

Sept. 2, 1952

B. IVINS ET AL

2,608,907

MACHINE FOR PREPARATION OF RELIEF MAPS

Filed Feb. 18, 1948

4 Sheets-Sheet 1

FIG. 1.

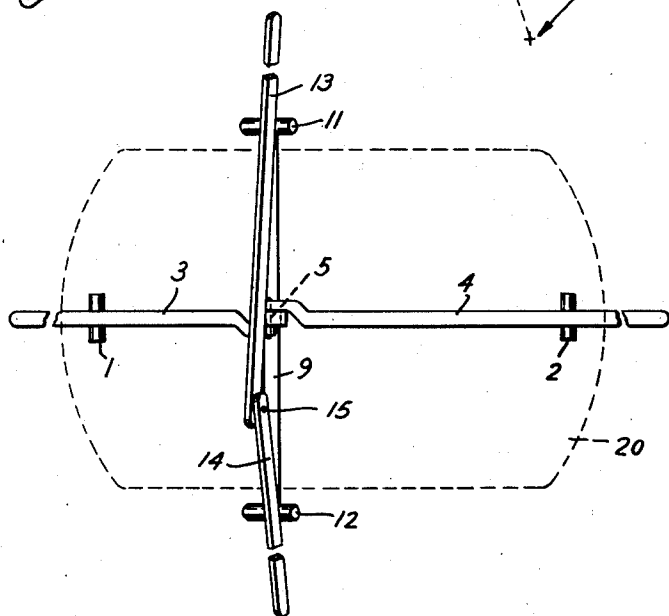
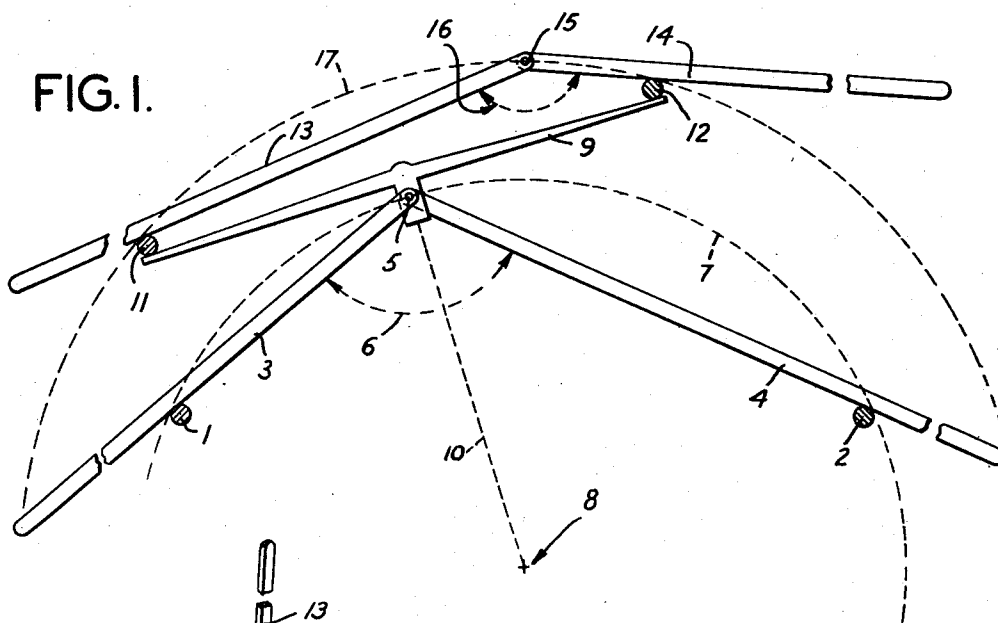


FIG. 2.

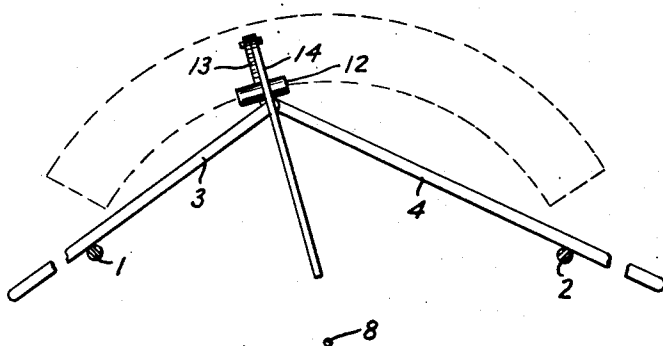


FIG. 3.

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4 Sheets-Sheet 2

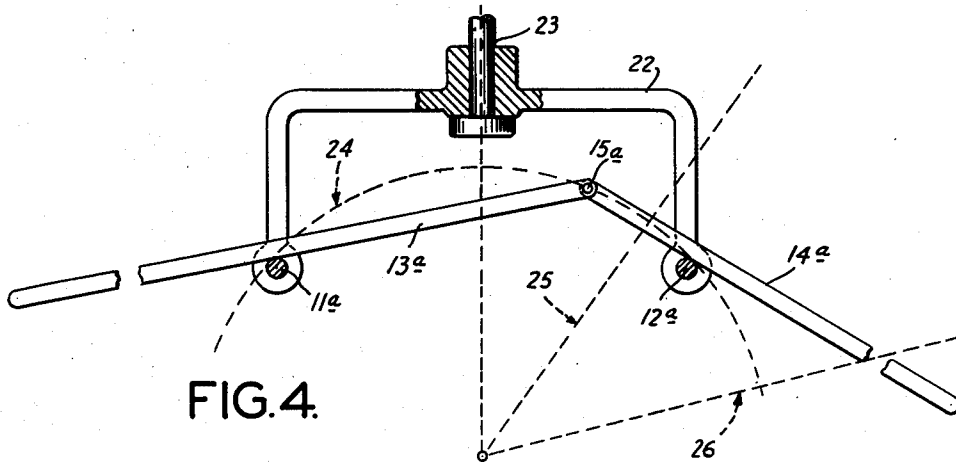


FIG. 4.

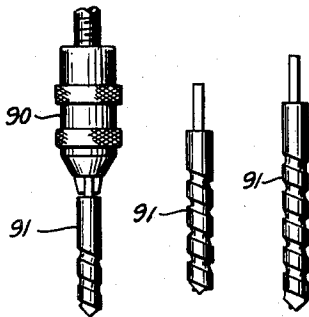


FIG. 8.

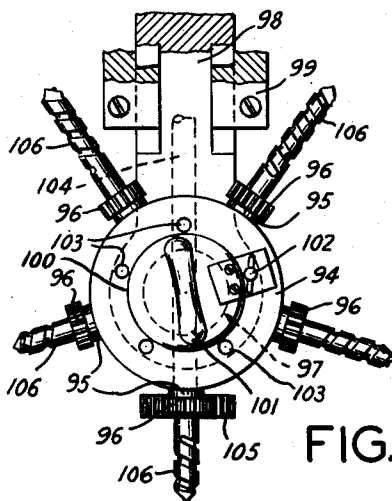


FIG. 9.

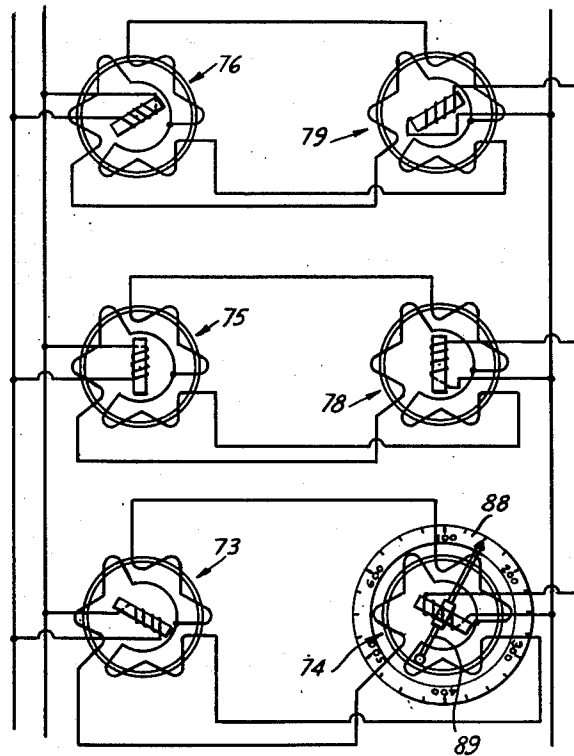


FIG. 6.

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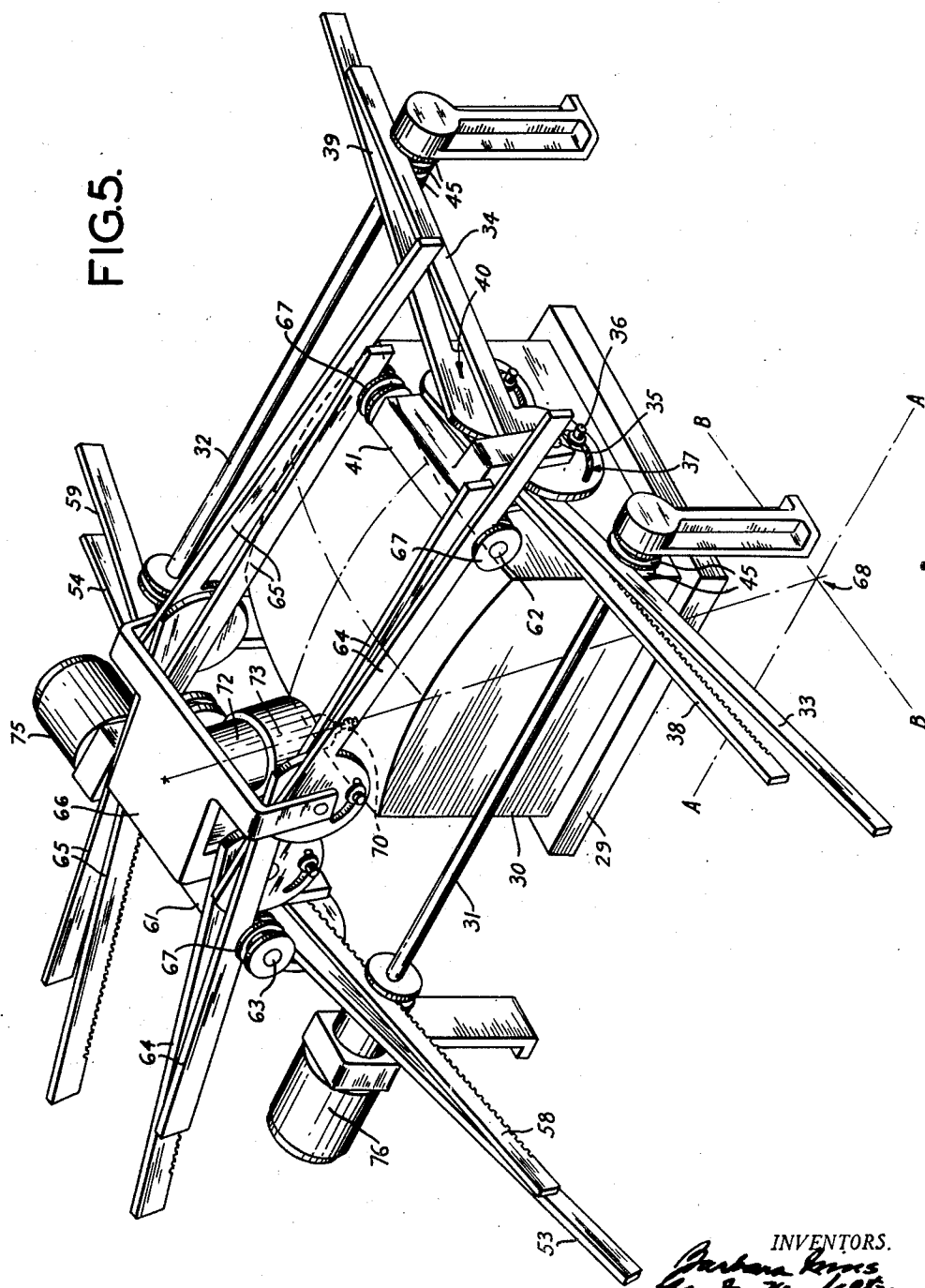
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MACHINE FOR PREPARATION OF RELIEF MAPS

Filed Feb. 18, 1948

4 Sheets-Sheet 3

FIG. 5.



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2,608,907

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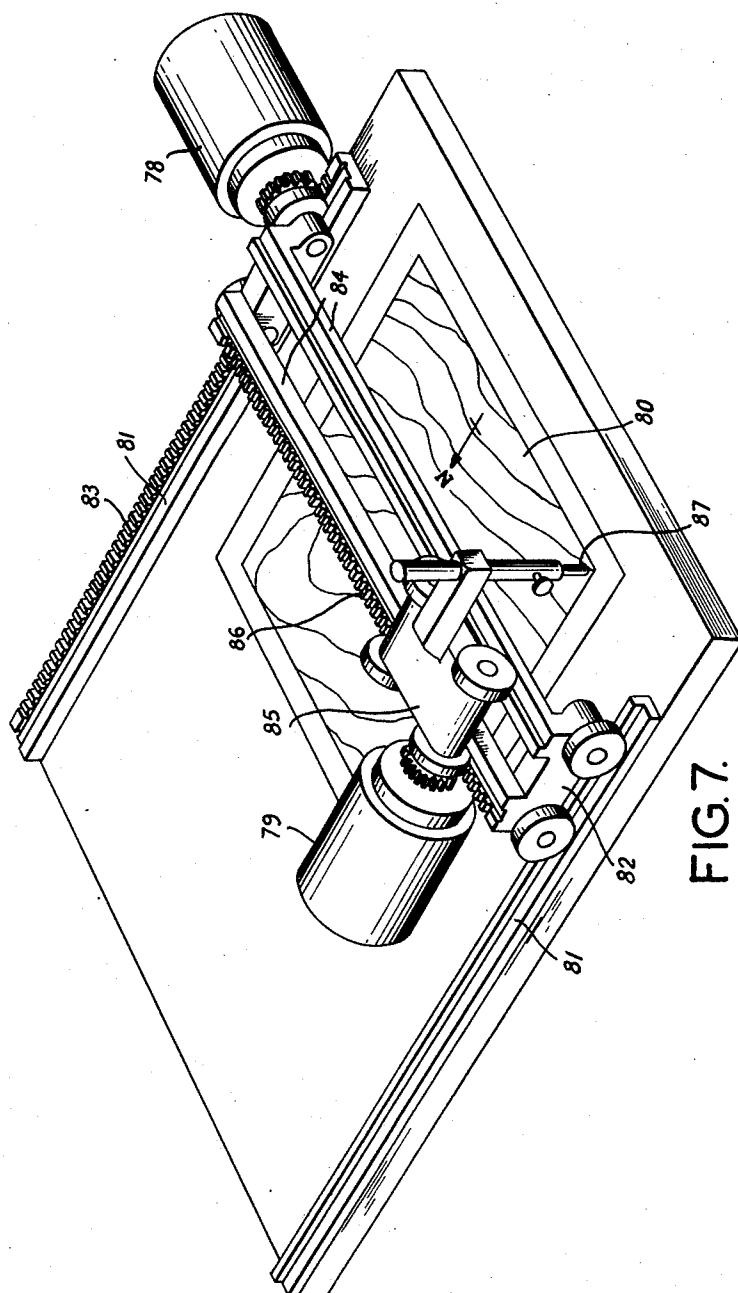


FIG. 7.

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UNITED STATES PATENT OFFICE

2,608,907

MACHINE FOR PREPARATION OF RELIEF
MAPS

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Application February 18, 1948, Serial No. 9,283

18 Claims. (Cl. 90—13)

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This invention relates to devices for making relief or three-dimensional maps, and particularly to devices of this kind which include curvature of the surface as a whole as one of the factors determining the form of the map. Thus a map produced by such a device may not only have the tops of the hills standing at the proper heights above the bottoms of the valleys respectively adjacent to them, but also as a whole the map may be curved in simulation of the curvature of the earth.

Speaking generally the invention concerns that type of mapping mechanism which, as commonly conceived, consists essentially of a stylus and mechanism to move the stylus to various positions latitude-and-longitude-wise with respect to a three-dimensional medium of some sort, and at each of those positions cause the stylus to cut into the medium deep or shallow as may be necessary to appropriately outline the hills and valleys to be portrayed. For example, the stylus may be a rotary drill and the medium to be marked a block of plaster, the drill being driven into the plaster at each of a large number of places to a depth corresponding to the elevation of the corresponding point on the land being mapped. Or the stylus may be a rotary drill capable of cutting at its side as well as at its end. The tool or stylus then may be moved bodily through the plaster block sidewise, crossing and recrossing it repeatedly along different paths, and at the same time cut deeper or shallower into the plaster as the elevation of the land changes from point to point along corresponding paths on the terrain. When a sufficient number of such cuts have been formed (speaking generally, the greater the number of cuts the greater will be the degree of accuracy of the map), the walls and projections between cuts may be broken out and the generally rough surface remaining smoothed off more or less to blend the bottoms of adjacent cuts into each other. The result is a model of the terrain mapped at whatever horizontal and vertical scales may have been chosen for the operation.

Curvature is brought in as a factor by, as it were, measuring the depths of penetration of the tool into the medium from the center or centers of the desired curvature. According to the present invention, the curvature is introduced by employing, speaking generally, supports disposed at opposite sides of the apparatus from each other, and a structure, generally arched in form, to run back and forth over those supports, across the space between them, and additionally that is so arranged that it is independently movable in a direction or directions which is or are at an angle

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or angles to its movements on the said supports. In the course of the movements of the structure, each of its parts describes (i. e. moves along, as it were) a curved surface which is a composite of the two motions or sets of motions. The stylus or the medium to be marked (usually the stylus) is mounted on the structure, and the relative latitude-and-longitude movements of the stylus and medium are brought about by moving the structure. At the same time the stylus and medium to be marked are made adjustable toward and from each other, one with respect to the other, independently of the supporting structure, so that the stylus can be made to penetrate into the medium various distances, during the course of the operations, without an accompanying change in the length of the radius or radii of curvature of the surface described by the part of the structure to which the stylus or medium is attached, and the depths of penetration are measured from, as it were, the surface described by that part of the structure. Where the data for the relief map are to be taken from a contour map about as described hereafter, and in any other situations where the medium is to be marked along equi-elevational lines, the stylus-medium adjustment can be made by the use of styli of different lengths, one for each level, and a holder for the styli that is of such nature that one stylus can be substituted for another readily. In the alternative, either the medium to be marked or the stylus can be mounted in a holder or carrier that is capable of projecting and retracting the medium or stylus, as the case may be, variable distances from and toward the other holder, bodily, and more or less directly toward and from the curved surface described by that part of the structure on which the holder is mounted. Such an arrangement is suitable both for cases where equi-elevational lines are followed in marking the medium and cases where more or less continuous changes in the depth of penetration are required. The result is the incorporation into the relief map of a curvature which more or less corresponds to the curved surface described by the part of the movable structure on which the stylus or medium to be marked is mounted, although not necessarily of the same radii as appears hereafter. If both motions or sets of paths of the part of the structure which carries the medium or stylus are circular, and have coincident centers (i. e. the same center, or intersecting centerlines, or the center of one on the line of centers of the other), the curvature of the map will be spherical curvature. Preferably the arrangement is a composite of two systems, one of which consists of parallel side

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supports and a structure mounted on them for movement in the one direction but which is so constrained inherently that in moving on its supports at least a part of it moves about a particular center or line of centers, and the other of which consists of a second pair of supports mounted on and at opposite sides of the first structure and a second structure mounted on the second pair of supports for movement in the second direction, but which also is so constrained inherently that at least a part of it too moves about a particular center or centers. The stylus or medium is mounted on such a part of the second movable structure.

It is desirable that the curvature be adjustable, so that different maps can be given different curvatures. This can be accomplished readily with the arch-form type of structure as appears hereafter. Preferably too the arrangement is such that the bodily movement as the stylus penetrates deeper into the medium it marks and withdraws, is along radii of the curvature. This also is readily accomplished with the arched type described hereafter. However such radial movement is not altogether necessary; for example it will not be necessary where the map spans very small arcs and where the degree of accuracy required of the map permits of the errors which non-radial bodily movements of the stylus tend to introduce, or where a correction is applied for those errors. When a positive map is desired (i. e. one in which the hills project above the valleys) the medium on which the stylus acts can be located between the stylus and the centers of curvature; when a negative is required (i. e. one in which the valleys project outwardly from the hilltops) the stylus can be located between the medium and the centers.

The scales of the vertical and horizontal measurements and of the radii may be alike, or they can be different as desired.

The accompanying drawings illustrate the invention as applied particularly to the preferred composite structure and the preferred radial movements.

In those drawings Figs. 1 to 4 are diagrams referred to in describing the principles underlying that preferred type of composite structure. Fig. 5 is an isometric projection of a machine constructed and operating in accordance with those principles. Fig. 6 illustrates diagrammatically a type of apparatus by which the operations of such a machine as Fig. 5, for example, can be directed. Fig. 7 illustrates a device whereby the data required by such a machine as Fig. 5 can be obtained from a contour map. Figs. 8 and 9 illustrate alternative details representatively.

Referring to Fig. 1: If 1 and 2 are two pins or short bars fixed in position and projecting from the paper as it were, and if 3 and 4 are two straight rigid bars which rest on 1 and 2 and which are rigidly joined at 5 so that the angle 6 between them remains constant, then so long as the common plane of the two bars 3 and 4 (i. e. the plane which passes through the joint 5 and also through both bars 3 and 4, or which is parallel to both those bars if they are offset one from the other) is perpendicular to the axes of the two bars or pins 1 and 2, the joint 5 must be in the arc 7 of a circle the center of which is at 8. In other words, the joint 5 may be moved from near 1 to near 2, or from 2 to 1, but in moving between these two places describes or passes along the arc 7; it can take no other

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path. Also, if two other pins or short bars 11 and 12 are carried on the joint 5 so as to move with it, but always are held parallel to the pins or short bars 1 and 2 and also are so held that a straight line 9 joining them is at right angles to the radius 10 from the center 8 to the joint 5 regardless of where 5 may be along the arc 7, and if 13 and 14 are two straight rigid bars which rest on the short bars or pins 11 and 12 and which are rigidly joined at 15 so that the angle 16 between them remains constant, then so long as the common plane of the two bars 13 and 14 is perpendicular to the two bars or pins 11 and 12 and the bars 3 and 4 are constrained to move as before described, the joint 15 must remain in the arc 17 of a circle, the center of which also may be at 8. In other words, the joint 5 can be moved from near 1 to near 2 and vice versa, and the joint 15 can be moved from near 11 to near 12 or vice versa, simultaneously or independently of each other, but during such various movements the joint 15 either remains at rest in or moves along the arc 17; it can take no other path, providing the conditions mentioned above are observed. In brief, the system 1—2—3—4, and the system 11—12—13—14 mounted on it, are two independently operable systems taking part in determining the path and momentary positions of the joint 15 (and the paths and momentary positions of every other point on the upper structure 13—14), and under the conditions pointed out the movement of the joint 15 is constrained to an arc of a circle.

Now if instead of mounting the system 11—12—13—14 in such a position that the common plane of the bars 13 and 14 is the same as the common plane of the bars 3 and 4, the system 11—12—13—14 is swung around 90° as it were, i. e. so that the axes of the short bars or pins 11 and 12 are at right angles to the axes of the pins of short bars 1 and 2, as shown in the plan view of Fig. 2 and in the elevation of Fig. 3, and consequently the paths of movement of 15 under the action of bars 13 and 14 are at right angles to the path of movement of joint 5, then as joint 5 moves between 1 and 2 and joint 15 moves between 11 and 12, the joint 15 will describe or move in a section or arc of a curved surface, every other point on the upper structure 13—14 will describe a curved surface also, and if, for example, both the center of the motion of joint 5 on the bars or supports 1 and 2, and the center of the motion of the joint 15 on the bars or supports 11 and 12, are at the same point such as 8, the surface described by the joint 15 will be a spherical surface, such as indicated at 20 in Figs. 2 and 3, also centered at 8.

Fig. 4 illustrates a variation of the foregoing. In this figure 11a and 12a are two spaced pins or short bars which can be regarded as generally corresponding to the pins or bars 11 and 12 of Figs. 2 and 3. Two straight rigid bars 13a and 14a, joined at 15a at a fixed angle to each other, rest on the pins or bars 11a and 12a. The two pins or bars 11a and 12a are carried by a bracket 22 which is mounted on and rotatable around the center line of the pin or shaft 23; it may be rotatable around this pin or shaft as shown. If the supporting structure or bracket 22 is held at rest and the structure 13a—14a is moved, in the plane of the paper, so that the joint 15a passes from 11a to 12a or vice versa, the joint 15a will travel the circular arc 24 and every point adjacent 15a also will travel in a circular arc;

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they can follow no other paths. On the other hand, if the structure 13a—14a is held at rest on the pins or bars 11a and 12a and the bracket 22 (and therewith the angled or arch structure 13a—14a) is rotated on 23, the joint 15a will remain at rest in space if it is in the axial center line of 23, but if the joint is at any other place between 11a and 12a, then the joint will travel in a circular path at right angles to the paper, the particular path traveled depending on the position of the joint with respect to 11a and 12a. Likewise each other point on the structure 13a—14a between 11a and 12a will travel a circular path, except as a point may be on the axial center line of 23 at the moment. The center line of these circles (i. e. the line joining the centers of the various circles) will be the axial center line of the pin or shaft 23 of course. It follows accordingly that if the structure 13a—14a is shifted back and forth on its pins or bars 11a and 12a, and simultaneously the bracket 22 is rotated or oscillated, the joint 15a will describe an arc of a spherical surface, and likewise every point on structure 13a—14a adjacent 15a will describe an arc of a spherical surface. They can follow no other paths.

It is to be observed that the foregoing is generally true regardless of whether or not the center line of rotation of the bracket 22 is on a perpendicular to a line joining the bars or pins 11a and 12a as shown. Thus, for example, the pin or shaft 23 can be so displaced that its axial center line (and accordingly the axis of rotation or oscillation of the bracket 22) is along the line 25, or along the line 26. In all such cases also the joint 15a and all points on the structure adjacent to it, will describe arcs of curved surfaces as the structure 13a—14a is shifted on its pins 11a and 12a and, in effect, simultaneously therewith the bracket 22 is rotated or oscillated on 23. Whenever the center line of the rotation or oscillation (e. g. 25, or 26) passes through the center of the circular arc 24 described by the joint 15a in moving on the pins or bars 11a and 12a, the arcs described as the composite result of the various motions, will be arcs of spherical surfaces, otherwise they will be arcs of other curvatures as will be understood.

According to the present invention, speaking generally, the holder for the stylus or the medium to be marked by the stylus is mounted on the upper structure 13—14 of a composite of the type shown in Figs. 2 and 3, or on the structure 13a—14a of a composite of the type shown in Fig. 4, the holder for the other (i. e. the medium or the stylus) being mounted above or below that structure. Usually the holder that is mounted on the structure, is mounted at or near the point 15 or 15a of the structure or at a point corresponding to the point 15 or 15a. The two structures 3—4 and 13—14, or 23 and 13a—14a, or structures corresponding to them, are then shifted to establish various desired latitude-and-longitude relations between the medium and the stylus, and either the holder for the stylus or the holder for the medium to be marked is moved toward and from the other as necessary to enable the stylus to outline the hills and valleys within the medium in a vertical direction. Generally at least the mounting of the movable holder (or both of the holders if each is movable toward and from the other) is such that the stylus can be penetrated into the medium to be marked independently of the structure (13—14, 13a—14a) on which one of them is mounted, i. e. without

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changing the angle between its parts or shifting it, and generally at least the range of movement is such that, independently of the structure except for the movements necessary to establish latitude-and-longitude positions, the stylus and medium can be brought to their various relative latitude-and-longitude positions without engagement of the stylus with the medium. The extent of the projections and retractions may be measured with respect to the point on the respective structure to which the stylus or the medium (as the case may be) is attached. If the mounting is at the joint 15 and the center of the path of the joint 5 is coincident with the center of the path or paths described by the joint 15, or if the mounting is at 15a and the axis of rotation of bracket 23 passes through the center of curvature of arc 24, the curvature of the map produced by the device will be a spherical curvature.

The stylus or the medium to be marked can be mounted at various places on the upper structure or sytem. Preferably it is mounted at the joint 15 or 15a (or at a corresponding point in action). Also the bodily movements of the stylus or the medium, one toward and from the other whereby the stylus is driven into the medium and withdrawn, can be at right angles to the plane that, at point 15 or 15a wherever this may be in its travels, is tangent to the surface described by that point as it moves from one position to another. With this mounting and the penetrating action in this direction, and assuming that the arc described is spherical, then the curvature of the map will not only be spherical, but also it will have the same center as that point (e. g., at 8), and the penetration of the stylus into the medium to be marked will be along radii of the curvature and therefore suitable under all conditions to outline the hills and valleys properly. Further, with such relations the relative angular movements of the medium and the stylus will tend to equal the angular movements of the joints so that the medium and stylus can be brought exactly to the various desired latitude-and-longitude positions quite readily and simply. As alternatives however, the stylus may be so mounted on the composite structure that it bisects the angle of the structure (e. g. 16), or the medium to be marked may be so mounted on the composite structure that, say, its vertical center line bisects this angle, or either may be mounted on and projected from one of the bars at a point more or less remote from the joint 15 or 15a. In all such latter positions also the sidewise bodily movement of the element that is mounted on the composite structure tends to be along a spherically curved surface (assuming that the supporting structure is arranged for spherical curvature), but usually at least the center of the curvature will not be at the coincident centers but at a more remote point. Further, the movements by which the stylus is penetrated into the medium to be marked will not then be along radii of the curvature at all times, and the angular movements will not be wholly equal to, for example, the angular movements of the joints 5 and 15. Accordingly such alternative mountings of the stylus or medium tend to introduce difficulties and errors into the map, and we prefer those mountings wherein the movements of the stylus into the medium to be marked and the reverse, are at right angles to the tangent plane as before described, although, as before indicated, an alternative mounting may be used when the degree of accuracy permits the errors inherent

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in the alternative mounting, or when corrections are made for those errors.

It will be understood of course that any desired radii of the curvature can be given to the two structures or systems. Thus the radius of the path of joint 5, i. e. the radius of the curve 7, is equal to the distance from the pin 1 to the pin 2 divided by two times the sine of the angle 6, and the radius of the path of joint 15 is equal to the distance from pin 11 to pin 12 divided by two times the sine of the angle 16. By giving such factors appropriate values therefore, the two radii can be made of any desired lengths.

Fig. 5 illustrates the form of machine built and operating in accordance with the foregoing which we prefer at present. The holder 29 of the medium to be marked 30, holds this medium in a fixed position. The medium may be a block of plaster. At its sides (or at its sides extended) two spaced parallel shafts 31 and 32, which correspond to the bars or pins 1 and 2 of Figs. 2 and 3, are carried in fixed bearings. At one end of the machine, two straight rigid bars 33 and 34 are joined together at a pin 35 at appropriate angle to each other. Preferably this angle is adjustable; e. g. the two bars may be loose on pin 35 and a clamping bolt 36, passing into or through one of them and through an arcuate slot 37 in the other, may be employed to lock the bars together at the desired angle. The two bars 33 and 34 rest on the two shafts 31 and 32. Also two other straight rigid bars 38 and 39 rest on the shafts 31 and 32 adjacent the bars 33 and 34, and are joined together at 40 at the same angle as the bars 33 and 34; they may be connected in the same manner as 33 and 34. However the joint at 40 is spaced somewhat from the joint at 35. A bracket 41 is carried on the hinge pin 35 and the corresponding hinge pin at the joint 40. One of these four straight bars, for example 33, is provided with gear teeth at one edge and the shaft 31 on which it rests has fixed to it a gear wheel meshing with the teeth on the bar. The other bars 33, 34 and 39 may slide on plane surfaces on the shafts 31 and 32. Collars 45 carried on the shafts at the sides of the four bars hold the bars in planes perpendicular to the axes of the shafts. Accordingly when the shaft 31 is turned forward or back its gear and the gear teeth on bar 33 cause the bars 33, 34, 38 and 39 to move lengthwise of themselves on the two shafts, and in turn carry the bracket 41 with them. However the arrangement described is such that at all times the bracket 41 is held tangent, or parallel to the tangent, of the circle in which joints 35 and 40 run, at whatever place the bracket may be at the moment. The bars 33 and 38 correspond to the bar 3 of the previous figures, and 34 and 39 correspond to 4, and the bracket 41 can be considered as corresponding in action to the joint 5 of Figs. 2 and 3.

At the opposite end of the machine are four similar straight rigid bars 53, 54, 58 and 59, similarly fastened together in pairs at the same angle as bars 33 and 34, similarly carrying a similar bracket 61, and similarly resting on the shafts 31 and 32 and similarly movable by the shaft 31. These also can be considered as corresponding to 3, 4 and 5 of Figs. 2 and 3.

A shaft 62 is mounted in the bracket 41 transverse to shafts 31 and 32, and a parallel shaft 63 is mounted in bracket 61. These two shafts correspond to the pins or bars 11 and 12 of Figs. 2 and 3. Four bars 64, respectively joined together

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in pairs at equal angles and with their joints displaced somewhat from each other, rest on adjacent ends of the shafts 62 and 63; also four similar and similarly connected bars 65 rest on the opposite ends of the shafts 62 and 63. In construction and arrangement each of these two groups of four bars is similar to the group 33, 34, 38 and 39. A carriage 66 is mounted on the pivot pins of the eight bars 64 and 65, above the plaster block 30 to be cut by the stylus. One of the bars 64 and one of the bars 65 is provided with gear teeth and the shaft 63 has fixed to it gears meshing with the teeth of these two bars respectively. The other six of these bars may ride on smooth surfaces of 62 and 63, and as before the shafts 62 and 63 are provided with collars 67 to hold the bars 64 and 65 upright. By turning the shaft 63 forward and back therefore the carriage 66 can be oscillated between 62 and 63. However the arrangement is such that at all times the carriage 66 is held, at a point midway between the joints of the respective pairs of joints of those bars, wherever they may be at the moment, tangent, or parallel to the tangent, to the paths of those joints in being shifted on the shafts 62 and 63, and this in conjunction with the tangency of the brackets 41 and 61 before described, causes the carriage 66 to be at all times in a plane, or parallel to a plane, that locally is tangent to the curved surface described, as it were, by the carriage 66 as it moves under the joint actions of both geared shafts. The bars 64 and 65 correspond to the bars 13 and 14 of Figs. 2 and 3, and so far as the action of joint 15 has been described, the carriage 66 can be considered as corresponding to that joint.

While the spacing between the two shafts or supports 31 and 32 of the lower structure is fixed, the radius of curvature of the path of this structure in moving over those shafts (e. g. the radii of the paths of the brackets 41 and 61), can be made to be of substantially any length by setting the bars of the pairs 33—34 and 38—39 at an appropriate angle to each other at their joints 35 and 40 and similarly setting the bars of the pairs 53—54 and 58—59 at an appropriate angle at their corresponding joints. Likewise the radius of curvature of the path of the upper structure in moving over the upper or movable supports, i. e. the shafts 62 and 63, can be made to be of substantially any length that may be desired by similarly setting the bars of the various bar-pairs of the groups 64 and 65 at appropriate angles to each other at their joints. In the present instance the radii of the joints 35 and 40 and the corresponding joints of the opposite bar-pairs 53—54 and 58—59 are assumed to lie in the line A—A and the radii of the joints of the bars 64 and 65 to lie in a line B—B which intersects A—A at 68. As a result the stylus carriage 66, in moving as directed by the bars describes a spherical surface centered at the intersection 68.

The stylus 70 is a rotary drill capable of cutting at its side as well as at its end. Its holder may be an ordinary drill chuck mounted on the carriage 66 for reciprocation toward and from the carriage and the holder 29 of the medium to be marked. A motor 72 on the carriage 66 rotates the chuck, and therewith the drill, continuously during the operations, and a mechanism 73, also mounted on the carriage 66 and of a form appropriate to the form of operations contemplated but preferably a synchro type mechanism, reciprocates the chuck as directed

to cause the drill to penetrate into and withdraw from the medium 30, and in the present instance also causes the drill 70 to cut deep or shallow into the medium as the mechanism is directed. In the present instance the stylus or drill 70 is projected and retracted perpendicularly to the carriage 66, and accordingly perpendicular to the tangent plane of the carriage 66 before referred to.

The stylus-projecting mechanism 73 may be a synchro receiver (see Fig. 6 also), or a servomechanism controlled by such a synchro receiver, which projects the drill more or less deeply into the plaster block 30 as directed by a synchro transmitter 74, Fig. 6. Likewise the shaft 63 may be oscillated by a synchro receiver 75, or a servomechanism controlled by a synchro receiver, as directed by a synchro transmitter 78, and also the shaft 31 may be oscillated by a synchro receiver 76, or a servo controlled by a synchro receiver, as directed by another synchro transmitter 79, Fig. 6. This is a convenient arrangement whereby the operations of the mapping machine can be directed electrically. Thus by actuating the synchro 78 the stylus can be moved, say, latitude-wise, and by the synchro 79 it can be moved, say, longitude-wise, and accordingly by the conjoint action of the two the drill can be made to, say, cut a trace or series of traces in the face of the plaster block or other medium 30 and thus made to occupy successively selected positions corresponding to certain places on the terrain being mapped. By simultaneously oscillating the rotor of the synchro 74 in accordance with changes in level of the ground from each of those places to the next, a trace or traces will be cut to depths representative of the hills and valleys of the ground as will be apparent. The map may then be completed by breaking away the walls between the traces and smoothing the rough surfaces as before explained.

The required data, i. e. the data of longitude and latitude and elevation, can be supplied to the rotors of the transmitting synchros 74, 78 and 79 in various ways as will be understood, manually or otherwise. Also the data may be collected and transmitted to the transmitting synchros in various ways. As one example, Fig. 7 illustrates an arrangement for deriving the data from contour maps.

In Fig. 7, the contour map 80 is laid on a board carrying rails 81 on which a carriage 82 runs. At one end the carriage 82 carries the synchro transmitter 78 which has a gear on its rotor shaft meshing with a rack 83 affixed to the board. Also the carriage 82 carries a pair of rails 84 on which a second carriage 85 runs, and a parallel rack 86. The second carriage 85 carries a tracing point 87 and also the synchro transmitter 79, Fig. 6, with a gear on its rotor shaft meshing with the rack 86. The elevation-transmitting synchro 74, Fig. 6, is assumed to be close to the hand of the operator of the device of Fig. 7, and its rotor manually operable by a handle 89; it may be provided with an index hand and a scale 88 on which the elevations represented by the various positions of the rotor are inscribed.

In order then to make a relief map from the data furnished by a contour map 80 (the motor 72, Fig. 5, being in operation and rotating the drill 70, and the drill being, say, elevated well above the plaster block 30) the operator selects a contour line on the map 80, and moves the tracing point 87 to some point on it. In doing this he moves the carriages 82 and 85, and there-

by shifts the rotors of the synchro transmitters 78 and 79 accordingly, and this causes the synchro receivers 75 and 76 to respond and thus place the drill 70, Fig. 5, above a spot on the block 30 corresponding to the latitude and longitude position of the tracing point. The operator now turns the handle 87 and thereby the rotor of the synchro transmitter 88 until its index hand points to the elevation represented by the contour line touched by the tracing point. In turn this brings the synchro receiver 73 into action, with the result that the drill is thrust down into the plaster block 30 to a position chosen as representative of that elevation. The operator now moves the tracing point 87 along the selected contour line, and thereby causes the drill 70 to cut a path in the plaster corresponding in shape to the contour line and at the selected elevation. When this cut is finished, the operator selects another contour line and moves his tracing point to it, thus shifting the stylus latitude-and-longitude-wise correspondingly. Also he turns the rotor of the synchro transmitter 74 to the new (higher or lower) elevation, and thereby changes the depth of the drill cut. He now moves the tracing point along this second contour line, and while doing this the drill 70 cuts a trace corresponding in shape to the shape of the new contour line and at a depth representative of the land elevation indicated by that contour line. Such operations are repeated at, say, each contour line of the map 80, and when all have been traced over the block of plaster is ready to have its standing walls broken away and its resulting surface smoothed as before described, thus completing the desired relief map.

It will be observed of course that in view of the receiving synchro or servomechanism 73 as described, the stylus holder illustrated in the present instance is of what may be called the incremental type. That is to say, it is capable of forcing the drill stylus deeper and withdrawing it by various increments, quite as though it consisted of a hand operated vertical screw having the drill rotating on its lower end. It is not necessary therefore, with the stylus holder of Fig. 5, that the stylus be moved along equi-elevation contour lines as described above; instead it can be moved along any paths, and by appropriate actuation of the rotor of the synchro transmitter 74 simultaneously, moved in depth more or less continuously as the land rises and falls along corresponding paths on the terrain being mapped. In view of this it is not necessary, with a stylus holder of this general type, that the mapping data be obtained from a contour map; the data can be derived from any other form of reports of surveys of the territory to be mapped, say in the form of continuous or intermittent reports of changes in elevation along paths crossing the land; the required data may even be transmitted to the mapping machine and applied by it while a survey is in progress.

On the other hand, when the stylus is to be moved along equi-elevation contour lines, a step by step form of depth adjustment can be substituted for the incremental type. Thus in lieu of the drill holder involving the motor 72 and synchro 73 of Fig. 5, a common form of drill chuck 90, Fig. 8, can be mounted on the carriage 66 by, for example, a common form of drill press so that its drill can be raised from or forced into the plaster block 30, and arranged to be rotated continuously by a motor, and a selection of drills 91 of various appropriate lengths provided. Thus

there may be a drill of suitable length for following the highest contour when the drill press holds the chuck at its lowest position, another a little longer for following the next lower contour, when the chuck is in the same position, a third sufficiently longer to follow the contour below the second, and so on for as many contours and depths as may be necessary. Thus one of the drills will be substituted for another in the chuck 90 as the operator completes tracing one contour and moves on to the next.

Or again, Fig. 9, a number of drills of various lengths, one for each of a number of contours, can be mounted in a magazine carried by, say, the carriage 66. The magazine illustrated comprises primarily an annulus 94 carrying in its circumference a number of rotatably mounted drill chucks 95. Each of these chucks carries a gear 96 for rotating it. The annulus 94 is mounted rotatably on a circular stub 97 projecting from a bracket 98 which is slidable in ways 99. These ways are mounted on, say, the carriage 66 of Fig. 5. A cap 100, having a projecting threaded bolt to screw into the face of the stub 97, serves to hold the annulus on the stub; a projecting wing 101 on the cap permits the cap to be unscrewed and reset readily, thereby permitting the magazine to be loosened for turning on the stub 97 so that each chuck 95 in turn can be brought to the lowest or operating position on the bracket 98. An arm on cap 100 carries a spring latch 102 to enter holes 103 in the annulus 94 so that the annulus can be held against rotation with any chuck lowermost. At its opposite side, the bracket 98 carries a shaft 104 which has a gear 105 fixed to its lower end in a position to intermesh with any chuck gear 96 that may be brought to it. The shaft 104 is slidable in a sleeve (not shown) which is driven continuously by a motor also carried on, say, the carriage 66, and which rotates the shaft. Each chuck 95 is furnished with a rotary drill 106 of appropriate length to cut one contour when in the lowest position on the bracket 98 and the bracket 98 is at its lowest position. The bracket 98 is arranged to rise high enough to permit even the longest drill to be withdrawn completely from the plaster block. In operation, the operator first selects a contour to be traced. With the bracket 98 in its highest position, he turns the annulus 94 to bring the appropriate drill for that contour to the lowest position on the bracket. He then (say again using the mechanism of Fig. 7) brings the tracing point 87 to some point on the selected contour (thereby placing the drill properly latitude-and-longitude-wise with respect to the medium to be marked), and with the drill being rotated by shaft 104, he moves the bracket 98 down to its lowest position, thereby penetrating the drill into the medium to the proper depth for that contour. The operator then traces along the selected contour, thereby causing the drill to cut a trace in the medium corresponding to the contour (the synchros on and controlling the shafts of the mapping machine shifting the drill sidewise as before described). When this contour is finished, the operator again raises the bracket 98 to its highest position, and then repeats the operation with, say, each of the other drills in the magazine. When the operator has traced all the contours for which the drills in the magazine are suitable, he may either substitute another set of longer or shorter drills in the chucks of the same annulus, or remove the magazine with its drills from the bracket and substitute another

magazine having a complement of drills suitable for proceeding with other contours. In either case he is then ready to proceed with further contours.

The foregoing will serve to illustrate the principles and application of our invention. It will be understood of course that the invention is not limited to the mechanism and operations described above in detail. For example, it is not necessary that the movement of the free end of the stylus be simply to and from the carriage on which the stylus is mounted; thus a map making method has been proposed in which the stylus oscillates; the oscillating form of stylus mounting can be employed here if desired, as will be apparent. Also the invention is not necessarily limited to the introduction of cylindrical curvature into maps. While cylindrical curvature seems to us at present to be the most important when curvature is required, it is apparent that cylindrical, elliptical and complex curvatures can be incorporated in maps if the desire for such curvatures should arise; this can be done by using different angular relations between the various bars and thereby employing different centers for the bar systems, by arranging the bar systems so that the paths of the joints of the two systems cross each other at angles other than 90°, etc., as will be understood from the foregoing.

In general therefore it is to be understood that our invention is not limited to the details of construction and operation described above except as appears hereafter in the claims.

We claim:

1. In a machine for making relief maps, supports spaced from each other, a structure movable on said supports, said structure having a surface arched across the space between said supports and said surface resting on said supports, the structure thereby being movable in a curved path crossing the space between the said supports and the structure also being independently movable in paths angled with respect to its said movements on said supports, each of said paths having a fixed center of curvature, a holder for a stylus, and a holder for the medium to be marked, one of said holders being mounted on said structure, and one of said holders being movable toward and from the other independently of said structure to cause the stylus to penetrate into the medium.

2. The subject matter of claim 1, characterized by the fact that the holder that is movable to cause the stylus to penetrate into the medium is the holder that is mounted on said structure.

3. The subject matter of claim 1, characterized by the fact that the stylus holder is the holder that is mounted on said structure and is the holder that is movable to cause the stylus to penetrate into the medium to be marked.

4. In a machine for making maps, supports spaced from each other, a structure movable on said supports, said structure having a surface arched across the space between said supports and said surface resting on said supports, the structure thereby being movable in a curved path crossing the space between the said supports and the structure also being independently movable in paths angled with respect to its said movements on said supports, each of said supports having a fixed center of curvature, a holder for said stylus, and a holder for the medium to be marked, one of said holders being mounted on said structure, and one of said holders being an

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incremental type of holder to project the element it carries toward and withdraw it from the other holder to different degrees to cause the stylus to penetrate into the said medium to various depths.

5. In a machine for making relief maps, supports spaced from each other, a structure spanning the space between said supports and movable thereon in a curved path crossing said space, a second group of supports mounted on said structure at opposite sides thereof, a second structure movable on said second supports, independently of said movement of the first mentioned structure, in a curved path substantially transverse of the first mentioned structure, said first and second mentioned curved paths having the same center of curvature, a stylus holder, a holder for the medium to be marked, one of said holders being mounted on the second mentioned structure and one of said holders being movable toward and from the other to cause the stylus to penetrate into the medium, a reversible motor to reciprocate the first mentioned structure on its supports as directed, and a reversible motor to reciprocate the second mentioned structure on its supports as directed.

6. The subject matter of claim 5, characterized by the fact that said holder which is movable, is movable toward and from the other independently of both of said structures.

7. The subject matter of claim 5, characterized by the fact that the stylus holder is the holder that is mounted on the second mentioned structure, and is the holder that is movable toward and from the other holder, and is an incremental type of holder to cause its stylus to penetrate into the medium to be marked to various depths.

8. In a machine for making relief maps, supports spaced from each other, a structure spanning the space between and movable on said supports and including at least two bars one of which rests on one of said supports at one side of said space and the other of which rests on another of said supports at the opposite side of said space and the said two bars being joined together between the said supports at an adjustable angle to each other, a second group of spaced supports mounted on said structure at opposite sides thereof, a second structure spanning the space between and movable on supports of the latter group and including at least two bars one of which rests on one of the latter supports at one side of the first mentioned structure and the other of which rests on one of the latter supports at the opposite side thereof and which are joined at an adjustable angle to each other, a stylus holder, and a holder for the medium to be marked, one of said holders being mounted on the second structure for movement by the conjoint action of the two structures moving on their respective supports, and one of said holders being movable toward and from the other to cause the stylus to penetrate into said medium.

9. The subject matter of claim 8, characterized by the fact that one of the first mentioned supports is a shaft having gear teeth, the said bar which rests on it has gear teeth meshing with the gear teeth of said shaft, one of the supports of the second group is a shaft and has gear teeth, one of the bars resting on the latter support has gear teeth meshing with the gear teeth of the latter support, and the said two shafts are rotatable independently of each other.

10. The subject matter of claim 8 characterized by the fact that the holder which is mounted on the second structure is the holder that is movable

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toward and from the other and is so mounted thereon that it is projected and retracted substantially at right angles to the plane which is tangent, at that holder, to the curved surface described by the part of the second structure to which the said holder is attached.

11. In a machine for making relief maps, supports spaced from each other, a first pair of straight bars spanning the space between and movable on said supports and between said supports being joined together at an angle to each other, a second pair of straight bars spanning the space between and movable on supports of those first mentioned, the bars of said second pair being respectively parallel to but spaced from the bars of the first pair and being joined together at a like angle, supports carried by the said two pairs of bars, a third pair of bars spanning the space between the first and second pairs of bars and movable on supports last mentioned and therebetween being joined together at an angle, a fourth pair of bars also spanning the space between the first and second pairs of bars and movable on supports last mentioned, the bars of said fourth pair being respectively parallel to the bars of the third pair and being joined at the same angle as the bars of the third pair, a stylus holder, and a holder for the medium to be marked, one of said holders being mounted on the said third and fourth pairs of bars.

12. In a machine for making relief maps, a pair of parallel shafts spaced from each other, a pair of straight bars resting on said two shafts respectively and joined together at an angle to each other between the shafts, a second pair of straight bars, remote from but respectively parallel to the bars of the first pair, also resting on the said two shafts and joined together at the same angle, a shaft mounted on each of said two pairs of bars, at right angles to the first mentioned shafts, a third pair of straight bars resting on the latter shafts respectively and joined together at an angle between the latter shafts, a fourth pair of bars, remote from but respectively parallel to the bars of the third pair, also resting on the latter shafts and joined together at the same angle as the bars of the third pair, one bar of each pair having gear teeth and the shaft it rests on respectively having gear teeth meshing with the gear teeth of the bar, and a stylus holder, adapted to project and retract a stylus with respect to the holder, mounted on the third and fourth pairs of bars.

13. The subject matter of claim 12, characterized by the fact that a synchro mechanism is provided to direct the rotation of each shaft having gear teeth and a synchro mechanism is provided to direct the projection and retraction of the stylus.

14. In a machine for making relief maps, a pair of parallel shafts spaced from each other, a pair of straight bars resting on said two shafts respectively and adjustably joined together at an angle to each other between the shafts, another pair of straight bars resting on the said shafts respectively, adjacent the first mentioned pair, and adjustably joined together at an angle to each other, the joints of the two bar-pairs being displaced from each other transversely of the two shafts, a bracket mounted on the said two pairs of bars adjacent the joints thereof, a shaft on said bracket transverse to the said two shafts, a like group of four bars also resting on the said two shafts but remote from the first group, a bracket similarly mounted

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on the second group and a transverse shaft on the latter bracket, two similar groups of four bars each resting on said transverse shafts remote from each other, at least one bar of the first mentioned two groups and at least one bar of the last mentioned two groups having gear teeth and the shafts on which the said two bars rest having gear teeth meshing with said gear teeth of the bars whereby the oscillation of those shafts will shift the bar groups transversely of the shafts on which they rest respectively, a stylus holder, and a holder for the medium to be marked, one of said holders being mounted on the last mentioned two groups of bars adjacent the joints thereof and one of said holders being movable toward and from the other to cause a stylus in the stylus holder to penetrate the said medium.

15. The subject matter of claim 14, characterized by the fact that the bars of the various pairs of the first mentioned two groups of bars are joined together at like angles, and the bars of the various pairs of the second mentioned two groups are joined together at like angles.

16. The subject matter of claim 14, characterized by the fact that a synchro mechanism is provided to direct the oscillation of each of the said two shafts which have gear teeth, the stylus holder is the holder that is mounted on the bars and is the holder which is movable with respect to the other, and a synchro mechanism is provided to direct the projection and retraction of the stylus holder.

17. The combination with the subject matter of claim 16, of a carriage movable across a contour map, a synchro transmitter connected to said carriage for actuation thereby, a second carriage mounted on the first mentioned carriage for movement thereon transversely to the direction of movement of the first mentioned carriage, a synchro transmitter connected to said

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second carriage for actuation thereby, electrical connections to connect said transmitters one to each of the synchro mechanisms of the shafts of said mapping machine, and a synchro transmitter connected to the synchro mechanism which directs the projection and retraction of the stylus of the mapping machine.

18. In a machine for making relief maps, a bracket, a mounting for said bracket on which the bracket can be turned angularly, supports carried by said bracket, said supports being spaced from each other, an arched structure movable on said supports in a curved path crossing the space between said supports and having a center of curvature that is located in the axis of said bracket extended, a holder for a stylus, and a holder for a medium to be marked, one of said holders being mounted on the structure, and one of said holders being movable toward and away from the other independently of said structure to cause the stylus to penetrate into the medium.

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