Topographic and Geological Mapping in the West of Ireland

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A series of topographic and geological maps of Connemara in the West of Ireland have been produced and published by the Department of Geography and Topographic Science at the University of Glasgow over the last twelve years. The work, in collaboration with the Department of Geology, ensured the publication in cartographic form of the results of many years of research on the geology of the west coast of Ireland and in particular, Connemara and South Mayo.

The author describes the surveying, photogrammetric, and cartographic operations undertaken by undergraduate and postgraduate students for the purpose of the systematic topographic mapping of Connemara at a scale of 1:10,000 to act as a base for the publication of a series of detailed geological maps of the Connemara area at a scale of 1:10,000, and the production of overview geological maps at a scale of 1:63,360.

The production of large-format multi-coloured maps incorporating so much detailed topographic and geological information has involved many man-years of effort. The author is confident that they will bring to a wider audience the results of the devoted scientific research carried out by many geologists in the West of Ireland.

INTRODUCTION

Over the last thirty years, the Topographic Science section of the Department of Geography and Topographic Science at the University of Glasgow has undertaken a wide-ranging programme of project mapping, besides carrying out its normal function of conducting teaching and research in each of its component disciplines - namely surveying, photogrammetry and cartography. The rationale for undertaking these mapping projects has been to give undergraduate and post-graduate students additional training to supplement that given in practical field and laboratory classes and field camps by undertaking real live projects to a professional standard. This allows them to integrate all their different courses in surveying, photogrammetry and cartography within the context of a complete mapping project. Also it enables them to relate their theoretical academic studies to the practical survey and mapping work that they are likely to encounter when they pursue a professional career in this field. This has proven to be a valuable, indeed indispensable, part of the programme. Furthermore, rather than simply carrying out such a project as an exercise over the same piece of ground every year, the mapping projects have mostly been undertaken to assist field scientists with the publication of their research work. In the U.K., a large number of topographic, geological, vegetation, and archaeological maps have been produced and published, especially in certain more remote areas of the country - in North Wales and in the North and North-West of Scotland. Also in the 1960s and 1970s, a number of maps of glaciers in Switzerland, Iceland and Norway were produced to show their advances and retreats during this century. However with the inflation of the mid-1970s and the sharply rising costs which resulted during that period, it became too expensive to travel to and operate in these countries with large student parties.

Just at that time, Professor Leake was appointed to the chair of Geology at the University of Glasgow. He and his colleagues and post-graduate students, together with their collaborators in the geology Departments of Irish universities, had in fact been carrying out research on the geology of the west coast of Ireland, especially in Connemara and South Mayo, for many years. This had involved a huge effort in terms of systematic geological field survey and the associated laboratory work. While parts of this work had been published in the form of papers, monographs, etc., including a number of small-format black and white maps incorporated in these publications, no attempt had been made to publish all their meticulous and detailed field work in the form of a systematic series of multi-coloured geological maps. Once this became known to the Topographic Science group, a discussion then took place with Professor Leake and his colleagues about the possibility of a collaborative project to ensure the publication of all this material in cartographic form. The geologists assured us that the whole area is of especial interest and importance, both in terms of the geology of the British Isles and also since it is the nearest link in the Old World to the Appalachian Mountains in the New World. The result of these discussions was an agreement to collaborate on the mapping of Connemara, and gradually, over the last twelve years, a series of topographic and geological maps of the area have been produced and published.

When the initial situation was examined, it was in fact rather daunting:

Topographic Maps:
The old six-inch (1:10,560 scale) topographic map series of the Ordnance Survey (O.S.) of Ireland produced last century had last been revised in the period between the turn of the century and the start of World War I. The maps were very out-of-date in terms of their content and were inadequately contoured.

Geological Maps:
For the area of interest, these comprised the uncoloured and hand-coloured 1:63,360 scale maps of the Irish Geological Survey dating from the 1860s and 1870s. Obviously these maps were completely out-of-date and, in particular, there was no cartographic record of the large amount of geological survey and research undertaken in Connemara and South Mayo in recent years.

Survey Control:
This comprised points fixed by the O.S. of Ireland mostly during the 19th Century triangulation and mapping. Many of these points had been destroyed or could not be located. At the start of the mapping work described in this paper, only 4 or 5 new triangulation points had been established in the area by the O.S. of Ireland, although some more have been added by trilateration in recent years.

Since all the detailed systematic geological mapping of Connemara had been carried out by Professor Leake and his collaborators using the old 19th Century 1:10,560 scale maps as the topographic base, one possibility was simply to try to bring out a series of geological maps on this base. However, since this map series was so out-of-date in terms of its topographic detail, and was uncontoured, there seemed little point in pursuing this particular approach. Furthermore, since the whole of Ireland had been covered by the 1:30,000 scale aerial photography flown by IGN in the mid-1970s, it seemed best to start all over again with a new topographic base produced photogrammetrically.

So after considerable discussion with Professor Leake and his colleagues, a three-pronged programme of mapping was decided upon. This involved:

(i) the systematic topographic mapping of Connemara at 1:10,000 or 1:10,560 scale to act as the base for
(ii) the publication of a series of detailed geological maps of the Connemara area, again to be produced at 1:10,000 or 1:10,560 scale; and
(iii) the production of geological maps at 1:63,360 scale of both Connemara and South Mayo (Fig. 1(a)), which would present a summary and overview of the geology of this part of West Ireland.

In fact, parts (i) and (iii) are those which have been tackled first. Part (ii) could not be undertaken until the topographic mapping had been completed for a given area. The resources available for the survey and mapping work, comprising field survey control, photogrammetric operations (aerial triangulation, stereo-plotting, etc.) and cartographic/reprographic work, were those of our small Department in Glasgow. The mapping programme had inevitably to be rather low key since it had to be fitted in between the prior demands of teaching, research, etc. The work has been carried out by (i) final year B.Sc. honours students in Topographic Science, and (ii) a number of post-graduate students following Diploma or Master's degree study programmes, with the support of our Departmental technical staff of cartographers and photographers.

The work started in 1978 and continued till 1983/84, by which time, a number of sheets had been completed. Then a gap occurred while mapping projects were carried out in other areas in the U.K. The work in West Ireland recommenced in 1987/88 and is still in progress.

1:10,000 SCALE TOPOGRAPHIC MAPPING

This topographic mapping has been completed over the whole area of central Connemara, starting at Lough Corrib and running westwards through the Corcogemore Mountains, the Maumturks, Lissoughter and the Twelve Pins (Fig. 1(b)). Also the topographic base has been produced for the coastal area from Slyne Head through the Errismore and Errislannan Peninsulas, and northwards to the area just north of Clifden. Over this last summer (1990), the control surveys for the area between Clifden and the Twelve Pins and the areas to the north of Clifden and to the south of the Twelve Pins have been completed, and currently the photogrammetric and cartographic elements of the topographic mapping of these areas are being undertaken in Glasgow.

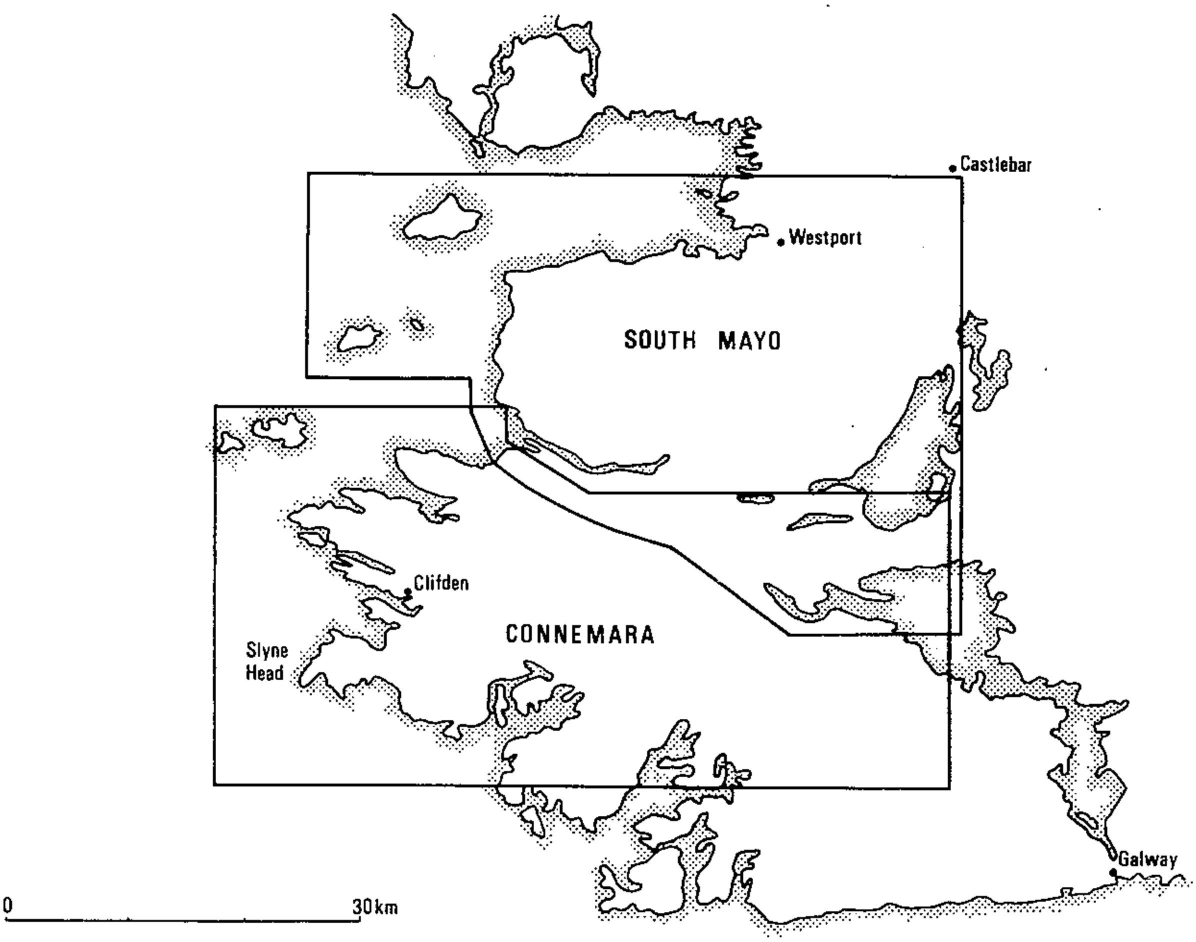

Fig. 1(a). Coverage of 1:63,360 Scale Geological Maps of Connemara and South Mayo.

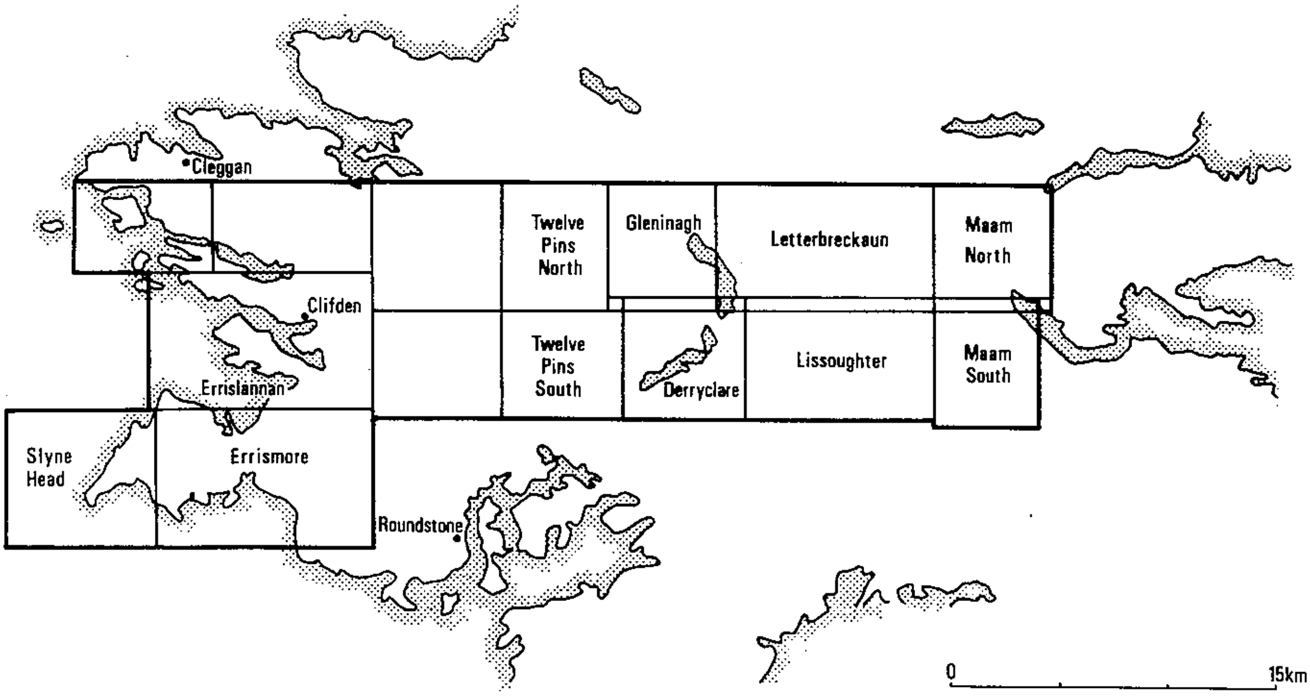

Fig. 1(b). Topographic Map Coverage of Connemara at 1:10,000 or 1:10,560 Scale.

SURVEY CONTROL NETWORKS
Since only 4 or 5 of the new O.S. of Ireland primary triangulation points existed for the Connemara area, extensive secondary triangulation, trilateration and traversing has been carried out to provide a denser network of control points from which photo control points could be fixed to enable the stereo-photogrammetric plotting to be undertaken. Different areas have been tackled in different ways, depending on the topographic characteristics of the terrain being mapped (and the weather).

Maam/Maam Cross Area
For the topographic mapping of the area around Maam and Maam Cross, starting at the west end of Lough Corrib and running westwards including the Corcogemore Mountains, a party of 6 students put in all the survey control over a three-week period. Originally a triangulation scheme was envisaged, and a thorough reconnaissance was carried out for this purpose. But in the end, a long period of very wet weather resulted in this scheme being abandoned, and all the control was put in by traversing following the roads and valleys and low ground in the area.

The main traverse started at the O.S. trig. point at Shannawona in the south and closed on the O.S. trig. point at Mauntrasna in the north. From this, 2 subsidiary loop traverses were run to provide photo control (Fig. 2). The instruments used were Kern single-second reading theodolites and a Hewlett Packard 3800B EDM instrument. In terms of accuracy, the main traverse between the two O.S. of Ireland trig. points closed to 1 part in 53,878 of the distance (40km) measured, while the subsidiary north loop traverse (13.7km) around Maam closed to 1 part in 49,514 and the south loop traverse (23km) closed to 1 part in 78,798. The heights produced by trigonometric levelling using vertical angles had closures of +1.8m over the main 40km traverse; -0.5m over the north loop traverse; and -0.04m over the south loop traverse. An initial Bowditch-type adjustment of the traverses was carried out in the field, supplemented by a least squares adjustment based on observation equations which was implemented as a program written by the students and carried out on the ICL mainframe computer back in Glasgow.

Based on these adjusted traverse points, a further 32 photo points were fixed on which the absolute orientation of the stereo-models was based.

Western Maumturks/Lissoughter Area
During the next year, again a party of 6 students undertook the provision of control to the west of the previous area. This covered the area of the western Maumturk Mountains and Lissoughter up to Derryclare Lough and Lough Inagh, together with the flat area immediately to the south. In fact, the weather was rather better and a secondary triangulation/trilateration network (Fig. 3) was successfully established, based on the two O.S. of Ireland trig. points at Shannawona and Loughaconnera. The angular observations for this network were carried out using Kern and Zeiss Jena single-second reading theodolites, while the distances were all measured with a Tellurometer CA-1000 microwave EDM instrument. Again the closures were excellent - circa 20 seconds in 2 triangles only, all the rest being much less. The computation of the planimetric co-ordinates and heights was carried out on the University's ICL mainframe computer using a least squares adjustment based on observation equations and employing the

CONTROL NETWORKS

△ O.S. of Ireland Triangulation Stations
▵ G.U. Triangulation Stations
• G.U. Traverse Stations

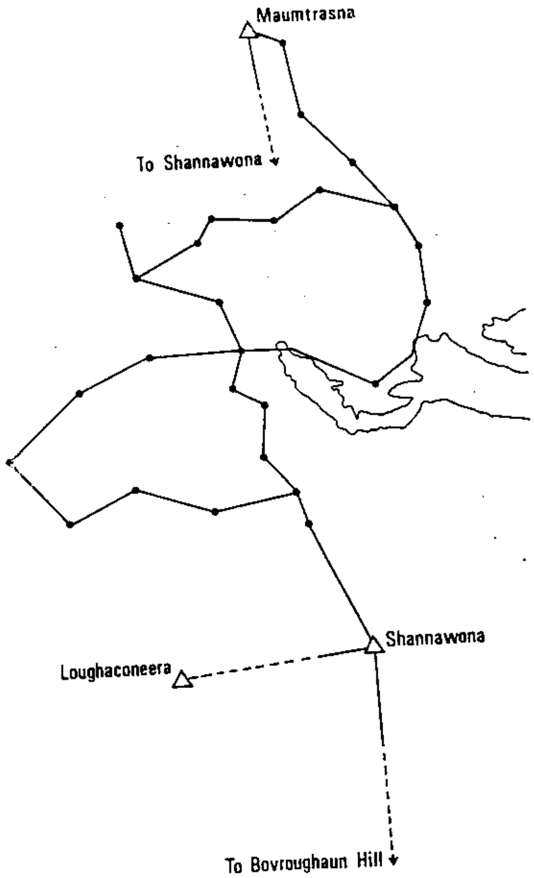

Fig 2. Maam / Maam Cross Area

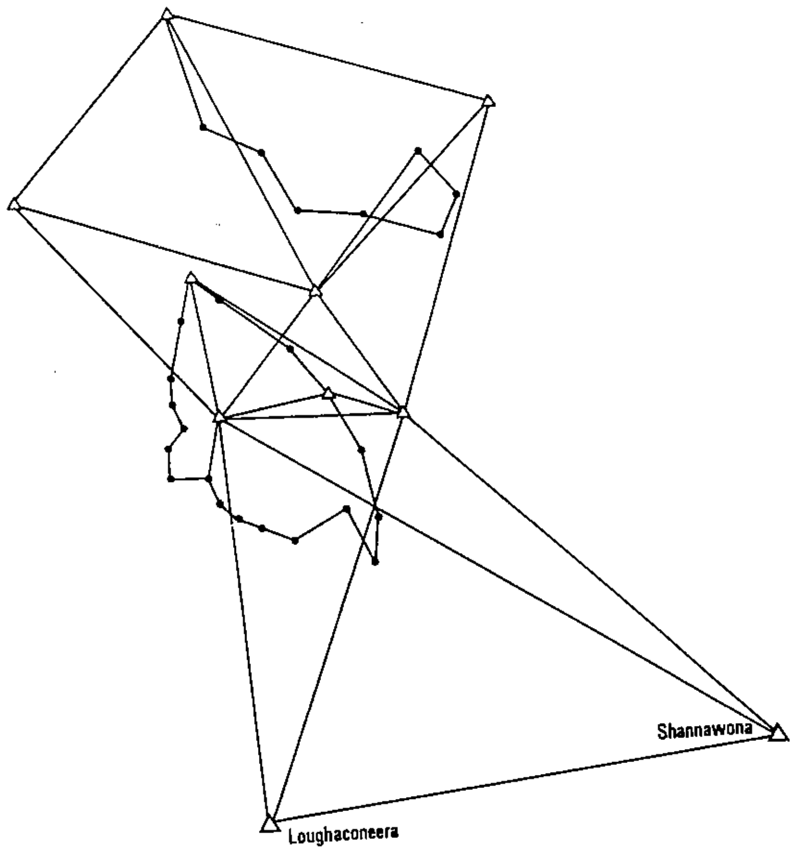

Fig 3. Western Maumturks / Lissoughter Area

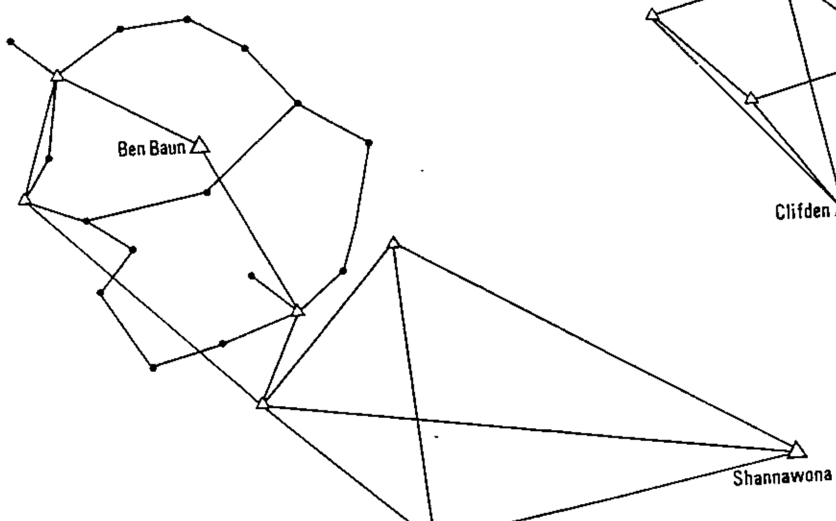

Fig 4. The Twelve Pins Area

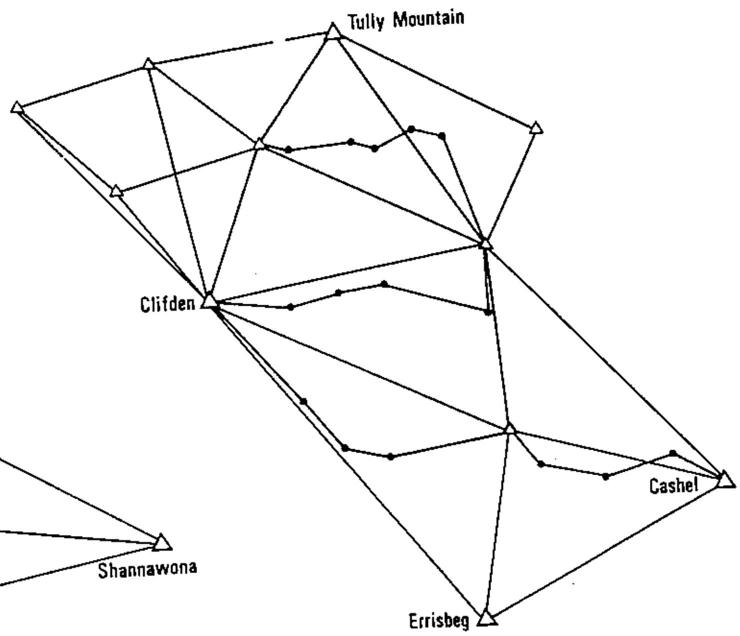

Fig 5. Clifden / Cleggan / Roundstone Bog Area

variation of co-ordinates method. The closures were excellent - the only worry being the discrepancy of 0.34m (shorter) between the directly measured Tellurometer distance and that derived from the co-ordinates of the two existing O.S. pillars.

In addition to the main triangulation, two traverses were run between triangulation stations using the single-second reading theodolites and AGA Geodimeter 12 and the Hewlett Packard 3800B EDM instruments. These were necessary for the fixing of the photocontrol points. Again the misclosures were small: 0.47m over the 21.8km long south loop traverse (=1:46.000); and 0.5m over the 18.3km of the north traverse (=1:34.000). The heights in all traverses closed to <10cm. Again about 30 photo points were fixed to give fully controlled stereo-models.

The Twelve Pins Area

The next party of 6 students tackled their area in a completely different way since it comprised the Twelve Pins of Ben Beola, a great deal of which comprises steep-sided hills with a substantial area at a relatively high altitude.

Again the instrumentation used was the same as before - Kern and Zeiss Jena single-second reading theodolites and the Tellurometer CA-1000, Hewlett Packard 3800B and AGA Geodimeter 12 EDM instruments. Connection to the two main O.S. of Ireland trig. points (Loughaconnera and Shannawona) and the existing G.U. triangulation point on Lissoughter was made by triangulation via a braced quadrilateral (Fig. 4), but all the rest of the control was carried out by traversing around the perimeter of the Twelve Pins, with a couple of cross traverses to stiffen up and check the perimeter traverse, including a connection to the O.S. of Ireland trig. point at Ben Baun. All the long traverse lines were measured using the CA-1000 microwave instrument; while all the short leg lines were measured using the HP 3800B electro-optical instrument. The closing errors and accuracies achieved on the long traverses - 1:190,000 for 44km and 1:170,000 over 36km - were quite outstanding. Quite a number (11 sets of 3) of photo-points were established, but not all of the stereo-models could be fully controlled, so aerial triangulation of the small block of photos was resorted to on the return of the group to Glasgow.

The aerial triangulation of the eight stereo-models covering the area in two strips was carried out on a Galileo Stereosimplex IIC instrument equipped with linear encoders and interfaced to a Wang 2200 S desk-top computer (Petrie and Adam, 1980). The independent model (semi-analytical) method was employed and a block adjustment carried out using the Department's own SBAIM block adjustment program with quite adequate results for 1:10,000 scale mapping.

Clifden/Cleggan/Roundstone Bog Area

This is the area lying to the west and south-west of the Twelve Pins for which the control surveys have only just been completed by a group of 11 students. The whole area was covered by a fully observed triangulation-cum-trilateration network (Fig. 5) based on the newly established O.S. of Ireland trig. points at Cashel, Errisbeg, Clifden and Tully Mountain. This resulted in additional secondary control points being established throughout the area. The observations for this network were carried out using Wild and Zeiss Jena single-second reading theodolites for the angular measurements, while the distance measurements of all the sides were carried out with Microfix microwave EDM instruments. Once again, excellent closures were achieved - with almost all figures closing to 10 seconds or better, only a single misclosure of 24 seconds for a centered polygon being worse than this.

As with the previous areas, a series of traverses was run between these points to allow photo control points to be established in suitable positions to permit the setting-up of the stereo-pairs for the photogrammetric compilation of the topographic base map. As before, this supplementary traversing and photo point fixing was carried out using electro-optical EDM equipment, in this case, Wild Citation CI-410 and 450 and Distomat DI-20 instruments mounted on Wild theodolites. However, due to the malfunctioning of some of this equipment, the Microfix microwave EDM instruments were also used to complete some of the traversing. The accuracies achieved were again high - misclosures of 1 part in 35,000 over distances of 11km and 21km respectively.

While rapid computational methods - equal shifts adjustments for the triangulation figures and the Bowditch method for the traverses - were carried out in the field for checking purposes, currently a full least squares adjustment of the whole network on the ICL mainframe computer is being undertaken at the University using the Geodetic Suite written originally by Professor Cross (1984) of the University of Newcastle-upon-Tyne and modified slightly by the Mapping & Charting Establishment for use on ICL/VME systems (Ruffhead 1986).

Coastal Areas

The area stretching from Slyne Head eastwards along the Errismore Peninsula and northwards past Ballyconneely and Mannin Bay to Ballinaboy and Clifden has also been plotted. Given the large amount of identifiable detail in this low lying and well populated area, planimetric control for mapping has been derived mainly from well-defined points on the existing six-inch (1:10,560) scale O.S. topographic maps with their co-ordinates in the Cassini Projection system transformed into their corresponding Irish National Grid co-ordinate values on the Transverse Mercator Projection. The heights required for levelling the stereo-models are given by the numerous spot heights located on roads and hills and also by using the level surfaces provided by the long lengths of coastline and the numerous small loughs present in the area. Where control has been sparse, resort has been made to aerial triangulation, e.g. the three stereo-models covering the Slyne Head area were triangulated using a Wild Aviomap instrument equipped with the RAP system and fitted on to the existing control using the measured model co-ordinates and a block adjustment program.

PHOTOGRAMMETRIC PLOTTING

All the aerial photography used in the mapping work in Connemara formed part of the national coverage of the Republic commissioned by the Geological Survey of Ireland. It had been flown by IGN in April 1973 using a Wild RC8 camera equipped with a Universal Aviogon lens with a focal length of 152.72mm. From the average flying height of 4,720m, this gave a photo scale of approximately 1:30,000. The film diapositives used in the stereo-plotting machines and the prints used in the field and in the laboratory were all supplied by the O.S. of Ireland.

Most of the stereo-plotting has been carried out by final year honours undergraduate students on the Department's Kern PG2, Wild B8 and Galileo Stereosimplex IIC stereo-plotting instruments (Fig. 6), though the Slyne Head area was plotted by a post-graduate student using the Wild Aviomap + RAP combination mentioned above in connection with the triangulation of this area. The most recent stereo-plotting of the coastal areas of Errismore and Errislannan running north to Clifden

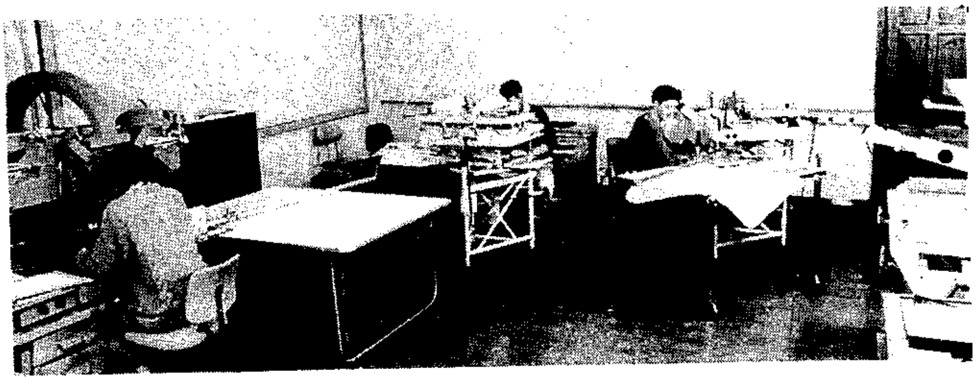

Fig. 6. Stereo-plotting Instrument Laboratory at the University of Glasgow.

has been plotted by a Departmental teaching assistant who has previously worked professionally as a photogrammetrist with a commercial air survey company in the U.K.

With regard to the relative orientation of the models, this has always caused difficulties to the students who are fairly inexperienced in these matters when they begin their projects. In particular, they experience difficulties in the very hilly areas, arising from the large Z-ranges, and in the coastal areas, due to the incomplete models resulting from the large areas of sea which occur in many of the

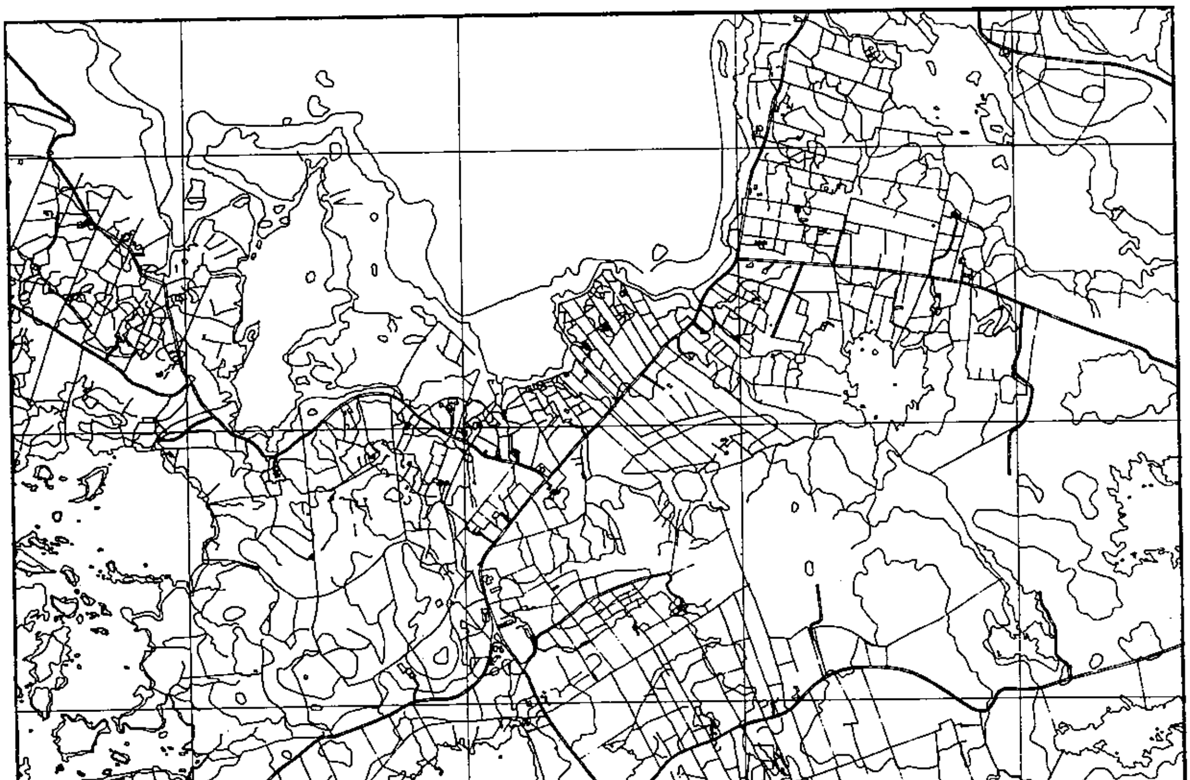

Fig. 7. Sample Stereo-photogrammetric plot of part of the Errismore Area.

models. But they do learn to cope with these difficulties and to solve the associated problems to produce satisfactory orientations of the stereo-models.

Also the plotting of the planimetric features - roads, field boundaries, bridges, buildings, streams, lochs, forest boundaries, etc. (Fig. 7) - has proven not to be too difficult once experience has been gained by the students. However it must also be said that, in many ways, this has been the least satisfactory part of the mapping work for the following reasons:

(i) The aerial photography taken in 1973 is now badly out of date, especially having regard to the large number of new houses and buildings which have been erected in the coastal area in recent years. However this is a much smaller problem inland where such changes are relatively few in number.

(ii) The students vary a lot in their devotion to duty during plotting, some taking great care to ensure as complete a plot as possible, while others are less thorough and miss some obvious features.

(iii) The implementation of a thorough and systematic field check would of course do much to repair the omissions mentioned in (i) and (ii) above, but it has not been possible for logistic and financial reasons to implement such a procedure when based far away in Glasgow, Scotland.

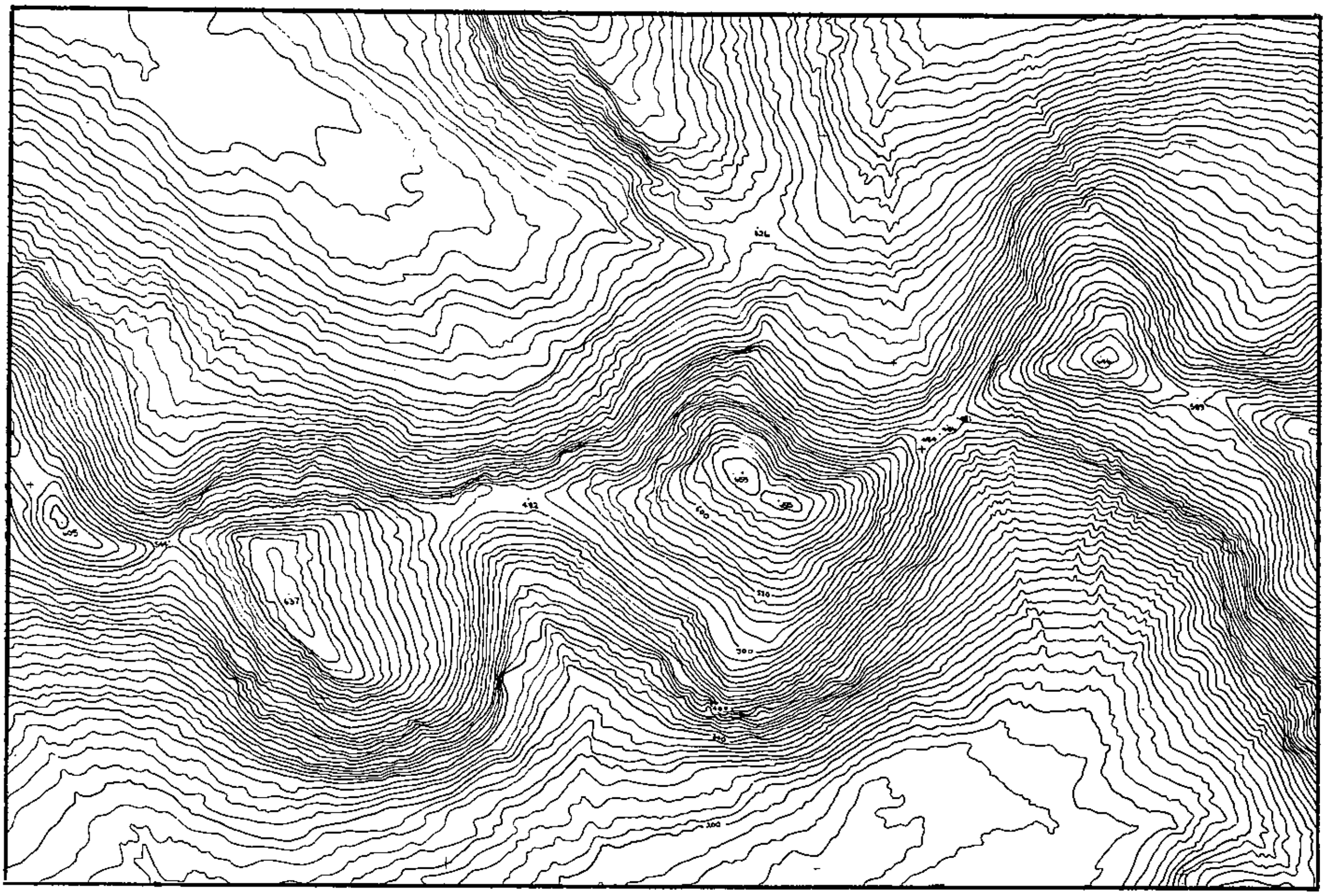

Fig. 8. Contour Plot of Part of the Twelve Pins Area.

The contouring has been executed using a vertical interval of 10m. Here again, the students carrying out the work find difficulties in the quite extensive areas of shadows encountered in the hilly areas of the Corcogemore Mountains, Maumturks and the Twelve Pins and also in contouring the very flat areas of bog and loughs present to the south of the main Galway-Clifden road. However, even with these shortcomings and difficulties, the contours (Fig. 8) give, for the first time, a really good idea of the terrain surface shapes and landforms present in the area, which is an absolute requirement if the final map is intended to adequately represent the geology of the area and to assist in its interpretation.

Once plotting of all the individual stereo-models has been completed, the plotted data is then compiled on to sheets of stable polyester material, typically with all the planimetric detail and water detail (streams, loughs, etc.) on one sheet and all the contours on a second sheet. Registration is ensured by the pre-punching of the sheets and the exact superimposition of the grid lines present on each.

CARTOGRAPHY

All the topographic map sheets produced by the undergraduate students have been produced as provisional editions in the form of three- or four-colour proofs - usually comprising

(i) Black: border and grid lines; roads, tracks, paths, etc.; buildings, ruins, etc.
(ii) Blue: line features - rivers, coastlines, lough outlines, etc.; and water areas - loughs, reservoirs, etc.
(iii) Brown: both standard and index contours.
(iv) Green: woods and forested areas.

All the line detail is produced by scribing on suitably coated polyester sheets using sapphire point scribe tools, while all the areas are produced by cutting open window masks using scalpels. The names, numbers, symbols, etc. are stuck up using adhesive backed film, the actual text, numbers, etc. being produced in the required typeface and at the correct size using a Barr & Stroud Photonymograph photo-lettering machine. Since these "stick-ups" are all produced in positive form, they first have to be converted photographically to negative form by contact printing in a vacuum frame. This then ensures that all the reprographic material (scribes, masks, lettering) is in negative form, which is necessary to produce the final coloured proof using the Kwikproof method. The flow diagram included as Fig. 9 summarizes the cartographic/reprographic method used to produce the 1:10,000 scale topographic sheets.

1:10,560 SCALE GEOLOGICAL MAPS

At the present time, three of the topographic base maps for the coastal area have been used as the basis for the production of geological maps at the 1:10,560 scale. These have been produced

(i) by conventional manual methods using scribing, masking and photolettering techniques and conventional photographic/reprographic processing, followed by offset-litho printing; and
(ii) using digital/automated cartographic methods, again followed by photographic processing and offset-litho printing.

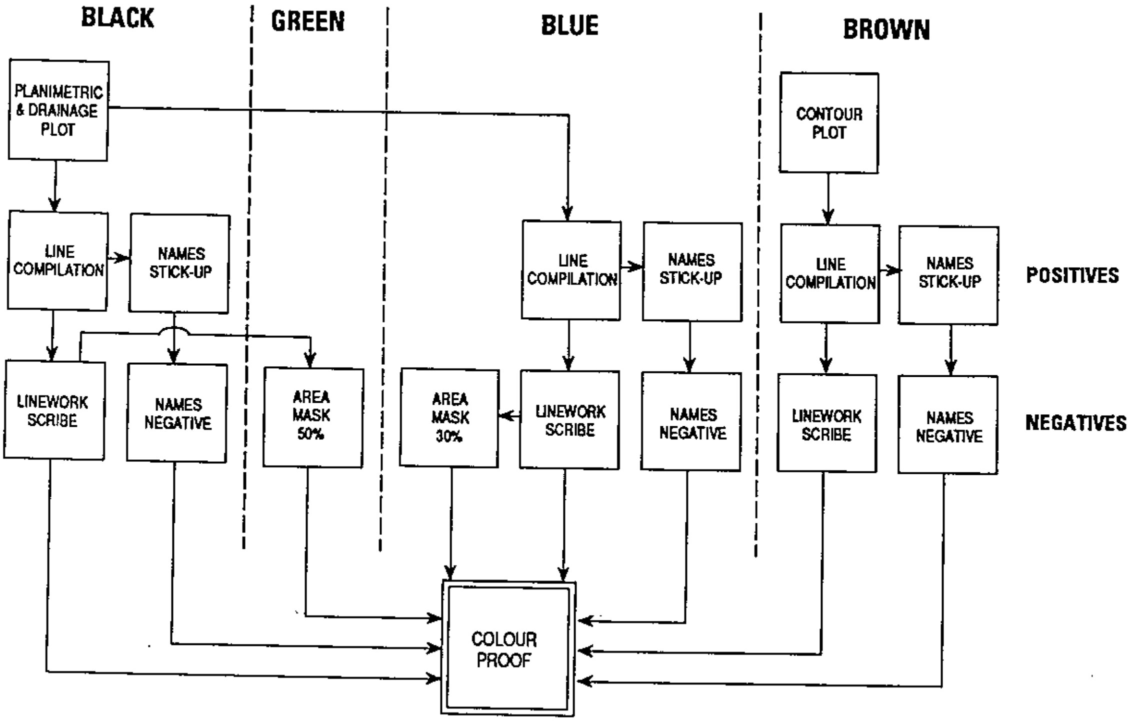

Fig. 9 Flow Diagram for the Cartographic Production of the 1:10,000 Scale Topographic Maps of Connemara.

In both cases, the photogrammetrically plotted topographic base map has been overlaid by a punched, registered sheet and all the geological information, such as boundaries, faults, folds, dykes and veins, has been transferred from the geologists' field documents. These take the form of the small slips or cards into which the old O.S. 1:10,560 scale topographic sheets had been divided for use in the field. While there are substantial changes between the old O.S. map and the newly plotted topographic base, it is almost always possible to recognise common points of detail such as walls, fences, loughs and buildings on the two maps. These are brought into coincidence using an optical transfer device - the Bausch & Lomb Zoom Transfer Scope (ZTS) - which can then be used to transfer the detail optically on to the new base sheet. The lines and symbols depicting the geological information are then inked up and the areas of different rock types are coded in different colours using coloured pencils. Given the very great amount of geological detail that has been mapped meticulously in the field, this compilation of the geological information on to the new topographic base is a very time-consuming procedure and has required great care and systematic checking. Also some degree of generalization has been necessary because of the density of small geological features. Luckily, in each case, a post-graduate student or assistant with a degree in geology has been available to make these decisions (under the general guidance of Professor Leake) about what should be omitted or simplified.

GEOLOGICAL MAP OF SLYNE HEAD

This map was produced as the prototype in the series by a Canadian Master's degree student in Cartography who is a geology graduate (Steinhauer 1986). She has designed the sheet (Map 2) in collaboration with Professor Leake. Needless to say, it incorporates many standard geological symbols, but the choice of colours for the different geological types on the sheet also reflects both geological convention with regard to type of rock (granite, gabbro, gneiss, etc.) and the range of rocks and their ages likely to be found in the west of Ireland. Since very many colours are needed to accommodate this range of categories, it was necessary to use the standard tri-chromatic process colours (cyan, magenta and yellow) for the areas, supplemented by black for the planimetric details, geological boundaries and structural symbols, and brown for the contours, making five colours in all.

The actual production method may be viewed as being a very extended and more complex version of that used for the topographic sheets and described above. All the line work which will appear in black, brown and blue (cyan) has been scribed on separate sheets; separate stick-up sheets have also been generated for the names, symbols, contour numbers, etc. to be produced in each colour; and individual masks have been cut for all the areas which need to be represented as different geological types. Again all the positive stick-up sheets have been converted to negatives and together with the negative scribes and masks have been used to make colour proofs on plastic using the Kwik-proof method. Once all the necessary corrections had been made, the separate components were combined by contact exposure to produce the colour-separated positive film transparencies for each of the five colours in which the map would be printed. From these, another set of proofs to check the colour appearance was made using the Cromalin process. Next, printing plates were made and a set of machine proofs produced on paper. Lastly the final multi-coloured maps were printed using standard offset litho procedures.

GEOLOGICAL MAPS OF ERRISMORE AND ERRISLANNAN

The cartographic production of the Errismore and Errislannan sheets lying adjacent to the Slyne Head sheet has been undertaken using entirely different digitally-based techniques. Thus the prior photo-grammetric plotting and compilation and the transfer of the detailed geological information has been undertaken in much the same way as was done for the Slyne Head Sheet. However, all the compiled data - plani-metric, contour and geological - has been digitized manually using the Map Data system (Fig. 10), which comprises large-format tablet digit-

Fig. 10. Map Data Digitizing/Editing Systems Used for the Acquisition of the Topographic and Geological Data of the 1:10,560 Scale Geological Maps of Errismore and Errislannan.

izers attached to microcomputers (IBM-PC clones) to carry out the interactive digitizing/editing operations. Needless to say, the digitizing of so much topographic and geological information and its checking and editing via screen displays and hard-copy plots is an extremely exacting and time-consuming activity. The digitized line data is of the unstructured spaghetti type. Thus the polygons defining the boundaries of the areas which will be colour filled are not structured using nodes, segments, etc. with the appropriate topology (such as connectivity, adjacency) defined. Instead, each area is formed by placing a seed within the polygon from which the fill pattern will flood out until it meets the bounding lines of the area.

All of this area filling process has been carried out by Map Data Management at Kendal using its Scitex processor and software. Each area is filled with the individual dots required to give a tint pattern with the specified percentage (30%, 50%, etc.) and the specific orientation angle (15°, 30°, 45°, etc.) needed to avoid the generation of moire (interference) patterns in the finally printed map. This polygon area flooding/filling operation is carried out for each of the colour separations (cyan, magenta, yellow, black) in turn, being combined with the digitized line work and symbols for each colour. This allows an initial check by the operator to see if there are any obvious errors or omissions in the digitized data. For example, if there is a small break in the line enclosing an area or polygon, or if the line has not been properly closed during digitizing, the flooding operation will continue outside the required area. This must be corrected and the area reprocessed. Then finally the whole of the data is rasterized and a colour proof is made by dumping each coloured screen image on to a colour thermal wax transfer plotter. Since this type of plotter can only print out an A4-sized image, it has needed eight of these images to produce a proof of the Errismore sheet which is 1m by 80cm in size.

The eight A4-sized images were then mosaiced together to give a composite proof which was then systematically checked for errors, omissions, etc. back in Glasgow. All necessary corrections were made using the digitizing/editing facilities of the Map Data work stations and the disks were then sent back to Map Data Management in Kendal for reprocessing of the corrected data. Finally the data for each colour separation was rasterized and down-loaded on to a magnetic tape which was then sent off to a bureau - Bartholomews in Edinburgh - which has a Scitex 280 raster film plotter with a very high resolution (2,000 dots per inch) that can accommodate the large formats required. The five colour separated films have been generated on the Scitex machine and then returned to Glasgow for combination with the appropriate lettering "stick-ups" which have been produced manually. Again a Kwik-proof has been made for checking purposes and the map will go off shortly to the printer for plate-making and printing.

At the moment, it definitely takes very much longer to produce the map digitally than by conventional manual methods and it is much more expensive to do so. Also it is a singularly unforgiving process. The occurrence of a few errors or omissions during digitizing means that the whole of that particular colour separation, needs (expensive) re-processing, whereas the same errors might involve only a few minutes work altering a scribe or mask using the traditional manual method. Obviously part of the long time taken to produce this map using digital methods results from the steep learning curve involved in introducing this process, but even allowing for this, it really is a complex and inflexible operation. Now that experience has been gained, it is hoped that the adjacent sheet to the north (the Errislannan sheet), which is currently being produced using this digital method will go more quickly, but it is still an open question whether it is economic to produce multi-coloured maps in this way at the moment. However, the digital method is being persevered with in order to get to grips with the new raster-based film plotter technology for multi-colour map production. With the expected improvements in this technology, such as faster processors, the availability of large-format full-colour raster plotters at a lower price, and the development of Postscript-compatible film plotters, hopefully more economic processing of the data and easier production of the final colour-separations will result in the future.

1:63,360 SCALE GEOLOGICAL MAPS OF CONNEMARA AND SOUTH MAYO

The two geological map sheets of Connemara (Map 1) and South Mayo (Map 3) have been produced to a common specification and in the same general style to give continuous cover of the area. As mentioned above, they are intended to give an overview of the geology of this part of the West of Ireland. In the case of the Connemara sheet, since much of the geology of the area has been mapped by Professor Leake and his colleagues in great detail at 1:10,560 scale, most of the preliminary work involved generalization and simplification of the geological information for its presentation at the much smaller 1:63,360 scale. However, a few parts of the Connemara sheet had not been mapped in quite the same detail and for these areas, such simplification has not been necessary. In the case of South Mayo, the geological information has not been available to quite the same level of detail, so the map has been produced by its authors (i.e. the geologists) compiling and joining together all the published and unpublished geological information which exists for the area. While this means that the quality and reliability of the geological information is rather more variable than for the Connemara sheet, nevertheless it was felt valuable to produce the sheet as the first colour printed map of the area showing its geology in any detail. It can be viewed as a statement of the present state of knowledge of the area and a basis on which to plan research and carry out more detailed mapping in the area in the future. Already it has stimulated new geological work and exposed unresolved problems.

The base on which the two maps have been constructed is of course quite different to that of the 1:10,560/1:10,000 scale sheets. The information given on the Irish Ordnance Survey 1:63,360 scale sheets has been used as the topographic base for each of the two maps. Since the individual sheets did not fit together too well, it was first necessary to recompile on to a single base sheet all the planimetric and contour information contained on the film transparencies of the sheets received from the O.S. of Ireland. At the same time, some generalization took place, since not all the information given on these O.S. sheets was needed for the topographic base for the geological map. Each of the base sheets has been constructed on the Irish National Grid (which is metric based), but the contours and spot heights are given in feet, since they are only available in this form on the existing O.S. of Ireland six-inch (1:10,560) and one-inch (1:63,360) maps.

As far as the cartographic production is concerned, this followed the same general methodology as that described above for the manually produced larger-scale sheet of Slyne Head. The same procedure of scribing, mask cutting and stick-up lettering was followed for both sheets with, of course, the additional burden of dealing with and incorporating many more individual geological types into the map design, resulting in large numbers of masks having to be cut for the multitude of areas of different geological types. Proofs in colour were produced on plastic sheets using the Kwikproof process as before. Then after corrections had been made to the scribes and masks, the final colour separations were produced on film. Once again, proof copies were produced in colour from these film transparencies using the Cromalin process before the printing plates were made. Machine proofs on paper were then produced before the final colour printing was undertaken.

For the Connemara area, two additional sheets were produced. The first is a map giving (i) the fold traces showing the anticlines, synclines, etc., and (ii) the metamorphism of the Dalradian rocks, printed in colour over the same topographic base as the geological map and produced at the same scale (1:63,360). In addition, a second sheet was produced in full colour giving a whole series of cross-sections constructed mostly in a north-south direction to give the user an idea of the geological structures present in the area.

In the case of South Mayo, only two north-south cross sections were constructed; one across the western part of the area, the other across the eastern part. These were incorporated directly into the South Mayo geology map and appear along the lower edge of the sheet. Fold traces for this area were incorporated into the geological map as there was less complexity than in the Connemara map.

1:50,000 SCALE GEOLOGICAL MAP OF BENNA BEOLA

Because of the special interest in the geology of the Twelve Pins of Benna Beola (Map 4), a rather more detailed map and a separate sheet with cross-sections has been produced for Dr. Tanner who had mapped the area geologically. This was carried out partly by Mr. R. Boud of the University of Leeds and partly by two overseas students following the post-graduate Diploma Course in Cartography who undertook the final production of the sheets as their Diploma projects. The cartographic methods used were pen and ink drawing of the line work and the use of dry transfer lettering for the text and legend by Mr. Boud, followed by the masking, photo-lettering and colour proofing procedures already described above which were used by the two students. The final paper copies were printed in multiple colours using standard offset litho technology and methods.

CONCLUSION

The account presented above is intended to give the reader some idea of the methods used to produce the new topographic and geological maps of Connemara and South Mayo. Obviously the production of all of these large-format multi-coloured maps incorporating so much detailed topographic and geological information has taken many man-years of effort. The maps have been produced rather slowly over quite a long period of time by a small academic department as a secondary activity to its teaching and research. However, it is hoped that they will bring to a wider audience the results of the devoted scientific research carried out by many geologists in the West of Ireland. The 1:63,360 scale geological map of South Mayo has already been published, forming part of a monograph on the geology of the area (Graham, Leake and Ryan 1989). It is expected that the 1:63,360 scale geological map of Connemara and its accompanying Fold Trace map and cross sections, together with the 1:10,560 scale geological maps of Slyne Head and Errismore, will all appear shortly as part of a Royal Irish Academy memoir (Leake and Tanner 1991). The work continues and hopefully a further series of maps will be published as a result. Those who wish to obtain copies of these maps can do so by contacting Professor Leake, Department of Geology and Applied Geology, University of Glasgow, Glasgow, G12 8QQ, Scotland, U.K.

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two coastal sheets of Errismore and Errislannan. Several Diploma in Cartography students executed small pilot projects to prove various aspects of the cartographic design of different sheets, while four Diploma in Photogrammetry students carried out the stereo-plotting of part of the Twelve Pins area. Last but certainly not least, there are the thirty or so final year honours undergraduate students in Topographic Science, each of whom has spent a large part of their final year undertaking the field survey, photogrammetric and cartographic work required to produce the topographic base sheets for their projects. Their contribution has been quite remarkable.

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