THE PRESENT POSITION OF GEODESY.

THE article by Commandant Bourgeois in the *Revue Générale des Sciences* for April 30, on the present position of geodetic science is both instructive and useful with reference to those problems in geodesy which are just now before the scientific public of this country. There is, in the first place, a notable scheme for the construction of a geodetic arc in Africa which shall extend from the Cape to Cairo. Of this Commandant Bourgeois has taken due note, entering rather fully into the details of such difficulties as its projectors may find in the way of its successful accomplishment. There is also an agitation recently started amongst astronomers and surveyors, which has for its object the revision of the geodetic triangulation of England in order that it may be brought into line, scientifically, with the geodetic triangulation of adjoining countries, and take its place (as it should) as a link in more than one European system of which the value would be largely increased by this extension. Of this Commandant Bourgeois takes no note (probably because he is unaware of its existence), nor does he concern himself with any past achievements in the field of geodesy in which England has borne a part either at home or in India.

The object of the article is to place before the reader the effect of fresh inventions and new methods in developing existing geodetic projects, but it would have added much to the interest of it if so competent an expert as Commandant Bourgeois had written something about the change which has come over the objective of geodetic science which justifies its continued application to modern fields of surveying. These are utilitarian days, and seeing that the science of geodesy long ago evolved all the necessary factors for the reduction of astronomical and terrestrial observations by giving us certain mathematical formulæ based on the measurement and form of the earth, and that no subsequent investigations will ever seriously affect those deductions, it may well be doubted if any State financial assistance would be justifiable for the mere purpose of refining and polishing the results of what would be a purely abstract scientific inquiry. Geodetic arcs measured simply for the purpose of ascertaining the nature of certain eccentricities in the figure of the globe will no longer be regarded as worthy of the saving grace of State financial support, and it will remain for their projectors to prove that some other and more practical end is to be served by them if they wish for substantial recognition.

There is, of course, another (and an insufficiently appreciated) end to be served by such exact scientific processes as are involved in the measurement of a "great arc"; and if we drop the somewhat misleading term "geodetic," and simply appeal to the absolute necessity for a strong initial backbone of first-class triangulation as the basis of every survey scheme of any consequence at all—a backbone which will support the weight of any subsequent superstructure of looser and more rapid forms of triangulation which may be built upon it, and thus give solidity and homogeneity to the whole mapping of a vast area (such as Africa, for instance), we only indicate the same thing under a far more practical and intelligible form. All surveyors are agreed as to the necessity for such an initial backbone, although perhaps opinions may differ as to how far it should be extended. The great value of Commandant Bourgeois's article lies in this—that he shows clearly and concisely how the best possible scientific results may be obtained by means which not long ago were unattainable, and which involve half the expense, with (possibly) double the accuracy of those older methods which cost the country so much in the past, and (in the case of England, at least) have not proved satisfactory in the end.

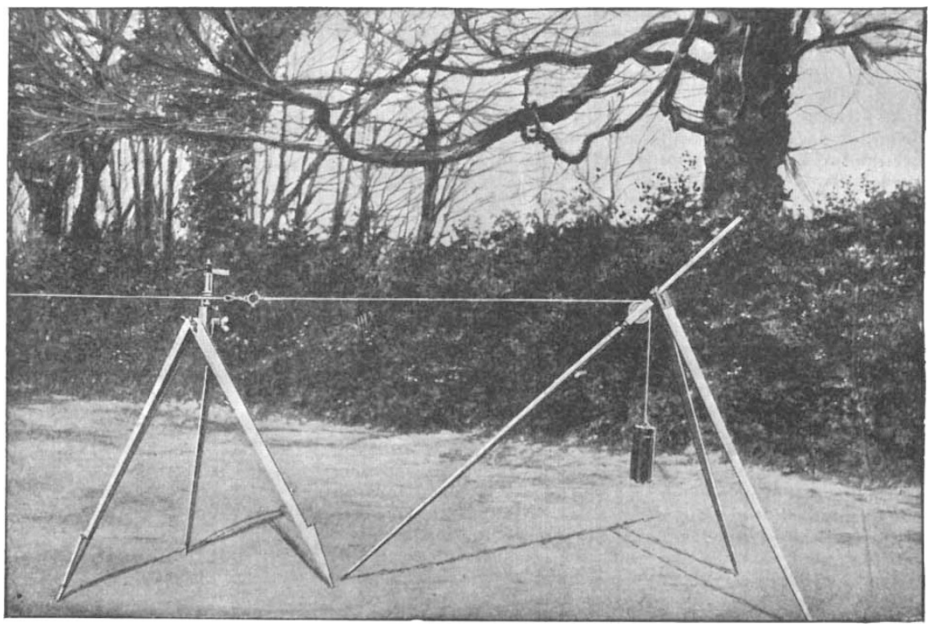

FIG. 1.—Jäderin apparatus placed in position for base measurement.

The Jäderin apparatus for base measurements, and the application of the French metal "invar" (an amalgam of 64 steel to 36 nickel) to it, is perhaps the most important of all recent improvements in the process of constructing a primary, or "first-class," triangulation. The old, clumsy, and inconvenient method of measurement by compensation bars has, we hope, disappeared for ever. The Jäderin tape has been exhaustively tested under other conditions than those mentioned by Commandant Bourgeois, and it has been found to stand the test of extremes of climate quite sufficiently well. The author indeed advocates its use for the measurement of long bases in supersession of the system of extension by triangulation from a short one. The rapidity and accuracy with which this method can be applied to the base measurements connected with a long series of principal triangulation is instanced in the case of the North American meridional arc, which has been measured on the 98th degree of west longitude. In this instance nine bases were measured in one field-season

lasting six months. Five tapes were made use of, all five being tested over one kilometre of distance to determine their relative equations. These may be expressed by 1/690,000 maximum and 1/1,200,000 minimum of probable error. Altogether more than 69 kilometres of base measurement were effected at a cost of 160 dollars per kilo. Commandant Bourgeois maintains that the limits of probable error in linear measurement are in satisfactory relation to the limits of probable error in the angular measurements of the instrument used for triangulation. But he does not fully describe the latter. One of the essential features in modern principal triangulation is the employment of instruments of half the size and about one quarter the weight of those which were deemed necessary twenty-five years ago. Improvements in graduation and, above all, the introduction of the micrometer eye-piece have so far added to the accuracy of modern theodolites that a 12-inch instrument in India now takes the place of the 24-inch

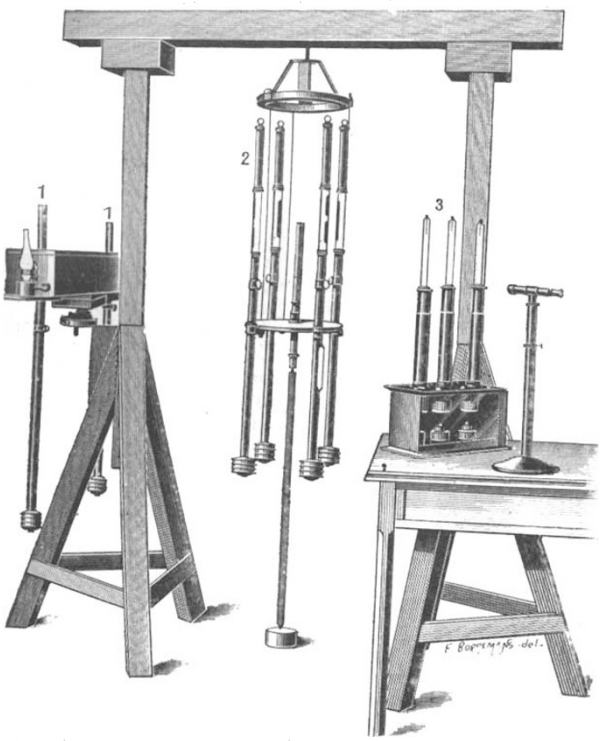

FIG. 2.—Apparatus of M. Hecker for measuring the intensity of gravity in the open sea by comparison of the readings of the barometer (1 and 2) and hypsometer (3).

and 36-inch instruments formerly used. Surveyors will probably have their own opinions as to the methods of observation indicated by Commandant Bourgeois. The German method approved by him, and adopted in France, appears to contemplate certain irregularities in the signals for observation which ought not to exist. It will probably be found that the system of observing should be adapted to the atmospheric peculiarities of the district in which the observations are taken. But the German method is well worth the careful attention of English surveyors.

That part of the article which deals with the deflection of the plumb line and the intensity of the force of gravity, has a most interesting reference to M. Hecker's apparatus for investigating these problems in ocean spaces by means of a comparison between barometric and hypsometric observations; the general result of such observations taken in the Atlantic between Bahia and Lisbon being to prove that there is no great variation between the results determined in the deep sea and on the Continent. M. Hecker is still engaged in this branch of geodetic inquiry.

The reference to the African are now contemplated, and to an equatorial arc recently measured by French scientists in the Republic of Equador in South America, should be studied together, for the experience obtained in the latter points some useful morals for the consideration of those who may undertake the measurement of the former. The physical conditions of the country and the variations of an unusually tempestuous season presented but small obstruction to the progress of the work compared to the hostility of the indigenous Indians. Stations were destroyed and markstones uprooted with such persistent animosity in Equador that a great part of the observations had to be repeated. If principal, or geodetic, triangulation is to serve the purpose of scientific investigation only, the destruction of the observing stations would not be of so much consequence, when once the chain of triangles composing the arc was finally complete. But it is obvious that if any useful ulterior purpose of map-making is to be served by the expensive process of laying down a backbone of well-fixed points, it is all important that every station and every markstone should be preserved with the utmost care. In spite of most elaborate precautions these most necessary indications are sometimes lost in India, and fresh observations have to be made in order to redetermine their position. Isolation of the instrument during the process of observing is almost always imperative, although it occasionally happens that a considerable area of hard rock exists of sufficient stability to serve as the basis of the observing station without involving any artificial isolation. But the building of isolating pillars and the erection of cairns over them for protection almost inevitably attracts the attention of the tribespeople in the neighbourhood, and the result is subsequent destruction.

The only way to safeguard with any prospect of success against the utter waste of time and money which is involved by the destruction of signals and markstones, after the triangulation has been effected with scientific precision and rigorous methods of observation, is to fix, *pari passu* with the principal triangulation, a large number of secondary points scattered over the face of the country, consisting of natural features which it is impossible to remove, or for Indians to identify. It cannot but happen that principal triangulation carried through an arc of 65° of amplitude in such a country as Africa will involve a great deal of native hostility, and its preservation finally will be almost an impossibility. It will be most necessary, therefore, to take all classes of observations that have eventually to be taken from any one station at one and the same time of occupation. It may indeed be an open question whether one or two short principal series from the coast westward, following, say, the Zambesi and the Uganda Railway to the meridian of 30° E., would not sufficiently answer the utilitarian purposes of a basis for African surveys were they connected by secondary or even tertiary triangulation at their extremities, and the connection pushed northward to meet a third principal series on the Nile. This, however, is but a side issue prompted by the perusal of the admirable article in the *Revue Générale des Sciences*.

One especially interesting result of the observations for level deflection taken in connection with the Equador arc, is an indication that the compensation of exterior mass by interior deficiency, or want of density, indicated by such observations at certain Himalayan stations, does not exist in the equatorial region of the Andes. T. H. H.