ture, humidity, cloudiness, and wind. The trade wind, limited to about 1000 metres in thickness, varies in direction between north and east, is damp, and usually carries cumulus or strato-cumulus clouds in its upper portion. Above the surface trade is a current about 2000 metres in depth, varying in direction between north-east and north-west, but coming always from a direction to the left of the lower wind when facing it. This current is extremely dry and potentially warm, and its velocity is usually much greater than that of the lower wind. At their plane of meeting occurs a belt of calms or light winds with a marked inversion of temperature, and this rise of temperature is

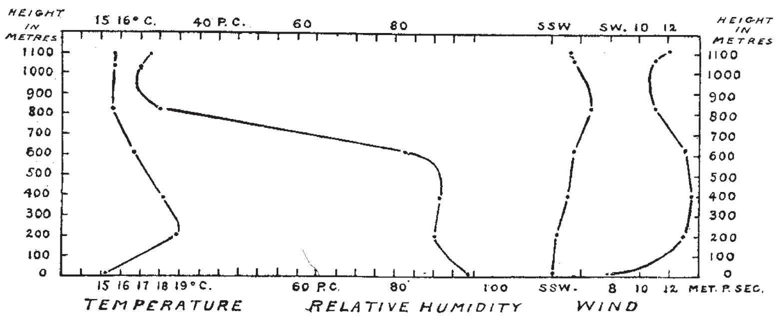

FIG. 1.—Vertical Distribution of Temperature, Humidity and Wind, June 6, 1905; Lat. 40° 33′ N., Long. 46° 43′ W.

accompanied by a very decided fall of humidity, the relative humidity in some cases falling to nearly zero. The third stratum, which begins at a height of about 3000 metres, moves from a direction varying between east and south or south-west, being generally from the east in equatorial regions and from the south between latitudes 15° and 30° N. As observed on the Peak of Teneriffe, this stratum was dry in its lower portion, but had a slightly larger vapour contents than the air immediately below. Alto-cumulus and alto-stratus clouds were seen floating in it at a height of perhaps 4000 metres or 5000 metres, and from them light sprinkles of rain fell occasionally. In passing into this upper current a rise of temperature was noted, but this was less marked than

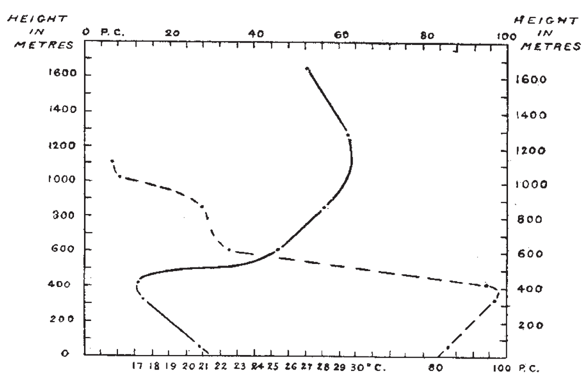

FIG 2.—Vertical Distribution of Temperature and Humidity, July 12, 1905; Lat. 27° 30′ N., Long. 16° 48′ W.

the rise encountered above the surface trade. Mr. Clayton also deduces the following facts from the observations:—(1) the bases of the cumulus clouds are low over the ocean, rarely exceeding 500 metres; (2) the height of the inverted temperature gradient varies from day to day between 300 metres and 1500 metres, with a probable average of 1000 metres, and its height also appears to undergo a diurnal change, being lowest at night or in the morning and highest in the afternoon; (3) the adiabatic rate of decrease of temperature prevails over the ocean at night as well as during the day.

The vertical distribution of temperature and humidity revealed by our observations up to a height of 4000 metres agrees in general with that found by Prof. Hergesell during the cruises of the Prince of Monaco's yacht in 1904 and 1905 (see *Comptes rendus de l'Académie des Sciences,* January 30, 1905, and *Bulletin du Musée Océanographique de Monaco,* November 30, 1905). From the latter publication it is interesting to learn that a balloon, liberated by Prof. Hergesell on August 7 last far to the westward of the Canary Islands, indicated the same currents which were found by us in the neighbourhood of these islands, since it met the south-east and south-west winds above the north-east trade. It is significant that this balloon reached a greater height than did the other balloons, which showed winds having a northerly component. We perceive that Prof. Hergesell no longer denies the possibility of an upper anti-trade in a lower latitude than the Canaries, but now simply states that in the central part of the Atlantic he found almost exclusively north-west winds, from which he concludes that the route followed by the currents bringing the air from the equator appears to be less simple than had been supposed, and seems to depend on the relative positions of the continents and oceans. The study of the daily isobars over the ocean, which was first made under the direction of Le Verrier in 1864, showed that the pressure is not distributed in uniform belts, and that the isobars are everywhere deflected by the influence of temperature distribution dependent upon the land and sea, relations which were demonstrated by M. Teisserenc de Bort's study of isonormals more than twenty years ago. Hence it would appear that there are certain regions where the anti-trade is more regular than elsewhere, the zone between the Cape Verde and Canary Islands being no doubt one of these; but this view is quite contrary to the idea that the south-east and south-west winds observed in the upper atmosphere near these islands, and hitherto accepted as proof of the anti-trade, are due to local influences, which Prof. Hergesell still affirms to be true.

A. L. ROTCH.
L. TEISSERENC DE BORT.

THE TRANSFORMATIONS OF ROCK-MASSES.[1]

THE study of the changes which rock-masses undergo under natural conditions is in itself by no means an inconsiderable branch of geology, and its pervading importance throughout the whole field of the science brings it continually to the front in stratigraphical as well as petrological research. The literature of the subject is a large one, but until now no serious attempt has been made to deal fully and comprehensively with the principles and phenomena of metamorphism as a whole. Prof. van Hise's wide experience in the Lake Superior region and elsewhere has made him well fitted for a task to which he has devoted seven years of labour; and the outcome of that labour, as represented in the massive volume before us, will have a permanent value for all who come after him in this field.

This treatise, as we are told in the preface, is "an attempt to reduce the phenomena of metamorphism to order under the principles of physics and chemistry, or, more simply, under the laws of energy." Metamorphism is understood to include all alterations of all rocks by all processes. This extension of customary usage may be defended on logical grounds, and it has the advantage of constantly keeping in view the essential unity underlying the complex operations of nature; but it involves a corresponding enlargement of the subject-matter. The scrupulous—almost relentless—manner in which the author follows out in every detail the general scheme of treatment laid down further swells the bulk of the volume, and, brought out in the handsome style which characterises the produc-

1 "A Treatise on Metamorphism." By Charles Richard van Hise. (Monographs of the U.S. Geological Survey, vol. xlvii.) Pp. 1286 and 13 plates. (Washington, 1904.)

tions of the Survey, it is physically not an easy book to handle.

In the first chapter a general discussion leads to the conclusion that the most important factor in metamorphism is the depth of the rocks below the surface. In the upper zone of the earth's crust the chemical changes are such as result in the production of simpler compounds from more complex ones, while in the deeper part the reverse is the case. The starting point of the author's treatment is this antithesis between the upper zone of *catamorphism* and the lower zone of *anamorphism.* It appears to us that, while the broad rule here laid down is doubtless of significance, it has scarcely sufficient precision to serve as a basis of classification. The productions of muscovite from orthoclase, and of natrolite from albite, are, according to this geological distinction, catamorphic changes, but it cannot be said that they result in the formation of simpler from more complex compounds.

The second chapter deals with the forces of metamorphism, and the third with the agents of metamorphism, *i.e.* especially gaseous and aqueous solutions. This involves a *résumé* of the principles of physical chemistry, so far as they are applicable to the subject. Although somewhat handicapped by the author's scepticism concerning the doctrine of electrolytic dissociation, this summary will be very useful to students of geology. Chapter iv. treats of the characteristics of the two zones of metamorphism. The law is found to be that in the zone of catamorphism the alterations are attended by liberation of heat and expansion of volume; in the zone of anamorphism by absorption of heat and diminution of volume. The zone of catamorphism is divided into the belt of weathering, lying above the level of underground water, and the belt of cementation, lying below that level; and the geological processes characteristic of these two belts are contrasted.

Chapter v., which might perhaps have been abridged without impairing the value of the book, considers the actual alterations undergone in nature by each of the rock-forming minerals. The chemical reactions are illustrated by equations, and the percentage increase or decrease of volume is calculated in each case. The precise application of these calculations is perhaps debatable, since special assumptions have to be made regarding such gaseous and soluble substances as take part in the reactions, and in some cases the equations themselves are rather conjectural. The next three chapters are an analysis of the processes of change in the belt of weathering, the belt of cementation, and the zone of anamorphism respectively. Under the last head the most important discussion is that relative to secondary gneissic and schistose structures. The author concludes that "Rock-flow is mainly accomplished through continuous solution and deposition, that is, by re-crystallisation of the rocks through the agency of the contained water. But rock-flow is partly accomplished by direct mechanical strains." The ninth chapter deals with the phenomena of metamorphism of individual rocks, and with this the systematic treatment of the subject ends; but there remain some interesting chapters applying the principles enunciated in this treatment to certain other branches of geology.

Chapter x. discusses the difficulties which metamorphism often introduces into stratigraphical investigation and the manner in which these difficulties may be overcome. The next chapter, which is the most novel part of the book, has for its subject the relations of metamorphism to the distribution of the chemical elements. It is shown that, as compared with the parent igneous rock-masses, most sedimentary rocks become impoverished in certain elements, which are thus segregated in particular deposits. Some of the numerical results are of a surprising kind. Thus, it is calculated that to oxidise the ferrous iron of the original rocks to the ferric state, in which most of it occurs in the sediments, required 35 per cent. of the oxygen now in the atmosphere. To oxidise the sulphur and iron of iron-sulphides to produce the sulphates of the ocean and gypsum deposits, with concurrent transformation of the iron to the ferric form, required one and a half times the oxygen now in the atmosphere. The final chapter, occupying no less than 240 pages, might perhaps have been deemed sufficiently complete in itself for separate publication. It is practically a treatise on the principles of ore-deposition. The subject is one upon which much divergence of opinion is still found. Prof. van Hise, as is well known from his former writings, has devoted long study to it, and the complete exposition which he now offers will be read with general interest. From his point of view, the majority of ore-deposits have been produced by metamorphism, in the broad sense of the term already defined, and it results that the theory of their genesis consists mainly in bringing the phenomena which they exhibit under the general principles of metamorphism. The conclusion is reached that in many cases the ores have resulted from repeated segregations of the kind considered in the preceding chapter.

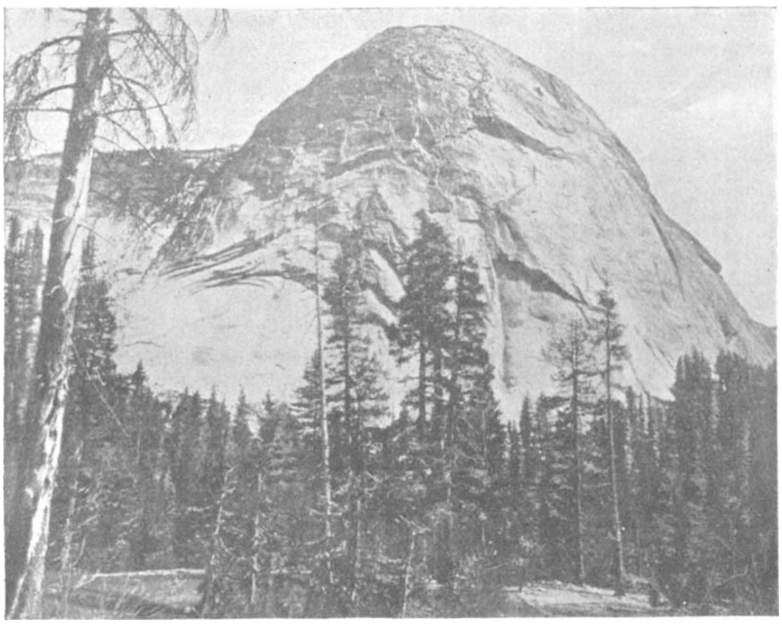

FIG. 1.—Fairview Dome, Sierra Nevada, from the north; illustrating the manner in which granite scales parallel to the periphery as a result of expansion and contraction due to changes of temperature.

It is impossible to study Prof. van Hise's work without admiring the boldness of his design and the skill with which it is carried out, and being grateful for the stores of carefully arranged information which he has brought together. We must readily admit, too, that he has done good service in insisting upon the necessity for the geologist to familiarise himself with the recent progress of physical chemistry, a knowledge of which, as van 't Hoff and others have shown, is a pre-requisite for attacking many of the most pressing problems of geology. Granting this, however, we may still be permitted to doubt whether a purely geological subject like metamorphism is most advantageously dealt with in the manner which is appropriate to the exact sciences. In such a formal schematic treatment there is some danger of making it appear that our knowledge of metamorphism is to be deduced from chemical principles instead of depending upon observation. Although the criticism would not be a just one in the present case, we venture to express a wish that the author had chosen to describe the facts first and explain them afterwards, and that he had made freer reference to actual rocks and specified localities.

A. H.