

# CONSTRUCTION OF PLASTIC TOPOGRAPHICAL RELIEF MODELS.

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Topographic relief models, three-dimensional miniatures of the Earth's surface, have always been particularly attractive in connection with the study of numerous problems. They have shown themselves distinctly superior, in practice, to the two-dimensional map, when used, for instance, in determining shaded or sunlit areas in mountainous districts under the various lighting conditions encountered throughout the different seasons. Scale models permit an objective and analytical study of the various cases and also the photographic reproduction of the aspect of the terrain with a sufficient degree of accuracy, by means of artificial insolation or lighting of the plastic form by, for instance, the Heliodont or Polyheliometers such as the Setti Skiascope or the Balopticon.

Surface scales generally vary from 1: 1 000 000 to 1: 50 000, differences in scale being as a rule exaggerated in relation to the horizontal distance, occasionally as much as 10 times for the 1: 1 000 000 scale, with certain shaded areas to reinforce the effect of relief. For certain detail models, mapping scales of 1: 10 000, 1: 5 000 and 1: 250 are used, even larger scales being adopted, for instance in the study of hydraulic, port or city installations.

The usual sources of material for these models consist of maps, charts, vertical or oblique air-photographs, stereoscopic views, kodachromes, mosaics, etc., giving details of the configuration of the terrain.

For the construction of the final drawing, preference is given to maps on which the contours are marked, the latter forming the basis of the relief picture by being cut out and enlarged. The different parts are then adjusted by photography to the desired scale and reassembled by means of cellulose tape.

With regard to papier mâché and plaster of Paris models, this special assemblage is made on one or several 1/6th-inch thicknesses of news board reinforced by a 1/4-inch sheet of plywood held by a frame of 1-inch  $\times$  2-inch lumber. If a certain portion of the model represents water, pebbly-grained beaverboard or veneer may be advantageously used as it lends a realistic appearance to the water areas when painted. Each contour is then carefully cut out by means of a cut-awl machine driving a chisel-pointed cutter, ready to receive a strip of corrugated paper board cut in widths corresponding to multiples of the height of the scale contour interval, less the thickness of the news board, and secured edgewise to the base model, using rubber cement.

Each successive contour panel is raised to its proper elevation in a similar manner until the whole core of the model is built up. This method represents a saving in weight, with no loss of solidity, over the older methods in which the contour panels were held by the "wooden peg and pin" system.

Squares of cheesecloth cut to convenient size according to the character of the model, dipped in wheat- or paper-hanger's paste, are used to cover the core thus established. This cloth covering serves to take the mixture of papier mâché (4/5ths) and plaster (1/5th) which will constitute the model and several coats of which are applied thinly, the surface being smoothed by means of the fingers or a small brush. Retouches are carved out using a moto routing tool — and this is where the skill of the operator becomes necessary to interpret faithfully the geographical forms of the original.

After thorough drying, several coats of shellac are applied if reproductions from the mould are desired. The next procedure is to pounce in details such as roads, railways, navigable waterways, forests, houses, etc., and their coloration with appropriate smooth or ground sprayed cork paints.

Plywood cuts are applied to the four lateral sides. If more than one copy of the model is required, the mould is fittingly prepared and plaster casts taken. The

procedure is somewhat as follows : A small paint brush dipped in a mixture of stearine and kerosene is passed over the model, and above is laid wet moulding plaster covered with several folds of burlap cut so as to allow an overhang of from 4 to 6 inches all round ; the fabric must be forced into all the details of the terrain ; the mould frame of 1-inch  $\times$  2-inch lumber is kept in position by a series of twists of burlap. After the mould is set, it is sufficient to lift the frame straight up to obtain the reproduction.

#### Preparation of Rubber Casts.

Rubber casts of models possess the advantage of being lighter in weight and capable of being rolled up for convenience in transport ; they are obtained by spraying a latex solution over a plaster mould maintained at a given temperature over a certain length of time. Instead of stearine to prevent sticking, liquid soap is used. The mould obtained may be said to have the form of an open box, with the top of the walls slightly higher than the least elevation appearing on the model, with the result that placed upright on a flat surface, the elevated points near the outer edges of the mould will be self-supporting. The mixture consists of liquid latex and whitening paste and shades of colouring adapted to the aspect of the soil are used. Before moulding, the core must be everywhere carefully dusted with mica or talc powder and six or seven heavy coats of latex are sprayed over the entire mould by means of a special projector (gun). The whole is reinforced by several folds of burlap. One completely cured cast can be turned out in approximately eight hours ; the cured casts are then painted and marked with the conventional symbols in the usual way. Due to a shortage of latex, satisfactory results are being obtained with the synthetic rubber, neoprene.

To prepare rubber models, a matrix is constructed in plasticene clay consisting of one-third paraffin, two-thirds bees-wax, dry water clay, petroleum jelly ; this mixture enables several moulds to be obtained.

Rubber castings can be obtained from neoprene (synthetic), vultex (or prevulcanized natural latex), or lotol latex moulds. Rubber must be sprayed under pressure against the walls of the mould to the extent of six or seven coats giving a total width of  $\frac{3}{16}$ ths of an inch ; hollows are built up with sponge rubber, sawdust, hemp fibre or burlap, and the whole is covered by a sheet of burlap previously cut to the required size. This sheet serves as a foundation and is in its turn sprayed with rubber.

Finally the whole is subjected to high-temperature ( $160^{\circ}$  F.) - ( $70^{\circ}$  C.) sulphur vulcanization for from four to six hours in order to avoid any later shrinking before the casts are pulled.

There then remains only the painting. Ordinary oil base paint thinly sprayed, or brushed, is preferably used. A mechanical dotting pen or stencil masks may be used according to the guide model and in conformity with the conventional standards adopted. Finally, a coat of fixative and protective varnish composed of white shellac with a small proportion of castor oil added, is sprayed over the entire surface of the model when the paint is thoroughly dry.

The U. S. A. Coast and Geodetic Survey has developed a new procedure for producing relief models in vinylite which retain all the details figured on the basic map including contours and the different shades of colouring, and which are especially convenient for use in aircraft.

In 1928, Mr. John J. Braund conceived the idea of printing contour maps on sheets of soft aluminium and embossing the relief to fit the configuration of the terrain as indicated by the contours. This method produced a lightweight relief model from which a great number of reproductions may be obtained figuring all details relating to watercourses,, agriculture, forests, etc. Further developments of this idea led to the production of very lightweight models ; in particular, one of them was compiled by combining the U.S.A. Coast and Geodetic Survey aeronautical charts with a series of Continental Slope charts on the scale of 1: 120 000 designed by the geologist Dr. A. C. Veatch and based on an intensive survey of the peculiarly characteristic region of canyons and valleys which indent the continental shelf of the United States from Georges Bank to Cape Henry, while the continental portion of the model extends to Rochester (New York) and the Southern shore of Lake Ontario.

More recently, a relief model of the San Francisco Bay area was constructed with vertical scale exaggerated ten times. A special feature of this model is the addition of the whole triangulation net of the area based on geodetic controls. The triangulation

net of the area is represented on the model by red yarn secured to the tops of mountains or to the high points of the established triangulation station. The precise level lines are indicated by means of cellulose tape in contrasting colours. This model illustrates the use that may be made of relief models as teaching aids, representing, as it does, the actual principles attached to surveying and mapping.

#### **New Process for Constructing Plastic Relief Models.**

The new process developed and improved by the U. S. A. Coast and Geodetic Survey and the Civil Aeronautics Administration (C.A.A.) depends entirely on the use of the *Braund* reliefograph which serves to build up the original or master model, from which as many reproductions as desired may be obtained. The master model is obtained by embossing on a stock sheet of semi-soft aluminium about 0.010-inch thick, coated on both sides with a special metallic coating which leaves a grained surface suitable for lithographic printing. The sheet is embossed from the back; the map therefore is reproduced by photography on both surfaces of the aluminium sheet after it has been sensitized. The two prints must be made in perfect registry both on the upper and lower faces of the aluminium sheet.

The Reliefograph (Figure 1) includes a rapid-pulsation embossing tool driven by an electric motor, an embossing table covered by a sheet of rubber and a series of frames of various sizes fitted with tension grip clamps to hold the sheet of aluminium firmly in place; the reliefograph is also provided with a convenient arrangement of the necessary controls and gauges for accurate work. The whole is carried by a rigid iron table.

The aluminium sheet containing the reproduction of the map or chart forming the basis of the model is placed and locked in the machine by means of tension grip clamps holding the sheet firmly parallel to the established plane and under drum head tension; any distortion during the work of embossing is thus impossible. The embossing frames are mounted on machined guides permitting them to slide freely so that the plate may be led to a convenient location over the table. A line gauge serves to keep the height of the frame in proper relation to the limiting plane of the embossing tool. Each contour is then embossed separately to its predetermined height by the pulsating hammer (embossing tool). The tool can be moved in a horizontal plane; at its extremity a special chuck is designed to receive a variety of rubber embossing tips; a handwheel provides for the raising and lowering of the frame controlling the limiting working plane, i. e. the depth of punch; a universal altimeter indicates on the dial the position of the working plane; the height of the table is adjusted so that the metal sheet comes in contact with the rubber surface of the table during the work of embossing. This contact occurs when the tool reaches the pre-determined limit of the working plane corresponding to the contour for which the embossing is done. Moreover, the operator can lower or raise at will the end of the tool in relation to the working plane by turning the handle used to guide the tool. A rheostat foot control governs the pulsation rate of the hammer.

Each area enclosed by two consecutive contour lines is worked in succession, beginning with the lowest contour. After all the areas have been successively treated, the soft metal model is sealed with a lightweight plastic material which hardens quickly; the material usually employed is paraffin or hydrostone which holds the metal rigidly in position; thus, what is termed the original or master model is obtained; it is now turned right side up and mounted in a rigid supporting frame. The cast known as the "female" cast is now produced by covering the original model with the required amount of hydrostone; rods placed at certain selected points of maximum altitude are fitted in the original so as to leave holes in the female cast allowing the use of the vacuum process. When the female cast has hardened, it is removed and placed in the duplicating machine shown on *Figure 2* which is comprised of a vacuum box of suitable size to lodge the completed cast.

#### **Duplication of Models.**

The use of the female cast in conjunction with the duplicating machine enables reproductions on sheets of opaque white vinylite to be very quickly obtained. First, all mapping details are printed on the sheets, kept flat, in conventional colours and according to standard rules.

The firm of Williams & Heinz, Lithographers, Washington, has made a study of special inks and processes for printing topographical data in colours on flat plastic sheets. At present, acquired experience and improvements enable reproductions not only of the linear part in several colours, but also half-tones, to be made with great delicacy.

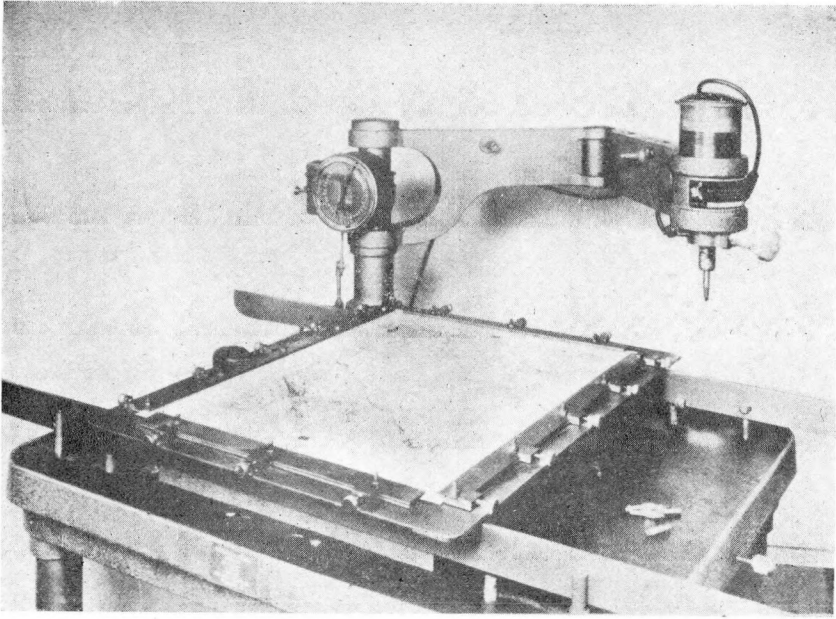


FIG. 1.  
Braund Reliefograph.



FIG. 2.  
U. S. Coast and Geodetic Survey Duplicating Machine.



FIG. 3.  
Salvadori drilling-machine  
(fresatrice)

This reproduction is accomplished by the use of a proof printing press. The plastic sheet so printed is placed over the female cast, the printed side in contact with, and strictly in relation to, the mould.

The whole is then placed in the duplicating machine ; the lid is lowered and locked tight to the body. This lid has been constructed with heating elements that can be applied as required. The air is withdrawn from the vacuum chamber through the use of a vacuum pump and the sheet of vinylite is thus pulled tightly against the mould. The vinylite is then heated and as the heat increases the vinylite becomes soft and is drawn down into the female mould with considerable force. The plastic matter is drawn to the lowest depths in the mould at maximum vacuum pull and when the proper degree of heat is reached.

The embossed vinylite is then allowed to cool in the mould, the vacuum pull being maintained and air allowed to circulate in the frame. When the mould is completely set, the lid is raised and the vinylite shell model of the original is withdrawn.

The plastic model is now ready to be mounted and for this purpose sheets of cardboard or masonite board are used, opaque tape being applied along the edges ; light wooden frames may also be used.

The complete cycle of operations occupies only a few minutes ; hundreds of relief maps can be produced by this method in the time it formerly took to complete only a few plaster models. Another consideration is economy in weight and in price. A 17- × 22-inch plaster model weighs approximately 50 pounds, while a plastic sheet reproduction of the same size weighs 4 ounces only. A portfolio of 12 plastic maps sells for only \$ 30 (Thirty dollars), far less than the cost of a single plaster model.

At present plastic maps are being extensively used as teaching aids in geology and geography classes ; they are widely applied in the numerous fields mentioned throughout this article ; and in the study of geology, of erosion control, for agricultural purposes, and for reclamation work in connection with irrigation.

The Aero Service of Philadelphia, Pa., in addition to air-photography instruments such as projectors, stereoscopes, manufactures reliefographs and all equipment connected with this specialized field.

A description of the Richarme pantograph-cutter for Charts in Relief appeared in *International Hydrographic Review* Volume XXVI, No. 2, November, 1949.

Some ten years ago the Military Geographical Institute of Florence perfected a system for the manufacture of plastics using the Salvadori drilling-machine (*fresatrice*) which, with a basic map, enables a block of clay to be cut out by mechanical means and with absolute accuracy with regard to relief of the terrain, directly in a parallelepiped following the suitably prepared plastic model, i. e. eliminating the various tiers. After the map has been printed on elastic transfer paper which lends itself to modelling, it is stuck onto the model.

Normally, the Military Geographical Institute of Florence produces plastic models to scales of 1: 25 000, 1: 50 000 and 1: 100 000. The cost of a 16" × 16" model is dependent upon the proportion between flat and undulating or mountainous parts and may vary as much as from 5,000 to 20,000 liras. The Institute fills orders for special plastics, and also makes transport cases together with reproductions from plastics having special characteristics. Prices are indicated in *Universo* (Revista dell'Istituto Geografico Militare, No. 4, Florence, July-August, 1950).

Since 1940 the French National Geographic Institute has produced maps that vividly portray the shape of the terrain. The oldest documents in France of this type date back to relief maps of fortified towns on the scale of 1: 600 made in answer to a request of Louis XIV, and a great many can still be seen in the Beaux Arts collection in the Hotel des Invalides museum.

Modern mass production methods at the National Geographic Institute consist in embossing maps printed on special paper by pressing them between a matrix and counter matrix made of some hard material. The matrix and its counterpart are first obtained by constructing a plaster model reproducing the terrain on the scale of the map. In order that constant dimensions may be retained, a copy of the map to be reproduced in relief is made on 'invar' paper, the hydrographic areas are plotted in blue, and contour levels in sepia. The main contours are then gone over with inks of different colours, making it easier for the operator to follow along the curves, and obviating the danger of errors.

The mechanical carving of a thick plaster block of the same size as the map is done with a pantograph-cutter of the type described in *The International Hydrographic Review*, Volume XXVI, No. 2, November, 1949, page 156. The pantograph, which has arms of even length, is supported by a bar; on one side of the latter is a stationary plate on which the map is placed, and on the other a movable plate carrying the plaster block. The pantograph arm above the map is worked by the operator, who follows the contour levels with a tracer; the bit with which the other arm is equipped automatically goes into action and digs out a groove in the plaster block.

Beginning with the highest altitude, the plaster is cleared away from outside the groove; the plate carrying the plaster block is then raised to a height corresponding to the distance of the contours at the scale required. The carving is completed by breaking down the tiers obtained in this way with a plaster scraper in order to create a continuous relief surface. Ground photographs or sets of stereoscopic views of mountain ranges are used as guides for this purpose.

The matrix is obtained by running cement into the plaster cast.

The embossing is then done on paper having long and flexible fibres and able to withstand considerable distortion without cracking. Embossing at the National Geographic Institute is done in the cold state, and the degree of hydraulic pressure obtained amounts to between 25 and 35 kg. per square centimetre.

Embossed maps on the scale of 1:50 000 are ready for delivery as soon as they come off the press. Their cost is low: about 3 000 francs for those in high relief. Wooden frames may be used to ensure better rigidity. Mounting of relief maps is greatly simplified if balsa wood is used in building up the profiles.

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