Nameless Peaks of the Andes

September-November 2015
Expedition Report

Written by Suzie Imber

Contents

Abstract

Suzie Imber and Maximo Kausch used the latest digital elevation model of the Andes, combined with a supercomputer at the University of Leicester, to generate the first objective list of independent 5000+ metre mountains in the Andes. They set out to climb as many of their list of unclimbed mountains as possible over a two month period. They targeted the PUNA region of the Andes, and despite battling extreme weather, reached the summit of 12 mountains, 6 of which they believe were unclimbed in the modern era of mountaineering. They found a number of substantial Incan ruins, several of which were discovered on the summit of their mountains, and will return to the same region in 2016 to continue their exploration.

1. History of Mountaineering in the Andes

The Incan Mountaineers

The first recorded large-scale mountaineering endeavours in the Andes occurred between 1400 and 1550, by the Incas, who left evidence of their climbs on the summit in the form of large stone structures, as well as ceremonial artifacts, including mummies and statues (Figure 1).

Figure 1. Incan statue, credit: WGBH Educational Foundation

Figure 2. Incan stone structure credit: Pedro Hauck

While there is clear evidence of religious ceremonies taking place on the summits of some mountains, there are many summits characterized by small stone towers known as Apechetas, built by the Incas for unknown reasons. Furthermore, the Incas built many small stone structures in valleys, for shelter and for their animals (e.g. Figure 2).

One of the goals of our expedition was to climb to the summit of mountains so remote that they have never been seen in the modern mountaineering era, looking for signs of the Incas, and trying to understand their motive for climbing. We spent many weeks searching google earth imagery to find new structures, and plotting the location of known ruins. We can say for sure that the Incas were not climbing the highest mountains, or even necessarily the most prominent. We also discovered many ruins in remote valleys, and used these to track the routes of the Incas through the remote PUNA.

Modern Mountaineering

In the modern era of mountaineering, many expeditions have been launched to climb the highest peaks of the Andes. All of the existing 6000m peaks have been climbed (the last Sierra Nevada, in 2014), and many 5000m peaks have also been climbed, although most of these have been climbed only once, or at most a handful of times.

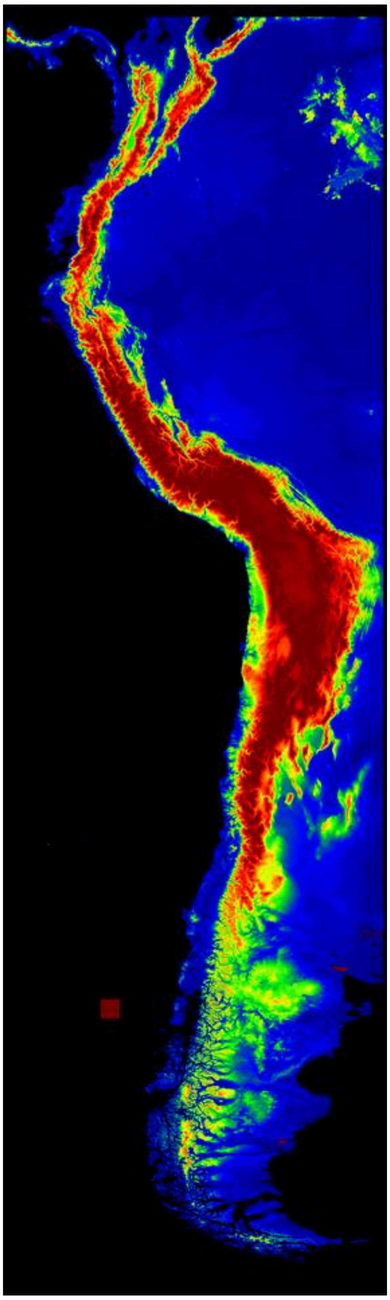
Public records of first ascents of the highest Andean mountains are available, but a large number of the 5000m mountains that have been climbed have been recorded only in trip reports, or by local mountaineers. The most extensive list of 6000m Andean peaks and first summits was drawn up by Scottish Mountaineer John Biggar. He originally identified the peaks using maps of the area, and published his list of 6000 metre mountains in a book entitled 'The Andes', and on his website. The data that is publically available on his website does not give the exact location of the mountains on his list, only a 1 degree grid cell containing the mountain, and occasionally a photograph, so this information is of limited use as a comprehensive list for mountaineers.

For the last few years, Max Kausch has been on a mission to climb all of the 6000 metre mountains in the Andes, and had been using data from google earth to identify these mountains. In 2014, Max and I began to compile our own, list of mountains in the Andes, driven by Max's need for an objective method of identification. The accuracy of the measurements used in John Biggar's list was unknown, and the public availability of satellite altitude measurements was such that we believed it may be possible to generate a more accurate list.

2. Identifying Independent Mountains

Max and I began by accessing altitude data using Google Earth, however the raw altitude data is not publicly downloadable, and online requests for data at specific latitudes and longitudes must be made. We decided that we needed a digital altitude data set on a regular geographical grid to perform a more accurate analysis.

I am a university lecturer in the Department of Physics and Astronomy at the University of Leicester in the UK, and my speciality is space plasma physics, more specifically solar wind-magnetosphere coupling at Mercury and the Earth. While this area of expertise may not seem relevant, I have extensive experience



writing computer programmes to perform complex data analysis routines on very large data sets. I contacted the Earth Observation Science Research Group at the University, who were very happy to give me access to their digital elevation model (DEM) of the Andes. This was regularly gridded, and stored on the University supercomputer. I gained access to the supercomputer (known as ALICE), and began writing computer code to automatically identify all of the independent mountains in the Andes.

Figure 3. The digital elevation model provided by the Earth Observation Science Group is plotted on a fixed latitude-longitude grid, with colour representing altitude. One in every 100 data points is plotted here, to reduce the size of the plot.

Mountain-Finding Algorithm

The first step is to identify all 'bumps' in the data with maxima over 6000 metres. This is relatively straightforward; there are over 1000 such summits. Most of these are localised sub-peaks of higher mountains, and as such are not counted as independent mountains in their own right. Figure 4 is a screen capture from google earth, with containing three peaks in the foreground. The two peaks on the left are sub-peaks connected to the higher, independent peak on the right.

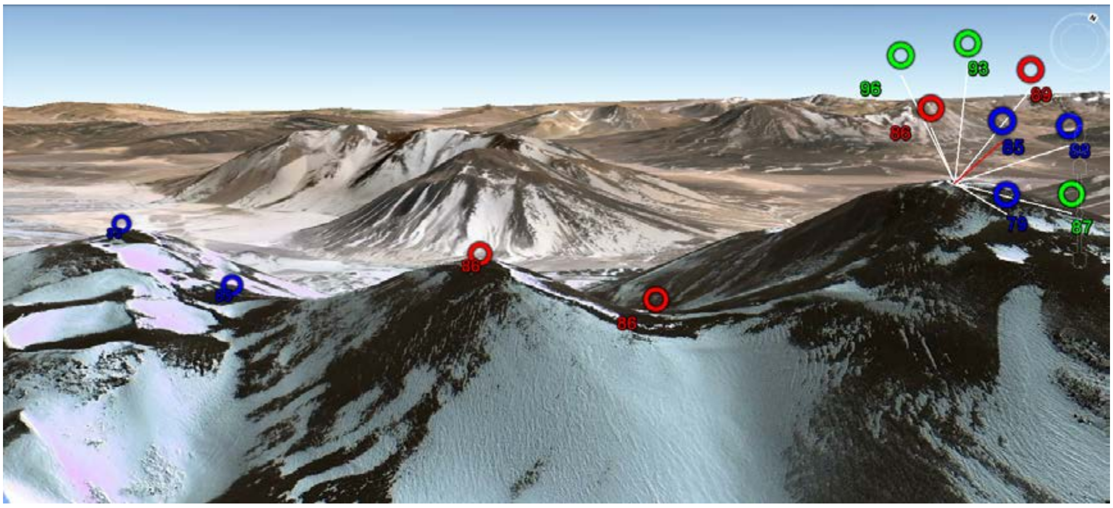


Figure 4. A screen capture from google earth showing one independent mountain (on the right), and two sub-peaks.

The goal of our research was to try to identify all of the independent mountains in the Andes over 6000 metres in altitude. When considering the independence of a mountain, a key parameter that must be calculated is the altitude of the key col. This is the altitude of the highest col connecting a given peak to any higher mountain. The higher mountain is then known as the father. It is NOT the height of the father that determines which is the key col (the father could be any mountain that is higher than the peak in question), it is the height of the col connecting the two. This idea is sketched in Figure 5, where three mountains are depicted. The central mountain is the one in question, and it has a higher mountain on either side. Even though the mountain on the right may be the highest of the three, the key col is the one connecting our central mountain with the mountain on the left, as this col is the highest in altitude.

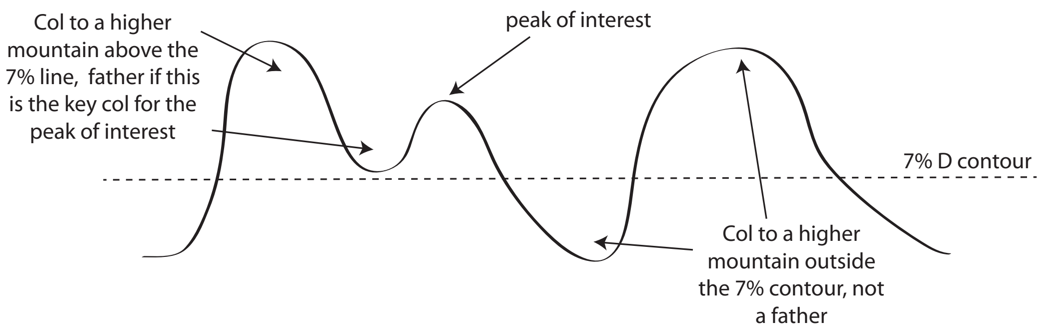


Figure 5. The key col is the highest col connecting a peak to any higher mountain. That higher mountain is then called the father mountain.

Going back to Figure 4, it can be seen that the two sub-peaks are highlighted by red and blue coloured circles. Corresponding coloured circles can be seen located along the ridge connecting those mountains to the mountain on the right (their father). The location of the second coloured circle (on the ridge) is the location of the key col for those sub-peaks.

Prominence

The list of 6000m mountains published by Mr. Biggar used a criterion known as prominence to define the independence of a mountain. The prominence is defined as the altitude of the peak, minus the altitude of the key col for that peak. A minimum prominence is generally required; Mr Biggar chose 400 metres for his list. Comparison of mountain ranges across continents is not trivial, as this prominence criterion must by definition vary, depending on the height of the mountains. The high mountains of the Himalayas would be expected to stand much higher relative to their key cols, than Snowdon in the UK (barely 1000m high), so the prominence threshold is arbitrarily selected for a given mountain range.

Dominance

We decided to use a different criterion for independence, known as dominance. This divides the prominence by the altitude of the mountain, thereby providing a relative measure of the extent to which a mountain stands above its surroundings. Setting this threshold to a constant number allows us to apply the same criterion to any mountain worldwide, and removes some of the arbitrary nature of the prominence criteria, although clearly the percentage dominance applied is still arbitrarily selected. We decided to use the 7% dominance threshold commonly used in the mountaineering community, however we calculated the dominance of all of the potential peaks on our list, such that we could adjust the threshold without having to redo the analysis.

Geometrical Considerations and Measurement Accuracy

Identifying independent mountains is more computationally complex than it sounds, due to the nature of the problem and the size of the data set. By definition, the key col for a given mountain may be located at the other end of the mountain range, therefore it is not possible to split the data into pieces for the analysis. We observed that such an extreme case is rare, however it is relatively common for mountains to be located a significant distance from their key col. Our data set contains ~1.6 billion data points, and therefore the analysis is computationally intensive, and the application of our automated algorithm requires the resources of our supercomputer.

Solving the intricacies of the problem and running our code on the Andes altitude data took several months, as each potential peak must be analysed independently. We successfully identified 110 mountains over 6000 metres, and recorded detailed information about their dominance, prominence, father mountain, and the location of their key cols. Importantly, we also obtained this information for every potential peak, allowing us to redefining the dominance threshold if required, without repeating the calculations. We were unable to ascertain the error on the altitude measurements that made up the DEM, however we compared the DEM measurements with a series of GPS measurements made by Max during a previous expedition. The discrepancy between the methods was ~±25 metres, although we recognise that both measurement techniques have independent errors associated with them. The DEM measurements mostly come from satellite measurements made using radar altimetry, and the nature of this measurement technique means that summit altitudes can only ever be under-estimated, however col heights could be overestimated, or underestimated. We folded our best estimate of the associated errors into the algorithm and compiled a further list of mountains that are sufficiently close to the 7% threshold that the error in the measurement may change their classification.

5000 metre mountain list

Having obtained our list of 6000 metre mountains, we then decided to run the same code on the 5000m mountains in the Andes. We had ~36,000 local peaks to check, and it took some time (even on the supercomputer) to generate our 5000m peak list. We concluded that there were 1129 5000+ metre mountains in the Andes, and generated a google earth file showing their locations. Max obtained a map showing the known names of mountains in Chile, Bolivia and Argentina, and we researched past expeditions to see which of these mountains had been climbed. This included looking for past trip reports, and talking to local mountaineers, such as Johnson Reynoso, based in Famatina.

We noticed that many of these mountains, particularly in the PUNA region, did not have a name, and several with names did not appear to have been climbed. We decided to launch an expedition to climb some of these nameless, unclimbed (as far as we could tell) mountains in the Andes. Only by getting to the top could we ascertain whether there were any signs of previous expeditions to be found there.

3. Maps

Below is a map of the PUNA region, which encompasses northern Argentina, the adjacent Chilean Andes, and extends into southern and western Bolivia.

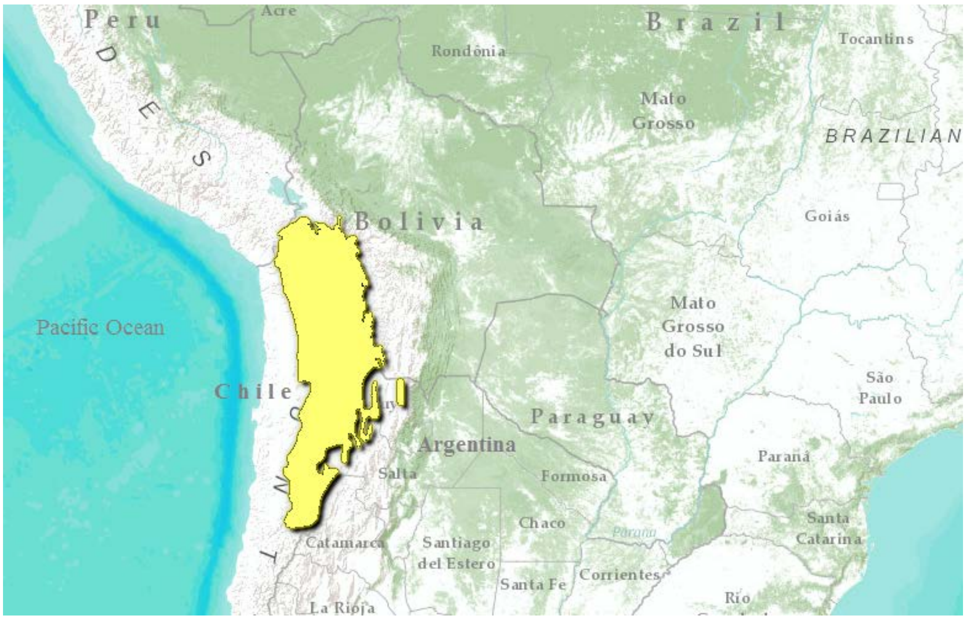


Figure 6. A map showing the location of the PUNA region
Source: http://www.eoearth.org/view/article/151003/

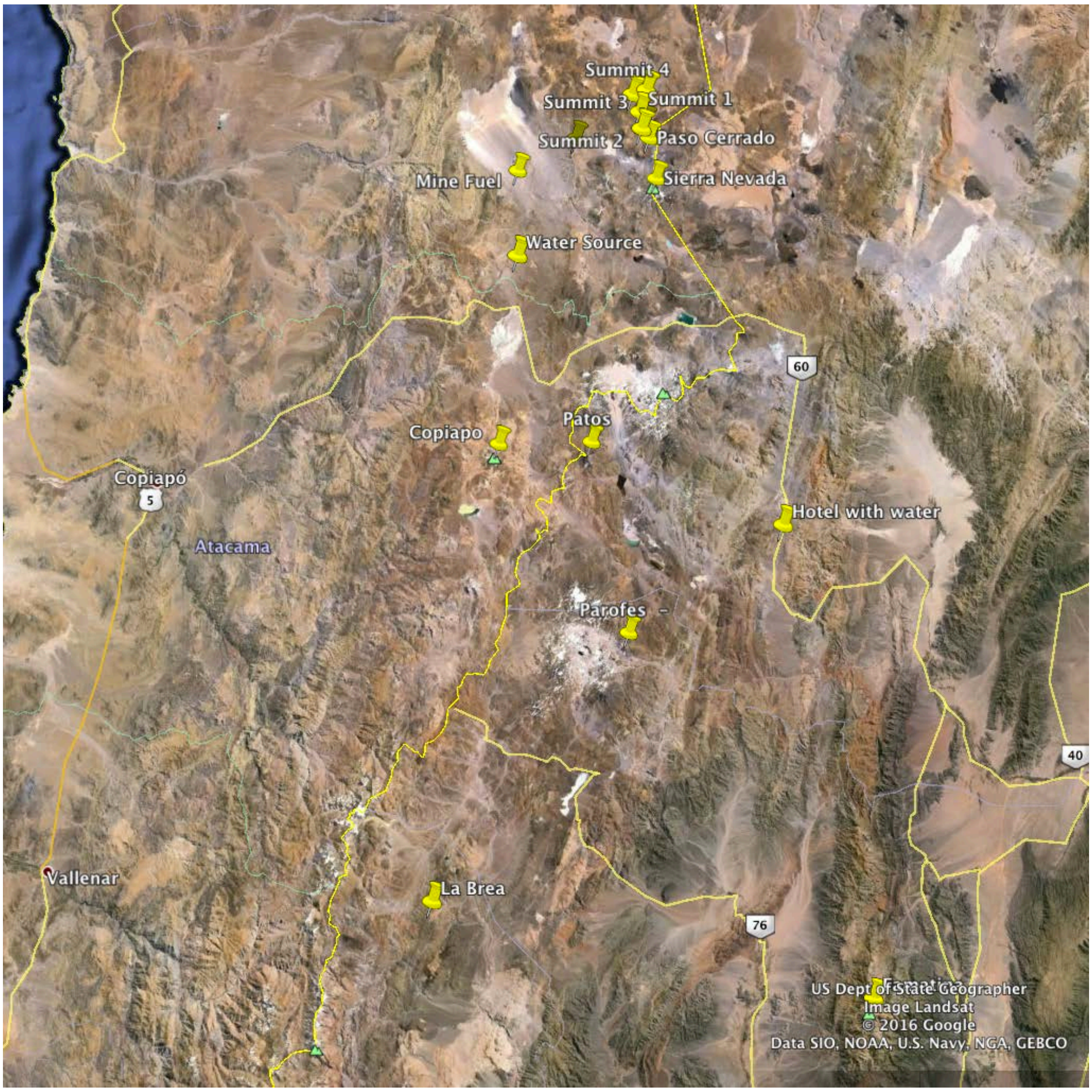


Figure 7. The locations of the mountains we climbed on the expedition, along with water sources.

Figure 8. A closer look at the mountains around the Lagunas Bravas region, with the location of both of our camps marked.

4. Team Members

Dr. Suzanne Imber is a 32 year old university lecturer and research scientist in the area of Space Plasma Physics at the University of Leicester, UK. She is an experienced high altitude mountaineer, having climbed in Alaska (Denali, 2008), the Andes (Aconcagua 2007, Huayna Potosi 2005) and the Himalayas (Ama Dablam 2010), as well as rock climbing and winter mountaineering in the UK. She is also an elite lightweight rower and former international lacrosse player.

Maximo Kausch is a 34 year old mountaineering guide, born in Argentina but raised in the UK and Brazil. He is South America's most experienced mountaineer, and currently holds the world record for climbing 6000+ metre peaks in the Andes (68 out of a total of 110). He has extensive experience in the Alps (Eiger via Lauper and Mittelegui, Matterhotn via Lion, Monte Rose, Grand Jorasses, Mont Blanc via 6 different routes, etc), and has worked in the Himalaya for 6 years as a mountain guide (Cho Oyu 5 times, Lhotse, Shishapangma, Gasherbrum II, Hidden Peak, Ama Dablam 3 times, Pumori, etc) and also in the Tien Shan and Pamir (Korjenevskoya and Communism Peak). Maximo has lived in the UK for 11 years although spends the majority of the year either guiding commercial expeditions, or working towards his goal of climbing all 6000m mountains in the Andes.

Driver and additional climbing member:
Pedro Hauck, 34, was born in Campinas in the countryside of Sao Paulo State, Brazil. He began to climb when he was 16 years old, first ascending the green mountains of Serra de Mantiqueira, and later rock climbing. His first experience of climbing at altitude was Cerro Plata (5950 metres) in the Argentinian Andes, at the age of 18. He has now climbed over 90 mountains in the Andes, 39 of which are over 6000 metres in altitude. He works as a mountain guide, and is the editor of the most popular mountaineering website in Brazil.

5. Timeline of Expedition

Expedition Timeframe: 1st September-7th November 2015.

1st September-4th September: prep for expedition in Curitiba

4th September-7th September: drive to Fiambala, Argentina

7th September-11th September: acclimatisation. Our intention was to cross the border into Chile at the San Francisco Pass, but the border was closed and we had to retreat to Fiambala.

12th September: acclimatisation climb, Famatina, 6100 metres, Argentina (Pedro & Suzie), Figure 9a and b and map.

Figure 9a. Pedro at the summit of Famatina.

Figure 9b. Suzie at the summit of Famatina.

13th-25th September: rest in Chilecito. Our plans were delayed by a combination of the huge earthquake off the coast of Chile (Copiapo), bad weather, and the replacement of the head gasket in Conway after the engine froze.

26th September-30th September: acclimatisation, then Suzie, Max and Pedro summited a potential unclimbed mountain, 5225 metres on 30th September. We now believe that this was a second ascent of La Brea, Figure 10.

Figure 10. Pedro, Max and Suzie at the summit of La Brea.

1st October-2nd October. Return to Chilecito for food and fuel. Cross the border to Chile over the San Francisco Pass and travel to the Laguna Verde (Figure 11). We stayed in a hut here, next to some hot springs.

Figure 11. Laguna Verde

3rd-6th October We drove into the remote PUNA and set up camp near a beautiful lake (Figure 12). This is marked as Camp One Lagunas Bravas on Figure 8.

Figure 12. Our camp next to some Incan ruins on the shore of a lake in the remote Lagunas Bravas region. We (Suzie, Max, Pedro) climbed four 5000ers from here.

We proceeded to climb 4 mountains in three days, 5050 metres, 5304 metres, 5268 metres and 5223 metres (Max, Pedro, Suzie), the first of which we believe may have been climbed, but the rest we believe are unclimbed (Figures 13-15). The peaks are marked as Summits 1-4 on Figure 8. We set up an intermediate camp at a location marked as Camp Two Lagunas Bravas on Figure 8.

Figure 13. Suzie at the summit of the first 5000 metre mountain.

Figure 14. Suzie and Max at the summit of the second 5000 metre mountain.

Figure 15. Suzie standing by the Incan Apocheka at the summit of the 3rd peak.

On 7th October we realised we were low on fuel, so we drove to Copiapo, Chile, to resupply.
9th-15th October: attempted to return to the Lagunas Bravas region but were caught in a storm and waited it out at the hut at Laguna Santa Rosa (Figure 16).

Figure 16. A stroll at the Laguna Santa Rosa.

We met up with two friends who had their own car (Caio Vilela and Jovani Blume) and intended to head for the Lagunas Bravas region but were forced to return to Copiapo for food and water and to escape the bad weather (Figure 17).

Figure 17. We tried to leave Santa Rosa and head back up into the mountains but the weather was terrible, and the cars had mechanical issues.

16th-17th October: We drove to Lagunas Bravas region, climbed Sierra Aliste (possible first ascent), 5200 metres (Suzie, Max, Pedro, Caio, Jovani). Our camp was destroyed by high winds & the Troller was frozen, so we were forced to return to Copiapo for repairs, with Conway towing the Troller (Fig 20) .

Figure 18. Ascent of Aliste (Max and Suzie, photo credit: Caio Vilela)

Figure 19. Summit of Aliste (Suzie, Max and Pedro, photo credit: Caio Vilela)

Figure 20. Conway tows the Troller back to Copiapo.

18th-20th October: We were forced to stay in Copiapo for repairs and to wait for the extremely high winds to subside.

21^{st}-23^{rd} October: Approach and climb Mt Copiapo, 6100 metres. The approach road was destroyed in the flash floods of 2014 and we had to rebuild it to approach the mountain (Figure 21). Intermediate camp was established at 5100 metres. Successful ascents by Suzie, Max and Pedro (Figure 22).

Figure 21. Suzie and Max (and Pedro!) rebuild the road up to Mt Copiapo.

Figure 22. Max on the summit of Copiapo, just before my camera froze.

24th October: Suzie flew home

25th October-7th November Max, Pedro and Jovani continued and climbed Patos (6240 m), Sierra Nevada (6140m), un-named mountain, first ascent (they named it Paso Cerrado) and another un-named mountain they named Parofes, 5845 metres, the highest unclimbed in mountain the Andes (Figure 23). These mountains are marked on Figure 7.

Figure 23. Pedro on the summit of Mount Parofes.

6. Expedition finances

Finance Awarded:

Mount Everest Foundation	£2,900
British Mountaineering Council	£500

Expedition Expenditure:

Flights	£1000
BMC Insurance	£800
Fuel for Conway	£1,000
Expedition Food	£500
Accommodation	£400
Vehicle Repairs	£1,000

7. Expedition logistics: vehicles, food, water, roads, mines, weather

Vehicles

Our main vehicle was Conway, Pedro's 15 year old Landrover Discovery 2 (Figure 24). Conway was in great condition before the trip, however by the end he had sustained significant damage and undergone multiple repairs.

- Most significant was the brutal cold of the PUNA, which froze our antifreeze and cracked the water reservoirs in the engine. Subsequent miles without coolant damaged the head gasket which had to be repaired, at significant expense, and this repair took ten days. Availability of Landrover parts was the main problem, as the head gasket had to be brought by bus from southern Argentina. I am also unconvinced by the quality of our initial batch of antifreeze (purchased in Brazil).
- Both bumpers were severely damaged by driving over rough terrain and through rivers, and after the trip were replaced by sturdier metal bumpers.
- The wind was so strong that it ripped the doors out of our hands, and damaged the hinges. We rigged up some ropes to prevent the doors from flying open to prevent further damage.
- After the snowfall there was a lot of mud, slush and snow to drive through, and this splashed under the engine and caused one of the oil radiators to overheat. We were unable to fix this problem on the fly, and had to return (very slowly) to Copiapo to undergo further repairs.
- We experienced significant damage to the tyres from the rough terrain resulting in several punctures.
- The wind was so fierce that it picked up rocks and threw them into the car. This smashed one of Conway's windows.

Half way through the expedition we were jointed by a mechanic friend with his Brazilian Troller 4x4. This vehicle was also rendered unusable by the extreme conditions in the PUNA, specifically:

- The engine froze entirely, and we were able to pick up pieces of solid antifreeze (Figure 25). This resulted in several pieces of the engine cracking and requiring repair.
- The Troller suffered from significant overheating due to cracks in the water reservoirs caused by freezing damage. It leaked antifreeze throughout the expedition, and had to be topped up. I believe we may have unintentionally exacerbated the problem by topping up with pure antifreeze – more on this later.

Figure 24. Pedro and Conway.

Figure 25. Frozen anti-freeze pulled out of the engine of the Troller!

Food and cooking

We were able to stock up on high quality food in Fimbala, Copiapo and Chilecito. The cost of food in the supermarkets in Argentina was not high, but in Chile prices were akin to those in UK supermarkets. We stocked up on gas canisters in Brazil, but were able to buy more in the supermarket in Copiapo without difficulty. We also bought reasonable quality anti-freeze there.

Water

We carried many gallons of fresh water in large containers as the amount of snow in the PUNA region is variable in the Spring season. We were also well aware that many water sources contained significant quantities of minerals, making them toxic. We were aware of two locations where safe drinking water could be obtained.

1. The hotel located on Route 60 from Fiambala to the Chilean-Argentinian border at the San Francisco Pass (marked on Figure 7). An outdoor tap was available for us, even out of season.
2. A river crossing at 26°43.874' S and 69°3.960' W provided us with fresh (although silted) water on multiple occasions. The location of this water source is marked on Figure 7, and a photo is provided in Figure 26.

Figure 26. Suzie and Max collect water, photo credit Caio Vilela.

We made the decision to leave some water in one of the high altitude huts on Route 60 on the Argentinian side of the border, to save transporting it backwards and forwards, and because we knew we would need more water when we returned to cross the border. Upon our return however, we discovered that these containers of water had been stolen.

Crossing Borders

The drive from Curitiba, Brazil to Fiambala, Argentina was relatively straightforward. We elected to cross the border from Brazil into Argentina at the small town of Barracao, and this crossing was uneventful. We would recommend crossing the border there.

Our subsequent border crossings were all between Argentina and Chile. We attempted to cross the San Francisco Pass (along Route 60) multiple times during our expedition, never without incident. Our expedition fell early in the season, such that we were among the first vehicles to attempt to cross the border since the previous southern hemisphere autumn. We were held up when officials closed the border due to high winds (on two occasions), and suspected snow (we later found out there was no snow), causing significant delays to our expedition. There are a series of huts on the Argentinian side of the border on Route 60, where expedition members may find shelter if required to wait for the border to open. Expeditions should be aware that the Argentinian border post and the Chilean one are located many miles apart, and there is a requirement for all parties crossing one border to check in at the other border post within 24 hours, even if they subsequently return to the large swathe of land between the border posts to continue their expedition.

Offroad Driving

During our expedition we experienced unusually heavy snowfall on one occasion in October, which forced us to retreat to Copiapo from the remote PUNA. We did not have sufficiently rugged tyres to cope with deep snow, and the roads quickly became impassable due to large drifts. I speculate that snow chains would have helped in this situation, however the winds were far too high to allow us to climb, and looking at the larger picture, retreat was the only viable option. A photograph demonstrating the driving conditions is presented in Figure 17.

Fuel

Max and Pedro have extensive experience crossing the Chilean-Argentinian border at the San Francisco Pass. They have tried to cross with spare canisters of fuel for their vehicles in the past, and have had them confiscated. They have also been able to buy some fuel (to replace that confiscated) at the border in the past, however we suspect this cannot be relied upon. Vehicles are inspected at the Argentinian and the Chilean border posts for stores of fuel, fresh food and other contraband.

As mentioned briefly in the timeline, we found ourselves low on fuel at one point during our expedition, deep in the remote PUNA, very possibly without sufficient fuel to return to civilization. We managed to drive to a large mining complex and asked them if we could buy some fuel for our vehicle (even a litre or two would have helped), however they refused to sell us fuel, at any price. The location of this mine is marked on Figure 7.

Land mines

We obtained a map of known areas of land mines along the Argentinian-Chilean border. This was not an extensive catalogue, but provided some indication of regions to be avoided. We also searched on google earth imagery for any indication of exploded mines in the areas we were approaching. The land mines are generally located on or close to the border, and care must be taken when approaching this region.

Key Lessons Learned

I have leared so much from the expedition that I will do differently in the future. I suspect the quality of the anti-freeze available in Brazil (a country where temperatures rarely go below freezing) may be too low for the conditions we experienced at high altitude in the extreme PUNA. I also learned that getting the exact ratio of water to anti-freeze is imperative, as too much antifreeze will actually *increase* the freezing point of the mixture. Topping up with anti-freeze regularly when water levels are low probably results in a mixture containing too much anti-freeze, which is then more likely to freeze during extreme conditions. I suspect this is what happened to the Troller during the second part of the expedition.

There were several occasions when we found ourselves attempting to traverse deep snow, ice, or deep sand (sometimes a mixture of all of these). I believe that snow chains or sturdy traction mats may have helped us to more easily gain access to the most remote regions of the PUNA.

Having now fitted a large roof rack to Conway, in future we will be able to carry more water, and more containers of fuel, subject to the border controls discussed earlier. This will enable us to go deeper into the PUNA without worrying about running out of fuel.

There is no getting around the necessity to cross borders during an expedition such as this, but certainly minimizing the number of crossings would be an advantage, as each crossing holds the potential for significant loss of time.

The weather in the PUNA is brutal, with high winds nearly all of the time. Our expedition ran from September through to November, and this time frame has been relatively mild, with low winds, in previous years. 2015 was an exception to this however, with extreme weather, which caused significant delays and damage to equipment and vehicles. We will be returning to this region in 2016, but have decided that our expedition will run from October through to the start of December, in an attempt to maximize the likelihood of favourable weather.

More Information

Suzie had a website dedicated to the expedition, and kept a blog of the adventures, which can be found here:
http://andesexpedition.co.uk/ab/index.php/suzies-andes-blog/

A map, to track the progress of the team was automatically updated, and is located here: http://andesexpedition.co.uk
This map was viewed thousands of times during the expedition!

Pedro kept an extremely detailed blog of the expedition, in Portuguese:
http://www.pedrohauck.net

Since our return, many articles have been written about our expedition, on mountaineering websites and mainstream news outlets such as BBC Brazil, National Geographic Brazil, The President and Go Outside. I have given public talks at the University and local mountaineering clubs and have been invited to speak at a Midlands BMC event, and at The Explorers Club in New York.

Looking Forwards

Max, Pedro and I fulfilled our dream of climbing some of the most remote mountains in the Andes, having discovered them with the mapping technique we developed. We discovered Incan ruins on the way, and brought back a wealth of GPS altitude data to compare with the digital elevation model we used. We did not manage to get to all of the mountains on our list, and indeed have since identified several more mountains that we believe may be unclimbed in the region. We are currently planning a return to this region in October-December 2016 to continue our quest to visit the most remote mountains on the planet. Furthermore, I am now running the mapping code on the Himalayan altitude data that is available and comparing the results with previously compiled lists, to see whether there are any mountains to be discovered in that region.

We sincerely thank the Mount Everest Foundation, the Rothschilds and the British Mountaineering Council, without which this expedition would not have been possible. You have helped us to take the first step of what we believe will be a journey that lasts the rest of our lives.