The time is usually best determined by measuring the zenith distances of stars situated not far from the prime vertical ; then, the latitude and polar distance being known, the hour angle *P* of the spherical triangle is found by calculation. Time may also be determined by observing the transits of stars over the wires of the tele­scope of a theodolite set up in the meridian.

The longitude may be determined either absolutely, by purely astronomical methods, as by observations of the moon’s motion, or differentially, with the aid of telegraph lines and travelling chronometers. Absolute longitude is the geographer’s great difficulty ; for much time must be devoted to the observations, and much more to their re­duction, when undertaken with the object of fixing the relative positions of the stations of a survey. The obser­vations are of various kinds,—(1) lunar distances, *i.e*., the distance between the moon and the sun or one of the stars given for this purpose in the *Nautical Almanac·,* (2) lunar zenith distances, observed at points of the moon’s path where the conditions are favourable ; (3) lunar transits over the meridian, observed with transits of the moon-culminating stars given in the *Nautical Almanac ;* (4) lunar occultations of stars ; (5) eclipses of the sun and moon ; (6) eclipses of Jupiter’s satellites. The first method requires the employment of a sextant or other reflecting instrument ; the second may be accomplished with either a reflecting instrument or a theodolite ; the third with a theodolite ; for the last three a good astronomical telescope is wanted. The first, when carried out strictly, requires three observers,—one to measure the lunar distance, while the others are measuring the zenith distances of the moon and the star ; but, as the last two are not wanted with great accuracy, the several observations may be taken in succession by one person, and the observed zenith distances afterwards adjusted to the time of the lunar distance.

The effects of errors of observation in these methods are as follows. In (1) an error in time produces the same error in the longitude, and an error of one second of arc in the distance pro­duces two seconds in time in the longitude. In (2) an error of one second in time produces at least thirty seconds of time error in the longitude, and one second of arc in the zenith distance at least two seconds of time in the longitude. In (3) to (6) an error of time pro­duces the same error in the longitude. The first method is pre­ferred by seamen and travellers, who are more expert in the use of the sextant than of the theodolite. The second method is pre­ferred by those who are more familiar with the theodolite, and who are equipped with one of good telescopic power. It gives very good results when the observations are made at the most favourable time, which occurs when the resultant of the moon’s motion in right ascension and in declination lies in the direction of the observer’s zenith ; this time may be readily found by graphical projection on a chart of the heavens.

Differential longitude may be determined chronometri- cally, on land as at sea, by carrying about several well­rated chronometers and comparing their times with the local times deduced from observations of the sun and stars ; or electro-telegraphically, by interchanging signals between two stations connected by a telegraph wire, and ascertain­ing the local times at which the signals are transmitted from and received at each station.

*Hypsometry.—* Determinations of height form a very necessary part of geographical reconnaissance. Whenever triangulation is possible, vertical angles may be measured and the heights ascertained in regular succession. But in a traverse this is scarcely practicable ; breaks of continuity in the verticals are liable to be of frequent occurrence, and then recourse must be had to observations of the pressure and temperature of the atmosphere, or of the temperature of the vapour of boiling water, from either of which fairly correct heights may be deduced differentially under normal atmospheric conditions in settled weather. The instruments employed for this purpose are mercurial and aneroid baro­

meters and boiling-point thermometers; descriptions of them, and the formulæ employed in reducing the observa tions, are given under Barometer (vol. iii. pp. 381-387). Here it is only necessary to add that the date and hour of every barometric observation should be recorded, and the observations referred for reduction to those taken at the same time at one or more of the nearest standard meteoro­logical observatories ; otherwise corrections should be given to the barometer readings for the hour of the day and the month of the year, in order to reduce them as nearly as may be to the local mean altitude of the mercury. The index errors of aneroid barometers, being liable to varia­tions, should be determined from time to time by observa­tions at stations of known altitude, or by comparisons with boiling-point thermometers.

VII. Nautical Surveying.

Nautical surveying has for its object the determination of the configuration of land which is covered and concealed from view by water, more particularly along the foreshore of a coast-line, and wherever navigation is carried on in comparatively shallow waters and a knowledge of the depth of water is of great importance ; it has likewise to lay down the positions of oceanic islands, shoals, and rocks, and generally to delineate whatever land exists imme­diately above or below the surface of the ocean. Its methods differ according as they are performed in or out of sight of land. When in the vicinity of land it is pre­ceded by a survey of the coast-line and a belt of the country beyond, which must be of sufficient breadth to furnish suitable points of reference for the survey opera­tions on the water, and may have to be extended inland to embrace those peaks of distant hill ranges which are prominent objects at sea for the guidance of mariners. This done, the nautical survey is carried on in boats, by taking soundings and determining the positions of the boats by observations to some of the points already fixed on land. The observations are necessarily made with sextants and magnetic compasses only. With the former the angles between conspicuous land-marks are measured, and, as the angle between any two points is half the magnitude of the angle between the same points at the centre of the circle which passes through them and through the boat, the measurement of two angles between three points enables two circles to be drawn on the chart, the intersection of which will generally indicate the position of the boat with sufficient accuracy. Occasionally, however, it happens that the positions of all three points on shore and the boat also lie actually, or very nearly, on the circumference of one and the same circle ; then a bearing taken with the compass will fix the position of the boat on the circumfer­ence of the circle. Time is noted whenever soundings are taken, that due allowance may be made for the rise and fall of the tide. All the sounding stations are not fixed by observations to points on shore, as just indicated, but only a certain proportion, and between them straight lines of sounding are run, with intervals measured either by a patent log, or by time, or by counting the strokes of the oars ; whenever possible the lines of sounding are carried parallel to each other. Sounding is the most important part of a nautical surveyor’s duty and that on which his character mainly depends. It is essentially the work of the sailor, for in carrying it out the accidents of wind and water—the direction and force of the wind, the rise and fall of the tide, and the velocity of currents—must be duly taken cognizance of and the work managed to suit wind and weather ; on the other hand, the work on land may be done by landsmen. Nautical surveying, out of sight of land, rests on astronomical determinations of latitude and time, chronometric longitudes, and dead reckoning by log.