Mechanical equinoctial dial by Wm. Deane of London, c. 1690 (from *Sundials*, by F. W. Cousins, p. 65). (Photo by courtesy of the National Maritime Museum.)

two chief classes of such sundials—compass and altitude dials—nor does he draw attention to the defects of altitude dials, and he omits any description of ring, disk and quadrant dials. His historical series starts with the dial of Ahaz of about 700 BC and he omits the important Egyptian dials of about 1500 and 900 BC in the Berlin Museum. A minor point of criticism is that in dealing with the Equation of Time on page 74 he makes no attempt to dissect this into its two principal harmonic components. The only specific errors I wish to quote are the name of Hepslow for Henslow at the top of page 74, and in the photograph of a proposed Noon Mark on page 203, where the lower XI should be IX, and the month-end dots in the same region have a strange spacing.

Summing up, the book (apart from the blemishes I have mentioned) is an excellent compendium, attractively presented, of essential facts and figures relating to the theory and practice of the construction of sundials; and the fact that three alternative methods of layout are given for most of the principal types of dial should make it useful to a wide range of potential users. F. A. B. WARD

LANDMARK IN GEODESY

Mathematical Geodesy

By Martin Hotine. (ESSA Monograph No. 2.) Pp. xvi+416. (US Department of Commerce, Environmental Science Services Administration: Washington, DC, October 1969.) $5.50.

THIS book is indeed a new book on geodesy in that it treats the whole subject from a completely new standpoint and with the powerful technique of tensor calculus which is also completely new to most geodesists. The basic premise is that all geodetic measurements and concepts can be expressed as geometrical properties of a three-dimensional manifold, and a Euclidean metric suffices. Tensor calculus then enables geodetic and physical properties to be expressed in general form, particularly those which are invariant with the coordinate system, and they may be transformed very simply from one system to another.

The following illustrates the power of Hotine's use of tensor calculus. It is shown that the geometry of the Newtonian gravitational field can be treated as a special case of a (ω, φ, N) coordinate system, in which ω is longitude, φ latitude and N potential. Using Fermat's principle of least action, a light ray becomes a geodesic of the curved space obtained by conformally transforming the space in question to a curved space with scale factor n, the index of refraction. The whole of the theory of dynamic satellite geodesy is derived from Newton's second law of motion, which is first expressed in a general coordinate system. Then, although the whole concept of least action is Newtonian and the equations of motion referred to accelerating (rotating) axes are not Newtonian, the geodesic principle, the principle of least action and Newton's second law of motion are all shown to be equivalent.

Parts one and two of the book explain tensor notation and discuss the geometric properties of three-space expressed in this notation. Part one derives, or indicates the derivation of, formulae which will be used later. Part two derives coordinate systems of special interest in geodesy, and transformations between them, from a general class of three-dimensional systems. Part three applies the results of the first two to geodetic problems —to atmospheric refraction, computation and adjustment of control frameworks, potential and gravity anomalies, and to geometric and dynamic satellite geodesy. Finally, there is an index of symbols and a complete summary of formulae.

I disagree with some of the strictures made on current "classical" geodetic theory, in particular those on the classical use of the Laplace azimuth equation (paragraphs 14 and 15 of chapter 19). The tenor of the book could be considered to be given by the opening sentence of the preface: "This book is an attempt to free geodesy from its centuries-long bondage in two dimensions". When one comes to chapter 26, entitled "Internal Adjustment of Networks", it is, however, stated that, in adjustment by the widely used method of "Variation of Coordinates", the β (geodetic zenith distance) equations should properly be given less weight than the α (geodetic azimuth) equations because of uncertainties in angular refraction and, as their interaction is so limited, "the two sets of equations might be solved separately". This is indeed what is done in "classical" theory and practice, for the very reasons stated. Recent research, however, gives hope that it may soon be possible to measure angular refraction in the field with relatively simple field equipment to an accuracy commensurate with other measurements. When this day dawns, geodesy will indeed be freed from "its centuries-long bondage in two dimensions".

The real tenor of the book, however, is the unification of the whole of geodetic theory with complete mathematical rigour and elegance. In concept and in execution it is a beautiful piece of work and a fitting finale to the lifetime's work of the author. It is indeed a book which appears once in a generation and it is tragic that the author did not live to see the fruits of his labours. A. R. ROBBINS

STRUCTURES REVEALED

Methods for the Study of Sedimentary Structures

By Arnold H. Bouma. Pp. xvi+458. (Wiley (Interscience): New York and London, October 1969.) 190*s*.

THE interest shown by geologists in sedimentary structure has fluctuated over the years. Sir Charles Lyell and James Hall, working early in the past century, gave for the first time detailed descriptions of many structures, and Henry Clifton Sorby, in the 1850s, showed how such structures as ripple marks and cross-bedding could be understood physically and used for environmental interpretation.