Heights of Intrigue

A short story on mountain heights

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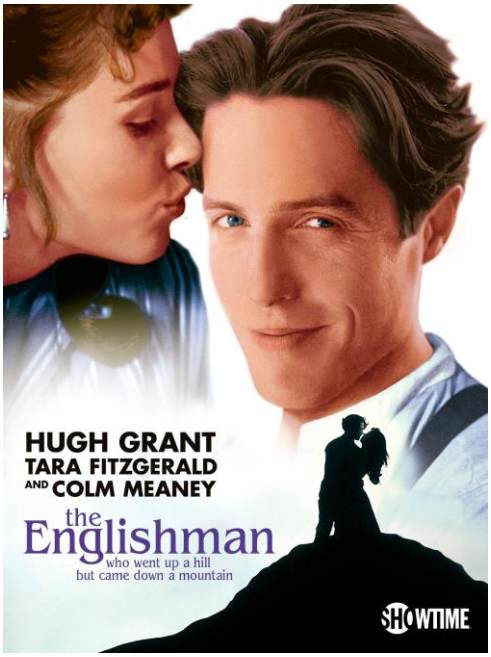


What is the difference between a 'hill' and a 'mountain'? The small South Wales village of Ffynnon Garw's only claim to fame is their mountain, promoted as the "first mountain inside of Wales" - but is it a mountain, or merely a hill?

In 1917, while the war in Europe rages, two English cartographers arrive to measure it. The villagers are very proud of their "mountain" and are furious to find that it is in fact a "hill" as it doesn't reach the required height of 1000 feet to be officially mapped as a mountain.

Not to be outwitted by an English rule, and their surveyors enforcing it, the villagers set out to make their hill into a mountain - but to do so, they must keep the English from leaving before the job is done.

Did anyone ever see that delightful Hugh Grant film "The Englishman that went up a hill and came down a mountain"?

To understand why the welsh locals went up the "hill" to painstakingly add 20 feet of earth to make it into their beloved "Mountain" is a thought provoking action and one which went a long way to explain the passionate feelings behind a mountain's height.

For the Welsh folk of the village, it was typical that it was an English surveyor who announced it as only a hill, narrowly failing its prerequisite height to be classified a mountain.

British military surveyors have been busy for centuries exploring and determining mountain heights across the globe - how then, does controversy still abound on the heights of mountains?

The heights of mountains around the world have been a source of fascination and intrigue since records began provoking intense and passionate debate amongst governments, climbers, surveyors and countryfolk worldwide. Strange then, that in the modern era of high-tech computers and space probes, we still lack definitive heights in particular regions of the globe.

Meeting the Chilean General of the IGM, author with back to camera.

For the climber returning from a peak, one is often asked *"how high is it?"* before being questioned about the difficulty, duration or equipment needed to succeed on the climb. In many parts of the world, and in particular, the Andes and the Himalayas, the question "how high is it?" is not easily answered. Maps are often sketchy or inaccurate and the methods of calculating a mountain's height may differ from region to region. Some methods such as accurate triangulation and modern-day geodetic GPS surveys are, for instance, slightly more reliable than calculations from satellite imagery or air photography, but not without their limitations.

In this article I will attempt an overview of the problem based on research for expeditions involving both climbing and technical surveying and exploration. Without delving into deep technicalities of survey techniques, I hope to show a perplexing situation that exists worldwide with particular emphasis given

to South America which is a topographer's nightmare! We will hopefully see that heights are argued over vehemently, not easily determined and quite often subject to nationalistic bias.

The Apogee Expeditions

So where did I begin to culture a passion for mountain heights? It all began in 1992 when the first 'Apogee' expedition unfolded in Ecuador. As a military surveyor in the British Army, it was apparent that our surveying skills could add an extra dimension to the adventurous training aims the Army so encouraged. Military Survey is steeped in adventurous and exploratory history, reflected by the many deeds of 'derring do' that early British military surveyors accomplished across the globe. Our intent was to rekindle that adventurous history and exploration as modern-day Royal Engineer surveyors, but at the same time contribute to the geographic discovery of the world remote mountain ranges by undertaking geodetic mountain surveys.

Establishing survey control in the Atacama Desert

Ecuador became a labour of love for me – the first major military survey mountaineering expedition to work alongside our host nation counterparts. The source of intrigue lay in the height of Chimborazo, once believed to be the highest peak in the world. The 'Apogeans' completed an accurate GPS height survey of the peak, working in close collaboration with the Ecuadorian IGM, and also heighted 4 other Andean volcanoes during the course of a 6-week expedition. The Instituto Geográfico Militar were particularly impressed with our post processed results and have since established our reading of 6,257m as the official height, as opposed to the 6310m still published on many other maps.

The peculiarities associated with South American heights thereby became apparent during the research of survey data for the Ecuadorian trip, and became even more confusing when I carried out research on some of the Chilean giants. The Apogee expeditions have since gone on to undertake mountain surveys and complete satellite image maps in the Indian Himalayas, in Africa, in the Atacama Desert, and in Patagonia, as well as an unexplored range on the Kazakh/Chinese border. Each had its own fascinating dramas and Chile in particular, added to the height conundrum of South American peaks when we were convinced that we might just prove that Ojos del Salado was the highest mountain in South America - read on to understand more of the intrigue.

"Depending upon which map you look at, there are mountains with different heights and national bias across the south American continent"

The Himalayas

It is perhaps best to begin with the Himalayas where early exploration, surveying and daring exploits eventually led to a systematic survey of the Indian subcontinent, supervised by British surveyors. William Lambton, the founder of the Great Trigonometrical Survey of India, began this massive project in 1800 before Sir George Everest continued as Surveyor General of

India in 1830. Everest continued Lambtons work probing north towards the Himalayas where he established the Survey of India HQ at Dehra Dun. During this period up to 1843 when he retired, Everest masterminded the gridiron system of triangulation which provided the framework for detailed surveys. Perhaps his most incredible feat was the foundation of the mathematical spheroid which best fitted the figure of the earth, or geoid in India. All positions and officially accepted heights in India are to this day, still referenced to this spheroid - the Everest spheroid.

It wasn't until after Everest's retirement that most of the great peaks were observed by theodolite from distant stations with calculations adjusted and recorded at Dehra Dun. National mapping was produced at various scales and the accuracy of these early surveys bear great testament to those pioneers who endured all manner of risk and danger to life in their quest to explore the "blanks on the maps". In essence, the majority of Himalayan peaks lie in some sort of pecking order but have not been without controversy regarding definitive heights. The heights of the great peaks are not yet exact. They are as precise as scientific observations can make them given that technical unknowns in corrections still prevail.

Some years ago, it was announced that K2 was measured as being higher than Everest. To settle the argument, Italian scientist Ardito Desio measured both peaks in 1987 using GPS and electronic theodolite technology. The height of K2, after corrections for refraction and other errors came out at **8616m** +/- 7m, compared to Colonel Montgomery's original height of **8611**m during the Survey of India in 1858. The traditional height of Everest (first observed in 1850 but subject to further height corrections thereafter) is **8848**m, a figure retained on current mapping of the area despite modern data quoting it as even higher. Desio calculated it at **8872** +/- 20m. The reason why the Survey of India Office will not change it's height to the modern figure (24m higher) is because of a lack of definitive data to finally confirm separation values of the Geoid and spheroid in the Himalayas, an ongoing technical anomaly. As with Everest, so with the other great mountains. Kangchenjunga at **8598**m is not far off the height of K2 and it has been intimated that it could displace K2 if more was known of the geoidal separation in these parts. It is a great tribute to those early surveyors that their figures do not differ substantially from those of modern-day techniques. I for one advocate the retention of traditional heights until more is known of the separations.

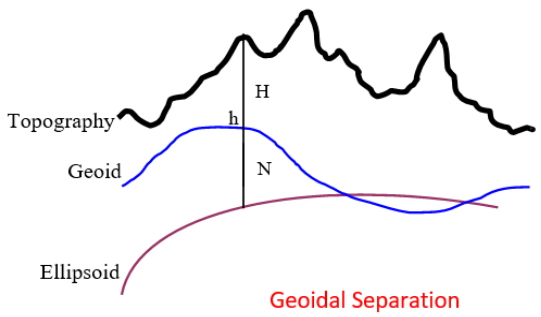
Military Surveyor carrying out traditional theodolite observations in Nepal 1983.

Determination of heights

This is a good place to look briefly at how heights are determined. The greatest problem of heightening a peak lies not solely with the techniques used, but primarily with the shape of the earth. The earth is oblate in shape (flattened at the poles) and not a true mathematical surface, which presents great problems to geodesists and topographers alike. The **geoid** or earth's figure is not a true spheroid, mean sea level erratic and not a true spheroidal surface, and we do not know where it is under a particular mountain. Specific mathematical spheroids are devised for numerous regions of the world and calculations maintained from their central datums. Transformations are

"Because peaks have not been triangulated… a curious chaos now exists in South American heights"

made to relate observations to mean sea level and there are numerous associated problems in providing definitive heights.



H = Height AMSL
h = Spheroidal height.
N = Geoidal separation

The ellipsoid is the mathematical sphere, which differs around the globe, and is used to calculate mathematical coordinates in X,Y and Z.

The **geoidal separation** must be calculated and accurately known to reference heights to mean sea level. This separation is the distance between the earth's figure (geoid) and the mathematical spheroid which is not easily determined. Tidal shifts around the world add to the problem where maximum accuracy is required. Much work is ongoing to improve geoidal knowledge to reduce the separation errors to a minimum and the advent of GPS networks and gravity measurements will go a long way to solve them.

Nowadays a world geodetic reference system is in place (WGS 84) enabling us to relate all worldwide heights to one datum point and therefore make comparisons of peaks across the globe. Practically though, many mountains around the world have not been privy to the aimed theodolite and have not been accurately triangulated.

Curvature of the earth, light refraction and deflection of the vertical are for instance some of the problems associated with traditional theodolite observations reduced in error by complex tables and calculations. Photogrammetry and remote sensing surveying can accomplish heights for peaks where mountains have not been subjected to triangulation. Many peaks around the world have been heighted in this way but the method requires accurate ground control and slight imperfections in determining the horizontal position of a peak can result in major changes of the vertical. This is also true of traditional methods because the separation values of the Geoid will change with ground position. Each method will have it's own integral problems in minimising errors but the advent of GPS has made significant breakthrough to solve and assist in many of these problems. GPS has added a new dimension to geodetic surveying allowing for incredible accuracy in horizontal position. By virtue of it's increasing accuracy and speed, the results of satellite geodesy are used more and more in related disciplines such as geophysics and oceanography. GPS heighting, is however, still subject to the errors of geoidal separation values necessary to calculate elevations to mean sea level.

South America

Unlike the Himalayas, the South American Andes was not subject to a systematic continental survey, although early pioneers did much to improve the geographic knowledge of the range. In the early part of this century, frontier surveys and boundary commissions (some of which were by British military surveyors) established heights for many peaks, but because most were not triangulated, a curious chaos now reigns in terms of definitive heights.

National mapping agencies, most of which are military, are responsible for publishing heights heights on their maps and therefore are open to national bias. Just scanning different atlas's and maps of varying scales will subject the researcher to an inordinate number of different values for just one mountain - the cause of much frustration! Most reliable heights in South America only become exposed following detailed research from the methods employed and not just from official mapping. Most reliable heights are still gained from the early frontier surveys and known triangulation of peaks.

El Nino devastates Chile in 1997 causing delays for me to get to the Andes. We were the first winter expedition to climb in the Ojos region that year.

Aconcagua for instance was always declared by the Argentinians as being **7,035m** until such time as Adams Carter got **6,960m** earlier this century - even then the Argentinians maintained it above 7,000m for some time. In consequence to this, the Chileans (not a great lover of their neighbours) announced that they also had a seven thousander, **Ojos del Salado** being **7,084m** and again Adams Carter disproved this in 1957 by getting **6885m** - still the most reliable figure for the mountain, and based on theodolite observations.

Military Surveyors carrying out geodetic GPS surveys in the Atacama Desert in 1997

Both these peaks have been triangulated and are therefore reasonably accurate unlike many other peaks in the South Americas. Despite these fairly accurate readings, Ojos del Salado has now tumbled to number three in the western hemisphere following the arrival of revised Argentinian mapping (1991) declaring Pissis (obviously in Argentina) as being higher. Ojos has actually fallen to **6864m** and **Pissis** grown 3m to **6882m**. Such is the height debacle in S. America.

Chile of course maintains the height of **6893m** (Ojos) published on most official maps including the restricted 1:50,000 series of the border region the peak lies on. All the heights above are based on the local S. American spheroid where again separation values are not fully known.

The basis for the recent Argentine figures comes from US satellite imagery and an Argentine photogrammetric survey which despite the method employed, is still subject to bias. This mapping along with John Reinhard's article on the heights of South American peaks, compelled Canadian Greg Horne to carry out a GPS survey of **Pissis**. In 1995 Greg undertook the survey, by differential techniques, and got **6872m** tied into Chilean control stations. He hoped to get assistance from the Chile IGM but was denied by it's Director, Colonel Pablo Gran, who simply stated that **Ojos** was the second highest at **6893m and growing 2cm per year due to plate tectonics**. Discussion closed.

Atacama Desert Disputes

The Puna region of the Atacama Desert (covering both Chile and Argentina) houses **35 peaks of the 99 in South America that are over 6,000m high**, 6 of which are in the top 10. It is an area that has witnessed little exploration or surveying and has subsequently led to vigorous debate over the heights of its mountains.

This is compounded by the fact that the contested border of Chile and Argentinia runs through the middle of the Atacama Desert with each country declaring their peaks higher than the other. Such confusion led to my research on South American heights and to lead an expedition to Ojos del Salado to height the mountain using GPS technology. In August and September 1997, a team of 12 military surveyors set off with 2 Chilean IGM surveyors on a mammoth journey to the remotest part of the Andes, hoping to settle the Ojos argument for good. As fate would have it, the 2 years of research and planning were scuppered by the effects of 'El Nino' which rendered the North of Chile 'impassable'. Amongst the

devastation and floods that El Nino had inflicted on the country, the team were denied access to Ojos by the sheer quantity of snow acting as an obstacle to get anywhere near the peak. Having stopped some 80km short of Ojos, the team set about heighting 3 other volcanoes to establish the accuracy of the Chilean survey network, and were impressed by the results. Copiapo, an active volcano, was heighted using differential GPS, and was within 3 metres of the published IGM heights of 6,080 – this has thereby given credence to the published Chilean heights of Ojos del Salado and again gives rise to an authoritative survey that it is firmly established as number 2 in South America - with a remote chance of escalation to number 1 if any bias has been included in Aconcagua's height. Maybe one day, I'll return to find out!

The arrest of Augusto Pinochet in 1998 (by the Police in London) caused my 1998 return to be shelved until the political unrest subsided - interestingly, British military surveyors were involved in early boundary demarkations of these two great nations in 1904 and were again called upon to act as arbitrators between the two nations boundary disputes in 1970. Such a great history, and to walk in my military forefathers footsteps is a privilege indeed.

Unlike Ojos, **Pissis** had retained a remarkable consistency in height since Riso Patron surveyed it at **6779m** in 1902. Many other heights of Puna mountains decend from Patron's surveys and also those of Austrian geographer Walther Penck who was employed by the Argentinians to carry out a geographical survey during 1912-1914. In 1936/7 a Polish expedition traversed and climbed many peaks in the Atacama Desert adding great knowledge to the region with the discoveries of Inca remnants on many high peaks and active fumaroles on Ojos, making it the highest active volcano in the world.

Military surveyors conducting the post processing of survey data, in the Chinese border with Kazakhstan in 2000

Other peaks such as Nevado **Tres cruces** (**6758m** by photogrametric means, Riso Patron **6769m,** Polish survey **6630m**) have seen considerable debate as has **Mercadario (6770m)**, **Bonete (6759m)**, and **Tupungato (6570m)**. Huascaran in Peru is stable at 6768m and Illimani in Bolivia is accepted at 6462m despite previous Bolivian fantasies of 7,000m+ and some modern atlases showing 6882m. Further north Chimborazo in Ecuador has always been the centre of controversy, as has Cotopaxi, wrongly regarded as the highest active volcano in the world.

Chimborazo at 6310m was always considered the highest in the world - a belief that existed until the 1820's. Led by Charles-Marie Condamine in 1736, a French scientific expedition undertook a survey of the meridian at the equator to prove the world was oblate. The expedition declared Chimborazo as the highest in the world (which in fact it is if measured from the centre of the earth) and also started a series of disputes not resolved to this day. For example, **Cotopaxi** was measured at 5871m by Condamine, whereas Whymper got 5978m in 1880 and Martinez 5940m in 1906. Worst of all, 6005m was published by Arthur Eichler in 1970. **5897m** is the recognised height of Cotopaxi published by the Ecuadorians in 1979 and confirmed by my British military survey team in 1993.

Stuart Fairnington surveying on the summit of Chimborazo 6,268 in Ecuador

The perplexing situation with all peaks in Ecuador led to me mounting my first major mountaineering and surveying expedition, which, alongside Ecuadorian military surveyors, we heighted Chimborazo, Cotopaxi and Tungurahua by differential GPS. Stuart Fairnington post processed the results, getting **5896m for Cotopaxi** and **5028.7m for Tungurahua**, an increase of **13m** +/- 2m. **Chimborazo came out at 6268.2** +/ 2m, with **a reduction in height of 42m**. This reduction after corrections, was due to the fact that Chimborazo had previously been measured by photogrametric means, and because of the large expanse of the summit, was liable to misinterpretation of the exact heighest point. As discussed earlier, any change in summit position can radically change the separation value and subsequent height referenced to mean sea level.

The Ecuadorian IGM suitably impressed by our techniques, agreed to accept the figures, though I have yet to see proof that they are published. (Hopefully Betsy Wagenhauser's climbing guide to Ecuador will reflect these values.)

On reflection, I hope I have been able to cast some light on the intriguing nature of heights of mountains around the world and possibly even add fuel to an already vociferous debate on South American peaks. Further developments are likely to unfold this year when Major Rob Blackstock aims to take a team of surveyors to Bolivia to height numerous well known Andean giants which may help assist the development of a new South American pecking order – thereby keeping up British military survey influence on mountain heights. I certainly intend to finally return to Ojos in the coming years to settle that intriguing debate - who knows, Ojos could possibly come out higher than Aconacgua - **Now that would start an interesting argument amongst those continental peak baggers!**

Top 13 South American Heights

The heights given below are a **personal appreciation** based on research of the methods, reliability of observations, and impartiality. Independent (reliable) surveys are quoted for Ojos and Pissis to eradicate bias. At no time are aneroid measurements used which are totally unreliable. These are the 13 peaks above 6500m.

1. Aconcagua	Argentina	6959m	Adams Carter Survey, AIGM Mapping
2. Ojos Del Salado	Chile	6885m	Adams Carter Survey, AIGM
		6880m	Frontier surveys 1900
		6900m	University of Padua 1989 (unconfirmed)
3. Pissis	Argentinia	6872m	Greg Horne 1995
		6875m	Hans Stegman early 1900's
		6779m	Riso Patron 1902
		6875m	Sverre Aarseth 1994 +/- 50m!
4. Huascaran	Peru	6769m	Peru IGM
5. Bonete	Argentinia	6759m	AIGM 1991
6. Tres Cruces	Chile	6758m	Chile IGM 1990 1:50,000 (Restricted)
		6769m	Riso Patron 1902
		6749m	AIGM
		6603m	Russian 1980
7. Llullaillaco	Chile	6739m	Chile IGM
8. Mercedario	Argentinia	6670m	Riso Patron 1902
9. Cazadero	Argentinia	6637m	Riso Patron 1902
		6669m	Polish 1937
		6658m	AIGM 1991
		6693m	Russian 1980
10. Yerupaja	Peru	6634m	AIGM 1991
11. Incahuasi	Chile	6624m	Chile IGM
		6638m	AIGM
		6620m	Russian
12. Tupungato	Chile	6550m	Chile IGM
13. Sajama	Bolivia	6542m	BIGM
33. Chimborazo	Ecuador	6268m	Jenkins/Fairnington 1993
84. Copiapo	Chile	6,077 m	Jenkins /Burkes /Miles 1997
115. Cotopaxi	Ecuador	5896m	Jenkins/Fairnington 1993

Confirmation and further surveys are necessary to solve the places of Mercedario, (quoted as 6770m on AIGM maps) Tres Cruces, Bonete, Incahuasi and Cazadero.

Mick Jenkins is a Military Surveyor in the Royal Engineers. He is a specialist in mountain surveying and map making underpinned by his 21-year geographic career in HM forces, and by his 13 years experience of exploratory expeditioning. He has led numerous surveying and mountaineering expeditions working alongside host country survey agencies. Each expedition has produced satellite image maps, geodetic survey networks and collected geographic data of rarely visited mountain wildernesses. In the last 4 years Mick has exploited IT and communication technology to assist in the mountaineering and science objectives of Military Survey's '*Apogee*' expeditions. He intends to continue surveying the high mountains.

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Hans Stegman 1900	
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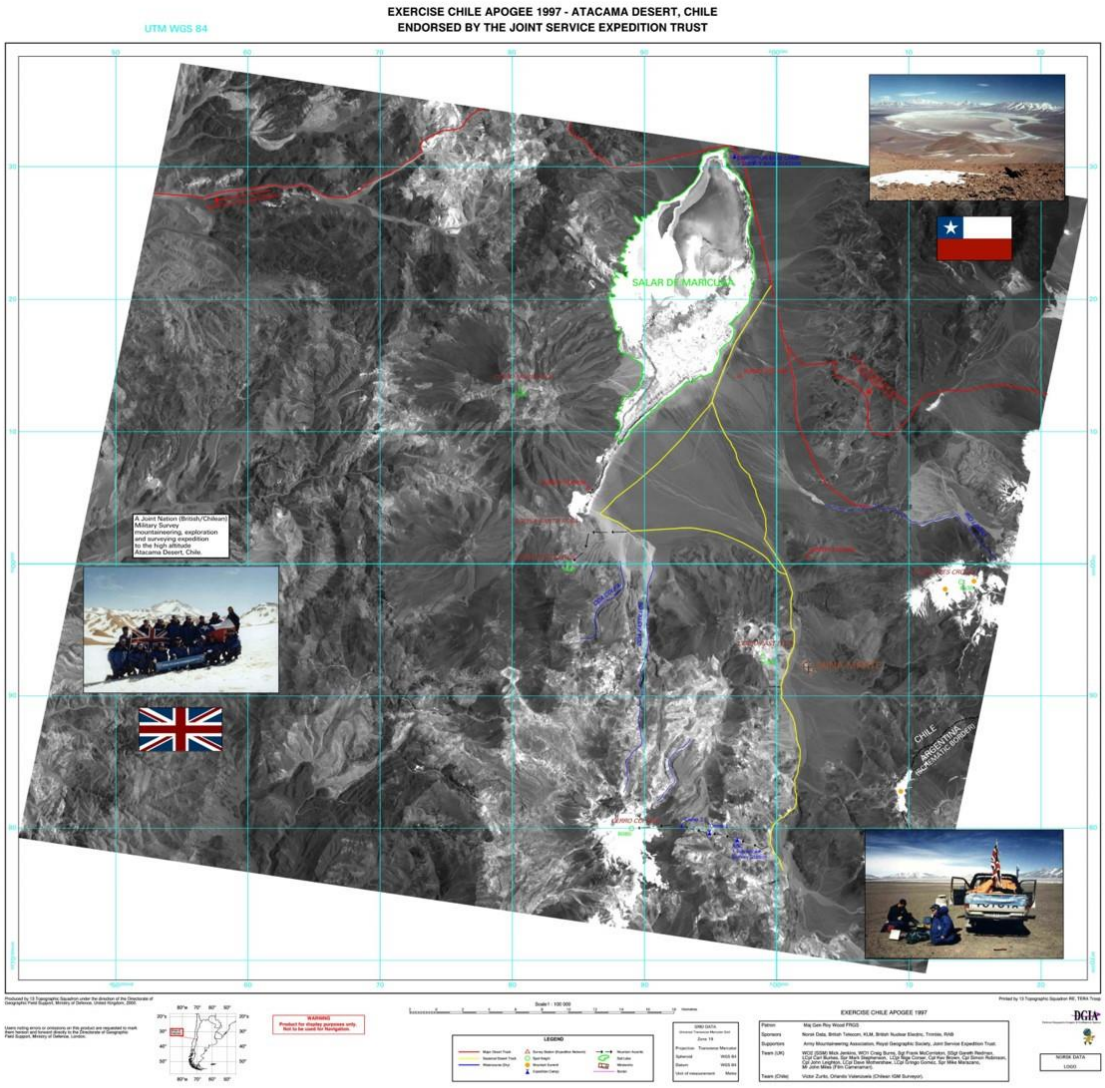
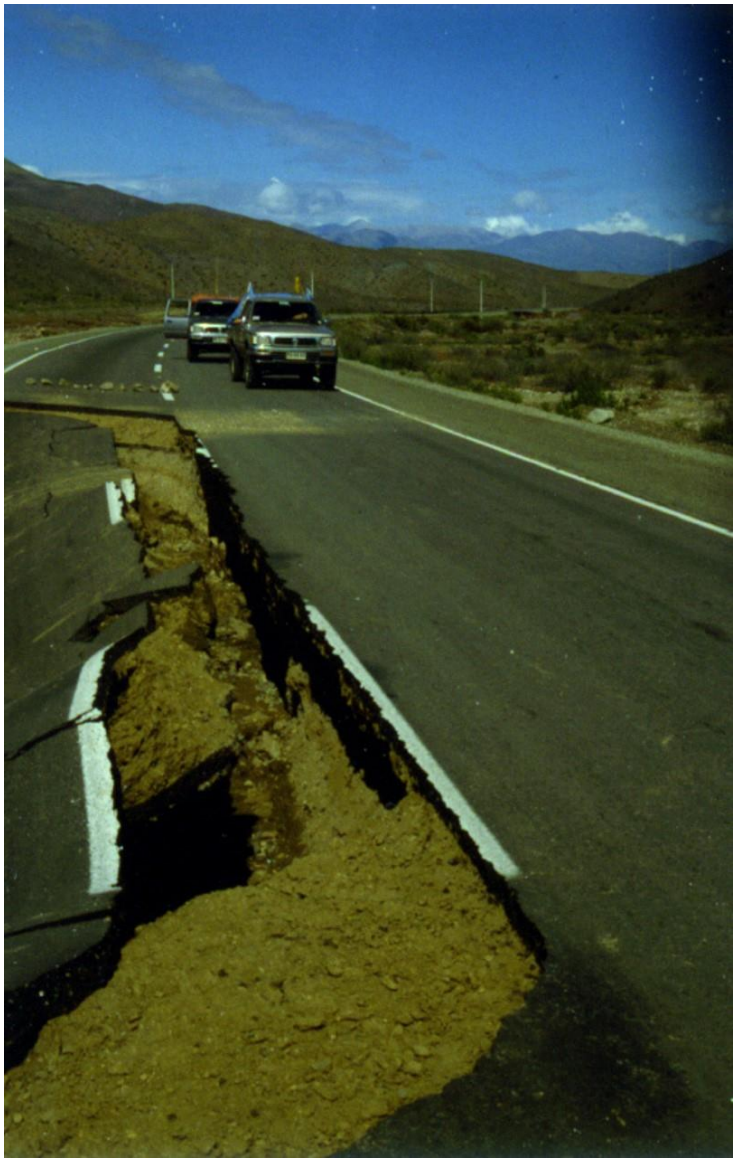
Andean Apogee (RGS)	Mick Jenkins 1993
Indian Apogee (RGS)	Mick Jenkins 1995
Chilean Apogee (RGS)	Mick Jenkins 1997
Kazakh Apogee (RGS)	Stuart Batey, Mick Jenkins 2000
Patagonian Apogee	Nathan Arnison 2001

One of the seven unclimbed mountains we managed to scale and name, in Kazakhstan in 2000, resulting in deep exploration of the Dzungarian Alatau on the Chinese border where we moved across three valleys and mapped the region.

Ladakh region, Himalayas, Mount Kang Yissay.

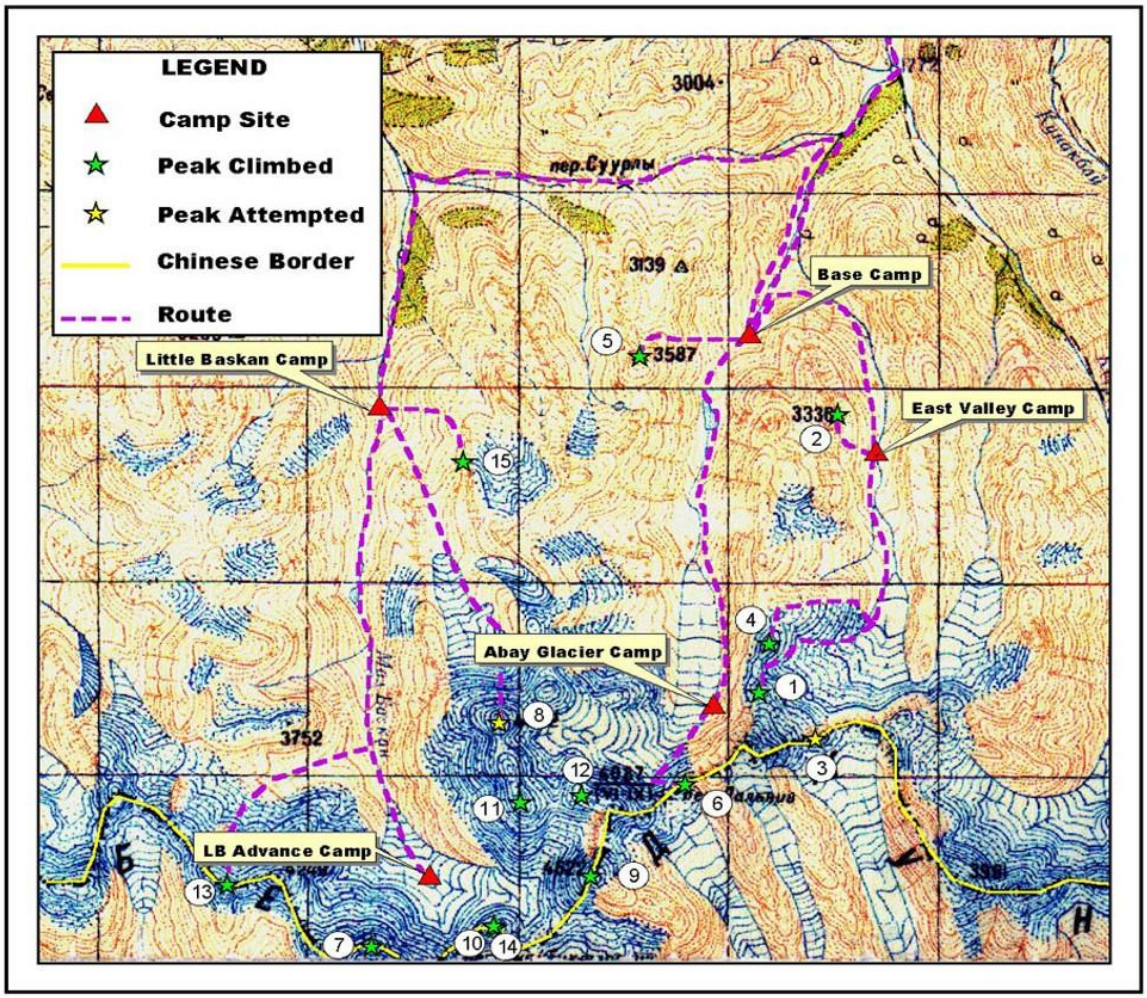




El Nino devastation in Chile, and celebrations with the Chilean Army post expedition. Author, second right front row.

All captured in the Discovery channel film, 'Conquering the mountain of fire.'

KAZAKH APOGEE 2000 MAP



SCALE
4 km

Seven unclimbed peaks were scaled in the Dzungarian Alatau on the Chinese border where we moved across three valleys and mapped the region and approaches to the high peaks in this rarely visited mountain range.