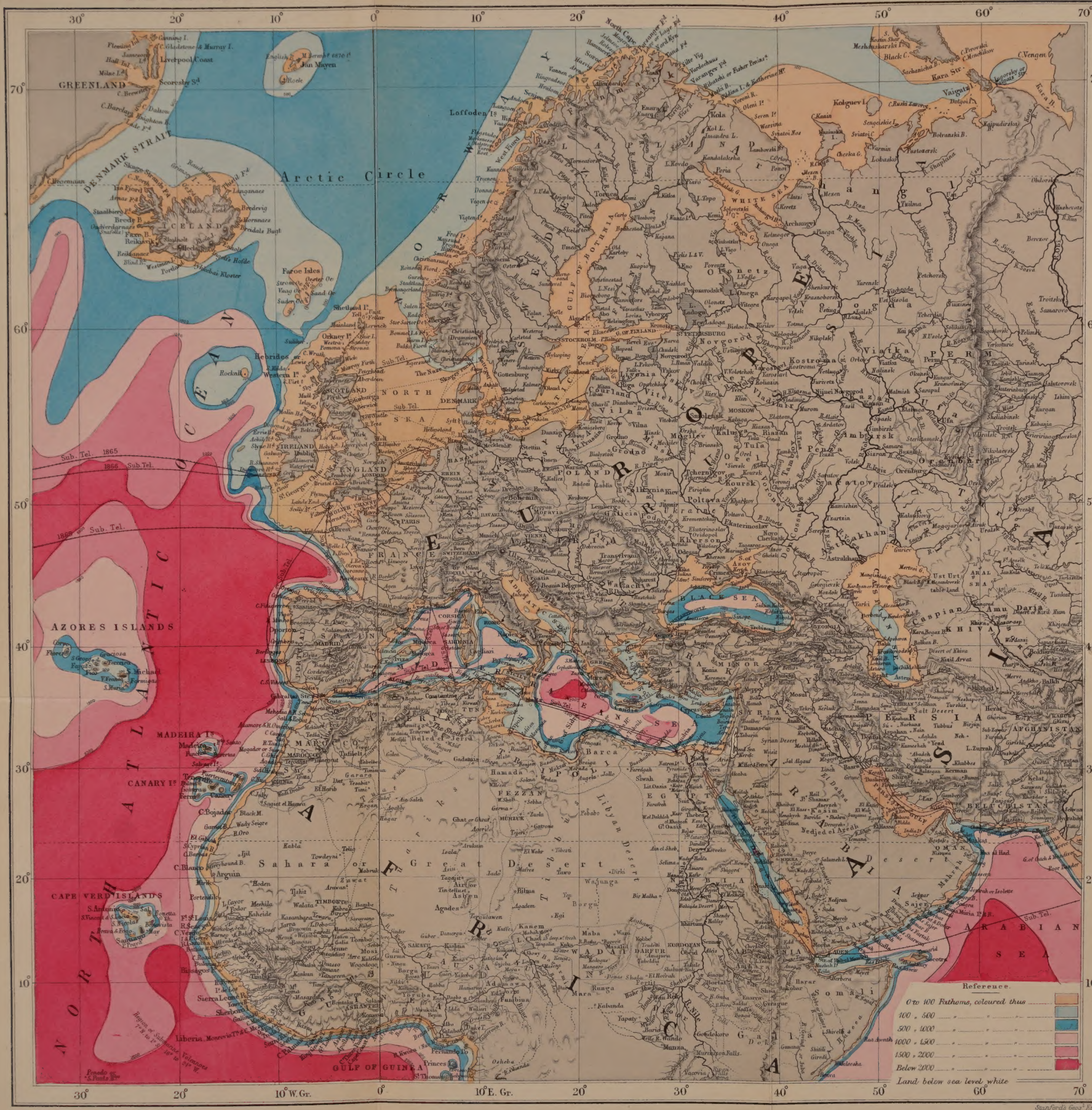
THE FLORA OF ALGERIA

W. MATHEWS, M. A.

MAP SHEWING THE SUBMARINE CONTOURS OF THE SHORES OF EUROPE, NORTH AFRICA & PART OF ASIA.



Stanford's Geog¹ Estab¹

THE FLORA OF ALGERIA,

CONSIDERED IN RELATION TO THE

Physical History of the Mediterranean Region,

AND

SUPPOSED SUBMERGENCE OF THE SAHARA.

BY

WM. MATHEWS, M.A.,

Formerly President of the Alpine Club.

LONDON:
EDWARD STANFORD, 55, CHARING CROSS, S.W.
1880.

The following essay was written in the beginning of the present year, for the Birmingham Philosophical Society. It was read before the Society on the 11th of March and 8th of April, and has just appeared in the second volume of the Society's Transactions. In publishing it in a separate form, the writer has preferred to print the paper as it was read, rather than attempt to alter the phraseology.

October, 1880.

The Flora of Algeria, considered in relation to the Physical History of the Mediterranean Region, and supposed Submergence of the Sahara.

"The student of history follows with intense interest the march of a conqueror or the migrations of a nation. . . . . Yet, absurd as it may seem to those who have not thought of such things before, there is a deeper interest in the march of a periwinkle and the progress of a limpet. It is easier to understand how the son of Philip made his way safely through the sea on his famous march from Phaselis, than to comprehend how the larva of a Patella crossed the fathomless gulf between Finmark and Greenland."

Edward Forbes.

An English traveller who, leaving, at the approach of winter, the leaden skies of his own country, crosses the Mediterranean from the south of France to Algiers, and sets foot for the first time on the soil of Africa, is struck by the novelty of the scenes by which he is surrounded. At the nearest point to western civilisation, he is brought into contact with eastern life, and all its associations. Strange groups of men, Moors in dresses of many colours, stately Arabs in white bernous, Touâregs from the great Desert with strings of camels, veiled women, mosques, from the towers of which the muezzin summons to their prayers the faithful followers of the Prophet, recall visions of the "Arabian Nights," and form pictures of endless interest and variety. If the traveller is a botanist, and turns his eyes from the human to the vegetable world, the sense of strangeness is by no means diminished. Instead of the hawthorn hedges of his own country, or the stone walls of southern France, he finds the enclosures guarded by sharp spears of aloe, or bristling barriers of prickly pear. When he quitted England, the flowering plants had already entered on their winter sleep. But in the lowland regions of North Africa the summer is the season of repose, the winter of rejuvenescence. After the scorching heats of summer, many species, revived by the first rains of autumn, are, in the month of November, already bursting into flower. Behind the city, up the hill side of the Sahel, are steep and narrow paved lanes, trodden by many generations of Moors and Romans, and perhaps still earlier races. Ancient olives, almost as old as the lanes themselves, frame them on both sides and, arching overhead, form a welcome shelter from the sun. A species of clematis *(C. cirrhosa L.)* festoons the olives from tree to tree, and hangs in clusters of wax-like blossoms. Beneath the olives, the banks are gay with flowers, an elegant jonquil, *Narcissus oxypetalus* of Boissier, and the African cyclamen, with great polygonal marbled leaves, being strikingly beautiful and conspicuous. From the crest of the hill, which commands a noble view of the Lesser Atlas, the lanes lead through rich groves of orange out into the open country, where occasional strips of primæval land that has not yet passed beneath the plough, covered with lentisk and dwarf fan palm, and fringed with thickets of arbutus and arborescent heath, give character to a landscape which when once seen can never be forgotten.

After a few days' experience of the country, the idea of contrast with the vegetable life of Europe is gradually weakened, and at length gives way to a feeling of an opposite nature. The prickly pear and aloe are natives of tropical South America, and are modern importations into Europe. With the exception of the cyclamen, which is nearly related to a European species, all the plants above mentioned occur in some part or other of West Mediterranean Europe. The vegetation, as a whole, reminds the traveller of the shores of Spain, and of the French and Italian Riviera. He sees in his daily walks many species which he has gathered as rarities in the west of England, or on the coasts of the Channel Islands. At last he asks himself— Am I indeed in a new continent, or only in a part of Europe? This question, so far as it admits of an answer from a review of the Algerian Flora, will be considered in the present paper.

I shall not weary you with an account of the various contributions to our knowledge of the Botany of North Africa, from the date of the "Flora Atlantica" of Desfontaines, published in the sixth year of the French Republic, to the present day. Suffice it to say that the most compendious view of the vegetable population of Algeria is afforded by the "Catalogus Plantarum in Algeriâ sponte nascentium," by the late Mr. Giles Munby, of which the second and last edition was published in 1866. In order that the contents of this catalogue may be intelligible, it will be useful to give, by way of preface, a short description of the physical structure of the country.

The French colony of Algeria, which was first conquered in 1830, but not completely subdued and occupied until the surrender of Abd-el-Kader in December, 1847, extends along the southern side of the Mediterranean from the border of Marocco to that of Tunis. Its length from west to east is about 620 miles, its breadth from north to south about 250. Its area is usually taken at 150,000 square miles, or three-fourths of that of France. This area is approximate only, as the country has no natural limit on the south, and the boundary varies from time to time according to the distance to which it is convenient to the French authorities to extend their rule over the tribes of the Great Desert. The region thus defined is naturally divisible into three strips or zones, roughly parallel to the coast of the Mediterranean, the Tell, the Hauts Plateaux, and the Sahara. The Tell, or cultivated country, extends from the sea, inland, to a distance of from 50 to 100 miles. It is traversed from west to east by the range of the Lesser Atlas, which rises at many points to a height of 5,000 feet, and occasionally to 6,500. Beyond the Tell are the Hauts

Plateaux, an undulating tract of steppe land devoid of trees, but covered with stunted brushwood. Its width, from the edge of the Tell to that of the Sahara, is about 100 miles. It rises from the southern foot of the Atlas, in terraces parallel to the Tell, the highest of which is about 3,000 feet above the sea. The principal watershed of Algeria is the crest of the Hauts Plateaux. South of this line the streams flow towards the Sahara, where they discharge themselves into a series of salt-water lakes, known as Chotts or Sebkas, a few of which are slightly below the level of the Mediterranean. Some of these Chotts are enclosed among the terraces of the Hauts Plateaux. A large part of the northern slope of the Hauts Plateaux is drained by the Chelif, the largest river in Algeria, which runs from the watershed northward to Boghar, where it crosses the Atlas through a gap in the chain, and then flows eastward to the Mediterranean. During heavy rains the Chelif and other Algerian rivers roll down vast volumes of water, but in ordinary times they present the appearance of deep valleys of erosion, with insignificant rivulets trickling along the bottom. There are two important groups of mountains in Algeria, lying off the main range of the Lesser Atlas, and considerably surpassing it in height. These are the Djur-jura range, in the Kabyle country, (7,542ft.,) and the range of the Aurès, (7,611ft.,) in the region of the Hauts Plateaux. The latter is the highest group in Algeria, and may perhaps be regarded as an outlier of the greater, or Maroccan Atlas. The country is divided for administrative purposes into three provinces—Oran, Algiers, and Constantine, which cross the natural divisions at right angles, so that each includes a portion of the Tell, Hauts Plateaux, and Sahara.

My personal knowledge of Algeria (so far as it extends) was gained in the autumn and winter of 1876, when I spent ten weeks in the country, travelling about fifty miles inland to the great cedar forest on the crest of the Atlas at Teniet el-Haad; and subsequently as far as Cherchel, a town situated on the coast, about the same distance from Algiers on the west. I was unable to penetrate into the interior any further than Teniet, or to see the vegetation in its full beauty in the months of February, March, and April.

The botanical regions adopted by Munby do not exactly correspond with those above described. He divides the country into the Littoral region, Hauts Plateaux, Atlantic region, and Sahara, extending the term "Hauts Plateaux" so as to include both sides of the Atlas, and referring to the Atlantic region the higher portion of the mountain chains. It must be remembered that the term "Atlantic," used in connection with North African botany, refers exclusively to the Atlas Mountains, and has no reference to the Atlantic Ocean. It is to be regretted that Munby has not given a complete list of the plants of each region; he has only noted the species that are peculiar to any one or two of them.

2,964 species of Phanerogams and vascular Cryptogams are included in the Algerian catalogue. Since the date of its publication the census has been somewhat increased, but as the additional plants are too few to affect our conclusions, and information respecting them is not easily accessible, I have not thought it worth while to include them in the enquiry. On the other hand, the tendency of modern botanists, especially those of the French school, is to an excessive subdivision of species. Many of the plants enumerated by Munby as distinct species would be regarded by most English botanists as mere varieties of other forms. The opinions of botanists as to the proper limits of specific forms are, however, so divergent, that I have preferred to collate Munby's catalogue as it stands, and to reserve this question until we come to consider what proportion of the North African Flora may be regarded as endemic. Some introduced plants, now more or less naturalised, and a few duplicated species must be omitted. Deducting these, which number thirty-one, from the 2,964, the census is reduced to 2,933. It is the distribution of these plants which we have now to consider.

Few facts in Botanical Geography are more remarkable than the capacity of some forms to spread themselves over large areas, and the restriction of others to spots of very limited extent. It is obvious that plants of the first habit will afford very little information as to the former relations of land and water in the Mediterranean region, and that the first step in the enquiry must be to eliminate from our materials all the species of wide distribution. With this object I have collated the Algerian Flora with the "Summa Vegetabilium Scandinaviæ" of Fries, Garke's "Flora of North and Middle Germany," and Crépin's "Flora of Belgium." Fries divides Scandinavia into Lapland, Finland, Norway, Sweden, Gothland, and Denmark; Gothland being that southerly prolongation of the Scandinavian peninsula, which projects, opposite to Denmark, beyond the southern end of Norway. The plants of Denmark and Gothland exhibit a considerable divergence from those of the other divisions, and a marked affinity to the Germanic type of vegetation. It has, therefore, appeared to me desirable to remove them from the Scandinavian province, and to tabulate them separately as belonging to the Danish division of the Germanic province. The latter may be defined as consisting of the three sub-provinces of Denmark and Gothland, North and Mid-Germany, and Holland and Belgium; South Germany being excluded, as largely affected by the Flora of the Alps. I have not thought it necessary to make any separate examination of the Flora of Holland.

Making the comparisons in the order above indicated, and omitting in each successive operation the plants identified in the one preceding, we have the following results :—

Scandinavian	....		392
Germanic.—Denmark and Gothland	...	102	
North and Mid-Germany	...	146	
Belgium	....	13	
		——	261
			653

As very nearly all the 392 Scandinavian plants are also found in Germany, we may group the whole 653 together as the

Germanic element in the Algerian Flora, and before dismissing it from view, examine briefly its bearing on the phenomena of plant distribution.

The first point to be noted is the preponderance of grasses. In the Algerian census the Compositæ stand first with thirteen per cent., the Leguminosæ second with eleven-and-a-half per cent., and the Gramineæ third with eight per cent. of the population. But in the Germanic portion of the Flora the numbers are —Gramineæ ten, Compositæ eight, Leguminosæ six per cent. The next feature for remark is that the Germanic plants are very unequally distributed among the various natural orders. Out of sixty-three Ranunculaceæ, twenty-four, or more than one-third, are Germanic. But in Cistineæ the Germanic species are only two out of fifty-one, or less than one twenty-fifth. Again, out of sixty-seven Liliaceæ, five only are Germanic; while in Potameæ the Germanic species are nine out of thirteen; in Juncaceæ twelve out of twenty-one; and in the genus Carex twenty-three out of twenty-nine. Of the 653 species, about one-half are plants useful to man, weeds of cultivated ground, or inhabitants of fresh water. The plants of cultivated ground have doubtless been dispersed by human agency, those of fresh water by aquatic birds, as described by Darwin in the twelfth chapter of the "Origin of Species." The remaining half have probably travelled over continuous land. It may be remarked, finally, that the vegetable inhabitants of Algeria, as of other countries, are made up of groups, with widely different powers of accommodating themselves to varying conditions of existence. Thus, as we have seen, 13 species have their northern limit in Belgium, 146 in North Germany, 102 in Denmark and Gothland, while 392 are spread over the larger part of the Scandinavian peninsula. The latter group have a vast range from west to east, as well as from south to north, many of them occurring in northern temperate America, and across the whole of northern Europe and Asia. As for the aquatic species, their range is amazing, extending even into the southern hemisphere. Some of them are found in Australia and

New Zealand, and two, *Montia fontana* and *Callitriche verna*, as far south as Kerguelen's Land, where they grow in company with *Limosella aquatica*, a common European water plant, not yet detected in Algeria.

Deducting from the 2,933 Algerian plants the 653 of wide distribution, we have remaining 2,280, of which it may be said with certainty that no one of them is found, in a wild state, as far north as Belgium in western continental Europe. As the next step in the investigation, I have collated these plants with Gussone's "Flora Sicula," Bertoloni's "Flora Italica," "The Flora of France," by Grenier and Godron, and that of Spain by Willkomm and Lange. I have also had recourse to the "Sylloge Floræ Europeæ" of Nyman, and the two parts of his "Conspectus," published very recently. The effect of these comparisons is to bring into view the relations between the plants of Algeria and those of the European portion of the western Mediterranean basin. It appears that 1,537 species, out of the 2,280, or more than two-thirds, are indigenous to some part or other of that region. These belong to a great group of plants, the so-called Mediterranean Flora, which, commencing in the Azores and Canaries, is spread along both shores of the Mediterranean, passes by way of Greece, Turkey, and Southern Russia to the Caspian Sea, extends through Asia Minor and Syria into Persia, and even reaches Cabul. Of these 1,537 species, 575 occur in every part of the region, being found in Spain, France, Italy, and Sicily. The remaining 962 present special peculiarities of distribution.

We have next to enquire how many Algerian species are found in the Levant. For this purpose I have made use of the "Flora Orientalis" of Edmond Boissier, the eminent Genevese Botanist. This work, unfortunately, is not completed, the Gymnosperms, Endogens and vascular Cryptogams being as yet unpublished. It is necessary to make an estimate for these classes founded on the percentages in the exogenous orders; the analysis must therefore be regarded as approximate only. The countries included in Boissier's great work are Greece, European and Asiatic Turkey, South Russia, Persia, Turkestan, Afghanistan, Beloochistan, Arabia, as far as the Tropic of Cancer and Egypt to the first cataract. We find as the result of the comparison that of the 653 Germanic plants about 90 per cent. are Oriental ; of the 575 widely spread West Mediterranean about 85 per cent.; and of the 962 restricted West Mediterranean about 35 per cent. are Oriental. We find further that the Algerian Flora contains 180 Oriental species, or thereabout, which are absent from West Mediterranean Europe.

Of the 2,933 members of the Algerian catalogue we have now accounted for all but 563, concerning which enquiry must now be made whether the whole of them are well defined endemic species. My friend, Mr. John Ball, the author of the "Spicilegium Floræ Maroccanæ," who has favoured me with his assistance upon this point, is of opinion that at least 100 out of the 563 are undeserving of specific rank, and are varieties only of plants included in the preceding groups. Of the remaining 463 about 100 are peculiar to the Sahara, and belong to a different type of distribution from the Flora of the northern part of the Algerian province.

The results of these analyses are set forth in the following table :—

			Approx. propor. of Oriental species.
Total number of Algerian species......		2,933	
Species of wide distribution, (Germanic group)........................		653	90 p. c.
West Mediterranean group—			
Widely spread	575		85 p. c.
Restricted	962		35 p. c.
		1,537	
Oriental species absent from West Mediterranean Europe		180	

Remanet—			
Plants improperly described as species	100		
North African	363		
Saharan	100		
	——	563	
		——	2,933

The restricted West Mediterranean plants have been submitted to further analysis with the following result :—

Occurring both in Sicily and Spain...	169
In Sicily but not in Spain	152
In Spain but not in Sicily	572
In neither	69
	——
	962

It appears from the above tables that, of the 1,537 West Mediterranean species, 1,316 are found in Spain and 896 in Sicily. These figures imply the former existence of bridges of land connecting North Africa with Spain and Sicily, and show that the Spanish line of migration has been more effective than the Sicilian in the proportion of 3 to 2. Of the Spanish group of 572 species 338 are confined to the south of the Pyrenees. Of the remaining 234, 204 extend into France, part of them passing north of the Alps into Hungary and South Russia, and another part into Upper Italy, whence they spread downwards towards the south. In the Sicilian group of 152 species, 63 do not occur north of Sicily; the remainder pass into Lower Italy, and a few extend into France. Thus we have in the Italian peninsula the curious phenomenon of the dispersion in contrary directions of two groups of North African plants, the one downwards, the other upwards, the number of species in each case gradually diminishing in the direction of migration. The 338 Spanish plants which do not cross the Pyrenees present a still more remarkable phenomenon, 70 of them reappearing in the Levant, without leaving the slightest trace either in Sicily or Italy.

We may now turn our attention to the 463 species which remain after subtracting the Germanic, the Mediterranean, and Oriental forms. 100 of these are species which, so far as the limits of Algeria are concerned, are peculiar to the Sahara, the Flora of which will be discussed in a later part of this paper. Deducting these we have, as the ultimate result of our analysis, a group of 363 species in Algeria north of the Sahara which we have not identified with European or Oriental forms. It must not be too hastily assumed that these are all endemic species peculiar to North Africa, including in that term Marocco and Tunis as well as Algeria. The Spanish peninsula has been very imperfectly explored, and it is highly probable that some of these plants will be found in it. A few of them are tropical species of wide distribution. I do not imagine that more than about 300 of these plants will prove to be endemic species peculiar to North Africa. It is worthy of remark that only 40 species from this group have hitherto been described from Marocco.

There is one question of great interest connected with North African Botany which may be briefly considered in this place. Here is a country traversed by a chain of mountains, probably contemporaneous in its origin with the great ranges of central Europe, the Pyrenees, the Alps, the Carpathians. Deducting the forms of wide distribution, the Alpine chain has one-half of its species common to the Pyrenees, two-thirds common to the Carpathians, and one-fourth common to the Altai.* What is the relation between the Flora of the Atlas and that of the Alps? The answer is rather startling. The three natural orders most characteristic of Alpine regions are those that take their names from the saxifrage, the gentian, and the primrose. In the Flora of Algeria these are reduced to the narrowest limits. Of the genus Saxifraga there are six representatives; two are the widely-spread forms *Saxifraga granulata*

---

* Ball, "On the Origin of the Flora of the European Alps." Proceedings of the Royal Geog. Soc., New Series, Vol. I., pp. 573, 576.

and *Saxifraga tridactylites*, the remaining four are species belonging to the south of Spain. The genus Gentiana is conspicuous by its absence. The only representative of the genus Primula is the common primrose. *Arabis alpina*, *Rhamnus alpina*, *Ononis cenisia*, *Aronicum scorpioides*, *Hieracium saxatile*, *Erinus alpinus*, *Calamintha alpina*, are, if I am not mistaken, the only plants of the Algerian Atlas belonging to the typical Flora of the Alps.

Before quitting this part of the subject, it will be useful to take a rapid glance at the distribution of the plants of the British Isles, for our knowledge of which we are mainly indebted to Mr. Hewitt C. Watson, one of the earliest and ablest workers in this field of enquiry.

The number of species enumerated in the seventh edition of the "London Catalogue of British Plants," exclusive of Characeæ, is 1,665; of this number 1,465 are Alpine, Scandinavian, or Germanic, 1,386 of them being found within the Germanic limits as defined in this paper.

In the remaining 200 species we have—

Aliens more or less naturalised..................	24	
Segregates of uncertain distribution (Rubus, Hieracium, &c.)	57	
	——	81
Species belonging to South-west Europe............		114
,, ,, South-east Germany ...	1	
,, ,, Arctic regions	1	
,, ,, America	3	
	——	5
		——
		200

Of the 114 species belonging to South-west Europe 57 extend to Algeria.

The following points may be particularly noticed:—First.—The poverty of the Flora, one plant for every 74 square miles over a total area of 122,500 square miles, as compared with one in 51 in Algeria, over 150,000 square miles, and one in 47 in France, over 200,000. Secondly.—The great preponderance of Germanic forms. Thirdly.—That there does not occur, throughout the whole extent of the British Isles, a single well-defined endemic species. Fourthly.—The number of Mediterranean plants that are found on the south and west coasts. In passing from North and Mid-Germany to Belgium we only obtain, as we have seen, 13 additional Algerian plants. But by passing into Britain the number is increased by 57. The proximity of the sea on the western coast, and the curving northwards of the isothermal lines, due to the Gulf Stream, have the same effect on the distribution of plants in the British Islands that a southern latitude has upon the distribution of the plants of the Continent. One Mediterranean form, *Ophioglossum lusitanicum*, previously only known in Guernsey, within the British area, has recently been discovered in the county of Donegal.*

Having examined the facts of the distribution in Europe and Asia of the Algerian Flora, it remains to consider the bearing of those facts upon the physical history of the Mediterranean region. Two preliminary questions of great importance present themselves on the threshold of this enquiry; first, the existing configuration of the submarine shores and land surfaces of the European continent and neighbouring islands; secondly, the sequence of Geological events which have led to that configuration, and have influenced the present distribution of the vegetation of the world. Clear ideas upon both these subjects are essential to a right understanding of the problem.

I have placed upon the wall a coloured map of Europe, by Professor Ramsay, with the heights of the land and depths of the sea, between different specified levels, distinguished by appropriate colours. The map is useful as showing at a glance

---

* H. Chichester Hart, "Flora of North-Western Donegal," Journal of Botany, Vol. XVII., 1879, p. 149.

the general contour of the whole European area, but for our purpose it has two defects: the green and blue tints are not distinguishable from one another except by daylight, and the vertical distances apart at which the levels are contoured disguise some of the more interesting features of the configuration. I have, therefore, placed by the side of the map a series of Admiralty charts, coloured in such a manner as to bring those features into salient relief. The space between the shore and the 100-fathom line is coloured brown, between the 100 and the 1,000-fathom line blue, beyond the 1,000-fathom line pink. Intermediate depths are distinguished by differences in tint of the above three colours. (The submarine contours are shown on the map opposite the title page, where, however, the subdivisions of the brown are necessarily omitted in consequence of the smallness of the scale.)

Commencing our review with the west coast of Europe and the North Sea, you will observe that a rise of twenty fathoms in the sea bottom, over that area, would unite the counties of Norfolk and Lincoln with Holland and Denmark, and convert the Dogger Bank into an island. A rise of ten fathoms more, or thirty fathoms, would unite England to the Continent from Beachy Head to Flamborough Head, convert the English Channel into a river valley, unite Anglesea to the Isle of Man and Galloway, and turn the Irish Channel into a narrow strait. Fifty fathoms would extend the line of union of England and the Continent from the Lizard almost to Peterhead, close the Irish Channel, and join Ireland both with England and Scotland. An elevation of 100 fathoms would raise up a great plateau of land, entirely surrounding the British area, extending from Brittany to the Shetland Isles, terminated on the north-east by a sharp promontory, and divided from Norway by a deep trench, occupied by an arm of the sea. The remarkable depression just mentioned is about 500 miles long, of an average width of fifty miles, and an average depth of fifty fathoms below the 100-fathom line. It is shallowest at about the middle of its length, and deepest at its commencement between Denmark and Norway, where it forms a basin 330 fathoms deep below the 100-fathom line. The British Isles would thus become a portion of the European continent, more than three times as large as France. Beyond the 100-fathom level, the slope of the sea bottom increases very rapidly, and a further rise of 400 fathoms, giving a total of 500 fathoms, or 3,000 feet, would make scarcely any difference in the contour of the land.

We may now pass to the shores of France and Spain, where the brown tint on the next chart shows the extent of sea which would be converted into land by an upheaval of 100 fathoms, from the south of Ireland to Bayonne. On the coast of Spain, the strip between the shore and the 100-fathom line is reduced almost to nothing. From the south of Ireland to Lisbon, the bed of the sea is so steep that, in a horizontal distance of fifty miles, the depth increases from 100 to 2,000 fathoms. The deepest part of the Bay of Biscay, between Cape Finisterre and Ushant, is slightly over 16,000 feet.

The next point of interest is the Strait of Gibraltar, which at its narrowest, a little east of Tarifa, is about ten miles in width. A rise of 100 fathoms would reduce the width by one-half. It is worthy of note that the shallowest and narrowest parts of the strait do not coincide. The former is between Capes Spartel and Trafalgar, along which line a rise of 200 fathoms would produce an isthmus between Africa and Europe. Between Gibraltar and Ceuta the depth is so much greater that a rise of 500 fathoms would be necessary to produce a direct land communication between them.

The submarine shores of the Mediterranean, with some striking exceptions, have as steep a gradient as those of the Bay of Biscay. An upheaval of 100 fathoms along the Mediterranean area would unite Minorca with Majorca, Sicily with Italy and Malta, turn the Adriatic into dry land from Trieste to Monte Gargano, and close the Dardanelles and Bosphorus. It would also bring above water the greater part of an immense shoal which extends underneath the surface of the Mediterranean between Tunis and Sicily, and reduce the interval between those countries from eighty miles to twenty. In other parts of the area its effect would be inappreciable. A rise of 200 fathoms, as in the case of the Strait of Gibraltar, would bridge across the remaining twenty miles of sea between Tunis and Sicily. It would, however, be of so little use in other quarters, that we may as well take at once the whole step that is required, and consider the effect of an upheaval of 500 fathoms, or 3,000 feet, over the entire Mediterranean region, as shown by the contour line drawn at that level on the charts. This would close the Strait of Gibraltar, unite the Balearic Isles to Spain, Corsica to Tuscany, throw a great bridge of land across from Tunis to Sicily, Calabria, and European Turkey, convert the Ægean into dry land, and unite Crete with Greece, Asia Minor, Cyprus, and the north of Syria. The effect upon the remainder of the Mediterranean would be to convert it into two great basins, the eastern of which would be, in its deepest part, upwards of 10,000 feet in depth. If the upheaval extended still further eastward, it would raise the bottom of the Dead Sea above the level of the Mediterranean.* It is matter for regret that the deeper parts of the Mediterranean have been very incompletely sounded, and that the contour lines to some extent are necessarily conjectural.

Very few of the existing European rivers appear to have left their traces, as valleys of erosion, on the sea bottom. The natural result of the gradual submergence of the lower end of a river valley would be the silting up of the submerged channel. We find, accordingly, opposite the mouths of many of the larger rivers, considerable tracts of shoal water.

It would be interesting to examine the changes of contour

---

* The deepest part of the bed of the Dead Sea appears to be 2,600 feet below the level of the Mediterranean. See note on page 37.

which would be produced by subsidence, as well as those due to upheaval. I shall limit myself to pointing out that a depression of 100 fathoms would all but unite the Gulf of Lyons with the Bay of Biscay, and interpose an arm of the sea between the Cevennes and the Pyrenees. It would also lay under water a great part of Germany and European Russia, unite the Black Sea with the Caspian, the former with the Baltic, and the latter with the White Sea.

In tracing the series of geological changes which have affected the contour of the land and the migrations of plants, it will be sufficient to commence our retrospect with the Tertiary era, itself an insignificant fragment of geological time. The Tertiary division of sedimentary strata, as defined by Lyell, commences with those deposits in which we first find evidences of existing species of marine shells, and ends with those in which we last find evidences of extinct ones. It has been subdivided by Lyell into the three subordinate groups of Eocene, Miocene, and Pliocene. The Pliocene beds are those in which more than half, the Miocene those in which less than half the species are recent, the Eocene those which contain only a small percentage of existing forms. The percentage difference between Eocene and Miocene is somewhat indefinite, and the line is drawn by British and foreign geologists whenever they happen to find a convenient break in the strata of their respective countries. It must be borne in mind that these divisions are founded exclusively upon the marine testaceous mollusca, which form a very large proportion of their fossil contents. It must also be remembered that, to determine the age of any Tertiary deposit, we require a large collection of its included fossils, and that no trustworthy conclusion can be drawn from a few isolated species.*

The marine testacea appear to have been less susceptible to change than animals of higher organisation. In the age succeeding the Pliocene we have evidence of the existence of a number of extinct mammalia. We are thus introduced to a

* Lyell, "Elements of Geology," 6th Edit., ch. xiii., p. 187.

group of deposits in which all the testaceous mollusca, but some only of the mammalia, belonged to existing species. These deposits have been variously described as post-Tertiary, post-Pliocene, Pleistocene, and Quaternary, names all more or less open to objection. I shall use the latter term, which is that adopted by French geologists.

The Quaternary mammalia occur in river gravels, and in the hyæna dens and other bone caves which are scattered over Western Europe and North Africa from Yorkshire to Algiers, in which vast quantities of the remains of extinct and living species are found intermingled. The caves north of the Pyrenees exhibit an extraordinary mixture of Tropical and Arctic forms, the bones of the panther, lion, hyæna, and hippopotamus being associated with those of the glutton, musk sheep, reindeer, and mammoth. It is in this part of the geological record that we have the first evidence of the existence of man, in the worked but unpolished flint and stone implements which are found with the remains of the Quaternary mammalia, and which have received the name of Palæolithic.

The Quaternary deposits are succeeded by those classed together by Sir Charles Lyell under the head of "Recent," in which all the organic remains, with the possible exception of the Irish elk, belong to living species. The recent period is divided into the pre-historic and historic, and the former is subdivided into the Neolithic or polished stone, the bronze, and iron periods. In the Neolithic period man had attained a considerable degree of civilisation, and was associated with the domestic animals, which Palæolithic man did not possess.

The animal and vegetable remains of the earlier Tertiary deposits in the northern hemisphere afford evidences of a tropical or sub-tropical climate, extending equably or with little variation from the Tropic of Cancer to the Pole. It is probable that the temperature was gradually declining from the commencement of the Tertiary era, but in the Pliocene period the decline becomes more apparent, and the Quaternary era is introduced by a great secular refrigeration. This is known as the Glacial or Great Ice Age, during which large parts of Northern Europe, Asia, and America were covered with ice, glaciers extended far beyond their present limits in the Alps, Pyrenees, and Caucasus, existed in Scotland, Wales, and Iceland, and were formed even as far south as the Greater Atlas and the Lebanon. The exact relation in time of Palæolithic man and the Quaternary mammalia to the various glacial deposits is at present uncertain, the opinions of geologists being much divided upon this question.

The refrigeration reached its climax during the Quaternary era, and was followed by a secular increase of temperature, which has probably continued, with some oscillations, to the present day. That a general amelioration of climate has taken place in Europe in the historical period is proved by the retreat of the reindeer, which existed in the forests of Germany in the time of Julius Cæsar, and in the north of Scotland in the reign of Henry II. Full information upon all questions relating to the Quaternary mammalia, so far as our present knowledge extends, may be found in the works of Professor Boyd Dawkins, who has specially devoted himself to this branch of geological research.

The physical changes which have taken place on the earth's surface since the commencement of the Tertiary era can only be described as prodigious. Rocks of Eocene age are intercalated with older strata in the main ranges of the Alps, and have been elevated to a height of 11,000 feet. Beds of Miocene age were deposited unconformably upon them, and, in the flanking or sub-Alpine ranges, have been raised, as in the well-known case of the Rigi, to a height of 6,000 feet. What the Alps were like in pre-Tertiary times we cannot so much as conjecture. It is certain that they owe their present configuration to two great upheavals, one of post-Eocene, the other of post-Miocene date. The Pyrenees, Atlas, and other east and west ranges of the old world were contemporaneous in the origin with the Alps, and subject to similar influences.*

* Lyell, "Principles of Geology," 10th Edit., chap. x. Murchison, "The Geological Structure of the Alps," Quarterly Journal of the Geological Society, Vol. V., p. 157. Studer, "Geologie der Schweiz."

The changes of level, due to volcanic action, are scarcely less striking than those just described. The volcanic mass of Mont Dore, which rises to a height of 6,238 feet above the sea, and the volcanic cones which astonish the traveller in central France, were elevated in Tertiary times, and have since become extinct. The eruptions which ultimately piled up Etna to a height of 10,872 feet commenced in later Pliocene times, and Vesuvius is still more recent. Strata of newer Pliocene age cover nearly half the island of Sicily, and have been raised to an altitude of 3,000 feet. One argillaceous bed found at a height of 1,258 feet, near the foot of Etna, and associated with some of its most ancient lavas, has yielded 148 species of shells, of which only eight per cent. are extinct, the remainder being still existent in the neighbouring parts of the Mediterranean. These facts are interesting, as fixing the date of the origin of the mountain, and as showing the kind of evidence necessary to determine the age of a Tertiary or post-Tertiary deposit.*

It is certain that in Pliocene times England was united to the Continent; it is probable that the union was continued into the Glacial age. In the latter, a great movement of depression affected the northern part of Europe, which submerged beneath the sea most of the northern and central portions of the British Isles, the whole of north Germany, part of Scandinavia, and a large area in Russia. During their submergence the moraine matter accumulated by the Glaciers was rearranged by the sea, and distributed as drift, till or boulder clay in various parts of Britain; and thousands of erratic blocks frozen into ice-rafts were floated southward, and dropped upon the sea bottom. Boulders of Arenig felsite, found on the hills about six miles west of Birmingham, up to a height of about 900 feet above the sea, and beds containing Arctic shells of recent species, occurring in North Wales at a height of 1,400 feet, give for these localities the minimum limits of submergence, which

---

* Lyell, "Elements," ch. xiii., pp. 189-194; ch. xxxi., xxxii. "Principles," ch. xxiv., xxv., xxvi.

there is good reason for believing exceeded 2,000 feet. Whether England and France were ever absolutely severed during this epoch is a doubtful question. It is certain that the submergence was followed by a re-elevation, during which Britain was raised to its former level, and the mountain valleys again filled with ice. One of the consequences of these movements was the almost entire destruction of the indigenous British Flora, and the re-colonisation of the country from the Continent, which accounts for the non-existence of endemic species and the great preponderance of Germanic plants.

The vertical range of the oscillations in level which affected Britain during the Quaternary era cannot have been less than 3,000 feet. I have dwelt at some length upon these phenomena for the purpose of showing that movements in the Mediterranean region on a similar scale, and during the same period, would have nothing unusual in their character, that there would, on the contrary, be reason for surprise if they had not taken place. These oscillatory movements may be ascribed to tangential stresses in the earth's crust, due to the gradual cooling of its mass. The effect of such stresses would naturally be to throw the crust into ridge and furrow, like the folds in a cloth pushed along a table by the hand. We may expect to find the crests of the ridges succeeded by hollows, at a greater or less distance, measured transversely to the crests, according to the smaller or greater intensity of the tangential forces.

The causes of the present distribution of the vegetation of the world were first indicated by Darwin, in the 11th and 12th chapters of the Origin of Species. The problem, so far as it relates to northern temperate Europe, has been studied in detail by Mr. John Ball, and the results of his researches given to the public in a lecture "On the Origin of the Flora of the European Alps," delivered at the Royal Geographical Society on the 9th of June, 1879.* Another eminent botanist, Professor Engler, of Kiel, has published the first part of a treatise on the same

* "Proceedings," New Series, Vol. I., p. 564.

subject, but this book has come into my hands too recently to enable me to avail myself of its contents.

To understand the distribution of the existing Flora of the northern hemisphere, we must carry our thoughts back to Miocene times, when a large assemblage of plants of a tropical or sub-tropical character covered the land from the Tropic of Cancer to within ten degrees of the Pole. Their remains, entombed in the fresh-water Miocene deposits, which are scattered over Europe, and extend into Greenland and other parts of the Arctic regions, show a marked affinity to the present vegetable inhabitants of California and Japan.* Now, consider what must have taken place as the climate became colder towards the close of the Tertiary era, and finally assumed an Arctic severity in glacial times. The plants in any given zone of latitude would be sorted by the increasing cold. Those unsuited to the colder climate would be driven into the zone below, where they would find their proper temperature, but be subjected to new conditions of various kinds. The hardier species would remain behind, but their inter-actions would be changed, and they would be affected by migrations from the zone above. The ultimate effect would be a migration southward across both old and new worlds of a vast number of species. When the European stream reached the foot of the Alps, it would divide into two branches, the one travelling into France and Spain, the other into Hungary, Turkey, and the Levant. At the same time with these southerly migrations, the Alpine species would move in a contrary direction, first descending from the mountains into the plains, and then travelling northward. At the time of the great submergence, most of the plants of northern Europe must have been destroyed. As the cold declined, and the climate gradually grew warmer, the migrations would still continue, but some of the movements would be reversed. The southern species would return northward, the Alpine species would travel, partly to the mountain summits,

---

Lyell, "Principles," ch. x.; "Elements," ch. xv.

partly to the Arctic zone. We cannot fail to perceive what large specific modifications must have been produced by these changes, and how easily they account for many facts which appear at first sight very difficult of explanation. Such are the affinities between the Alpine and the Arctic Floras, the occurrence of the same species in the old and new worlds, in south-west Europe and the Levant, and at many points where migration in direct lines between them would appear to have been impossible. These north and south movements will not, however, account for all the phenomena of distribution. There must have been also large transfers of plants from east to west, or *vice versâ*.

After this long digression we may take up the thread of the main argument and proceed to the consideration of the land connections which united Europe and Africa in former times. It will be well to anticipate in this place two objections which may be brought against the evidence afforded by the distribution of plants. It may be urged that their seeds may be carried through long distances by the wind, and that the plants themselves, as well as their seeds, may be dispersed by other means than migration overland. Among such means are birds, ocean currents, and the various agencies of human intercourse ; the latter being especially effective in a region like the Mediterranean, which for so many centuries has been one of the principal lines of traffic of the human race. Now, although the excessively minute spores of cryptogams are largely distributed by the wind, there is no reason to believe that the seeds of phanerogams, even those provided with special organs for flotation in the air, can be blown across wide spaces of sea. So far as the other causes have operated, their tendency has undoubtedly been towards uniform dispersion of vegetable life, and by no means in the direction of those remarkable phenomena of restricted distribution to which I have called your attention.

There is one class of evidence which is entirely free from any suspicion of error from the causes above referred to, I mean that which geology affords of the distribution of mammals, particularly of those which lived in the Quaternary age.

The geology of Gibraltar has been studied by a succession of eminent English geologists, among whom I may mention the names of the late Mr. James Smith and Dr. Falconer, and of Mr. Busk, Professor Ramsay, and Mr. James Geikie. The jurassic limestone, of which the rock of Gibraltar is composed, contains numerous bone caves, which have yielded a rich harvest of mammalian remains, including those of the spotted hyæna, lion, panther, lynx, serval, and felix caffer, the spotted hyæna, serval, and F. caffer being species now peculiar to Africa. The African elephant has not yet been detected at Gibraltar, but has been found by Mr. Lartet in a bed of gravel near Madrid, along with the striped hyæna, another African animal. It has also been found in the Sicilian bone caves with the lion, spotted hyæna, and other species. On the other hand, *Elephas meridionalis*, an extinct South European species, has been discovered in Algeria, whither it must have migrated from the south of Europe. The Quaternary hippopotamus, *(H. major,)* a species nearly related to, if not identical with, the living African species, had an immense range. It lived in Africa, Spain, Sicily, Italy, France, in England as far north as Yorkshire, and probably in Germany also. The remains of a smaller species of hippopotamus *(H. Pentlandi)* have been found in large quantities in Sicily, Malta, Candia, and Greece.*

None of the northern mammalia, such as the mammoth, reindeer, woolly rhinoceros, and musk sheep have been found in the Gibraltar bone caves, or (with the exception of the mammoth) elsewhere in the Spanish peninsula. They flourished, however, in large numbers in central France, the caves of Perigord, in the valley of the Dordogne, having yielded immense

* Ramsay and Geikie, "Geology of Gibraltar." Quart. Journ. Geol. Soc., Vol. XXXIV., p. 505. Dawkins, "Pleistocene Mammalia," (Pal. Soc.) Cave Hunting, ch. x.

quantities of the bones of the reindeer, and also remains of the mammoth, including a tusk, upon which some Palæolithic Giotto has engraved an etching of the mammoth itself. On the Italian peninsula the mammoth is known to have ranged as far south as Rome, but in Spain its range is uncertain.* Its remains have been found in a limestone cavern in the neighbourhood of Santander, under conditions which would appear to imply that it actually lived in that locality.

It may be inferred from the facts above stated that in the Quaternary era, North Africa was connected with the south of Spain on the one hand, and with Sicily on the other. The method in vogue among geologists of re-constructing the geography of that age is to raise the land bodily 3,000 feet, and to convert the Mediterranean into two land-locked salt water basins, leaving the rivers flowing into them just as they do at present. Some writers have speculated upon the extent to which the level of the water would be reduced by the excess of evaporation over supply. It is just possible that at some time or other in geological history some such conditions may have obtained. A current sets at the rate of two miles an hour through the Strait of Gibraltar, from the Atlantic to the Mediterranean, which can only be due to an excess of evaporation in the latter. It is certain that if the Strait were closed at the present time, the level of the Mediterranean would decline. But we know that in Quaternary times the temperature was lower than at present. It is at least probable that the volume of the rivers was larger. The Mediterranean basins may have been sea water basins, with outlets to the ocean other than those at present existing; they may have formed a chain of fresh water lakes, like those in the valley of the St. Lawrence. Again, an elevation of 3,000 feet in one locality would imply a compensatory depression in another, and equal movements of upheaval at two points distant from one another need not necessarily have been simultaneous. The problem is

* Leith Adams, Quart. Journ. Geol. Soc., Vol. XXXIII., p. 537.

one of extreme complexity, and cannot be solved in any such off-hand manner as that above referred to. For its further elucidation we must now resume the examination of the botanical evidence, and without troubling ourselves about the widely-spread species, whether Germanic or Mediterranean, concentrate our attention upon the restricted Mediterranean and Oriental plants.

I have divided the restricted Mediterranean species into four groups, according as they occur in Spain and Sicily, in Sicily, in Spain, or in neither, and have made a complete analysis of their distribution, which is set forth in the following table :—

Restricted Mediterranean Species.	Number.			Oriental Species.
First group, (A,) Sicilian Spanish :—				
1.—Absent from France and Italy	44		...	20
2.—Present in Sicily and Lower Italy	101		...	65
3.—Present in Spain and France	24		...	8
	——	169	—	93
				55 p.c.
Second group, (B,) Sicilian, not in Spain :—				
1.—Absent from France and Italy	63			
2.—Present in Sicily and France	2			
3.—Present in Lower Italy	63			
4.—Present in Italy and France.........	24			
	——	152		
				Ab. 35 p.c.
Third group, (C,) Spanish, absent from Sicily :—				
1.—Absent from France and Italy	338		...	70
2.—In Italy but not in France	30		...	22
3.—In France	84		...	22
4.—In France and Upper Italy	120		...	58
	——	572	—	172
				30 p.c.

Fourth group, (D,) absent from Spain and Sicily :—

1.—In France and Italy	15		
2.—In France	9		
3.—In Italy	23		
4.—In Mediterranean Islands...........	22		
	——	69	Ab. 25 p.c.
		—— 962	

If we extract from the above table the figures which represent the migrations between Algeria and Sicily on the one hand, and Algeria and Spain on the other, we find—

For the first, A + B	169	
	152	
	——	321
For the second, A + C	169	
	572	
	——	741

showing a great preponderance of species on the latter line of migration. A glance at a geological map of Europe, or at the map at page 251 of the tenth edition of Lyell's " Principles of Geology," will show that about two-thirds of the Spanish peninsula has been dry land since the commencement of the Tertiary era, while, on the other hand, the island of Sicily has been mainly, if not wholly, beneath the sea during some part, at least, of the same geological period. The great antiquity of Spain is one very probable reason for the richness of its Flora, and for the numerous interchanges of species into the neighbouring continent. The sub-groups A (2) and B (3) show the range of the Sicilian species into Italy. The plants in these sub-groups are principally confined to lower Italy, a few of them only having strayed to the north. The preponderance of the numbers in the former over those in the latter group show how power of diffusion in latitude as well as in longitude is united in the same group of species.

I have already called your attention to the absence from

Sicily of a number of Oriental species which occur in South Africa and in other parts of the West Mediterranean region. These are the Oriental group absent from western Europe, and the Oriental elements in the sub-groups C (1) and C (2.) We may restrict our attention to those plants which do not pass north of the Pyrenees.

These Oriental species may be tabulated as under:—

1.—Oriental plants absent from Western Europe	180
2.—Oriental plants in Italy and Spain	22
3.—Oriental plants in Spain	70
	272

It thus appears that there are in Algeria 272 species of Oriental plants not occurring in Sicily, 92 of which have penetrated into Spain, but have not passed north of the Pyrenees, and that 22 out of the 92 are to be found in Italy, but are, with few exceptions, restricted to the southern part of the peninsula. The question is by what route did they travel between North Africa and the Levant?

If we examine the eastern distribution of these species, we shall find that many of them occur in Greece, European Turkey, East Germany, South Russia, Asia Minor, and Syria, or some of these countries, others again in Egypt, Arabia-Petræa, and Arabia, the remainder in both these regions. At least half of the 272 species are absent from the southern side of the Levant and must have migrated from the north of the Levant and North Africa, or *vice versa.* Among the species which have travelled along this line but have not passed into Europe, one may be particularly mentioned, one of the most interesting in its distribution, as it is one of the noblest of the creations of the vegetable world, I mean the cedar of Lebanon. This magnificent tree, which unhappily may be said to linger rather than flourish in the Algerian Atlas, is found scattered in scanty patches in several parts of the chain, but nowhere in abundance except at Batna, and in the celebrated forest at Teniet el-Haad. Here on the steep sandstone cliffs which form the crest of the Atlas, 5,000 feet above the sea, the cedars climb along the ridges, and may be recognised by the traveller, dark and sharply cut against the sky-line, thirty miles away. The trees, in exposed situations, present short trunks crowned by flat tables of foliage, but in sheltered spots, and notably in that known as the "Rond Point des Cèdres," the boles are of amazing height and beauty. Sections of cedar trunks with 500 rings and upwards may be occasionally seen in houses in Algiers, but one of the trees at the Rond Point, in apparently vigorous health, is probably from 1,000 to 1,500 years old. The companion tree was burnt by the Arabs a few years ago. The Atlantic cedar is a distinct variety of the *Cedrus Libani*, or cedar of Lebanon, and has been described as a species under the name of *Cedrus Atlantica*. Another cedar nearly allied to the *Cedrus Libani* is the *Cedrus Deodara* of the Himalayas. The nearest point to North Africa where the cedar is again met with is on the mountains of Cyprus, where it was discovered by Sir Samuel Baker in September, 1879. The discovery was communicated to the Linnean Society by Sir J. D. Hooker, on the 20th November, 1879.* Sir Joseph Hooker considers the Cyprus cedar to be another variety of the cedar of Lebanon, and names it *Cedrus Libani, var. brevifolia*. He states "that in size of cone, and in size, form, and colour of leaf, the Cyprus approaches the Algerian far more closely than it does any Taurian, Himalayan, or Lebanon cedar." The differences of race in the Algerian, Cyprus, and Lebanon cedars imply a great lapse of time since their habitats were severed.

One explanation, and one alone, will account for these phenomena of distribution. Sicily, geologically speaking, is of very recent origin. Before its existence the ranges of the Atlas

---

* On the Discovery of a Variety of the Cedar of Lebanon on the Mountains of Cyprus, with letter thereupon from Sir Samuel Baker, F.R.S. Journal of Linnean Society, Botany, Vol. XVII., 1880, p. 517.

must have extended into Greece. It is not necessary to suppose that the cedar and other species travelled in a direct line between North Africa and Syria, as they may have radiated into their present habitats from some point further to the north. I incline, nevertheless, to the belief that the Atlantic chain extended from North Africa to the Lebanon, and that the mountains of Crete and Cyprus are surviving fragments of it. The mountains of Andalusia and Marocco must also have been attached across the present site of the Strait of Gibraltar, and it is not unreasonable to suppose that the two unions may have been simultaneous. We are thus provided with a land route for the migrations of Atlantic plants between Spain, North Africa, and the north of the Levant, and can understand how the species which travelled along it may have left a few traces in lower Italy.

One cannot examine the distribution of Mediterranean plants without being struck by their extension into the islands of the North Atlantic Ocean, some of the species ranging into the Canaries, others as far west as the Azores. These clusters of islands, with the Madeiras and the islands off Cape Verde, have been classed together by botanists under the name of Macaronesian. They possess a Fauna and Flora which, whether regarded as a whole, or as distributed among the subordinate groups of islands, are among the most remarkable on the surface of the globe. The Flora, in the main, is Mediterranean in its affinities, but is distinguished by the large proportion of endemic species, mostly of Mediterranean types. Thus, out of about 1,000 species enumerated by Webb and Berthelot in the "Phytographia Canariensis," 367, or more than one-third, are regarded as peculiar to the Canarian Archipelago, a very few only of these being also Madeirian.* The Fauna is still more remarkable. 1,449 species of beetles are recorded by Wollaston in his "Coleoptera Atlandidum," from the Madeiras and Canaries, 243 only being common to the two groups. Of the

*Hooker and Ball, "Marocco." Appendix E.

whole number of species, 1,039 have not been detected elsewhere, and the majority of these are certainly endemic. The remaining 410 are inhabitants of Central or Southern Europe or of Northern Africa. The Macaronesian Islands are of volcanic origin, and were elevated in later Miocene times, as proved, at least in the cases of the Azores, Madeiras, and Canaries, by shells of that date included in the volcanic tuffs of those islands.* The four groups are separated from one another, and from the neighbouring continents, by great depths of sea, extending in the cases of the Azores and Madeiras, to upwards of 2,000 fathoms. Whether they have ever been united to Europe and Africa is a moot question among naturalists. If they have, the connection must have been severed long enough to admit of the production of the endemic forms of animal and vegetable life, implying a lapse of time compared with which the Quaternary and pre-Historic ages were of short duration.

From the fragment of the so-called Lusitanian Flora, which survives in the south and west of Ireland, it was supposed by the late Edward Forbes that Ireland was once connected with the Spanish peninsula and the Azores. The evidence, in my judgment, is not strong enough to warrant the conclusion, and there are some facts, to be mentioned presently, difficult to reconcile with it.

We have seen that, in order to explain the present distribution of vegetation, it is necessary to suppose the mountains of Andalusia united with those of Marocco, and the Algerian Atlas extended into Asia along the northern side of the Levant. Is it possible to assign any approximate date to this configuration, and with what other geographical conditions did it co-exist ?

The strata opposite to each other at Capes Spartel and Trafalgar are represented by Dumont as of Eocene age,† and

---

* Lyell, "Elements," p. 667.

† Dumont, "Carte Géologique de l'Europe."

were once continuous. The first union of Spain and Marocco in the Tertiary era must, therefore, have been due to a post-Eocene upheaval. The occurrence of Miocene strata in the Algerian Atlas renders it probable that the union was post-Miocene, and the possibility that the Canaries were attached to Africa at the same time gives additional weight to this supposition. The chain which united North Africa with Asia Minor must have been elevated and submerged prior to the formation of the newer Pliocene deposits of Sicily. It may be safely inferred that the union existed in older Pliocene times. In a later age, the part of the chain between Tunis and Greece must have subsided below the sea level and the newer Pliocene beds of Sicily been deposited upon it. At the time of the elevation of Vesuvius and Etna, it was again raised above the waters, and the land connection re-established as a line of migration for plants and animals in the Quaternary era. After the second upheaval, there was a second submergence, and this again was followed by a slight elevation, as proved by the evidence of modern sea beaches on the Mediterranean coasts. The geological phenomena of the Strait of Gibraltar are considered by Messrs. Ramsay and Geikie to afford, for that region, evidence of a very similar history.

If the western Mediterranean basin existed during the interval above indicated, there is no reason for assuming it to have been a closed salt water lake. If you will look at the map of the west coast of France, you will see that the north and south shores of the Bay of Biscay, if continued in the same directions, would meet near Carcassonne. This angle of the great Biscayan depression is filled with strata of Miocene age, deposited in a sea which was continued in a narrow strait between the lowest spurs of the Pyrenees and the Cevennes, into the Gulf of Lyons at Narbonne. The Miocene strait is represented at the present day by a valley, along which the French have constructed the celebrated water way of the Canal du Midi for the conveyance of traffic from the Mediterranean to the Garonne. The Miocene beds near Bordeaux are overlain by the sands of the Landes referred by French geologists to the Pliocene period.* The same deposits appear in patches covering the Miocene in the upper parts of the Garonne valley, implying that the Miocene and Pliocene beds of Aquitania were deposited during a period of subsidence, and that the Pliocene beds were denuded during a subsequent period of upheaval. The marine connection between the Gulf of Lyons and the Mediterranean may, therefore, have been open in the late Tertiary or early Quaternary times, and have formed a channel for the migration of maritime plants between the S.W. of England and the Mediterranean. The evidence from the distribution of marine shells points in the same direction. In his "Natural History of the European Seas," Edward Forbes has called attention to the Lusitanian and Mediterranean forms interspersed among mollusks of Celtic type on the shores of the French department of Finisterre.† "It is," he adds, "worthy of remark that the greater number of these species are dwellers on the verge of low water mark—either above or below it. Moreover, they are mostly rock shells, so that their presence here, separated frequently as they are from their brothers by the sandy shores of the southern half of the Bay of Biscay, is an anomaly not easy, at least by ordinary causes, to be accounted for." If these species migrated, as they probably did, from the Mediterranean to Brittany, by the Miocene strait of Carcassonne, the explanation of the anomaly is an easy one, but it is inconsistent with the hypothesis of a direct land connection between the Asturias and Britain. The date of the upheaval which closed the strait of Carcassonne might, perhaps, be determined by a careful study of the range, in the south of France, of the northern group of the Quaternary mammalia.

The extension of the Atlas from North Africa into Greece and Asia Minor, implying as it does the severance of the waters of the Black Sea from those of the Levant, must have been

---

* Élie de Beaumont, "Carte Géologique de la France."

† pp. 92, 93.

correlated with geographical conditions widely different from those now existing in the eastern part of the Mediterranean region. The lower valley of the Danube down to its junction with the Black Sea is filled by strata of Miocene age. The same deposits occupy the valley of the Dnieper, and are extended beyond the watershed of that river to the shores of the Baltic, where they are overlain in Prussia by the northern drift. Large tracts of land in the vicinity of the Caspian and Aral seas are composed of calcareous and sandy beds of brackish water origin, implying the existence in older Pliocene times of a great inland sea as large as the Mediterranean, reaching from the Bosphorus to the margin of Thibet.*

The Fauna of the Black Sea, though consisting almost entirely of Mediterranean forms, presents in the paucity of its species a marked contrast to that of the Mediterranean. Of the species of mollusks in the latter, the number of which has been variously estimated at 600, 700, and 850, sixty only pass into the Black Sea, where they are associated with a few Aral and Caspian shells. The molluscan Fauna of the Caspian is very limited, about twenty species only having been found in that sea, and these all characteristic of brackish waters. Half the species are forms of Cardium, and about a third of the whole are endemic.†

At the time of the extension of the Atlas from Africa to Asia Minor, the Black Sea communicated with the Baltic by the Miocene strait of the Dnieper, and possibly had outlets into the Arctic Ocean. River valleys must have existed on the northern side of the chain from the crest down to the sea level. It is natural to suppose that one of such valleys followed the line of the Dardanelles and Bosphorus. I have not succeeded in finding evidence of the date at which the northern outlets of the Black and Caspian Sea were

---

* Lyell, "Elements," p. 209.

† Forbes and Austin, "Natural History of the European Seas." Woodward, "Manual of the Mollusca," pp. 361-365.

finally closed. An upheaval in this region may have been coincident with the subsidence of the Ægean, and the Bosphorus and Dardanelles may owe their present form to the eroding action of an effluent river, flowing in an opposite direction to the slope of the original valley. According to the latest authorities, the Caspian is eighty-three feet below the level of the Black Sea, a difference which is usually ascribed to excess of evaporation in the former.* The region between the sea of Azoff and the northern part of the Caspian is occupied by deposits of Quaternary age, but the isolation of the area from the Mediterranean is probably of greater antiquity.

The geographical relations of the Levant during the period under consideration are less easy to unravel than those of the Black Sea and Caspian. Palestine presents, as is well known, an unique phenomenon in geography, that of a river running for its entire course, or very nearly so, from its source to its exit, below the sea level. The water level of the Dead Sea is about 1,300 feet below the Mediterranean,† and the sea itself is 1,300 feet deep.‡ There can be little doubt that the valley of the Jordan, together with its prolongations of the Wady el-Arabah and the Akabah Gulf of the Red Sea were formed by sub-aerial erosion at a time when the land stood far above its present level, and that the line of valley has been crossed by a transverse axis of upheaval. The Red Sea, if its bed were raised at its southern end to an extent of only 200 feet, would repeat upon a grander scale the phenomena of the Jordan, and exhibit a valley 1,400 miles in length, with its

---

* Lyell, "Principles," ch. vi., p. 111.

† Exactly 1,292·1 feet, according to the Map of Western Palestine, published by the Committee of the Palestine Exploration Fund.

‡ The Dead Sea was sounded by Lieut. Lynch—see "Narrative of the U. S. Exploring Expedition." London, 1849—see also Smith's Dictionary of the Bible, article "Sea, the Salt," Vol. III., p. 1,175. The deepest sounding was 1,308 feet, so that the maximum depth of the bed below the level of the Mediterranean is 2,600 feet.

lowest point 1,000 feet beneath the sea level, and a lake of intense saltness at the bottom.

By what route, if any, the waters of the Levant found an exit to the ocean when the present western channel was closed, it is not easy to determine. If there was an open sea connection between the Levant and the Gulf of Guinea, across what is now the Great African Desert, the difficulty would vanish. It is possible that this may have been the case during some part of the Tertiary era, but it is not necessary to have recourse to this hypothesis. Assuming that the Levant existed as a rock basin during the period under consideration, it may have been a closed sea, have had a marine connection with the Red Sea, or formed a fresh-water lake, with an effluent river through the Gulf of Suez. The form of this gulf, and the shallowness of its bed, as compared with the Red Sea itself, and with the Gulf of Akabah, lend support to the latter supposition. Some information on this subject may be expected from a comparison of the Fauna of the Red Sea and the Levant.

The number of species of Testaceous Mollusca in the Red Sea has been estimated at 408, in the Levant at about 500, 76 only being common to the two. Of these 76, however, 47 are species of very wide distribution, which may have migrated into both these areas from the Atlantic Ocean.* Deducting these species from each of the three groups, the numbers are reduced as under :—

Levant	453
Red Sea	361
In both	29

It thus appears that, deducting the forms of wide distribution, 8½ per cent. only of the Testaceous Mollusca of the Red Sea pass into the Levant. The same proportion, or something like it,

* Forbes and Austin, p. 253.

holds good for the other groups of its marine inhabitants. It may be inferred that any marine connection between the Red Sea and the Mediterranean is of great antiquity, and was not of long duration.

An upheaval of 3,000 feet in the land at the northern end of the Red Sea would revolutionise the physical geography of Egypt. Even if the elevatory movement died out gradually towards the south, and were unaccompanied by any corresponding depression, it would lift the Delta of the Nile above the level of the Albert Lake of Sir Samuel Baker. I need scarcely remark that maps, professing to restore the ancient geography, in which the Nile is depicted as pouring its waters into a sea, the shores of which are raised 3,000 feet above their present level, are purely chimerical.

It may be matter for surprise that only a passing allusion has been made to the so-called submergence of the Sahara, a favourite doctrine at the present day both with the general public and among men of science. The question is of so much interest that it deserves special examination. I purpose, therefore, to devote the remainder of this paper to as thorough an investigation of the subject as the time at our disposal will allow.

The Great Libyan Desert, extending in longitude from the Atlantic Ocean to the Valley of the Nile, and in latitude from the Hauts Plateaux of Algeria to the northern edge of the Soudan, occupies an area of upwards of 3½ millions of square miles, and is approximately equal to the Continent of Europe. Moreover, the same physical conditions by which it is characterised extend across the Red Sea, prevail over nearly the whole of Arabia, and in parts of Persia, Beloochistan, and Scinde. These conditions are the intersection of the country by wadys, or valleys of erosion, resembling river channels in every respect excepting that they are apparently devoid of water; the existence of extensive deposits of earthy and alkaline salts; the occurrence of masses of drifting sand, frequently accumulated into chains of dunes several hundred feet in height; an atmosphere of excessive dryness; and above all, by extreme variations of temperature. I use the word Sahara in its popular sense as a synonym for the Great Libyan Desert, though it is sometimes restricted to the northern part of it.

The popular idea is that nearly the whole of this vast area occupies a cup-shaped depression in the African continent, divided from the Mediterranean on the one hand and the Atlantic on the other by narrow sand bars, which it is only necessary to cut through to flood the whole region with sea-water. It is supposed that in early historical times the Sahara formed part of the Mediterranean Sea, and that the final upheaval which restricted the Mediterranean to its present limits took place at or about the date of the Christian era. One almost expects evidence to be brought forward of the Phœnicians having sailed directly from the Levant to the Gulf of Guinea, and having founded a colony at Cape Coast Castle. The substitution of three million square miles of sea-water for the existing Libyan Desert would no doubt have a perceptible effect upon the climate of Europe; and as it has actually been proposed to cut through the bars, considerable uneasiness has been felt on this account. Whether any or what extent of depression below the sea level occurs on the Atlantic edge of the Sahara I am unable to say, no authentic information on this head having yet been published, although a scheme for flooding the desert from this side has for some years existed. On the Mediterranean side we are more fortunate, the Chott region in this quarter having been surveyed and levelled in 1875-6, by M. le Capitaine Roudaire, of the French État Major, and the results of his labours are published in the interesting report which I have placed upon the table.* I will briefly describe the physical structure of the region in question.

The Great Desert is entered from Algeria at two principal points—El-Aghouat, in the province of Algiers, and Biskra, in

* Roudaire—" Rapport sur la Mission des Chotts. Études relatives au projet de mer intérieure," 2me Edition. Paris, 1877.

the province of Constantine. El-Aghouat is 200 miles due south of Algiers, and is about 2,400 feet above the sea. Biskra, on the other hand, is only 120 miles south of the coast, and about 400 feet above the sea, so that it is some 2,000 feet below the level of El-Aghouat. 50 miles south of Biskra, and 170 miles east of El-Aghouat, is the Chott Melrhir, a salt-water basin which receives the drainage of the Aurês Mountains, and of all the country south-east of a line drawn from Biskra to El-Aghouat.

The Chott Melrhir is the most easterly of three chotts which lie in a depression opening out into the Gulf of Gabès, the other two, the Chott Rharsa and the Chott Djerid, being in Tunis, and the latter being separated from the Mediterranean by a neck of land about twelve miles across. The distance from the western edge of the Chott Melrhir to the Gulf of Gabès is about 220 miles. The Chotts Melrhir and Rharsa have been determined by Captain Roudaire to be 80 feet below the sea level, the Chott Djerid to be 50 feet above it, an awkward impediment to canalisation, as the latter chott occupies nearly one-half of the entire distance. The submersible area of the Chotts Melrhir and Rharsa appears to be about 3,000 square miles, a tract about the size of the island of Corsica. It is drawn to scale upon the Mediterranean chart, and you may judge for yourselves the relation it bears to the area of the Great Desert.

The structure of the Chott Djerid is very curious. Captain Roudaire described it as a vast subterranean lake, covered with a crust composed of a mixture of salt and sand. It is crossed by a caravan road which is very dangerous to travel on as the crust sometimes gives way, and men and horses are lost in the waters. A story is told, on Arab authority, that on one occasion, a caravan of 1,000 laden camels was crossing the chott, when the leading animal wandered from the track and the others followed him. In a very short time the whole caravan was engulfed, and no more was to be seen of the 1,000 camels than if they had never existed. Captain Roudaire proposes to unite the Chotts Melrhir and Rharsa, and then to cut through the bar which divides them from Chott Djerid. In three years' time the submarine waters of the latter lake will have flowed into the two former, and the three chotts will form a single lake forty feet below the sea level. Nothing more will then be necessary than to cut a canal to the Gulf of Gabès, capable of carrying sufficient water into the chotts to supply the loss by evaporation, and the result will be an inland sea of about 5,000 square miles of area, by which English vessels may convey into the port of Biskra, Birmingham or Manchester goods in exchange for the dates of the Sahara. Notwithstanding the commercial attractions of the project, it is by no means certain that the necessary funds will be subscribed by the public, or that if they are, the engineering works will be so easy as M. Roudaire imagines. In any event we may dismiss from our minds all feeling of anxiety as to the effect upon the climate of Europe of the submergence of the chotts.

Whatever may be thought of M. Roudaire's "Projet de Mer Intérieure," there can be but one opinion of the merits of the geodetical operations by which the configuration of the region has been ascertained. The contours were determined by upwards of 6,000 observations with the spirit level along lines of a total length of 675 miles. The field work occupied 179 days of unremitting labour, in an unhealthy country, devoid of the means of subsistence, where, owing to the necessity of camping in the neighbourhood of wells, the observers, in addition to the work along the line of levels, had often to walk from twenty to thirty miles a day from and to the camping-places.

The scientific conception of the submergence of the Sahara differs from the popular in the absence of any hypothesis of level, and in pushing back the date of the occurrence from historic into geological time. If any doctrine could be considered as definitely established by the almost unanimous verdict of presumably competent judges, this would be one. Sir Charles Lyell, Professors Ramsay and Boyd Dawkins, Mr. Wallace, Dr. Tristram, Mr. George Maw, Mr. Ball, among

English; Herr Escher von der Lindt, M. Desor, M. Cosson, among foreign men of science, have expressed themselves in its favour. "We find," writes Sir Charles Lyell,* "that the Desert of the Sahara was under water between lat. 20 deg. and 30 deg., so that the eastern part of the Mediterranean communicated with that part of the ocean now bounded by the West Coast of Africa." Mr. Wallace writes,† "The important fact has now been ascertained that a considerable portion of the Sahara south of Algeria and Morocco was under water at a very recent epoch." In the face of such an array of authorities, it seems almost a presumption to ask for even a suspension of judgment. I shall venture, nevertheless, to examine the evidence upon which this conclusion is founded, and then to consider how far it is justified by what is really known of the physical geography of the Great Desert, and of the distribution of plants in the northern half of the African Continent.

That the Sahara was once a part of the sea bottom would be in no way remarkable, as the same might be said with perfect justice of most other portions of the land surfaces of the globe. The question of interest is, at what geological epoch was it last in this condition? M. Cosson shelters himself under the prudent phraseology, "*à une époque géologique relativement récente*," which may mean anything from the date of the chalk to that of the Irish peat bogs.‡ Mr. Wallace and Mr. Ball express themselves in language of equal caution. It is fortunate that some of our authorities are more explicit.

There is one remarkable difference between the southern hemisphere and the northern, viz., that in the former there is a great preponderance of sea in the region of the tropics, in the latter a slight excess of land. There is good reason to believe that the Antarctic ice fields are far more extensive than the Arctic, and some geologists suppose that the first set of conditions are

---

*Principles, 10th Ed., Vol. I., p. 250.

† "Distribution of Animals," Vol. I., p. 38.

‡ Le règne végétal en Algérie, p. 46.

connected with the latter by the relation of cause and effect. If we lay the northern half of Africa under water, we shall have an approximation to the existing condition of the southern hemisphere, and be able to account for the Glacial epoch in the northern. We have only to raise it again and to substitute for the sea the desert and the Sirocco, and the glaciers will disappear. Such is the theory of Escher von der Lindt, adopted by his countryman Desor, and supported by the authority of Sir Charles Lyell.* Those English geologists who, like Professor Ramsay, have difficulty in admitting it in its full extent, allow it a contributory effect. They agree in placing the submergence of the Sahara in the Quaternary age, and in assigning it to the Glacial epoch, and they consider its re-elevation to have been contemporaneous with the cessation of glacial conditions in Central Europe. The views of Sir Charles Lyell are expressed at length in his presidential address to the Bath meeting of the British Association in 1864, but the theory is more concisely stated by Professor Desor in the Bulletin Soc. Scien. Nat. Neufchâtel, 1864. Not having the original at hand, I quote from a translation by Professor Ramsay in the Geological Magazine, Vol. I., 1864.

"The idea of a slow but recent elevation of the Sahara had already been mooted as a theory by M. Escher, and it was a source of lively satisfaction to him to find his hypothesis confirmed on the spot. The presence of this sea was referred to by M. Escher to explain certain phenomena in our country connected with the Glacial period which ended when this sea disappeared. Is it possible to form an idea of the climatal conditions imposed on Europe by this vast extent of water? We may do so when we consider the influence exercised by the burning winds which come from the Sahara, and which are so justly called *snow eaters and glacier destroyers*. While the Sahara was covered with water our glaciers never felt the burning breath of the Föhn and Sirocco; the winters, never opposed

---

* "Elements," 6th Edition, 1875, ch. xii., pp. 174, 175.

by a lukewarm breeze, could accumulate their snows and their ice, and extend the borders of their empire. But when the desert was dry what an effect must have been produced by the first visit of the Föhn to the enormous Glaciers of our Alps! What torrents! What deluges of water! What ravages, especially on the southern slope! and how easy to comprehend the erosion of the mountains, and the levelling of the plain of Lombardy, subjected to these rude assaults, and covered with erratic *débris!*"

You will be anxious to learn what foundation there is for this superstructure, what proof, I mean, of three million square miles of North Africa having been actually under water in the Quaternary era. If you will refer to the most recent and most approved works on African geography, you will probably find it stated, either that fossils, evidently of marine origin, or that shells of existing Mediterranean species have been found in the Sahara. The first statement is consistent with the beds containing them being Palæozoic, the second is consistent with their being very early Tertiary.

The arguments relied upon by scientific writers who advocate the submergence theory are—

Firstly.—The contour of the country, some of the hills presenting flat tops at a uniform level crossing the stratification.

Secondly.—The occurrence of sand dunes and so-called Quaternary loams.

Thirdly.—The extensive deposits of earthy and alkaline salts.

Fourthly.—The existence of beds containing recent Mediterranean shells.

Mr. George Maw, who made a rapid journey to El-Aghouat in the spring of 1873, and communicated to the Geological Society the results of his observations,* lays great stress upon

---

* "Geological Notes on a Journey from Algiers to the Sahara." Q. J. G. S., Vol. XXX., p. 105.

the first two arguments. Speaking of the flat-topped hills, he writes: "I can only account for their contour by marine denudation." Again, "The plain south of the Djebel Sahari is covered with a deposit of grey silty loam, before referred to as the Sahara loam, and here we have clear evidence of recent marine submergence in the occurrence between the Djebel Sahari and the Hauts Plateaux of an extensive range of sand-hills."

It may be answered, first, that in the absence of organic remains, no argument may be more fallacious than that from contour; that similar contours are to be seen in every dry desert country, and may be due to other causes than marine denudation. Secondly, that there is no evidence of either the silty loam or the sand dunes being of marine origin; that the sea could not create the sand, it could only select it from previously existing materials, and that the sorting process might be effected by other agencies. M. Desor gives up the sand argument. "What," he writes, "is the origin of this sand? Does it come from the sea, as has been long supposed, or is it produced in place? M. Vatonne, Mining Engineer, in his journey to Rhadames, has settled this question, having demonstrated that the dunes are the result of sandy formations decomposed in place."

Other writers rely upon the argument from salt. Large tracts of the desert are covered with a saliferous crust, supposed to have resulted from the evaporation of the sea. M. Desor and Mr. Wallace lean to this view. Mr. Maw, however, proves conclusively that the salt is derived from the decomposition of saliferous marls containing masses of rock salt and gypsum, resembling the Keuper deposits of Worcestershire and Cheshire, from some of the beds of which he obtained fossils referred by Mr. Etheridge to the Cretaceous or Neocomian age.

Dismissing the argument from contour as of no value, and allowing Mr. Maw and M. Desor to cancel each other as to the argument from sand and salt, we are reduced to the argument from shells.

I need scarcely remark that if the Sahara has been sea bottom in Quaternary times, we may expect to find in some part or other of its area fairly complete collections of existing Mediterranean species, just as in Sicily we have Pliocene beds, with 146 species of Mediterranean shells, of which ninety-two per cent. are recent, and that in default of such evidence all other arguments in favour of submergence must be regarded with extreme suspicion. Mr. Wallace writes :—" Over much of this area sea shells, identical with those now living in the Mediterranean, are abundantly scattered, not only in depressions below the level of the sea, but up to a height of 900 feet above it."* What those species are, with one exception, or where they are met with, he does not tell us. For information on this head we must again refer to M. Desor. The observations of this geologist were confined to the region of the Melrhir and Tunisian chotts. In this district, in a bed of sand, beneath the superficial gypsum, he discovered a cockle and a whelk. The former shell, which was found in some abundance, and over a wide area, he refers to the *Cardium edule*, a common European species. Now the *Cardium edule* is characteristic of brackish water, and as M. Desor himself admits, indicates rather estuarine than marine conditions. By what logical process he infers that because the Chott region was once an estuary the whole of the great desert was a sea, I have been unable to discover.

One follows with great interest the pages of Mr. Maw's paper, hoping to find at last decisive evidence of the existence of modern shell beds. But just as it appears within our grasp, it vanishes like the mirage in the desert. Mr. Maw writes :— " I am also informed by Mr. Tristram that concrete shell beds, similar to those on the coast, occur in this neighbourhood," (*i.e.*, on the Hauts Plateaux.) " He does not mention

* "Distribution of Animals," Vol. I., pp. 38, 39.

their altitude, which, however, cannot be less than from 2,000 to 2,500 feet. They form a most important point in the evidence of Sahara submergence to which I shall have to make further reference." I cannot find in the pages of the Great Sahara* of Dr. Tristram, or elsewhere, any description of the discovery of recent marine shells in this locality; a discovery of such capital importance, if true, that it is astonishing that the fullest details respecting it should not have been made public.

The fact of the submergence of the Sahara implying a subsidence of nearly 3,000 feet lands us in hopeless perplexities respecting the date of the occurrence. Mr. Maw supposes that the subsidence was followed by an upheaval of from 3,000 to 6,000 feet, and that the re-elevation was contemporaneous with the production of glaciers in the Greater Atlas. What then, I ask, becomes of the beautiful theory of Messrs. Escher and Desor? Messrs. Boyd Dawkins and Wallace imagine that the depression of 3,000 feet in the Hauts Plateaux was coincident with an elevation of 3,000 along the Mediterranean coast line. The oscillations in level which have affected North Africa extended, as we have seen, to the whole Mediterranean region, the axes of the disturbances running, as Professor Boyd Dawkins has pointed out, for great distances from east to west. It is in the highest degree improbable that a depression of the magnitude required by Mr. Maw can have taken place in the Hauts Plateaux without submerging the Isthmus of Suez, the maximum height of which above the sea level is only 100 feet, and it is as nearly certain as any fact in geology can be that the Isthmus of Suez has not been submerged since the commencement of the Quaternary era.

Considering the vast extent of the Sahara we cannot expect to acquire an adequate conception of its physical geography from writers who have penetrated no farther than from 50 to 100 miles within it, and whose observations have been limited to a

* "The Great Sahara: Wanderings South of the Atlas Mountains." The Rev. H. B. Tristram.

few days or weeks. The best English account of the region is to be found in the interesting work of Dr. Tristram, before referred to, and even he did not pass very far beyond the limits of the French dominion. For the most complete description of the Sahara yet published we are indebted to M. Henri Duveyrier, who spent 29 months in the country, in the years 1859, 1860, 1861, and whose itineraries cover a total distance of upwards of 3,000 miles. The picture which he gives is so interesting that I shall endeavour to place it before you. The facts gain, rather than lose in attractiveness, from their being unmixed with fiction.*

The distance as the crow flies from Tripoli to Timbuctoo is about 1,500 miles. About midway between the two points is an elevated plateau of table land, rising near its centre into a mountain range called Djebel Hoggar or Ahaggar. This part of the Sahara is inhabited by the powerful and predatory tribe of the Touâregs; it has not been visited by any European, and what knowledge is possessed of it is derived entirely from native sources. The mountain range is said to be covered with snow for three months in the year, and, as well as the surrounding plateaux, to be occasionally visited by torrential rains. Its height, according to M. Duveyrier, is from 6,000 to 7,000 feet, but if the statement as to the snow is trustworthy this must be an under estimate. However this may be, there is no doubt that the plateau is seamed on all sides by valleys of erosion radiating from the central mass. These have three general directions, south into the valley of the Niger, west into the Atlantic, and north into the Lesser and the Greater Syrtis. They either are from the commencement, or very soon become, wadys, or river valleys apparently devoid of water. The absence of water is apparent only; every wady, besides occasional torrents in its channel, has a constant stream flowing underground. Where the water is accessible, either by artesian or ordinary wells of

* "Exploration du Sahara. Les Touâreg du Nord," Henri Duveyrier, Paris, 1864.

moderate depth, the wady gives rise to an oasis, and date culture and population are the result. The most important wady on the northern slope is the Igharghar. It runs by Tuggurt into the Chott Melrhir, has a total length of from 700 to 800 miles, and many tributary branches, on one of which is the oasis of Waregla, the furthest point of the French dominion.

M. Duveyrier's observations on the origin of the sand dunes might be studied with advantage by English geologists. He shows that they are entirely due to the disintegration of the superficial portions of the various rocky plateaux which surround the regions of the dunes. The most notable cause of this disintegration is the extreme variation in the temperature, the thermometer sometimes rising to 150 deg. F. in the sun in the day-time, and sometimes sinking as low as 20 deg. in the night. These figures do not, I presume, refer to the same time of year. I find in M. Duveyrier's meteorological register night temperatures in the hottest months as low as 70 deg., which would indicate a range of 80 deg. F. in ten hours, *i.e.*, from four A.M. to two P.M. The rocks of the plateaux being unprotected by any vegetable covering, are exposed to the full influence of this range of temperature. As the disintegration proceeds, the siliceous particles are carried away by the winds and deposited in dunes, which cover extensive tracts of the Sahara ; some of the dune regions attaining an area of 5,000 square miles, and entirely concealing the wadys. The products of the disintegration are also transported by the torrents, which in time of rain pour suddenly down the wadys, at least in their higher parts. M. Duveyrier relates that on one occasion he saw a torrent descending at the rate of a metre a second, and conveying a vast quantity of *débris;* and that, on another occasion, thirty-four persons and a great number of camels were drowned by a similar inundation. The disintegration of the strata is no doubt assisted by the beds of salt and gypsum which many of them contain, and which cause the waters of the wadys to be almost constantly brackish.

Although the Djebel Hoggar has not actually been examined by Europeans, there is some reason to believe that it is granitic. There are probably extinct volcanic cones on its northern slope, as volcanic scoriæ are stated to have been found in the northern wadys. M. Duveyrier carefully examined the geology of the regions he visited, and submitted to eminent French palæontologists the fossils which he collected. A large area north of the Djebel Hoggar was found to be occupied by Devonian rocks, and these were succeeded northwards by beds of Neocomian and Cretaceous age. The Djebel es Soda in the Tripoli desert, south of Mourzouk, was ascertained to be of volcanic origin. There is no mention in M. Duveyrier's work of the discovery, in a fossil state, of recent marine shells of any description. Three species of Planorbis and three of Physa were obtained from recent fresh-water deposits at El-Ouad and Ghadâmes. They are described in a Supplement by M. Bourguignat, who draws from them the amazing conclusion that this part of the Sahara, "which was, a few thousand years ago, a vast and profound sea, has been slowly and gradually raised during the human epoch."

The valleys of the Sahara must have had their origin at a time when the climate of North Africa was very different from the present. I believe them to be at least as old as the Glacial epoch, and to have remained above the sea level since the time of their erosion. The wadys of the Mediterranean versant of the central plateau almost all converge to the Chott Melrhir, which, with the area now occupied by the Tunisian Chotts, formed the estuary of a large river system. Its waters must have conveyed into the Gulf of Gabes a large mass of sediment. Now, perhaps, the most noticeable feature in the submarine contour of the Mediterranean is the shoal between Tunis and Sicily. With the possible exception of the embouchure of the Po, there is nothing at all approaching to it in extent at the mouth of any existing river which flows into the Mediterranean. From the nature of the bottom, as described in the Admiralty chart, it would appear to be the silt of a large river. It may be further inferred from the contours that the silt has been carried out to sea until it has abutted on the island of Sicily, and has formed an extensive deposit between Sicily and Africa, through which a channel has subsequently been cut by a marine current.

Much additional light has been recently thrown upon the structure of the Chott estuary by two French geologists, M. H. le Châtellier,* who was attached to the staff of M. Roudaire, and M. Edmond Fuchs.† M. le Châtellier points out that the saliferous deposits which are found in this region up to an altitude of more than 100 metres above the sea, do not show on analysis the same composition as modern sea salt. He states further that the only fossil which occurs in the Chott deposit is the cockle discovered by M. Desor, and this shell has been pronounced by no less an authority than M. Quatrefages to be a distinct species from the common Mediterranean cockle.

M. Fuchs, who has made a special examination of the Isthmus of Gabes, carries the argument still farther than M. le Châtellier. He considers the Isthmus to be composed of Cretaceous or Lower Eocene rocks surmounted unconformably by beds of Miocene age. The deposits actually encasing the Chotts he regards as Pliocene. On the Mediterranean side of the Isthmus M. Fuchs found at a height of from 12 to 15 metres above the sea, raised beaches containing numerous shells of living Mediterranean species. On the opposite side of the Isthmus the entire Chott depression, although examined with the greatest care, did not yield a single Mediterranean shell.

It appears from these facts not only that the land surface of North Africa is of great antiquity, but that the wadys converging to the Gulf of Gabes have been actually divided from the Mediterranean for a long term of years. It appears further that a desert region differs essentially from a fluviatile in this respect, that the entire products of sub-aerial erosion are scattered over its surface, instead of being conveyed into the rivers and carried out to sea.

---

* Bulletin Soc. Géog. de Paris, 6me Série. Tom. XII., pp. 211, 212.
† Ditto Tom. XIV., p. 248.

I now propose to examine the submergence theory from the point of view of the distribution of plants, and to trouble you with some further botanical statistics. We have unfortunately no complete census of the plants of the Algerian Sahara. Dr. Tristram,* in an appendix to his work, enumerates 712 so-called Saharan species, but as he includes the Hauts Plateaux within the Saharan limits, his list will not serve our purpose. M. Cosson, whose knowledge of the Saharan vegetation is greater than that of any other living botanist, estimates the number of species in the Saharan region of the province of Constantine at 560. The number for the whole Algerian Sahara is somewhere between the figures of Dr. Tristram and those of M. Cosson, and may be roughly stated at 600.

I have extracted from Munby's catalogue all the species specially assigned to the Sahara. They may number 275, and may be classified as under:—

Sahara	251
Sahara and Littoral............	18
Sahara and Hauts Plateaux. .	5
Sahara and Atlas	1
	275

It may be assumed that the remaining species indigenous to the Sahara are widely distributed in Algeria, and that these 275 species form the typical Flora of the Algerian portion of the Desert. They are remarkable for the predominance, among the larger orders, of the Cruciferæ, Salsolaceæ, and Boraginaceæ; among the smaller, of the Resedaceæ, Zygopbyllaceæ, Paronycheæ, and Plumbaginaceæ.

The 275 Saharan species may be divided into the following groups:—

European	70
Oriental	105
Remanet	100
	275

*App. viii.

Of the 70 European species 35 are confined to Spain. Of the 105 Oriental species very nearly all are Desert forms, belonging, not to the Mediterranean, but to the Egypto-Arabian type of distribution, some of them extending into the deserts of Persia, Beloochistan, and Scinde. The remaining 100 are endemic forms, or at any rate, plants not hitherto found beyond the limits of the Sahara. 16 out of the 275 occur in the Canaries.

We have already seen that a large portion of Britain was submerged during the Glacial age, that its indigenous Flora was almost destroyed, and that the result has been that no well defined endemic plant is to be found in the British Islands. If the Sahara had been subject to similar conditions during the same geological period, it might be expected to exhibit similar phenomena of plant distribution. We find, on the contrary, not only that it contains a large proportion of endemic species, but several remarkable endemic genera, which we cannot suppose to have been devoloped since the close of the Glacial epoch.

Again, if we deduct from the Algerian census of 2,933 the 251 species not found north of the Sahara, we shall have a census of 2,682 species for the remainder of the country, which may be estimated at 100,000 square miles. This is at the rate of one species for every thirty-seven miles of area, and indicates a Flora nearly twice as rich as that of Britain. The plants of North Africa, like those of Europe, must have been driven southwards by the cold of the Glacial epoch, and have returned northwards at its close. But if we imagine the sea to have extended in Glacial times to the southern foot of the Atlas, how could such migrations have taken place? All the less hardy species must inevitably have been destroyed, and North Africa would exhibit at the present day, not a rich, but a very impoverished Flora.

There is another point of interest connected with the vegetation of Algeria which I must not omit to notice, and that is its relation to the Flora of the Abyssinian Highlands, from which it is separated by upwards of 2,000 miles of desert. The most notable feature in the Abyssinian Flora is its affinity to that of Senegambia, on the opposite side of the continent. But, besides the Germanic plants, of which it contains somewhat less than 100, it has 49 species common to Algeria, 46 of which are European, and of these all but four are Spanish. Nearly all the 49 are Oriental plants, and fifteen are also Canarian.*

From whichever point of view the doctrine of the recent submergence of the Sahara be regarded, whether from that of the physical geography of Africa, or from that of the distribution of plants, it appears equally incredible. By recent submergence, I mean any submergence of post-Tertiary date. Beds of Miocene age on the southern slope of the Atlas indicate marine conditions in that locality in earlier Tertiary times, and resemblances said to exist between the Faunas of the Levant and the Gulf of Guinea, lend some colour to the hypothesis of a former union between those seas. How far the evidence goes I am unable to say, this part of the problem having been very imperfectly studied. If it should be found to justify the conclusion, the connection must be assigned to an earlier epoch than is commonly imagined.

* For the plants of Abyssinia, see Richard. "Tentamen Floræ Abyssinicæ." Paris, 1847, 1851.

Printed at the Herald Office, Union Street, Birmingham.