Field Techniques Manual:
GIS, GPS and Remote Sensing

- <u>Section D: Planning & Practicalities</u>

Chapter 17: Case Studies

17 Case Studies

17.1 Bogda Shan Expedition 2000

The Bogda Shan 2000 Expedition was a multi-disciplined research project, jointly funded by the RGS-IBG, Imperial College Expedition Fund and the University College London Convocation Fund. The expedition was led by Alex Atkinson with assistance from co-organiser Martin Whiteside. The project studied environmental change, basic geology and other physical disciplines in the Bogda Shan range of mountains in Xinjiang Autonomous Region of the People's Republic of China.

Many GISci techniques were used, including large volumes of GPS data, targeted remote sensing and GIS analysis. One of the most important aspects of the expedition that benefited from GISci was the pre-expedition planning. Due to the political sensitivity of the region, the best maps available before the expedition were 1:1,000,000 ONC charts and 1:500,000 Tactical Pilot Charts. These charts showed a basic layout of the area but could not be used for placing base camps or detailed project planning.

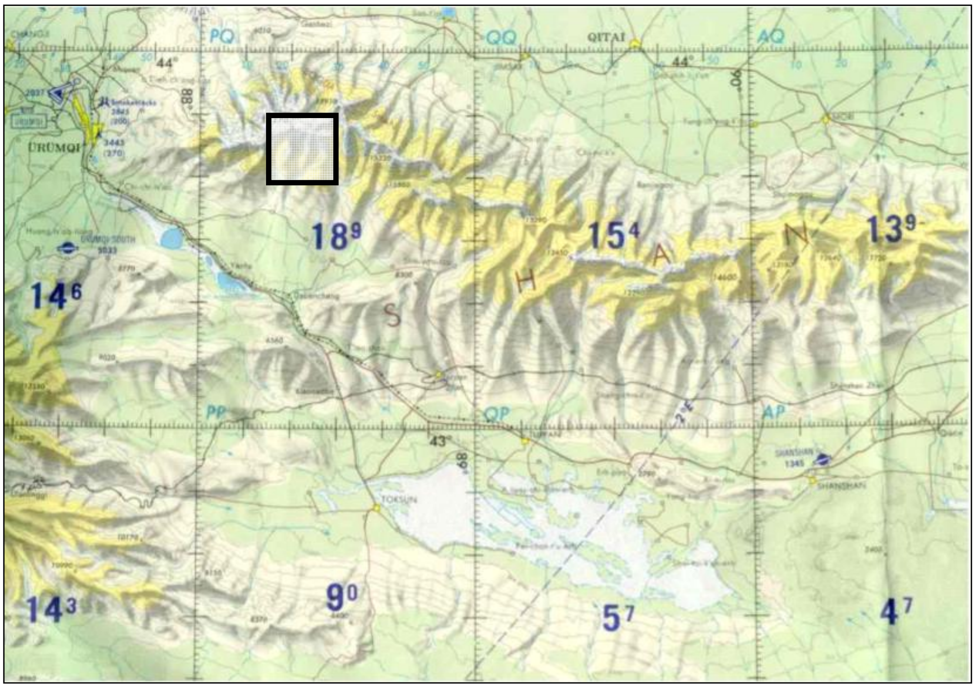

Figure 17-1 1:1,000,000 scale ONC map of the Western Tian Shan and Bogda Shan. The map was one of the most detailed documents available in the UK prior to the expedition. The black square shows the approx. 10 km x 10 km area studied by the team.

As an alternative to standard maps, the expedition used Landsat images. Landsat ETM+ multi-spectral imagery is approximately equivalent to a map of 1:75,000 scale. The advantage of multi-spectral imagery is that it can be analysed to show specific features of the terrain. The expedition needed to find a location to place the base-camp that was close enough to the mountains for easy access to study the glaciers, without being too high in the mountains where conditions would be too harsh. A Landsat image (bands 4, 3, 2) shows vegetation in a bright red colour. By studying where the red colour on the image ended the team could select an area within the vegetation line but close to the study area. The next image shows the study area. Basecamp was selected to be at the confluence of the two tributary streams. The data suggested the area was vegetated, and as the photograph inset shows, this was the case when the team arrived. The results of this pre-field study can be seen in Plate 22.

A more detailed examination of the streams size was possible by using band 8 of Landsat ETM+ data. Band 8 is a panchromatic band with four times the detail of the Landsat multi-spectral data. The team also used Corona spy satellite data that had nearly 50 times the detail of Landsat Band 8. These high-resolution black and white datasets allowed excellent planning at approximately 1:25,000 scale.

The datasets were also used as accurate base maps for the geological mapping. High resolution Corona data is so accurate that individual boulders and outcrops can be located on it. Corona data was used for field sketches that were referenced against GPS co-ordinates and digitised into Arc View 3.1. When in the GIS the data can be overlaid back onto any of the raster data. Plate 22 shows an overlay of various lithological units on the Landsat ETM+ panchromatic data.

The Bogda Shan Expedition could not have taken place without using GISci techniques to aid in the planning of the work. Without remote sensing data there would have been no way to plan where basecamp was to be situated or what areas would be accessible. Significant time would have been wasted in the field and the work would have been of a much lower quality had these steps been missed out. Some of the main GISci tools and techniques are shown below in Table 17-1.

Table 17-1 GISci techniques used by the Bogda Shan Expedition.

		Type	planning	navigation	analysis
GISci data	GPS	8/12 channel	×	✓	✓
	remote sensing data	Corona	✓	×	✓
	remote sensing data	Landsat ETM+	✓	✓	✓
GISci tools	GIS	ArcView 3.2	✓	✓	✓
	image processing	ER Mapper 6.0	✓	×	✓
	GPS download	GPS Utility 4	×	✓	✓

The Imperial College Bogda Shan Expedition obtained Landsat imagery through EurImage and the data was processed using the Intercollegiate Remote Sensing Facilities at Imperial College London. The work was supported and approved by the Royal Geographical Society (with IBG) 'Expedition Research Grant', with accompanying grants from the Imperial College Exploration Board and the University of London Convocation Award.

17.2 GISci helps in conquest of Everest

No prior altitude experience, no mountain training, no climbing equipment, and success at the world's highest peak – climbing will never be the same again…

I have spent the last 5 years with two big dreams. The first is to do a hobby for a job (in my case this involved becoming an academic). The second is to have a chance of a stab at Everest. To most of us such dreams are just that – dreams. But on 24 August 2001 they became reality for me: at exactly 5pm, myself and 15 Environmental Science degree students made it, without oxygen, to the summit of Everest. Between us we had climbed nine different routes to the top, including previously unclimbed routes or new variations on existing lines. Even the East Face was attempted with success gained via the central buttress and a new route tracing a line north of the trinity gullies. The whole expedition had taken just four weeks from start to finish and my employers (Charles Sturt University in Australia) had generously covered the entire cost of the trip. Only one student had ever done any climbing before, yet despite our novice status, everyone summited via their chosen route. There was not a single fatality, nobody suffered any frostbite, only occasionally did anyone break sweat and by 6pm we were all back in the pub with a well earned beer in our undamaged hands. Surely this will go down in history as one of the greatest climbing achievements of the 21st Century?

All this probably seems totally unbelievable and I expect that you are wondering how we did it. Well, maybe this article has been a little misleading so far, because the truth is that no one went anywhere near the mountain - not the real mountain anyway. You will not find Charles Sturt University recorded in the Everest role of honour because the students were studying and climbing a virtual Everest from the comfort of an air-conditioned computer laboratory in Wagga Wagga, Australia; the flattest continent on the planet. Instead of the usual ice axes, crampons, down suits and extreme physical effort we climbed the highest peak on Earth with nothing more than some basic knowledge about mountain land-forming processes, a PC, mouse and keyboard and some sophisticated geographic information system (GIS) software.

The idea for this daring mission had come partly from my love of mountaineering and partly from a belief that, with the right research and development, geographic information systems could become a useful arsenal in the climbers rack. Put very simply, GIS can be thought of as mapping and analysing the world around us on a computer. It has been successfully used for some years to assess risks in the physical environment. I wondered if it could be used to deliver climbing information to high-altitude expeditions by using digital maps of mountains to quickly identify and map mountain hazard information such as avalanche zones, provide information on air temperature, air pressure, wind chill and identify locations suitable for establishing high altitude camps. If it were possible, combining the experience of the climber with such maps could produce a powerful resource to the climber prospecting for new mountain routes.

Figure 17-2 One of the students looks for a suitable route up the Lhotse face.

So, the mountaineering challenge was offered to the students together with a highly accurate computer map of Mt. Everest and some information about the basic causes of slab avalanches. On top of this they researched the logistics of establishing a high altitude camp and what is currently possible for the human body at altitude, such as the maximum elevation gain a climber can be expected to make per day at altitude. Armed with this knowledge and fully equipped with state of the art GIS packages, the students set about finding a new, logistically and physiologically-possible route to the top. The GIS was used to identify and map areas where avalanches might occur, locate suitable camp locations, trace the ascent route and provide route data such as total elevation gain per day and the gradient at any point on the route. Within four weeks the new routes were born and 15 young environmental scientists were on top of the world. The 3D maps produced are shown in Plate 24, Plate 25, Plate 26 and Plate 27.

Whilst the technology is impressive it certainly represents a rather clinical and simplified version of the high-drama reality of high altitude ascents. However, the research and development has only just begun. Imagine a computer program where you could sit at base camp with your laptop computer and draw your mountain route onto an on-screen map of the mountain. Now put in your age, some information about previous high altitude experience, some physiological information about yourself and the latest weather report. Sit back whilst the computer undertakes complex, physically-based atmospheric modelling to predict the air pressure and ambient air temperature at any point on the mountain. Relax whilst the computer processes these data and wind speed estimations and uses these to estimates wind chill and predict a climber’s likelihood of frostbite. Let the computer integrate this data and the current knowledge of high altitude physiological relationships to calculate information about the stress your body will be under at any point on the climb and the calorific intake your body will need to meet the stress and make a successful ascent.

This may all sound like pie in the sky but it is, in theory at least, possible. As a result of the advances in computing power, the accurate on-screen 3D maps of the mountains, which are capable of telling you information such as the altitude, slope orientation and gradient at any point on your route, are already available. There is a growing pool of information about physiological stresses experienced by high altitude. These have been collected by numerous medical expeditions to Everest and others of the world's high peaks. These data can be fed into GIS-based models of physical processes (such as avalanching) and human physiology. The atmospheric physics is well understood and the academic expertise is also there to put the data together and allow predictions about the physical and physiological stresses on a climber during a climb. With such a tool in the climber's rack would high altitude climbing ever be the same again?

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17.3 Jarlhettur Ridge, Iceland

The Jarlhettur ridge in central Iceland is of significant environmental interest, as it lies on the edge of the Langjokull ice cap. The ridge is a geologically recent volcanic structure, composed primarily of loosely consolidated volcanic ash and lava. This ridge has naturally dammed a meltwater outflow from the Langjokull ice cap and the glacial lake, which has formed as a result, now covers over two square kilometres and contains a huge volume of water.

The geological materials that form this dam are relatively weak and some are porous. There is evidence that previous breaches, which significantly lowered lake levels, have occurred very recently and a further breach could release a catastrophic flood into the outflow river. As human developments in Iceland include habitation on the floodplain of this outflow, a breach may result in significant loss of life.

Clearly, gaining a good understanding of the detailed geological makeup and structures of this ridge are key to ensuring that hazards are assessed appropriately. This can be difficult in a location as remote as this, and fieldwork is time consuming, arduous and expensive. Detailed mapping of the area would be key to optimising the amount and level of detail possible in a field campaign.

Mapping in Iceland is developing fast. The area has recently been mapped commercially for the first time by the Icelandic mapping agency ‘Landmaelingar Islands’ at 1:50000 scale. Unfortunately this scale of map was too small and more detail was needed to properly plan a field survey. NERC agreed to collect aerial photography and airborne remotely sensed data of the area in 2001.

The aerial photos were very detailed and 57 were needed to cover the area of interest. These were photocopied to enlarge them and the copies used to collect and identify ground control on a reconnaissance visit to the area in 2002. GPS was used to identify features on the photos and the co-ordinates were recorded directly on the copies. The photos were then scanned, processed photogrammetrically using the ERDAS OrthoBase Pro software and the GPS co-ordinates for ground control and mosaiced together to produce both a seamless Digital Elevation Model and a seamless orthophoto.

The resulting orthophoto mosaics were then printed with a grid system matching the Icelandic national grid, as used on their 1:50,000 map sheets, titles, north arrows etc. The prints were produced at various scales from 1:10,000 to 1:2,500. These were then laminated and were used to plan and carry out a more detailed field survey, which took place in August 2003. An example of the data produced for use in Iceland, including a section of the glacial meltwater lake, is shown in Plate 28.

17.4 A semi-desert soil erosion and landslide site

Areas of severe soil erosion and gullying that are relatively unsuitable for farming are known as ‘badlands’: their very irregular, often poorly-accessible terrain makes them a challenge for surveyors. High levels of Ca or Na in silty/clayey soils – quite a common feature over sedimentary deposits in arid and semi-arid regions – lead to the development of soil pipes, which in turn facilitates the formation of gullies. This was one of the erosion problems being examined in the Luangwa Valley fieldwork cited elsewhere in this book, but it is also a problem in many Mediterranean landscapes, such as SE Spain (viz Figure 12-1). The example given here, the Mocatan Valley near Sorbas, Almeria, is further complicated by the badland terrain developing on and around a large landslide (Mather *et al.* 2003; Faulkner *et al.* 2004). The area can be seen in Plate 12.

17.4.1 The Mocatan catchment – the problem

The Mocatan catchment study area is of interest, as the knick point of a rejuvenation event is currently progressing upstream into the tributary valleys and gullys of the system. The rejuvenation event was initiated by a river capture event, dated at around 100,000 years ago, which lowered the base level for the local river system by around 90 m. This knick point is providing local river systems with substantially increased stream power, leading to rapid erosion and over-steepening of valley sides. To compound this, the region is currently undergoing tectonic uplift, >15 m since the capture event.

The geo-materials in the area are very prone to piping. This process occurs when a geo-material that is low in certain ions and also low in clay, is exposed to a hydrologic gradient. The material will contain micro-fractures, which present little resistance to significant water pressure. The flow of water through these cavities rapidly erodes them, producing underground pipes that can be up to a metre or so in diameter. These channels frequently collapse, and pose a hazard to people and vehicles. The speed at which the material is eroded poses a more significant threat to farming, as substantial volumes of sediment are released by the process.

The climate in Almeria exacerbates the soil piping problem, in that the area is semi-desert, with the characteristic flash-flood and drought sequence of such areas. Flash floods precipitate very rapid erosion, causing pipes to develop very rapidly. Anthropogenic disturbance of the landscape also exacerbates the problem, as agricultural terraces provide perfect hydrologic gradients for soil pipe development. Road cuttings and other surface modification also precipitate piping.

The concept of pipe development is well established, but the distribution of susceptible materials, of anthropogenic disturbance and the pipe relationship with the topographic surface and consequent distribution of vegetation was not clear in southern Spain. There was a clear need to map accurately where pipes occurred topographically, where on landscape surfaces they tended to be initiated and what management strategy for these landscapes was advisable to minimise their impact. The study described here attempted to help address these issues.

17.4.2 The approach

To fully analyse the instance of piping in the Mocatan catchment, a detailed three dimensional model of the area was needed. NERC air photos from two dates were available, but investigation of the accuracy possible from extract of elevation data via digital photogrammetry yielded too much error. A field survey using a total station was therefore considered the best option.

To geo-locate the total station points, a network of base stations were established using a differential GPS system. Using a Leica total station system yielded an accuracy of ~10 cm in X, Y and Z. Seven stations were surveyed, selected for their line-of-sight coverage of the study area. Once located, these stations were used to survey-in the study area using the total station. Topographic breaks of slope were surveyed, a series of points collected from each allowing reconstruction of the landscape. An example of the data recorded for each survey point is shown in Table 17-2.

Table 17-2 Data collected from the total station survey of the landslide study area. Only 7 of the 260 surveyed points are shown: note that the heights in this subset range from 514.83 m to 561.04 m. EASTINGSCO and NORTHINGSCO are the x *(EASTINGS) and* y *(NORTHINGS) co-ordinates, corrected to Spanish national grid (UTM zone 30s, international 1950 datum).*

POINT_NUMB	EASTINGS	NORTHINGS	HEIGHT	EASTINGSCO	NORTHINGSCO
2,1	6696.9	3859.2	545.80	586696.9	4103859.2
2,2	6689.5	3841.3	551.10	586689.5	4103841.3
2,3	6673.5	3830.5	552.63	586673.5	4103830.5
2,4	6672.6	3817.2	559.07	586672.6	4103817.2
2,5	6645.1	3808.4	561.04	586645.1	4103808.4
2,6	6629.5	3823.2	549.96	586629.5	4103823.2
2,7	6617.5	3825.0	549.93	586617.5	4103825.0

The points collected were then imported into ArcGIS GIS software and a Triangulated Irregular Network (TIN) constructed from them. This was done on a laptop in the field at the end of each day so that subsequent field days could be used to position points to fill in perceived gaps in the network. Plate 30 shows the final TIN from field data only.

During data collection, field sketches were also drawn, locating accurately the pipe entrances and exits. The field sketches could be drawn to scale, as tracing paper was used with graph paper, with the map grid drawn on below. Various elements were also included in the sketches and topographic features sketched in. These field sketches were subsequently scanned in and geocorrected, allowing updating of the TIN model with the information from the sketches. That allowed a more detailed model to be constructed than the survey points alone. Plate 29 shows the updated TIN.

The sketch maps were also valuable, after scanning and geocorrecting, for producing a pipe map of the area. This allowed the estimation of connectivity between pipe entrances and exits to be made (otherwise a difficult task in such an arid environment), as well as providing a clear delineation of the topographic positions of pipe entrances and exits. Plate 31 shows a part of the sketch map: the points in red are the locations of points surveyed by the total station where detailed observations were made. Geocorrection of the sketch maps allowed them to be integrated with the total station elevation model and viewed in 3-D, as shown in Plate 32. This process aided the visualisation of the landscape, particularly where the areas where pipes were located.

Using co-ordinate data collected from the field, a set of aerial photos were ortho-rectified to provide an image layer for analysis. This was an invaluable supplement to the field data, in that it clearly defined the density variations of vegetation in the area. Vegetation is clearly an important factor in soil piping, as the data from the study area indicated a very high correlation between slopes undergoing piping and dense vegetation.

It is possible that the vegetation is preventing a proportion of rainwater from running off the slope and therefore water is being retained on these surfaces. The retention means more water percolates into whatever natural pores or passages are available, therefore pipes are more likely to form. It is also possible that the substantial interweaved shallow root system of the semi-desert plants hold the surface together and prevent collapse of underground channels until much more substantial structures are formed. However, the plant root systems could also cause the opening and development of soil pipes in the first place!

Vegetation density is clearly therefore a critical component of soil piping. The air photo datasets provided information about the vegetation density in the area. Geo-correction of the photos allowed comparison of vegetation in entrance-rich and entrance-poor areas to help define more accurately on what slope, in what position, below what type and thickness of vegetation, soil pipes develop. Figure 17-3 shows an ortho-corrected colour aerial photo draped over the elevation data to produce a 3-D model to help us understand and interpret the inter-relationships between topography, vegetation and soil pipes.

GIS, remote sensing and field survey have all been combined in this study to produce information of critical importance to the aim of the research project. Much of this work was undertaken prior to the field visit, which allowed more effective use to be made of the limited time available for fieldwork. A good understanding of all the techniques, their advantages and their limitations, was critical to achieving the project goals.

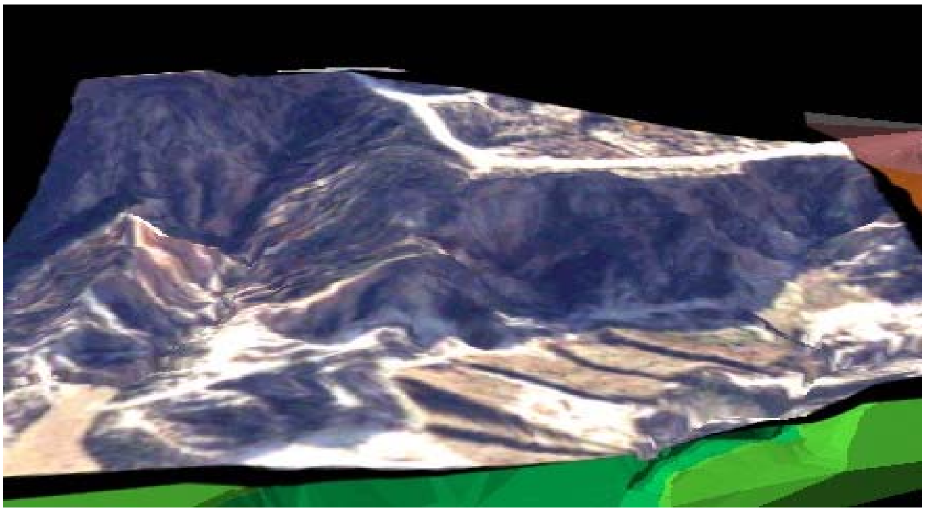

Figure 17-3 An airphoto draped over the geomorphology-modified TIN, aiding visualisation of the landscape. Airphoto courtesy of the UK Natural Environment Research Council.