angles to it, and of a scale *C* to the plate of the alidade of the hori­zontal circle in a plane parallel to that of the vertical circle. The microscope is

furnished with a diagonal eye­piece, through which the obser­ver looks down on the scale. The scale is divided into 100 equal parts, and is mov­able in its bed­plate through the length of one of these di­visions by one rotation of a mi­crometer screw, with a large head, *D*, the cir­cumference of which is divided into 100 equal parts, each divi­sible into fifths by a vernier. The microscope has a fixed wire in a diaphragm at its eye end, *A,* and, when the tele­scope is set on an object anil the wire is seen between a pair of divisions on the scale, the scale is

moved by the micrometer screw until the nearest division is brought under the wire ; the scale reading corresponding to the horizontal position of the telescope being known, the difference between it and the reading when the telescope is pointing above or below the horizontal plane is the tangent of the arc of elevation or depression, to radius = the perpendicular from the axis of rotation of the tele­scope to the scale. Thus

both the distance and

the height of any point

over which a staff of

known length has been

set up vertically may be

readily determined with

fair accuracy. Let *O* (fig.

9) be the position of the

transit axis of the telescope, *OA* the direction of the telescope when horizontal, and *Oa* the corresponding direction of the micro­scope at right angles to the scale *amn* ; let be a distant point over w’hich the staff *MN* has been set up vertically, and let *m* and *n* be the graduations under the microscope when the tele­scope is pointing to the bottom and top of the staff ; then, since *MN* and *Oa* are known, the horizontal distance *OA* and the height *AM* are determined from the proportions

*OA : oa*

*AM : am } : : MN : mn*

It is essential that the focusing tube of the microscope should always move parallel to the visual axis when different divisions of the scale are being brought into focus, otherwise errors materially exceeding the quantities appreciable by the micrometer may be caused. The linear results thus obtained are satisfactory when the subtense staff is set up at a moderate distance; the instrument has often been used with advantage in localities where measur­ing chains could not be conveniently employed. As an angular instrument it is identical with the ordinary transit theodolite, as will be seen from the figure, which may be referred to as illus­trating the description of that instrument; the foot-screws are represented as resting on a plate such as is usually fixed on the head of a folding tripod stand, their lower extremities, as well as the grooves in which they are placed on the plate, being concealed from view by a capping upper plate, which is clamped over their shoulders to prevent the instrument from falling off the stand.

In any theodolite with a telescope of the ordinary form the height of the pillars must necessarily be somewhat greater than half the length of the telescope if stars in the zenith are to be observed or if the telescope is to be completely rotated on its transit axis ; the higher the pillars the higher the centre of gravity, the less perfect the stability of the instrument when set up for observation, and the greater its weight and cumbersomeness for transport. In Germany and Russia theodolites and transit instruments are sometimes em­

ployed in which the eye end of the telescope tube is removed—a counterpoise to the object end being substituted in its place ; and a prism is inserted at the intersection of the visual axis with the transit axis, so that the rays of light from the object-glass may be reflected through one of the tubes of the transit axis to an eye-piece in the pivot of this tube. In this case the pillars need only be high enough for the counterpoise to pass freely over the plate of the horizontal circle ; but the observer has always to place himself at right angles to the direction of the object he is observing.

The levelling instrument consists of a telescope which carries a long spirit-level parallel to itself and is mounted on a horizontal plate, which is fixed rigidly either on the head of a vertical axis revolving within a socket in the centre of the pedestal or on that of a hollow cone revolving round a vertical axis which projects upwards from the pedestal. There are various forms of the instru­ment ; in the Y-level the telescope rests on a pair of Y’s, in w’hich it can be both rotated and turned end for end ; in the dumpy level the telescope is rigidly attached to its supports, and its tube is made shorter and of greater diameter, to carry an object-glass of shorter focal length and larger aperture. A magnetic compass is attached to the instrument to enable the bearings of the levelling staves to be taken whenever desired. Levelling staves are of a variety of patterns and are graduated in various ways, best on both faces and dissimilarly, for a check on accidental errors of reading, as indicated in sect. III.

Reflecting levels are portable instruments which may be held by the hand for rough and rapid survey work. They are of two forms : in one an image of the eye of the observer, in the other an image of the bubble of a spirit-level, is seen by reflexion on a level with the observed object. The first consists of a square of common looking-glass, which is set in a frame suspended from a ring on the line of prolongation of one of the diagonals in such a manner as to swing freely but not turn round on its axis of suspension ; the frame is weighted by a metal plate behind, to which it is so adjusted that, when suspended, the plane of the surface of the mirror will be vertical. A small portion of the glass at one end of the horizontal diagonal is either cut away or unsilvered. When the image of the observer’s eye is seen on the diagonal, all objects bisected by the diagonal, whether viewed through the opening in the mirror or by reflexion, are on the level of the eye. The second consists of a tube open at the object end and closed at the eye end by a disk w’hich is perforated w’ith a sight hole ; a mirror filling up half the section is fixed in the tube, facing the eye end at an angle of 45° with the axis ; and an all-round transparent spirit-level is mounted over an opening above the mirror, and its bubble is seen by reflexion in the axis of the tube. Abney’s level is of the latter construction, but w’ith the spirit-level attached to the alidade of a graduated arc fixed to one side of the (rectangular) tube ; thus vertical angles as well as levels may be determined w’ith it.

The optical square is a reflecting instrument indicating a right angle, and is of great use in laying off perpendiculars for the measurement of offsets from a line of survey. It consists of two glass plates, one wholly the other partially silvered, W’hich are fixed permanently in a shallow circular box at an angle of 45°, so that any two objects seen together through a sight hole in the box- one directly through the transparent portion, the other by reflexion in the mirror of the partially silvered glass plate — subtend an angle of 90° at the point W’here the observer is standing.

*Blotting and Plot-measuring Instruments.—*These comprise linear scales, common compasses, and angular protractors for laying off distances and angles measured on the ground, proportional com­passes and pantagraphs for reproducing a finished plot on some other scale, and opisometers and planimeter for measuring plotted lines and areas.

Scales are divided, cither decimally or fractionally, into equal parts, each of w’hich is a portion of a fixed unit of length, as a foot or an inch ; some are subdivided more or less minutely through­out their entire length between a pair of parallel lines ; others are subdivided at their extremities only. Diagonal scales are formed by eleven equidistant parallel lines, the outer ones of which are divided primarily and subdivided into tenths at their extremities. The primary divisions are joined by cross lines perpendicular to the eleven parallel lines ; the end subdivisions are joined diagon­ally, the first on the lower line with the second on the upper, and so on, each diagonal cutting every horizontal line in a point a tenth of a subdivision beyond the cutting point on the parallel line below, as measured from any one of the perpendicular lines ; and each of these tenths is further divisible into tenths by measuring from the perpendicular at intervals of tenths between the parallel lines ; thus great precision of measurement is obtained.

The Marquois scale and triangle consist of a scale divided throughout into equal parts more or less minutely and a right-angled triangle of which the hypothenuse is three times the shortest ∣ side. An arrow is drawn perpendicular to the hypothenuse to 1 serve as a pointer to the divisions of the scale. The third side has a bevelled edge for ruling. When the triangle is placed w’ith its hypothenuse against the scale and is moved along it, all lines drawn