

# The Underwater Topography in Expedition Atahuallpa 2000: The connection with archaeology and Geology Sciences

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## Abstract

With the Atahuallpa Expedition in August 2000, the cultural association AKAKOR GEOGRAPHICAL EXPLORING Onlus realised a multidisciplinary project in the waters of Lake Titicaca (Bolivia), in which underwater topography played an important role, serving the explorers.

The extreme conditions in which the work was carried out (3812m altitude) combined with the technical difficulties due to the nature of the project, forced the divers to adapt to the Bolivian physical-social system, using simple but efficient instruments and work techniques. In this article the author wishes to highlight the technical-operative aspects adopted during the expedition which brought concrete results over a short time scale and with limited costs.

## Geographical localisation and physical characteristics of the work area

Lake Titicaca in South America extends along the heart of the high plain divided between Peru and Bolivia at an altitude of 3812m, at the feet of the western front of the Cordigliera Andina whose peaks stand at over 6000m.

The lake is 176m long in the northwestern-southeastern plane, 70km wide and has a surface area of 8400km<sup>2</sup>, with a maximum depth of 283m in Bolivia.

## Characteristics of the Lakewater

The average monthly temperatures of the surface water of Lake Mayor between 1977 and 1979 (Carmouze et al. 1983) vary between 11.25 and 14.35°C, the minimum in August and the maximum in March. The average annual temperature (1977-79) is 13.0°C.

Occasional measurements taken in Lake Mayor (Gibson 1964, ILTIS 1987) demonstrate a minimum of 10.9°C at the end of July and a maximum of 17°C in February, whilst Lake Minor shows extremes of 8.5°C in July and 18.5°C in February.

In Lake Menor, the transparency of the water varies between a minimum of 4.5m and a maximum of 10.5m (Richerson 1977). Observations taken in 1982 show a maximum of 13.3m visibility which increased to 15.7m in 1984-85 (Alfaro and Roncal). In the Bolivian area of Lake Mayor five series of measurements taken at nineteen stations, show average visibility of 11.8m in June 1985, 11.9m in December 1985, 13.2m in April 1986, 12.4m in October 1986 and 13.9m in February 1987 with values between 7.5m and 18.5m (ILTIS 1987).

## The Theory of Akakor Geographical Exploring

Recent studies have shown that 10,000 years ago Lake Titicaca had a smaller surface area due to an arid climate and the influx of alluvial deposits carried by the numerous torrents. The level of the lake dropped almost to drought levels, giving the possibility to new civilisations, however, to expand along its fertile banks. Successive natural events have brought the lake to today's levels submerging centuries of history.

Akakor's archaeologists believe that civilisations grew up on the now-flooded shores of the antique lake, and that interesting ruins remain on the lakebed near to several islands. It was around these islands - Island of the Sun, Island of the Moon, Koa Island and Pallalla Island - that the research of the Atahuallpa 2000 Expedition was concentrated.

## Aim of the topographical survey

The topographical surveys of the archaeological sites identified in Lake Titicaca had the following aims:

- to draw up sufficiently detailed maps of the lakebed explored to allow the elaboration of geological and archaeological studies and theories of the Atahualpa project;
- to construct a basic network in which the minor samples and eventual findings on the lakebed can be fitted.

## Working methods applied

The choice of the working methods applied was heavily influenced by the difficult work conditions:

- the high altitude of the lake (3812m);
- the difficult access to the underwater work areas caused by the long distances and the complex morphology of the terrain.

The altitude of the lake led to specific immersion techniques and consequently limited the productivity. The difficulties in reaching the work areas also compromised the transport and use of technically advanced equipment, due to their size or fragile nature.

Simple yet reliable topographical techniques and instruments were therefore employed, easy to use in stressful or difficult conditions.

The first topographical operations conducted were the localisation of several points, limited in number yet precisely localised, which serve as reference points for the successive operations. These points made up the horizontal support network. The operations were carried out using triangulation and polygonation techniques due to the nature of the sites and the kind of information required for the archaeologists.

The geometric plan of triangulation is made up of a large number of triangles placed side by side with one side in common, obtaining between them the points to read; polygonation on the other hand, consists of measuring directly all the angles and sides of a polygon obtained by joining the points two by two.

Due to the difficult terrain, the problems connected with repetitive dives at high altitude and the extreme conditions linked to the work areas, these techniques were adopted because they don't require sophisticated or heavy, cumbersome equipment.

**Triangulation Method:** to begin with we carried out an inspection of the lakebed to ascertain its morphological characteristics, the types of vegetation and the level of visibility: elements which, together with the expanse of the area, led to the choice of the points to read, called trigonometric vertices. The lines of sight linking these points formed the sides of the triangles. One side of the first triangle was measured, called the triangulation base, from which the other sides were calculated based on the measured angles, after applying the sine theorem. Having established the direction of one side, the direction of the others were then established and the relative positions of all the vertices could be calculated in cartesian co-ordinates.

This method needed only basic underwater topographical instruments; a lanyard measurement reel, a diving suit compass, depth gauge and a tape measure.

**Polygonation Method:** The conditions of the lakebed and the precision required limited the choice of the points to distances between five and thirty metres. When the polygon touched two trigonometric vertices, it was done so that it had a flattish plane, or in other words, so that the angles were almost flat. When the lakebed to measure was quite spread out, several polygons were created in three distinct levels of importance: the primary polygon, the secondary and then detail polygons.

Often, for several smaller areas, one polygon was enough without using triangulation: in these cases the points were chosen specifically to obtain a closed polygon so having the possibility to carry out checks and compensation of the measurements.

**The "Squaring" or Grill Method:** This is the most practical method to survey a site of archaeological interest. Some of the sites identified by the archaeologists of Atahualpa were covered by a fixed geometric grid made up of a series of orthogonal co-ordinates extended between two perimeter points, to form a mesh with dimensions relative to the size of the area.

To avoid distortions due to the flexing of the lines under water, this technique required the use of a non-extending flexible cable or, where possible, the use of a rigid quadrant: a modular framework constructed using any available materials, such as plastic tubes (PVC) filled with sand or metal tubes with a cross-section of 30mm, distributed in quadrants of two by two, three by three or four by four metres, with vertical support legs regulated according to the lakebed morphology.

### Topographic survey and design

The topographic design and survey consists of determining the form and dimensions of the natural characteristics (rocks, pits, algae, etc.) and artificial characteristics (habitat, ruins, general finds, etc.) of the lakebed and to represent these characteristics on a map using conventional symbols, in a clear and precise manner.

The planimetric position and the depth of the various points chosen in the area to map, must be sufficiently numerous to allow a faithful reproduction of the lakebed characteristics on the final design. The distances and angles measured are cross-referenced to already known points and directions, and are generally executed using simple and quick instruments and equipment such as a tape measure, a compass and depth measure.

The correct choice of the points to map was very important for the project: for the sites containing archaeological finds or human remains under the sand (discovered in the waters of Titicaca by the Akakor divers) important vertices from a scientific point of view were chosen, whilst for the natural lakebed locations cardinal points such as large masses, notable depth variations or artificial stakes appropriately placed were chosen. The choice of the points for the depth readings was more delicate, as it was necessary to take note of all the points in which there was any notable variation in the slope or in the direction of the level curve. Fortunately Lake Titicaca has a relatively regular lakebed, with fairly consistent variations in its level, which follow the profile of the surrounding hills.

The scale of the map was chosen according to its eventual purpose (archaeological, geological, hydrological), whilst the distance between the level curves was fixed at 1/1000th of the scale denominator.

For the Atahuallpa project the scientists had requested scales such as 1:1000, 1:1500, 1:2000 as these could be traced on a normal field table whilst the morphological and archaeological details of the lakebed could be shown with sufficient precision.

The reference points were surveyed with great precision, to limit the errors in the location of the detail points which in turn would be compounded by the map scale. Therefore, on a map with a scale of 1:2000 with a graphical precision of +/- 0.25mm, realised with a normal field instrument (a sharp pencil), this meant a lakebed error of +/- 0.50m.

The data and information recorded was then transferred to graphical form on a map, clearly noting the depth next to each point. With the help of the notes taken and the sketches made, the points were joined up to obtain the planimetry. To obtain all the depth points through which the level curves pass, linear lines were drawn up between the measured points. In a few cases, the level curves were obtained using the sections method, measuring various vertical sections of the lakebed from the noted points: after having drawn up the vertical sections in scale, the positions of all the depth points were drawn up and then transferred to the map.

The map was completed by the use of symbols and inscriptions to identify particular characteristics on the lakebed, such as sandy areas, the presence of algae, stones and rocks, or archaeological finds.

In the map's margins the scale, the distance of the depth lines and geographic and magnetic north were indicated. To help the passage from the graphic measurements to the real ones, the graphic scale was also shown: from left to right along a straight line, segments were drawn up representing, in scale, 1m, 2m, 5m, 10m, 100m, etc. Starting from the same initial point on the straight line but to the left, a one metre segment divided in ten equal numbered parts was shown. Using only field instruments (a compass) it was quick and easy to obtain real lengths and distances without using calculations, which greatly helps those who have to work in difficult conditions or a hostile environment.

The designs and drawings of the structures discovered during the digs were also very relevant. One may believe that photography could replace traditional designs, but this isn't true. The archaeological design presents the unequivocal advantage of combining an objective representation with subjective selection and interpretation of reality. The Akakor divers had to try during the dives to represent in a scientific-

documentative way, tablets and structures of historical interest. The designs were then immediately copied on paper and were then studied to draw up sections and plans of possible ancient constructions.

### Instruments and tools

The following is a list of the instruments used during the topographical surveys in the underwater archaeological work areas of Lake Titicaca. They are terrestrial tools modified to make them lighter, less bulky and safer. Some of these modifications were carried out in the work camps using available materials and according to the required needs.

**Tape Measure:** a normal rewindable tape measure normally used for terrestrial topography. The tape measures available for the use of the expedition's underwater divers were of 20m, 30m or 50m depending on the area to be measured. Important characteristics to obtain the maximum efficiency were:

- stainless steel construction;
- winding handle to speed up the rewinding of the tape;
- security attachment ring.

**Lanyard Measuring Reel:** the reels used during the expedition are made up of a reel on which is wound a plaited white nylon cord of 3mm thickness and at least 100/150m long. Every five metres, the cord has a reference knot with a white band of reinforced tape on which is written in indelible ink the progressive distance in metres from zero. The precision depends on the elasticity of the material (test elasticity of approximately 20-25cm every 10m). The cord, working in water, will eventually show a physical shortening variable depending on use, but averaging approximately 5% after 2-3 years.

**Signal Strips:** these are strips formed of white and red stripes normally used to mark out work areas in terrestrial sites. In underwater work sites they are used in the same way to indicate the extremes of the area to map or survey.

**Underwater Compass:** the divers have used commercial high quality instruments.

**Depth Meter:** use of the computer has been consolidated due to the levels of reliability reached, both in terms of use and of the precision of the data.

During the topography of the archaeological sites in Lake Titicaca, Aladin computers were used which proved themselves to be efficient even at such high altitudes (3812m), at low temperatures and for numerous consecutive dives.

To obtain a correct reading, the depth meters were basically rested on the lakebed at the point where the depth reading was to be taken.

**Full Face Mask:** during long work operations in cold water, requiring high levels of concentration such as for underwater topography, the divers needed thermal operation, comfort, the possibility of communication and good visibility. The use of full face masks avoids the need for an uncomfortable mouthpiece, and permits the nasal breathing of filtered air, facial protection, and improvements in the work conditions increasing performance.

The use of the full face mask became extremely important, above all for underwater topographical techniques involving more than one element. Co-ordinating six divers distributed over a front of ten metres, involved in a carpet rake of the lakebed with a visibility of one metre, would have been particularly difficult and wouldn't have given the same results in terms of speed and efficiency without the use of communications systems.

Equally, for drawing up of grids for the vast and morphologically complex archaeological sites where visible contact between the operators is often difficult or impossible, the use of full face masks proved essential.

The detailed planning of the operations is fundamental, but obviously cannot foresee problems that may emerge during the dive. Vocal communication in real time between the operators allows, for example, to verify dubious measurements, to correct the positions of the instruments, and to signal problems without the need for visual contact.

It is also beyond discussion that this equipment greatly aids the security of the work dives. The possibility to notify problems or uneasiness during difficult dives allows one to work with greater tranquillity and attention.

The Atahualpa expedition used Ocean Reef equipment, appreciated for its light weight, robust construction, ample visual field, ease of fit, stability at low temperature, and reliability.

**Blackboard:** essential for underwater topographical work. Large blackboards with fine writing were used to record the data collected and to realise designs underwater. The sizes used were: 15x20cm for explorative sketches; 20x30cm for instrumental surveys.

## Survey Team

The personnel for the underwater topographical team of the Atahualpa project was made up of an underwater survey technician and three expert support divers.

The teams of two were chosen according to the difficulty of the work to be carried out, the necessary immersion time for the survey and the underwater visibility conditions.

The cost factor is also an element that cannot be overlooked in an expedition of this nature.

For this reason underwater topography must be carried out with great precision (relative to the work environment) and in the minimum possible time, having by necessity limited autonomy. This means providing the necessary data for the scientists in the shortest possible time to leave more time for analysis, which is notoriously long and laborious.

Perfect harmony in the survey team is necessary to guarantee the above. The underwater operators must have knowledge and command of the techniques adopted and a notable understanding with each other.

The organisation of the expedition allowed the perfection of underwater communication, above all through the use of the specialist equipment such as the masks which allow direct communication. This allowed us to increase the precision of the work whilst at the same time reducing the immersion times by 30%.

We cannot neglect the importance in the context of underwater topography in a scientific expedition of the transcription of the survey data during the day. This should be done, if possible, immediately after the dive, or at the latest in the evening after the completion of the work operations, to avoid losing the significance of the notes or the sketches, often recorded during difficult dives with little time available.

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