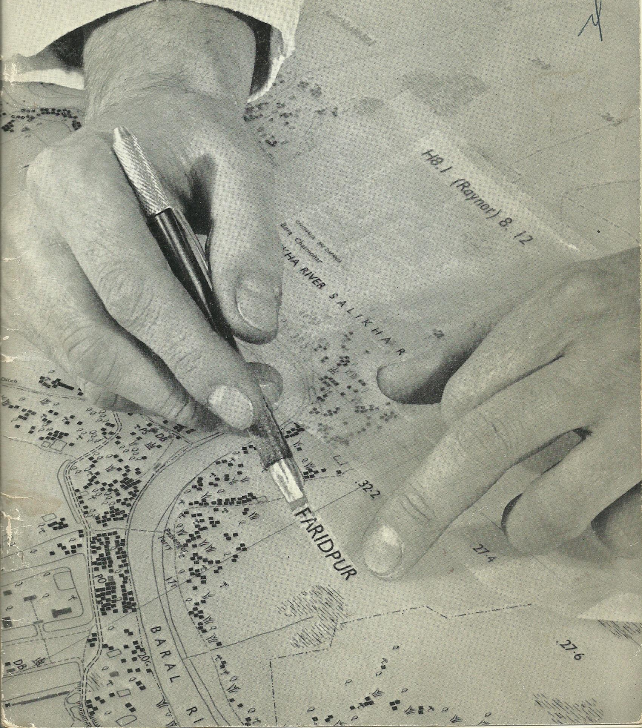
The Monotype Recorder Precision in map making

Volume 43 Number 1 Summer 1964



A copy of *The Monotype Recorder* is sent gratis to every printing office with 'Monotype' machines. Copies of this number are on sale at five shillings each.

Front cover: Lettering produced on a 'Monotype' Photo-lettering Machine being patched up on a plan at Fairey Air Surveys Limited.

Precision in map making

The Monotype Recorder *Volume 43 Number 1 Summer 1964*

The Monotype Corporation Limited

Pictorial Machinery Limited

The publication of this number of *The Monotype Recorder* coincides with the 20th International Geographical Congress and the 11th General Assembly of the International Geographical Union.

This number of *The Monotype Recorder* is set in 'Monotype' Ehrhardt Series 453 and was printed in England by W. & J. Mackay & Company Limited of Chatham.

Introduction

The 20th International Geographical Congress and the 11th General Assembly of the International Geographical Union are being held in London over the period from 20 July to 28 July 1964. It was the prospect of these events that sowed the germ of the idea for an issue of *The Monotype Recorder* devoted to map making.

In writing for a mixed audience of geographers, cartographers, and printers, it has not always been easy to gauge the appropriate level of knowledge and experience. On the one hand we have endeavoured in as simple terms as possible to introduce our regular readership to the skills of the surveyor – on which the work of cartography is based – so that both printers and typographers may have a clearer idea of what is involved in the preparation of a map for reproduction and of its ultimate function. On the other hand we have described the processes of map reproduction in such a general way that we hope geographers may obtain a better understanding of photo-mechanical and printing techniques. In approaching our subject from these two standpoints, it is possible that the cartographer, who stands somewhere between the printer and the geographer, will tell us that our efforts have not provided him with anything new. At least a better understanding between all the people involved in map making may be promoted by the simple articles that follow.

In setting down our terms of reference we must begin with a few negative statements as to what this *Recorder* is not. No attempt has been made to delve into the history of map making, although some of the sections include a very brief account of the beginnings of a technique or of an organization. Readers anxious to look back over the past are referred to the current number of *The Penrose Annual* containing an article by R. A. Skelton called 'The early map printer and his problems' which represents a good introduction to the subject.

If the *Recorder* is not concerned with map making in the past, neither is it concerned with what map making might be in the future. At the same time it must be recognized that cartography is on the brink of a great technical upheaval. Seemingly, automatic cartography is beginning to take shape and a prototype of the first system, a British one, may well be demonstrated at the International Congress mentioned earlier. The prototype of the Bickmore-Boyle System of Automatic Cartography has resulted from co-operation between Dobbie McInnes (Electronics) Ltd. and the Cartographic Department of the Oxford University Press with official encouragement and financial aid coming from the Department of Scientific and Industrial Research. Earlier studies for investigating the practicability of the basic concept were backed by The Delegates of the Oxford University Press. The system is the joint brain-child of Mr. D. P. Bickmore (Head of the Cartographic Department of the Oxford University Press) and Dr. R. Boyle, a Director of Dobbie McInnes. In a talk on the BBC Third Network, printed in *The Listener* of 30 January 1964, Mr. Bickmore said the system 'consists of a table on which a hand-made map compilation is placed: the lines on this draft are then followed or "read" with a pointer. As this pointer moves over the map, streams of x and y co-ordinates are fed to magnetic tape, giving thousands of positions per inch of line, and to an accuracy of three-thousandths of an inch. The information on the magnetic tape is coded into such features as rivers, coastlines, contours, outlines of built-up areas, and so on. A second plotting table is then brought into operation by the tape. On this table is mounted a projector with a fine beam of light; this moves again with great precision and plots lines of varying thickness on to sensitized film. The scale of the map can be altered and variations of map projection can be achieved by feeding the tape through a computer. The system will short-circuit many of the laborious production and checking stages that at present separate the map compilation from the finished negatives or positives from which it is printed.'

In the same talk, Mr. Bickmore referred to the *Atlas of British Flora* in which the distribution of 3,000 vascular plants was mapped from researches carried out by the Botanical Society of the British Isles. Each botanist was made responsible for a 10-kilometre square area of the country and given a list of the plants to be covered by the survey. Thus armed, each observer had to record the occurrence or absence of the listed plants in his area. If a plant was seen in an area, a black dot signified its presence on the map. All the information collected from the 'field' was stored on punched cards for processing in a special machine which placed the dots in the appropriate squares on the map. These two examples show that cartography is very much on the move and within the next few decades exciting changes can be expected.

Since the *Recorder* is concerned neither with the past nor with the future, the five short essays that follow are intended as a general statement of current practice in this country. No lengthy reference is made to cartographic establishments abroad or to maps from overseas, a decision prompted by the London venue of the 20th International Geographical Congress with which an exhibition of British maps will coincide. This is not to say that our eyes have been shut in an insular fashion and readers will appreciate that superlative cartographic work and map printing is carried out all over Europe, the United States of America, as well as other places. Nevertheless, British maps are not put to shame by comparison at an international level and one American authority has described the Ordnance Survey sheets as some of 'the best topographic maps of the present'.

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Ordnance Survey

Ordnance Survey is the subject of the first of the short essays that follow this introduction, an organization which has made possible the proud boast that Great Britain is the best mapped country in the world. The skills of the surveyor, cartographer, and printer are marshalled and blended by the Ordnance Survey to produce the exquisite maps on sale to the public. And judging by the number of buyers that clamour around the map counter of the HMSO shop in Kingsway, London at lunch times, the quality of Ordnance Survey maps is beyond doubt in the minds of users.

One of the aspects of map reproduction that astounds most is the hairline registration necessary in the colour printing, as demonstrated by a road filling flanked by two very fine outlines. This calls for painstaking preparation of artwork, stable materials, and skilled printing. It is significant, therefore, that the Ordnance Survey half-inch map of Greater London won the trophy for outstanding presswork in the Photo-Litho and Offset Awards for 1962 sponsored by *The Litho-Printer* magazine.

For help in preparing the article on Ordnance Survey, we wish to thank the Director-General; Brigadier R. A. Gardiner, MBE; and Mr. R. Horner. For assistance in choosing photographs we are grateful to Major R. E. J. Lower.

Aerosurveying

One of the newer techniques which has enabled the Ordnance Survey to record topographical features quickly and accurately is aerosurveying: the topic for our second article. Aerial photography and the associated science of photogrammetry have placed a very comprehensive tool at the disposal of cartographers, a tool which has become progressively more precise since the second world war. Apart from being precise, aerosurveying is also quick and very much relevant to the current demand for maps by under-developed countries who wish to find out about the resources of their lands and the prospects for cultivation. It is somewhat shattering to realize that a United Nations Committee announced soon after 1945 that less than 2% of the world's land areas had been mapped at a scale of 1/25000 or larger. As Mr. Bickmore pointed out in his Third Programme talk, the time intervening between the map compilation or original survey and the finished negatives or positives for making printing plates is often inordinately long. In a sense this legitimate moan still applies in aerosurveying where the airplane photography easily outpaces the plotting from stereoscopic pairs of photographs. For rush work the photomap (essentially a mosaic of photographs) has by-passed the bottleneck and acted as a spur for civil engineering projects in newly emerging nations. Nevertheless, the advent and maturity of aerosurveying and stereoplotting has considerably advanced the state of world mapping, although areas of Africa, South America, and Asia have still to be mapped adequately.

Mr. J. W. Barnby, Managing Director of BKS Air Survey Ltd., has given valuable assistance in the gathering of information for the article on aerosurveying and so has Mr. J. D. L. Symingtom from the same Company. We are also grateful to this Company for allowing us to reproduce a specimen of its work and for providing us with some photographs to illustrate the text.

Navigational charts

Aerosurveying has not revolutionized the collecting of information for Admiralty Navigational Charts which are the talking point in the next section of the *Recorder*. Ships and echo-sounders remain the staple equipment of the marine surveyor. Marine surveying is a never-ending task and one imagines that at times it can be rather tedious with the ship taking soundings up and down parallel tracks and getting nowhere fast in the travelling sense. That it can be a dangerous job is tragically mirrored by the recent deaths of two men from the inshore squadron HMS Echo.

Coastal waters constitute the chief preoccupation of survey crews because in these areas most of the dangers to navigation lurk, and the siting of navigational aids, such as lights and buoys, must be made known on charts. Where the sea bed is soft and mobile, the need for the constant checking of surveys and the amendment of charts is obvious. Every 6 months the Thames Estuary surveys come up for revision and the same applies to other busy or hazardous stretches of water. In 1959 a survey of the Goodwins by HMS Echo and the Royal Navy survey motor launch 3516 revealed significant shifts of the sand banks from the previous complete survey in 1947. Set this kind of information against a background of nearly 30,000 ships cruising through the Dover Straits each year and the importance of the work is clearly seen. Great stress has been placed on the ever-present demand for revised and up-to-date charts and herein lies one of the reasons for the continued use of copper plate engraving as an accepted part of chart production, even though the demise of this delightful craft is virtually complete in other branches of map making. Copper plates are wonderfully amenable to revision. Furthermore, the peppering of point symbols over a chart, particularly sea depth soundings, is ideally suited to the copper plate method which remains more economical than the newer scribing techniques. However, copper plates simply provide the means for preparing artwork which is eventually printed by offset-lithography. Another problem arising from constant chart revision is the need to print small quantities and to produce them efficiently and economically.

Although this section of the *Recorder* is headed Navigational Charts no attempt has been made to deal with aeronautical charts, though the modern airliner carries all kinds of mapped information for radio navigation, take-off and landing, and so on. One of the chief problems with aeronautical charts is that an aircraft can cross the country depicted very speedily, a problem increasingly aggravated as aircraft fly faster and faster. The only solution would seem to be the drastic reduction of scales coupled with an enlargement of charts, a point demonstrated by one of the American space craft being equipped with a chart at a scale of over 800 miles to the inch! That there are limitations to the size of charts for convenient handling in supersonic and other aircraft scarcely needs emphasizing and to overcome the difficulty some American planes embody a 10-inch display screen on to which a chart is projected from a 35mm. film. Push button control enables the display to be switched as required.

We are indebted to Mr. R. E. Clarke and Mr. V. G. R. Hildreth of the Admiralty Hydrographic Establishment at Taunton for helping so generously with this section of the *Recorder*.

Thematic mapping

To most people a map is traditionally a topographical sheet or school atlas; but the language of cartography has expanded way beyond these narrow limits and the spatial or geographical significance of all kinds of statistics are now mapped for the guidance of scientists, economists, and planners. These special cartographic subjects are covered by the general term 'thematic mapping', the fourth topic in the *Recorder*. Thematic maps are used by countless people, including geologists, agriculturalists, industrialists, communications experts, meteorologists, and so on. Perhaps the pinnacle of thematic mapping in the United Kingdom is to be seen in the recently published *Atlas of Britain* by the Oxford University Press which depicts a host of information in a visually exciting and scientifically precise manner. Some of the subjects dealt with in this magnificent folio, include: relief and geology; climate; water; vegetation and forestry; agriculture and fisheries; industry; demography; and communications.

Earlier in this introduction, it is stated that cartography is based on the skills of the surveyor. However, to embrace the newly expanding language of cartography, the traditional connotation of the word 'surveyor' needs to be broadened. All maps are based on 'surveys' of one sort or another. For topographical mapping, the surveyor 'spies out the land' with precise instruments and records the relevant information for the cartographer: this being the more familiar idea of a survey. But a map showing sheep distribution must begin with a different kind of survey, a statistical survey telling of the numbers and whereabouts of the animals in the area concerned.

For help with this section on thematic mapping we are indebted to Mr. D. P. Bickmore of the Oxford University Press. More general information on map compilation methods has been generously given by Mr. John Bartholomew of John Bartholomew & Son Ltd., and Mr. H. Fullard and Mr. H. Pickles of George Philip & Son Ltd.

Map design and typography

All maps have to be designed, whether based on an original survey or compilation, or whether topographical or thematic. The design and typography of maps takes up the last section of the *Recorder*. Both these subjects have tended to be neglected in the past, although a greater awareness of their importance seems to be sweeping through the industry at the present time.

Map projections in this section are merely touched upon and discussed in broad terms, but innumerable books and articles have been published on the subject. Indeed, one eminent cartographer consulted during our researches confided that far too much energy and effort had been dissipated on map projections which could have been more beneficially channelled into design.

Map typography is a subject of obvious interest to The Monotype Corporation Ltd. It has taken on an added importance with the emergence of the 'Monotype' Photo-lettering Machine, a device designed with specialized needs in mind, such as those encountered in cartography. Nevertheless, a special cartographic type face does not exist in this country and there is an urgent need for 'scientific' research into the lettering for maps. Signs of life are beginning to show in this direction. The Chart Reproduction Committee of the Joint Advisory Survey Board is already interested in the problem, so is the Cartographic Sub-Committee of the Royal Society.

Useful talks with all the people already mentioned, besides many more too numerous to name, have constituted a sound basis for the design section of the *Recorder*, while the published work of Arthur H. Robinson in *The Look of Maps* and the *Elements of Cartography* has provided the cornerstones of our study.

No claims to originality can be made for the present work. Several books of reference have been tapped and these are listed at the ends of the appropriate sections. L.W.W.

Ordnance Survey maps

The Ordnance Survey is the official mapping authority for Great Britain. Its surveying work is carried out at three basic scales: 1/1250 (approximately 50" to the mile) for major towns, 1/2500 (approximately 25" to the mile) for minor towns and rural areas, and 1/10560 (6" to the mile) for moorlands and mountainous regions. All other scales published by the Ordnance Survey are accomplished by derived mapping. Some 80% of the post-war 1/1250 survey has now been completed which is way ahead of the 12% for the 1/10560 and the 17% for the 1/2500 series.

Printed in black only, the 1/1250 and 1/2500 large scale plans are used almost daily in the offices of surveyors, civil engineers, estate agents, solicitors, local authorities, and government departments. Moreover, the minuteness of the detail shown on the plans is complementary to the large scales and includes roads, buildings, house and street names, fences, railways, embankments, rivers, vegetation, bench marks and triangulation points, spot heights, administrative and parliamentary boundaries, and places of historical interest. An extra refinement on the 1/2500 plans is the indication of land parcel numbers and acreages: the latter being computed electronically on planimeters in many cases.

Most of the 1/10560 and 1/25000 (2½" to the mile) medium scale maps are derived from the large scale plans, although the basic six-inch areas are being covered by a new survey from air photographs. Each of these medium scale series will eventually cover the whole of the country which means the production of nearly 13,000 different sheets: around 10,000 at the six-inch scale and something between 2,000 and 3,000 at the 2½-inch scale. When one realizes that the 1/25000 maps are printed in four colours and that the 1/10560 consist of two colours, the enormousness of the task becomes apparent. In an attempt to rationalize production, the map detail is carefully generalized and drawn to a specification serviceable at both scales.

Of the small scale maps issued by Ordnance Survey, the 1/63360 (1" to the mile) is probably the best known. This series covers the whole of the country and comprises 190 sheets each now printed in six colours. Of these, about a dozen sheets come up for complete revision every year: the frequency of amendment depending on the area mapped. Some sheets are brought up to date every 7½ years, others every 15 years, and the remainder every 25 years. Footpaths, rivers, streams, woods, railways, youth hostels, electricity transmission lines, antiquities, National Trust areas, contour lines at 50-foot intervals, and roads classified by colour and marked with their Ministry of Transport numbers represent just a few of the features shown on the one-inch maps and help to explain their popularity with hikers, cyclists, and motorists. Tourist Maps, a by-product of the one-inch series and taken from the same reproduction material, are issued for certain holidaymaking areas like the Peak District. These sheets are most attractive with contour layered tints supplemented by hillshading.

To compile the 17 sheets in the 1/250000 (¼" to the mile) series, the material for the one-inch maps is generalized and redrawn. These maps, designed principally for motorists, are revised every 3 years and reprinted in ten colours. Additionally, the quarter-inch maps provide a base for a special series of charts used by civil and military aircraft.

Maps at the scale of 1/625000 (10 miles to 1") are derived from the quarter-inch series and cover the entire country in two sheets. Various scientific data are mapped at this scale, such as rainfall, land use, population density, steel and iron distribution, railways, electrical statutory supply areas, geological formations, etc. These statistical or scientific maps are produced for various public and government bodies, instanced by the Geological Survey and Museum, and the Ministry of Housing and Local Government. Another recent publication at the 1/625000 scale is a route planning map for motorists which traces the road network and emphasizes by means of colour the increasing links provided by motorways.

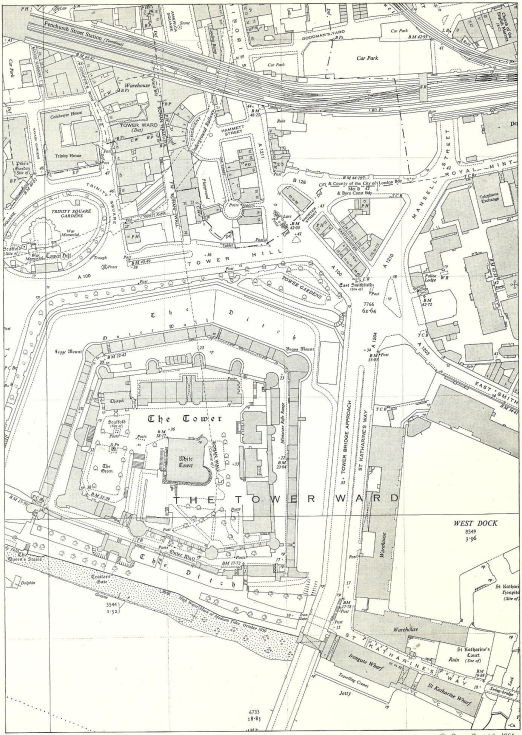
At an even smaller scale of 1/1000000 is the map taking in the whole of the country, with the exception of Ireland, on two sheets. This is in the process of being drawn to the latest specification of the International Map of the World and will provide a useful and handy general reference to the country.

A number of historical maps prepared by the Archaeology Division of Ordnance Survey are on sale to the public. Among the periods and subjects dealt with are: Monastic Britain, Southern Britain in the Iron Age, Roman Britain, Britain in the Dark Ages, and quite recently a delightful map of Hadrian's Wall.

Other miscellaneous maps are produced to varying scales from time to time by Ordnance Survey, like the map of the Royal Botanic Gardens at Kew for the Ministry of Agriculture, Fisheries and Food.

History

Although the official history of the Ordnance Survey dates from 10 July 1791, the original idea of a national survey has much longer roots stretching back to the Battle of Culloden in 1746 where the Duke of Cumberland defeated the Young Pretender. Thereafter, operations by Cumberland's force in the Highlands were seriously hampered by a lack of accurate maps and gave rise to an order from the Quartermaster-General to survey the area at a scale of 1/36000. During the next 8 years vast areas of the Highlands and Lowlands were surveyed, but the work came to a premature end with the



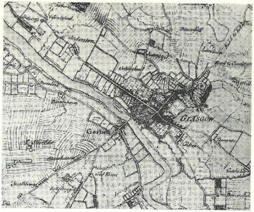
Made and published by the Director General of the Ordnance Survey, Chessington, Surrey, 1964.

Portion of the Ordnance Survey 1/2500 plan of the Tower of London area. (*Crown copyright reserved.*)

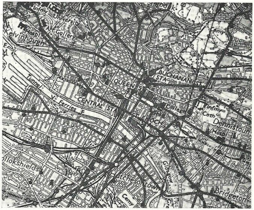
flaring up of the Seven Years' War in 1755. William Roy, a young engineer and assistant to the Quartermaster-General, had been one of the mainsprings of the survey while it lasted, an experience sparking off in him an enduring interest in mapping which continued unquenched until his death in 1790. After leaving the Highlands, Roy produced several reconaissance maps though he did not gain official recognition in this field until 1765 when entrusted, on appointment as Surveyor-General of Coasts and Engineer, with the organization of military surveys in Great Britain. From this time onwards, Roy constantly stressed the need for a systematic national survey, a viewpoint which met with apathy and never received serious consideration until after the American War in 1783 when interest was slowly whipped up. Under the watchful eyes of George III, a triangulation to ascertain the difference between the meridians at the Greenwich and Paris Observatories was started in 1787 and concluded in 1788. But still the onus for undertaking geodetic observations rested in private hands, such as the Royal Society in which Roy was a leading light. Then in 1791, one of Roy's keenest champions, the third Duke of Richmond serving as Master General of Ordnance decided to rope in surveying as an activity of the Board of Ordnance, a step probably made a little easier by the threat of an invasion from the Continent.

Only a few surveyor-draughtsmen, backed up by a sprinkling of military personnel from the Engineers and Artillery, were employed by the new Department which had its headquarters in the Map Office of the Tower of London until 1841. In that year the buildings were destroyed by fire necessitating removal of the Ordnance Survey – a title originating somewhere around 1820 – to Southampton. At the outset, the Survey was charged with the responsibility of mapping the entire country at a scale of 1/63360 and set about establishing a framework of control points by triangulation. Just as the project was advancing nicely, a Select Committee in 1824 demanded an urgent survey of Ireland at a scale of 1/10560 for valuation purposes which meant that for the next two decades the resources of the Department were deflected from the original goal and channelled towards a new end. By 1840 only Scotland and the six northern counties of England remained unmapped at the 1/63360 scale, but experience in Ireland led to a tempering of the original programme with a decision to survey these outstanding areas at a scale of 1/10560: a course of action implemented up to 1853. Due to preoccupation with Ireland, the Principal Triangulation of Great Britain had to be shelved temporarily until 1838 when it was taken up again and pushed steadily to completion by 1852. Over the next one hundred years this vast network of control was to function as the basis for mapping Great Britain. It is quite stunning to reflect on the precision of this early triangulation, particularly if one takes into account the somewhat primitive instruments available, the extensive nature of the work, and the awkwardness of transportation.

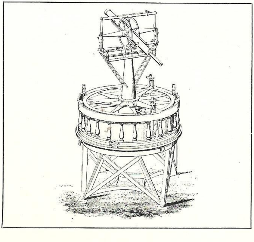
Around 1853 a long controversy began to brew as to the most suitable scale for mapping the country, remembering that both the 1/63360 and the 1/10560 had been tried in different areas. After sounding out the opinions of interested users, such as civil engineers and land surveyors who were



General Roy's map of the Glasgow area dating from the 18th century compared with a contemporary Ordnance Survey map of the same region.



Ramsden's Great Theodolite.



very active during the Industrial Revolution, a departmental committee recommended that all cultivated areas (which excluded moorlands and mountainous terrain) should be surveyed at a scale of 1/2500. The Treasury went along only partially with the scheme and restricted the programme to areas where the six-inch survey was operable. Durham was the area chosen for a pilot survey at the 1/2500 scale, but a mandate to go on with the rest of the work was withheld by an adverse vote in the House of Commons during 1857 which brought matters to a standstill. Considerable criticism was aroused by this obstruction which resulted in the setting up of a royal commission to look into the subject. As a result, the 1/2500 scale received the all clear in 1858 and was extended in 1863 to the southern counties which were still mapped only at the one-inch scale. By 1895 the survey was complete.

Outward recognition that the civil work of the Ordnance Survey had long preponderated over the military occurred in 1870 when control passed from the War Office to the Ministry of Works. Some years elapsed before the Survey changed hands again and came under the Board of Agriculture – now the Ministry of Agriculture, Fisheries and Food – although nearly all its men were regular soldiers.

With the successive outbreaks of the South African and the 1914–18 wars, the resources of the Ordnance Survey were severely strained by strategic priorities which precluded up to the minute maintenance of the large scale plans (1/2500). Equally damaging was the economic retrenchment during peacetime which seriously curtailed the scope of the Department's work. Consequently, the rapid development of housing estates and roads in the 1920s and 1930s outstripped the documentation of them by Ordnance Survey. A huge backlog of revision piled up and administrative efficiency became deeply impaired. Moreover, many of the plans were so out of touch with reality that revision became unthinkable and nothing short of a resurvey would put the records straight. Matters plunged to such a low ebb that a Parliamentary Committee under Viscount Davidson was established in 1935 to investigate the position and to prescribe remedial action. It is the findings of this committee, published in 1938, that constitute the 'charter' for the Ordnance Survey today.

Four salient recommendations were made by the Davidson Committee. Firstly, that a National Grid calibrated to the international metre should be implemented as a standard system of reference for the whole country and superimposed on maps and plans of all scales. Secondly, that urban areas should be surveyed at a scale of 1/1250 and that a method of continuous revision had to be devised to keep the new large scale plans abreast of changes on the ground. Thirdly, that the 1/2500 survey had to be drastically overhauled and planned on a single national projection to supersede the old County Series which was drawn on the Cassini projection to some 39 different meridians and suffered from serious shape distortion. Fourthly, that the 1/10560 scale maps should continue as a national series, each sheet taking in an area of 25 square kilometres. Overall these recommendations were quite sweeping and meant a fresh triangulation for the country.

Immediate headway on the Davidson proposals was barred by the second world war when the onset of bombing aggravated the problem of revision even more. But in 1944 the proposal for a 1/1250 survey was officially accepted and the committee's plea for instituting a method of continuous revision was resolved, a good thing too when one considers massive post-war developments. Work on retriangulation had started way back in 1935 and with the war intervening primary observations did not finish until 1952. Another decade was needed to complete the secondary and tertiary observations.

Aerosurveying techniques have been a boon to the Ordnance Survey since their adoption soon after the war and have enabled work to progress at a rate commensurate with the changes on a small and densely populated island committed to a Beeching plan for the railways, vast motorway and road construction projects, the redevelopment of existing towns (e.g. Coventry and Plymouth) and the establishment of new towns (e.g. Basildon and Crawley), besides all the other building of less gigantic proportions taking place.

Close co-operation between cartographer and printer is essential to a worthwhile map, since advancement in one aspect of the work can call for a corresponding refinement or spurt in the other. Thus, as the duties of the Ordnance Survey have gradually widened throughout its history, so the printers have been eager to try new techniques for increasing efficiency and capacity. Numerous improvements in map printing have stemmed from the Survey and one example relating to the pioneering of photolithography will demonstrate the point. In 1859, Colonel Sir Henry James in Southampton perfected a lithographic process by which an image was drawn on paper, photographed into a negative, and printed down on to a paper sensitized with dichromated gelatine or gum. Next, the contact print was inked up and developed and the image transferred to a zinc plate. In a Report to Parliament in 1859, James inserted a sample print by 'photo-zincography' together with a brief explanation of the process. The anticipated saving to the Treasury on the production of official maps was reckoned at £30,000. Putting the arguments for the process in a nutshell, the Gernsheims[1] claim that: 'Photo-zincography was by far the quickest and cheapest method of completing the survey of Britain which had been started in 1799 and was not completed until January 1870, by which time, of course, all the earlier sections were hopelessly out of date. It saved the Government the long and expensive procedure of altering the old steel plates, or in the case of expanding industrial districts, the necessity of hand-engraving new plates.'

Organization

As previously stated, the Ordnance Survey is a department of the Ministry of Agriculture, Fisheries and Food with a staff of about 4,500 including 27 RE officers amongst the senior appointments. Annual expenditure by the Survey approaches £5,000,000, but about a quarter of this is recoverable through mapping services and map sales and royalties: the latter amounting to something like £150,000 per year. At the head of the Ordnance Survey is a Director-General assisted by a Director of Field Survey and a Director of Map Production and Publication, both posts being held by Brigadiers. A senior civil servant attends to establishment and financial matters.

Two sections, employing around 1,700 surveyors, come under the supervision of the Director of Field Survey: (1) Geodetic Control Division and (2) Field Division. Provision of triangulation and levelling control, together with air surveys, are the chief responsibilities of the former; while the latter ensures the completion of detailed surveys and the compilation of manuscript field documents from which maps and plans can be drawn. Both divisions are centred on Chessington in Surrey though the field work is organized through six regions. Archaeology Division is another branch of work controlled by the Director of Field Survey.

Under the Director of Map Production and Publication are: (1) Large Scales Division, (2) Small and Medium Scales Division, and (3) Publication Division. Compilation, drawing, and reproduction for the 1/1250 and 1/2500 plans are carried out by the Large Scales Division at Southampton, while parallel work on all other scales is discharged by the Small and Medium Scales Division in another part of the same city. At Chessington, the Publication Division deals with the storage and distribution of maps and plans. Within the next few years, new offices for mustering the scattered resources of the Survey are to be built in Southampton and this will no doubt ease organizational problems.

Levelling

On Ordnance Survey maps all contours and heights are expressed as so many feet above mean sea level, the datum point being at Newlyn, Cornwall. Between 1915 and 1921 the Tidal Observatory at Newlyn collected hourly records of the sea level from which a 'mean' was calculated as the reference plane for all Ordnance Survey levelling. On the harbour wall a permanent Bench Mark Bolt is established at 15.588 feet above datum. Furthermore, a tide gauge continues to gather a contínous record of the sea level.

There are three orders of Ordnance Survey levelling all conforming to the same basic principles but differing in degrees of accuracy, namely: geodetic, secondary, and tertiary. To leave a permanent physical record of levelling throughout the country, a series of bench marks are established to denote points of known heights precisely determined and recorded with levelling instruments. Owing to land developments and changes brought about by mining subsidence, a fair number of bench marks are apt to disappear or need renewal over the years. Consequently, if the network of control is to remain substantially intact some form of regular maintenance becomes imperative. Cyclic relevelling was instituted by the Ordnance Survey in 1956 to deal with subsidence areas every 5 years, normal areas every 20 years, and mountainous regions every 40 years, a system which allows a tight rein to be kept on vertical control.

Geodetic points provide a rigid and precise framework for the lower orders of levelling and are indicated by Fundamental Bench Marks sited at intervals of roughly 30 miles. Among other places around London, these marks can be found at Hatfield Peverel, Snodland, Croydon, Hemel Hempstead, Wallingford, Wye, and Buntingford. In an attempt to secure permanency, the fundamental marks are positioned and constructed with the utmost care, the Geological Survey being consulted to verify the stability of the chosen site.

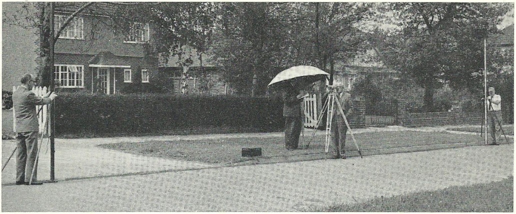
Secondary levelling is achieved by breaking down the polygons of the geodetic network. Flush brackets and bolts spaced up to 2 to 3 miles apart are used for indicating secondary points and in between them cut bench marks give an overall density of eight to the mile in urban districts and four to the mile in rural areas. Tertiary blocks come within the secondary network and relate to smaller areas. Wherever possible these are of sufficient density to show a line of levels on all large scale plans with bench marks at a frequency of eight to the mile in urban districts and four to the mile in rural areas. All levelling computations are processed on punched cards and offered for sale to the public as Bench Mark Lists, an invaluable publication for engineers, surveyors, and the like.

It took from 1912 to 1921 to complete the Second Geodetic Levelling of the country and many years passed before the Third Geodetic Levelling was undertaken between 1951 and 1959.

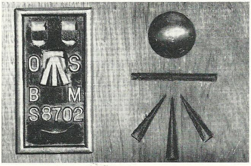
Triangulation

Horizontal control, as opposed to the vertical control afforded by levelling, is accomplished by a process of triangulation which was first applied by Willem Janszoon Blaeu in 1610, the man responsible 10 years later for improvements in the traditional hand printing press. Ordnance Survey maps are founded on a network of control points, the positions of which have been ascertained by triangulation. As a beginning, a base line is accurately measured and from the terminals a series of triangles covering the whole of the country are built up by observing angles with theodolites. Hitherto base measurements have been made with Invar tapes suspended in catenary, a somewhat laborious process instanced by 42 men taking 24 days in 1937–38 to measure the Ridgeway Base. With the advent of new instruments of greater scope, the taping of bases has probably gone for ever. And little wonder when one realizes that 4 men equipped with tellurometers needed only 2 days to measure the same base. Besides speed, the tellurometer system makes an economic use of labour and permits lines to be measured that would be impossible with tapes. In essence, tellurometers are electronic instruments used in pairs to measure the transit time of radio waves along a given line. Velocity of the radio waves can be calculated with due allowance for meteorological influences, so that all the factors are at hand for determining the distance between stations.

Stations of primary triangulation are generally about 30 miles apart and located high up on hilltops or tall buildings. Their positions are picked out initially by reconnaissance and stone or concrete pillars are used to mark them in readiness for gathering readings with a geodetic theodolite. In the Highlands and other places difficult of access, the station marking parties and others engaged on tellurometer traverses have been transported by helicopters. In flat and wooded country where the lack of suitable sites for triangulation stations is something of a problem, the construction of Bilby steel towers will sometimes be necessary. These consist of an inner tripod supporting the theodolite and an outer skeleton structure holding the surveyors. Bilby towers can reach up to 103 feet and take about 5 hours to erect. As the triangulation party progresses, so the towers are taken down and loaded on to trucks for re-assembly

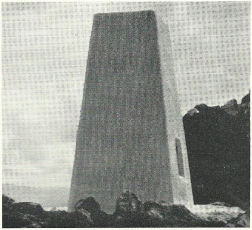


ABOVE Levelling party making observations in the field.

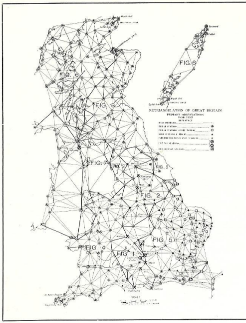


ABOVE Various bench marks used by the Ordnance Survey to indicate points of known heights above mean sea level as determined with levelling instruments. *Left*: a flush bracket of new design. *Top right*: a bench mark bolt. *Bottom right*: a cut bench mark.

BELOW Concrete pillar marking a triangulation station.

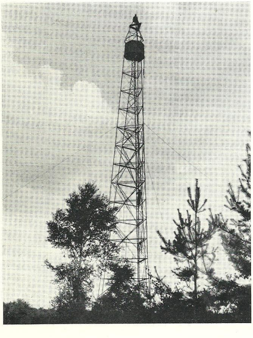


BELOW Tellurometers are one of the newer instruments that have eased the task of the surveyor. They are used in pairs to measure the transit time of radio waves along a given line.



ABOVE Retriangulation of Great Britain showing the primary observations.

BELOW A Bilby tower used for observing triangulation angles in flat and wooded country. The photograph shows clearly the double tripod principle of construction, the inner one for holding the instrument and the outer one for supporting the surveyors.



further down the line. Before dismantling, the position of each tower is carefully marked for future reference.

Primary triangulation originates from one terminal on the base line and all angles are measured 32 times to 0.1″ of arc. With the Davidson Committee's recommendation of a single national projection, the retriangulation of Great Britain started in 1935 and because of the delay occasioned by war the primary observations were not finished until 1952 which included connections to Ireland and France. Additionally, the Caithness and Lossiemouth bases were established. Secondary and tertiary triangulations took another 10 years to complete.

Using selected sides of primary triangles, the country is divided into secondary figures with stations at intervals of 5 to 7 miles and a further breakdown into a tertiary network spaces control points at distances of approximately 3 to 4 miles. Tertiary triangulation has not been undertaken in mountain and moorland areas. Instead triangulation points are chosen and measured on aerial photographs and processed in computers to furnish adequate control for stereoplotting. In areas for surveying at the 1/1250 scale, a fourth-order triangulation is necessary to provide controls roughly 2 miles apart or less.

Minor control

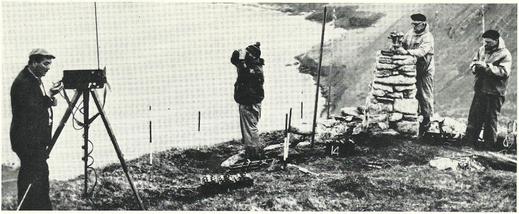
All large scale survey is carried out at the 1/1250 scale by tacheometry or aerosurvey. Minor planimetric control points – derived from the tertiary and fourth-order triangulations with a steel tape and microptic theodolite – are established for this work, although the density and pattern of minor control will necessarily vary to suit either tacheometry or aerosurvey. With aerial techniques, an average of 15 to 20 minor control points per square kilometre is required all selected from photographs and confirmed in the field. Sparser minor control will suffice for tacheometry and the control points, known as Permanent Traverse Stations, are separated by about 1,200 metres and denoted as concrete blocks, rivets in roads, or cross-cuts on manhole covers.

Field documents

Field documents employed for the 1/1250 survey are 20-cm. square anodized aluminium plates. Four of these, used on the butt-joint principle, constitute a 1/1250 plan and each must conform to a strict specification of thickness between 0.060″ and 0.072″, straightness along the sides to within 0.005 cm., and a length not varying by more than 0.003 cm. Control points are plotted on the plates with co-ordinatographs, the permanent ones being enclosed by yellow symbols and the non-permanent ones by blue symbols. These points are also plotted on plastic sheets for the 1/2500 overhaul and for the continuous revision process at both the large scales.

Once the control points have been put down, the documents are passed to either air survey or tacheometric survey for the plotting of instrumental detail in red.

Ordnance Survey photographers fly in aircraft hired from the Ministry of Aviation Flying Unit and from commercial firms. From the stereoscopic pairs of photographs obtained it is usually possible to plot in red on the butt-joint plates about 60% of the detail, the rest being collected by the field surveyor. Readers are referred to the section on aerosurveying.

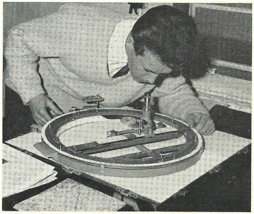


ABOVE Triangulation party on St. Kilda. In areas of outstanding natural beauty the triangulation pillars are built in local stone as shown in this photograph.

BELOW Tacheometric survey in progress: the Self-Reducing Tacheometer can be used for measuring both angles and distances.

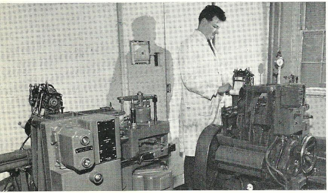
BELOW Plotting control points on field documents with a co-ordinatograph, the permanent ones being enclosed by yellow symbols and the non-permanent ones by blue symbols.

BELOW Plotting a tacheometric survey on butt-joint plates with a polar co-ordinatograph.

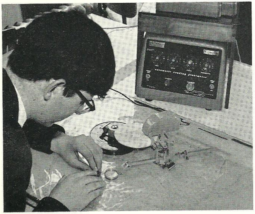


ABOVE Four butt-joint plates being loaded into the vacuum copyholder of a fixed-focus camera.

BELOW Lettering for all Ordnance Survey maps is produced on 'Monophoto' Filmsetters.



BELOW For calculating the acreages (to two decimal places) of land parcels for insertion on the 1/2500 plans, an Automatic Reading Planimeter is used.



Tacheometry is the standard ground instrumental survey method. For this work, the Self-Reducing Tacheometer mounted on a tripod is used together with two graduated rods which can either be held manually or supported on tripods while readings are taken. In addition to functioning as a theodolite for angular measurement, the distance between the tacheometer and rod can be measured optically on the general principle of coincidental images found in photographic range-finders. As the tacheometric work progresses, so the surveyor enters details of each 'tachy' station on an observation form which is broken down into three parts noting respectively: (1) tachy traverse observations, (2) tachy point observations, and (3) a sketch plan of the points and reference objects. When this form returns to base, the detail is plotted on the butt-joint plates with a polar co-ordinatograph and inked over in red. Basically the co-ordinatograph is a large circular protractor spanned by a distance scale carrying a combined microscope and pricker unit. Distance measurements can be set to 0.05 metres and angles to 1 minute within a plotting range of 250 metres at 1/1250.

Once the instrumental detail has been plotted on the butt-joint plates from tacheometric observations or stereoscopic examination of aerial photographs, they go into the field for the graphical detail survey to be fitted into the red framework. For convenience of handling, the plates are assembled in groups of four in a sketching case and constitute a continuous drawing surface which can be extended in any direction by the removal and replacement of the appropriate plates. Since there are no margins to harry the surveyor, the continuation of a line from one plate on to the next does not create a problem, an advantage reflected in the standard of draughtsmanship. To compile the graphical survey, which is drawn in black on the butt-joint plates, very modest instruments are employed, such as a 20-metre tape, a set square, and an optical prism. Other jobs completed at this stage include: the collection of road, district, and feature names and house numbers; the checking of bench-mark positions and the insertion of levelling information; the indication of vegetation with conventional symbols and abbreviations; the transfer of archaeological surveys to the field document; and the perambulation and mereing of administrative boundaries. Finally the field documents are thoroughly checked by senior surveyors to iron out all snags and ambiguities before the reproduction processes begin.

Reproduction of 1/1250 plans

Reproduction of the 1/1250 plans begins by mounting four butt-joint plates in the vacuum copyholder of a fixed-focus camera. After exposure to a photographic glass plate held by suction in the back of the camera, a negative is developed by visual inspection of a grey scale with strict control exercised over processing conditions to reduce the number of variables. All these precautions are reflected in the amazing uniformity of reproduction throughout the whole series of plans, there being hardly the slightest discrepancy in the quality of line.

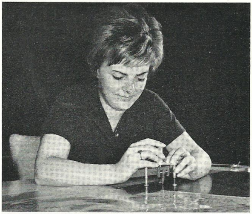
Next a master positive of the border to surround the plan is printed down by the gum reversal process on to an enamelled aluminium plate and dyed in black after development. Within this framework is fitted a ferro-prussiate blue print produced from the glass negative of the butt-joint plates. Guided by the blue key, the draughtsman is able to ink over the lines in black taking care to standardize their thickness. Names are added to this fair drawing as stripping-film positives produced by means of 'Monotype' Keyboards and 'Monophoto' Filmsetters. Cartographic symbols are held as master negatives for contacting on to stripping film as required and after waxing these too are stuck down on the enamelled plate. Once the copy has been finalized, it goes back to a fixed-focus camera for the production of a negative from which an albumen image is made on zinc for printing by offset-lithography. Thus, the whole production sequence is undertaken with stable materials – metal and glass – which lessens the risk of inaccuracies creeping into the plans.

Reproduction of 1/2500 plans

The Ordnance Survey is committed to producing 1/2500 scale plans for the whole of Great Britain except in mountainous regions, an immense task involving the publication of nearly 180,000 plans. It should be mentioned that these plans are usually printed in pairs, covering an area of 2 kilometres by 1 kilometre. Even areas surveyed at 1/1250 are not excluded from this scheme and when these larger scale surveys exist the 1/2500 plans are derived from them. To do this, eight 1/1250 originals (to cover the 2 × 1 format) are printed down photo-mechanically in their correct relative positions on two white enamelled aluminium plates. These are photographed in a fixed-focus camera set at 2:1 reduction. From the resultant negatives, contact prints are made on glass on which the border, grid and marginal information has already been printed. The glass is used to yield a negative for platemaking. In effect, nothing is re-drawn though land parcel area readings need to be incorporated. These are expressed down to two decimal places of an acre as calculated with planimeters, though a measuring scale devised by a member of the Survey in 1850 still lingers alongside the newer electronic methods.

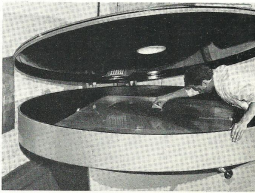
Where 1/1250 plans are not available for a given area, the conversion of the old 1/2500 County Series to the National Grid system is a rather more tricky business. As a jumping off point, a direct print on plastic is taken from the existing lithographic plate in black ink. This goes into the drawing office for compiling on a sheet of glass which carries the standard grid in blue. Since the old County Series were on the Cassini projection and to different meridians, as opposed to the new plans being on the Transverse Mercator Projection, the plastic sheet will need to be cut and thin slices removed here and there until the blue grid on the glass and the black grid on the plastic coincide. Cow gum is used for sticking down the pieces of plastic on to the glass. Using a positive reversal technique, the assembly is printed down on the smooth side of a plastic sheet and developed and dyed in red. This 40-cm. square document is now ready to go into the field for overhaul, the new detail being drawn on the reverse or matt surface by the surveyor.

To reproduce the amended plastic document, a sheet of glass is coated in a vertical machine of the squeegee pattern with a semi-opaque, yellow vitrascribe solution. On this surface, a ferro-prussiate blue key image is made from two plastic

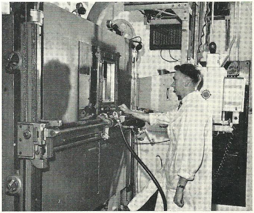


ABOVE Scribing map detail on glass with a circle cutter.

BELOW 'Lithotex' Whirler Type 121 in use at the Small Scales Division of the Ordnance Survey.



BELOW Most of the Ordnance Survey small and medium scale series are obtained by derived mapping. For this purpose, the large scale work is photographically reduced and then stepped up on a 'Monotype-Huebner' Step-and-Repeat Machine.



documents which serves as a guide to the draughtsman when scribing the detail in the yellow base material. Chisel-shaped steel scribing tools made for all the gauges of lines specified on Ordnance Survey maps are used and although sapphire tools have been tried they do not react too well on glass. Not only is a consistent line more easily attained with a scribing tool than with a pen, but the process has proved to be very much quicker particularly for curved and irregular detail. As a result of the scribing process, a direct negative is produced for contacting on to another sheet of glass coated with dichromated polyvinyl alcohol (PVA) and on which border and grid material has previously been arranged. Cut-N-Strip masks may necessitate a third printing down for the incorporation of stipple. Finally names set by 'Monophoto' Filmsetters on stripping film are stuck down on the red PVA positive which can now be contacted into a glass negative for platemaking.

Continuous revision

In map making one of the thorniest problems is to keep abreast of changes on the ground, especially in a densely populated and highly industrialized country like Great Britain. Acting on the advice of the Davidson Committee, a continuous revision system was put into operation at the end of the second world war. Procedure is fairly simple and commences soon after an edition has been published by obtaining a ferro-prussiate blue print of the plan on plastic. This is sent to the field unit responsible for the particular area. New developments are surveyed as they occur, the results being drawn in black on the plastic sheet using the blue key as a framework. It is the aim of the surveyor to ensure that the plan never lags behind ground development by more than a few days. Simultaneously, the surveyor will prepare a tracing to indicate any detail that no longer applies and must be omitted from future editions. According to the extent of change and the age of the previous edition, so a decision to reprint will be reached and at this juncture the revised plastic sheet and deletion trace are sent to the Large Scales Division at Southampton. On receipt of these, the obsolete detail is duffed out from the negative of the previous edition, enabling a revised red PVA positive to be made on a fresh sheet of glass. From this a reverse-reading positive in blue is made on another glass base which, in turn, is coated with vitrascribe and then receives a carefully registered reverse-reading negative blue print from the plastic field document. The new detail can then be scribed for combining photomechanically as a PVA black image with the red PVA positive made from the original duffed negative. Names and vegetation, etc. are added to complete the positive from which a fresh negative can be made for platemaking. 'Lithotex' Whirlers and Vacuum Frames are used for much of the photomechanical work.

Small and medium scale maps

Except for the basic 1/10560 maps, all medium and small scale work is prepared by derived mapping using drawing and scribing techniques. Obviously the large scale material must be generalized for this purpose, a job demanding considerable experience and a thorough grasp of the capacities of photomechanical processes. Multi-colour printing is the most glaring difference between the small scale maps and the monochrome large scale plans and the Ordnance Survey have a battery of up-to-date lithographic machines to tackle the work. Most of the register is extremely tight and calls for stability in the raw materials used for both the preparation of artwork and printing. Consequently, the paper used by the Ordnance Survey contains some rag and is matured at the mill to a moisture content of $7\frac{1}{2}\%$: the waterproof wrappings remaining unopened until the packages enter the machine room.

Relief detail

Methods of showing relief detail on Ordnance Survey maps vary with the different scales. In the monochrome 1/1250 and 1/2500 plans elevation is denoted by a sprinkling of spot heights. But moving down the scales contour lines appear for the first time on the 1/10560 maps, an innovation suggested by the Lord Ellesmere Commission way back in 1851 to augment the hachuring of those days. Almost a century later, the Davidson Committee recommended that the interval of contouring should be closed up in order to depict altitudes more efficiently. More recently, to create an illusion of three dimensions, the contour lines on some of the 1/63360 tourist maps have been supplemented by layer tints and hillshading. One method used by the Ordnance Survey is to draw the hillshading in pencil on grained astrafoil for reproduction by the halftone process and overprinting on the map. For the inexpert map reader, the presence of hillshading gives an immediate impression of the lay of the land and experiments are continuing at Southampton with more refined methods. Rock depiction is a kindred technique being used for some of the Highlands maps, the draughtsman working from an examination of aerial photographs through a stereoscope.

The Ordnance Survey has been publishing maps for well over 150 years. Throughout its long history no effort has been spared to provide the public with a precise and attractive product. Willingness to analyse its maps with a view to their improvement lies at the root of a not inconsiderable success. Moreover, the fostering of a pioneering spirit in its employees has blossomed into countless minor and major inventions in surveying, cartography, and printing for the general betterment of these subjects and these results were not achieved against an academic background or one sheltered from chilly economic winds. That the Ordnance Survey is very much a *going* concern is conveyed by the output for 1962 in which over 40,000,000 impressions emerged from the presses. Current issues are averaging 3,000,000 maps every year and over 11,000,000 maps are held in stock.

References

[1] *The History of Photography* by H. and A. Gernsheim (Oxford University Press, 1955)

We wish to acknowledge the assistance of the Ordnance Survey in the preparation of this section of the *Recorder*

Aerosurveying

Aerial photographs are one of the newest and most comprehensive sources of information available to the cartographer and can be provided by a number of commercial companies in the United Kingdom, such as BKS Air Survey, Fairey Air Surveys, and Hunting Aero Surveys. Furthermore, the increasing accuracy of aerosurveying techniques since the 1939–45 war has encouraged the Ordnance Survey to switch to aerial photography for much of its 1/1250 survey and all of its 1/10560 resurvey. On the latter maps the contouring of the country at 25-foot intervals has been accomplished almost entirely with stereoplotting instruments, except for the flatter areas where the conventional field survey was adjudged to be more economical. In addition, the revision of 1/2500 scale plans of small settlements and rural areas is carried out from aerial photographs wherever developments and changes have been extensive. While the commercial companies crew and operate their own aircraft, the Ordnance Survey hires planes from the Ministry of Aviation Flying Unit, but supplies its own camera operators, who are responsible for the photography.

History

Gaspard Felix Tournachon the celebrated French aeronaut and portrait photographer, known as Nadar (1820–1910), was the first to succeed in obtaining an aerial photograph and he soon recognized that the combination of flying and photography would be a boon to map making and military reconnaissance. Using the Ambrotype photographic process and a captive balloon, Nadar's initial experiments were most depressing with one black picture after another coming from the camera. But, in common with other pioneers, his dogged persistence eventually paid off. One day, early in the winter of 1855 when the cold had caused the gas in the balloon to contract, Nadar took off with the valve closed and managed to obtain a faint though plain photograph at an altitude of approximately 80 metres. From this Nadar reasoned that the hydrogen escaping from the open valve had ruined the previous photographic plates. Eager to polish the technique, the Frenchman continued to experiment and took some lovely aerial views of Paris. On these later sorties the balloon reached greater heights and photographing was carried out, on occasions, from altitudes in the region of 1,500 feet.[1]

Balloon photography in those far off days was fraught with all kinds of hazard and difficulty. Wet collodion photography was the most satisfactory medium available and this meant that within the cramped and unsteady space of the balloon basket – which was rigged out as a dark-tent – the French aeronaut had to formulate and develop his photographic plates. Further complications arose from the rather rough cameras in use at that time and for which Nadar devised an improved shutter operated by pulling on a length of string. To cap all this, exposures could only be made at quiet lulls in the flight between successive vacillations of the balloon. The camera was housed either vertically in the bottom of the balloon carriage with the lens pointing downwards to give a straight bird's-eye view of the ground below, or more usually pointed from the side to take an oblique shot.

Nadar was granted French patents for his scheme and apparatus in 1855 and secured similar protection against copyists in England on 29 October 1858. Perhaps uncharacteristically, politicians were quick to appreciate the strategic and military significance of aerial photography and at the outbreak of the Franco-Austrian war in 1859 the French War Minister solicited Nadar's help, but as a radical Republican he declined to accompany Napoleon III on his expedition. Nonetheless, the pictures produced previously by Nadar were used for mapping in 1858 by Laussedat, a French military engineer.

Long before aircraft were dreamed of for surveying purposes, the principles of photomapping had been carefully worked out and established on the ground. Many countries, including the United Kingdom, Canada, and Switzerland, used the phototheodolite for ground surveys. This instrument allows angular measurements to be made in order to indicate the direction in which the photographs were taken and enables the positions of points appearing in the pictures to be fixed. Even with the widespread acceptance of aerosurveying, terrestrial photography is still valid for certain kinds of work.

Rather surprisingly the relationship between air photography and mapping was not fully realized or explored until snapshots obtained with hand-held cameras during the 1914–18 war were studied. During the inter-war years the Americans were especially active in this field. For example, by 1920 the US Coast and Geodetic Survey had mapped the Mississippi delta from aerial photographs and using the same technique the Hydrographic Office surveyed Cuba in 1928.[2] With the outbreak of the 1939 war, the military demand for maps greatly increased and the need for rapid surveys of inaccessible country occupied by the enemy served as an immense boost for air photography with the result that hundreds of square miles were scanned and mapped by flying. As a prelude to the invasion of Normandy, the allies were busily engaged on the mapping of Northern France to a scale of 1/2500 from aerial photographs and some 700 new sheets[3] were issued to pave the way for the D-day offensive. Similar projects were completed over Egypt, Sicily, Italy, and Southern France. Thus, by 1945 the aerial camera was looked upon as a powerful mapping tool and its entrenchment has continued up to the present day.

Applications

Aerial pictures used in conjunction with stereoplotting machines and co-ordinatographs are of considerable assistance to cartographers; but other sciences and technologies involving the use of land are also keen to assimilate information collected from the air. Some random examples will demonstrate the usefulness of aerial records. By reference to photographs forestry experts can determine the tree density and size of growth in a given area, while the depiction of woodlands by infra-red photography enables the various tree species to be easily distinguished. Also tidal surveys often employ infra-red photography to bring out the division between the actual water level and the wet foreshore.

Mining geologists and prospectors frequently base preliminary investigations on stereoscopic pairs of photographs to gather knowledge on land configurations, structures, and vegetation, and to study outcrops and faults. Similarly, agriculturalists can estimate crops and assess the suitability of land for a particular sort of cultivation by analysing the detail of aerial photographs and by making intelligent deductions. Sometimes shallow waters can be charted from the air.

Road and railway engineers are basing routes and plans on the results of aerosurveys to an increasing extent and many miles of motorway in this country were foreshadowed in the first instance as an air photograph. Aerosurveys also blaze the trail for irrigation and hydro-electric schemes. Cost is an important factor in vast construction programmes of this kind and money cannot be squandered on unnecessarily elaborate survey methods. Therefore, it is interesting to note that despite the high capital investment of cameras and plotting instruments, the cost of an air survey compares very favourably with the expense incurred by ground methods for quite small areas. In the case of larger areas of survey, there is a preferable saving in time and money by aerial methods. Obviously innumerable factors can tilt the cost of an aerosurvey one way or the other not least among them being the type of landscape, the width and scale of survey, the interval of contouring, and the nature of spot level requirements. Data published in 1958[4] suggested that the cost per mile length of survey in open undulating country to a scale of 1/500 and to variable widths of 200 to 450 feet would come within the bracket of £350 to £550. In urban areas where widths of 150 to 300 feet might suffice for planning purposes the cost was broadly the same. Ignoring open traverse surveys, the cost of aerial cover over specified areas, such as that necessary in constructional work, was assessed at £12 to £20 per acre in built-up areas and at £7 to £12 in open country.

Volumetric computations based on the contour details from aerosurveys are another off-shoot in this field. Electronic digital computers deal with a wide variety of problems, and soon work out the volumes involved in: (1) motorway and trunk road cut-and-fill earthworks; (2) reservoir capacities at different water levels; (3) coal stocks held at electricity generating stations; and (4) quarry and gravel pit capacities.

Advantages

Erwin Raisz has described[5] air photography as the greatest advance in mapping since the invention of the compass. This is by no means a rash claim if one considers the sweeping areas of land that can be recorded in detail on film within a very short time. Moreover, the extreme accuracy of plotting machines which draft maps and plans from stereoscopic pairs of photographs reduce the possibility of human error to a minimum. Aerial surveys plotted with 1-foot contours to a scale of 1/500 are guaranteed by BKS to a ground accuracy of within 6 inches in both vertical and horizontal measurements, although in practice the tolerance shrinks to something considerably less. Smaller scale plans are offered with corresponding degrees of preciseness.

Inhospitable country – exemplified by swamps, deserts, icy wastes, precipitous terrain, and dense forests – poses enormous problems for the ground surveyor, but an aircraft is not barred or troubled by obstacles on the ground and can reach an exact location swiftly and easily. Even on engineering projects in tame country, the convenience of access provided by an aerosurvey can be a telling factor. Intense traffic may seriously delay an accurate ground survey along a road, a nuisance which the aerial photographer is spared. Nevertheless, some ground survey is necessary to round off and/or to precede aerial surveys and the amount will vary according to the kind of plan or map being produced. Roads, rivers, lakes, forests, towns, villages, and so on can all be plotted with consistent accuracy from photographs, but names must be gathered by research on the ground. Boundaries of parishes, towns, counties, and countries will rarely be self-evident on photographs, and field examination will be vital for their determination. Furthermore, a network of ground control points or co-ordinates identifiable on the photographs must be available before plotting can begin.

Preparatory to ground surveys it is customary to obtain permission from land owners or tenants for admission to their property and this often arouses anxiety as to the purpose of the survey. Sometimes considerable time is wasted in fruitless discussion, the squashing of rumours, and the allaying of fears. And after all this interference, complaints and claims may be received in its wake for alleged damage to property or crops. Aerial survey reduces all these snags and overcomes the need for entry to land except at isolated points for minimal ground checking. However, on occasions even this can be restricted conveniently to common land.

Aerial photography, allied with stereocontouring machines, enables the elevation of land to be plotted with uncanny accuracy. BKS Air Survey Ltd. produces plans to scales of 1/250 and 1/500 with contours at 1-foot intervals; others are prepared to a scale of 1/1250 showing 2-foot contours; and 5-foot contour lines appear on plans scaled at 1/2500. In precipitous country it is necessary to widen the interval of contouring, otherwise the lines will be so closely packed that detail will be obscured.

Disadvantages

Prominent among the disadvantages of aerial survey in this country is the shocking climate. Adverse weather conditions can curtail flying time quite drastically. Even more frustrating are those days when flying is possible, but the overall drabness precludes photography. One authority has asserted that there are in an average year some 30 cloudless days ideally suited to airplane photography, but with improved high resolution camera lenses, faster film speeds, and electronic contact boxes for photographic printing, the drawback of dull weather conditions has tended to be less of a nuisance than formerly. It is now possible to achieve good photographic images in overcast conditions which means that operations can proceed over most of the year. Depending upon the information required from an aerosurvey, so the season for flying must be picked accordingly. Where accurate ground detail and precise contouring are essential to a finished map, the optimum time for flying in this country would be between September and May. With the leaves off the trees and the fields emptied of standing crops, the likelihood of misrepresenting ground levels is considerably reduced. Thus, deciduous forests can only be surveyed really critically over this period. Lighting is probably at its best and most uniform 2 hours before noon and the 2 hours afterwards. Throughout this time the shadows will be small and unobtrusive. Snow pictures are not sympathetic to mapping, but can be very revealing in war when reconnoitring enemy territory.

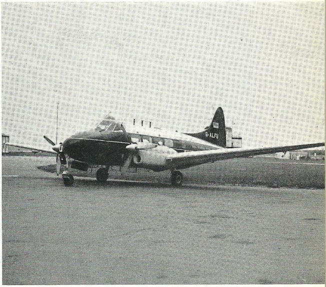
Photographs will from time to time be required for information other than that relating to ground altitudes and land forms, and to aid subsequent interpretation – perhaps for mapping – special flying conditions may be imperative. For example, long shadows can be helpful when attempting to identify archaeological sites and Raisz quotes a case of the remnants of a Roman legion camp being unearthed from an adumbrated outline appearing in the wheatfields of an aerial picture. Farmers had suspected nothing of the kind on the ground.

Two further, though rather minor, detractions of aerosurveys should be mentioned. In urban districts, the overhanging eaves of houses, etc. tend to hide from the aerial camera anything beneath them, including the true ground lines of the buildings and a small field survey party will be required to fill in missing detail. The other demerit becomes evident when operating in the locality of an airport where the constant inflow and outflow of air traffic is liable to hinder progress. Strict Air Ministry control is maintained over flight lanes in these areas and survey craft must operate as directed by the Area Flying Controller along previously agreed flight paths.

Types of air photographs

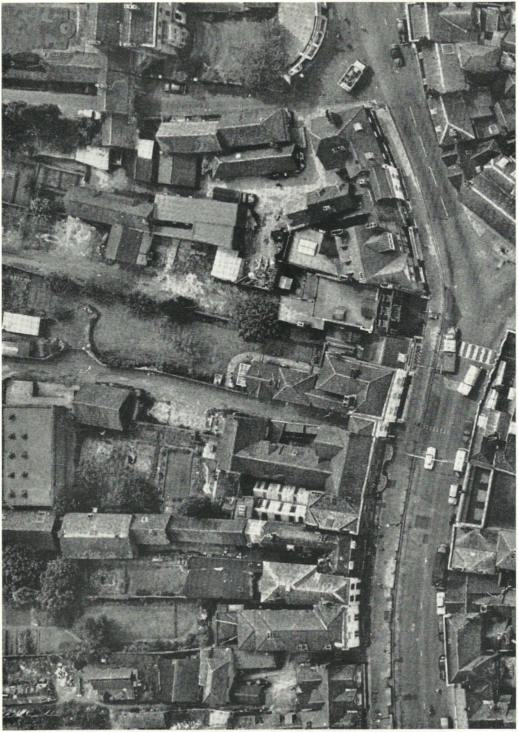
Aerial photographs can be either *vertical* or *oblique*, and they may be taken or used as pinpoints, strips, and block cover.

For vertical photographs, the camera points straight down from the aircraft in level flight to give a plan or bird's-eye view of the ground below. Since distances and directions appear essentially true on this sort of picture, they can be used directly for mapping with exact contours plotted by viewing stereoscopic pairs. However, the features seen in a vertical photograph have an almost eerie look to the naked eye, an effect heightened perhaps by the lack of colour. Hydrographic features are outstanding in black; hills appear to be somewhat flattened; and the variations in vegetation and cultivation, although discernible to the uninitiated, require skilful interpretation. Yet, with stereoscopic examination and knowledge-



A De Havilland Dove aircraft of the Civil Aviation Flying Unit hired by the Ordnance Survey for aerial photography.

Ordnance Survey camera operator at work in an aircraft.



Aerial photograph of Dorking High Street . . .

. . . together with the 1/500 plan derived from it.

able 'reading', the wealth of material provided by a vertical photograph is quite staggering and with colour photography developing in leaps and bounds the applications could widen even more in the future.

Oblique photographs, which have a lesser relevance to mapping, are taken with the camera pointing in a slanting direction towards the ground. They may be either *high angle* in which the horizon is visible, or *low angle* in which it is not. On this kind of photograph the features on the ground are not so startling or strange and approximate to the views seen from the windows of an aircraft.

Aircraft and camera

For the purposes of BKS Air Survey Ltd., the Anson aircraft has proved to be most suitable for low and slow flying. This fits in with the general pattern of small aircraft being adopted increasingly over recent years for air survey work, a practice prompting the design of correspondingly compact and light cameras. The Wild RC8 Film Camera is a good example of this type of equipment and by totting up the components used by BKS, the overall weight comes to little more than 260 lb. With this camera, the principal functions of the operator are limited to checking the rate of wandering lines in the viewfinder telescope of the overlap regulator and to adjusting the camera for drift compensation. Once properly set up and started, the camera will shoot a series of exposures taken in rapid succession with due allowance for picture size, the degree of overlap between each frame, the flying height and speed of the aircraft, and the focal length of the lens. Other functions automatically discharged by the camera mechanism include: shutter release, film feed and flattening, the operation of an exposure counter, and the recording of exposure data. This last point is an interesting one and the detail recorded often covers a bubble clock showing the level of the camera at the moment of exposure, the reading on the altimeter, the time of each exposure, the focal length of the lens, and the date and serial number of the picture. Furthermore, at each exposure fiducial cross marks – needed in subsequent photogrammetric work – are optically projected on to the four corners in addition to mechanical marks printed in the middle of each side. Joining the fiducial marks together on a finished bromide print would indicate its principal point of photogrammetry. In a truly vertical photograph, the principal point will be in the dead centre of the picture, but if the camera was tilted slightly during exposure it will be off centre and nearer to one of the edges.

Distortion-free high-resolution lenses are common to most aerial cameras. The 'Aviogon' wide-angle lens, having a focal length of 6 inches, used on the Wild RC8 camera by BKS has a distortion tolerance of only ± 0.01 mm. which gives an inkling of the critical nature of the work.

Most aerial photographs have a finished size of 9 inches square. Fairly fast films, like Kodak Super XX and Ilford HP3, in 200-foot rolls by $9\frac{1}{2}$ inches wide are popular for air work, yet the resulting prints must not be too grainy otherwise the photogrammetric engineer when tracing the pointer around features in the photograph on the stereoplotting machine might lose its path amongst a coarsely-mottled background.

Numerous multilens cameras are also available for aerial photography, such as the trimetrogen camera housing three lenses: one pointing straight down for obtaining vertical photographs and two others taking pictures obliquely to the left and right reaching to the horizons. Some hundreds of square miles can be documented in this way and a special rectoblique plotter has been devised for the map location of points in the oblique photographs.

Photographic flight

Before operations in the air can begin, the photographic flight must be carefully planned, a task usually based on Ordnance Survey maps in this country. Large-scale maps are not suitable for this job because the flight across one will take such a short time, and airmen are keener on small-scale maps for planning. In addition to marking out the district to be covered, the air navigator/photographer will break down the area into a series of flight lanes ensuring that every part of the country for mapping receives adequate photographic overlap both longitudinally and laterally. In the line of flight, an intervalometer or similar instrument set to complement the pre-arranged speed of the aircraft will automatically govern the rate of exposure to ensure that each photograph overlaps its sequential neighbours by 60%, or less commonly by 80%. On reaching the end of its first flight line, the aircraft will return along a parallel course to produce a lateral overlap between photographs of 30%. Thus, every point on the ground will occur in several pictures, a system necessary to get stereoscopic pairs of photographs for relief viewing. Flight lines must be straight, since an aircraft has to bank in order to follow a curve or change of direction and as a result the camera would not be vertical. Therefore, where the passage of, say, a river is to be surveyed, it could only be shot as a single strip if its meanderings and twists came within the compass of the lens travelling in a straight line. Broader deviations from the straight and narrow might require the planning of a rather tortuous flight. Sometimes markers are laid out on the ground for the guidance of the navigator and indicate the centre line of a strip survey.

Where the focal length of a lens and the height of an aircraft are known, the scale of a photograph can be calculated quite easily. If one assumes that the lens has a focal length of 6 inches and photographing was undertaken at an altitude of 12,000 feet, the scale of the pictures would be 1/24000.

$$\frac{6}{12 \times 12{,}000} = \frac{1}{24000}$$

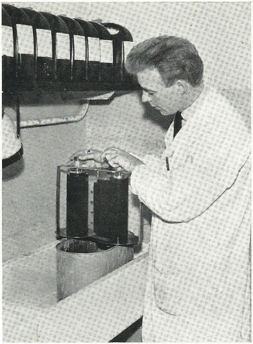
In simple terms: the longer the focal length, the larger the scale; and the greater the height of the aircraft, the smaller the scale of the picture will be. The kind of calculation worked out previously gives an accurate answer when the actual height of the aircraft is known, but usually the only reliable figure available is the altitude of the plane above mean sea level. In mountainous country, the height of an aircraft above the ground will fluctuate appreciably. For example, an aeroplane flying at 20,000 feet above sea level over mountains would shoot photographs of variable scales if the peaks rose to 10,000 feet and the valleys dipped to 5,000 feet. This could be proved quite simply by using the formula given above. On this occasion a 5-inch lens will be assumed.

$$\frac{5}{10{,}000 \times 12} = \frac{1}{24000} \textit{ scale at the mountain peaks}$$

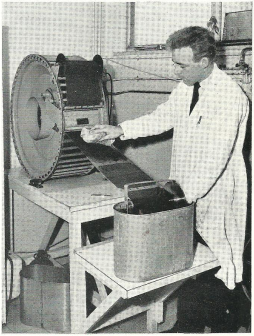
$$\frac{5}{5{,}000 \times 12} = \frac{1}{12000} \textit{ scale at the bottom of the valleys}$$

BKS surveys are commonly carried out from a height of about 1,300 feet. Gentle hill undulations in the United Kingdom do not create many scale problems, although variations in excess of 300 feet cannot be reconciled with the tolerances built into the stereoplotting machines.

During photographing the pilot keeps the plane at an even and level height and watches its direction by compass and by observing relevant landmarks. For open traverses, the newer radar navigational aids have increased the possibilities of aerosurveying and provide the means of fixing the position of an aircraft exactly, thereby whittling down ground work to even slighter proportions. Many areas during the last war were mapped from aerosurveys with the aid of radar fixation in lieu of ground control, a system which developed into a joint operation by the Royal Air Force and the Royal Engineers using suitably modified and specially equipped Mosquito aircraft.[3]



ABOVE Processing of the roll film for aerosurvey work is done in a series of tanks, the material being wound through the solutions from one cassette on to another.



BELOW Drying the 200 feet of film after processing.

Film processing

After a flight, the panchromatic film is developed in complete darkness by time-and-temperature control. Special tanks – for each of the processing stages – represent standard items of darkroom equipment and in each the film is wound gently through the relevant solution from one cassette on to another. After processing, the film is dried over a slowly rotating drum.

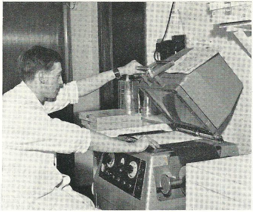
Having processed the negatives, the next step is to prepare photographic prints on paper for field work and diapositives on glass for photogrammetry: the science by which the photographs are translated into maps. At the BKS laboratories in Leatherhead, Surrey, special electronic contact boxes, capable of removing any cloud shadow concealing ground detail in the negative, are employed and this costly equipment incorporates both cathode-ray tubes and photo-electric cells.

Stereoplotting machines

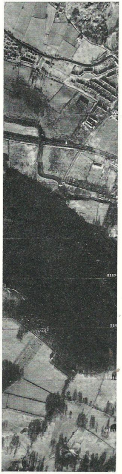
Ground control points form an integral part of an aerosurvey, and usually two plan and four elevation points per overlap are required, each one being readily identifiable on the photographs. In essence the ground party will establish the heights and distances of these co-ordinates and from them all other ground features can be mapped in plotting instruments.

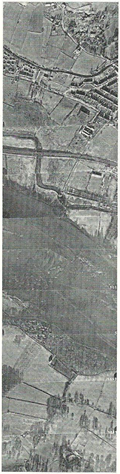
On return to the laboratories, a base plot on Melinex of the ground control points is prepared. Next, two glass diapositives, showing a 60% overlap, are mounted independently into a stereoscopic plotting machine coupled to a co-ordinatograph. These machines have facilities by which the attitudes of the diapositives can be altered to simulate the camera position at the time of exposure and thereby correct for aircraft tilt and for any bumps and inconsistencies in the flight.

Binocular eyepieces, which magnify the diapositives six times, are fitted to the plotting machines and allow the images to be viewed stereoscopically for mental fusion into something rather like a three-dimensional or plastic model. As a reference point for plotting, the instrument has a floating needle or spot which may be guided by hand-manipulated controls around the features depicted in the diapositives. These movements are transmitted to and echoed by a pencil in the tracing arm of the co-ordinatograph which draws lines on the Melinex base plot to build up a map or plan directly from the photographs. Various expedients are adopted at this stage for pushing the work forward. Instead of drawing a closed rectangle to demarcate a house, the operator of the stereoplotter will normally be content to denote the four corners for connecting at a later date. By altering the gears of the plotting arm, the scale of a plan can be enlarged or reduced. Considerable training is needed to operate plotting machines effectively and inadequate stereovision can give rise to difficulties for some people. Co-ordination of eye and muscle is a prime requisite for the work. When plotting contour lines, the floating reference spot must be maintained at one level, if it is not two spots will be seen.



ABOVE An electronic contact box for producing photographic prints. This device, fitted with scanning apparatus, prevents any cloud shadow on a negative from obscuring ground detail on a subsequent print.



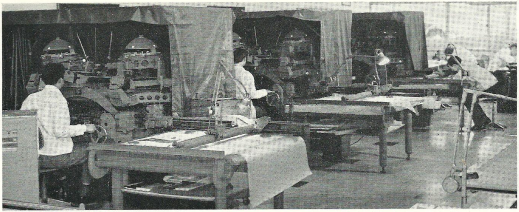


Reproduction

Once the pencil plot on Melinex has been advanced to a nearly finished state on the stereo machine, it goes back into the field for checking. At the same time any detail hidden from the aerial camera by the foliage on trees, the overhanging eaves of buildings, or the superstructures of bridges is filled in. Once this has been done, the processes of reproduction can be started. In this section of the *Recorder* we intend to describe the reproduction systems seen at BKS Air Survey Ltd. who produce mainly large-scale plans for civil engineers, public authorities, and the like, although they do undertake widespread topographical surveys on occasions. However, most of their work consists of one-off jobs, a characteristic reflected in the reproduction techniques employed and the absence of printing machines.

In the drawing office, the pencil machine plot is overlaid with a sheet of Astrascribe consisting of a plastic film base carrying a reddish, translucent, and actinically opaque coating. Then, with sapphire cutting tools, the draughtsman traces over the lines of the pencil plot to scrape away the coating. Any accidental scratches are duffed out so that the open or engraved lines can next be dyed with etching ink through the scribed stencil. When the lines have been firmly dyed, the coating is dissolved away with methylated spirit to leave the plan outlined on a transparent base. Lettering can now be applied to the detail in the form of waxed stripping film, although the amount of 'labelling' required on plans compiled by BKS is somewhat limited. Alphabets and figures of 'Monotype' Gill Sans are held as standard negatives taken originally from letterpress reproduction proofs and these can be contacted on to stripping film as required. Place names are compiled by cutting out and patching up individual letters.

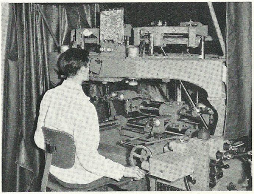
Contour lines, for merging ultimately with the detail of a plan, are stereoplotted on a separate sheet of Melinex and reproduced as a positive transparency by the Astrascribe method. To facilitate the reading of elevation, every 10-foot



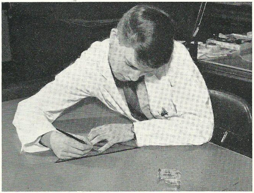
ABOVE Part of the stereoplotting room at BKS Air Survey Ltd.

LEFT Two strips of aerial photographs: one printed ordinarily and showing detail concealed by cloud shadow and the other printed in an electronic contact box which has automatically uncovered the hidden detail.

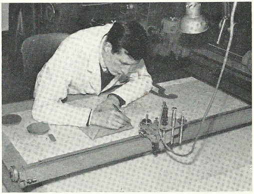
RIGHT An operator looking into the binocular eyepieces of a stereoplotting machine for viewing two glass diapositives produced from aerial photography. The floating needle or spot reference in the machine is guided round the detail by hand-operated controls, the movements being conveyed to a pencil in the tracing arm of a co-ordinatograph.

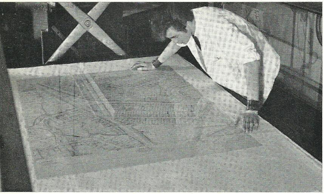


BELOW A BKS draughtsman working on a sheet of Astrascribe and cutting a straight line in accordance with the pencil machine plot underneath. For scribing curved lines the tool in the foreground is used.

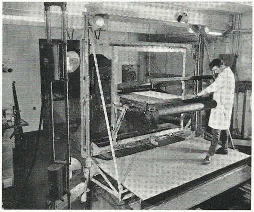


BELOW An operator completing a pencil plot at the table of a co-ordinatograph.



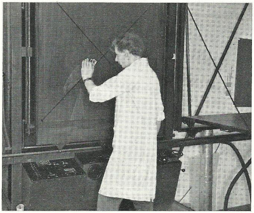


ABOVE Loading the 'Lithotex' Printing-Down Frame which was specially built by Pictorial Machinery Ltd. for BKS Air Survey Ltd. Plans up to 10-feet long can be exposed in the Frame.



ABOVE Loading the copyholder of the 'Lithotex' camera.

BELOW Focusing on the 'Lithotex' process camera built by Pictorial Machinery Ltd. for BKS Air Survey Ltd. in order to copy plans accurately to various scales.



line on plans contoured at 1-foot intervals is drawn to a wider gauge than the intervening ones, and similar aids to legibility are implemented for other work. Sapphire scribing tools of different gauges allow distinctions of this kind to be effected quite easily. Spot heights and contour altitudes are indicated with Gill Sans figures made up from waxed stripping film and wherever possible are arranged to read up hill.

For combining the plan detail and contour lines, a sheet of Astrafoil is coated in a 'Lithotex' Whirler with a solution of dichromated gum arabic and when thoroughly dry receives a contact print of the detail in a 'Lithotex' Printing-Down Frame. Afterwards the unexposed dichromated gum is developed out with a solution of lactic acid and calcium chloride, thereby uncovering the Astrafoil beneath and permitting black dye to be rubbed on to it through the light-hardened background coating. Finally the coating is washed off leaving the plan detail in black against a clear Astrafoil ground. Now the contour lines can be added to the plan in precise register by the same gum reversal process, but a red dye is used instead of a black one to produce a most attractive two colour end product. Astrafoil has proved to be most satisfactory and remarkably stable, neither expanding nor contracting to any significant degree in normal atmospheric conditions, a feature which preserves the scale accuracy of a plan.

Some of the Astrafoil masters produced by BKS have an extra refinement in which the detail and contour lines appear in black with the house blocks stippled in red. To achieve this, a positive mask for the house stipples is produced on a sheet of Peelcoat which consists of a film base laminated with a coherent red substance. At the outset the Peelcoat is sensitized with dichromated gum arabic and receives a contact print from the plan detail positive. All the unexposed gum, equivalent to the outline, is developed out allowing the red Peelcoat underneath to be etched in methylated spirit. Finally the light-hardened gum is dissolved away to reveal the plan as transparent lines peeping through a red background which acts as a guide to the draughtsman for peeling off the red layer where no tints are needed. Thus, the houses will show as tiny red blocks on a transparent ground, in effect a positive mask.

Using gum reversal techniques, the plan detail and contour lines are successively printed down and dyed in black on Astrafoil. This sheet is then sensitized again with dichromated gum and contacted firstly under the Peelcoat mask and secondly under a stipple film. Development in lactic acid and calcium chloride uncovers the stipple which is dyed in red. Washing off the light-hardened gum completes the job.

In advance of the Astrafoil masters, BKS Air Survey occasionally supply customers with preliminary sepia copies taken directly from the machine pencil plots, a service of considerable value in civil engineering projects where work at the site can forge ahead without delay. These preliminary plots are reproduced on Melinex or Mylar materials presensitized with a diazo compound which receive a contact print from the pencil plot. Development of the diazo material in ammonia gas concludes the process and the customer is furnished with a secondary copy from which dye-line copies can be taken on standard office equipment. It is worth noting that many of the plans dealt with by BKS reach 'outsize' proportions and for printing-down purposes they commissioned Pictorial Machinery Ltd. to build a vacuum-frame commensurate to the work handled. For copying plans precisely to enlarged or reduced scales, a 'Lithotex' camera was specially built for BKS requirements.

Air photo reading

Apart from the drawing of roads, railways, and houses, the cartographer must be able to extract and interpret other information from aerial pictures relating to vegetation, cultivation, hydrography and so on. It has been hinted previously that vertical photographs are not easy to read, since the human eye is not accustomed to looking directly down at the earth, and even from an aircraft window the passenger gets an oblique view. Consequently, the efficient interpretation of an air photograph requires considerable practice and must be founded on a systematic analysis which takes into account the shape, size, shadow, tone, texture, and associations of features.

Shape provides a useful clue to the identity of an object and few people are likely to mistake the ribbon of a road, the fuzziness of a tree, or the meanderings of a river. Natural features are characterized by irregular shapes while artificial or man-made ones tend to be fairly regular. However, generalizations of this sort can be misleading and several exceptions come to mind, such as quarries which can be extremely ragged. If one considers a single shape, such as a circle, this could be a number of things. It may be a pond, a static water tank, a gasometer, a sewage filter bed, a large chimney, a water tower, or a roundabout.[6] Consideration of size and associated features will soon eliminate some of these, while shadows will often give away the shape in profile.

Size can be determined in a number of ways and where the scale of a photograph is known this presents no difficulty. If the scale is unknown it may be ascertained by measuring objects of standard sizes, such as football pitches or tennis courts. Comparison between the size of one object and that of another can also be most illuminating.

In monochrome photographs, the various shades of grey if studied carefully are helpful in recognizing objects and represent the amount of light reflected back into the camera. Water will appear very dark, usually darker than land, and often completely black. Normally sand will reproduce as white; tarred roads have a lighter appearance than railway tracks; conifers look darker than deciduous trees; a pasture of short grass photographs lighter than a field of ripe wheat; and so on.

Likewise, the photographic textures of fields and growths are quite distinctive: orchards have an unmistakable chequered pattern brought about by the regimented rows of trees; the furrows of a ploughed field give rise to a dark-toned and streaked pattern; reclaimed land bears the tell-tale marks of ditches and irrigation channels; and woodlands show as roughly-mottled areas in which the density of the canopy sometimes reveals the kind of tree.

Finally, the associations of an object on a photograph will help to reveal its character, the circular features quoted above provide a good example of this. A roundabout would be at a busy road junction; the large chimney would relate to a factory; the filter beds would be on the outskirts of a village or town; the gasometer would be connected to a power station with railway lines and coal stocks; the pond might be in a field, a park, or alongside a road; in each case the associations would be quite individual.

Aerosurveying and its associated science of photogrammetry are relatively young and provide the cartographer with an excitingly quick and probing source of information. What is more important, the data gleaned by this method is comprehensive and precise. Thus, with the ever-mounting demand for up-to-date maps, the part played by aerosurveying is bound to become even more prominent in future years.

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[3] *Air Survey* by C. A. Hart (The Royal Geographical Society and John Murray, 1948)

[4] *Aerial Survey in Major Road Improvement Schemes* by Col. T. U. Wilson, C.B.E., T.D., D.L., M.I.C.E., M.I.Mun.E. ('The Surveyor')

[5] *Mapping the World* by Erwin Raisz (Abelard-Schuman, 1956)

[6] *Air Photo Reading*: Part II of the War Office Manual of Map Reading, Air Photo Reading, and Field Sketching (Her Majesty's Stationery Office)

We wish to acknowledge the assistance of BKS Air Survey Ltd., Leatherhead, Surrey in the preparation of this section of the *Recorder*

Navigational charts

In a sense navigational charts are the eyes of the mariner inasmuch as they provide a detailed picture of both the hazards and clearways that lie hidden beneath the surface of the seas and oceans. Unlike the user of topographical maps who can verify the information given by reference to constantly visible landmarks, the navigator at sea must place complete reliance in charts at least where underwater features are concerned. Therefore, as the keystone to the safety of shipping, the mariner's charts must be compiled with thoroughness and printed with the greatest possible accuracy, and the use of standard symbols admits of the inclusion of considerable detail. Even so, a good chart will not be cluttered with facts which are not relevant to navigation and which would give rise to confusion. All kinds of details are indicated on a chart, such as: prominent natural and artificial points along coast lines which might serve as landmarks to shipping; the proper courses for entering ports and channels and the buoys marking them; the siting of lights together with abbreviations denoting their characteristics; the nature of the sea bottom and depth soundings; the position of shoals, wrecks, coral reefs, eddies, kelp, and other dangers; the chart datum and tidal information; and so on.

History

Serious marine surveying and charting in Britain dates from the 18th century with the work of Captain James Cook, who pioneered a new standard of exactness by carefully observing bearings and by fixing positions along the St. Lawrence River at a time when the North American war was imminent. The only really significant work by a Britisher before this was Captain Greenville Collins' *Great Britain's Coasting Pilot* published in 1695. Throughout the last half of the 18th century, the intensity of marine surveys in home waters and abroad increased tremendously and although the Admiralty commissioned much of the work precious little reached the seaman in chart form. Those charts that were issued originated from private sources. Seemingly the surveyor had to pass on the results of his work to the Admiralty, but retained the copyright and was free to publish the material independently for personal profit. It is hardly surprising that by this haphazard arrangement the Admiralty amassed a wealth of undigested material.

Growing agitation by mariners for reliable charts finally paid off in 1795 when Alexander Dalrymple was appointed Hydrographer to the Navy Board. His terms of reference were 'to take charge of such plans and charts as are now or may hereafter be deposited in this office belonging to the Public, and to be charged with the duty of selecting and compiling all such information as may appear to be requisite for the purpose of improving the Navigation, and for the guidance and direction of the Commanders of Your Majesty's Ships.' All this had to be accomplished on an annual budget of £470 which included the Hydrographer's salary.

Dalrymple was a celebrated geographer and had undertaken a good deal of hydrographic surveying for the East India Company. His influence at the Admiralty was felt immediately. Besides putting into order the vast stock of charts and information that had accumulated over the years, he managed to initiate new charts and to purchase plates from other publishers. But as a scientist, the standards of accuracy and completeness that he imposed were a trifle finnicky, a characteristic that ultimately proved to be his undoing because it led to delays in publication. Early in the 19th century when the Napoleonic war was flaring, the Navy required a flood of charts, not the mere trickle that Dalrymple was providing. Gradually the discontent mounted and in 1808 reached a climax with the enforced retirement of the Admiralty's first Hydrographer. Captain Thomas Hurd took over the job immediately and within a short time managed to establish a regular supply of charts to all stations. Even more important, the complete dependence on outside surveying sources was broken in 1811 with the initial appointment of surveying officers and in 1814 surveying ships appeared for the first time in the Navy List. Furthermore, he was later to be responsible for making Admiralty charts available to the merchant marine.

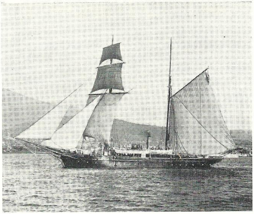
Hurd channelled most of his energy into the naval and surveying side of operations where his credentials were second to none. Between 1791 and 1799 he had carried out a thorough survey of Bermuda which set a pattern for preciseness and clarity. As Hydrographer he delegated the responsibility for chart production to his assistant, John Walker, who came from a family steeped in map-engraving traditions. This neatly balanced combination of surveyor and engraver lasted until April 1823 when, if legend be true, Captain Hurd disappeared and was never seen again. Seven months elapsed before Captain William Parry, who had just returned from a second Arctic voyage, was put in charge of the department, a somewhat odd choice which ignored the availability of experienced marine surveyors. Despite the gap in leadership, the progress of charting the seas continued as shown by the mammoth 30,000 miles survey of the African coasts by Captain W. F. Owen which took 5 years to complete.

Parry spent more than half of his 6 years as Hydrographer in expeditions to the North and the burden of organizing surveys as well as chart production fell heavily on the shoulders of John Walker. Worse was to come when widespread post-war economies demanded the cutting back of naval expenditure and led to the dismissal of several survey officers and the cancellation of some chart issues. One officer axed in this way was Owen, who was in the middle of preparing a survey for production; but after a time these setbacks were made good. In 1825 the first *Catalogue of Admiralty Charts* emerged and swift on its heels came the first volumes of *Sailing Directions*, the latter managing to distract even Parry momentarily from his preoccupation with the Arctic.

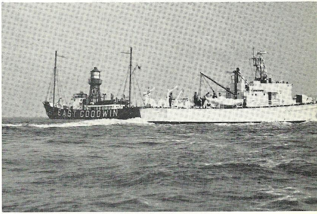
At last, in 1829, the restless Parry resigned as Hydrographer and his duties were inherited by Francis Beaufort. Expansion of trade at this time gave an immense boost to marine surveying and Britain, undergoing an industrial revolution and probably foremost among manufacturing nations, was anxious to secure overseas markets. Existing sea passages had to be charted and made safe and new routes needed opening up by navigators and surveyors. Over this period British ships were surveying almost everywhere, except the coasts of those nations that had established hydrographic offices of their own. For example, in 1807 the US Coast Survey was founded, although its first charts did not appear until 1844; and the Hydrographic Office of the US Navy dates from 1866.[1] However, this kind of national development was by no means world wide with the result that British survey vessels operated in foreign territorial waters throughout Europe, Africa, South America, and Asia. Admiralty surveying resources in the middle of the 19th century must have been under great strain, since the work was not only far flung but never ending. Then, as now, resurveying was necessary to keep up to date with the rapid changes that occur where the sea bed is soft. And even where the bottom is rocky and hard, resurveys are needed from time to time in order to remain abreast of new navigational standards or to ensure the safe passage of new ships with deeper draughts. Also, if one considers the rather primitive methods available to marine surveyors in the middle of the last century their achievements come more truly into focus and seem quite prodigious. FitzRoy's vessel, the Beagle, used for surveying the east and west coasts of South America had a burthen of only 235 tons and steam ships did not materialize until much later. Fathoming of the sea depth had to be undertaken by the hand casting of a plumb-line which was a long winded affair. It was not until 1878 that the first Lucas sounding machine came into service. On top of all these difficulties, the marine surveyor was shut off from outside contacts for long periods.

Beaufort continued as Hydrographer until 1855 and his 25 years in office were packed with incident and progress. In 1831 the importance of survey work won recognition as an independent Admiralty department. With the new status came broader responsibilities and in 1842 a Compass Section was started, a development brought about by the old wooden-wall vessels being superseded by iron ships and the resulting need for correcting compass readings to compensate for the disturbance caused by the ship's own magnetism. Then, 2 years after John Washington had succeeded Francis Beaufort as Hydrographer of the Navy, the publication of *Notices to Mariners* commenced to promulgate important navigational changes and dangers at the earliest possible moment.

It cannot be denied that the pace of scientific progress quickens in times of strategic need. After the 1914–18 war, the

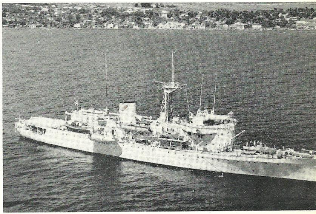


ABOVE HMS Dart (1882–1904) was used for surveying in the south-west Pacific and in the waters of Australia and Tasmania. (*Reproduced by permission of the Hydrographer of the Navy.*)



ABOVE HMS Echo, one of the Royal Navy's inshore survey craft designed for work in coastal waters, photographed against the East Goodwin's lightship.

BELOW HMS Vidal, the largest of the Royal Navy's survey vessels.



changes brought about in marine surveying techniques were revolutionary and sprung mainly from the French pioneering of the echo-sounder, an instrument infinitely more rapid in ascertaining sea depths than the best mechanical devices geared to a plumb-line. Likewise, the prismatic astrolabe for making accurate observations of latitude and longitude came into being. Electronic methods for fixing the positions of ships were probably the greatest contribution of the last war, a refinement which the Hydrographic Department of the Admiralty earned by producing 30,727,000 charts and diagrams between 1939 and 1945, as opposed to 3,500,000 over a like period in peace.[2]

Sources of information

Charts compiled and published by the Admiralty cover the shores and waters of the world. Over 3,500 navigational charts are published every year, amounting to something like 2,000,000 copies for supply to the Navy and for sale through agents to merchant shipping. To maintain the accuracy of these charts and to undertake new surveys, the Admiralty taps a number of information sources.

For charting home waters, a fleet of vessels is deployed by the Royal Navy which includes: two large ships, HMS Dalrymple (1,600 tons) and HMS Scott (830 tons); three inshore squadrons, HMS Echo, HMS Egeria, and HMS Enterprise; and two shore-based establishments using 50-ton launches. Their work is supplemented by plans and surveys provided by port and harbour organizations dotted around the coasts, such as the Port of London Authority. Additionally, the Admiralty is responsible for surveying the waters of overseas territories which come under the jurisdiction of the British Government, like the Falkland Islands and Hong Kong, and for this purpose other survey ships are employed: HMS Vidal (2,173 tons), HMS Dampier, HMS Owen, and HMS Cook (each 1,600 tons). These vessels are also engaged from time to time on oceanographic surveys along principal shipping routes.

Another stack of information is gleaned from foreign government charts, publications, and *Notices to Mariners*. This free exchange of data is made possible by membership to the International Hydrographic Bureau which receives the support of well over 30 nations. The principal objects of the Bureau are: (1) to co-ordinate hydrographic work throughout the world in order to make navigation safer and easier, (2) to secure uniformity in charts and hydrographic publications with regard to symbolization, etc., (3) to encourage the adoption of the best available methods for hydrographic surveying, and (4) to promote improvements in the theory and practice of hydrography. Founded in 1921, the Bureau is centred on Monaco and performs some excellent work.

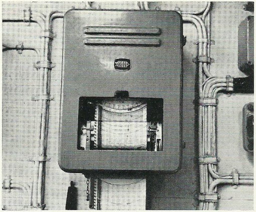
Plans and surveys from harbour authorities throughout the world are extremely valuable in keeping Admiralty charts up to date and sometimes independent surveying organizations, such as commercial companies, send in useful and original material. It seems possible that this source of information could grow in volume during future years as more and more prospecting for minerals in the sea bed is tried. Last, but by no means least, the ordinary naval and cargo vessels travelling the seas as part of their normal business – and not equipped specially for surveying – often spot navigational hazards and will despatch reports to the Admiralty for the amendment of charts.

Echo sounding

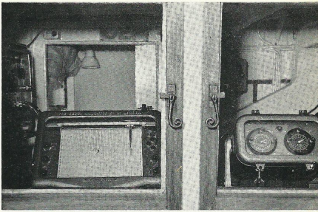
Soundings of sea depths are scattered over a chart in a seemingly higgledy-piggledy manner; but in places like the approaches to ports and harbours they uncover for the navigator the obstructed and shoaler parts of a channel and pick out the safe passages. They are expressed in fathoms and feet for depths of less than 11 fathoms, and to prevent the possibility of misinterpretation the feet readings appear as inferior figures. On some older charts fractional parts of a fathom are shown instead of feet. Elsewhere, in deeper waters, the soundings are given in even fathoms, but in all cases the exact positions are the centres of the spaces occupied. Certain depth contours are also traced with pecked lines, such as the 1-, 3-, 6-, and 10-fathom lines in coastal waters. On Admiralty charts, a blue tint covers the area between the high water and 3-fathom lines and a ribbon tint reinforces the shoal side of the 6-fathom line. Underlined figures on rocks and banks which uncover at low water express the heights in feet above the datum of the chart.

Echo-sounders are the instruments employed on survey ships for determining the depth of the sea at any given point. In essence, an echo-sounder is a device which transmits short pulses of sound from the bottom of a ship, measures the time taken for the echo to bounce back from the sea bed into a receiver, and records the measurement graphically on paper as the depth of water. Two basic principles lie at the root of echo-sounder engineering: (1) there is always a measurable time lapse between the sending out of an original sound and the return of its reflection or echo, and (2) that sound travels through water at a known speed and at greater distances than in air without being weakened. However, its velocity does vary slightly according to the temperature, pressure, and salinity of the water, but in hydrographic surveying a correction factor can be applied to remedy any divergences when interpreting the echo trace for plotting.

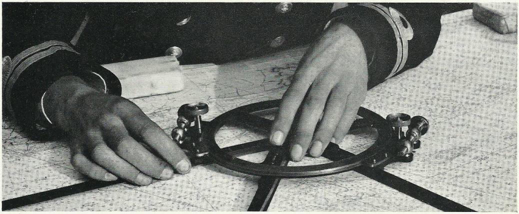
Often the transmitter oscillator responsible for projecting a sound is welded to the inside of the vessel's hull near to the keel, while the receiving oscillator which picks up the echo from the sea bed occupies a similar position on the opposite side of the ship. A mean velocity for sound of 4,800 feet or 800 fathoms per second has provided the basis for all echo-sounders made by Kelvin Hughes and all calculations for scales use this figure. Thus, if it takes exactly one second for the sound emitted by a transmitter to reach the sea bed and travel back again to the receiver, the overall distance covered will be 800 fathoms though the depth of water is only half this, that is 400 fathoms. Therefore, any fraction of a second will correspond to an equal fraction of 400 fathoms. As a result, the time intervals involved in echo soundings for marine surveys in shallow waters are extremely small. For graphically recording the soundings taken, a chronograph is used which incorporates a time-measuring device, governs the sound transmission system, and controls the markings of a stylus or pen against a reference scale on paper. In this way the contours



A Kelvin Hughes Echo-Sounder showing the paper on which the trace will be prepared.

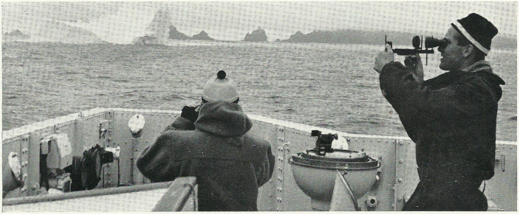


Track plotter and decometers forming part of the Decca Navigation System.



ABOVE Plotting a ship's position on a chart by means of a station pointer.

BELOW Taking bearings with a sextant on board HMS Owen.



ABOVE An echo-sounder of Admiralty design in use on board ship.

BELOW Reading an Ekman Current Meter on board HMS Dalrymple.

of the sea bottom are traced in one continuous line and to a staggering degree of accuracy. Kelvin Hughes claim that the results achieved with their MS26 echo-sounder, designed specially for hydrographic surveying, can be guaranteed under still water conditions to a tolerance of less than 3 inches. Just as remarkable is the operational rate of the instrument which takes 533 soundings per minute or one sounding every ninth of a second. This means that a survey craft travelling at 6 knots would collect a sounding at every 1.14 foot advance. Its effective sounding range starts at a few inches of water and extends to 540 feet. To maintain precision, the trace is made on a dry paper which is stable in all the varying conditions of temperature and humidity likely to be encountered in service. The length of the paper roll is 50 feet which lasts for 10 hours in operation: in effect the paper moves at one inch per minute. After the paper has been marked it is automatically re-wound on to a receiving spool for safe storage until required in the charting room.

Caution is necessary when sounding because false echoes can arise from dense layers of fish or plankton masking the bottom; while tidal streams with solid particles in suspension sometimes create feathery echoes.

Fixing position

Besides determining the depth of the sea at a given point, a survey vessel must be able to locate a sounding exactly. As long as charted points on the shore are visible, there is no great difficulty. The most usual method is by compass bearings of suitable objects. Since a fix by only two bearings is not sufficiently reliable, a third or check bearing must be taken and the coincidence of the resulting three lines on the chart denotes the ship's position. Another method is to take horizontal sextant angles of well-defined objects and to plot these on a chart with a station-pointer. The latter consists essentially of three arms attached to a circle made of celluloid. When the arms have been positioned so that they correspond with the angles between the objects, the pointer is placed on the chart and the centre of the circle indicates the exact position of the vessel. Although outside the scope of the *Recorder*, countless other methods are used by navigators for ascertaining the position of a ship when in sight of a shore.

Electronic systems for fixing the positions of ships in the open sea and far from land were sparked off by the 1939–45 war and probably the two best known methods are Loran and Decca. Admiralty charts are produced for both, although the Royal Navy's home survey fleet is fitted out with Decca receiving equipment.

Loran stations are established on many coasts around the world, spaced up to 600 miles apart and usually in the form of one master station and one or two slave stations. From the master station a very short radio signal is transmitted, followed by a signal from the slave station. On the ship, the two signals are received on a cathode ray indicator which enables the operator to determine the difference in arrival time. This, in turn, denotes that the ship must be along a parabolic line overprinted on Admiralty Loran charts. Another signal is taken from a second Loran station and the intersection of the two lines gives the fix. Loran has a range of roughly 700 miles.

Decca employs the same parabolic system as Loran, and a number of transmitting beacon stations have been erected in the United Kingdom and on the Continent. By means of special receiving equipment in a ship and navigational charts overprinted with a lattice of parabolic position lines, the ship's precise location can be ascertained. The Decca range is approximately 300 miles and the system tends to be confined to ships in home and coastal waters.

Charting

Shore lines and topographical features on a chart are surveyed by the old principles of triangulation and levelling, but newer instruments such as the tacheometer and tellurometer are used. Air surveys are also employed. However, on a chart it is the hydrographic detail which captures the imagination of the layman. A survey vessel equipped with a modern echo-sounder and an electronic fixing system can chart enormous areas of water quickly and thoroughly. Survey vessels take lines of soundings by running up and down parallel tracks until an area is fully covered, although shoals and other hazards will need closer examination. All surveys are directed from the Hydrographic Offices of the Admiralty at Cricklewood in London and commanders of vessels will be instructed to chart a given area at a particular scale. Interpretation and processing of echo traces are carried out on board ship and the completed surveys go to the Hydrographic Offices for further work. Unlike the finished charts which have a relatively sparse number of soundings, the sea areas on plans coming from survey vessels are packed solid with depth readings. If these were reproduced in facsimile, the ordinary mariner would be confused by the mass of detail and unable to work out and plot legible courses on the charts. At the Hydrographic Offices, the surveys are overlaid with a sheet of Permatrace and on this a draughtsman working in conjunction with an hydrographer will trace off the material required for the finished job. Considerable skill and knowledge is required to generalize the mass of detail and infinite care is exercised to ensure that during the selective process no dangers to navigation are overlooked; numerous checks being implemented to forestall mishaps. Contour lines are another refinement stemming from the drawing office and these are traced from the multitude of soundings. Any additional notification of navigational dangers by vessels sailing in the area, or from other independent bodies, are compiled by the draughtsman and incorporated with the Navy's survey. The resulting drawing on Permatrace – showing a much more open and legible chart than that emanating from the ship – is then passed on to the printer for reproduction. Thus, although soundings on a finished chart may look haphazard and scant, they represent a true if broad picture of the sea bottom.

Projection and scales

Most Admiralty charts are on the Mercator projection, although a few Gnomonic ones appear from time to time. Mercator's projection, dating from 1569, is quite remarkable and of great assistance to the navigator. It has vertical meridians and horizontal parallels and is the only projection that shows rhumb lines or compass directions as perfectly straight lines crossing each meridian at the same angle. This means that the navigator can read a pre-plotted course directly from the Mercator chart and by keeping the ship in that direction appear to travel straight to a destination, although actually a curved line is followed.

As previously stated, the meridians and parallels of a Mercator projection are respectively vertical and horizontal. This means that the meridians are spaced equally and true to scale on the equator; while the parallels are spaced in such a way that by taking any small area, the relation of scale along the meridians and along the parallels is the same as on the globe. Such a scheme leads to a marked scale exaggeration towards the poles. Consequently, a nautical chart often shows a numerical scale only (e.g. 1/5000), but the border is broken down into degrees and minutes from which distances can be reckoned because a nautical mile is roughly equal to 1 minute of latitude. The nautical mile is an interesting measurement, though a somewhat elastic one. Formerly it was defined as 1 minute of latitude, but the distance that this represented tended to be shorter at the equator than near to the poles. Subsequently, the Admiralty became rather more specific and gave it a mean value of 6,080 feet. Not all countries accept this standard. Where graphical scales do appear on charts, the sea mile is often broken down into 10 cables.

It is impossible to be definitive about the scales used for Admiralty charts because these do vary widely. But broadly speaking, the harbour charts are prepared at a scale of 1/50000 and sometimes larger; coastal charts usually come within the range of 1/50000 to 1/500000; while smaller scales suffice for ocean charts.

Chart datum

Current Admiralty surveys are geared to a chart datum of the Lowest Astronomical Tide, that is the lowest predictable water level under average weather conditions. Irrespective of the circumstances under which soundings are taken, all are corrected and expressed ultimately in relation to this internationally recommended base line. Some commercial ports favour different, and less foolproof, planes of reference and in these cases extra caution is necessary on the part of the mariner. For Admiralty charts founded on foreign surveys, the datums are always those employed by the hydrographic authority of the country concerned.[3]

Most charts carry a table of tidal information which denotes the height above the chart datum of mean high and low water at both the spring and neap tides.

Compass roses and symbols

Compass roses on charts are most distinctive, both in design and positioning. They have two concentric dials: the outer one calibrated in degrees from the true north, and the inner one divided into quarters of points and showing magnetic north. As an essential working tool, the navigator does not want to hunt down the compass rose to an insignificant corner on a chart and for this reason it usually occupies a prominent position in the deep sea areas. More than one compass rose is included on larger charts.

Symbols and abbreviations on navigational charts have been

Hydrographic symbols cut by The Monotype Corporation Limited

Light — Green can buoy — Yellow can buoy

Barrel buoy — Foul ground

Rock with 6-feet or less water over it at chart datum

Rock awash at the level of chart datum

Rock awash at the level of chart datum

Topmarks of buoys or beacons

Mooring buoys

Light vessel — Triangulation point

Wreck showing any portion of hull at chart datum

Dangerous wreck of which masts and funnel are visible

Wreck over which the exact depth is unknown

Anchorage for large vessels

Temple — Mosque — Moslem tomb

Windmill — Church — Radar reflector

Black can buoy — White can buoy

Red can buoy — Blue can buoy

Black and white vertical stripe can buoy

Black and white chequered can buoy

Red and white chequered can buoy

Black conical buoy — White conical buoy

Red conical buoy — Green conical buoy

Black and white horizontal stripe conical buoy

Black and white chequered conical buoy

Red and white chequered conical buoy

Black and white horizontal stripe conical buoy

Red and white horizontal stripe conical buoy

Yellow conical buoy — White spherical buoy

Black and white horizontal stripe spherical buoy

Spar buoy — White pillar buoy

A B C Positions for which information regarding tidal streams is given on the chart

standardized by the International Hydrographic Bureau and many of these were specially cut as matrices for the Admiralty by The Monotype Corporation Ltd. Taken overall the symbols and abbreviations cover a wide range of features, such as sand-hills, coral reefs, fiords, anchorage limits, harbours, berth numbers, lighthouses, light vessels, buoys, beacons, radar stations, fog signals, wrecks, shoals, fishing zones, ice barriers, submarine cables, soundings, depth contours, mud banks, tides, currents, and so on. A small selection of the hydrographic symbols produced by The Monotype Corporation Ltd. are shown in a table on the left. By having a codified and generally accepted language of symbols, the hydrographer can pack a good deal of information on a chart without creating a feeling of overcrowdedness or of running the risk of baulking navigators.

Reproduction

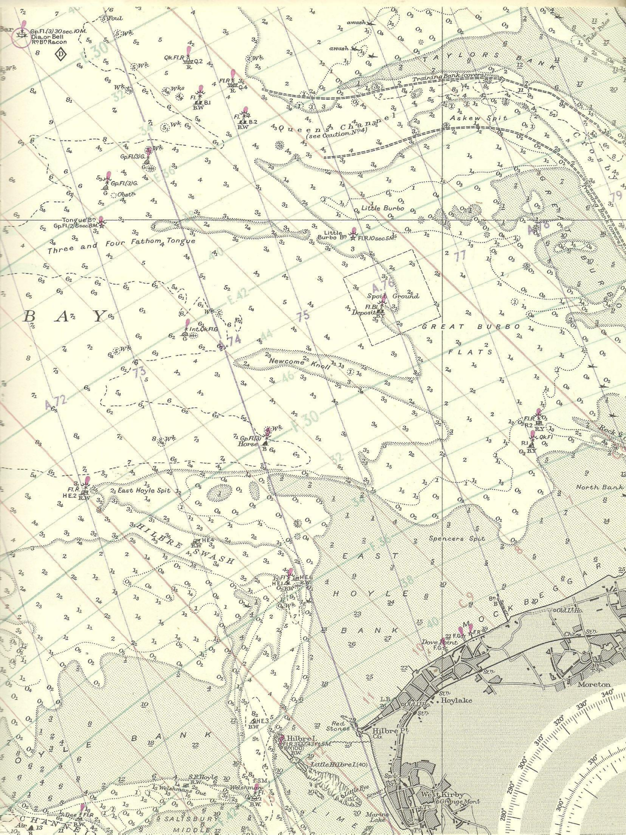
To pick up the story of chart production we must revert to the generalized drawing on Permatrace prepared by the draughtsman from the original survey. Once the Admiralty printer receives a copy of this, a decision is made as to which of two production methods will be implemented, either engraving on a copper plate or drawing on an enamelled aluminium surface. Whatever the outcome, the image will end up eventually on an albumen plate for lithographic printing by rotary offset presses.

In readiness for copper plate engraving, the Permatrace drawing is contacted into a photographic negative from which a blue key can be made on a copper plate. To do this, the copper is coated with a solution of dichromated casein in a 'Lithotex' Whirler and when dry receives a contact print from the negative in a 'Lithotex' Printing-Down Frame. Afterwards the plate is immersed in water to dissolve away the unexposed emulsion, thereby allowing the light-hardened casein image to be dyed blue. This image now serves as a guide for the engraving and etching processes to be performed on the surface of the copper.

Gravers and burins controlled by the steady and sure hands of a craftsman are used to engrave the continuous and straight lines of a chart. But the dotted and pecked lines, delimiting the depth contours, are tentatively run into the copper with the aid of a tiny roulette wheel and are finally deepened for printing by pricking or cutting, the technique depending on the character of the line.

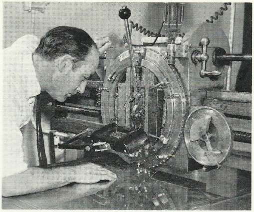
Soundings are stamped into the copper plate by a hand-operated machine holding a series of male dies mounted around the edge of a wheel, the dies range from 0_1 (that is 1 foot) up to 9_5 (that is 9 fathoms and 5 feet). Double figures for fathom readings in deep water must be compiled from two appropriate dies. To operate the machine, the selected die is simply positioned over the blue key on the copper and indented into the plate. Instead of the nasty crunch expected, the process is surprisingly gentle. The degree of metal displacement is very slight with the impression scarcely exceeding a depth of 0.003″. Bulk lettering in straight lines, seen in the titles of charts, is also composed on the stamping machine, but the hand engraver produces most (if not all) of the other wording much of which wanders along unruly curves or lies at awkward angles.

INSET Portion of an Admiralty chart overprinted with Decca lattice lines.



Taylors Bank
Training Bank (covers)
Queens Channel
(see Caution No 4)
Askew Spit
Crosby
Little Burbo
Little Burbo Bn
Tongue Bn
Three and Four Fathom Tongue
B A Y
Spoil Ground
Deposit
Great Burbo
Flats
Newcome Knoll
Horse
East Hoyle Spit
Hilbre Swash
North Bank
Spencers Spit
East
Hoyle
Bank
Mockbeggar
Dove Point
Hoylake
Moreton
Red Stones
Hilbre Pt
Hilbre I.
Little Hilbre I. (40)
Little Eye
West Kirby
Marine Lake
Grange Mont
Hoyle Bank
Welshmans Gut
Salisbury
Middle
Channel
Foul
Obstn
Gp.Fl.(3) 30sec.10M.
Dia. or Bell
RoBnRacon
Qk.Fl.R.
Gp.Fl.(3)G.
Gp.Fl.(2) 5sec.8M.
Fl.R.10sec.5M.
Int.Qk.Fl.G.
Gp.Fl.(3)
Qk.Fl.
Old Lt.Ho.

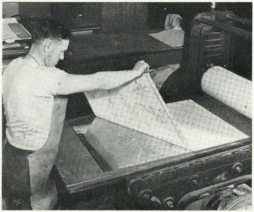
Engraving chart detail in copper.



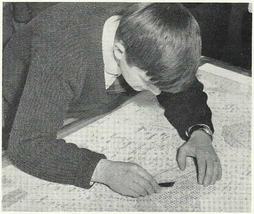
Stamping sea depth soundings into a copper plate.

Local etching of chart detail into a copper plate.

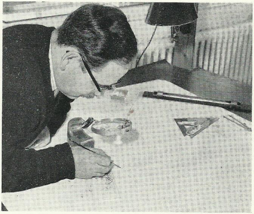
Taking a proof from a copper plate.

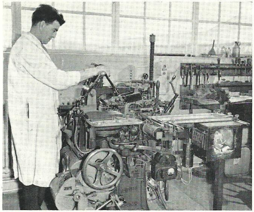


Patching up hydrographic symbols on to a sheet of Cobex.

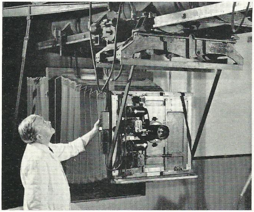


Painting in chart detail on an enamelled aluminium plate.

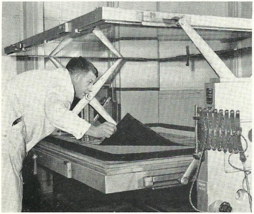




ABOVE 'Monotype' caster used for setting the names on Admiralty charts.
BELOW Focusing the 'Monotype-Huebner' overhead camera automatically for precise sizing.



BELOW 'Lithotex' Model X Printing-Down Frame used in chart production.



Coral reef, low water rock, and certain other features are not reproduced on charts by mechanical stipples or shading, but are symbolized in a rather picturesque manner not unlike the hachuring seen on some old maps. To etch this work into the copper, a thin layer of bituminous wax is spread over the area to be treated and the engraver, guided by a superimposed blue key, cuts through this ground to uncover the copper beneath. Nitric acid, applied locally, then eats into the plate as required. At the bottom of some charts, a profile of the land is included to assist the mariner in finding his bearings. These are etched into copper plates with considerable artistry by using a wax ground as described above, but to bring out the various tones fine etching is practised by progressively stopping out given areas with varnish.

Compass roses, tidal tables, and similar repetitive details are photo-etched into the copper from standard diapositive images. For this purpose, the plate is sensitized with a solution of dichromated glue and contacted under a positive. Next, development in water washes away the unexposed glue to bare the copper underneath and the image is dyed to facilitate inspection. To form an enamel-like acid-resist through which etching with ferric chloride can be accomplished, the insolubilized glue remaining on the copper is burned-in. Once etching is over, the plate can be cleaned in readiness for proofing. Thus, the various components of a chart are built up on a copper plate by a number of different processes and by a team of hand engravers which must be unique in the world.

From the copper plate a number of proofs are taken on heavy and rugged presses for verification by hydrographers. And once approval has been obtained, the copper plate is finally proofed on a sheet of Ozakling which can be contacted photographically into a negative for lithographic platemaking on zinc by the albumen process. In the meantime, the original copper is carefully stored until required for revision, a subject that will be dealt with later on.

The other and newer method of producing Admiralty charts is founded on enamelled aluminium plates, but like the copper engraving process the sequence begins by making a contact negative from the original Permatrace draught. Then, by means of the casein process, two blue key images are prepared respectively from the negative on a sheet of Cobex and on a sheet of Scribecoat.

On to the Cobex various chart elements are patched up to the blue key in the form of waxed stripping-film positives, such as place names, compass roses, soundings, and tidal tables. All place names and symbols emanate from a 'Monotype' Keyboard and Caster and reproduction proofs are taken from the type matter for photographing on a 'Monotype-Huebner' camera. The resultant negative is contacted on to stripping film. Depth soundings for patching up are obtained by a similar process, except that the reproduction proofs come from a copper plate produced on the stamping machine. Diapositives of compass roses and tidal tables finalize the Cobex sheet which is then contacted into a negative for reproduction as a black albumen print on an enamelled aluminium plate.

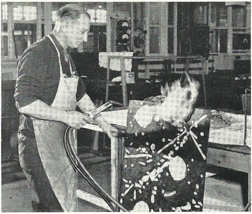
Meanwhile, the Scribecoat bearing the other casein blue image undergoes attention from another draughtsman who, with the aid of sapphire scribing tools, scrapes the continuous lines and land profiles, etc. into the actinically opaque lacquer-like layer, thereby producing a direct negative for printing down as a black albumen print on to the enamelled aluminium plate already bearing the place names. Finally, a casein blue print is made on the same enamelled plate from the original negative taken from the Permatrace drawing and this serves as a guide for the draughtsman to ink over in black the dotted and pecked fathom lines and any other work which could not be done conveniently by scribing. Having combined all the chart components in this way, the enamelled plate is ready for photographing into the finished platemaking negative.

Masks for confining land stipple and mud cross-hatching, etc. to given areas on the printing plates are produced in a number of ways. One method is to make blue key images on Cobex and to paint out the areas free of stipple with plast-opaque. For printing down, the stipple films are simply interposed between the plate and the mask.

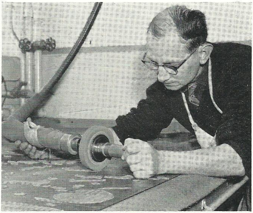
Throughout the photographic processes, the need for undoubted accuracy is of paramount importance and the 'Monotype-Huebner' camera has contributed handsomely to the degree of exactness maintained in Admiralty charts. A good many jobs are still copied on photographic glass plates, but as film becomes more and more stable so this practice will decrease. Already a 0.007″ Estar-base film is tending to oust glass. Several 'Lithotex' Contact Boxes are used in the dark-rooms and these cope with a large volume of work, while other equipment manufactured by Pictorial Machinery Ltd. predominates in the printing-down sections.

Once the final negative is obtained, whether via the copper or enamel process, a lithographic image can be made by sensitizing a grained zinc plate with a film of dichromated albumen. When thoroughly dry, the plate receives a contact print from the negative and is inked up ready for development in water which leaves the printing image on the zinc surface in the form of light-hardened albumen with an ink top.

Admiralty navigational charts are usually printed in three colours only: black for the detail, blue tint for the shallow water areas, and magenta for flashing the positions of lights. Decca and Loran lines will necessitate extra printings. It will be appreciated, therefore, that on charts the white paper is by no means obliterated as on many contour-layered topographic maps. And the chief reason for this seeming frugality is purely functional in that the mariner requires a sympathetic and unobtrusive surface on which to plot courses. Furthermore, the chart will be used over and over again for this purpose and consequently must be able to withstand fairly rough handling when old courses are erased and new ones plotted. A stout and durable paper, containing a good proportion of rag in its furnish, is employed and accounts for a large percentage of the production costs. Since the average length of run scarcely exceeds 300, the need for some kind of rationalization of method in the machine room becomes imperative and this is achieved by keeping each of the presses in a given colour, either black, blue or magenta. Thus, the printing of a chart will not be confined to one machine, but usually involves three. To forestall registration difficulties all the paper is properly conditioned before going on the machines. Where the number of lights indicated on a chart are very few, perhaps less

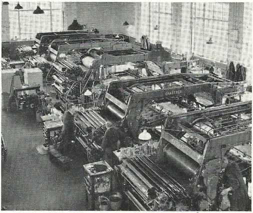


ABOVE After the electrolytic deposition of new areas of copper on a plate preparatory to chart revision, the background 'masking' wax is melted with a torch.



ABOVE Grinding down to plate level new deposits of copper in readiness for engraving revisions.

BELOW A few of the machines used for printing charts.



than five, the expense of making and printing a special magenta plate is not considered worthwhile and the flashes are stamped on the finished sheets by hand.

Some foreign charts are a little more colourful than the British ones, but an enlivening of this kind must still observe working requirements. For instance, the land areas on German charts are coloured, whereas the British favour a somewhat conservative and dull black stipple. Yet in both cases the seas show as white paper.

Chart revisions

One of the biggest bugbears in chart production is the constant need to revise existing material. All sorts of contingencies can soon make a chart obsolete, such as: the silting up and the dredging of harbours, the re-positioning of buoys, the changing of lights, the natural and rapid shifts that occur where the sea bed is soft, the intensity of new surveying and resurveying, and even the development of new ships with deeper draughts impose fresh navigational standards, particularly oil tankers in this modern age. In busy stretches of water, like the Thames estuary, the frequency of revision is not much longer than 6 months with survey vessels operated by both the Royal Navy and the Port of London Authority maintaining a ceaseless vigil over the sea bottom to spot any movement which could constitute a danger to navigation. As a result, any printing method must have sufficient built-in flexibility to accommodate these amendments with the least possible bother.

Corrections of a comparatively small nature are made directly to the albumen printing plate by: (1) removing outdated work with caustic potash, (2) preparing the zinc surface with alum and nitric acid, and (3) drawing in revised work with litho drawing ink. There is a limit to the number and extent of amendments that can be effected in this way, since the plate grain becomes debased and creates difficulties during machining. Any correction embodied on the printing plate must also be carried out on the copper and enamel masters to keep them up to date.

More extensive corrections must be done on the copper and enamel originals and new printing plates made. Obsolete work on an enamelled aluminium plate can be quickly eradicated by scraping at the white surface, thereby permitting fresh matter to be inked in or patched up as bromide prints.

To correct a copper master, the plate has to be cleaned and the *standing* areas (i.e. those not requiring revision) stopped out with beeswax. Then, by a process of electrolysis, a growth of copper is obtained on the area to be altered. Afterwards the wax is melted from the standing areas and the new copper deposit is ground down to plate level for re-engraving.

Obviously the notification of changes to charts must reach the mariner as quickly as possible and the promise of a new edition at some nebulous future date is not good enough. Consequently, a weekly bulletin giving information about important navigational dangers and changes as they become available is put out under the heading *Admiralty Notices to Mariners*. On receiving these, the navigator can make the necessary amendments to charts by hand usually with waterproof violet ink. Likewise, the stock of charts held by the Hydrographic Supplies Department at Taunton is maintained in the same manner, so that every chart leaves complete with up to the minute information. It is interesting to thumb through an *Admiralty Notices to Mariners* in order to see the sources and authorities for the varied and scattered changes. One edition included the following: HM Surveying Ship Dalrymple; Trinity House; HM Australian Surveying Ship Paluma; HM New Zealand Ship Takupa; Timaru Harbour Board; Hydrographic Offices in Norway, Denmark, and France; and a host of others.

Publications

Other publications put out by the Hydrographic Office as aids to mariners are worth mentioning. The *Admiralty List of Lights, Fog Signals and Visual Time Signals* is published annually and covers the world; the *Admiralty Tide Tables* also appear annually but in three volumes dealing respectively with European waters, the Atlantic and Indian Oceans, and the Pacific Ocean and adjacent seas; the *Admiralty Lists of Radio Signals* come in five volumes touching on communications, navigational aids, metereological services and observation stations, and radio time signals; and finally the *Admiralty Sailing Directions* consist of 74 volumes of world-wide scope.

It will be realized from the foregoing that the Hydrographic Department of the Admiralty has been in existence for nearly 170 years and today publishes over 3,500 navigational charts (besides air charts for the Fleet Air Arm) which provide complete world cover for shipping of every nationality and size. Its surveying methods, founded on a sound basis of tradition, are forward looking and modern with a watchful eye being kept on the future possibilities of aerosurveying for marine purposes. Its printing side, although apparently quaint from the general printer's viewpoint, has a finger on the pulse of current advancements and is gradually changing over from copper plate photographic originals to the sleeker enamel process, a development which threatens the demise of yet another old craft which spiritual man can ill afford to lose. No doubt all sorts of changes will be seen in both marine surveying and chart printing in future years, but through all this one thing remains certain, the accuracy of the Admiralty chart will not be compromised.

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We wish to acknowledge the assistance of the Hydrographic Department of the Admiralty in the preparation of this section of the *Recorder*

Thematic mapping

It has been suggested that 'almost any kind of information is mappable'[1] if not map-worthy, a view upheld by a glance at the *Atlas of Britain* recently published by the Oxford University Press, which clearly demonstrates the expanding language of cartography and the immense capacity of maps for showing the spatial or geographical relationships of all kinds of data. Maps dealing with landforms; geology; climate; water; vegetation and forestry; agriculture and fisheries; industry; demography; and communications; besides a host of other subjects can be found in the *Atlas of Britain*, all of which assist scientists, economists, and planners to see the immediate areal significance of statistics. Within the limited space available in the *Recorder* it is only possible to mention a few of the problems involved in the making of thematic or analytical maps. Likewise, only random examples of the techniques used for mapping quantitative data can be touched upon.

Dot maps

Perhaps the simplest method of illustrating density of distribution is that of peppering a compiled base map with dots of uniform size each representing a specific value, say 5,000 people on a population map or 100 acres of land on an agricultural map. This technique gives a good visual impression of relative densities and is superior to most other methods for showing fairly accurately the location of various phenomena. Theoretically the dot map also provides the reader with precise arithmetical information made possible by multiplying the number of dots by their unit values, but in practice this is rarely done and the person in search of more precise details would revert to the statistical source which should be indicated on the map.[2] From the cartographer's point of view, the dot technique has the added attraction of simplicity in so far as the number of dots to be disposed in a political or civic region can be easily determined by dividing the statistical total by the unit value of each dot. Several maps in the *Atlas of Britain* make use of the dot technique, such as that depicting wheat distribution on which each dot represents 100 acres of land and is also 100 acres at the scale of the map: a happy coincidence! Pig distribution throughout the country is shown by the same method with each dot denoting 1,000 animals. On other maps in the atlas, two distributions are shown simultaneously by using dots of different colours as exemplified by some of the forestry maps.

For a map to mirror a distribution accurately, the dot size and ascribed unit value must be wisely chosen: these two factors being inseparable. Some cartographers claim that on an expertly designed map the dots will just fuse to form dark areas in the crowded parts of a dense distribution; whereas if a distribution is sparse the map will reflect this by the dots not massing too closely and looking excessively dark, even in the comparatively concentrated regions. Other cartographers insist that the dots must always be countable and should never be allowed to merge. In general terms: if the dots are too big, they will coalesce too much in the 'packed' areas, thereby losing their meaning and suggesting unwarranted density. Conversely, if the dots are too small, they will not bring out any overall visual patterns of distribution and will appear scattered and insignificant. The unit value assigned to the dots will also influence the effectiveness of a map. Where the value is too high, the number of dots will be so reduced in number that no distinct patterns of incidence emerge from the map; whereas a unit value that is too low gives rise to a myriad of dots which might convey an impression of accuracy unjustified by the original statistical survey and create problems in squeezing all the dots on to the map in denser areas. Several aids for ascertaining the most appropriate dot size and unit value for a map have been evolved, such as the nomograph devised by J. Ross Mackay.[3] Moreover, the cartographer normally experiments with trial tracings to assess the visual validity of a given scheme in both the denser and more scattered areas of a distribution.

Correct location of the dots depends upon a thorough understanding of the distribution. Erwin Raisz[4] asserts, as a general rule, that every dot should 'be in the centre of gravity of distribution in the region it represents'. He goes on to cite a case of a dot indicating a certain number of people in a township. On the finished map the symbol would be placed in that part of the township at the 'centre of the population'. Not all data, however, are so easy to analyse and no map is better than its sources of information. For example the data available may relate to broad regions like northern Scotland or Wales, or in less trying conditions to counties. In these cases, all the cartographer will know is that an x number of dots is to be arranged within known administrative boundaries. Often the statistics will give no inkling as to the whereabouts in these areas of dense and scattered distributions, facts which the cartographer must collect from other sources, such as the study of relevant topographical, soil, climate, and other maps. On occasions a visit to the area may be necessary and discussions with acknowledged experts in the map subject will throw extra light on the problem. The temptation to indulge in vague generalizations must be resisted in order to preserve the scientific integrity and objectivity of a map. For example, 'sheep are not always found in the uplands, nor barley in the drier parts.'[5] Where no detailed information is available, necessitating the even distribution of dots in each 'statistical division', the respective boundaries should be shown on the map in order not to mislead the map reader.

Isopleths

Isopleth is the generic term for a line on a map connecting points of the same quantitative value. If these lines join up places with equal rainfall, they are known as isohyets. Places of equal temperature are connected by isotherms. Sunshine values are indicated by isohels, barometric pressure by isobars, frost by isocrymes, and so on. Even the familiar contour line used for linking locations of the same elevation are sometimes called isohypses and work on the same *principle* as the isopleths used in statistical mapping. Often the belts between isopleths on climatic and other maps are coloured distinctively to assist the user to pick up values quickly and accurately.

If a map of annual rainfall is to be compiled the scientific observations of weather stations must first be plotted on the base map to constitute a kind of framework from which isohyets or contours of rainfall can be interpolated or traced. This synoptic or broad view of rainfall distribution can only be built up by making inferences and assumptions as to the nature of rainfall existing at the innumerable points separating each weather station. The accuracy of the generalization will depend on a number of factors, not least among them being the density of the weather stations, the knowledge possessed by the cartographer of the area being mapped and of the other interrelated factors having an influence on the map subject which, in the case of rainfall, would include the altitude of the ground, etc. At the best of times, therefore, the isopleths on a climatic map must be in part hypothetical and open to error. Where the density of weather stations is heavy this error will tend to be less than where observations are few and far between. On the maps of Annual Rainfall and Annual Sunshine in the *Atlas of Britain*, the traditional isohyets and isotherms have been rejected as not sufficiently accurate. Both these maps are based on Meteorological Office statistics from some 250 observation stations distributed somewhat unevenly throughout the country: abundant in the south and sparse in the north. Too few, in the words of D. P. Bickmore,[6] 'to justify drawing a network of firm contours round them'. Instead, the observations made at each weather station are located and enclosed in coloured circles: nine categories on the sunshine map and eight categories on the rainfall map. This system allows precise data to be read off at the individual points, while valid cartographic generalizations are conveyed by the agglomerations of coloured circles without misleading the eye with unjustifiably firm lines.

Flow lines

Movement of vehicles, goods, and passengers along roads, railways, airlines, shipping routes, inland waterways, migratory paths, etc. may be represented on maps by flow lines. Thus, a statistical map of railways will not only show where the tracks are situated, as on topographical maps, but additionally will carry some indication of the volume of traffic passing along them. One of the commonest ways of expressing quantitative flow is by graduating the thickness of the lines, each unit of width having a specific value, say 100 trains. However, this system is not always workable or ideal. For instance, the daily inflow and outflow of railway traffic to and from London is enormous. If this traffic were depicted with flow lines of graduated thickness, the converging lines would fuse or merge way outside the capital and lose their meaning for the map reader. Consequently, in the *Atlas of Britain* the traffic flow on railways is shown by lines of different colours and patterns, a method more apposite to the detail that had to be piled on the map. As a result it was possible to classify the railway lines into nine groups, ranging from lines with only one to ten trains daily up to busier stretches of track having between 301 to 400 trains per day. On the same map, the volume of traffic on ferry services is denoted by lines of varying thicknesses.

Whilst on the subject of flow lines, it is worth repeating that a map can never be better than its sources of information. The map in the *Atlas of Britain* showing the number of vehicles passing along A roads per day is based on the census of 1954 because of the absence of more up-to-date information. Elsewhere in this *Recorder* the inordinate amount of time intervening between a survey and the preparation of positives and negatives for platemaking is commented upon. But there is another side to the coin and the long manual processes involved in the preparation of a map are not the only bottleneck. The time separating a statistical survey or census and the processing of the returns takes an enormous amount of time which means that the cartographer has little chance of producing really up-to-date maps. Nevertheless, there is hope for the future. If the traffic surveys or population censuses can be recorded on magnetic tape for feeding, with the aid of a computer, into a cartographic system working from such a tape – like the Bickmore-Boyle System of Automatic Cartography (see Introduction) – the possibilities for truly 'topical' mapping would appear most rosy.

Proportional circles

Another popular cartographic technique for illustrating quantitative data is that of the proportional circle and 'pie-graph'. By this method a distribution on a map is shown by circles of different sizes, the area of each being proportionate to the amount represented. Some preliminary investigation is necessary to determine the most appropriate scale of the circles, the aim being to avoid overcrowding or emptiness on a map. On some maps the information will mass together in such a way that the overlapping of symbols may be inevitable and the reader must interpret the data with due allowance for the eclipsed or underlying symbols. This slight complication need not deter the map designer, for if intelligently tackled the judicious overlapping of symbols gives a good indication of density. The maps of Annual Industrial Fuel Consumption in the *Atlas of Britain* using this technique are a model of clarity and even in the most crowded regions, like the Black Country, the system does not fail to communicate the vital information. On these maps nine proportional circles are employed ranging from the smallest which represents 1,000 to 4,999 tons of fuel consumption up to the largest denoting 2,000,000 to 3,000,000 tons.

More than one kind of data can be shown on a map by means of proportional or graduated circles broken down into segments, each of which is proportional to the total amount represented. By colouring each sector distinctively, the legibility of the map is greatly enhanced. On the fuel consumption maps in the *Atlas of Britain*, the circles are divided into grey segments for coal, yellow for gas, green for electricity, and red for oil, a technique which allows a good deal of data to be stacked on a map.

The centres of proportional circles are always sited at the centre of gravity of a distribution. And when dividing them it is advisable to mark off the smallest portions first so that any cumulative error will be largely confined to the major segments.

Bar graphs

Bar graphs constitute another means of representing quantities on maps and in some respects are more easily commensurable than graduated circles, although the latter give a better idea of point location than the former which seem more apposite to mapping statistics relating to fairly broad areas – such as counties – with their boundaries prominently outlined on the map. The difficulty is that they have no centre and are therefore hard to pin down to an exact spot. In essence, a bar graph consists of a series of columns proportional in length to the quantities represented. The columns may be *vertical* or *horizontal*; and *simple*, when each bar displays a total value, or *compound*, when each bar is divided and tinted or coloured differently to show an analysis of the total value. Seemingly vertical bars are more easily evaluated, but in any event the bars are drawn to a scale of pre-determined values. If several different but related distributions are to be depicted on the same map, differently coloured bars can be arranged adjacent to one another. This method can again be seen in action by reference to the *Atlas of Britain* in which the farm deliveries of fertilisers per acre of crops and grass (excluding acreage of rough grazings) is shown by counties. The county boundaries are firmly defined and within each is printed the relevant bar graph. No less than four distributions are 'stacked' on the map. Lime fertilisers are depicted by blue bars, the scale of these being one-inch to 300 lb. per acre. Nitrogenous fertilisers are indicated by orange bars, phosphatic fertilisers with red bars, and potash with purple bars, all to a scale of one-inch to 30 lb. per acre.

Many other methods for mapping statistics are employed by cartographers, such as: graduated volume symbols (e.g. spheres and block piles), comparable pyramids, divided rectangles, and so on.

Class intervals

In all statistical mapping the choice of class intervals is of paramount importance. If they are too small, the map will become cluttered with irrelevant detail. If too big, the salient differences of a distribution will be lost. Jenks and Coulson[7] suggested five desirable characteristics in class intervals which had to: '(1) encompass the full range of the data; (2) have neither overlapping values nor vacant classes; (3) be great enough in number to avoid sacrificing the accuracy of the data, but not be so numerous as to impute a greater degree of accuracy than is warranted by the nature of the collected observations; (4) divide the data into reasonably equal groups of observations; and (5) have a logical mathematical relationship if practicable.'[7]

Atlas of Britain

Throughout this article constant reference has been made to the *Atlas of Britain* which brings together a series of interrelated thematic maps and provides an opportunity for making comparisons and for gaining a balanced and 'round' picture of the areas mapped. In a talk on the BBC Third Network, which was subsequently printed in *The Listener*, D. P. Bickmore emphasized this aspect of cartography and map study. He stated that it would be 'dangerous to look only at the botanical maps without looking also at the map of water balance; useless to look at the map of railway traffic movement without also considering where new industrial building has been happening. The national atlases of many countries have been made with this purpose of bringing together a permanent record of the material resources of the country. Finland published its first national atlas in 1899 and has recently published its fourth edition. Canada published its first edition in 1906 and its third edition in 1957. The purpose of these large and expensive atlases is not only to group together a series of separate analytical maps, but to provoke comparisons between them so as to give a balanced view of the areas with which they deal – the whole atlas is greater than the sum of the separate maps.' In the *Atlas of Britain*, this country has at last been mapped in a comprehensive way.

One final point is worth making. It is too often assumed that the theory of thematic or analytical mapping applies only to small scale or atlas cartography and has nothing to contribute to topographical work. But an increasing number of cartographers are beginning to realize that the types of features selected as the constituents of a topographical map (e.g. relief, vegetation, etc.) should each be subjected to the same analytical thought. As an example, the Ordnance Survey shows 'rough pasture' on its maps without bothering to define scientifically the groups of plants and grasses covered by this term.

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Map design and typography

'One of the ways in which cartography differs from art is in the relative lack of flexibility in the modes of presentation on maps. This limiting factor in the visual design of a map makes itself felt in a number of ways, but none so fundamentally as in the matter of map projections. The projection constitutes a systematic reference frame and once chosen does not allow arrangement of the shapes defined thereon except through changes in orientation.'[1] These words are a fair summing up of the basic discipline underlying cartographic design and in the case of map projection visual considerations must nearly always take second place to functional requirements.

Representation of the spherical earth on a flat sheet of paper can be accomplished in a number of ways, but all are covered by the general term *map projections*. There are numerous projections each of which has certain properties and characteristics making it suitable or unsuitable for given jobs. An overall best projection does not exist. For example, a projection sympathetic to the mapping of the Soviet Union, which spreads over 5,000 miles east to west, would scarcely hold good for a country like Chile stretching more than 2,600 miles north to south and reaching an average of only 150 miles east to west.[2] Thus any attempt to say that one projection is better than another without specifying conditions of use is tantamount to claiming that a fork is better than a knife.

Only on a globe will all geographical relationships be shown truly, and the representation of the earth on a plane surface must introduce some imperfections. Erwin Raisz[3] defines a projection simply as 'any orderly system of parallels and meridians on which a map can be drawn' and goes on to point out that in any projection system only the meridians or only the parallels or some other lines can be true: in effect the same length as on a globe of similar scale. Projections are usually classified according to their principles of construction. Thus, cylindrical, conical, and azimuthal projections are based respectively on the geometrical projection of the earth's grid upon a cylinder, a cone, and a plane. Such a classification is far from being definitive and Raisz admits that most projections have not been constructed along these lines and many cannot be related to either a cylinder, cone, or tangent plane and were evolved by other methods. As the derivation of map projections is outside the scope of the *Recorder*, a more fruitful basis for discussion would be to look briefly into the characteristics of some projections and to assess their value to the cartographer.

Equivalence in a projection means that any region, large or small, occupies the same area on a map as on a globe of corresponding scale. It is desirable that maps showing distributional data should have this characteristic, otherwise their usefulness will be undermined by creating the impression of false relative densities.

One eminent cartographer has indicated that subjective ideas of the comparative extent of political regions can go awry where non-equivalent projections are frequently employed. He asserts that countless people confronted with this type of map have gained the mistaken notion that Greenland is much bigger than Mexico, whereas the two are very nearly the same size.[4]

Representative of the equal-area group of projections is the Bonne having a central meridian free of distortion along its length while any parallel may be selected on which to centre the projection. Scale and angular distortion increase rapidly away from the central meridian and for this reason the Bonne projection is rather more fitted to mapping an area with a greater north-south expanse. Other projections giving equivalence are the Albers dating from 1805 and the Lambert Azimuthal Equal-Area which was devised in the 18th century. The Albers projection includes two standard parallels free of angular deformation along their length, a feature suited to the mapping of territories in the middle and low latitudes with a greater east-west spread. It has straight-line meridians and circular parallels. Besides possessing equivalence, the Lambert Azimuthal Equal-Area projection is useful in mapping continents and large areas generally.

Conformality in a projection denotes that the shape of any *small* area on a globe will be preserved on a map and that the angles around any point or location will be correctly represented. These properties are of great value to navigators on air and sea charts and to a lesser extent on topographic maps, although conformality in the latter is by no means indispensable and its significance must be related to the eventual use of the map. Moreover, the average topographic map deals with such a tiny section of the earth's curved surface that any divergence from actuality will usually be very slight. Nevertheless, Ordnance Survey maps are now prepared on the Transverse Mercator projection which gives conformality, small scale error in a limited space, and which allows a National Grid reference system to be superimposed with ease and compatibility.

Perhaps the most widely known of the conformal projections is the Mercator, on which most of the Admiralty charts are drawn. On this projection, dating from 1569, all loxodromes or compass directions appear as straight lines and consequently simplify matters for the navigator. However, the Mercator projection enlarges areas in the higher latitudes, a drawback which tends to preclude its application to anything outside nautical charts.

Azimuthality in a projection means that all places are in their true direction from the centre of the map. Furthermore, linear and area scale variations are symmetrical around the centre

INSET Portion of a road map recently produced by John Bartholomew & Son Ltd.

Nottingham
Derby
Leicester
LEICESTER
RUTLAND
Birmingham
Coventry
Rugby
Royal Leamington Spa
NORTHAMPTON
Northampton
Peterborough
The Fens
HUNTINGDON
Huntingdon
Ely
CAMBRIDGE
Cambridge
Bedford
BEDFORD
Luton
HERTFORD
Hertford
BUCKINGHAM
OXFORD
Oxford
St. Albans
Watford
MIDDLESEX
LONDON
Chelmsford
ESSEX
Colchester
Harwich
Ipswich
SUFFOLK
NORFOLK
Norwich
King's Lynn
The Wash
Great Yarmouth
Lowestoft
Sheringham
Cromer
Felixstowe
Clacton on Sea
Southend on Sea
Gillingham
Margate
Canterbury
Maidstone
KENT
Dover
Folkestone
Hastings
Brighton
Eastbourne
Worthing
Chichester
Portsmouth
Southampton
Winchester
HAMPSHIRE
Guildford
SURREY
SUSSEX
Reading
BERKS
Windsor
Croydon
Royal Tunbridge Wells
Newport
ISLE OF WIGHT
Bournemouth
Salisbury
Calais
Boulogne
le Touquet-Paris-Plage
C. Gris Nez
STRAIT OF DOVER
To Hook of Holland (7 hrs.)
To Rotterdam (12 hrs.)
To Antwerp (12 hrs.)
To Ostend
To Dunkirk
To Le Havre
To Esbjerg
Beachy Head
Dungeness
Selsey Bill
St Catherine's Pt.
The Needles
North Foreland
South Foreland
Foulness I.
Orford Ness
ISH CHANNEL
FRANCE

point. Of the azimuthal projections, the Gnomonic has particular relevance to navigation because all straight lines on the map represent the tracks of great circles; these being the shortest distance between any two points on the globe. Consequently, on a Gnomonic chart the mariner needs only to join the points of departure and destination with a straight line to plot the quickest possible route. However, as compass directions constantly change along a great circle track – an impracticable situation when steering a ship – the navigator can transfer a course from the Gnomonic to the Mercator grid and draw a series of rhumb lines approximating to the curve to obtain a set of rationalized compass readings. Ocean charts are commonly on the Gnomonic projection.

The Azimuthal Equi-Distant projection has become quite popular for certain atlas maps. With this projection, all the azimuths originating from the centre have a constant linear scale along their lengths which means that all places are shown in their correct relative positions and distances from the centre. Any other correlationship not involving the centre will be inaccurate.

Dozens of other projections exist, all differing in one respect or another, but selection in nearly every case will be determined by the function of the map and the size and shape of the area, rather than by the visual pleasantness of the shapes created. To the average graphic designer accustomed to manipulating and forming shapes quite freely, the working framework established by a map projection must seem unattractively rigid, yet some licence remains to satisfy visual niceties. For example, equivalence has been quoted as a prime requirement in distribution maps and a number of projections possess this characteristic, including the: Azimuthal Equal-Area, Sinusoidal, Mollweide, Eckert, Albers, Bonne, and Lambert Equal-Area. Any one of these projections would satisfy the functional needs of accurately depicting distributions and in reaching a final choice the cartographer can allow visual considerations to enter the reckoning. He will also be guided by a wish to show shapes correctly. Anyway good design will never ignore function. Therefore, when a cartographer safeguards conformality in a navigational chart, minimum error and adjacent fit for sheet survey maps, or equivalence and minimum shape distortion in atlas maps, he is practising good design. By waiving the functional needs of a map and giving vent to some 'arty' whim, the reverse could be said.

Once an outline or shape has been defined mathematically by projection, the cartographer must select the material to be shown on the map, a process governed largely by its expected applications. A good deal of topographical detail must be sacrificed on maps showing historical sites, sunshine hours and rainfall, or horse distribution throughout the world, although there must be enough to orientate the map reader. An expensive, but effective method, of ridding statistical and scientific maps of excessive topographical detail is to print a transparent overlay sheet with the relevant information which can be used by the reader as required. This procedure would seem to be very appropriate to national atlases where the same area recurs on almost every page and the danger of losing the overlay is lessened by providing a pocket for it on the inside of the atlas cover. Few things impair the legibility of a map more than overcrowding and the selection and generalization of material to appear within a projected outline is a critical and difficult problem in cartography. Even worse, firm yardsticks are not easily laid down. As an instance, nothing could be simpler than to specify that all towns with a population below an arbitrarily set figure will be left off a particular map, but it could give rise to anomalies. A town with a relatively small population in, say, the rural west of England may be very important commercially and socially in its area, whereas a town with many more inhabitants in the densely populated south-east of England may be quite unimportant regionally or nationally for that matter. This kind of problem must be carefully weighed up by the cartographer before filling in the detail.

Having selected the elements to constitute a map, the degree of importance appropriate to each item has to be resolved. In a sense, the components of a map are somewhat heterogeneous and the cartographer must try to inject into a compilation some form of unity and harmony. This does not mean that certain elements cannot be given extra visual significance as, for example, the roads on a tourist map; but the method must be considered in relation to other items. All items must be clear and legible and the cartographer has a number of variables at his disposal for accomplishing this end, such as the map typography, the design of symbols and lines, the use of stipples and shading, the deployment of colour, and so on. Some of these and other factors will be considered in the next few paragraphs.

Typography

Lettering on maps is a most contentious subject and has caused more than one cartographer to despair of ever reaching a satisfactory solution. Raisz comments that: 'Lettering is one of the most baffling problems of cartography. The essential trouble is that lettering is not a part of the picture of the earth's pattern but is a necessary addition for the identification of features. The names by their bulk cover up many of the important elements of the real landscape and prevent the reader from seeing the map as a picture of the earth. On small-scale maps, city names often cover hundreds of miles in length, even if printed in the smallest readable type, and their least disturbing placement is a trial to cartographers. The development of expressive cartography has been hindered more by lettering than by any other cause.' This seems to be a fair statement of the problem, if a somewhat gloomy one, but it made Arthur Robinson see red. 'This attitude towards lettering, although undoubtedly extreme, is a reflection of the modern trend toward self-expression. There would seem to be reasonably sound theoretical basis for this view with respect to topographic maps of very large scale, but even in such cases the gross assumption that all places and symbols can be made self explanatory or will be known to the reader is undoubtedly erroneous. To put it simply, cartography is a medium of presentation for spatial data and it follows that when such data requires identification, then that identification becomes an integral part of the map.' Probably many other shades of opinion exist between the views expressed by these two writers, but clearly the subject cannot be dismissed lightly.

Formerly the lettering on maps was applied freehand with a pen or brush. And later, with the advent of copper plate engraving, the letters were cut into metal with a burin or graver. Both these media were wonderfully elastic and allowed the place names to be extended or condensed at will to fit in with the surrounding map detail. Nowadays almost all map lettering is produced by typographical means, either as metal in the first instance or directly on to film. Yet very little research has been done on map typography in this country and there is an urgent need for objective tests to be undertaken to assess the suitability of various letter forms. Up to the present, all the scientific investigations into type usage and legibility have related to matter for continuous reading as found in books and the findings could well be misleading as the basis for future cartographic practice.

What, then, are the necessary characteristics in a type face for map work? Firstly, it must be realised that the cartographer is dealing with words rather than sentences and that every letter making up a word is vital because the majority of place names will be unfamiliar to the map reader and often in foreign languages or transliterations. Furthermore, in some cases the words will be very widely letterspaced in order to span a political region or range of hills leaving each character standing alone virtually for individual consideration. By normal typographical standards some of the letterspacing would be thought excessive, but in cartography the spread of a name helps to indicate the extent of a feature and can be very useful where boundary lines are obscured by complex background detail. Another peculiarity of map typography is that the letters will not always have a horizontal base line. River names are usually positioned to parallel the meanderings of the stream, a practice which clearly associates the lettering with the object identified, prevents the possibility of confusion, and prompts the eye movement necessary for tracing the feature. Many cartographers favour italics for denoting the hydrography on a map, but the bending of this kind of lettering to coincide with the sinuosities of a river interrupts its fluency and unity. One wonders whether roman would not be more appropriate for this purpose. Apart from river names, the crowded parts of a map often require the lettering to be placed at an angle or on a curve and any type face designed for cartographic work would have to take this into account and attempt to retain the unity of the letters under these very trying circumstances.

To minimize interference with cartographic detail, the majority of typography involves very small point sizes coming within the range of $3\frac{1}{2}$ to 8 point. Not unconnected with this requirement is the trend toward filmsetting in cartography. With these techniques, the various point sizes are obtained by photographically enlarging or reducing from standard sets of matrices, a procedure calling for a corresponding allowance or latitude in the original letter design. Most of the currently available type faces were conceived, in the first instance, for casting in metal with each point size designed specially. But as filmsetting machines reached perfection, so many of the *traditional* type faces underwent adaptation for these newer methods. Thus, we have 'Monophoto' Times New Roman and the like. Yet the problem has not suddenly arisen and had to be faced for many years in map work and elsewhere with the sticking up of reproduction proofs taken from metal type for photomechanical reproduction and was referred to as long ago as 1928 by Captain J. G. Withycombe of the Ordnance Survey.[5] Type faces available on 'Monophoto' Filmsetters and 'Monotype' Photo-lettering Machines are fitted for all type sizes within a specified range and without loss of character or proportion. Indeed, with its multiplicity of type styles and sizes, photographic typesetting has been a boon to cartography both economically and qualitatively. Moreover, the future need for type faces suitable for photographic enlargement and reduction is liable to grow as cartographers make more and more use of microfilm records where a reduction by 20:1 and subsequent enlargement without loss of character will be desirable.

One of the most deeply ingrained conventions in map making is the distinguishing of features with different styles and weights of letters. As an example, the recent Ordnance Survey Route Planning Map at a scale of 1/625000 shows the names of settlements as follows:

(1) towns with a population of over 1,000,000 in 11-point Times roman capitals;
(2) towns with a population between 400,000 and 1,000,000 in 10-point Times roman capitals;
(3) towns with a population between 100,000 and 400,000 in 8-point Times roman capitals;
(4) towns with a population between 20,000 and 100,000 in 6-point Times roman capitals;
(5) towns with a population under 20,000 in 6-point Times roman upper- and lower-case; and
(6) villages in 5-point Times italic upper- and lower-case.

In addition to these typographical changes, the town symbols are also different for large towns, other towns, and villages. Similar distinctions are made on other maps and between different features, such as the names of districts and hill ranges. It is problematic, therefore, as to whether a single type face with the usual family variants would suffice for map work, the need being perhaps for several readily recognizable and easily differentiated type faces. A suggestion, incidentally, in antithesis to general typographical practice where the mixing of type faces tends to be frowned upon. The convention of making typographical distinctions on maps has been questioned on more than one occasion and not without good reason. It can be argued that if the cartographic detail is carefully depicted by the thoughtful use of colour and unambiguous symbols and that the lettering is suitably placed, the possibility of misinterpretation without the aid of typographical variation becomes negligible.[6] Nevertheless, when a reader is confronted by a map packed with information, the increased clarity afforded by typographical changes can scarcely be challenged. Who could, for instance, mistake the lettering used on Ordnance Survey maps for denoting antiquities?

Another condition peculiar to map typography is that the lettering has to be deciphered against a complex multicoloured background consisting of things like hypsometric colouring, hillshading, road and railway networks, and tinted areas delimiting woods, etc. Often the lettering itself is printed in different colours. The influence of coloured backgrounds on the legibility of type faces in cartography is a subject that has not been investigated scientifically, but tests have been conducted in general printing though the relevance of the results to map making must remain in doubt. Sometimes a name on a map must run over several dark and light colours, whereas the researches into general printing practice have considered the use of type on a flat area of one colour only. Tests carried out by F. A. Taylor[7] showed that for high *distant* visibility black lettering on a yellow ground was best, followed by: black on white, red on white, and dark green on white. For high *near* visibility, perhaps a factor of some significance in maps, the following combinations were the most successful: black lettering on an ivory ground, green on ivory, black on orange, and green on white. Similar tests were tried by Paterson and Tinker[8] in which the degrees of legibility were expressed as a 'slower reading' percentage. In these black on white proved to be the most efficient, while green lettering on a white ground resulted in only a 3% slower reading, followed by blue on white 3.4%, black on yellow 3.8%, red on yellow 4.8%, red on white 8.9%, white on black 10.5% and so on to some very unlikely combinations.

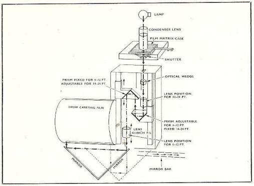
One further requirement in a type face designed for map work is that it must be suitable for printing by offset-lithography though the possibility of using other processes in the future, such as Xerography, must be borne in mind. Any type face for lithographic reproduction needs to have a fairly even weight and colour with open counters and any serifs should be firmly bracketed.[9]

These, then, are the demands imposed on a type face for map work. Having laid down the conditions of use, it is interesting to look at the characteristics listed by John S. Keates[10] as vital to an ideal cartographic series of faces. These were: (1) that the face should be large on the body and narrowly set with short ascenders and descenders, and good open counters; (2) that diagonal stress was preferable to vertical stress in a cartographic serifed letter; (3) that there should not be too much contrast between thick and thin strokes; (4) that a plain italic without fancy letters was desirable; (5) that all capitals should range on the same base line to preclude the idiosyncratic type of letter, such as the Baskerville J; (6) that a semi-bold version would be useful for emphasizing certain cartographic detail; (7) that a matching sans serif was essential to the legibility and harmony of a map; (8) that a condensed version in all sizes above 10-point should be available; and (9) that some form of related decorative capitals should complete the typographical range.

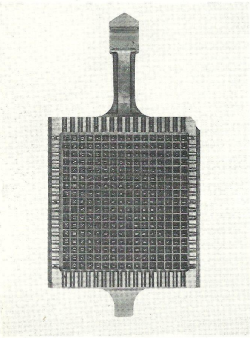
Having considered the requirements of a good cartographic face, one wonders how current practice compares with these? All the major map producing organizations in Great Britain are from necessity, rather than choice, using type faces inherited from the book, newspaper, or general printer. Thus, Ordnance Survey maps carry names in Times New Roman, Gill Sans Medium and Light, Spartan, and Garamond; while George Philip & Son Ltd. besides these use Plantin, Perpetua, and Rockwell. Other map printers use a comparable range. With its small x-height and light weight, the fairly widespread use of Perpetua in map printing is hard to understand. On the other hand there are other type faces that could well prove to be most apt if tried, such as the 'Monotype' Univers family in which the numerous weight and width variants would answer many cartographic needs. Equally important, Univers is one of the few existing type faces that was conceived from the outset for photographic typesetting and therefore behaves beautifully when enlarged or reduced. Eight experimental maps – using various type faces – have been prepared by Miss Alison Shaw of the Oxford University Press, with the assistance of the Graphic Design Department of the Royal College of Art, in collaboration with Mr. John Dreyfus of The Monotype Corporation Ltd. and these will be on view at the 20th International Geographical Congress. They are also included as a loose inset at the back of this *Recorder*. Amongst these experiments are maps with Univers lettering which should give some indication as to the suitability of this type face for map work.

Mention of Univers and its family variants raises two interesting queries: the first concerning the respective merits and demerits of serifed and unserifed letters for cartographic work, and the second concerning the effectiveness of a uniform style of type on a map instead of the current mixtures of serif and sans serif letters.

Scientific investigation has shown sans serif to be the worst of all type styles for word recognition. Serifs are not mere excrescences in letter design serving no useful purpose. Their presence helps to bind the separate letters into word-wholes; lessens the effect of visual spread; and makes a clear distinction between individual letters, even between those of similar shape. The last point exposes one of the weaknesses of the sans serif form in which it is difficult to decipher many of the letters in isolation, such as the capital I, lower-case l, and figure 1. Due to the wide letterspacing of some names on maps, this difficulty will be aggravated and even worse certain parts of the letters will be obscured by map detail or hindered by dark backgrounds. Despite all these logical arguments, one wonders whether the visual marshalling of type is not more important than the actual type style itself? As an instance, the De la Rue *World Atlas* is an excellent example of a carefully reasoned and predominantly sans serif typography in which cartographic distinctions are achieved with letters of varying weights and widths, but all having a basic design relationship. Indeed, one of the advantages of the monoline serifless letter is that it can be easily adapted to different weights and widths whilst retaining the essential character of the face. This brings us to the matter of a uniform style of lettering for maps rather than an assortment of serif and serifless letters. There are 21 variants of Univers (i.e. in weight, slope, and width) which if skilfully handled would surely cover all necessary cartographic 'inflexions' and at the same time improve the unity of the overall map design? However, even this can be challenged on the grounds that the distinction between Light and Medium or Bold and Extra Bold is too subtle for map work and would strain the perception of a reader. But the Light and Bold or the Medium and Extra Bold (together with their width variants) could be used as combinations on separate maps, say in an atlas, probably to very good effect. Perhaps more definite conclusions will emerge from the Univers maps mentioned earlier.

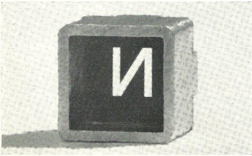


ABOVE Optical system of a 'Monophoto' Filmsetter.



ABOVE Film matrix case of a 'Monophoto' Filmsetter containing 272 characters.

BELOW A 'Monophoto' film matrix.



Some mention must be made of the 'mechanical' methods being used for lettering maps. As previously stated, the spread of filmsetting in cartography is scarcely surprising when one looks at the advantages to be gained from such a step. Since lithographic images for map printing are prepared photomechanically on metal plates, the direct link up with filmsetting is obvious and the avoidance of a letterpress detour necessary with reproduction proofs does not need stressing. Additionally, the capacity to blow up and reduce letter images from standard sets of matrices opens up a wide typographical range at modest cost. The Ordnance Survey at Southampton use two 'Monophoto' Filmsetters and five 'Monotype' Keyboards, an installation which produces lettering for the entire series of maps issued by this organization. In simple terms, the basic function of a Filmsetter is to project character images directly on to a sheet of sensitized film or paper according to coded information passed on to the machine by signals on a perforated paper ribbon produced by the companion keyboards.[11]

Both Fairey Air Surveys Limited and the Cartographic Department of the Oxford University Press, have installed 'Monotype' Photo-lettering Machines: equipment designed for photographing individual characters direct on to film or paper which can be operated at any speed up to 60 characters a minute. Characters are selected manually by a dialling operation, after which the cycle of operations is controlled automatically by sequential electrical and electro-mechanical components. Both the 'Monophoto' Filmsetter and the 'Monotype' Photo-lettering Machine are designed for operation in normal daylight conditions, but adequate darkroom facilities should be close at hand for loading the film drum and carrier respectively and for processing the exposed material.

John Bartholomew & Son Ltd. use hand-set type, cast outside on 'Monotype' machines, from which reproduction proofs are taken for sticking up on to artwork in readiness for photomechanical reproduction. Alternatively, a photographic negative is made from the proofs for contacting into a stripping-film positive which can be waxed and patched up to an outline on glass. Also, some of Bartholomew's maps are derived from old copper plates which necessitate the hand engraving of revisions. Likewise, a large proportion of Admiralty navigational charts are prepared as copper plate engravings and incorporate hand-cut lettering. The other method of compiling artwork for Admiralty charts makes use of enamelled aluminium plates on to which place names are printed photomechanically. They are set and cast on 'Monotype' hot-metal machines and the reproduction proofs taken from the type are photographed. One regrettable feature in the enamel system of preparing Admiralty charts has been the perpetuation of copper plate styles of lettering for certain features, such as depth soundings, a legacy defended on the grounds of aesthetics, exclusiveness, and custom. But the original copper plate styles grew naturally out of the burin or graver working on the surface of the metal and guided by the hands of a craftsman, the newer enamel technique has nothing to do with this wonderful tradition and should develop styles of lettering apposite to mechanical typesetting and lithographic printing. It is rather like forcing a woodworking machine to make furniture imitative of hand workmanship, an act of design dishonesty. Far better to allow the machine to make furniture within its capacity and which can be judged on its own merits.

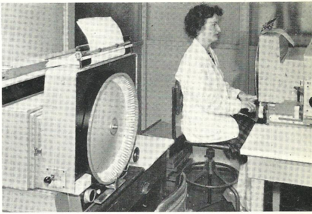
The positioning of lettering on maps is subject to one cardinal rule requiring the name to refer unmistakably to the feature identified. Names of countries, oceans, mountain ranges, and the like are usually spread by letterspacing to span the area labelled and at the same time to show the shape 'trend' of the feature by bending into an appropriate arc or by running at an angle. This requires careful planning to ensure that the letters are evenly spaced and do not clash with other lettering or map detail. Most other lettering must run in accord with the parallels of the map projection to avoid the confusion of too many competing angles. In many projections this will mean that the lettering has to be placed on an angle. Polar projections are particularly troublesome in this respect. Though, to overcome this difficulty, the graticule of the map can be restricted in certain cases to the water areas (which carry few names) or can be marked off along the map border. However, the usefulness of some maps would be impaired by such expedients which means that there is no alternative but to apply the lettering with due regard to the tracks of the parallels.

River names are not normally spaced out like those of countries and the lettering usually parallels the course of the stream. Also, it would seem preferable to curve the names in a manner that keeps the upper portions of the letters closer together, since this part of the lower-case characters contains more clues to their identity. Convention seems to favour, where possible, the positioning of the name along the south bank and when the river runs more or less north-south on the west side. However, general rules of this kind cannot be rigidly adhered to in map design and more often the availability of space will determine placement.

Names of woods, lakes, swamps, islands, etc. are best positioned either completely within the feature identified or completely outside it, especially if the subject is depicted differently from the surroundings.

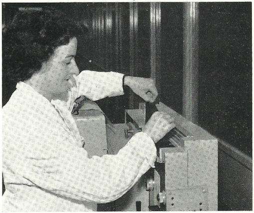
To avoid the possibility of confusion, the names of cities and other point locations should be placed slightly above or below and to one side of the town stamp or symbol. If the name is positioned directly in line with the symbol to the west or east, the two may merge and give rise to misinterpretation by the map reader. When a town is confined to one side of a river, the name should accompany the symbol on the correct bank to promote clarity. Names of harbours and coastal towns can run into the sea where space is usually unlimited, a practice which helps to relieve the more congested areas of a coast.

Map typography does not begin and end with the names relating to actual cartographic detail and too often the lettering and design of legend boxes and map titles look as if they have been treated as an afterthought or as a necessary nuisance. There seems to be plenty of room for improvement in these areas of map design and a more enterprising selection of type faces would constitute a good beginning. An inkling of the possibilities open to the cartographer when designing titles is shown in the recent map of Hadrian's Wall published by the Ordnance Survey in which a Roman inscriptional letter was

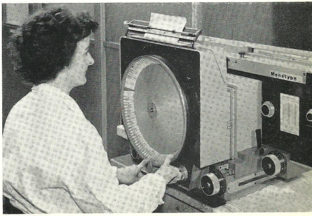


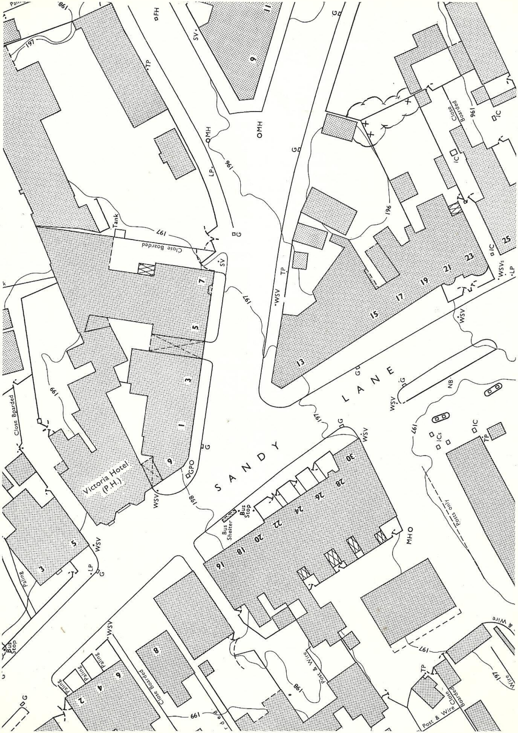
ABOVE 'Monotype' Photo-lettering Machine installation at Fairey Air Surveys Limited.

BELOW Removing the film carrier.



BELOW Dialling a letter.





Part of a plan produced by Fairey Air Surveys with lettering from a 'Monotype' Photo-lettering Machine.

adapted for the purpose. Unhappily this production is an exception and many map titles seem to be clumsily overweight with the type face used for identifying cartographic detail retained in a bigger size for the title. Word and line spacing also needs to be more painstakingly managed. A notable exception to these criticisms in the United Kingdom are the maps of the Oxford University Press in which design has clearly been thoughtfully worked out with due regard to both aesthetics and function.

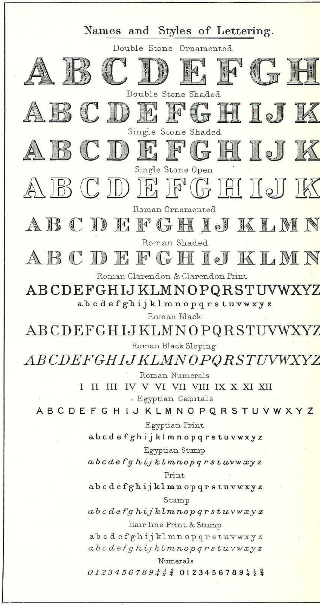
Colour

Colour in cartography has always been considered important, although it did not come into widespread use until chromolithography was developed during the first half of the 19th century.

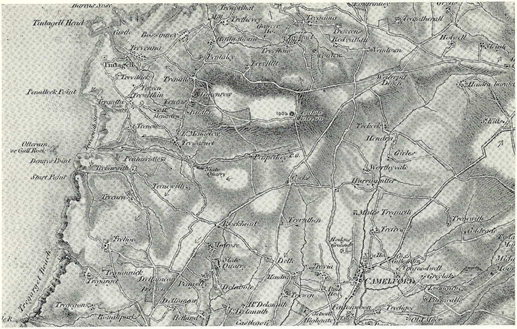
For landform representation on maps, the use of colour has become almost indispensable. Nowadays it is customary to show the lower areas in greens, the intermediate altitudes in yellow, and the higher elevations in browns or near-reds. For temperate regions this progression simulates the colours of nature, but its validity for desert or Arctic regions would appear most questionable. This convention of using colours in the order of the spectrum was introduced on a map of Ben Nevis by E. G. Ravenstein and has been used uncritically and slavishly ever since by many mapping agencies. Indeed, the convention is now so deeply implanted in the minds of most map readers that one wonders if it will ever be possible to shake it off should subsequent scientific investigation prove it to be wrong.

Justification of the system is usually based on colour associations. Thus, on topographical maps, the lowlands and fertile valleys are green, the seas are blue; while the same principle is carried over to thematic mapping where red denotes high temperatures, brown indicates soil, and so on. Furthermore, the indication of altitude tints according to the order of the spectrum is defended because this arrangement of colours gives a stereoscopic effect in which the warm colours advance and the cool colours retreat to create an illusion of three dimensions. It is also pointed out that by restricting the darkest colours to the highest altitudes, where detail is quite sparse, the legibility of the map will not be compromised.

Not all cartographers are convinced by these arguments and feel that objective tests into the colouring of hypsometric layers, rather than the blind acceptance of convention, would pay dividends. They assert that, with the traditional scheme of layering, by far the lightest and most visible areas on the map are the intermediate altitudes coloured yellow which rarely carry the heaviest detail. They claim that the arguments of colour association are inane and misleading. The mountains are not red, the oceans are only occasionally blue, while lack of consistency in the symbolism is amply demonstrated on some maps in which parts of the Sahara Desert, being under 1,000 feet, appear in green! Robinson questions the soundness of associating contour colours with ground colours and appeals for a more rational approach to selection based on the preciseness of definition, the lack of discord, the relative transparency of the colours, and the degree of continuity created by bands of colours in juxtaposition. The last point is an interesting one,



Specimen of copper plate lettering used on Admiralty charts.



Portion of a hachured map of Cornwall published originally by the Ordnance Survey in 1813 with railways inserted to 1889. (*Crown copyright reserved.*)

for educationalists frequently complain that the present method of layer colouring encourages children to see landforms as terraced or stepped. By reducing the contrast of the colours, this impression can be lessened.

Investigations have shown that the eye is more sensitive to red than any other colour, followed by green, yellow, and blue. Thus, the printing of red roads on maps intended for motorists and tourists would seem to be a sound practice, while the degree of emphasis given by the series of colours named could be of significance in statistical mapping. Also relative to statistical maps is the fact that primary colours, such as yellow and red, are quite definite and individual, whereas the secondary colours like orange are less so. Since orange contains yellow and red, the value of employing *definite* and *derived* colours for depicting interrelationships in cartography is obvious. In other words, colours on thematic maps are not used merely to create a cheerful effect, but provide a simple method of relating different categories of information.

Another interesting aspect of colour in cartography concerns the conditions and illumination under which the map will be used. Different kinds of illumination can alter the look of a colour quite appreciably. For example, Taylor states that a brown in normal daylight will appear as: (1) chocolate brown under tungsten filament light, (2) yellowish-brown under fluorescent light, (3) brown under sodium discharge light, and (4) grey under mercury discharge light. Other colours will change just as remarkably under similar circumstances. During the last world war when maps and charts had to be viewed in the dimmest of lights or under special illumination, the colouring had to be selected accordingly. For this reason, thousands of aeronautical charts were printed specially in colours such as purple, orange, and brown which were easily discernible under an amber-red or ultra-violet light.

Before leaving the subject of colour in cartography, one or two random points are worth mentioning. It is curious to reflect that the map printer begins work with a white sheet of paper and then proceeds to block out every part of this base with flat or tinted areas of colour. Surely white could be used more widely in the design of maps? Up to a few years ago it tended to be reserved for the very highest altitudes in hypsometric colouring – presumably simulating the snow peaks of mountains – or for political areas in dispute. But the latest road maps by John Bartholomew & Son Ltd. use a white base most effectively and for the good of legibility.

Black has been the dominant colour for map outlines for far too long, but more and more map organizations are experimenting with other colours of a less obtrusive and harsh character for this purpose. The Ordnance Survey have used grey for the detail of their recent Route Planning Map and dark blue for the outline; George Philip & Son Ltd. favour a dark blue as the outline for many of their atlas maps; the Oxford University Press have employed a brown most tellingly and so have John Bartholomew & Son Ltd. Another custom which is fading away rapidly involved the use of band tints on political maps to reinforce or emphasize the boundaries of countries, states, and counties. If the boundary lines were functioning adequately, this practice amounted to nothing more than wasteful duplication.

Symbols

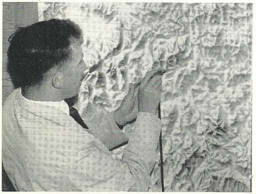
Cartographic symbols represent a kind of specialized shorthand which allows the maximum amount of information to be put on a map in the clearest possible way.[12] A good symbol is one that suggests the feature represented and scarcely needs a legend for amplification.

Features on a map are symbolized in various ways and often with old established signs that have been used for many many years. At the same time new symbols are being designed as required. For example, the Ordnance Survey has recently introduced some new symbols for their tourist maps to denote such items as fishing grounds, mountain chair lifts, car ferries, motorway service areas, and other objects.

Cities, towns and villages are symbolized as dots or circles or a combination of the two and are graded according to the number of inhabitants. On some maps the large towns are represented by tinted areas and crossed lines indicating a street system. Church symbols always incorporate a cross. Those with a spire show the cross on top of a dot, those with a tower have the cross on top of a square, and those without either are simply located with a cross alone. Other point symbols show the sites of battles with crossed swords, the location of antiquities, wireless aerial masts, windpumps, windmills, lighthouses, post offices, telephone kiosks, trigonometrical pillars, youth hostels, railway stations, and a host of other things. Moreover, the ordinary dot is useful in statistical mapping for showing distributions. In this case, the point symbol can be repeated so that the aggregate number represents an overall total or the massing of the dots can be varied to symbolize relative densities.

ABOVE Making a hillshading model with plasticine for photographing on a process camera.

BELOW Hillshading being produced with an air brush at the Small Scales Division of the Ordnance Survey.



Roads are generally shown as coloured lines falling within parallel black outlines. They are usually classified according to a colour code and identified by their Ministry of Transport numbers. Railways were formerly shown by two parallel lines with alternating black and white patches or as a single line with tiny crossties at regular intervals. But in many recent maps these traditional symbols have given way to a single line, perhaps due to the adoption of scribing where the detailed work would hardly be feasible. However, the single line for railways can be easily confused with that for rivers, although the growing practice of printing the hydrography of a map in blue – the railway lines being in some other colour – should forestall misunderstandings. Boundaries are generally shown as pecked lines made up of dashes and dots.

Countless other symbols are employed on maps for denoting deciduous trees, coniferous trees, rough pasture, marshland, quarries, canals, orchards, and so on. In fact, the design of symbols is probably one of the most pleasing visual aspects of a map. For analytical or thematic mapping in which qualitative and quantitative data have to be symbolized, various techniques are employed ranging from dots of specified values to divided circles, bar graphs (or block diagrams), flow lines, etc.

Relief features

The depiction of landforms and relief on maps is an absorbing, if difficult, problem and one which stems from an attempt to show three dimensions within the limits of two.[13] Moreover, man is accustomed to seeing mountains from below, rather than from above as shown on a map.

Early maps either did not attempt to indicate relief features or represented them by tiny 'mole-hills' which denoted the approximate position but little else. Contour lines were introduced into mapping in 1728 by N. Cruquis, a Dutch engineer, to show the bed of the Merwede River for navigational purposes. And in 1737, Buache followed suit by using contours to delineate the various depths of the English Channel. Some years elapsed before the method was applied successfully to land maps and the first important contour map was of France by Dupain-Triel in 1791.

Contour lines are drawn at definite intervals on a map and join together points of equal elevation, the interval of contouring being largely dependent on the scale of the map, the nature of the relief detail, and the accuracy of the survey. Normally the heights are expressed in feet above mean sea level. The chief advantage of contours is that the height of any point on a map can be ascertained within the limits imposed by the vertical interval.

To render hill features visible at a glance to the untrained eye, a method of hachuring was devised by L. C. Müller in 1788. In 1799 Lehmann suggested a scientific system of hachuring in which the hills were indicated by short parallel lines, varying in thickness with the slope, and drawn in the direction along which water would run on the surface. A steep slope was depicted with thicker lines, and a gentler slope with lighter and more open lines. Hachures are not exact measurements of elevation like contours and approximate more to a portrayal of the lay of the land. The disadvantage of hachures on older maps was that the density of the lines tended to conceal other detail, although the method was very popular with military surveys during the 19th century. Hachuring has now fallen into disuse and is really a relic of old copper plate maps. It has been superseded by contour lines and layered tints and by hillshading. Nonetheless, the method was well adapted to the representation of flat and mountainous territories and had an immense capacity for detail, much of which is lost in the contour intervals of modern maps, but for rolling hilly country the hachure was dismally dark.

Hypsometric colouring or altitude tints have already been mentioned under the heading of colour. The Bartholomew Half-Inch Map was the first topographic series to make use of layer colouring and the earliest specimens date from 1878. Contour layering is admirably suited to the greatly generalized relief information contained in small scale maps. On layered maps the visual need for contour lines would appear superfluous and they are gradually being omitted from many maps of this kind, a trend which will lessen the complicated pattern of lines on small scale work.

Hillshading on maps creates an impression of three dimensions and often supplements contour lines and layered tints. At the Oxford University Press, a three-dimensional model of the ground is built in sheets of plastic and filled in with plasticine to simulate the undulations of the terrain. The model is then mounted on the copyboard of a process camera, illuminated from the north-west corner, and photographed through a halftone screen for overprinting on the map in a suitable colour. Sometimes brown is used for this purpose or grey. Other organizations, like George Philip & Son Ltd. and John Bartholomew & Son Ltd., prefer to draw the ground relief in pencil on grained astrafoil as if it were lit from a north-westerly direction. This is photographed through a screen in readiness for lithographic platemaking and printing. Certainly one gets the best of both worlds by having contour layers and hillshading on a map, the former to give a precise elevation reading in feet within the limitations of the vertical interval and the latter to provide an immediate impression of the landforms.

Plastic relief maps or models are another interesting development for showing landforms picturesquely. To produce these, the topographical detail is printed on a sheet of vinyl plastic which, in turn, is softened by heat and pressed into a steel mould. These relief models are rather more expensive than flat maps, but are very useful for educational purposes. They have obvious detractions for field use because they cannot be folded and for the same reason inside storage is something of a problem.

Miscellaneous

Other design elements in a map can only be touched upon rather fleetingly. Most maps carry an indication of their scale expressed either numerically or graphically. Numerical scales are widely represented as a fraction, such as 1/63360. This means quite simply that one inch on the map corresponds to 63360 inches in nature. The graphical or rod scale usually records the mileage along a graduated line and offers some scope for the imaginative designer. An advantage of the graphical scale is that it will remain true should the map be reduced photographically.

The vast majority of maps are oriented with north to the top of the page and any departure from this long-standing convention would certainly cause some head scratching amongst most map readers. This being so, the inclusion of a compass rose is something of a formality and only on navigational charts does it function as a working tool.

Without doubt, the design of maps is a most complex subject which only a few years ago was firmly entrenched in convention. Since the second world war, more and more people have questioned the logic of old precepts and found adequate answers wanting. As a result, a new willingness to experiment has changed the outlook for map design and bigger strides forward can confidently be anticipated in future years.

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We wish to thank Mr. D. P. Bickmore and Miss Alison Shaw of the Oxford University Press and Brigadier G. Bomford for help given in the preparation of this article.

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