ink. When a map is photographed in several sections, as often happens, each section overlaps well all round to enable the transfers from the different negatives to be neatly joined together without showing lines of juuction ; if the whole is too large to be printed on a single sheet of paper, it is cut up into sections for printing separately.

The object of photo-typography is to obtain by photographic agency a surface block which may be set up with type and printed in the same way as a woodcut. The image may be obtained on a zinc plate by transfer in the same way as for photo-zincography, or it may be printed directly from a reversed negative. In the latter case the zinc plate is usually prepared with a thin coating of bitumen, a substance which has the property of becoming in­soluble under the influence of light, so that, when after exposure the plate is washed with turpentine or benzole, the image remains on the zinc, while the ground is washed away. In both cases the image is strengthened by careful inking and by the application of powdered resin, which the plate is heated sufficiently to melt. The image is then etched with nitric acid. The operations of inking, applying resin, and biting with acid are repeated several times, until the plate is bitten sufficiently deeply to give clear prints. In another process, which is perhaps preferable for fine work, a mould is obtained by electrotyping a relief in swollen gelatin, the surface of which has been metallized with plumbago or bronze powder. These processes are largely used for producing small maps to illustrate books and newspapers, but not for maps of ordinary size.

The three mechanical processes just noticed are only applicable to maps drawn in line, and to get good prints every line should be of the same blackness, though of different breadth. Attempts have been made to reproduce brush-shaded drawings, exhibiting con­tinuous gradations of shade, by photo-lithography and photo-zinco­graphy, but with very partial success, and only by breaking up and destroying the continuity of gradation. The following processes are specially suited for reproducing maps in half-tone.

In photo-collotype, so-called from the printing surface being of gelatin, a plate with a perfectly smooth surface, usually of thick glass, either is coated with a sensitive mixture of gelatin and bichromate of potash, upon which the photographic image is pro­duced by the action of light through a *reversed* negative, or is employed to support a gelatin film on which the image has been imprinted from an ordinary negative, and which is attached to the plate w’ith suitable cement. The gelatin when properly moistened possesses the valuable property of receiving a greater or less amount of ink in different parts of the image in exact proportion to the intensity of the action of the light on each part ; thus it is capable of reproducing the most delicate gradations of shade. The process is admirable for maps of small size, w’hich only require a single plate, but is not suited for making a combination of sections to form a map of ordinary size ; nor can additions or corrections be made on the gelatin film, which is, moreover, so tender that it does not readily permit of a large number of prints of uniform quality being taken, and is easily damaged.

The several methods of obtaining an incised image on a copper plate by means of photography are broadly divisible into the two groups of electrotyping and etching processes ; one of each will be briefly noticed. (1) A positive pigment print, forming a relief in hardened gelatin, is developed on a silvered copper plate by the ordinary operations of the autotype or pigment printing process ; it is then blackleaded and copper is deposited on it to form an electrotype intaglio, from w’hich prints may be taken in the usual way, three to four weeks being required for the deposition of enough copper to produce a plate of sufficient thickness. (2) A negative pigment print is developed on a highly polished copper plate, upon w’hich a very fine grain of powdered resin has been deposited and fixed by heat. The intaglio is obtained directly on the plate by biting in with a solution of perchloride of iron, which penetrates the gelatin film with comparative ease in those parts representing the shades and lines of a map, where there is little or no gelatin, and thus bites the copper to a considerable depth, while in the parts representing the blank spaces and ground of the map, w’here the gelatin is thicker, it penetrates W’ith more and more difficulty as the thickness of the gelatin increases, and in the highest blanks should leave the copper untouched. The operation of biting takes only a few minutes, and the gravure is remarkable for its delicacy of gradation and richness of effect ; there is, however, some difficulty in etching to the proper depth so that the plate may stand much printing without the loss of the finest tint. In both cases the copper plates have to be protected by a facing of steel before they can be printed from. The processes have not yet been used to any great extent for maps w’ith half-tones, but they are very promising. For maps in line the first method gives excellent results, and is largely employed in the Austrian and Italian surveys.

X. Instruments.

The instruments employed in survey operations are broadly divisible into two classes, one for making the

requisite linear and angular measurements on the ground, the other for plotting the data thus acquired on paper’ and for measuring from the map, when completed, lengths and areas which it may not be convenient to calculate from the numerical data. As a rule different instruments are employed for the mensuration on the ground and for the plotting on paper ; but to this rule there is a notable exception in the plane table, by means of which all bearings may be drawn directly on paper with a sight rule, without previous measurement of any kind, and thus a plot of the ground may be constructed without employing any other instrument.

*Field Instruments.—*These are of two classes,—linear, for deter- Innung distances directly by actual measurement along the surface of the ground, and angular, for determining the bearings of, or the angles between, any objects. Some instruments are automatic, as the needle, which points to the magnetic north, the plumb-line and the spirit-level, w’hich indicate the direction of gravity, and hypsometers of various kinds, for measuring altitudes ; others are entirely controlled by the manipulator. Some require to be rigidly supported on the ground, as measuring bars and theodolites ; others are adapted for flexible supports, as reflecting and magnetic instruments, which may be employed either on land or on the oscillating deck of a ship at sea. Some, as magnetic compasses, measure angles in the horizontal plane only ; others, as theodolites, in two planes,—one horizontal, the other vertical ; others, as reflect­ing instruments, in all planes ; others, as levelling instruments, measure nothing, but simply indicate a plane of reference. And there are certain instruments by which angles are measured in the ordinary way, and direct distances are determined by micrometric measures of the small angles subtended at a distance by objects of known dimensions.

Linear instruments are of two classes,—one for exact measure­ment of base-lines the lengths of which are required to be known with great precision, the other for ordinary and rough measure­ments. Among the former may be included the Colby apparatus of compensation bars and microscopes, described in sect. I., § 2 (p. 696 above), Bessel’s apparatus, those of Struve and the United States Coast Survey, and Porro’s (adopted by the Spaniards and the French in Algiers), which have already been described in Earth (Figure of the), vol. vii. pp. 598, 600, and Geodesy, vol. x. pp. 163, 164. For less exact but still essentially accurate measures the instruments most commonly employed are the brass or steel chain of 100 links, the graduated metallic tape, and the offset pole.

For reconnaissance and rough measurement, perambulators, with wheels of known periphery and dials to indicate the number of revolutions, are largely used in India. Crinoline wire has been employed w’ith advantage in Australia ; it is so light that a length of 1000 feet or more may be easily carried, rolled on a drum, by one man, who pays it out as wanted ; he is usually followed by another, who commences rolling it up at the opposite end when an entire length has been laid out on the ground. Air lines are sometimes measured by stretching the wire over the tops of trees in valleys obstructed with forest, also the breadths of rivers by resting the wire on logs anchored at suitable intervals to support it above water.

Angle-measuring instruments are of two classes, direct and re­flecting. Both are provided with an aligner, usually a telescope, which is pivoted over the centre of the graduated circle or sector : in one the aligner is pointed in succession to any two objects the angle between which is being measured ; in the other it is pointed to one object, while an image of the second is thrown on the first by double reflexion from a pair of mirrors. Reflecting instruments are largely employed in nautical surveys, as they can be held by the hand and do not require a rigid support ; but they are very rarely used in land surveys. A description of them will be found under Sextant (vol. xxi. pp. 724-725). They give the angle in the plane in w’hich they are held ; and, whenever this plane is sensibly oblique to the horizon, the angle must be reduced by cal­culation to the plane of the horizon before it can be employed in the work of a land survey. The other instruments give the required horizontal angles, whatever the altitudes of the objects observed.

The circles of angle-measuring instruments are usually divided into 360 equal parts called degrees, and subdivided into spaces ranging downwards from thirty to five minutes of arc, according as the diameter of the circle is increased. Smaller arcs are measured by interpolation between the subdivisions, w’ith the aid of a circle reader which moves with the aligner. All instruments except those of the simplest form are supplied with one or more circle readers and spirit-levels and a telescope ; these important adjuncts, which are common to so many instruments, will therefore be first described, and afterwards the more important instruments which are employed in connexion with survey operations.

Circle readers are of two kinds,—the vernier and the microscope.