lavas of the plateaux which are more or less metamorphosed around them, and are traversed by a fringe of finer-grained sills and veins of dolerite, gabbro, troctolite, picrite, &c., which have often insinuated themselves between the sheets of the plateau-basalts. The coarse-grained and banded gabbros may have consolidated at some depth; at least nothing is yet certainly known of their superficial equivalents.

The third stage of activity, probably long posterior to the second, likewise furnishes no evidence of any superficial ejection. It is recorded by a series of markedly acid rocks—obsidians, felsites, rhyolites, porphyries, granophyres, and granites. These rocks form huge conical hills, which in outward aspect recall the trachytic Puys of Auvergne. They traverse alike the plateau-basalts and the bosses of gabbro, into which they send many dykes and veins. They also project numerous thick sills into the formations lying underneath. The rocks around these acid protrusions have been greatly metamorphosed, while the granophyres and granites have in turn undergone considerable change in composition from having caught up and assimilated sometimes a fourth of their bulk of basalt or gabbro.

After the uprise of the granophyres with their surrounding network of felsitic dykes and veins, a new ascent of basic material manifested itself, recalling that of the earliest basalt-dykes, but on a minor scale. The dykes then formed cut all the other members of the volcanic series, including the granophyres. No trace remains of any superficial discharges connected with these latest dykes. If they ever gave rise to outflows of lava, these have long since disappeared in the vast denudation which the Tertiary volcanic rocks have undergone.

The latest eruptions of North-Western Europe, forming the Tertiary volcanic series, are shown by Sir Archibald Geikie to have far exceeded in area, and possibly also in bulk of material discharged, all the eruptions that had preceded them in the geological record.

We learn further that neither in their forms or products, nor by their extent and vigour, did the volcanic manifestations of the successive ages of the geological past materially differ from those of the present time. There is assuredly no evidence that volcanic energy has gradually waned since the dawn of geological history.

A consideration of the distribution of the volcanic rocks in time shows not only how singularly uniform the course of volcanic activity has been, but that there is no evidence of the cessation of any of the broader petrographical types during geological history. Quite as much variety may be observed among the erupted materials of Tertiary time in Britain as among those of the early ages, when the earth was younger and its volcanic vigour might be supposed to have been greater and more varied than it is now.

From the evidence detailed in these volumes, it appears that the sequence from basic to acid discharges was on the whole characteristic of each eruptive period. It is obvious however, the author observes, that as the protrusions of successive periods took place within the same limited geographical area, the internal magma during the interval between two such periods must in some way have been renewed as regards its constitution, for when, after long quiescence, eruptions began once more, basic lavas appeared first, and were eventually followed by acid kinds.

Various opinions have been propounded as to the cause or causes of the differentiation observable in erupted masses, but none of them are entirely satisfactory. We must await the results of further exploration in the field and of continued research in the laboratory.

What appears to have taken place within a subterranean molten magma which has been propelled into the earth's crust as a boss or laccolite, with or without a connected system of dykes, may possibly be made to throw some light on the remarkable changes in the characters of lavas successively erupted from the same vent during the continuance of a volcanic cycle. Whether or not any such process of differentiation can be proved to take place within a subterranean volcanic reservoir, the sequence of erupted lavas bears a curious resemblance to the order in which the constituents of some large bosses succeed each other from margin to centre (vol. i. p. 92).

Sir Archibald Geikie has written the history of the ancient volcanoes of Britain in a series of attractive chapters, which he has illustrated with more than four hundred sketches, photographs and maps. But the fine work with which he has enriched science is much more than a detailed description of the crystalline rocks of his own country. He elucidates their structure and arrangement, and explains thereby their history. He rises from a consideration of facts to a discussion of the cause of volcanic phenomena. He makes the extinct volcanoes bear their testimony in favour of the uniformity and unity of the laws of nature. His work will remain one of the monuments of our time, establishing for the future the conception of the continuity of volcanic phenomena from the earliest periods, and, so far as the geological records go, demonstrating that the interior of our planet has reacted on its exterior in the same way and with the same results. CHAS. BARROIS.

AMERICAN MATHEMATICS.

Higher Mathematics: a Text-book for Classical and Engineering Colleges. Edited by Mansfield Merriman and Robert S. Woodward. Pp. xi + 576. (New York: John Wiley and Sons. London: Chapman and Hall, Ltd., 1896.)

THIS is a style of mathematical treatise to which we are not accustomed in this country, from the luxury of the print and size of page, as well as for the refreshing novelty and interest of the contents.

Till recently, it was thought that the study of mathematics was not likely to flourish in America, as *trop vieux jeu* by the side of the new physical and biological sciences. To-day, however, it is the American student who is the most enthusiastic follower of recent mathematical development, while we in this country are being left far behind.

The words on the title-page—A Text-book for Classical and Engineering Colleges—the equivalent of our own—For Schools and Colleges—is not, however, taken, as with us, to be the rendering of *In usum Delphini;* all human interest arising from the application of theory has not been carefully eliminated from the pages, as

likely to confuse or excite the mind of the student; on the contrary, the various contributors insert carefully chosen appropriate illustrations as the best means of elucidating the difficulties of the abstract theory. With us the spirit of the schoolmaster is too much abroad in our mathematical writings; it has even been objected that these illustrations tend to obscure a subject, as it were, with the smoke of its own guns: a musty simile in these days of smokeless gunpowder.

Thus, for instance, the solution of a quintic equation is presented as required for the determination of the supply of a water-main (p. 13); very vulgar this, our college professor will say. So, too, the intuitive reasoning of a graphical procedure with an appropriate diagram has been freely employed to replace the tedious and unconvincing procession of formulas which impede the progress of our own students. A mention of M. Félix Lucas's electrical determination of the roots, real and imaginary, might well have found a place here.

Each of the eleven chapters of the book is undertaken by a different writer—Chapter i., on the Solution of Equations, by Mansfield Merriman; and Chapter ii., on Determinants, by Laenas Gifford Weld; both complete and original in their way.

The treatment, in Chapter iii., of Projective Geometry, by George Bruce Halsted, is very bright and stimulating; this is a subject ignored in our own mathematical curriculum.

The two forms of spelling "centre" and "center," appear on the same page (95); the second is, of course, phonetically correct, as the English pronunciation always inverts the liquid and the vowel in the French spelling, here and in all similar words.

Chapter iv. is on Hyperbolic Functions, by James McMahon. Our scholastics look upon this subject as a temporary fad, which has not come to stay; however, electricians find them indispensable, and many elegant electrical applications, among others equally important, of mechanical and astronomical interest, such as catenaries, loxodromes, charts, conjugate functions, will be found collected here.

The long form of these functions, cosh, sinh, tanh, . . . has been retained, with a suggestion that the ugly sounds they suggest should be avoided by pronouncing them *h*-cosine, *h*-sine, *h*-tangent, &c. But the modern continental practice is to abbreviate the symbols to ch, sh, th, pronouncing only the letters *c-h*, *s-h*, *t-h*, as with the Elliptic Functions; so also for their inverse functions, ch^{-1}, sh^{-1}, th^{-1}, employed here, for their obvious advantages in integration. A well-arranged table concludes this chapter; we miss, however, Bernoulli's numbers in their proper place in the expression of tan x, th^x, . . .

Prof. Byerley, of Harvard, contributes Chapter v., on Harmonic Functions. When his genial treatise on Fourier's Series and Harmonic Analysis made its appearance, some four years ago, it was welcomed by all physicists as the long-desired manual, which placed this subject before them in an intelligible manner, devoid of artificial obstacles and impediments. Unfortunately the treatise fell into the hands of mathematical critics, who could see little merit in the book, because it passed over in silence the tedious, and useless, arguments concerning the legitimacy of the expansions. If an electrician is to employ a Fourier Series, he will content himself with the first two or three terms of the series; just as the calculator of mathematical tables will not, for practical purposes, employ more than three, or four terms at most, in Taylor's Series. But where the applicability becomes doubtful, by reason of the neighbourhood of a discontinuity, he will assure himself, by a diagram such as those on p. 199, of the limits of the divergence.

These difficulties concerning the discontinuity of functions is very properly relegated to another chapter, number vii., on Functions of Complex Variables, by Thomas S. Fiske, which gives us a very clear account of the most recent manner, of the school of Weierstrass, of approaching such refinements of argument. We are pleased to find the name "one-valued function" instead of "uniform function," which is misleading to the beginner.

Prof. Woolsey Johnson, of the U.S. Naval Academy, contributes Chapter vii., on Differential Equations. His own formal treatise on the subject is well known and highly popular; and the present chapter incorporates the essential, or what Maxwell called the "gentlemanly," knowledge of the subject.

The next two chapters—Chapter viii., on Grassmann's Space Analysis, by Edward W. Hyde, and Chapter ix., on Vector Analysis and Quaternions, by Alexander Macfarlane—seem to us by comparison to be of the nature of luxuries, appealing to the purely analytical spirit; although even here electrical applications are introduced to show how the theories may be usefully applied.

Chapter x. is a short and useful *résumé*, by R. S. Woodward, of the principal parts of Probability and the Method of Least Squares, with which every physical student should now be familiar; and the volume concludes with Chapter xi., on the History of Modern Mathematics, by David Eugene Smith, in which the author is compelled to apologise for the incompleteness imposed upon him by the exigencies of room, but which, nevertheless, provides the most important details required for reference.

The account given by the Editors, in the preface, of the work expected of the average American student, shows that the standard of requirement is much higher than in this country, and not hampered by traditional prejudice.

A. G. GREENHILL.

OSTEOLOGY.

The Vertebrate Skeleton. By Sidney H. Reynolds, M.A. Pp. xvi + 559. (Cambridge: University Press, 1897.)

THIS most recent addition to the Biological Series of the Cambridge Natural Science Manuals edited by Mr. A. E. Shipley, is an attractive-looking volume, well printed, and with the monotony of the text agreeably broken by a judicious use of small capitals, italics, and clarendon type. The numerous illustrations, which are probably accountable for the high price (12*s.* 6*d.*) of the book, though simple in execution are clear in detail, and, on the whole, chosen with discretion. The majority of the figures have not been published before, and are based on specimens contained in the Cambridge University Museum and the Natural History Museum, London. The text is remarkably free from typographical errors, but is frequently bald in style and irritating from