GIS in the real world: Using mobile technology in fieldwork (MOTIF)

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Abstract

Fieldwork has long been the centrepiece of experiential learning in geosciences and gives students vital mechanisms to deploy and develop skills and enhance understanding in the real world. As universities develop capacity for eLearning, Kingston University London is developing GIS based applications of mobile technologies combining real-time mapping, satellite and geospatial data. The MOTIF project develops new and exciting approaches to fieldwork and methodologies for effective implementation and enhanced learning. The School of Earth Sciences and Geography has leading expertise in GIS and was the first European University to offer a BSc degree in GIS. Here, we report developments in using GIS and mobile technologies to deliver fieldwork programmes in Malta and Scotland. ESRI ArcPad and ArcGIS software was used to collect and analyse data and present results for a range of projects. Such developments in implementing mobile technologies in fieldwork are important in enhancing field based learning and the wider curricula.

Introduction

Fieldwork in the geosciences has long been an important centerpiece of experiential learning (Coorey, 1992; Kolb, 1984). Students use the real-world laboratory to study patterns and processes and to enhance their understanding of a wide range of the subject matter. The role of fieldwork has, however, been the focus of a growing debate on both its role and purpose in relation to the undeniable high cost (Kent *et al*., 1997; Hawley, 1996). The National Committee of Inquiry into Higher Education (DoEE, 1997), also placed a clear emphasis on skills development in UK University curricula with an emphasis on the need for a graduate to possess key skills in the use of information technology in addition to other important skills. Traditional fieldwork has therefore become vulnerable against this background, particularly since educational value is largely anecdotal and when "The dominant style of fieldwork which has developed is the excursion-type, commonly called the "Cook's Tour" which is characterized by a didactic/instructive teaching approach with passive student interaction" (Hawley, 1996, p243). Clearly, such an approach fails to grasp the opportunity presented by fieldwork to develop key skills in an exciting and dynamic manner (Grattan *et al*. 2005). This paper sets out an approach that embraces developments in the geospatial technologies of remote sensing, GIS, GPS, mobile computing (e.g. portables and PDAs), WAP-enabled mobile telephones, digital cameras and the internet for fieldwork. Technological innovation not only meets the important criteria for developing students' key skills in using information technology but they have challenged traditional approaches to fieldwork and underpinned updating of existing fieldwork activities and the exploration of new approaches (Teeuw *et al.* 2005).

The School of Earth Sciences and Geography has leading expertise in GIS and places fieldwork at the centre of its programmes ranging from geology to human geography. Decreasing costs of hardware and software, coupled with increased flexibility and useability, resulting from improvements in wireless technology, have provided a set of tools that are now able to be realistically used with large groups of students in the field. The opportunity now exists for implementing geospatial technologies usefully since many of the barriers to effective use in the field have diminished.

This paper reports on the development of two projects that have piloted the use of geospatial technology for fieldwork in Malta and Scotland. The fieldcourse to Malta (in the Mediterranean Sea) is taken by second year undergraduates studying human geography and GIS whilst Ullapool, Scotland is the location for geological mapping fieldwork; both of which require data collection and access to high quality spatial data in the field. Together, these examples illustrate the potential applicability of integrating geospatial technology to the study of geoscience in the field and offer a basis for reflection on the operational considerations for effective implementation.

Mobile tools for geographical fieldwork

Geospatial technologies for geographical fieldwork broadly fall into three main categories: spatial data collection tools; wireless communications; and remote data access tools (Green *et al*., 2002; Green and King, 2004). Data collection for geographical fieldwork commonly requires the determination of spatial location. Traditional fieldwork techniques have normally made use of printed or photocopied map extracts on which locations and annotations have been marked. Low cost mobile Global Positioning Systems (GPS) units now provide a means to measure location which can be subsequently marked on a paper map. Locational accuracy has improved from a pre-2002 accuracy of within 100m to between 10-20m. The advent of Differential GPS (DGPS) further improves locational accuracy to between 1-10m.

Portable computing power has both improved and become more affordable. PDAs (such as the HP iPAQ) can be used as a recording device rather than marking locations on paper maps which provides a mechanism for taking digital maps into the field. This is a less cumbersome approach than the paper alternative and means that alternative maps (e.g. different scales, themes, digital aerial photography or remotely sensed images) can be taken into the field in their digital form to provide more comprehensive and varied contextual information on the locations students visit. Additionally, recording of data can be done in the field without the need for sometimes lengthy data transfer from paper equivalents at a later stage. GPS also provides automated measurement of position which reduces the scope for student error when navigating, orienting or locating themselves either digitally or when using paper-based mapping.

A more expensive, although increasingly affordable, solution is to couple GPS with PDA devices using mobile GIS (e.g. ESRI's ArcPad). This provides an integrated platform for the digital acquisition, recording and mapping of data in the field. Improvements in connectivity between devices now make mobile GIS a far more flexible solution to mobile mapping. In order to make effective use of various devices there needs to be some connection made between them. Cables have never been a viable solution when taking equipment into the field largely because they are often bespoke, do not allow waterproofing and require a permanent physical connection between devices. Infrared (IR) connectivity was an improvement but still required devices to be positioned in such a way as to allow them to link wirelessly. As they require a line-of-sight they are not easily implemented in the field. Bluetooth technologies are significantly better since the devices do not have to be aligned to send and receive data, meaning that the orientation of devices in relation to each other is much less problematic and resulting in increased range. Devices can now be connected between 5-10m apart in physical terms, without loss of signal, that gives much greater flexibility for data collection.

Image compression algorithms allow previously prohibitively large datasets to be transferred into a form suitable for use with mobile GIS. One of the drawbacks of using PDAs has been the relatively low memory and storage capacity which has prevented often large digital data sets from being used effectively. LizardTech's MrSID image compression algorithm incorporates a patented wavelet based technique to significantly reduce large raster datasets (typically derived from satellite imagery or aerial photography) from gigabytes (Gb) to megabytes (Mb), so facilitating their effective use in the field. MrSID (.sid) can be natively read by ESRI's ArcPad. The ability to transfer large raster datasets to mobile devices allows the opportunity for rapid display, analysis and interpretation in the field, unhindered by file size or screen refresh rates.

The range of mobile data collection technologies now available, coupled with improvements in wireless communication and the physical size and power of microprocessors provide an extremely powerful alternative to traditional approaches in fieldwork for geoscience. Together, the technologies provide increased sophistication in what can be achieved in the field, leading to an improved use of time spent in the field to acquire data in greater quantity and quality (Pundt and Brinkkötter-Runde, 1998). There is also a growing appreciation that there are significant practical benefits to undertaking fieldwork using geospatial technologies that extend beyond simply replicating activities in a digital environment. Scope exists for enhancing the fieldwork experience and developing new and exciting applications.

The remainder of this paper describes two uses of geospatial technology in both physical and human geographical fieldwork and also reflects upon the effectiveness of the work and what future potential exists for further development. The basic techniques illustrate the potential for wide application in all geoscience subject areas where data is collected in the field.

Case study: Land use mapping in northern Malta, Mediterranean Sea

Second year undergraduates of the Human Geography and GIS degree programmes participate in a fieldcourse to Malta, in the Mediterranean Sea, during the latter part of their second year (Level 2). The fieldcourse is part of second year courses in geographical methods and project planning and provides a platform to give students experience of undertaking project planning, field based data collection, analysis and interpretation in preparation for final year dissertation studies. The week-long fieldcourse comprises a range of staff-led and student-managed exercises that combine the practice of geographical enquiry with the introduction of new techniques.

Malta is the largest of the Maltese Islands at 320 sq km (124 sq mi) and has a population of 391,700. As a fieldcourse destination it provides numerous opportunities for geographical enquiry, one of which is the changing agricultural economy that the island has experienced during the last 50 years. In 1957, agriculture accounted for 14% of the Gross Domestic Product (GDP) of the Maltese Islands but its importance to the Maltese economy has been in steady decline (Table 1).

The period since the mid-1950's has also seen a decline in the number of people involved full time in agriculture in the Maltese islands. In 1961 there were 16,145 farmers, of whom 45% were classed as full-time farmers (Vassallo, 1999). In 2000 the total number of farmers had reduced to 11,400, with only 974 classed as full time (Table 2, Malta NSO). Similarly there has been a drop in full time agricultural employment from 45% to 10%. As well as the huge reduction in the numbers of farmers, there has also been a shift in the age of those involved in agriculture towards the over 50s.

Year	% Contribution of Agriculture to GDP
2000	2.3
1998	2.7
1995	2.8
1990	3.4
1985	4.6
1980	3.8
1957*	14

Table 1. Contribution of GDP derived from Agricultural Activities. (Malta NSO; *1957 values taken from Charlton and Beeley (1987)).

Age (years)	Total Number of Farmers	Full Time	Part Time
Under 30	259	49	210
30 to 50	3414	419	2995
Over 50	7727	506	7221

Table 2. Age distribution of agriculturally-active individuals in 2000 (Malta NSO)

The amount of land under agricultural cultivation has also declined significantly since the 1950s. In 1956, 17,884ha were cultivated in some way with a further 2,550ha of land classed as derelict, out of a total land resource for the Maltese Islands of 31,559ha (Vassallo, 1999). In 1997, only 9593ha were classed as being agricultural. The biggest loss of agricultural land has come in areas that employ dry farming methods, where the total number of hectares under cultivation halved between 1956 and 1991 (Vassallo, 1999). In contrast the area of irrigated land has only reduced by about 12% over this same period. Urban/built up areas have increased from around 4% of the total land area in 1957 (Charlton and Beeley, 1993) to in the region of 21.4% in 1997 (Malta NSO).

The apparent decline in the importance of agriculture to the Maltese economy, and the reduction in the area of cultivated land, has been linked to a number of causal factors. Firstly, the expansion of urban areas has lead to a loss of agricultural land. Some of that expansion has been in the form of new developments to service rapid growth in the tourist industry, other developments have grown up to service government requirements for housing (Charlton and Beeley, 1987; 1993; Stainfield, 1999). Secondly, expansions in other parts of the economy have led to alternative higher paying employment, thus reducing the number of younger people going in to agriculture. Thirdly, the law on inheritance in Malta means that where farmers own their land they must divide it amongst their children when they die. This has led to a massive reduction in the size of individual fields, some can be only a few metres in size, which has made farming very uneconomical in some areas (Stainfield, 1999).

The overall aim of the fieldwork exercise is to investigate whether the decline in agricultural land noted in other studies, such as Charlton and Beeley (1987;

1993), is continuing today. As such, the fieldwork focuses on a land use study of Mellieha, in Northern Malta (Figure 1).

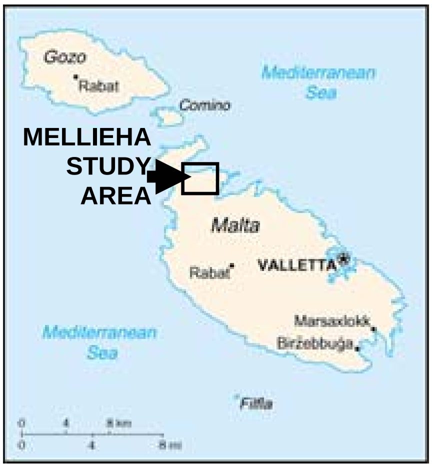

Figure 1. Mellieha study area

The north of Malta is characterised by ridge and valley topography caused by faults that run in a NW-SE direction. On the top of one of these ridges is Mellieha, which is a small town (big by Maltese standards) overlooking Mellieha Bay to the north and St Paul's Bay to the east. This area has been the focus of previous research carried out in the 1950s (by Durham University), the 1980s (by Charlton and Beeley, 1987; 1993) and, more recently, by successive groups of students from Kingston University. The area was originally examined because of the potential impact tourism might have on agricultural activities. In Mellieha, a massive reduction in the area under cultivation occurred between 1956 and 1984. Charlton and Beeley (1987) identified a number of specific causes for these changes that compound the national trend. Firstly, a large expansion in the built up area has occurred, due to the development of tourism in Mellieha and St Paul's Bays and the development of Government housing. Secondly the area became popular as a destination for retiring expatriates. Thirdly, enhanced transportation meant that people could commute from Mellieha to the new jobs that developed across the island in the 1960s and 1970s.

The fieldcourse exercise requires students to survey and map the study area and then interpret findings in relation to previous results to determine whether trends in agricultural decline persist and what factors might be shaping change. Previous fieldcourses have undertaken this exercise using traditional field-based sketch mapping. Photocopied base maps have been used in the field to plot, rather crudely, the extent of cultivated land and non-cultivated land, abandoned land and other features that may reflect the impact of changing agricultural practice on the landscape. This has been achieved by undertaking a visual survey of the area and annotating the base maps. The exercise has not required any significant understanding of geographical location and measurements to derive values of percentage decline in agricultural area have been approximate and provide only a rough guide. Students have produced maps of their results but given the limited facilities available these have also been rather simple in construction and have not enabled the deployment of any meaningful cartographic skills.

Piloting the use of geospatial technologies for land use mapping
During the 2004 fieldcourse, initial pilot studies were undertaken by staff to explore the potential for using geospatial technologies to undertake land use studies in and around Mellieha. iPAQ Handheld PCs (5400 series), Fortuna "Clip-on" Bluetooth GPS receivers and ESRI ArcPad (v6.0.2) were used to provide a mobile mapping platform (Figure 2).

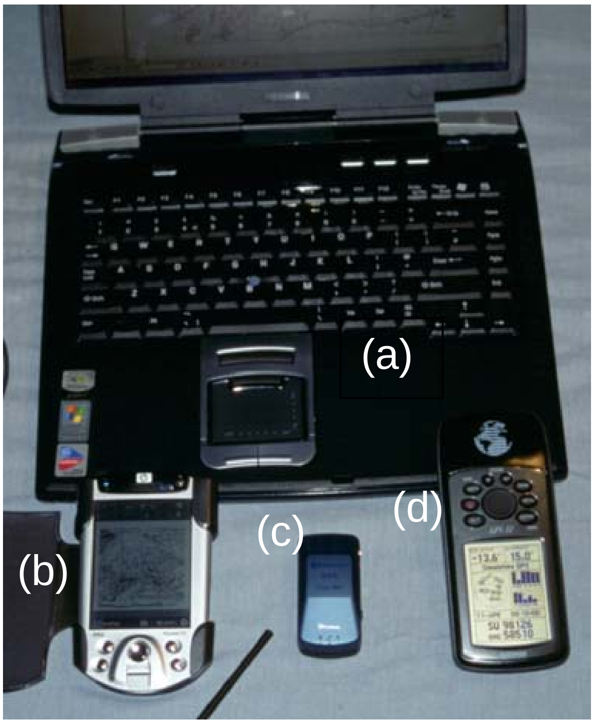

Figure 2. Equipment used for mobile mapping. (a) notebook computer running ArcGIS (version 9); (b) iPAQ handheld computer (5400 or 2700 series) running ArcPad (version 6.0.2); (c) Fortuna "Clip-on" Bluetooth GPS; (d) Garmin GPS 72 Receiver

A 1:10,000 Malta Environment and Planning Authority (MEPA) topographic map was scanned, georeferenced and used as a base map in ArcPad. The equipment was used to replicate the study students were undertaking using traditional field mapping to examine the practical issues of implementation. Data acquisition was limited to creating waypoints and trackpoints using the Fortuna GPS to automate coordinate measurement. Attempts were made to create polygons by navigating field boundaries but problems of access rendered this impractical. Positioning was typically within a 10m accuracy and allowed for positional information to be derived at a scale appropriate to the size of the study area (4 sq Km). It was clear that potential existed for implementation of the techniques and development of a suitable exercise was completed prior to the 2005 fieldcourse. Use of geospatial technologies required a somewhat different approach to the project since the technology itself requires some introduction to be used effectively. This was seen as an opportunity to extend the project to make experience of data collection using mobile mapping itself one of the key learning outcomes. In particular, familiarization with the equipment, as well as an understanding of geographical coordinate systems, Remotely Sensed (RS) data sources and Global Positioning System (GPS) technology became crucial to the students being able to tackle the project. This has several pedagogic benefits, namely that it allows the introduction of important new technologies in a practical setting; provides increased engagement with the exercise by students; improves reinforcement of key geographical concepts in data acquisition; and increases the scope for undertaking fieldwork of a greater depth and breadth.

Land use mapping exercise in Mellieha, northern Malta

ArcPad is pre-loaded with a dataset comprising a large scale, full colour 2004 digital orthophoto of the study area. This was purchased from the Malta Environment and Planning Authority (MEPA) and comprised a set of four orthorectified digital aerial photograph tiles of the study area to a resolution of 15cm. Each tile was in the order of 150Mb in size. Pre-processing of the data resampled the image to 30cm resolution, converted it to greyscale and created a mosaic of the tiles combined. This resulted in a MrSID file of approximately 2.5Mb for the mosaic image and was much more manageable for use in the field as it dramatically reduced refresh rates. The orthophoto was used simply to orientate the students in the field and to provide a context for their data gathering. Whilst data can clearly be collected without the use of a background image, being able to navigate the study area with reference to imagery was important. Imagery was preferred to a topographic base map since part of the exercise was to create a topographic base map. The full colour, 15cm resolution dataset was used for post-processing on laptops during evening sessions.

The ArcPad map file also has a range of pre-projected empty shapefiles that students populate with data collected in the field. These shapefiles also contain symbolization specifications. Additionally, a paper copy of the 2004 orthophoto and other historical aerial photographs and a field data collection form are provided. The GPS receiver connected to the iPAQ was used to gather positional data for point (waypoint collection) and linear (trackpoint collection) phenomena for the purpose of creating a topographic base map. Drop-down menus created using ArcPad Studio were used when entering positional data. The drop-down menus gave students a range of feature types to map and enabled them to enter attribute information and record the degree of precision. This provided a means of extending the previous paper exercise to create a geographically accurate topographic base map.

The paper copy of the orthophoto was annotated as a land use map of the study area, in a similar fashion to the original paper exercise. Subsequently, the areas marked on the map were transferred into polygons in the ArcPad map file and, again using previously designed drop-down menus, land use attributes were added. There were two reasons for approaching the mapping of polygons in this manner: one technical and one logistical. Firstly, the nature of the features being mapped meant that agricultural land was often both privately owned and inaccessible. In order to use the GPS for calculating field boundaries, for instance (by walking along the perimeter), it would be necessary to gain access and this was simply not feasible.

Additionally, much of the agricultural landscape is heavily terraced and simply not navigable on foot for automatic collection of geographical coordinates. Whilst it is feasible to draw boundaries from a distance using ArcPad, logistically, the exercise was undertaken by groups comprising 6 students since resources were not able to provide a set of mobile mapping equipment to each student. One drawback of the technological approach was that only one person can use the equipment at any given time and whilst students were required to each prepare a portion of the topographic and land use maps, it was a much more effective division of labour to ensure students were involved in mapping activities at the same time, contributing to overall data collection (Figure 3). It also provided a suitable means of enabling the students to latterly reflect upon the differences between paper-based field mapping and the use of technological approaches.

Figure 3. Kingston University student collecting land use data using iPAQ and Fortuna GPS (on belt) for part of Mellieha, northern Malta.

Whilst the majority of point features were gathered using automatic collection of coordinates, field data collection forms were also used to gather information on 10 clear point features of interest. This further enabled students to appreciate the different ways in which GPS data can be collected and recorded.

During the evening session, students were required to download their data into a laptop running ArcGIS (version 9). A project document had been previously prepared in ArcMap to contain a range of appropriate symbolization for the various features and attributes that the bespoke forms enabled. Thus, simply copying the student shapefiles to a suitable directory meant that the student data loaded into ArcMap and was symbolized appropriately. Students were able to spend some time preparing a layout of their data and were also able to use the full colour 2004 orthophoto (and other data sources such as older aerial photographs that had been georeferenced and a Digital Elevation Model). During this post-processing phase, students were also able to take measurements of the various land use types (specifically the area covered by different land use) and this provided information to compare with historical data in order to determine percentage change. Write-ups in fieldcourse notebooks required not only the consideration of land use change but a reflection on the process of traditional versus technological approaches to mapping for geographical fieldwork. This consisted of an assessment of error and uncertainty.

Figure 4 illustrates the results of a student land use survey, again depicting not only the polygon data collected in the field but the post-processed creation of a map layout incorporating some basic topographic detail (road layout) and overlay of the 2004 orthophoto. This data is much more comprehensive than previous surveys that only obtained a general picture of agricultural or non-agricultural land (1984 agricultural extent depicted in inset map). Finally, figures 5 and 6 provide an illustration of the way in which ArcScene can be used to provide alternative visualizations during the evening session after the fieldwork. This provides a highly interactive environment in which to examine the area.

The exercise was successful and provided scope for a much more detailed and comprehensive piece of work within the same time scale used on previous fieldcourses. Students were empowered by the use of technology to undertake the task and this improved not only the engagement of students with the exercise, but also the quality of the results in comparison with previous years. The consideration of a range of concepts that geospatial technologies rely on made the exercise more than just a study about agricultural change. Fundamental issues relating to the measurement of geographical position could be reinforced and developed as well as providing scope for reflecting on the benefits and limitations of data acquisition using geospatial technologies. The integration of GPS technologies into the field mapping activities made students aware of low-cost GPS surveying methods. In particular, techniques that can be used to increase positional accuracies were explained prior to their use. These included: field-work pre-planning to consider data collection during periods when the GPS constellation produces better positional accuracies (degrees of precision); the use of an external aerial to ensure maximum satellite visibility and partial reduction of multipath errors; point data collection over longer periods of time, with averaging of the resultant dataset; and the incorporation of wide area augmentation DGPS corrections, where available. Crucially, more accurate calculation of agricultural areas and an improvement in the mapped output was a significant improvement in the quality of student work. Use of the technology underpinned improved reporting of results using properly constructed maps and a more considered reflection of error and accuracy in mapping.

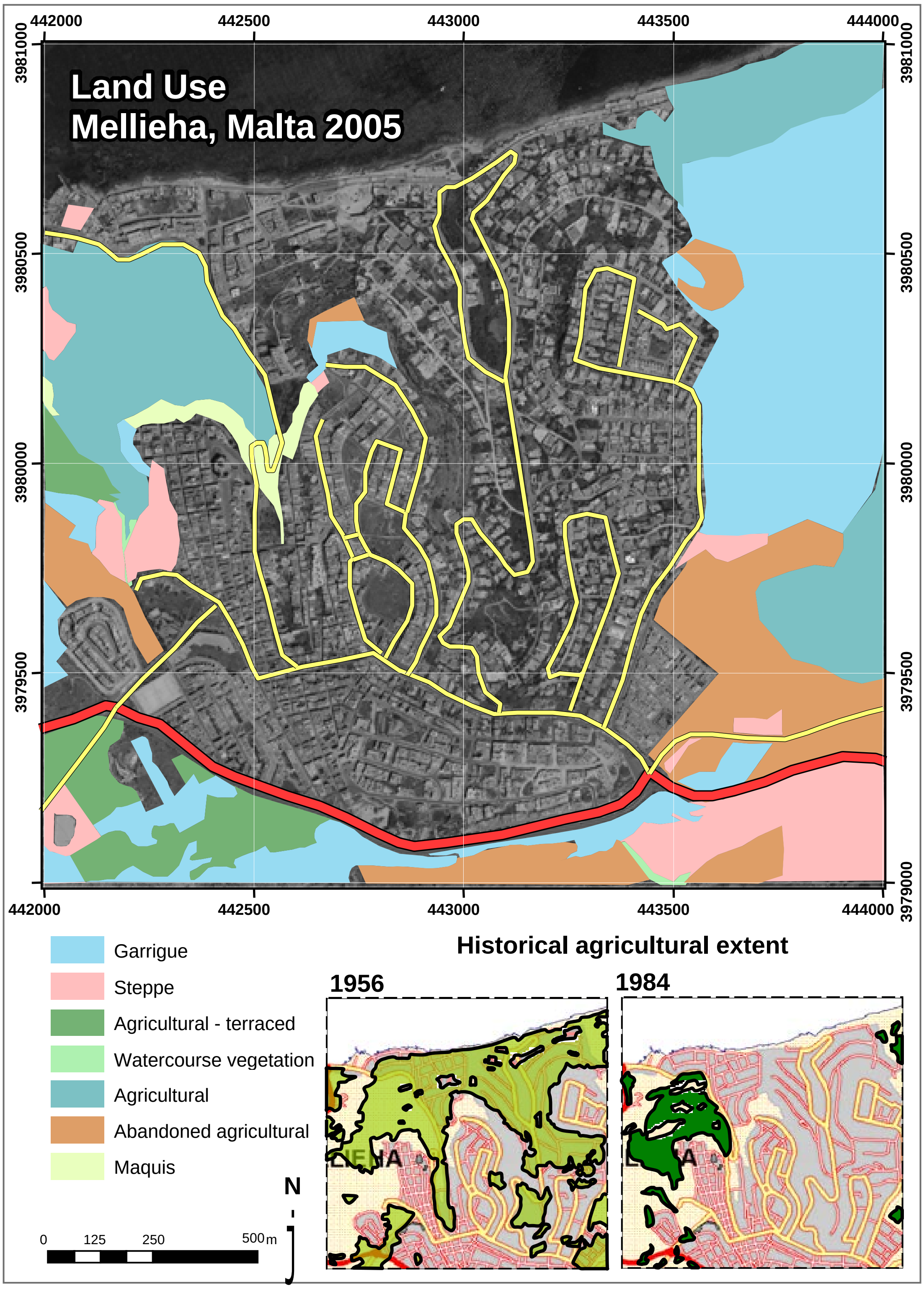

Figure 4. Land use survey and black and white orthophoto (30cm resolution)
Orthophoto and base map © Malta Environment and Planning Authority 2005

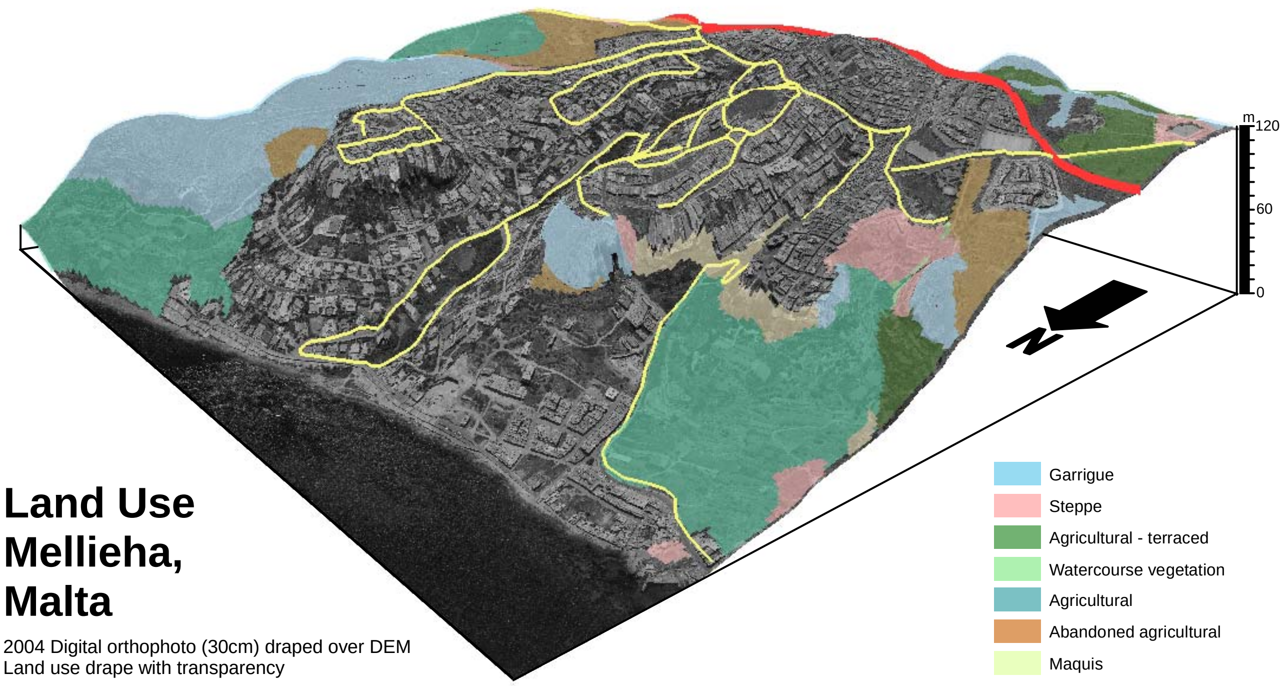

Figure 5. Land use survey draped over DEM
Orthophoto © Malta Environment and Planning Authority 2005

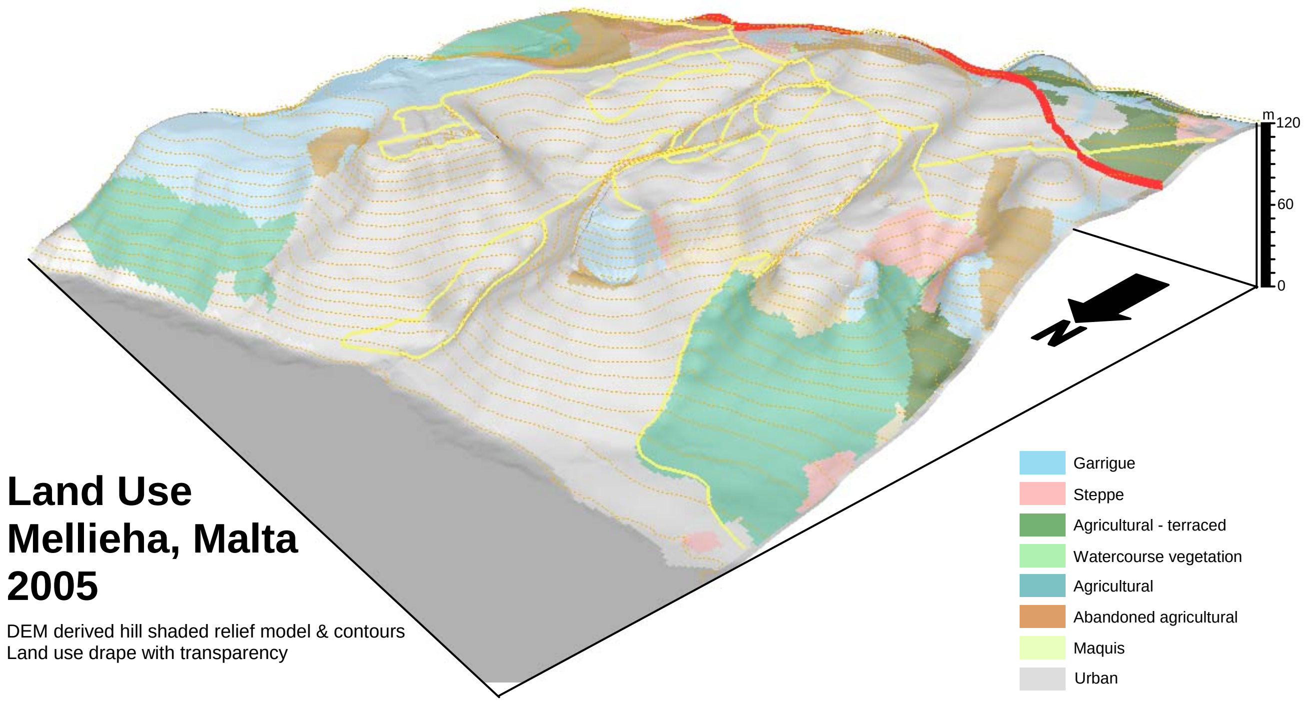

Figure 6. Land use survey draped over hill shaded relief model

Case study: Digital geological mapping in Ullapool, NW Scotland
Training in geological mapping at Level 2 for Geology, Applied and Environmental Geology and Earth Science students has employed traditional, well tried and tested, 1:10,000-scale exposure or “green line” mapping (e.g. Barnes, 1981; McClay, 1987; Figure 7). The training is carried out on a field excursion to the Ullapool district of NW Scotland and the area used is positioned geologically within the Moine Thrust belt, one of the major Caledonian Fault Systems of the British Isles (Woodcock and Strachan, 2002). This type of training is fundamental to Geology and Applied Geology degrees and is preparatory to level 3 independent mapping project and dissertations.

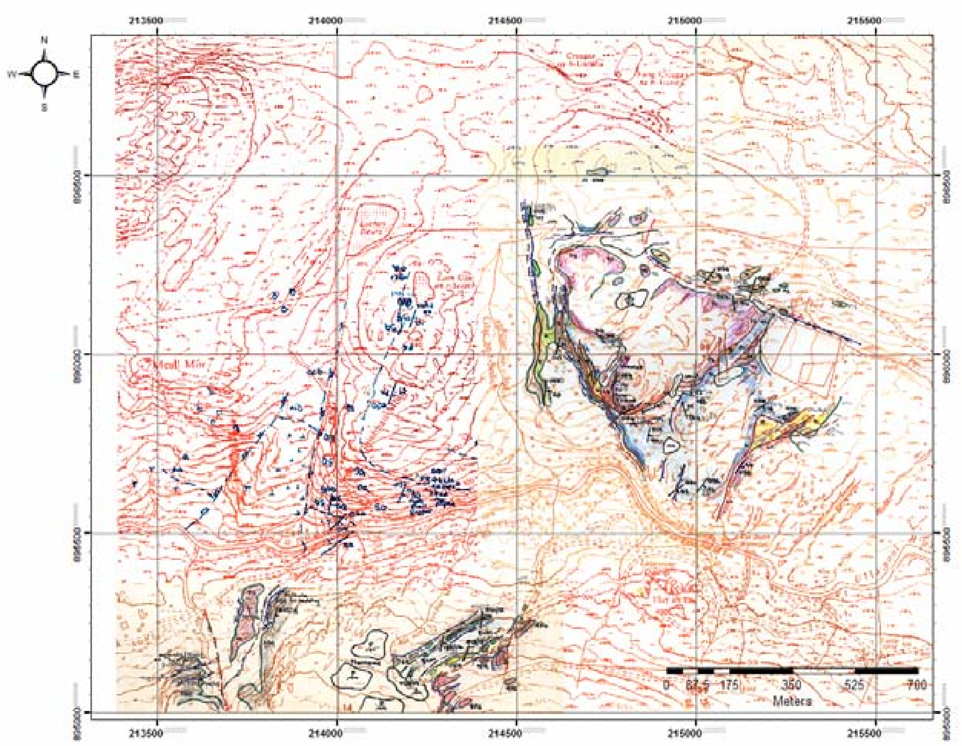

Figure 7 - Geological Map prepared by hand using the exposure or “green-line” technique. Base map © Crown Copyright 2005. An Ordnance Survey/JISC supplied service

The development of geological mapping using geospatial technologies comprises a digitally-based system that is complementary to basic geological mapping techniques. Primarily it replicates the approach that a professional field geologist takes in field mapping but using digital techniques. In addition, the new methodology incorporates the advantages of a GIS-approach to develop a new, more powerful, system for geological mapping (McCaffrey *et al*. 2003; Wilson *et al*. 2005).

The incorporation of geospatial technologies into geological fieldwork at Kingston was initiated in 2004. This was a pilot study using the same equipment described above (for the Malta fieldcourse) and enabled for differential GPS using the EGNOS system. A scanned version of the 1:10,560-scale topographical map that was used in the paper mapping exercise was loaded in ArcPad and orthorectified. The study used a simple proof-of-concept approach concerned with the initial logistics of geological data acquisition and assessment of the practical aspects of the equipment in the field during weather conditions that, at best, were unsettled.

Data acquisition concentrated on mapping geological boundaries as lines (Figure 8) and capturing lithological, stratigraphical and orientation data (principally dip and strike of bedding). The data were entered into the iPAQ PDA in the field using specific ArcPad forms relevant to geological mapping and created using ArcPad Studio application builder (Figure 9). In this way geological information could be easily and quickly recorded.

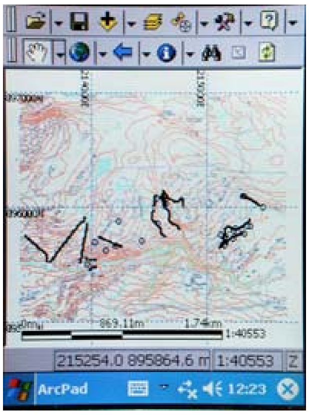

Figure 8. Screen image captured from Arc Pad showing a simple line representing a geological boundary. The grey dots are locations where data (lithology, dip and strike) are stored as shapefiles.

Figure 9. Form generated in ArcPad and used to record geological data, in this case lithology.

Practical issues that arose concerned mainly the precision of the positioning data – the scanned map contained inherent scale variations and, although the approach was generally suitable for reconnaissance geological mapping, it could not emulate the techniques used by geologists to rigorously justify the positioning of a geological boundary. In addition, presentation of orientation data as properly orientated symbols that could be “drawn” in the field in ArcPad was not implemented at this time – a serious drawback of the digital technique in relation to paper-based geological mapping. The Bluetooth wireless connection between handheld PC and GPS receiver was robust and avoided the inconvenience of hard-wired connections. The need to protect the equipment from the weather was no more inconvenient than shielding paper map and notebook.

Emulation of reconnaissance Geological Mapping

The digital mapping system was deemed evolved enough to allow students to use it during the 2005 fieldwork session. The topographic base map was drawn from the newly available Ordnance Survey 1:10,000 digital download raster images of the UK using 1:25,000 contour information of the same area (Figure 10). Used in conjunction with the Fortuna “Clip-on” GPS receivers positioning was typically within the 10m or better accuracy required in this form of geological mapping. Differential GPS from the EGNOS system was available but there seemed to be little practical difference in the precision offered by differential GPS in comparison with the 3D positional data offered in the absence of a differential GPS signal. This may be because the European EGNOS system is not yet fully operational.

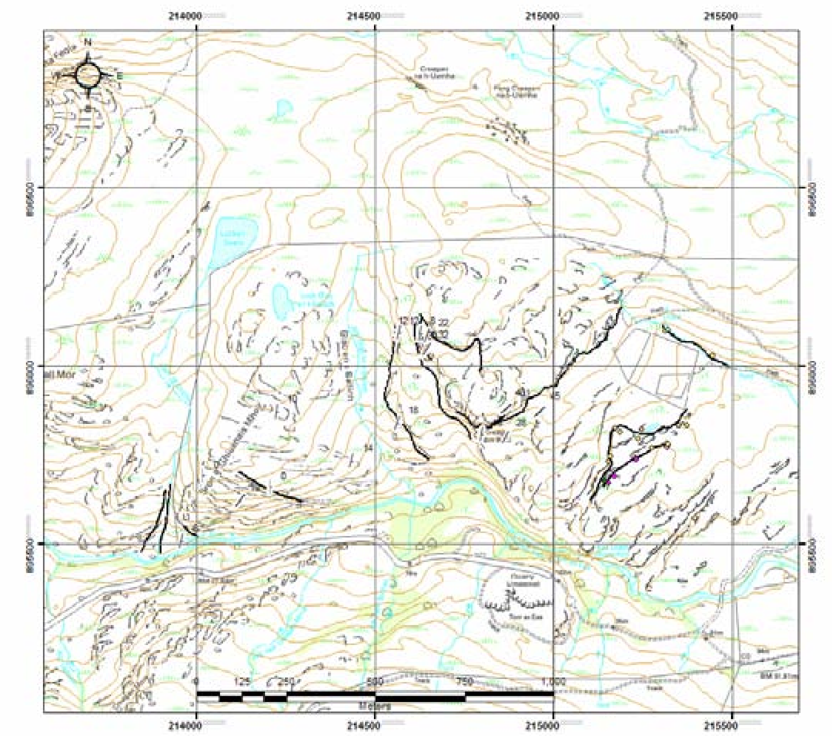

Figure 10. Ordnance Survey 1:10,000 topographic map of the Ullapool area showing geological boundaries established during reconnaissance and orientation data of bedding as dip and strike symbols. Base map © Crown Copyright 2005. An Ordnance Survey/JISC supplied service

The 2005 student exercise, like that of 2004, was a reconnaissance exercise rather than a rigorous exposure-mapping exercise. Groups of four students used handheld PCs (Ipaq 5400 series or 2700 series) and Fortuna Bluetooth GPS receivers (Figure 11). The reconnaissance mapping was again primarily concerned with recording linear geological boundary as shape files in ArcPad and point shape files that recorded strike/dip data. The mapping area was divided into four distinct areas with the ethos being that the entire mapping area would be completed on a reconnaissance level of detail when all of the students' contributions were compiled.

Figure 11. Kingston students mapping in the Moine thrust belt

Compilation was carried out in the evening after field work using a notebook computer running ArcGIS (version 9). The GIS also contained a DEM of the mapping area (Ordnance Survey Profile data), a scanned version of the published Geological Survey Geological Map of the area and scanned black-and-white aerial photographs of the area. A 2.5D model of the area was built using ArcScene, using a DEM generated from the 1:25,000 contour data to show students a model of the area that they were able to "fly through" in a virtual tour (Figure 12).

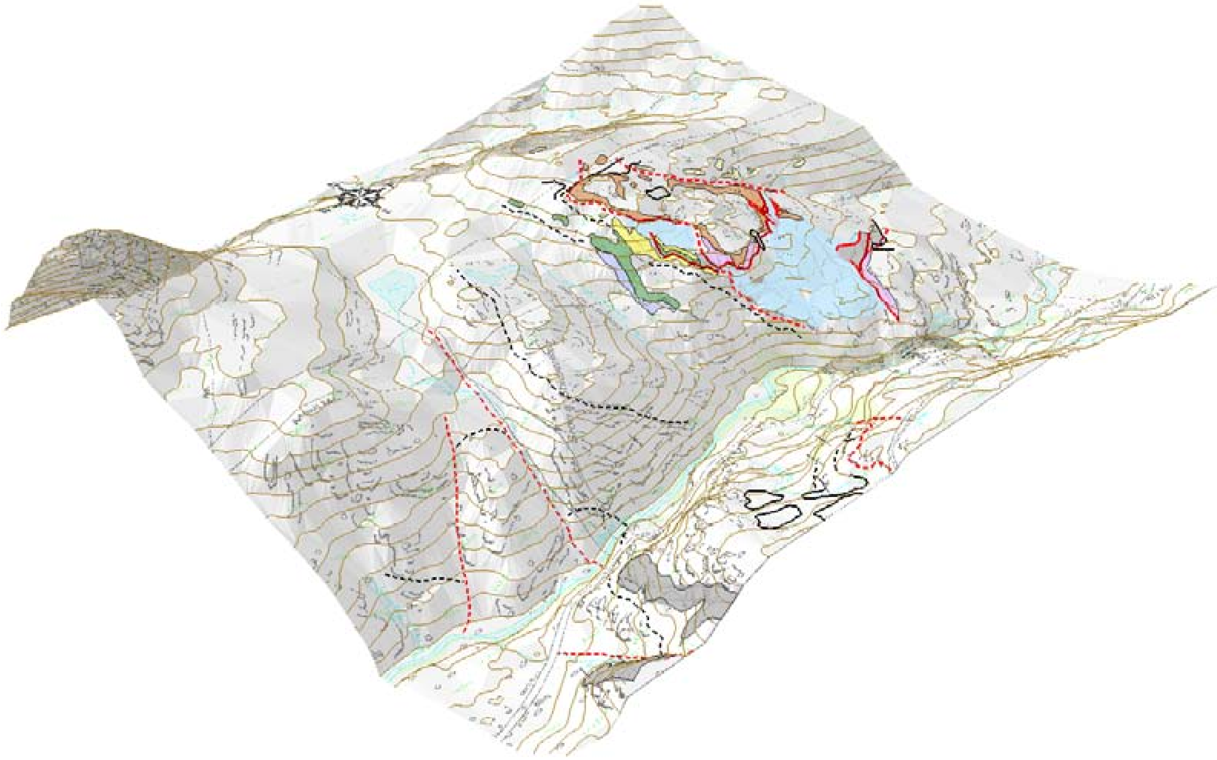

Figure 12. Geological boundaries draped over a DEM allowing a virtual tour to be created using ArcScene. Base map © Crown Copyright 2005. An Ordnance Survey/JISC supplied service

Looking ahead – towards emulation of "green-line" exposure mapping

During field work in 2005, and alongside the reconnaissance exercise, the digital mapping application was developed further by staff to more fully emulate rigorous geological exposure mapping. Two essential technical developments necessary for the transition from a reconnaissance technique to the emulation of "green-line" exposure mapping were made. Firstly, ArcPad Studio application builder was used to generate colour polygons in ArcPad which could then be used to represent the location and size of exposures of rock in the field using the handheld computer (Figure 13). The position of these exposures constrains the place where a geological boundary is drawn and represents a vital piece of scientific justification for boundary positioning on a geological map.

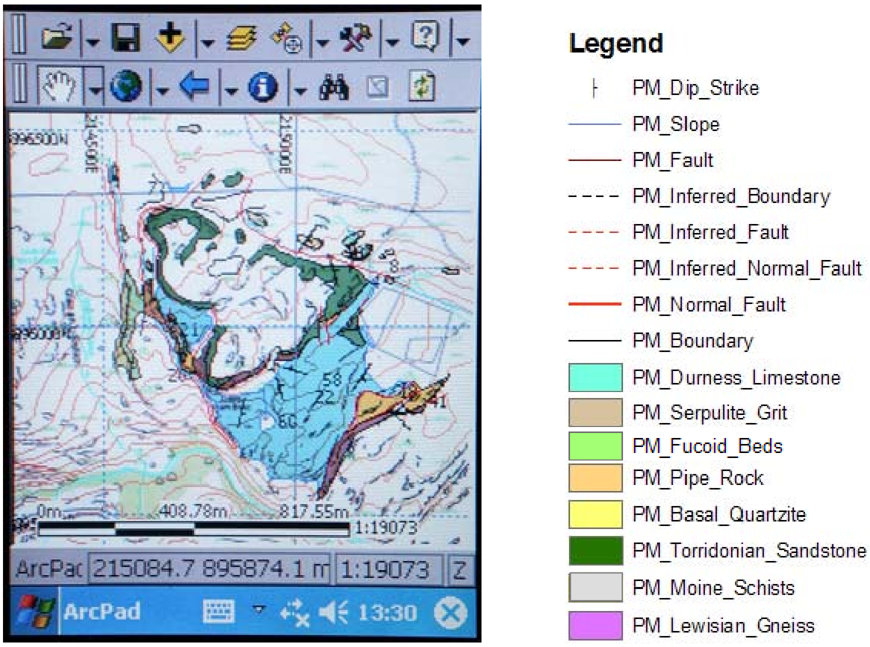

Figure 13. Emulation of exposure mapping using ArcPad. Captured screen image showing rock exposures coloured according to lithology and geological boundaries shown between them.

Secondly, geological mapping requires the symbol for orientation data (for example the dip and strike of bedding in a rock exposure) to be plotted at the time of measurement, in the field. This is necessary so that the practicing geologist can visualise the geology in 3D on location. This can never be a task for post-processing in the evening following fieldwork. During field work in 2005 we were also able to use ArcPad Studio application builder to plot and rotate symbols in the field in ArcPad, so that the geologist can plot orientation data on-the-spot (Figure 14).

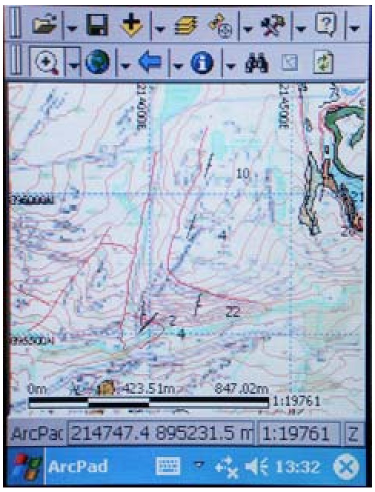

Figure 14. Emulation of exposure mapping using ArcPad. Captured screen image showing “green-lining” of exposed rock and proper representation of geological symbols in the field as measured in the field – an essential part of the geological mapping technique that must be emulated by the digital approach

With these two developments, we are now in a position to emulate geological exposure mapping in the field closely and field instruction in this method will take place in 2006 during mapping training. Students will also be offered the opportunity to carry out independent geological mapping and dissertation work using digital techniques.

The 2005 field work showed the advantage of implementing first-generation datasets as base maps. Using the downloaded Ordnance Survey raster base map and contour data we normally found <10m positional error when combined with the GPS. Positioning was further helped by the recent implementation of the EGNOS differential GPS system over Europe. During the fieldwork over 80% of the time we were able to acquire a DGPS signal that positioned the user very accurately (within 10m). Problems acquiring this DGPS signal were only made apparent when working very close to cliff sections where access to a clear sky / good signal was not always possible, although this emphasises that use of GPS complements but does not replace traditional map-reading skills.

Educational Benefits and Limitations: reflections on the Kingston Earth Science and Geography experience

Digital field mapping was completed by the students quickly and efficiently and the automated positional control was a real boon to Geoscience students who often struggle to read maps efficiently. Standard map reading is a skill that takes time to develop and many students find this one of the hardest things to accomplish during any mapping project or training exercise. We found during the 2005 fieldwork that students that appeared unable to grasp traditional paper mapping techniques were far more comfortable using the digital mapping equipment. Using the digital mapping equipment to confirm location made the students far more confident in their own abilities and allowed them to concentrate on the core subject matter of the mapping. Another typical concern of students is the fear of making irretrievable mistakes on paper, which again is removed by using the digital mapping equipment.

In terms of the Ullapool fieldcourse, the digital approach used allowed students to focus immediately on mapping geological boundaries, the primary objective of geological mapping, without the distraction of the initially “fiddlely” exposure mapping technique – this is dangerous scientifically however, because rigorous (as opposed to reconnaissance) geological mapping demands very careful justification of why a boundary is located where it is located (see below). The reconnaissance technique used was unsatisfactory in this respect.

In the evening compilation sessions, the primary advantages of GIS-based mapping: rapid compilation from several student groups to a single data-base, advantages of viewing data at different scales to see the spatial context of any subset of the data and the advantage of overlaying multiple data sets in the GIS, were immediately obvious to staff and students.

Post-processing of the reconnaissance mapping in the evening and combination of their work with other data layers helped students visualise the structural complexities of the geology or, likewise, the detail of land use extent and type. The ability to be able to construct 2.5D animations of the study area, draped with results of the day's work not only provides an alternative method of visualizing the work but also provides students with a focus of interest in an era when paper sketch mapping fails to capture their excitement.

During the Ullapool fieldcourse, a major limitation to the equipment were the elements, as typically mapping in Scotland is associated with rain. In the 2005 fieldwork week we were presented with frequent showers and two days of snow. Using handheld PCs with "weather writers" or proprietary waterproof cases is vital to properly protect the equipment but the technique is no more vulnerable to the weather than paper-based mapping. The Malta fieldcourse does not suffer with such inclement weather – maybe more a function of the desire of human geographers to work in pleasant weather, but that in itself does not provide a hindrance free operation. In Malta, the sunshine can be particularly bright and it is sometimes difficult to see the PDA screens. Whilst this is only a moderate nuisance, it does require some patience. In practice, the main practical difficulty was iPAQ battery life, particularly in the older 8500 series PDAs and this had to be monitored and managed carefully to enable a full days' work.

Students are now equipped at Level 2 in the use of geospatial technologies for accurate data acquisition. This extends their skills considerably and has already led to a number of students developing their independent research projects using mobile mapping for a range of purposes. Furthermore, mobile and internet GIS is becoming widespread and it is important our students are educated in developing technologies. Fieldcourse environments provide a perfect opportunity to introduce mobile mapping and GIS to students studying GIS but also to those studying geoscience subjects more widely. These are becoming key skills threads through our degree programmes.

We have found that to emulate traditional paper mapping with ArcPad is achievable by the detailed application developments described. An important issue concerns data backup and we intend to introduced a protocol for backing up data regularly by users during fieldwork. This is no more involved than backing up any other type of digital data but is particularly important during field work because the opportunity to return to an area when data has been lost may not be available.

A related issue concerns the field notebook. We intend to develop our system for mapping by using handheld PCs to record notes, sketches and digital photographs. Again, data back-up will be an issue but we believe that this approach to digital mapping can precisely emulate paper-mapping and bring to the science all the spatial advantages of GIS. We intend to develop fully digital mechanisms to record a range of data in the field to replace the paper based field notebook.

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