viagra Falls). Work continued to the last possible day (allowing for detackling) when a two-person team utilizing their last bolt and the expedition's last piece of rope (once again), explored and surveyed to a sump at -638m, convincingly exceeding Brazil's Grutas do Centenario as the deepest cave in South America. When Sima Pumacocha exceeded 500m in depth it also became the highest major cave in the world (4375m above sea level). Also during this expedition the very high entrance to Qaqa Mach'ay was discovered, and its entrance pitch dropped to confirm that the cave was 'going'. The small caves Yauricocha 1 and 2 were fully investigated, Cueva SP4 was explored and surveyed and the Puyo Valley was investigated but no explorations were undertaken. The expedition was joined by four Peruvian cavers, members of the Centro de Exploraciones Subterraneas del Peru, who conducted surface investigations and undertook probes into the upper sections of Sima Pumacocha.

4. 2004 Expedition Personnel

Core members of the 2001 and 2002 expeditions were augmented by additional cavers from Britain, Canada and Peru.

Photo: Edwars H. E. Tara

Back row, left to right: Peter, Martin, Ian, Greg, Taco, Yelinda (housekeeper), Mark, Jenny (cook), Henry, Chris. Front row: Edwars, Tom, Nick, MadPhil, Snablet, Jhon.

Participant	*Residence*	*Nationality*	*Home Club*
Greg Brock	UK	British	British Bristol Exploration Club
Henry Bruns	Canada	Canadian	Alberta Speleological Society
Jhon Huaman Canchanya	Peru	Peruvian	Centro de Exploraciones Subterraneas del Peru
Tom Chapman	UK	British	Westminster Speleo Group
Chris Densham	UK	British	Oxford University Caving Club
Mark Hassell	Canada	Australian	Alberta Speleological Society
Nick Hawkes	Peru	British	Bristol Exploration Club
Martin Holroyd	UK	British	Northern Caving Club
Taco van Ieperen	Canada	Canadian	Alberta Speleological Society
Peter (Snablet) MacNab	New Zealand	British	Bristol Exploration Club
Ian McKenzie	Canada	Canadian	Alberta Speleological Society
Phil (MadPhil) Rowsell	UK	British	Bristol Exploration Club
Edwars H. E. Tara	Peru	Peruvian	Centro de Exploraciones Subterraneas del Peru
Peter Whitaker	UK	British	White Rose Pothole Club

Initially this large team was intended to be subdivided by objective; nine members were to work on Sima Pumacocha while five were to work on Qaqa Mach'ay and the caves of the Puyo valley. In practice, however, there was a great deal of interchange with some cavers participating on explorations in all caves.

5. Location

The expedition area is reached after a full day's drive from Lima on roads that vary from excellent paved highway to dusty one-lane tracks. Generally speaking, the area is approximately halfway between the coastal town of Cañete and the inland city of Huancayo, accessed via the gravelled road that runs between the two.

The three entrances to Sima Pumacocha are all within a short, shallow canyon a hundred metres downstream of Laguna Pumacocha, itself located on a side-valley off the main road an hour's drive above the village of Laraos on the way to the San Valentin mine. A field camp consisting of tents, sleeping bags and other camping equipment was established near the upper entrance of Sima Pumacocha and centred around a primitive hut.

The entrance to Qaqa Mach'ay is high on the western arm of the Cerro Huampuna cirque, and may be seen by looking north from the high-point on the road several kilometres south of the San Valentin mine. No overnight stays were attempted here.

The Puyo valley area includes the notation 'tragadero' (stream sink) on the 1:100,000 scale topo sheet and was visited on foot by the 2002 and 2004 expeditions. A well-established trail on very easy terrain starts at the Chacachancha farmhouses a little way up the road above Tinco, continues up the 'puna' (high treeless valley) and reaches a ridge of limestone after a few kilometres. A series of closed depressions dotted with cairns (presumably to guide shepherds during periods of 'puyo', or mist) leads up this quiet and pretty valley. Lightweight backpacking and camping equipment was utilized while staying in the area.

Base camp was established at the Llapay powerstation. Here, bunkhouse accommodation and prepared meals added considerably to the comfort of expedition members and provided necessary electricity for recharging the drill batteries and operating laptop computers for recording survey data and downloading photographs.

6. Geology and Geography

Regional Setting

The cave area is located within the 100,000 scale Yauyos mapsheet number 25-L which was published in 1996 by the Instituto Geologico Minero y Metallurgico (INGEMMET). The entire mapsheet covers a half-degree quadrangle, which equates to just over 3000km^2. Les Oldham has mapped several areas within the mapsheet including the area directly over the Pumacocha cave while exploring for base and precious metals. During the course of his mapping Les first recognised the potential for major cave development in this area.

Geological controls are often the primary elements that dictate a cave's location and form. Caves form in limestone, and the best caves are developed in massive limestone with little or no interbedded silts, shales or other non-carbonate dominated lithological horizons. Within Peru, the best limestone for cave development is the Upper Cretaceous Jumasha Formation. The Jumasha limestones comprise a massive thickly bedded sequence of limestones and minor dolomites. Within the Yauyos mapsheet approximately 700km^2 of Jumasha limestones outcrop, making the area highly attractive for cave exploration and karstic studies. In the region of study this lithological unit has been estimated at approximately 400m thickness (Megard et al., 1996). Directly overlying the Jumasha Formation is another limestone unit known as the Celendin Formation that was also deposited in the Upper Cretaceous and has also been estimated as having a thickness of 400m. The Celendin Limestones are not as favorable for cave development due to common interbedded layers of gypsum, red-brown shales and some sandstone. Nevertheless caves can and do occur in this formation. Below the Jumasha limestone lie two further Cretaceous limestone bearing formations, namely the Pariatambo and Chulec formations. Together these form an estimated 330m of potential cave bearing stratigraphy. Jurassic age limestone also occur to the northeast of the principal area of study yet still within the Yauyos mapsheet. These are the Lower Jurassic Condorsinga unit of approximately 1000m thickness and the middle Jurassic Chaucha Formation of an estimated 300m thickness. In total therefore the region has over 2400m of limestone stratigraphy that has subsequently been thrusted and folded during a sequence of orogenic events. The deformation is likely to be closely associated to a period of intrusive activity during the Paleogene and Neogene epochs, which has left the limestones commonly tightly folded, and in many areas standing near vertical. During this period of deformation it is likely that many of the predominantly limestone hosted mineral deposits for which this area is famous for were formed. The principal mineral deposits of the region all have strong magmatic associations suggesting direct association with the Cenozoic intrusive activity.

A simplified geological map of the expedition project area may be found in Appendix IV.

Geology at Pumacocha

The development of the Sima Pumacocha cave system shows two key geological controls. Firstly its location is at the contact between a large Miocene age granodiorite and the intruded Cretaceous age Jumasha limestones. The entire catchment area of the drainage leading into the Pumacocha lake is over the granodiorite. The cave has formed where the lake outflow first meets the limestones. The second key control to the cave is the near vertical dips of the limestone bedding planes that have been thrust up into this position during various episodes of Andean Orogenies.

The presence of considerable cherty horizons which were located underground suggest that the mapped cave to date lies close to the lower contact with the underlying Lower Cretaceous Pariatambo Formation. Numerous ammonites have been observed within the cave at ammonite shaft however no attempt to classify these fossils was undertaken.

Geology and Geomorphology at Qaqa Mach'ay

Qaqa Mach'ay lies further to the south within the same Jumasha limestone band as Sima Pumacocha. The steeply dipping limestone beds is a common control similar to Sima Pumacocha as is clearly observed in the vast entrance.

Looking up Blue Lips Passage toward the entrance of Qaqa Mach'ay. Strong bedding-plane control is evident in the passage shape.

Photo: Ian McKenzie

The location of the cave is believed to be related to the more recent glaciation rather than geological controls. Cave development is believed to have initiated where glacial overflow passed a large bedding plane fissure, which subsequently has grown to the huge breakdown entrance observed today. The cave retains the last remaining icy remnants of the rapidly retreating glacier, clearly marked on topographic maps only 30 years old.

Geology at Puyo

The caves of the Tragadero Puyo region lie around the flanks of a 10km plus long anticline with a core of Lower Jurasic Condorsinga Limestone. Overlying the Condorsinga Limestones are sandstones and shales of the Middle Jurasic Cercapuqio Formation. The areas of best cave development has occurred at the contact between these two rock units. Caves were located at numerous locations around the anticline with also a few smaller pits located on the central part of the anticline. It is unclear from reviewing topographic and geological maps where the most likely area for resurgences to these systems may lie. Although it is possible that several caves of considerable length may be located through further exploration the depth potential in this area is likely to be limited despite its high elevation.

Mining Camps in the Area

The Pumacocha cave system lies between two active mining camps. To the south is the San Valentin polymetallic fault controlled orebody and to the north lies the larger mineral district of Yauricocha where many of the small lead/zinc/silver orebodies appear to occupy karstic or solution-collapse cavities. In both camps mineralization is located at or close to the contact between the Neogene granodiorite and the Jumasha limestones. The contact is sporadically mineralised along its length but it is considered that younger porphyritic intrusives are the true mineralisers that have taken advantage of the structural weakness and fault zones developed along the pre-existing contact. Zoned mineralogical systems exist at both San Valentin and Yauricocha, with Lead zinc peripheries and copper towards the central source intrusions. At the Sima Pumacocha cave system it is the same pre-existing contact between the granodiorite and limestones that has controlled the initial cave development.

Additional Comments on Geomorphologic Controls

Previous speleological expeditions to the Andes have commented on the lack of deep and well-developed caves and have attributed this in part to an effect of the excessive altitude (Imperial College, 1975). The argument proposed is that rainwater falling at such altitudes is less acidic since less CO_2 has been absorbed during the descent. As to whether this argument is valid or not is not here disputed, although the contribution of acidic waters is clearly a pre-requisite for large-scale cave development. The headwaters of Laguna Pumacocha rose over 30sq km of granodiorite bedrock and extensive glacial deposits. Poor drainage over the granodiorite has resulted in the development of peat bogs which themselves produce acid waters due to the decomposition of organic matter which produces CO_2 and therefore carbonic acid. Furthermore the oxidation of numerous pyretic sulphide veins within the granodiorite will also have contributed to the low pH of waters entering Laguna Pumacocha and subsequently Sima Pumacocha.

7. 2004 Cave Explorations

At 638m deep, Sima Pumacocha was already a significant cave, and with the most-geologically-likely resurgence 14km away and 1.1km lower than the entrance, expedition members were prepared for a major undertaking. Combined with the other objectives of the 2004 expedition, a larger, better-equipped team than in past expeditions was called for. Fourteen cavers spent two or three weeks in the field in September 2004.

Sima Pumacocha

A long-abandoned aqueduct intended to keep the lake's outlet stream on the surface had unexpectedly been repaired in the intervening years, which aided exploration (but didn't help the photographs) by diverting much of the water from the SP1 entrance. Unfortunately the aqueduct was quite leaky, and some water was now being delivered into the normally-dry upper shafts of the cave, making rigging and exiting SP2 more difficult.

After several days of rigging the previously-known parts of Sima Pumacocha, exploration commenced in the draughting climb up a muddy slope which was hoped to bypass the terminal sump. This exploration ended in disappointment after only twenty metres when the lead dropped

back down to the previously-known sump chamber, rather than bypass it. The sump itself had disappeared, and a dig at an impenetrable crack proved fruitless. This required some re-thinking of the strong exhaling draught, and the theory that the cave is being pressurized by an as-yet undetected underlying river cave passage has been countered by the less-dramatic theory that the draught may be internal circulation caused by its own stream.

Stream passage near the bottom of Sima Pumacocha.

Photo:
Martin Holroyd

The SP1 stream sink, with its much-reduced water volume, was rigged, explored and surveyed down to its connection with The Shining Path at about -300m. The passage is essentially a single shaft of 282m depth, thought to be the deepest in the Andes, which is followed by a short stretch of horizontal passage containing pools and cascades to the connection with the main cave. Although this added about 300 metres to the surveyed length of the cave, no additional depth was added. Sima Pumacocha remains at –638m, the deepest cave in South America.

The blind, 120m deep SP3 was descended, but no additional exploration was accomplished, or indeed is possible without extensive digging. Interestingly, the large amount of water now being channelled into the entrance (only thirty metres from the main SP2 entrance) by the leaking aqueduct was not seen in the main Sima Pumacocha passage until about -550m, suggesting a deep, parallel cave passage exists beyond the SP3 choke.

All passages in the cave were completely detackled with the exception of bolts, which could not be removed. Several ascending leads in the cave remain unchecked, and exploration in one descending passage (Road to Nowhere) ends at an undescended pitch.

Qaqa Mach'ay

Topographic maps drawn thirty years ago show Cerro Huampuna mantled with glaciers, none of which remain today. It is thought that Qaqa Mach'ay ('Cliff Cave') is an abandoned glacial sink formed on a geologically-favourable bedding plane. Its enormous entrance, approximately fifty metres long, thirty metres wide and fifty metres deep, leads to a square-shaped descending passage twenty metres high and twenty metres wide. Although this large passage is almost completely blocked by boulders, two possible continuations were noted.

The 2004 expedition explored both continuations. Blue Lips Passage essentially follows the left (as you face into the cave) wall down past boulders and ice masses. Four pitches of 20m, 10m, 10m and 5m lead to a disappointing boulder ruckle 104m below the entrance. Red Face Passage descends down pitches of 18m, 9m, 4m and 38m to a breakdown floor at –125m. Both passages draught slightly. These passages were named for the effects of high altitude, cold and sun on the cavers' complexions. About a third of the rigging in these passages was off ice-screws.

With an entrance elevation of 4930m above sealevel, Qaqa Mach'ay is the highest surveyed cave in the world. No open leads remain in the cave.

Caves in the Puyo Valley

Many of the obvious and easily-accessible entrances in this valley have been investigated; four were surveyed.

Tragadero Puyo is a large entrance that accepts one of only two small surface streams in the valley (the other sinks in gravel). It consists of spacious, mossy and quite beautiful entrance shafts of 30m and 18m dropping into a pair of large chambers. Unfortunately the water is lost even before leaving daylight and further explorations were through modest overflow passage down five more short shafts of 7m, 6m, 8m, 17m and 15m separated by short sections of tight rift. The cave draughts slightly; exploration was stopped at -107m when time ran out. Potential for further exploration is good, but may be restricted to thinner cavers by the modest passage size.

Two holes just a few metres to the right of Tragadero Puyo are in fact not physically connected to it. A spacious and attractive 44m shaft (Pozo Waqtanpi) is blocked at the bottom with no further passage and no draught.

A few hundred metres to the left of Tragadero Puyo and about fifteen metres higher is the large, square, unlikely-looking entrance to Cueva Puyo. A short ascent over scree leads to a stoop and, where two skylights appear, the cave begins to steeply descend down two pitches of 7m and 20m separated by rubble ramps. Exploration stopped at the head of a further pitch estimated at 20m deep. Although there is no strong draught, the cave remains a promising prospect.

About a kilometre downvalley is the large elliptical shaft of La Cueva de la Cuerna. A 47m pitch leads to a short passage that quickly chokes. A few bones at the bottom of the cave give it its name.

Entrance pitch of Tragadero Puyo.

Photo: Nick Hawkes

All four caves are at the contact between the valley floor and the vertically-bedded limestone ridge, except Cueva Puyo which is about 15m up. All of the Puyo valley caves are between 4400 and 4600m above sealevel and are amongst the highest surveyed caves in the world.

Some surface reconnaissance was conducted around and over the limestone ridge, and a great number of entrances and pockets were observed, some of which were investigated at close quarters. The area is felt to be worthy of further investigation.

8. Surface Investigations

Several areas of limestone were investigated in 2004 but no further caves of significance were discovered.

Laraos

A trail across the road (north) from Laraos was followed up as far as a small reservoir, then the ridge to the right (east) was ascended to the summit and an ancient watchtower - a hike of about two hours duration. Some hundreds of metres below this to the west are two short pits in vertical limestone beds that were descended with the aid of a handline. Both were blocked after a few tens of metres of passage.

A hike along the valley bottom the entire distance from Pumacocha to Llapay was undertaken, but no caves were found. A large spring is visible from the road a few kilometres above Laraos, and marks the northernmost point of a significant limestone band not checked by the expedition.

Pumacocha valley

The summit of the ridge forming the north side of the Pumacocha valley was followed westwards and thence down towards the Sima Pumacocha entrance. Several entrances were investigated but none were caves.

A recce south from the back-road between the San Valentin mine and Laguna Pumacocha noted three entrances (not investigated) and two 4m deep shafts (dropped to chokes).

Tintircullpa valley

A large entrance is visible looking south across the valley from the road just before the Pumacocha valley turnoff. This was investigated (no passage) during a hike south along the limestone/valleybottom margin right to the end of the limestone (about 5km) and back again.

Puyo valley

The limestone/valley margin adjacent to the series of large closed depressions along the Puyo valley was walked; most of the valley's surveyed caves are located on this contact. A very large entrance that is used as a corral at the most northwestern (downvalley) depression has no passage.

Hiking towards the Puyo Valley.

Photo: Ian McKenzie

Four parties walked the limestone ridges that form the northeast wing of the Puyo Valley. Some promising entrances were found high on the southeasternmost mountain at elevations up to 4850m; most were written off but one was abandoned after two short pitches due to lack of time and draught, and another horizontal crawl was abandoned at a tight bit.

Cerro Huampuna

Most of the Cerro Huampuna cirque was searched; no caves (other than Qaqa Mach'ay) were found. Extensive glaciers shown on the topographic map no longer exist.

Rio Alis

A drive up through the Tomas-Alis valley included a stop to investigate an entrance visible 100m up on a cliff wall, just past the first resurgence downstream of Alis. A small cave was found with 20m of spacious passage and many bats.

9. Equipment

Each individual provided their own personal caving equipment, which included Frog-style ascending systems and environmentally-friendly electric lights. Group gear included 1600m of primarily 9mm diameter rope and sufficient bolting hardware for over 200 new placements. The vertical nature of the caves required alpine rigging techniques with extensive use of rebelays, primarily off bolts but also employing chocks, natural anchors and, in the case of Qaqa Mach'ay, ice screws, to avoid rope abrasion. Two cordless electric drills and all surveying equipment was provided by expedition members or borrowed from their home caving clubs. Camping equipment was provided by individual expedition members or borrowed locally in Lima.

Some expedition members brought their own digital cameras of varying quality, and electronic flashguns with light-activated 'slave' triggers. A video camera was successfully utilized both on the surface and underground.

Due to the remoteness of the project area and the lack of cave rescue resources in Peru in general, the expedition brought along its own rudimentary rescue equipment, which fortunately saw no use.

10. Survey Standards

Conducting accurate surveys of all significant finds was a guiding principle of the 2004 expedition, and all surveying was conducted to BCRA Grade Five standards (compass and clino readings to nearest ½ degree; distances measured to nearest centimetre). All surveying utilized hand-held Suunto compass and clinometer instruments and plastic-fibre tapes, with data immediately recorded on paper and transcribed into electronic format at the earliest opportunity. Data manipulation employed the user-friendly On Station cave survey program, and final maps were drawn up in Canada and Britain in the weeks following the close of the expedition.

11. Travel and Accommodation

Expedition members individually purchased airfare from London, Calgary and Auckland. Overnight stays at Nick and Sophia Hawkes' house were necessary to accommodate late-night airport arrivals and departures at Lima. Three Toyota 4wd Hilux trucks were employed for the duration of the expedition.

Hut at Pumacocha.

Photo: Martin Holroyd

An excellent, well-maintained bunkhouse was utilized at the Llapay powerplant, and a primitive hut at Pumacocha served as both secure storage for the campsite and a cache for emergency equipment and supplies. Lightweight backpacking tents and camping equipment were employed during the Puyo investigations.

12. Medical Report

The expedition was plagued by a mysterious stomach and intestinal ailment that affected most members, some quite severely. Its source was unknown, but candidates include ingested tapwater (despite drinking bottled water from Lima) that may have been contaminated by mine tailings, eating undercooked food, or other local sources.

A few expedition participants suffered from mild altitude sickness (headache and nausea), but most were unaffected. All, however, felt the effects of the thinner air. It is a curious observation that most cavers seemed to do better underground in Sima Pumacocha than on the surface. One theory is that the exhaling draught is an indication that the cave environment is under higher pressure than the surface, with the denser cave air simulating lower-elevation conditions.

Bad weather including snow down to 4000m was experienced for the first five days. The high-altitude sun reflecting off the clean white snow resulted in some moderate cases of sunburn (after as little as thirty minutes exposure), which was treated with liberal application of skin moisturizer and more rigorous use of wide-brimmed hats.

13. Sponsors and Supporters

The 2004 expedition benefited greatly from the generosity of its sponsors.

Don Jesus Arias, owner of the San Valentin mine, provided our base-camp at the Llapay powerstation which included bunkhouse-style accommodation, a cook, housekeeping, food and even fuel for the vehicles. The loan of a rustic hut (elevation 4400m asl) close to the Sima Pumacocha entrances provided much-needed shelter for cavers exiting too late in the night to travel back to Llapay, and a convenient cache-point for emergency equipment. In addition, tours of the mine and concentrator facilities at San Valentin were provided by his friendly staff. The generosity and helpfulness of Don Jesus is truly outstanding and contributed enormously to each expedition's comfort.

Rio Tinto Exploration Peru graciously allowed the loan of two Toyota Hilux 4wd vehicles during each of the three expeditions. These four-door, four-wheel-drive vehicles are generally considered the best in the world for rough country work, and we were very fortunate to have their use. A third vehicle was rented during the 2004 expedition from Trinnys, who gave us discounted rates.

The *Ghar Parau Foundation* supported the 2004 expedition with a grant of £1000 which was put towards the cost of our 9mm rope.

The *Mount Everest Foundation* supported the 2004 expedition with a grant of £475 which was put towards the purchase of materials and the cost of renting a third vehicle.

Mountain Equipment Co-op of Canada provided a $500 grant-in-kind to the 2004 expedition, which included most of our bolt hangers and several oval carabiners.

Caving Supplies of Great Britain gave us excellent discounts and service for rope and other expedition gear.

Les Oldham provided a great deal of logistics organization and advice during the planning stages. It was, of course, Les who first recognized the cave potential of the sinking stream at Pumacocha. His friendship is greatly valued.

The people of Llapay, Laraos and the San Valentin mine were all very supportive and friendly, and expressed much interest in our explorations.

14. Further Reading

A more complete picture can be obtained by reading the Pumacocha 2001 and Pumacocha 2002 expedition reports. Reading the logbooks from each can give a greater feel for the flavor of these expeditions. Personal perspectives on these expeditions appear in British and Canadian caving journals. The expedition website is at http://members.shaw.ca/pumacocha ; Spanish summaries can be found at the CESPE website http://www.geocities.com/cespeleo .

15. Conclusions

Cave explorations in the Yauyos District of central Peru have yielded significant caves, including the deepest cave in South America (Sima Pumacocha) and the highest surveyed cave in the world (Qaqa Mach'ay). At 638 metres depth, Sima Pumacocha has challenged assertions that high-altitude karsts are incapable of producing major cave systems. However it remains unclear whether the conditions at Pumacocha are unique, or if further high-altitude deep caves will be found. All our discoveries are located over 4000m above sea level, and together constitute some of the highest explored caves in the world.

There is a great deal of local and expedition caving that has occurred in Peru over the years, of which we have only limited knowledge. The findings in this report are a small piece of the Andes cave puzzle that has been slowly assembled by Peruvian and foreign cavers over the past thirty-five years. Much work remains.

Cueva de la Cuerna.

Photo: Chris Densham

Appendix I

In order to place our cave explorations into context, expedition members researched cave literature and other sources to compile the following cave lists. Although these lists are the best we could come up with, they may well be incomplete and we encourage knowledgeable cavers to contact us with any corrections or additions.

South America's Deepest Caves

1. Sima Pumacocha (Peru) -638m
2. Gruta do Centenario (Brazil) - 484m
3. Millpu de Kaukiran (Peru) -407m
4. Gruta da Bocaina (Brazil) -404m
5. Sima Aonda (Venezuela) -383m
6. Sima Auyan-tepui Noroeste (Venezuela) -370m
7. Tragadero San Andres (Peru) -334m

South America's Deepest Shafts

1. Sima Aonda (Venezuela) 320m
2. SP1 in Sima Pumacocha (Peru) 282m (deepest shaft in the Andes)
3. Lago Azul (Brazil) 279m (274m underwater)
4. Sima Mayor de Sarisarinama (Venezuela) 275m
5. Sima Auyan-tepui Noroeste (Venezuela) 240?m (awaiting verification)

The World's Highest Surveyed Caves

1. Qaqa Mach'ay (Peru; -125m) 4930m above sealevel
2. Rangkul'skaja (Syjkyrduu) (Pamir, Tajikistan; -268m) 4600m above sealevel
3. Cueva Puyo (Peru; -48m) 4585m[1] above sealevel
4. Tragadero Puyo (Peru, -107m) 4570m[1] above sealevel
5. La Cueva de la Cuerna (Peru, -58m) 4400m[2] above sealevel
6. Sima Pumacocha (Peru -638) 4375m above sealevel

[1] GPS readings are approximately 100m higher than the 1:100,000 topo map suggests.
[2] Estimate only.

NOTE: mountains are filled with cracks and holes that might be interpreted as 'caves', and certainly these will occur as high as mountains go. Our definition rests on whether a cave has been deemed significant enough by its discoverers to be accurately measured (surveyed) and named. We recognize that this definition is somewhat arbitrary. Many cavers consider the highest cave in the world to be on the Rahkiot Ridge of Nanga Parbat in Pakistan at an altitude of 6645m, reported by climbers in 1963 as being 75m long but never visited by cavers. We also have no information on the following caves, allegedly in Peru and between 4000 and 4800m elevation: Cueva de Saco, Cueva de Sanson Machay, Cueva de Pachacayo, Cueva de Laurichoca, Cueva de Taypunta.

Appendix II

Explored Caves, 2001 - 2004

Name	Area	Depth	Length	Elevation
Sima Pumacocha	Pumacocha	638m	1427m	4375m
Qaqa Mach'ay	Huamapuna	125m	300m	4930m
SP3	Pumacocha	120m	125m	4375m
Tragadero Puyo	Puyo valley	107m	147m	4570m[1]
Cueva de la Cuerna	Puyo valley	58m	101m	4400m[2]
Cueva Puyo	Puyo valley	48m	59m	4585m[1]
Pozo Waqtanpi	Puyo valley	45m	45m	4570m
SP4	Pumacocha	17m	65m	4370m
Yauricocha 1	Yauricocha	15m	15m	4630m
Yauricocha 2	Yauricocha	(7m)[2]	(20m)[2]	4732m

[1] Based on two independent GPS readings. Topo map suggests ca. 4450m.
[2] Estimated.

Nick Hawkes at Tragadero Puyo.

Photo: Ian McKenzie

Appendix III

Names and Terminology Used in this Report

Quechua	Spanish	English
millpu (millpo, milpo etc.)	sima	pothole, abyss
t'oqo	pozo	hole
	tragadero	swillhole, swallet
puquio	manantial	spring
puna		high valley
mach'ay	cueva, caverna	cave
puyo (puyuho)		mist
cocha	lago, laguna	lake
	quebrada	creek
	cerro	mountain
huanca		stone
puma		mountain lion, cougar
qaqa		cliff
	cuerna	antler
waqtanpi		beside, adjacent

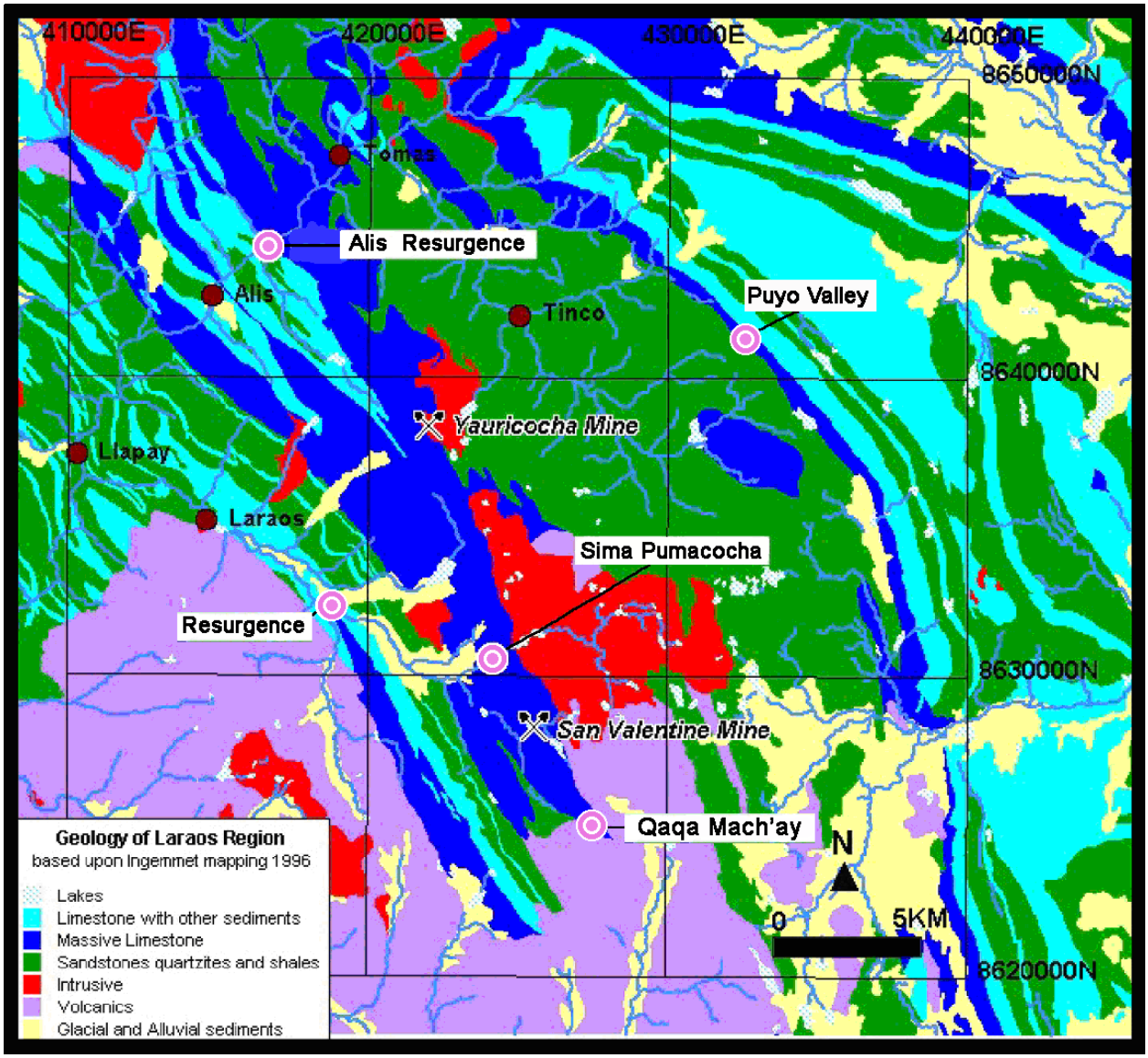
Notes

Some place-names in the Peruvian Andes combine the original Quechua name with a Spanish title. For example "Pumacocha" is a complete place-name in Quechua ("mountain lion lake"), yet modern maps show it as Lago Pumacocha ("pumacocha lake", fully translated to "mountain lion lake lake").

In naming caves, our expedition therefore felt comfortable using either Spanish, Quechua or a combination of both. Local Quechua landmarks (Pumacocha, Puyo) were combined with Spanish titles (sima, tragadero, cueva), or names and titles were created in either or both languages (Qaqa, Cuerna, Waqtanpi) by expedition members. SP3 is certain to connect with Sima Pumacocha, so retains its entrance designation rather than adopt an independent name. SP4 is almost certain *not* to connect with Sima Pumacocha, but as there is a strong likelihood that it has a local name that we were unaware of, it retains its entrance designation only.

Appendix IV

Geological Map



Appendix V

Cave Surveys, 2004 Expedition

(additional surveys may be found in the 2001 and 2002 Expedition Reports)

Sima Pumacocha Photo: Martin Holroyd

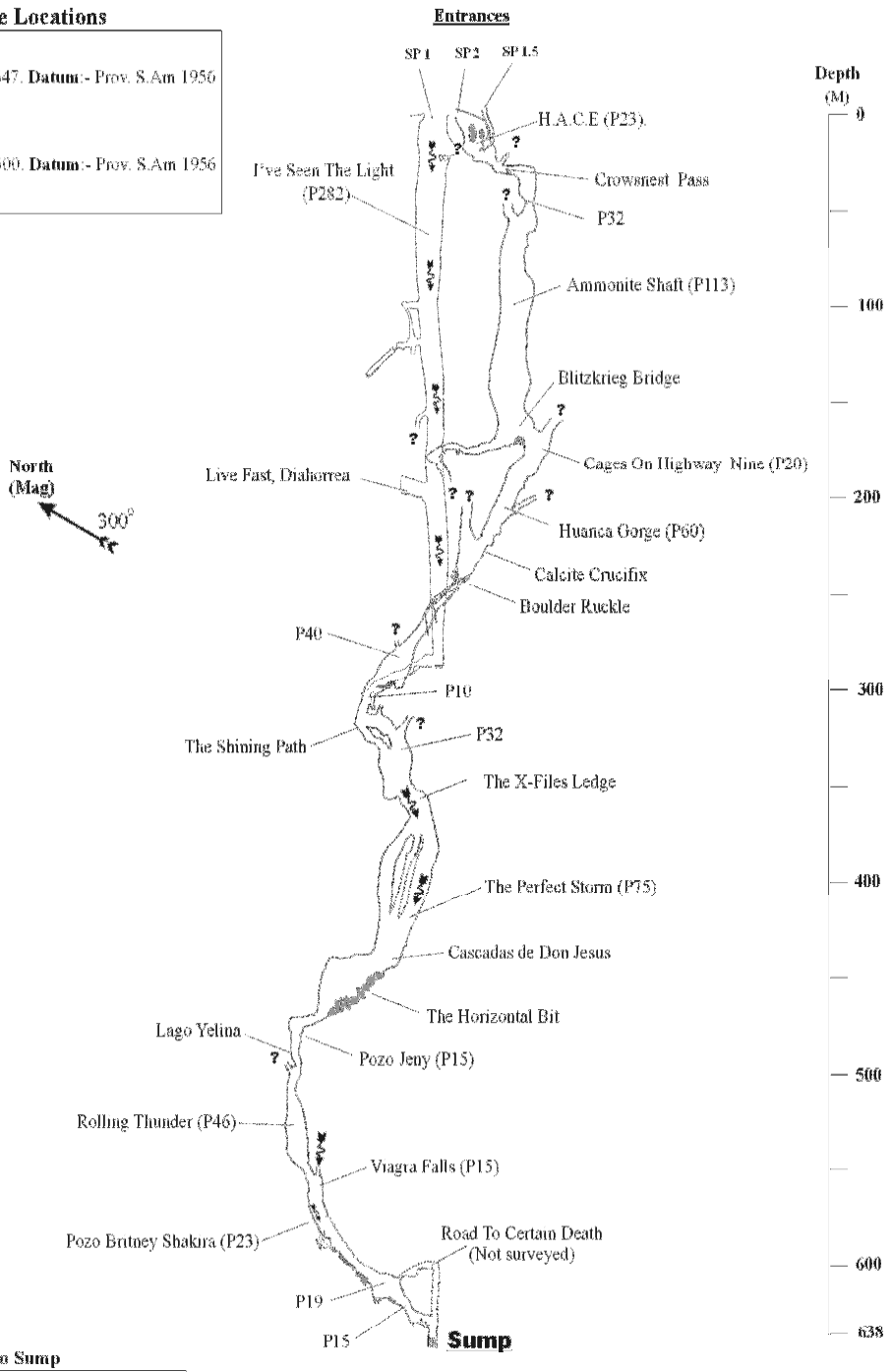
SIMA PUMACOCHA

Laraos, Yauyos District, Peru

Entrance Locations

SP 1
E 424265, **N** 8630547. **Datum**:- Prov. S.Am 1956
Altitude: 4378m

SP 2
E 424268, **N** 8630500. **Datum**:- Prov. S.Am 1956
Altitude: 4375m



SP 2 to Sump

BCRA Grade: Grade 4 (Entrance to base of Ammonite Shaft)
Grade 5a (Base of Ammonite Shaft to Sump)

Date: June 2001 & September 2002

Drawn By: Rob Harper (2002) **Updated:** Madpial Rowsell (2004)

Surveyed By : Rob Harper (BEC), Mark Hassell (ASS), Nick Hawkes (BEC), Tony Jarratt (BEC), Peter MacNab (BEC), Ian McKenzie (ASS), MattTuck (BEC)

Depth: 638m
Length: 1427m

SP 1 to Shining Path

BCRA Grade: 5c
Date: September 2004

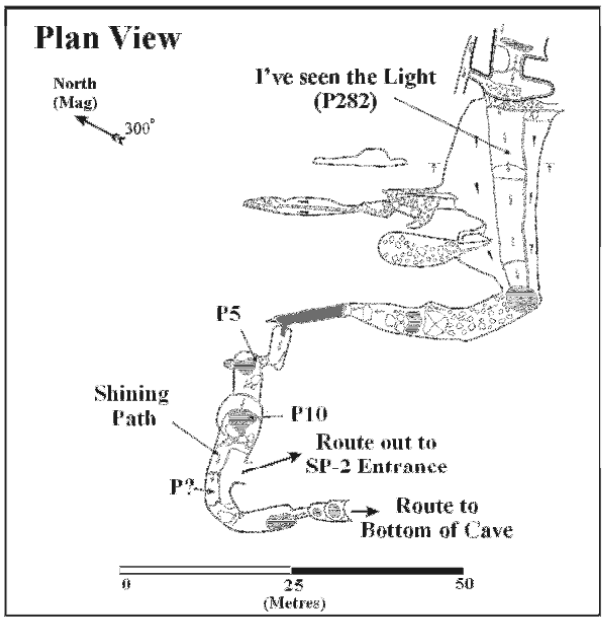
Drawn By: Madpial Rowsell (2004)

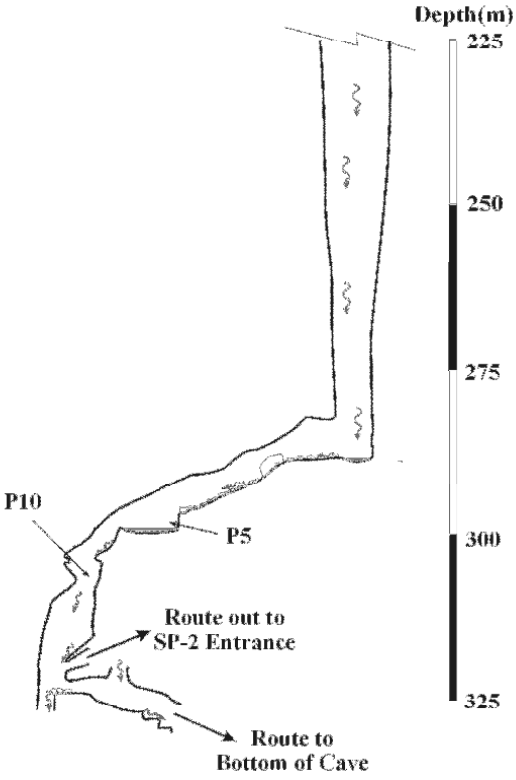
Surveyed By: Tom Chapman (BEC), Martin Holroyd (NCC) Madpial Rowsell (BEC)

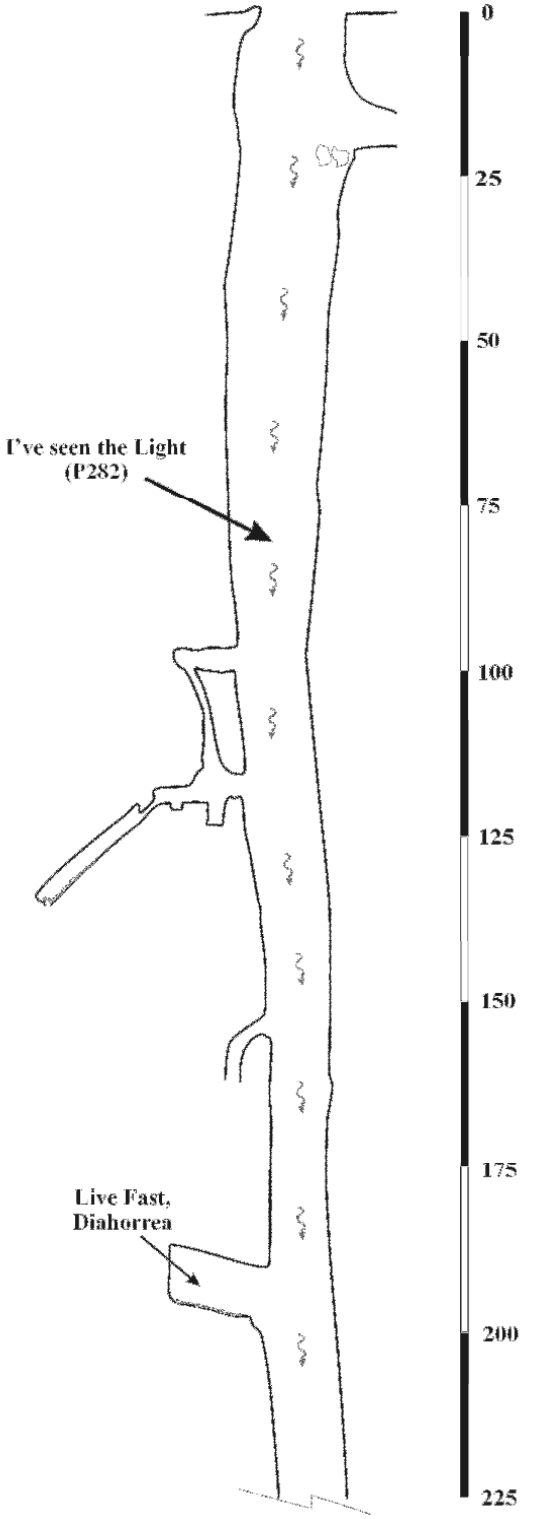
SIMA PUMACOCHA

SP 1 - Shining Path (SP 2)

Laraos, Yauyos District, Peru







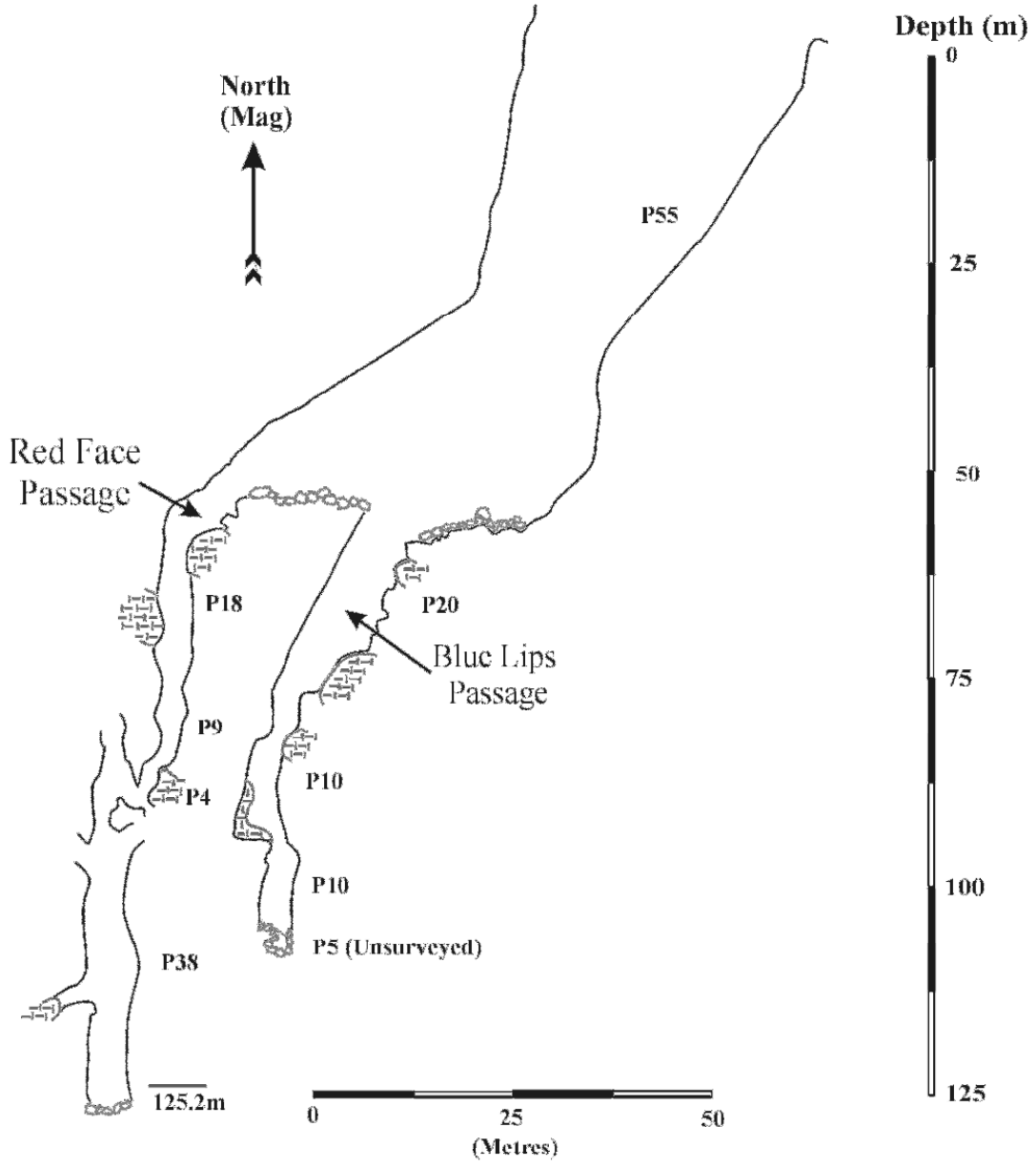
BCRA Grade: 5c
Symbols: U.I.S. 1999
Drawn By: Madphil Rowsell (2004)
Surveyed By: Tom Chapman (BEC), Martin Holroyd (NCC), Madphil Rowsell (BEC,)(Sept 2004)

Qaqa Mach'ay

Yauyos District, Peru

UTM: E0426903, N8625382. **Datum:** Prov. S.Am. 1956

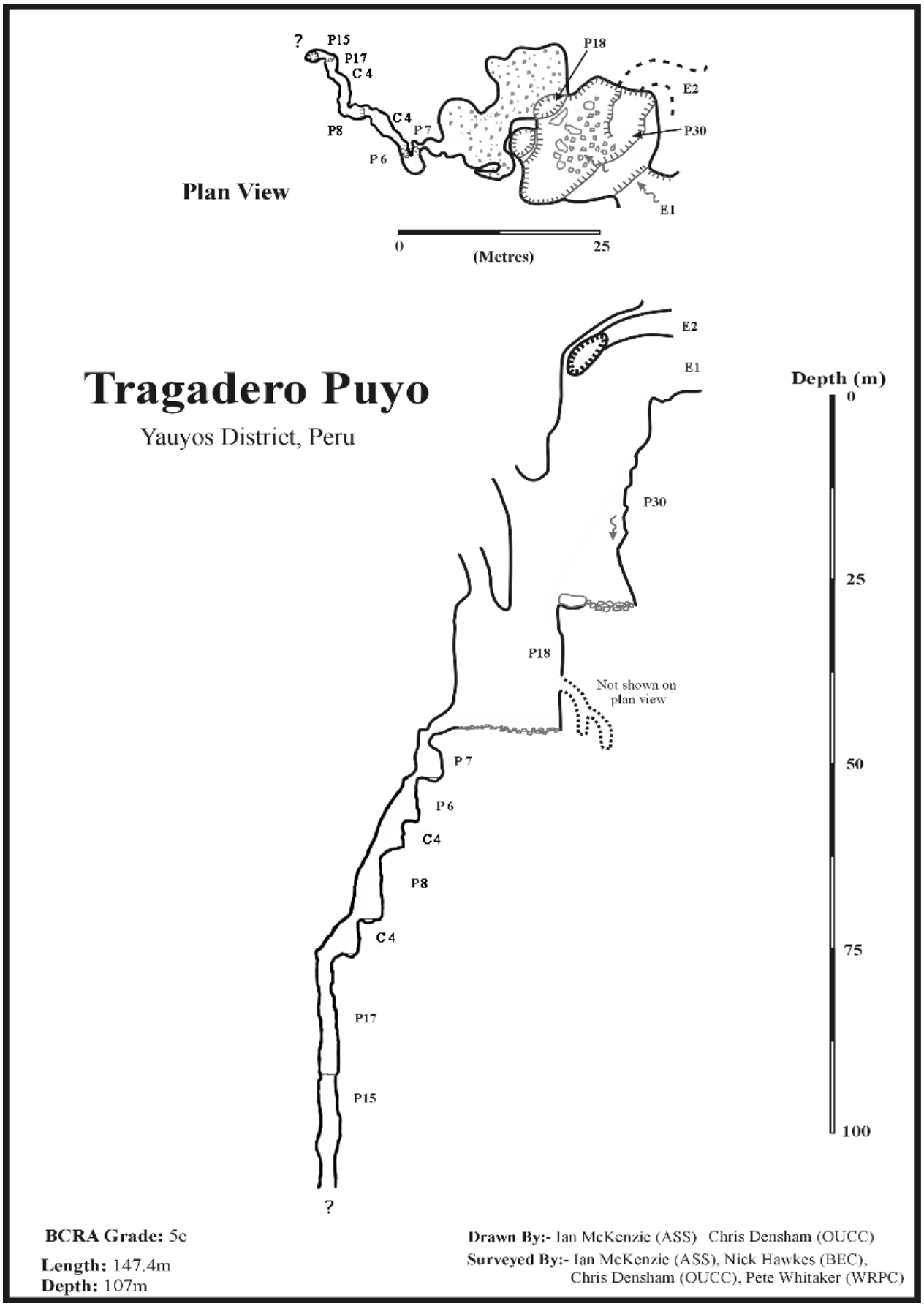
Altitude: 4930m



Drawn By: Ian McKenzie (ASS)

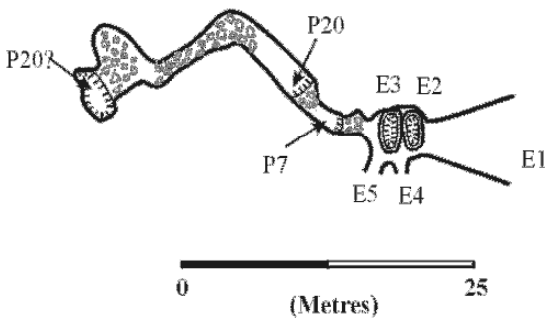
Surveyed By:
Henry Bruns (ASS), Chris Densham (OUCC), Martin Holroyd (NCC), Nick Hawkes (BEC), Ian McKenzie (ASS) (Sept 2004)

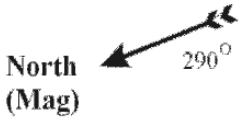
Depth: 125.2 m
Length: 300.1 m
BCRA Grade: 5c
Symbols: U.I.S. 1999

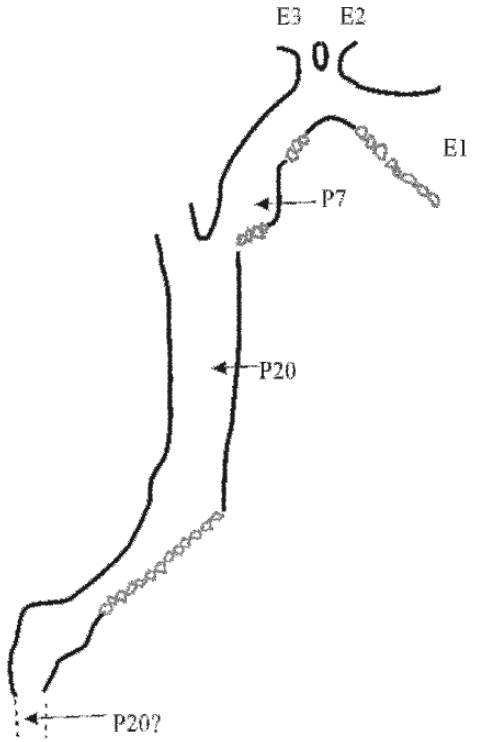

Plan View
? P15
P17
C4
C4
P8
P7
P6
P18
E2
P30
E1
0
25
(Metres)
Tragadero Puyo
Yauyos District, Peru
E2
E1
P30
P18
Not shown on plan view
P7
P6
C4
P8
C4
P17
P15
?
Depth (m)
0
25
50
75
100
BCRA Grade: 5c
Length: 147.4m
Depth: 107m
Drawn By:- Ian McKenzie (ASS) Chris Densham (OUCC)
Surveyed By:- Ian McKenzie (ASS), Nick Hawkes (BEC), Chris Densham (OUCC), Pete Whitaker (WRPC)

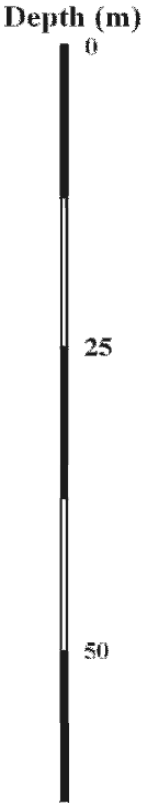
Cueva Puyo

Yauyos District, Peru







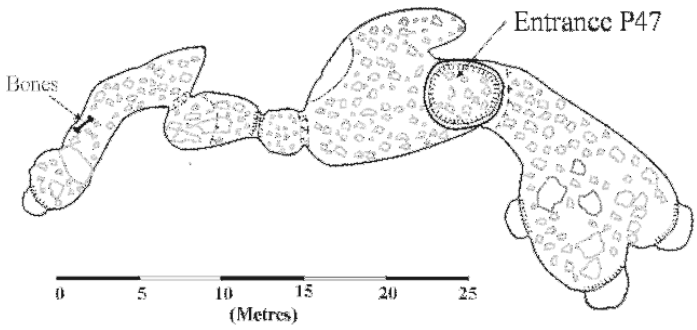


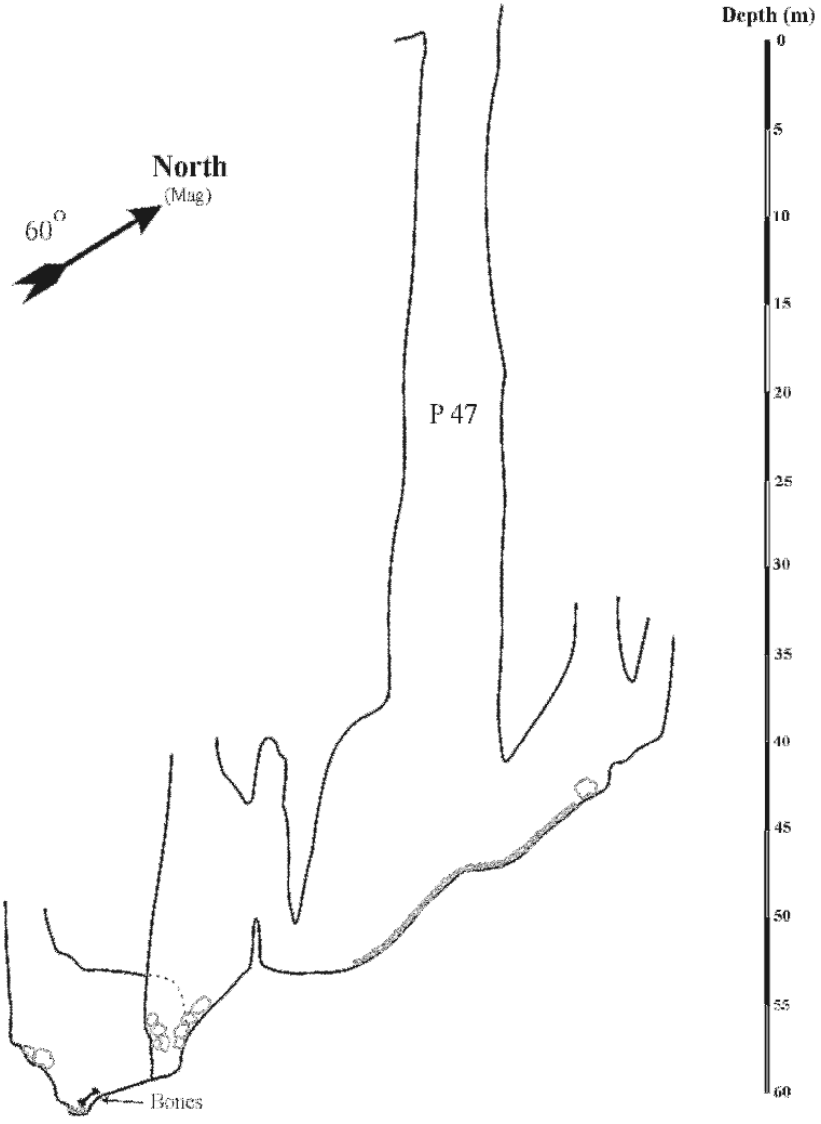
Length: 58.81m
Depth: 48.3m
BCRA Grade: 5c
Symbols: U.I.S. 1999

Drawn By: Ian McKenzie (ASS) & Henry Bruns (ASS)
Surveyed By: Henry Bruns (ASS), Nick Hawkes (BEC), (Sept 2004)

La Cueva de la Cuerna

Yauyos District, Peru



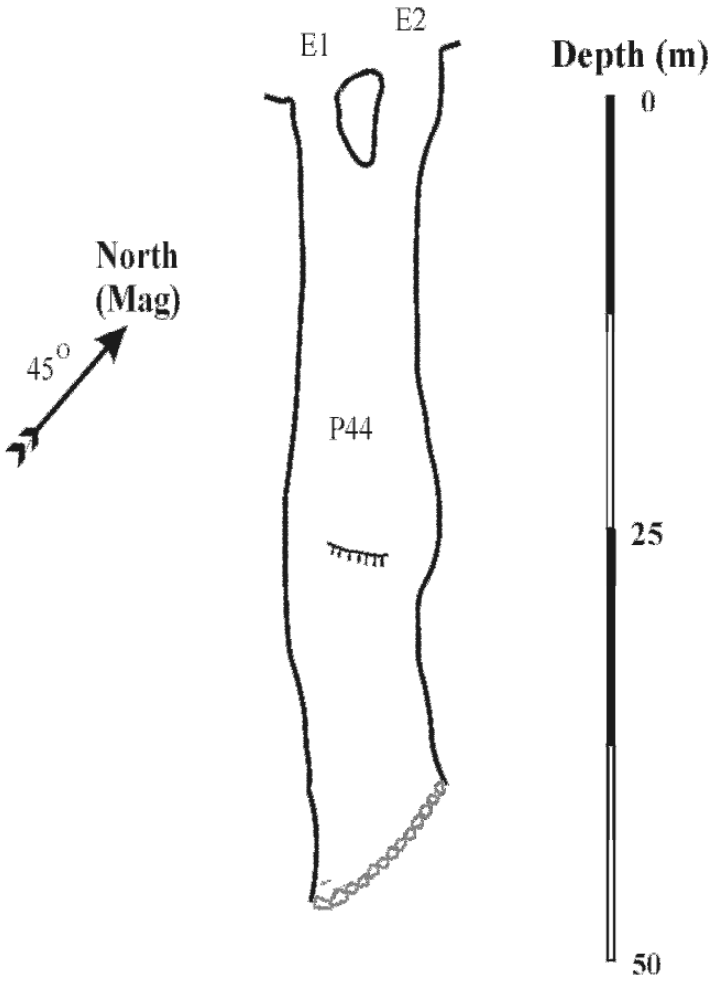


BCRA Grade: 5c
Symbols: U.I.S. 1999
Drawn By: Madphil Rowsell
Surveyed By: Martin Holroyd (NCC), Madphil Rowsell(BEC), 20/09/04

Survey Depth: 57.5 m
Survey Length: 101.3 m

Pozo Waqtanpi

Yauyos District, Peru



Depth: 45m

BCRA Grade: 5a

Symbols: U.I.S. 1999

Drawn By: Ian McKenzie (ASS)

Surveyed By: Henry Bruns (ASS),Nick Hawkes (BEC), Ian McKenzie (ASS); (Sept 2004)