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The Maltese Islands, with special reference to their geological structure

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THE MALTESE ISLANDS, WITH SPECIAL REFERENCE TO THEIR GEOLOGICAL STRUCTURE.

(*With Geological Map, two Lithographic Plates, and Woodcuts.*)

By John Murray, LL.D., Ph.D., etc.

Of the "Challenger" Expedition.

When, in the year 1530, the Emperor Charles v. of Germany handed over the sovereignty of the Maltese Islands to the Grand Master of the Knights of St. John of Jerusalem, a commission was despatched by L'Isle Adam to examine and report on the new possession. The report is said to have been to the following effect :—

"That Malta, about sixty miles in circuit, was but an arid rock, covered in many places with sand, and in a few with a light scattering of earth brought from the neighbouring continent, or from Sicily ; that it had neither river, nor rivulet, nor spring, nor any other fresh water for the most part, save rain preserved in tanks or cisterns, except a few wells, rather brackish ; that it produced a little corn, not half enough of anything to feed the scanty population ; that it would be a very unpleasant residence, particularly during summer ; violently, nearly intolerably hot, with not one forest tree, hardly a green thing to repose the eye upon ; and a sort of ill-walled town, called its capital, in the middle of the island, at a considerable distance from the sea ; that, however, the stone is not hard, but rather *tufo*, or soft, and easy to cut into any shape ; that the people speak a dialect of Arabic or Moorish, and are noted for their frugality of living ; that, for the rest, the harbours may be rendered good, and that what are termed *casali* are miserable villages or shocking huts, rather befitting fishermen and pirates than the renowned Hospitallers ; that as to Gozo it was too little, though, in comparison of Malta, fertile and pleasant."

Seddall,[1] after quoting the above condensed report from the writings of Lieut.-Col. Porter, says :—"This description of the islands and their inhabitants holds good in nearly every particular even in the present day." While the islands are said by this writer to be interesting from their association with great events in ancient and modern history, they are represented as presenting few attractions beyond the walls of Valetta ;

[1] *Malta : Past and Present.* By Rev. Henry Seddall, p. 40 ; London, 1870.

the only scenery is burning rocks of white limestone and dusty roads flanked with stone walls—not a tree to shelter, not a blade of grass to cheer the eye. The tourist who alights from passing steamers to spend a few hours or days in the city of palaces and stairs, sees little of remoter parts of the islands, and on continuing his voyage usually repeats :—

> "Adieu, ye joys of La Valette !
> Adieu, Sirocco, sun, and sweat !
> Adieu, thou palace rarely enter'd !
> Adieu, ye mansions where—I 've ventured !
> Adieu, ye cursed streets of stairs !
> (How surely he who mounts you swears).
>
> . . . . .
>
> I 'll not offend with words uncivil
> And wish thee rudely at the Devil ;
> But only stare from out my casement,
> And ask, for what is such a place meant ?"[1]

These adverse views of the islands are not, however, shared by the native Maltese, who regard themselves as descendants of the ancient Phœnicians. For them there is no place on earth more beautiful, more fertile, more to be desired than the islands that gave them birth. In ardent and patriotic language Malta is referred to as the "flower of the world."[2] The native of Malta is as attached to this so-called barren rock as the Irishman to the "green isle," or the Scotsman to "Caledonia stern and wild." It is an effort for him to leave his island home; when abroad he ever desires to return, and this he almost invariably does when he has accumulated a competence or is overtaken by misfortune.

After climbing nearly every hill-top, visiting nearly every ravine, sailing under the magnificent sea-cliffs, and enjoying the splendid climate of Malta and Gozo, one is inclined to share the enthusiasm of the natives rather than acquiesce in the unfavourable opinion of so many travellers; the Maltese Islands are possessed of much natural beauty, and are full of interest for the geologist, naturalist, archæologist, philologist, historian, political economist, and politician.

In this paper I propose to give the results of some observations and investigations carried on, at intervals, during the past two or three years, with reference principally to the petrographical characters and composition of the rocks of Malta, and thereafter to point out the conditions under which these rocks were in all probability laid down on the floor of the ocean. It will appear from these researches that the Maltese Islands, far from being barren rocks, are probably among the most fertile, as well as the most populous, lands of the globe. Before dealing with the geology of the islands, it is desirable to state the principal facts concerning their geographical position, climate, and past history.

Geographical Position.—The Maltese Islands are situated near the centre of the Mediterranean, about 60 miles directly south of Sicily, on the banks which connect Sicily with the African continent, and divide the Mediterranean into two deep hydrographical basins, an eastern and a

[1] Byron, "Farewell to Malta."

[2] *Fior del Mondo.*

western basin, in each of which there are depths exceeding 2000 fathoms. The banks between the west end of Sicily and Tunis are in no part covered by more than 200 fathoms of water, and between the east end of Sicily and Tripoli the depths do not exceed 300 fathoms, while the greater part of the area of these banks has a much less depth, the Maltese group being placed on the southern edge of an extensive bank with an average depth of less than 50 fathoms. The other islands situated on, or in close proximity to, these banks are Lampion and Lampedusa, near the African shores, and the volcanic islands of Pantellaria and Limosa, towards the centre of the channel. The famous Graham volcano, which was an island for a few weeks, and was actually taken possession of by the British, but has now been reduced by the waves to the condition of a shoal, was situated to the north-west of the Maltese group, as will be seen by reference to the accompanying bathymetrical map. This map also shows that an elevation of a little over 50 fathoms would connect Malta with Sicily and Italy, and that an elevation of a little over 200 fathoms would connect Europe with Africa in the neighbourhood of these banks. An elevation of 200 fathoms would also connect Europe with Africa at the Straits of Gibraltar, and cut off the Atlantic from the Mediterranean, for the depth of water at the straits is about the same as on the bank connecting Sicily and Tunis.

These islands are situated in a region where evaporation much exceeds precipitation, hence the specific gravity of the surrounding sea-water is 1·0300, which is much higher than that of the Atlantic, or of any waters in the open oceans. The temperature of the surface-water in this part of the Mediterranean sometimes reaches 90° F.; the mean temperature of the first 200 fathoms off Pantellaria was found by H.M.S. *Shearwater* to be 66°·7 F. The temperature of the bottom-water in the western basin of the Mediterranean is about 54°·5 F., and in the eastern basin 56°·0 F., these temperatures being fully 20° higher than the temperature of the bottom-water in the Atlantic at corresponding depths. This large body of warm water in the deeper parts of the Mediterranean greatly influences the climates of the coasts, and especially of the smaller islands like Malta.

Extent and General Appearance.—The group consists of two principal islands, Malta and Gozo. Midway between these are the small islands of Comino and Cominotto with several small rocklets, and off the south-west of Malta the rocklet named Filfla or Filfola.

The direction of the long axis of the islands, which, with the intervening channels, is 29 miles in length, is NW. to SE. Malta is 17·5 miles in length, 8·33 miles in breadth, and has an area of 95 square miles. Gozo is 9 miles in length, 4·5 miles in breadth, and has an area of 20 square miles; Comino is 1·2 miles in length, 1 in breadth, and has an area of about 1 square mile. The width of the channel between Malta and Gozo is about 3 miles. The highest points of the two main islands are about the same elevation, viz. 758 and 743 feet above sea-level. In Malta the cliffs on the west and south rise sheer from the sea to a height of 300 and 400 feet; to the north the land shelves to the water's-edge in many places, and on this side there are large bays and excellent harbours for all classes of shipping. At Valetta and St. Paul's Bay, where the Apostle Paul was wrecked,[1] however, there are some high cliffs. The hills, especially in Gozo, have generally the appearance of a truncated cone, due to the structure of the geological strata, as will be subsequently pointed out.

The general appearance of the islands is bare, owing to the want of trees and the immense number of stone walls that enclose the fertile fields. These high stone walls give an aspect of sameness, and the reflection of the sun's rays from their reddish or white surfaces becomes after a time very irksome. Viewed, however, from some of the higher hills of Malta and Gozo, the land appears green, fresh, and fertile, especially in the spring, as the walls do not from such a position conceal the growing crops.

CLIMATE.—The mean January temperature in Malta is 54°·5 F.; the mean temperature of the three winter months (December, January, February) is 56°·0 F.; the rainfall for the same months is 17·5 inches, and during this time there are frequently hail-storms, but no snow.[2] The mean annual temperature is 67°·3 F., and the annual rainfall 24·23 inches. During the eight cool months the thermometer only on rare occasions falls below 50°, and does not rise above 71° or 72°. In summer the heat is almost tropical, the temperature ranging between 75° and 90° F., and there is little or no rain. For three successive years—from 1467 to 1470—no rain is said to have fallen at Malta, and the islands suffered greatly from drought. In 1852 only 8·27 inches fell, and in 1866 only 10·49 inches are recorded.

The northerly wind is bracing, and sometimes approaches the force of a gale.[3] In February 1889 this wind was so cold that in driving it was necessary to wear heavy fur coats and jackets, and at times the wind was accompanied with such heavy falls of hail that the ground became quite white for an hour or two. The south-west wind—the Sirocco from the African deserts—is very enervating; though this is a dry wind in Africa, it is, in Malta, charged with vapour, and while it is blowing the pavements of the streets are wet and everything feels damp. There are no rivers nor marshes on the islands, but during heavy rains the valleys are filled with torrents. Springs are found at the junction of the upper limestone with the underlying beds of clay and marl. The rain is speedily absorbed by the porous rocks. Earthquakes are relatively frequent, and coincident with disturbances in the Eastern Archipelago.[4]

BOTANY AND ZOOLOGY.—The flora is almost identical with that of Sicily, nearly every Maltese species being also found in that island. It is less extensive, but this is due to the total absence of rivers, mountains, marshes, and lakes, to the exposure to maritime influence, to the preva-

[1] Acts of the Apostles, chap. xxviii.

[2] Fischer, *Studien über das Klima der Mittelmeerländer.*

[3] "Gregale," or Euroklydon.—Acts xxvii. 14.

[4] At Foum el Rieh Bay ancient cart-ruts terminate abruptly on the cliff edge, showing conclusively that large portions have fallen away in recent times. Similar cart-ruts and artificial rock-caldrons are beneath water at Marsa Scirroco, and indicate, along with other circumstances, a recent submergence of the islands.

lence of strong winds, and to the spare rainfall—insignificant from June to August. Professor Gulia enumerates upwards of 900 species, representing 84 natural orders. The only peculiar forms are:—*Centaurea spathulata* (Zerafa), from Wied Babu and Gozo; *Atriplex gussoniana* (Gulia), from Marsa Scala; *Cynnomorium coccineum* (L.), from Gebla tal General and caves in the cliffs under Casal Dingli, parasitic on the roots of *Inula erythmoides; Parietaria diffusa*, var. *populifolia* (Nyman), from Guina. Mr. A. Caruana Gatto states the following as the general differential characters of the Maltese flora:—(1) A marked want of trees and shrubs, there being only nine sub-spontaneous trees and less than thirty shrubs; (2) a small number of vascular plants; (3) a strong predominance of annuals; (4) few species in proportion to genera, being nearly two to one; (5) a great preponderance of *Leguminosæ Compositæ* and *Gramineæ*, these making up by themselves more than one-third of the flora; (6) a maximum of vegetation in March and April, a minimum in July and August; (7) an unequal distribution of species over the islands, many species being restricted to peculiar areas.

In the spring-time the numerous indigenous plants give an appearance of great wealth and beauty to some of the valleys of Malta and Gozo. The flowers of Malta have indeed long been celebrated, and Gozo and Malta have still a great reputation for excellent honey. In many of the rocky ravines and bare dry plains and plateaux, a few dry karubu trees, prickly pears, vines, figs, oranges, and pomegranates, alone dot the landscape, but in some of the small well-watered ravines of the south coast there are many trees and a grateful shade.

The indigenous mammalia of Malta belong to well-known European species:—the rabbit, weasel, hedgehog, Norway rat, species of mice, and bats. The famous Maltese dog appears to be nearly, if not quite, extinct. Among domesticated animals, goats are abundant, and supply the inhabitants with milk; the udders are enormously developed, frequently trailing on the ground. The sheep also give milk, and have much the appearance of goats. Mules, asses, and cows are used in the fields; the cattle do not give much milk, are all fawn-coloured, and have tall, gaunt, lanky bodies. The horses of Malta are small and have been much improved in late years. The mules and donkeys belong to a good breed.

A great many birds visit Malta for a few hours or days in their passage across the Mediterranean in the spring and autumn months, usually arriving and leaving at night; some species, however, remain a few months and breed *en route* to Europe. In certain years some species, rarely seen at Malta, arrive in great numbers. Only seven species are resident all the year round. *Thalassidroma melitensis* (Schembri), is a local variety of *Th. pelagica* (L.), restricted to the islet of Filfla, where it breeds.

Turtles are often taken by the fishermen around the islands; there is a land tortoise, several lizards, harmless snakes, and frogs. St. Paul, according to native tradition, banished venomous snakes from Malta, as St. Patrick did from Ireland. The lizards on the islet of Filfla are a beautiful brown black colour—thus different from those on the mainland. There are numerous species of land and fresh-water shells, fourteen of which are peculiar to the islands, two species of terrestrial Isopods, many insects and Arachnids. The seas abound in fish and all the usual marine plants and animals of the Mediterranean.[1]

SOILS AND AGRICULTURE.—We shall see later on that the whole of the soil of Malta is derived from the disintegration of the subjacent rocks. The natives have with great industry collected this residue of the rocks from cracks, crevices, and pot holes, to spread on their fields. There seems to be no foundation for the widespread belief that soil was imported into the islands in past times. The soils of Malta are all in accordance with the strata on which they rest. On the upper coralline limestone is red clayey soil; on the outcrop of the stiff yellow and blue clays, sometimes mixed with detritus from the yellow sand, it is blue or grey; on the upper series of the Globigerina limestone there is a whitish marly soil; and on the "Franca" again, red soil. The lower coralline limestone is likewise covered with a red soil in the few places where exposed on the surface.

With reference to this subject, Mr. Osbert Chadwick has furnished me with the following notes:—

"The theory of importation does not, to my mind, appear to be probable. It may be that some Grand Master imported some ship-loads of soil, though no difference is to be observed between any of the lands of the Order and others in the neighbourhood.

"If we suppose that out of the 95 square miles which form the area of Malta, not more than 10 are covered with red soil to a depth of 1′ 6″, then we have $\frac{10 \times 3097600}{2} = 15,488,000$ cubic yards; at 200 cubic yards to a ship-load this gives 77,440 ship-loads, or one ship a day for two centuries, all of which must have loaded at or near the same place, such as Marsala, where I observe that a similar soil overlies an apparently similar geological formation. The assumed 10 square miles is a guess only, but the figures give an idea of the magnitude of the operation. I am not acquainted with the documentary evidence as to importation of soil, but it must indeed be strong to be accepted. I have observed that the Maltese, like most meridionals, have a strong tendency to adopt the most heroic and marvellous solution of any given problem.

"Roman puzzolana, still imported in considerable quantities, has almost certainly been mistaken for earth. It is still much used in Malta for imparting hydraulic qualities to the fat lime of the country. I have used it largely myself. It is, apparently, a clay calcined by the juxtaposition of lava, and is of a chocolate red colour, much resembling the red soil. As fragments of puzzolana are to be seen imbedded in mortar of all ages, it is well that attention should be drawn to the circumstance to prevent the deception of future observers. At the same time, it is quite true that the greater part of the cultivable soil has been prepared artificially, and that in many cases it has been collected and carted to considerable distances. At the present day surplus vegetable soil from any building site, road scrapings, and the like, are removed to cover and reclaim barren tracts of rock."

[1] See papers by C. Wright, W. Grant, W. C. P. Medlicot, Dr. G. Gulia, Dr. A. L. Adams, T. Davidson, Marquis of St. George, and others.

All the soils contain a large quantity of carbonate of lime; in many instances I have found over ninety per cent., the soil being then little more than the broken-down particles of the underlying rocks. It is the boast of the inhabitants that not a spot capable of cultivation is uncultivated. In the high grounds every field is a terrace, a level surface with a thin covering of soil enclosed by stone walls, and probably nowhere in the world has skill and industry been better exemplified than in the cultivated lands of Malta. There are still, however, large areas which are unoccupied and capable of being reclaimed and covered with soil. The soil though thin is very fertile, from the presence of phosphates and alkalies in the underlying rocks, and is never allowed to rest, yielding two and three crops in the year. Cotton was at one time largely grown for export, but now only for home consumption. Large quantities of early potatoes are grown for the English market, and barley, wheat, maize, clover, peas, beans, onions, melons, cummin, grapes, oranges, figs, and other fruits and vegetables are produced for export or home use. The farm implements are of the most primitive description; the plough is light and single-handed, and can be carried on a man's back. There is no tax on land, and the farmer is free from tithe and poor-rate, there being no direct taxes or rates of any kind in the islands. There is, however, an import tax of 10s. per quarter on corn, and when some years ago there was a suggestion to remove this bread-tax, the people opposed the proposal;—at the present time bread is said to be cheaper here than at any other Mediterranean port. One-third of the land belongs to the Romish Church, one-third to the Government, and the remaining third to private individuals. The average rental for good productive fields is at present about £2, 10s. per acre, and £1, 10s. for medium productive fields. The agricultural produce at the present time would only supply about four months' food for the existing population.

HISTORY.—From its central geographical position in the Mediterranean,—midway between Europe and Africa, between the Pillars of Hercules and the Syrian coasts of Asia,—as well as from the fertility of its soil and the excellence of its harbours, Malta has, from the earliest times, been a place of great importance for all the maritime peoples of these regions, and at the present time is the principal British naval station outside of England, and one of the best fortified strongholds of the British empire. If we except some interesting but rather doubtful indications, a careful search in the fossiliferous caverns and caves of these islands has not as yet revealed any traces of prehistoric man, and none of the human monuments have with certainty been ascertained to belong to a historical period prior to the Phœnicians.[1]

Malta is believed to be the Hyperia[2] of Homer—the home of the Phæacians, a race of giants, while Gozo has been identified with the Ogygian Isle, where Ulysses took refuge, and tradition still points out the grottoes

[1] Davy, *Ionian Islands and Malta*, p. 112, London, 1842; Leith Adams, *Nile Valley and Malta*, p. 195, Edinburgh, 1870.

[2] *Odyss.* lib. 6.

of Calypso. Old historians and geographers agree in admitting that the islands were once the home of a race of giants, and this opinion was supported by later writers consequent on the discovery of huge mammalian ribs, bones, and teeth in the quaternary deposits, as well as on the presence of the still existing megalithic monuments.

The earliest inhabitants of whom there are any authentic traces are the Phœnicians; they are believed to have formed settlements in Malta 1500 years before Christ, and the "Eigantea" or Giant's Tower of Gozo, "Hagiar Kim" and "Mnaidra" in Malta, have been shown to be remains of their temples, while other rough stone monuments, pottery, glass vessels, sculptures, inscriptions, and rock-cut tombs equally remain to the present day as probably the best preserved and authenticated relics of this Semitic people—the greatest maritime race of antiquity. The present language of the Maltese is, indeed, a dialect of the Arabic, with many words adopted from the languages of other Mediterranean peoples, and it is stated to exhibit a great analogy with Chaldean, Hebrew, and Phœnician; it is, however, an unwritten tongue, without a literature or an alphabet. A Greek colony, probably from Syracuse, is said to have formed settlements in the central and elevated sites of the island about 700 years before Christ, living peacefully with the Phœnicians, who occupied the sea-shore. The sarcophagi of terra-cotta and other Egyptian remains were probably introduced by the Phœnicians, for it is well known that the Egyptians hated the sea, and that their vessels were usually manned by Phœnician sailors. Caruana has pointed out the great riches of the islands in Greek, Carthaginian, and Roman antiquities, as well as Phœnician, and has shown how these indicate a great prosperity in these islands in Pagan and early Christian times. Speaking of the remains of an ancient Greek building discovered in 1888, he says:—"These remains are of a great interest on account of the additional evidence they afford to the flourishing state of agriculture in these islands even in remote epochs, and to the existence of large plantations of olive trees at that time; an evidence which is further corroborated by the designation of the village 'Zebbug,' *i.e.* of olive trees, and of that of the other village 'Zeitun,' which means yielding oil. This discovery confirms, moreover, what has been stated on former occasions, that the eastern part of the island of Malta was in former days and at a remote period most inhabited and studded with large centres of habitation, of which nothing now remain but their relics and former nomenclature."[1] Diodorus Siculus refers to Malta under the name of *Melite* and Gozo under the name of *Gaulus*, and says:—"The inhabitants are very rich, inasmuch as they exercise many trades and in particular they manufacture cloths remarkable for their softness and fineness. Their houses are large and splendidly ornamented with projections and stucco."

When Carthage was at the zenith of its power, Malta appears to have been occupied by the Carthaginians, and was in their possession at the commencement of the first Punic war (264 B.C.). Several times the

[1] A. A. Caruana, 1888. See also his *Reports on Phœnician and Roman Antiquities*, 1881, 1882, 1885 and 1887.

islands were under the sway alternately of Carthaginians and Romans, and were finally held by the latter during the second Punic war (218 B.C.). Under the Romans the islands appear to have maintained their prosperity down to the commencement of the Christian era.

St. Paul was wrecked on the island of Malta in A.D. 58, and it appears to be admitted that this took place in the bay that now bears his name.[1] This circumstance led to the conversion of the Maltese to Christianity at a very early date; tradition says that the islanders have professed the Christian religion since it was first preached there by St. Paul. Christian monograms and inscriptions have been found dating back to the second century. A very large number of the extensive rock-cut subterranean tombs belong to the early Christian period, and are connected with places made out of the solid rock, evidently used for the celebration of religious ceremonies by the primitive Christians.

On the division of the Roman empire, in 395 A.D., the Maltese islands fell under the Eastern Empire, and the Vandals and Goths are said to have overrun the islands in the early part of the sixth century. However, a Byzantine garrison is mentioned as holding the islands in 870 A.D., in which year they passed to the Arabs, who held them for 220 years. If during this period the Maltese adopted the language of their conquerors, they did not adopt their religion, for the Norman knights, when they drove out the Arabs about 1090 A.D., were joyously welcomed by the Christian inhabitants. Malta passed under the authority of the German emperors in 1194 A.D., during whose occupation agriculture was totally neglected, under the Angevin kings of Sicily in 1266 A.D., and under the kings of Aragon in 1282 A.D., who held it for 248 years. In 1530 Malta and Gozo were taken possession of by the celebrated Knights of Malta, who held it for 268 years. In 1798 the Knights of Malta surrendered to Bonaparte, who remained six days on the island. In 1800 the French garrison surrendered to the British, and in 1814 the islands were formally ceded to the British Crown by the European Powers.

Population.—The Phœnician and Grecian remains show that in the earliest times these islands were the centre of an extensive trade and supported a large population. These remains, as well as the writings of Diodorus Siculus and other ancient authors, indicate a large amount of culture, comfort, and commerce, and the populations were then, in all probability, wholly supported by the produce of the islands. It is not possible to form any very correct idea of the actual number of the population in these early times. When the Arabs descended on the islands in 870 A.D. they are said to have put 3000 Greeks to the sword, and to have sold 3614 women and children for 5000 pieces of gold, which indicates a considerable population. When the Knights took possession it is said to have been 15,000, and to have been reduced to 10,000 after the memorable siege by the overwhelming force of Turks in 1568. In 1582 it is reported to have been 20,000. According to a census in 1632 the population was estimated at 50,113. In 1741 it was stated to be 110,000. When the French took possession in 1798 the number was

[1] James Smith, *Voyage and Shipwreck of St. Paul*, 1866.

114,000. Official returns in 1826 give the population of Malta and Gozo as 119,736. In 1881 the numbers were—Malta, 132,129; Gozo, 17,653; total, 149,782, exclusive of the English garrison, fleet, and their families, which numbered 10,000. The estimated population in March 1887 was—Malta, 138,826; Gozo, 18,627; total, 157,453. There are said to be 50,000 Maltese abroad, residing on the borders of the Mediterranean.

In Malta there are over 1471, and in Gozo 931 persons to the square mile. In England and Wales there are 446 to the square mile, and Belgium, the most densely populated country of Europe, has but 461 inhabitants to the square mile, so that the Maltese Islands are probably the most populous places in the world. This may be largely due to the passing trade, and to the presence of the British garrison and fleet. Malta is the port of call for the shipping engaged in the enormous trade that passes through the Suez Canal, between Europe and America in the west, and India, Australia, and other countries in the east, and since the British occupation enormous sums have been spent in making Malta one of the greatest fortifications of the world. We have seen, however, that Malta and Gozo supported large populations in times when none of these sources of wealth were in operation. They all along have been inhabited by a vigorous and prosperous race, which has an eventful history and often possessed a large measure of self-government. Whenever the inhabitants enjoyed security the fields were cultivated, ever yielding a sure return for the labour bestowed on them, and the population increased. When there was no security, as just before the arrival of the Knights, the cultivation of the islands was neglected and the population diminished. In tracing the geological history of the islands, I shall endeavour to show that prosperity has been quite as much dependent upon the fertility of the scanty soil, which is renewed year after year by natural processes, as upon the favourable geographical position or industry of the Maltese.

The population is almost exclusively Roman Catholic, and the difficulties about Maltese marriages now under discussion arise from the fact that canon law is recognised as the civil law of Malta. The population is increasing at a rapid rate, early marriages being encouraged by the Church, which provides each young woman with a small dowry. There is a large emigration of the surplus population to the northern shores of Africa, where the Maltese language is an advantage in trading with the Arabs, and where there is a demand for labour. Many of the large and beautiful churches met with throughout the islands have been built by voluntary labour, and nearly all the amusements and pastimes of the people are associated with Church festivals. There are many professional beggars in Valetta, but poverty in the proper sense of the term is practically unknown, the rural population being especially well-housed, regular, sober, industrious, and frugal. The peculiar dress at one time worn by the men has almost disappeared, but the graceful and becoming Faldetta is still worn by the women of all classes, with the exception of a few in Valetta, who of late years have adopted less elegant European head-dresses.

The language of the upper classes and of the law courts is Italian, but Italian is not understood by the peasantry any more than English; indeed, in the country districts and in Gozo, it is rare to meet with any natives who can speak English or Italian. One is particularly struck with the slight impression our ninety years' occupation has had upon the habits and customs of the Maltese. "Should the British leave the islands to-morrow," remarked a Maltese gentleman, "there would be no more traces of them in ten years than there are now of Greeks, Romans, or Arabs." The country population appears to be remarkably stationary, and to have mixed little with, or to have been little modified by, the successive dominant races who have for various lengthened periods held possession of the islands. This gives some ground for the prevalent belief among the Maltese, that the basis of the population, as well as of the language, is of Phœnician, or at least Carthaginian, origin.

GEOLOGY.

A few years ago I became interested in the microscopical structure of the Maltese rocks, from their resemblance in many respects to some of the deep-sea deposits collected during the *Challenger* Expedition. In the year 1888 I received from Surgeon David Bruce and Mr. Osbert Chadwick, a valuable series of rocks from the various strata in different parts of the islands, along with manuscript notes and sketches. I made a careful study of these specimens by means of numerous microscopic sections and chemical analyses. Subsequently, in the spring and summer months of the years 1889 and 1890, I paid visits to nearly every part of the islands with the view of studying the rocks *in situ*, and of observing their relation to each other.[1]

The rocks of Malta consist of a great series of nearly horizontal layers of crystalline, granular, or earthy limestones, together with a bed of greensand and a bed of stiff blue clay or marl; as follows:—

1. Upper Coralline Limestone (300 feet in Comino).
2. Greensand (from 0 to 35 feet).
3. Blue Clay (from 1 to 30 or 40 feet).
4. Globigerina Limestone (about 250 feet).
5. Lower Coralline Limestone (fully 500 feet).[2]

English authorities have classed these rocks sometimes as Eocene, sometimes as Miocene. Theodor Fuchs, who visited the islands in 1872, refers the two lower layers (4 and 5) to the Oligocene (Aquitanian), and the three upper (1, 2, and 3) to the Miocene. No. 1 he calls Leythakalk, No. 2 Greensand and Heterostegina Limestone, No. 3 Schlier, No. 4 Pecten layers of Schio, No. 5 Lower Limestone, and the whole series is, according to him, similar to the deposits of the Vienna basin. Seguenza regards the Malta rocks as Miocene, and compares them to similar deposits in Italy and Sicily. Many of the microscopic sections of the

[1] During my visits I was much assisted in my investigations by Messrs. C. H. Colson, J. H. Cooke, N. Tagliaferro, G. Gollcher, Rev. G. Wisely, Spiteri Bruno, and others.

[2] "Un Voyageur français" (1791), Boisgelin (1805), and Davy (1842), gave in their publications some account of the geology and petrifactions of the Maltese Islands, but the first

Globigerina limestone of Malta appear to me to be identical with the microscopic sections of Pliocene deposits of Sicily. While Spratt, Adams, and other English writers state that the fossils are nearly the same throughout the whole of the layers, Fuchs, on the other hand, finds a very marked difference between those of the three upper layers, which he considers Miocene, and the two lower ones, which he regards as Oligocene. He suggests that there has been some error in labelling the specimens which have been described by English writers, and that there has even been a mixture with specimens from the rocks at Syracuse. In addition to these Tertiary formations there are stretches covered with recent alluvium, and in some ravines, caves, fissures, and along the sides or at the heads of valleys, there are Quaternary deposits of red earth and rolled pebbles, in some of which numerous remains of extinct mammalia, birds, and reptiles, have been discovered. In one of these deposits at Marsa Scirocco, I found rolled fragments of a black limestone, which has not been found *in situ* on the islands.[1]

The accompanying geological map shows the distribution of these various strata in different colours, and is a modification of the one originally prepared by the Earl Ducie and Captain Spratt; it has been constructed for me, from the most recent surveys and latest information, by Mr. J. G. Bartholomew, F.R.S.E.

Malta is crossed by a grand fault nearly at right angles to its long axis, running from Madalena Bay on the north-east coast, to Foum el Rieh Bay on the opposite side of the island. A fault also runs across the south-eastern end of Gozo, nearly parallel to the grand fault in Malta. The land in the space between these two faults would appear to have been thrown down several hundred feet. In this way the great development of the upper coralline limestone in this region and the almost complete submergence of the lower coralline limestone, is to be

systematic description was published in 1843 by Captain T. Spratt. The following is his classification of the rocks, slightly modified by A. Leith Adams :—

No. 1.—Upper Limestone, greatest depth 250 feet, ... (=Upper Coralline Limestone, Murray.)	White rubbly limestone. Coarse-grained sandstone. White or grey-brown bed. Red coralline stratum.
No. 2.—Sand, greatest depth 60 feet, . (=Greensand, Murray.)	Red or yellow indurated rock. Black, with red patches, sand. Black-grained sand.
No. 3.—Marl, greatest depth 100 feet, . (=Blue Clay, Murray.)	Blue clay, with lighter-coloured bands.
No. 4.—Calcareous Sandstone, greatest depth 200 feet, ... (=Globigerina Limestone, Murray.)	Pale grey rock. Nodule seam. Fawn-coloured rock, with nodules of selenite. Nodule seam. Irregular bands of green-coloured nodules. Pale red or bluish rock. White rock, with chert nodules, then a seam of nodules, and lowermost a pale yellow sandstone.
No. 5.—Lower Limestone, greatest depth above sea 400 feet, ... (=Lower Coralline Limestone, Murray.)	Transition or scutella bed. Nodule seam. Concretionary and oolitic limestone. Irregularly compact, sometimes semi-crystalline.

[1] See Feilden and Maxwell, "Post-Pliocene Beds in Gozo."—*Il Barth*, p. 468 ; Valetta, 14th October 1874.

accounted for. The islands of Comino and Cominotto, which lie between these faults, are wholly composed of the upper limestone. There are some minor faults in St. Paul's Bay, and in the Melliha Valley, running across the whole width of Malta and parallel to the greater faults. Along the south coast of Malta — at Malak — there is also a fault with a great down-throw nearly at right angles to the above faults, which accounts for the fact that Filfla is wholly composed of upper limestone rocks, while the high cliffs of Malta opposite this islet are lower limestone and Globigerina limestone. In Gozo there is a fault apparently nearly parallel to this Malak fault, running from Miggiar Scini to the General's Rock. Near Ras il Kala and at Sclendi in Gozo, and also at Foum el Rieh Point in Malta, there are large triangular down-throws and up-throws. In sailing along under the high cliffs numerous other faults were observed, but it was impossible to trace them inland. At Macluba, near Krendi, there is a circular pit-like depression —a kind of circular fault—which seems to have resulted from a falling in of the strata, and there is a similar depression in Gozo near the General's Rock, described with some detail by Spratt. In the calcareous sandstone, or, as I prefer to call it, the Globigerina Limestone, there are numerous fissures and faults. These faults have an up- or down-throw varying from a few inches to six or seven feet. Similar small dislocations can be seen, but much less frequently and distinctly in the other formations. There is a slight dip in the strata to the NE. or ENE., the effect of which is that the lower beds are submerged along the eastern coasts, while they rise to a height of 300 feet along the opposite shores. There are numerous anticlinal folds, and near some of the faults the strata are tilted at considerable angles. On all sides, and on the surface of all the formations, there is abundant evidence of an immense amount of subaërial denudation.

I. UPPER CORALLINE LIMESTONE.—This is the uppermost of the Tertiary layers in the Maltese Islands. As will be seen by reference to the map, it covers large portions of the west and north-west districts of Malta, and forms a capping to almost all the higher hills of Gozo; the islands of Comino, Cominotto, and Filfla are entirely composed of these coralline rocks. In Comino the cliffs of this rock are 250 feet in height, and in places show distinct beds; but as a rule there is no marked bedding, but rather large patches of red, white, and yellow colour. Fuchs states that in their petrographical aspect these layers are identical with the *Leythakalke* of the Vienna basin. The texture of these rocks varies greatly, being sometimes rubbly, sometimes granular and porous, at other times compact and crystalline. Some layers appear to be wholly crystalline, and to have lost all traces of the original organisms of which they were doubtless composed. There are numerous casts of shells and other marine organisms, such as numerous large-sized Molluscs and Echinoderms, all indicative of a shallow-water deposit. When not composed of calcite of secondary formation, the rock is made up of the broken fragments of Nullipores, Corals, Echinoderms, Gasteropods, Lamellibranchs, Polyzoa, Crustacea, Ostracode valves, Serpula tubes, and many Foraminifera. The general appearance of the rock and the contained organisms, as seen in a microscopic section, is represented in Plate I. fig. 1. In some of these sections the fragments of calcareous Algæ prevail, while in others fragments of Polyzoa, Corals, and Foraminifera are the most abundant.

The analyses of a number of specimens gave from 82·97 to 91·90 per cent. of carbonate of lime, and nearly all the specimens contained traces of phosphoric acid.[1] The residue, after the removal of the carbonate of lime by dilute acid, consists of clayey matter and oxide of iron, with minute fragments of quartz, felspars, augite, zircon, tourmaline, and a few grains of glauconite, none of these, with the exception of the glauconite grains, exceeding 0·5 mm. in diameter;[2] in some specimens a few sponge spicules were observed. The thickness of the Upper Limestone varies greatly; it is probably over 250 feet thick in the island of Comino, but on many of the Gozo hills it is only a few feet in depth, and is fast crumbling away through the destructive action of the weather and the disintegration of the underlying Greensand.

This rock, from the nature of its organisms, would appear to have been laid down in quite shallow water, probably less than 50 fathoms, and possibly in depths mostly under 20 fathoms. The deposits out of which these rocks have been formed were in all likelihood built up in a warm open sea not far from a continental shore, but removed from

[1] A heavy granular specimen from the edge of valley at Ramla Bay, consisted almost entirely of carbonate of lime, with minute traces of phosphoric acid and magnesia. Five specimens from the summits of Gozo hills were all very rich in carbonate of lime, in one sample phosphoric acid (more than a trace) being present, and in another a trace of magnesia. No traces of phosphoric acid were observed in the samples from Comino, but a sample of a soil produced by the decomposition of the limestone, and procured from the top of the cliffs of this island, gave on analysis the following results:—

Carbonate of lime ($CaCO_3$),	16·75
Phosphate of lime (Ca_32PO_4),	2·22
Iron and alumina (Fe_2O_3 and Al_2O_3),	3·87
Carbonate of magnesia ($MgCO_3$),	0·44
Residue insoluble in dilute acid,	76·42
	99·70

The calcium phosphate is equivalent to 1·017 per cent. of phosphoric acid (P_2O_5).

The above insoluble portion was subjected to quantitative examination, and gave the following results:—

Iron and alumina (Fe_2O_3 and Al_2O_3) [the latter predominating],	62·65
Silica, (SiO_2),	31·99
Magnesia, (MgO),	1·97
Lime (CaO),	3·38
	99·99

Traces of phosphoric acid were obtained from two red-coloured, hard, and crystalline specimens from the upper edge of cliff, Lighthouse Hill. Two specimens from Citta Vecchia were white and friable, and contained traces of both phosphoric acid and magnesia. A cube cut by Mr. Chadwick from this stratum capping the hills round Notabile, shows traces of magnesia, but not of phosphoric acid.

[2] These mineral particles were determined by Professor A. Renard of Gand.

the embouchure of any large rivers. This appears to be indicated by the nature of both the organisms and the mineral particles.[1]

The following is a list of the Foraminifera observed in this formation :—

Biloculina elongata, d'Orbigny.
Spiroloculina tenuis (Czjzek).
Miliolina seminulum (Linné)
,, *oblonga* (Montagu) (?).
,, *trigonula* (Lamarck).
,, *subrotunda* (Montagu).
,, *auberiana* (d'Orbigny) (?).
,, sp. (?).
,, sp. (?).
Alveolina melo (Fichtel and Moll).
Textularia gramen, d'Orbigny.
Verneuilina spinulosa, Reuss.
Tritaxia sp. (?).
Clavulina sp. (?).
Bolivina sp. (?).
Cassidulina crassa, d'Orbigny.
Lagena sp. (?).
Nodosaria mucronata (Neugeboren).
Polymorphina gibba, d'Orbigny.
,, sp. (?).
Globigerina æquilateralis, Brady (?).
Globigerina bulloides, d'Orbigny.
,, *conglobata*, Brady.
Discorbina globularis (d'Orbigny).
,, *orbicularis* (Terquem).
Planorbulina mediterranensis, d'Orbigny.
,, sp. (?).
Truncatulina lobatula (Walker and Jacob).
,, *refulgens* (Montfort).
,, sp. (?).
,, sp. (?).
,, sp. (?).
Pulvinulina patagonica (d'Orbigny).
,, *oblonga* (Williamson).
Nonionina boueana, d'Orbigny (?).
Polystomella crispa (Linné).
,, *striatopunctata* (Fichtel and Moll).
Amphistegina sp. (?).

The most abundant species are *Miliolina seminulum* and *M. trigonula*.

[1] Mr. Colson supplies me with the following notes on building stones from the different layers of this formation :—" At the top of this Coralline Limestone, which contains four beds, is found the white rubbly limestone. This is entirely useless for any kind of building purposes, with the exception of very rough walls in the country, as it consists almost entirely of casts of shells, is very loose in structure, very porous, easily broken, and weathers into holes very quickly. This rock would probably make a fat lime if burnt. It is mostly found on the SW. hills and in some parts of Gozo. The second layer is almost identical in composition with the first, only differing in that the casts are very much smaller and the cementing material granular in appearance ; it is also, like the first, useless for building purposes of any but the roughest description. The third layer is much harder, closer in texture, and crystalline in structure, still containing large quantities of casts of shells, but they are generally smaller and harder than those in the beds above. This stone often presents a semi-translucent appearance. It is much used for building, especially in the districts where it outcrops, and, if well and carefully selected, is durable and weathers well. In some quarries the stone is much stratified in hard and soft layers, and great care is then required in selection. In the quarries of Melliha, for example, the stone in some parts is of the above character; in others it is full of cavities and fissures containing soft white powder, and weathers very badly; while in the remaining parts it is crystalline, semi-translucent in appearance, and, although it still sometimes contains numerous cavities, weathers very well. The stone quarried at Ta Ghalia, to the SE. of Citta Vecchia, is also from this bed, but, I think, from the lower part. The stone from this quarry is of two qualities: the better quality is the lower of the two, and is hard, crystalline, and translucent, contains very few cavities, only occasional casts of small shells, and weathers very well; while the second quality is softer, whiter, contains larger and more numerous casts of shells, larger cavities, containing white powder, and weathers badly. The best stone from this quarry works well, and takes a good polish, and blocks of a large size can be obtained. The lowest bed is mostly exposed as a capping to the conical hills in Gozo. It is hard, consists almost entirely of imbedded casts and shells, varies in colour from red to yellow, and takes a good polish. It is quarried under the name of Gozo marble, but it is difficult to obtain in any but small blocks, as the bed is thin and fissured."

II. Greensand.—This is a characteristic Greensand, containing a very large number of true glauconitic grains, together with many Foraminifera and fragments of other marine organisms, in nearly all respects identical with the green sands now in course of formation in modern seas. It has hitherto been known as the Black and Yellow Sands. The stratum varies greatly in thickness; in some places it is from 20 to 50 feet in depth, but is frequently absent altogether. The upper layers are usually of a yellowish colour, from the oxidation of the outer surfaces of the glauconite grains; this yellow colour is especially characteristic of the water-bearing strata. Frequently the sand is quite black, and consists almost wholly of glauconite. A fine variety of this black sand is used as blotting for writings on paper.

The carbonate of lime ranged in ten specimens from 28·65 to 89·63 per cent., and consisted of fragments of Foraminifera, Polyzoa, Molluscs, Ostracodes, otoliths of fish, Echinoderms, calcareous Algæ, and other organisms. The remains of dugongs, manatees, dolphins, whales, and sharks have been discovered in these greensand layers, which were evidently deposited in deeper water than the overlying coralline limestone. In some instances in Gozo, and in the cliffs near Dingli in Malta, *Heterostegina* shells exist in enormous quantities, and the rock has been called a Heterostegina Limestone. These shells are frequently found in long rolls, the one shell being laid sideways against the other. In such a sample the carbonate of lime is as high as 91 per cent.

Phosphoric acid and magnesia were found to be present in all but two of twenty samples that were examined for these substances, the phosphoric acid being very abundant in some nodules from this layer.[1] The mineral particles left after the removal of the carbonate of lime by dilute acid consist of glauconite, felspars, quartz, augite, hornblende, magnetite, zircon, and tourmaline. The glauconite grains have a mean diameter of about 0·5 mm.; the other mineral particles rarely exceed 0·2 mm. in diameter. The general appearance of a microscopic section of this sand is shown in Plate II. fig. 2. The relative abundance of the different fragments varies greatly in specimens from different parts of the bed.

The passage between this bed of sand and the overlying Coralline Limestone is often difficult to trace, but it is frequently marked by a bed consisting almost entirely of grains of calcite, each having in the centre a minute particle of limonite; a few Foraminifera and fragments of other organisms can, however, be traced among the grains of calcite. This layer may be seen extending downwards into the sandbed at some points, and has apparently been formed after the elevation of the land. The Greensand has no great horizontal extension on the surface of the islands. Through its weathering easily the overlying Coralline Limestone is undermined and falls away, forming steep cliffs at the tops of the hills,

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[1] Three yellow-coloured, friable specimens from the valley, Ramla Bay, and one from Nadur, contained small quantities of phosphoric acid and magnesia. Several red and yellow friable samples from Ghelmus contained much phosphoric acid, but no magnesia. Four samples from under the Upper Limestone at Lighthouse Hill contained both phosphoric acid and magnesia. Two specimens freshly cut from this stratum by Mr. Chadwick contained considerable quantities of phosphoric acid, but only traces of magnesia.

while the Greensand and Clay form the slopes at the base. It is this geological peculiarity which gives the Gozo hills the appearance of truncated cones, with table-like top[1] (see sketch at foot of map).

The following is a list of the Foraminifera observed in this formation :—

Miliolina bicornis (Walker and Jacob).
,, *seminulum* (Linné) (?).
Planispirina celata (Costa).
Haplophragmium sp. (?).
Textularia sagittula, Defrance.
,, *agglutinans*, d'Orbigny.
Verneuilina spinulosa, Reuss.
Tritaxia sp. (?).
Gaudryina sp. (?).
Bolivina karreriana, Brady (?).
,, *costata*, d'Orbigny.
Lagena sp. nov. (?).
Nodosaria scalaris (Batsch.)
Cristellaria obtusata, Reuss (?).
Polymorphina elegantissima, Parker and Jones.
,, *ovata*, d'Orbigny.
,, *lactea* (Walker and Jacob).
Uvigerina asperula, Czjzek (?).
Globigerina bulloides, d'Orbigny.
,, ,, var. *triloba*, Reuss.
,, *rubra*, d'Orbigny.
,, *inflata*, d'Orbigny (?).
Orbulina universa, d'Orbigny.
Truncatulina ungeriana (d'Orbigny).
,, *rosea* (d'Orbigny).
,, *lobatula* (Walker and Jacob).
,, sp. (?)
Pulvinulina schreibersii (d'Orbigny) (?).
,, *oblonga* (Williamson).
Rotalia orbicularis, d'Orbigny.
Nonionina boueana, d'Orbigny.
Polystomella crispa (Linné).
Operculina complanata (Defrance).
,, ,, var. *granulosa*, Leymerie.
Heterostegina depressa, d'Orbigny.

The most abundant species are :—*Miliolina seminulum, Gaudryina* sp., *Bolivina karreriana, Truncatulina ungeriana, Operculina complanata*, var. *granulosa*, and *Heterostegina depressa*.

III. Blue Clay or Marl.—This bed lies immediately under the Greensand, and has been estimated to have a thickness of thirty to forty feet in some places, but it is frequently much less, and occasionally it would appear to be wholly wanting, the Greensand or Heterostegina

[1] Mr. Colson says of the layers in this formation :—"The uppermost layer of the Greensand consists of a sandy rock indurated at the top with lime brought down with the water from the overlying stratum, and gradually passing at the bottom into the sand. It varies from hard to soft, and from white and yellow to red in different localities, and almost always contains black grains. The black and yellow sands with red patches in places follow next in order. These are utterly useless as stone, breaking up rapidly under the fingers, and, as they contain a large amount of clayey and calcareous matter, are not adapted for making mortar without very thorough washing ; as the outcrop is usually on a hill, the expense of cartage and washing would be very great in comparison with that of screening the dust and cuttings from working the third quality stone, so that it is never used. The most important outcrops of this stratum are on the SW. side of Malta, and at the top of the hills in Gozo. The next bed beneath is of a yellowish colour, containing more clayey matter than the layer above, and is sometimes more compact and harder, but is still entirely useless for any kind of building. It contains black grains from the layer above and indeed passes, in some places, insensibly into it. A lower bed consists of the same materials as the overlying layer, except that it does not contain so many of the black grains ; it is harder, but still soft and useless for building except rough work. It contains large numbers of enormous flat sea urchins. Fort Chambray in Gozo is partially built on this stratum, and stone from it has been used for building the walls of the old cemetery. These walls have weathered very badly, and show the harder fossils in high relief."

Limestone then resting directly on the great Globigerina formations to be presently described. Along many parts of the coasts, as at Fort Chambray and Ramla Bay in Gozo, huge mounds are met with sloping down to the sea and covering the lower formations; in these positions it appears to have been washed or forced out of its original position between the other formations. In all cases it is difficult to estimate the thickness of this clay, as it is usually banked up in terraces along the slopes of the hills, but it probably rarely exceeds 20 feet.

This clay is generally water-tight, so that the engineers in search of water always stop sinking when they strike this bed. Were it not for the retentive nature of this bed of clay, Malta and Gozo would have little if any water supply. At the level of this layer the Maltese run in tunnels to collect water for irrigation and other purposes, and the famous aqueducts, constructed over 200 years ago, carry water to Valetta from this layer for a distance of about eight miles. In two typical examples the carbonate of lime was 2·56 and 5·12 per cent. respectively of the whole deposit, but in some samples this clay or marl contained as much as 30 per cent. of carbonate of lime.[1] The carbonate of lime consists chiefly of Foraminifera and Coccoliths and Coccospheres, and among the Foraminifera *Globigerinæ* of the same species as those in the Globigerina Limestones are the most abundant. The mineral particles are likewise mostly identical in size and nature with those found in the Globigerina Limestones beneath, consisting of angular and rounded grains of quartz, augite, hornblende, glauconite, felspars, zircon, and tourmaline. The clay contains sulphate of lime, and iron pyrites is abundant, having collected around many of the fossils so as to render them indistinguishable. The lighter-coloured bands of the upper layers of the Clay are due to the higher state of oxidation of the iron in them, arising from contact with the water which rests on this and partially fills the Greensand above. This Blue Clay seems to be identical in its mineralogical composition with the residue of the blue patches in the Globigerina series to be mentioned hereafter. Fuchs at first believed this clay to be equivalent to the "Tegel" of Baden, but later, from a study of the organic remains, he considered it identical with the *Schlier* formation of the Vienna basin.

The clay is used for pottery when mixed with sand, and as puddle for dams in engineering works. For this last purpose it is wanting in cohesion, becoming gradually soft and wasting away when exposed to running water or rain. Several of the layers immediately underlying the clay are of a blue colour, and are regarded by some observers as belonging to the clay or marl; indeed, in some places there is a gradual transition from the clay to the Globigerina series, and it is difficult to say where the one begins and the other ends. Whenever the percentage of

[1] Two specimens from a cave near Fort Tigne contained phosphoric acid and magnesia in small quantities. In a specimen from marl heap, Ramla Bay, were found small quantities of magnesia and traces of phosphoric acid. Two specimens underlying the Greensand at Lighthouse Hill, Gozo, gave small quantities of phosphoric acid and traces of magnesia. Two cubic blocks cut by Mr. Chadwick yielded small quantities of phosphoric acid and traces of magnesia.

carbonate of lime is less than 30 per cent. I have regarded the layer as belonging to the clay.

The following is a list of the Foraminifera observed in this formation :—

Spiroloculina tenuis (Czjzek).
,, *tenuiseptata*, Brady.
Miliolina oblonga (Montagu).
,, sp. (?) [cast].
Planispirina celata (Costa).
Haplophragmium pseudospirale (Williamson).
Textularia trochus, d'Orbigny.
,, *agglutinans*, d'Orbigny.
,, sp. (?).
Gaudryina pupoides, d'Orbigny.
Clavulina communis, d'Orbigny.
,, *cylindrica*, Hantken.
Bulimina pupoides, d'Orbigny.
,, *buchiana*, d'Orbigny.
,, *elongata*, d'Orbigny.
,, *inflata*, Seguenza.
,, *elegans*, d'Orbigny.
,, ,, var. *exilis*, Brady (?).
Virgulina schreibersiana, Czjzek.
Bolivina textilarioides, Reuss.
,, *karreriana*, Brady.
,, *hantkeniana*, Brady (?).
,, *dilatata*, Reuss.
,, *pygmæa*, Brady.
,, *punctata*, d'Orbigny.
,, *costata*, d'Orbigny.
,, *limbata*, Brady.
,, *nobilis*, Hantken.
,, *robusta*, Brady.
,, *nitida*, Brady.
,, *reticulata*, Hantken (?).
,, *beyrichi*, Reuss.
,, ,, var. *alata*, Seguenza.
Cassidulina crassa, d'Orbigny.
,, *bradyi*, Norman.
,, *subglobosa*, Brady.
,, *lævigata*, d'Orbigny.
Ehrenbergina serrata, Reuss.
Lagena acuticosta, Reuss.
,, *orbignyana* (Seguenza).
,, *sulcata* (Walker & Jacob).
Nodosaria (*Glandulina*) *rotundata*, Reuss.
,, ,, *lævigata*, d'Orbigny.
,, *radicula* (Linné).
,, *hispida*, d'Orbigny.
,, *consobrina*, d'Orbigny.
,, ,, var. *emaciata*, Reuss.
,, ,, var. (?).
,, *obliqua* (Linné).
,, *scalaris* (Batsch).
Nodosaria communis, d'Orbigny.
,, *verruculosa*, Neugeboren.
,, *abyssorum*, Brady.
,, *pyrula*, d'Orbigny (?).
,, *roemeri* (Neugeboren).
,, *raphanus* (Linné).
,, *vertebralis* (Batsch).
,, *catenulata*, Brady (?).
,, sp. (?).
,, sp. (?).
Frondicularia inæqualis, Costa.
Rhabdogonium tricarinatum (d'Orbigny).
Marginulina glabra, d'Orbigny.
,, sp. (?).
,, sp. nov. (?).
Vaginulina sp. nov. (?).
Cristellaria nitida, d'Orbigny.
,, *compressa*, d'Orbigny.
,, *italica* (Defrance).
,, *costata* (Fichtel & Moll).
,, *gibba*, d'Orbigny.
,, *rotulata* (Lamarck).
,, *echinata* (d'Orbigny).
,, *calcar* (Linné).
,, *cultrata* (Montfort).
,, *papillosa* (Fichtel & Moll) (?)
,, *articulata*, Reuss.
,, *vortex* (Fichtel & Moll).
,, *orbicularis* (d'Orbigny).
,, *crassa*, d'Orbigny (?).
,, *tenuis* (Bornemann).
Polymorphina elegantissima, Parker & Jones.
,, *gibba*, d'Orbigny.
Uvigerina pygmæa, d'Orbigny.
,, ,, var. (?).
,, *brunnensis*, Karrer. (?).
,, *asperula*, Czjzek.
,, *angulosa*, Williamson (?).
,, sp. (?).
Sagrina dimorpha, Parker & Jones.
,, *virgula*, Brady.
,, *striata*, Schwager.
,, *columellaris*, Brady (?).
Globigerina bulloides, d'Orbigny.
,, ,, var. *triloba*, Reuss.
,, *inflata*, d'Orbigny.
,, *sacculifera*, Brady.
,, *æquilateralis*, Brady.
,, *helicina*, d'Orbigny.
,, *dubia*, Egger (?).

Globigerina conglobata, Brady.
,, sp. nov. (?)
,, sp. nov. (?)
Orbulina universa, d'Orbigny.
Pullenia quinqueloba, Reuss.
,, *sphæroides* (d'Orbigny).
Sphæroidina bulloides, d'Orbigny.
Discorbina sp. (?)
Truncatulina reticulata (Czjzek).
,, *præcincta* (Karrer.).
,, *haidingerii* (d'Orbigny).
Truncatulina ungeriana (d'Orbigny).
,, *pygmæa*, Hantken.
Anomalina ammonoides (Reuss).
Pulvinulina schreibersii (d'Orbigny).
,, *patagonica* (d'Orbigny).
,, *karsteni* (Reuss).
,, *oblonga* (Williamson).
,, sp. (?).
Rotalia soldanii, d'Orbigny.
Nonionina pompilioides (Fichtel & Moll).
Amphistegina lessonii, d'Orbigny.

IV. Globigerina Limestone.—The great series of rocks known under the name Calcareous Sandstones are much better designated by the term Globigerina Limestones, for they are chiefly composed of these minute shells and their broken-down remains, and none of the beds are largely made up of quartz sand, though that idea is conveyed by the word sandstone. The upper beds of the series have generally a blue or grey colour, and contain more clayey matter than the lower ones, which are for the most part red or rose-coloured. Indeed, the transition between the overlying clay and the upper beds of the Globigerina series is very gradual, so that some of the beds which I place here have been regarded by others as belonging to the clay or marl. These upper beds are especially characterised by a large number of irregular hematite nodules containing silica, alumina, manganese, phosphoric acid, and lime. These bluish-coloured beds in cliff sections often break up and form mounds in the same manner as the overlying clay, and are frequently interrupted by beds of a lighter colour. The lower beds supply most of the building-stone of the country, known among builders as third quality stone, first and second quality stone being derived from the crystalline beds of the Upper and Lower Coralline Limestones. The third quality stone is easily cut into large blocks by means of saws, and with axes and chisels it can be rapidly hewn into any required shape.[1]

While these rocks are for the most part of a reddish or yellow colour, along the cliffs on the coasts and in the cutting for the New Dock there are large more or less circular bluish patches, and it is noticed that these blue patches are removed to the greatest distance from faults and fissures. In the bluish or grey-coloured upper beds, and even in the overlying blue clay itself, the rocks on each side of a fissure have a red colour, the thickness of this reddish band on either side of the fault or fissure being less, as a rule, the more clay the bed contains.

The microscopic sections of the red rocks and the blue patches show no difference, so far as concerns the organisms, but the blue patches contain iron pyrites, which is absent in the red rock through oxidation, the iron pyrites often filling the Foraminifera and forming casts of the shells.

[1] Mr. C. H. Colson has shown that the Globigerina Limestone will absorb about one-fourth of its bulk of water in 24 hours, while the Upper and Lower Limestones will absorb only two or three per cent. of their bulk in the same time. One may thus readily believe that the foundations of Valetta and other towns situated on the Globigerina Limestones are saturated with the sewage of centuries.

The following are analyses of two samples provided for me by Mr. Colson from the new dock, at the same level, the one being from a blue patch (No. 2), the other from the red rock (No. 1).

No. 1 has a light reddish yellow colour which is retained on drying at 100° to 110° C. Dried sample gave on analysis:—

Carbonate of Lime ($CaCO_3$), . .	80·24
Phosphate of Lime (Ca_32PO_4), . .	3·57
Magnesium Carbonate ($MgCO_3$), . .	1·63
Calcium Sulphate ($CaSO_4$), . .	0·06
Iron and Alumina (Fe_2O_3 and Al_2O_3), .	1·13
Insoluble in dilute HCl (1 in 10), . .	12·88
	99·51

The part insoluble in HCl consists of ferric oxide, alumina, silica, and a small quantity of lime, but no phosphoric acid or sulphur compound. The silica seems to be mainly in combination with the alumina.

No. 2 has a light bluish green colour, which is retained on drying at 100° to 110° C. Dried sample gave on analysis:—

Carbonate of Lime, Iron and Alumina ($CaCO_3Fe_2O_3$ and Al_2O_3),	78·39
Phosphate of Lime (Ca_32PO_4), ...	2·70
Magnesium Carbonate ($MgCO_3$), ...	0·44
Calcium Sulphate ($CaSO_4$), ...	0·33
Insoluble in dilute HCl (1 in 10), ...	17·87
	99·73

The insoluble residue contains iron (chiefly in the ferrous condition), alumina (abundant), lime (small quantity), no phosphoric acid, traces of sulphur. The iron seems to be combined as silicate, as some difficulty in decomposing the compound was experienced, the colour remaining green even after repeated treatment with HCl, and subsequent evaporation. The sulphur is present as sulphide (pyrites, FeS_2), which on oxidation in the presence of bases would give Fe_2O_3, while calcium sulphate would probably be formed.

It thus appears more than probable that these blue patches will ultimately disappear with further oxidation; indeed it is evident to me that at the time these Globigerina rocks were first raised above the sea they were all of a blue colour, and that the red colour is entirely due to subsequent oxidation, the more porous calcareous beds having been oxidised at a more rapid rate than those containing a large quantity of clayey matter. Did we know the rate of this oxidation, we might calculate approximately the date at which these rocks were elevated from the sea, or the water-bearing fissures were formed.[1]

[1] The Messrs. Colson hold similar views as to the origin of the blue patches, and Mr. C. H. Colson has attempted such a calculation. They found in the centre of an old wall, built by the Knights 200 years ago, some stones of this blue rock entirely surrounded by a red zone 1½ inches in width—the result of oxidation since placed in the wall—say 1 inch in 133 years. The average distance of the water-bearing fissures from the blue patches is, at the New Dock, 5 feet. This would give, at the above rate, 7980 years since oxidation commenced from the fissures. It would really be a much longer time, for the rate of oxidation would be slower as the distance from the fissures increased, assuming the other conditions to be constant.

About nine or ten distinct beds are recognised, which, however, are occasionally locally developed, thinning out and disappearing in different directions. These beds differ considerably in colour, hardness, texture, and microscopic characters of the organisms or organic fragments. An examination of about forty microscopic sections of samples from different horizons and localities shows that the whole of the beds are principally made up of the shells of pelagic *Globigerinæ* and their broken-down remains. Mixed up with these are a few *Truncatulina*, *Pulvinulina*, and *Rotalia* shells, Ostracode valves, Echinoderm spines, and remains of other marine deep-water organisms. The general appearance of a typical specimen under the microscope is shown in Plate II. fig. 1. In some instances the *Globigerina* shells make up fully 80 or 90 per cent. of the whole rock. Some of the layers, on the other hand, are largely made up of amorphous carbonate of lime. In one stratum, immediately underlying one of the nodule beds, there are numerous small rhombohedral crystals of calcite, while Coccoliths, Coccospheres, and Rhabdoliths are abundant in several of the other beds. Pteropods are nowhere abundant, but their remains can be detected in many specimens of the rock, and their casts (*Hyalæa* and *Vaginella*) in phosphate of lime are numerous in and close to the nodule beds. Specimens of *Brissopsis* and of a small *Pecten* are numerous throughout these layers, but there is an absence of the large Molluscs and Echinoderms so numerous in the Greensand and Upper Coralline Limestone.

The analyses of a large number of characteristic samples of these rocks show that the percentage of carbonate of lime ranges from 63·20 to 94·73, but some of the upper transition beds contain only 30 to 40 per cent. They all contain traces of phosphate of lime and nearly all have in addition carbonate of magnesia. The phosphate of lime in many samples of the ordinary rock rises to 3 and 4 per cent., and the nodules from the various nodule beds contain frequently from 30 to 40 per cent.[1]

The residue left on the removal of the carbonate of lime by dilute acid consists of clayey matter, with oxides of iron, glauconite and minute mineral particles, these last consisting of splinters of quartz, felspars, tourmaline, zircon, rutile, augite, and hornblende; it is rare that any of these mineral particles exceed 0·1 mm. in diameter. It is this residue

[1] Five specimens were taken from watercourse below Inna Fora, Gozo; two of these gave indications of phosphoric acid in some quantity and traces of magnesia, while in three no phosphoric acid could be detected. A specimen from cliff above Ras il Kala gave indications of a small quantity of magnesia and traces of phosphoric acid. Three specimens from Fort Tigne gave no indications of phosphoric acid; in two, however, there were small quantities of magnesia. Two specimens from cliff at Lighthouse Hill contained small quantities of phosphoric acid and magnesia. Three specimens from a seam, half-a-mile west of Wied Talassiri valley, contained quantities of phosphoric acid, while one specimen yielded a considerable amount of magnesia. One specimen from Foum el Rieh Bay, and three from Citta Vecchia gave small quantities of phosphoric acid and traces of magnesia. A specimen from nodule bed, Casal Siggieui, contained traces of magnesia and a considerable quantity of phosphoric acid. Twelve specimens in the form of cubes were taken from the railway cutting at Notabile, and from shafts by Mr. Chadwick; these contained in the majority of cases only traces of magnesia, but the phosphoric acid was present in considerable quantities.

of the Globigerina Limestones that forms the greater part of the soil in all those portions of the islands where these rocks occupy the surface of the land.

The nodule beds are a characteristic feature of the Globigerina rocks, there being four or five of these at different horizons, two extending throughout the whole islands and others occurring locally or in patches. These beds are from a few inches to three or four feet in depth, and consist of an agglomeration of rounded pebble-like concretions, having a brown colour and often a smooth, glazed surface. The nodules vary from the size of a pea to several inches in diameter, are all phosphatic, and mixed up with them are numerous casts of shells, Corals, and Echinoderms, also phosphatic, together with remains of whales and other marine mammals, turtles, sharks, Teleostean fishes and Crustaceans. One bed rests upon a fawn-coloured rock, containing many minute crystals of calcite, and different in several respects from the rock in which the nodules are imbedded, but bands and patches of nodules occur where no microscopic or chemical difference can be observed in the rock above or below. Some of the microscopic sections of the nodules are different in texture from the matrix in which they are imbedded, but the great majority consist largely of *Globigerinæ* and other organic fragments, the same as in the surrounding Globigerina limestone, the only difference being the yellow colour due to the presence of phosphate of lime. The following are analyses of one of the typical nodules, and of the interstitial cement or rock in which they are imbedded :—

NODULE from Nodule Bed, Foum el Rieh Bay, Malta.

Sulphate of Lime ($CaSO_4$),	2·26
Carbonate of Lime ($CaCO_3$),	47·14
*Phosphate of Lime (Ca_32PO_4),	38·34
Alumina (Al_2O_3),	5·98
Oxide of Iron, (Fe_2O_3),	trace
†Residue,	6·08
	99·80

* Equivalent to 17·47 per cent. P_2O_5.

† The residue contains iron oxide in the ferric condition, alumina, a small quantity of silica and lime, but no phosphoric acid.

INTERSTITIAL CEMENT.

Carbonate of Lime ($CaCO_3$),	86·69
*Phosphate of Lime (Ca_32PO_4),	1·24
Sulphate of Lime ($CaSO_4$),	0·07
Alumina (Al_2O_3),	1·28
†Insoluble in dilute acid,	9·87
	99·15

* Equivalent to 0·568 per cent. of P_2O_5.

† This residue was red in colour and on examination yielded a small quantity of Fe_2O_3, abundant alumina, a quantity of silica, while lime was present, but no phosphorus or sulphur compound could be detected.

These nodules have hitherto been described as rolled pebbles, but they have evidently been formed *in situ* at the bottom of the sea, and are almost precisely similar to the phosphatic nodules dredged from modern sea-beds by the Challenger and other deep-sea expeditions. Nodules of chert and flint are found in some of the layers, and Mr. Colson has a large specimen of fossil amber found in the Globigerina Limestones at the New Dock, similar in all respects to the fossil amber in the Tertiary deposits of Sicily.[1]

By reference to the map it will be seen that these Globigerina Limestones occupy the surface in all the east and south-east portions of

[1] Mr. Colson says:—"The Globigerina Limestone seems to be divided into nine separate beds or layers, but of course these are not continuous in all places, as they thin out and disappear in different sections. No. 1, the first or uppermost layer, is a pale grey rock, and is well developed in the cliffs above the Monscair Rocks. This rock is quite soft, weathers badly, scaling off in successive flakes when exposed to the weather. It is of a dark bluish grey colour when freshly cut, but rapidly dries to a pale grey when exposed. It is not used for any but the roughest kinds of building. No. 2, the top nodule seam, is of no use at all in building. It consists of a conglomerate of shells, casts of shells in a peculiar dark brown polished material, corals, etc., in a brownish matrix which varies, in different places, from hard to soft. No. 3 is a thin layer of soft stone containing small nodules of selenite, manganese, etc. No. 4 is a nodule seam with the same characteristics as No. 2 layer, but rather thicker. All the nodule seams contain numbers of sharks' teeth, as, indeed, do all the layers in the calcareous sandstone and clay, but it is from this layer that the most plentiful supply is obtained by collectors. No. 5 is a band of greenish nodules often partially imbedded in the overlying layer. As far as I have seen, the green colour seems to be only on the surface of the fossils and nodules, and does not penetrate their substance. No. 6 is a pale red, yellow, or bluish rock. This bed has been cut through in making the new dry dock in the Naval Dockyard, to a depth of 130 feet, and from the evidence obtained in this cutting, it would appear that the whole of this rock was originally of a bluish grey colour. The stone from this bed weathers badly, but it is used for foundations and rough walls or inside thick masses of building, as it stands well when not exposed to the air. Fossils of any kind are very scarce in this bed. No. 7 is a whitish yellow fine-grained rock, with small nodules of chert, or hard substance resembling chert, scattered about in it. This bed and the underlying layer (No. 9), are the ones from which the greatest amount of building stone is taken. This layer, however, from being slightly harder, and from being more difficult to work, owing to the chert nodules, is not so much used as the one below, the average cost of working being about one-third more. The principal quarry of this stone is at Imghieret. In quarrying, a block is separated out by cutting a trench 4″ wide all round it, and it is then wedged up from the bottom. The mass is then split into smaller blocks with wedges, and dressed to the required size with large and heavy axes. No. 8 is a thin line of nodules, often missing, and of no use whatever for building purposes. No. 9: It is from this bed that the greatest quantity of building stone used in the island is obtained. It is a pale yellow limestone, mainly composed of very minute fossils; is soft and easily worked, but hardens somewhat when exposed to the air; weathers very well, and turns after a time to a light reddish brown colour. The stone is easily quarried with wedges, and dressed to size with broad-bladed axes. The principal quarries of this layer are at a place called Ta Daul. The quarries there, in section, are as follows:—About 2 feet surface soil, then 6″ to 2′ of broken and rotten rock called 'Torba'; below this 25 to 40 feet of good stone, followed by a layer of darker stone that will not stand exposure, called 'Saul.' This saul is, however, often used for foundations or in other situations where it is protected from the air. The good stone when quarried can be readily split up into thin slabs, which are used for paving stones in the island, and are also exported in large quantities to Turkey and other countries on the shores of the Mediterranean. Roofs are also made of thin slabs of this stone laid on timber beams, and covered with a layer of soft stone and chippings rendered with a mixture of puzzolana, lime and broken pottery, beaten down hard. No fossils of any size are found in this bed, except occasionally remains of saurians, etc., and a few shells.

Malta, and altogether over one-half of the surface of the whole islands. Fuchs regards these Globigerina Limestones and the underlying Coralline Limestone, as being of Oligocene age, and belonging to the upper (Aquitanian) series of the group, similar to those developed in Bromida in Italy.

These Globigerina Limestones appear to me to have been formed in deep water (300 to 1000 fathoms), at some distance from a continental shore, but still within the influence of the detrital matter brought down from the land by rivers.

The following is a list of the Foraminifera observed in this formation:—

Spiroloculina tenuis (Czjzek).
Haplostiche soldanii (Jones and Parker).
Textularia conica, d'Orbigny.
,, *agglutinans*, d'Orbigny.
,, *gramen*, d'Orbigny.
Gaudryina pupoides, d'Orbigny.
Clavulina communis, d'Orbigny.
,, *cylindrica*, Hantken.
Bulimina ovata, d'Orbigny.
,, *inflata*, Seguenza.
Bolivina dilatata, Reuss.
,, *robusta*, Brady.
,, *punctata*, d'Orbigny (?).
,, *beyrichi*, Reuss.
,, ,, var. *alata*, Seguenza.
Cassidulina crassa, d'Orbigny.
,, *subglobosa*, Brady.
Ehrenbergina hystrix, Brady.
Lagena sp. (?).
Nodosaria (*Glandulina*) *rotundata*, Reuss.
,, *radicula* (Linné).
,, *hispida*, d'Orbigny.
,, *roemeri* (Neugeboren).
,, *communis*, d'Orbigny.
,, *obliqua* (Linné).
,, *consobrina*, d'Orbigny.
Rhabdogonium tricarinatum (d'Orbigny).
Vaginulina sp. (?).
Vaginulina sp. nov. (?).
Cristellaria convergens, Bornemann.
,, *vortex* (Fichtel and Moll).
,, *cultrata* (Montfort) (?).
,, *calcar* (Linné).
Uvigerina pygmæa, d'Orbigny.
,, *tenuistriata*, Reuss.
Sagrina virgula, Brady.
Globigerina bulloides, d'Orbigny.
,, ,, var. *triloba*, Reuss.
,, *rubra*, d'Orbigny.
,, *inflata*, d'Orbigny.
,, sp. (?).
Orbulina universa, d'Orbigny.
Pullenia sphæroides (d'Orbigny).
Sphæroidina bulloides, d'Orbigny.
Discorbina bertheloti (d'Orbigny).
,, sp. (?).
Truncatulina reticulata (Czjzek).
,, *ungeriana* (d'Orbigny).
,, *præcincta* (Karrer.).
,, *haidingerii* (d'Orbigny).
Anomalina ammonoides (Reuss).
Pulvinulina berthelotiana (d'Orbigny).
,, *oblonga* (Williamson).
Rotalia soldanii, d'Orbigny.
,, sp. (?).
Nonionina pompilioides (Fichtel & Moll).

The species of Globigerinidæ are by far the most abundant in this formation.

V. Lower Coralline Limestone.—This formation, which is the lowest of the Malta series, is more crystalline than any of the others; it is generally semi-crystalline, but occasionally it is granular, and in very many respects resembles the Upper Coralline Limestone. The harder varieties are sometimes known as Maltese and Gozo marbles and granites; the same names are applied also to some of the harder varieties of the Upper Coralline Limestones. The Lower Coralline Limestone contains numerous fossils, but these are not easily removed in a perfect condition owing to the hard crystalline nature of the rock.

Over twenty specimens of this rock were examined by means of microscopic sections. Some of the sections showed that the rocks consisted almost entirely of Nullipores (*Lithothamnion*) and other calcareous Algæ, mixed up with which were a few Foraminifera and other organisms. In other sections the calcareous Algæ were not so abundant, and there were numerous Foraminifera belonging to the genera *Orbitoides*, *Heterostegina*, *Alveolina*, *Nummulites*, *Miliolina*, and *Operculina*, together with fragments of Molluscs, Polyzoa, Corals, and Echinoderms. The general appearance of a typical specimen is shown in Plate I. fig. 2. The size and character of the organisms seem to show that this layer, like the Upper Coralline Limestone, was laid down in comparatively shallow water, probably in less than 50 fathoms. The Scutella and nodule bed, which is regarded as the upper layer of the Lower Coralline Limestone, appears, however, to have been laid down in deeper water than the lower layers, for this rock is made up of much smaller fragments; there are a few *Globigerina* shells present, while the other Foraminifera are smaller, and the fragments of calcareous Algæ are more minute and much less abundant than in the lower beds. The nodular masses in the phosphatic layers are different in appearance from the phosphatic nodules in the Globigerina Limestone, being much larger and more irregular. In those portions which are wholly crystalline, no trace of organisms can, of course, be detected.

The analyses of three typical specimens gave respectively 98·58, 95·66, and 98·14 per cent. of carbonate of lime. The residue after the removal of the carbonate of lime by dilute acid was reddish in colour, and consisted of clayey matter, oxide of iron, and a few minute grains of quartz, augite, felspars, tourmaline, and glauconite; the largest fragments of these minerals did not exceed 0·1 mm. in diameter. Phosphoric acid and magnesia were present in small quantities in some of the specimens, but usually these substances were less abundant than in the upper series of the Malta rocks.[1] The colour of these Lower Coralline rocks varies from nearly pure white to red or cream and grey colour, and they crop out in different places all along the north-east and south coasts of Malta as far as the Great Fault, and in the interior along the edge of this fault, which divides Malta into two districts. They form many of the high sea cliffs, but do not occupy a large portion of the surface of the islands.[2]

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[1] Two specimens from Fort Tigne, three from Tigne Point, and four specimens from the Redoubt at Ras il Kala, gave traces of magnesia but no phosphoric acid. One or two specimens from oyster bed north of Redoubt contained a trace of phosphoric acid and a small quantity of magnesia. Two specimens from the valley of Wied Talassiri contained no phosphoric acid, but small quantities of magnesia. Five specimens cut from a shaft in Wied Islanda (?) by Mr. Chadwick gave no, or at most but a trace of, phosphoric acid, and small quantities of magnesia.

[2] Mr. Colson supplies the following notes on the building-stones:—"The Lower Limestone is the lowest and most extensively developed of the strata of Malta and Gozo, cliffs in the latter island rising 400 feet from the sea, being composed entirely of its different layers. From this stratum, or from the Upper Coralline Limestone, all the stone locally known as first and second quality hard stone is obtained, the difference between the two qualities being that, in the first, recrystallisation has taken place, while in the second the stone is in its original condition. Both the qualities are found in the same quarries; the second usually above the first, but often intermixed with it. The kind known as first quality is hard, crystalline, non-porous, generally varying in colour from brownish yellow to white in different localities, weathers very well and works easily, splitting straight and smooth. The second

The following is a list of the Foraminifera observed in this formation :—

Spiroloculina sp. (?).
Miliolina sp. (?).
Alveolina melo (Fichtel & Moll).
Textularia trochus, d'Orbigny (?).
Clavulina communis, d'Orbigny (?).
Bolivina sp. (?).
Globigerina sp. (?).
Planorbulina mediterranensis, d'Orbigny.
Carpenteria utricularis, Carter.
Gypsina sp. (?).
Heterostegina sp. (?).
Cycloclypeus sp. (?).
Rotalia soldanii, d'Orbigny (?).
Nummulites sp. (?).

The most abundant forms are :—*Alveolina melo*, *Heterostegina* sp., *Cycloclypeus* sp., and *Nummulites* sp.

QUATERNARY DEPOSITS.—Dr. Leith Adams, Spratt, Caruana, and others, have examined these deposits in many of the caves and fissures of Malta. Their general results may be thus summarised :—

Gandia Fissure.—Unfortunately Dr. Adams was not the first to explore this cave, yet, when re-opened by him, a large collection of bones

quality stone is softer than the first, is composed of distinct grains of varying sizes in different quarries, is porous, works easily, and weathers well, but not so well as the first. The uppermost bed is called the Transition, or Scutella, bed; it is not so much used for building as that from the third or bottom bed, as it is softer, often partly mixed with and merging into the calcareous sands of the overlying stratum, and contains more remains of Echini than the bed below. The stone quarried at Sannat, in Gozo, is from this bed. It is of a light yellowish brown colour, often spotted in all directions with brown spots (apparently caused by iron) and patches of softer stone, giving it a very disagreeable appearance, is fine-grained and not very durable, the stone decaying away and leaving the harder Echini projecting. This bed also crops out near Musta, in Malta, but here the stone is better and more crystalline than that from Sannat, although the two qualities (first and second) are much intermixed, and the stone therefore wears unevenly. The colour is cream or white. The nodule seam below the Scutella bed is of no use in building; it is to be seen in the quarries at Ghar-id-Dorf, in Gozo. Beneath this nodule bed is the lowest known bed of the strata of Malta and Gozo, and from this the greater part of the first and second quality stone is quarried. It crops out at many different places, both in Malta and Gozo. The principal quarries are :—1st, Hondok-ir-Rummien, where the stone varies in colour from dark to light brownish yellow, with occasional patches of dark red; it is very durable, hard, crystalline, non-porous, and according to the experiments made for the Civil Government by Mr. Kirkaldy, stands a higher crushing strain than any other stone in the island. 2nd, Ghar-id-Dorf, the stone from which is white or cream-coloured, crystalline, sometimes rather open-grained, durable, hard, and, from its evenness of colour, very suitable for building. Second quality stone exists in both of the above quarries, often intermixed with the first quality. Second quality stone is also obtainable at Fex Fux, where it is brownish yellow in colour, compact, sometimes porous, and weathers well, but not so well as first quality. The principal quarries in Malta are on and about the high ground, where the lower stratum crops out at Madalena, on the edge of the great fault, and at Malak on the south coast. The following are the characteristics of some of the best kinds of first quality stone quarried in Malta :—1st, A light brown stone, fine-grained, crystalline, clean bright fracture, hard, durable, rings clearly. 2nd, A light brown stone, the same as above, but with larger grains. The best is of very even quality, but is often found rather intermixed with second quality. 3rd, A white, hard, and brittle stone, with no apparent grain, with spots and patches of softer stone intermixed, durable and non-porous. All these kinds occur at Madalena and in the adjacent quarries. 4th, A white, crystalline, somewhat porous stone, with large grains, the interstices not always filled up, but hard and durable. 5th, A white crystalline stone, the same as above, except that the grains are closer and the stone is perfectly non-porous, The last two kinds are found at Malak, on the south coast, opposite the island of Filfla.

still remained for examination. This cave is of an irregular funnel shape, and was found to contain elephants' bones and teeth, bones of aquatic birds, and of rats and dormice. The cave is in the strata of the Globigerina Limestone.

Shantiin Fissure.—This cave also occurs in the Globigerina Limestone, and very closely resembles that of Gandia, with which it is probably connected. In addition to the remains mentioned above, a few sharks' teeth were obtained by Dr. Caruana, who examined this fissure.

Zebbug Cave.—A fissure in the Globigerina Limestone is 75 feet long, 5½ feet high, with a width of from 2½ feet to a few inches. It was thoroughly examined by Spratt, who found abundant remains of elephants and other animals and birds. Adams did not explore this cave.

Middle Cave.—Dr. Adams discovered this cavern, which is in the Lower Coralline Limestone. The organic remains included teeth and bones of the gigantic dormouse, teeth of the Miocene shark, exuviæ of frogs of the usual size, bones of a mouse not distinguishable from those of the common meadow vole, bones of *Anseres,* and of smaller water and, perhaps, land birds, bones of fishes, and a large lot of existent land-shells. The materials among which these remains were found are various and interesting. They were found to consist of (1) white calcareous cement on the floor; (2) three feet of reddish black loam, sometimes hardened by stalagmite infiltrations; (3) three to four feet of brick-red clay, interspersed with shelves, pillars, and hardened masses of drippings, underlying a shelf of stalactite; (4) three feet of stalagmitic red earth; (5) stalactitic drippings, hermetically sealing up the opening.

Mnaidra Gap.—Discovered by Dr. Leith Adams in the Lower Coralline Limestone. He first found rodents and elephants' remains, and afterwards the same with those of swans and other birds, fresh-water tortoise, with recent land-shells. The greatest length of this pit or gap was found to be nearly 100 feet, with a width of from 15 to 40 feet, and a depth of 18 feet. The top was sealed with red stalagmite, under which lay white calcareous drift and portions of parent rock, overlying a shelf of stalactite, which was succeeded by a band of red clay enclosing rounded stones, some of the latter resting on a lower stalactite shelf. Then came red loam, superincumbent on a belt of yellow loam, below which was a reddish black loam, on white calcareous drippings, with a white seam on the top. No organic remains were found in the red loam or below it.

Benhisa Gap.—A cavity in the Globigerina Limestone, somewhat of a punchbowl shape, open towards the sea. It is full of red soil and water-worn blocks of sandstone, among which elephantine remains were found, along with skeletons of dormice, fragments of bones of large birds, bones and traces of a huge fresh-water turtle, remains of lizards, land-shells, etc.

St. Leonard's Fissure.—This fissure, which occurs in the Globigerina Limestone, was found to contain remains of the pigmy elephant, imbedded in grey drift and angular fragments of the parent rock.

Melliha Cave.—Spratt found bones and teeth of hippopotami in this cave, and Dr. Leith Adams also procured like remains in a conglomerate composed of rounded and water-worn pebbles from the parent rock, with a paste of blue clay. This cavern appears to be situated in the Upper Coralline Limestone.

Malak Cave occurs in the Lower Coralline Limestone, 280 feet above sea-level. Its length has been given as about 30 feet, with a height of 4 feet. It contained an upper crust of stalactite and stalagmite, having no organic remains, passing into a grey sinter, tinged with iron, and presenting nodules and small seams of dark-brown loam. Here were found remains of existing land-shells, of the giant dormouse, and of birds, some of great size. Another band of stalagmite succeeded, covering a conglomerate composed of pebbles and clay, and containing remains of the river-horse. Dr. Leith Adams found an elephant's tooth.

The following are the animal remains found in these caves:—

Hippopotamus pentlandi.	*Myoxus melitensis*, Falconer.
Elephas melitensis, Falconer.	,, *cartei*, Adams.
,, *falconeri*, Busk.	*Arvicola pratensis*, Baillon.
,, *mnaidrœ*, Adams.	*Cygnus falconeri.*

MARINE DEPOSITS OFF MALTA.—The deposits now forming around the Maltese Islands resemble in many respects the Tertiary rocks that have just been described.[1] One specimen from Quarantine Harbour, Valetta, contained 81·57 per cent. of carbonate of calcium, consisting largely of Foraminifera, many of which are identical with those in the Tertiary rocks of the islands. In addition, this mud contained fragments of the shells of Gasteropods, Lamellibranchs, Crustacea, Echinoderms, Ostracodes, Polyzoa, a few Coccoliths, and many Corallines (calcareous algæ). Samples of the deposits from similar and rather greater depths outside the harbour were chiefly made up of calcareous algæ and large bottom-living Foraminifera. A specimen from 58 fathoms was a calcareous mud containing 73·71 per cent. of carbonate calcium, while one from 100 fathoms contained 75·84 per cent. At the latter depth the shells of pelagic species—such as Pteropods, Heteropods, *Globigerinœ*, and Coccoliths—were much more abundant than at 58 fathoms, the fragments of calcareous algæ being on the other hand less numerous and much smaller. In greater depths in the Mediterranean, the pelagic shells make up a still greater proportion of the carbonate of lime present in the deposits. The inorganic residue of these deposits consists of clayey matter, with some siliceous sponge spicules and a few diatoms, and fragments of quartz, felspars, augite, tourmaline, zircon, magnetite, and glauconite in the form of grains and casts of the Foraminifera.

The following is a list of recent Foraminifera observed in the deposits round the Maltese islands, down to a depth of 1469 fathoms:—

Nubecularia lucifuga, Defrance.	*Biloculina ringens* (Lamarck).
Biloculina depressa, d'Orbigny.	,, sp. (?).
,, *elongata*, d'Orbigny.	*Spiroloculina limbata*, d'Orbigny.

[1] Specimens of these deposits were procured for me by Surgeon David Bruce while stationed at Malta.

Spiroloculina nitida, d'Orbigny.
,, *grata*, Terquem (?).
,, *impressa*, Terquem.
,, *acutimargo*, Brady.
,, *excavata*, d'Orbigny.
,, sp. nov. (?).
Miliolina macilenta, Brady.
,, *seminulum* (Linné).
,, *oblonga* (Montagu).
,, *circularis* (Bornemann).
,, *tricarinata* (d'Orbigny).
,, *bicornis* (Walker & Jacob).
,, *reticulata* (d'Orbigny), var. (?).
,, *pulchella* (d'Orbigny).
,, *linnæana* (d'Orbigny).
,, *agglutinans* (d'Orbigny).
,, *venusta* (Karrer.)
Articulina sulcata, Reuss.
Vertebralina striata, d'Orbigny.
Planispirina celata (Costa).
,, *exigua*, Brady (?).
Cornuspira involvens, Reuss.
Peneroplis pertusus (Forskål).
Orbitolites marginalis (Lamarck).
Haplophragmium canariense (d'Orbigny).
Placopsilina cenomana, d'Orbigny.
Ammodiscus incertus (d'Orbigny).
Textularia agglutinans, d'Orbigny.
,, *aspera*, Brady (?).
,, *sagittula*, Defrance.
Verneuilina spinulosa, Reuss.
Clavulina parisiensis, d'Orbigny.
Bulimina aculeata, d'Orbigny.
,, *buchiana*, d'Orbigny.
,, *inflata*, Seguenza.
,, *subteres*, Brady.
,, *elegans*, d'Orbigny.
,, *marginata*, d'Orbigny.
,, *declivis*, Reuss.
,, *ovata*, d'Orbigny.
Bolivina dilatata, Reuss.
,, *textilarioides*, Reuss.
,, *punctata*, d'Orbigny.
,, *ænariensis* (Costa).
,, *robusta*, Brady.
Cassidulina lævigata, d'Orbigny.
,, *crassa*, d'Orbigny.
,, *bradyi*, Norman.
,, *subglobosa*, Brady.
Lagena quadricostulata, Reuss.
,, *clathrata*, Brady.
,, *acuticosta*, Reuss.
Lagena lævis (Montagu).
Nodosaria scalaris (Batsch).
,, *communis*, d'Orbigny.
,, *consobrina*, d'Orbigny.
,, *vertebralis* (Batsch).
,, *raphanus* (Linné).
,, *obliqua* (Linné).
,, *pyrula*, d'Orbigny.
Rhabdogonium tricarinatum (d'Orbigny).
Cristellaria cultrata (Montfort).
,, *gibba*, d'Orbigny.
,, *orbicularis* (d'Orbigny).
Polymorphina gibba, d'Orbigny.
,, *lactea* (Walker & Jacob).
Uvigerina pygmæa, d'Orbigny.
,, *angulosa*, Williamson.
,, sp. (?).
Globigerina æquilateralis, Brady.
,, *inflata*, d'Orbigny.
,, *rubra*, d'Orbigny.
,, *bulloides*, d'Orbigny.
,, *sacculifera*, Brady.
Orbulina universa, d'Orbigny.
Pullenia sp. (?).
Sphæroidina bulloides, d'Orbigny.
Spirillina vivipara, Ehrenberg.
Patellina corrugata, Williamson.
Discorbina globularis (d'Orbigny).
,, ,, (?), var. (?).
,, *orbicularis* (Terquem) (?).
,, *vilardeboana* (d'Orbigny).
,, *rarescens*, Brady.
,, *rosacea* (d'Orbigny).
Planorbulina aceroalis, Brady.
,, *mediterranensis*, d'Orbigny.
Truncatulina lobatula (Walker & Jacob).
,, *variabilis*, d'Orbigny.
Pulvinulina elegans (d'Orbigny).
,, *micheliniana* (d'Orbigny).
,, *auricula* (Fichtel & Moll).
Rotalia beccarii (Linné).
,, *schroeteriana*, Parker & Jones.
,, *orbicularis*, d'Orbigny.
,, sp. (?).
Polytrema miniaceum (Linné).
Nonionina umbilicatula (Montagu).
,, *boueana*, d'Orbigny.
,, *stelligera*, d'Orbigny.
Polystomella crispa (Linné).
,, *macella* (Fichtel & Moll).
,, *striatopunctata* (Fichtel & Moll).

On making a comparison of this list with the previous lists, it will be seen that of the 103 well-defined species of living Foraminifera in the

Malta seas, 16 are found fossil in the Upper Coralline Limestone, 17 in the Greensand, 37 in the Blue Clay, 20 in the Globigerina Limestone, and 2 in the Lower Coralline Limestone. Again, in the foregoing lists of Foraminifera observed in the Tertiary rocks of Malta, there are 137 well-defined species; and of these 54, or nearly 40 per cent., are now to be found living in the neighbouring seas. A more extensive examination of the rocks and the marine deposits will certainly result in large additions to the above lists, and to a larger percentage of species common to these Tertiary rocks and the marine deposits now in process of formation. It would be very interesting to make similar comparisons in other groups, but the materials are not at present available.

Origin of the Rocks and Soils.—The Tertiary rocks of Malta are of marine origin, and a careful examination of their fossil remains and inorganic constituents shows that they have all been laid down along a continental coast-line, but at very different depths and distances from the shore. During the time of their formation the coast-line evidently underwent a large oscillation of depression and elevation, and the physical conditions of the ocean, over the site of the present Maltese Islands, was, during the same period, subject to considerable changes. That continental land could not have been far distant while these rocks were forming on the floor of the ocean is shown by the presence of river detritus of a blue colour, and the greater or less abundance in all the rocks of fragments of quartz, tourmaline, glauconite, and other minerals; the small size, however, of these transported mineral fragments shows that none of the beds could have been laid down quite close to the shore or to the mouth of a river.

The Lower Coralline Limestone, although semicrystalline, is chiefly composed of the remains of calcareous Algae, and large thick-shelled Echinoderms, Molluscs, Crustacea, Foraminifera, and other animals that flourished in shallow water, in depths of 5, 10, or 30 fathoms. All these organisms lived on or attached to the bottom of the sea. From the small amount of detrital matter, the small number of transported particles, as well as from the nature of the organisms, these rocks must have been laid down on banks that were bathed by currrents coming directly from the open ocean, and yet only a few traces of pelagic organisms can be observed in the microscopic sections of the rock. The same thing obtains on shallow banks in the present oceans.

These shallow banks commenced subsequently to sink, and the Lower Coralline Limestone of Malta became covered over by beds indicative of deeper water: in the first instance by deposits composed of the broken fragments of shallow-water organisms, with an admixture of pelagic shells, and later on by deposits consisting almost wholly of the shells of *Globigerinæ*, Pteropods, Coccoliths, Coccospheres, and Rhabdoliths, organisms that lived in the surface waters of the ocean, but whose dead shells fell to the bottom, and there accumulated. Some of the middle and lower beds of the Globigerina Limestone appear to have formed in depths approaching 1000 fathoms. The fossil remains of fishes, Corals, Echinoderms, and Molluscs, as well as the great abundance of pelagic shells, likewise indicate the deep-water character of the Globigerina Limestone. I estimate that not more than six to eight per cent. of the carbonate of lime in these deposits is due to the remains of organisms that lived on the bottom of the ocean. The whole of these Globigerina rocks were of a blue colour when at the bottom of the sea—the same as the great majority of terrigenous deposits in existing oceans—the present red colour of the more calcareous beds being due to oxidation subsequent to elevation.

During the formation of the upper beds of the Globigerina Limestone an elevation of the sea-bottom commenced, the shore approached the site of the present Maltese Islands, there was a gradual, though fluctuating, increase of river detritus in the deposits, and the oceanic currents that passed over the spot became slowly mixed up with and replaced by currents containing a large quantity of river-water; these combined influences finally led to the formation of the Blue Clay that caps the Globigerina series of rocks. In still shallower water a Greensand was formed, in almost all respects similar to that now in process of formation on the Agulhas Banks, off the Cape of Good Hope, in depths from 40 to 200 fathoms. In modern seas glauconitic deposits are not met with in the central parts of the great ocean basins, nor where a rapid accumulation of river detritus is going on, but rather on continental banks swept by waves and by currents. Assuming the same distribution to have obtained in ancient seas we can form some idea of the geographical position of the Malta Greensand with reference to the adjacent Tertiary continent.

The Upper Coralline Limestone overlies the Greensand, and is a shallow-water deposit in all essential particulars resembling the Lower Coralline Limestone at the base of the series. It contains the same mineral particles, many of the same organisms, and was evidently formed under very similar conditions.

It would appear then, that the diversity observed in the various Maltese rocks is to be referred rather to the depth of sea and distance from land at which they were formed than to difference in time. It is evident that rocks which are now horizontal, and placed vertically one above the other, could not have been formed at the same time, but all the varieties of Maltese rocks could quite well have been forming along a coast line at one and the same time over an area of less than 20 miles square; some of the clay and greensand layers in Gozo may have been formed inshore at the same time that the upper layers of the Globigerina Limestone at Marsa Scirocco in Malta were being laid down in deep water seawards. At a not very distant but more stable part of the same coast line a coralline limestone may have been continuously in process of formation during the whole period represented by the Tertiary rocks of Malta; it may have been continuous on the one hand with the Lower Coralline Limestone, and on the other with the Upper Coralline Limestone, and contemporaneous also with the intervening greensand, clay and Globigerina Limestone. There must necessarily have been a great lapse of time between the formation of the Upper and Lower Coralline Limestones of the present Maltese islands, and in the interval many of the shallow-water organisms may have died out and have been replaced by others, but differences produced in this way in the character of the rocks would be much less than differences dependent on the depths at which the rocks were deposited.

The rounded nodules arranged in patches or extended beds at different horizons throughout the Globigerina limestones have generally been described as rolled pebbles, and consequently indicative of shallow water.[1] This interpretation cannot now be admitted. These nodules are all phosphatic, and in the nodule beds are associated with the casts of corals, shells, echinoderms, and fish remains, that likewise contain a large quantity of phosphate of lime. Except in the quantity of phosphates they contain these rounded nodules differ but little from the matrix in which they are imbedded. Their microscopic structure is often identical with that of the surrounding Globigerina Limestone, and they all contain the remains of the same pelagic organisms. Off the Cape of Good Hope the *Challenger* Expedition dredged from depths of 150 to 1900 fathoms many phosphatic nodules, almost the same in general appearance, chemical composition, and microscopic structure as those found in the Greensand and Globigerina rocks of Malta. Although the cause which led to the formation of these nodules may be obscure, there can be no doubt they were formed, and are now forming, at the bottom of the sea, especially along the continental slopes.[2] In the form of minute nodules, or casts of the pelagic Foraminifera, phosphates are sparingly distributed throughout the whole of the Globigerina and Greensand rocks, and there can be but little doubt that these phosphates are derived from the bodies of marine animals. It seems necessary however to call in some special or even abnormal conditions to account for the origin and great accumulation of phosphates in those nodule beds distributed at definite horizons throughout the whole horizontal extent of the formations. The recent deep-sea dredgings and trawlings seem to show that on certain areas of the sea-bed the animals are crowded together in great numbers, while adjacent regions are relatively barren; the nodule beds may represent the position of such fertile or prolific patches. But this explanation does not appear sufficient for the sharply marked and widely extended nodule beds; these probably represent periods of disturbance either on the neighbouring continent, or in the ocean, or both. The emission of gases from submarine volcanoes, or an abnormal outflow of river water from the land, frequently kills large numbers of pelagic creatures, and their dead bodies may at such times form a vast layer on the bottom. The phosphate of ammonia thus arising would, in the deposits in process of formation, be decomposed in the presence of carbonate of lime, giving rise to phosphate of lime and alkaline carbonates. The former, being insoluble, would accumulate by pseudomorphism and mechanically in nodular form in the deposits accumulating on the sea floor.

It is to be remarked that in the nodule beds the fossil remains are

[1] Leith Adams, *Nile Valley and Maltese Islands*, p. 127.

[2] *Narr. Chall. Exp.* vol. i. pp. 289 and 806; Murray, Bull. Mus. Comp. Zool., vol. xii. p. 52.

more abundant than in the other layers; these are for the most part present in the form of phosphatic casts of the shells, corals, and other organisms, the carbonate of lime shells themselves having disappeared. These animals were in all likelihood present on the bottom when the layers that now contain no trace of them were being laid down, but their thin and delicate shells were removed from the bottom by solution, as now takes place in modern deep-sea deposits.[1] Had the deposition of these phosphates not taken place at the time of the accumulation of the deposits on the sea-floor we might never have known of the presence of many deep sea and pelagic animals in these ancient seas. The teeth of sharks are relatively abundant in all the Malta rocks, with the exception

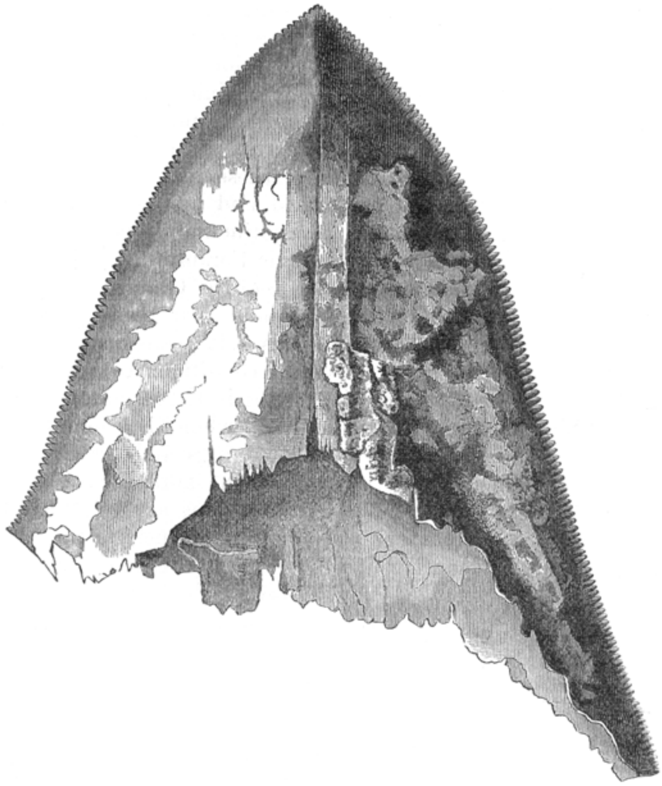

FIG. 1.—Tooth of *Carcharodon megalodon*, from 2385 fathoms in Central Pacific (Natural Size).

of the Upper and Lower Coralline Limestones, but they are much more abundant in the nodule beds than elsewhere, and this appears to point to the death of a large number of these animals at the time of the formation of the nodule beds, and therefore to some unusual disturbance

[1] Murray and Irvine: on Coral Reefs and other Carbonate of Lime Formations in Modern Seas; *Proc. Roy. Soc. Edin.* vol. xvii. p. 83, 1890.

in the ocean. The hard dentine or enamel of these teeth apparently withstands the solvent power of sea-water longer than the remains of most pelagic animals, so that it is unlikely many of them were dissolved away from the layers intermediate between the nodule beds. In the central regions of the Pacific the *Challenger* dredged more than 1500 sharks' teeth in one haul.[1] Some of these were identical with those found

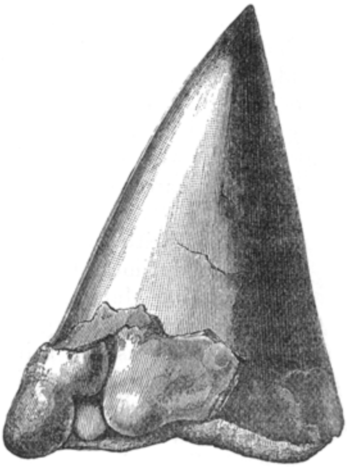

FIG. 2.—Tooth of *Oxyrhina trigonodon*, from 2350 fathoms in Central Pacific (Natural Size).

in the Malta rocks, as will be seen from the accompanying figures. The base and internal portions have, however, been entirely dissolved away, whereas these parts are preserved in the Malta specimens through the deposition of phosphates. One specimen was dredged in the bed of the Gulf Stream by Agassiz in the same condition as presented by the Malta specimens.

During the whole period of their formation, the Tertiary beds of Malta do not appear to have been above water, for we find no reliable trace of land surfaces. Some time after the formation of the Upper Coralline Limestone, however, the Mediterranean region underwent many great and probably sudden changes; the sea-bed, of which the Maltese rocks formed a part, was raised into a wide extent of dry land uniting the continents of Europe and Africa, and in all likelihood extending in the directions of the shallow banks delineated on the accompanying map. This land was covered with a varied and extensive flora, while herds of gigantic and pigmy elephants, hippopotami, ruminants, and carnivora, large dormice, large swans, fresh-water tortoises, and huge lizards found a home in its forests and rivers. All this extensive land surface has disappeared through subterranean movements and the disintegrating action of sea, wind, and rain, with the exception of the small Maltese islands, which, however, have retained in the diluvium of their caves the relics of a great continental land.

[1] *Narr. Chall. Exp.* vol. i. p. 809.

"The geologist, standing on the bare limestone cliff, and looking across the deep blue waters of the Mediterranean, might speculate on a time when Malta was portion of a continent extending far beyond the misty horizon,—of a land abounding with mountains, rivers, lakes, woods and forests, where strange pigmy elephants kept company with gigantic compeers, and where also river-horses in hundreds and thousands lived and died; of myriads of destructive rodents, huge fresh-water tortoises, and aquatic birds swarmed on the land or on the water; how, perchance, for unreckoned ages all had sojourned in safety on this ancient Post-Miocene land, until suddenly (it may be by degrees) it began to sink below them, and they were finally cut off from both continents; then, dying by starvation, they crowded together, and as pinnacle after pinnacle of rock was disappearing under the waves, boisterous billows washed their carcases into the hollows and rock fissures where we now find them."[1]

The quaternary deposits met with in caves, fissures, and some ravines, contain a few black rolled limestone pebbles which have not been derived from any of the existing Maltese rocks, and may therefore have been transported from the now-submerged land. But, on the whole, these quaternary clays as well as the soils of Malta have been derived from the disintegration and decomposition of the underlying Tertiary rocks, or precisely similar rocks that have now disappeared beneath the waves. Even the rocks that contain the highest percentage of carbonate of lime yield a small residue, more or less insoluble, composed of clayey matter, minute mineral particles and oxides of iron and manganese, which remains behind to form soil on the removal of the carbonate of lime in solution. This residue increases as the percentage of carbonate of lime decreases in the rocks; hence the soils are deeper on the outcrops of the Greensand, Clay, and Globigerina rocks than on the Upper and Lower Coralline Limestones. All the Malta soils are, however, largely made up of the broken and comminuted fragments of the calcareous rocks themselves, and as these, especially the Greensands, Clays, and Globigerina layers, contain phosphate of lime and alkalies, these substances, on the partial decomposition of the rock fragments with every shower of rain, are set free in the fields in a form suitable for absorption by the growing crop. In this way as the disintegration and denudation of the islands goes on through natural processes, the soil is being continually renewed and fertilised, and the islanders are therefore enabled to take two or three crops from the fields annually, without any extensive and continued system of manuring. It has been shown that the nodule beds are all phosphatic, some of the nodules containing a larger percentage than is shown in the foregoing analysis; the glauconitic nodules and casts of the Greensand are also rich in the same substance. Were the islanders to take the phosphatic nodules and casts from the Globigerina, Greensand, and Lower Limestone beds, break them up or crush them, and spread them on their fields, their labour would certainly be rewarded by more abundant harvests.

[1] Leith Adams, *l.c.*, p. 146.

It is thus possible, from a microscopic study of the different layers of Maltese rocks, to obtain a glimpse of the geographical distribution of land and water in this part of the Mediterranean region during the Tertiary period, and in some measure to connect the present fertility and prosperity of the Maltese islands with the functional activity of the marine animals that flourished in the surface waters of the ocean in bygone ages.

I have merely attempted to give a sketch of the geology of the Maltese islands. The microscopic sections that have been examined show that every layer is worthy of more careful study and detailed description. This is a field of research that might well appeal to the native Maltese. It is a pity that so many of the more valuable fossils have been taken away to foreign countries, and that no systematic attempt is being made to form, either in the university or in the public museum, a collection illustrative of the geology and palæontology of this group of islands. A complete series of the fossils from each bed so arranged as to permit of comparison would be an extremely valuable possession for Valetta. The study of such a collection, together with the petrographical characters of the various beds, and in connection with the results of recent deep-sea investigations, would certainly lead to valuable discoveries interesting to all scientific men, and would greatly redound to the honour of the Maltese people.[1]

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[1] I have to acknowledge the assistance of Mr. Frederick Pearcey in mounting and determining the Foraminifera, of Mr. James Ross in making the analyses, and of Messrs. James Chumley and John Gunn in other work in connection with the preparation of this paper.

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1882. G. M. Godwin. The Geology, Botany, and Natural History of the Maltese Islands.
1883. Miss L. T. Smith. Malta ; *Ency. Brit.*, ed. 9, vol. xv. p. 339.

Although not dealing exclusively with the geology of the group, the books named in the following list may be consulted with advantage :—

1764. J. Ray. Travels through the State of Venice, etc. ; *Harris's Voyages*, vol. ii. pp. 669-673. London.
1773. P. Brydone. Tour through Sicily and Malta ; London.
1776. J. Dryden. A Voyage to Sicily and Malta in the years 1700 and 1701 ; London.
1789. V. Denon. Travels in Sicily and Malta (translated from the French) ; London.
1791. Un voyageur françois. Malte (Saint Priest).
1802. Æ. Anderson. A Journal of the Forces which sailed from the Downs in April 1800, under the command of Lieut.-Gen. Pigot, till they arrived in Minorca, and continued through all the subsequent transactions of the army under the command of the Right Hon. General Sir Ralph Abercromby, K.B., in the Mediterranean and Egypt ; and the latter operations under the command of Lieutenant-General Lord Hutchinson, K.B., to the surrender of Alexandria, with a particular account of Malta during the time it was subject to the British Government ; London.
1805. L. de Boisgelin. Ancient and Modern Malta : containing a full and accurate account of the present state of the Islands of Malta and Gozo, the History of the Knights of St. John of Jerusalem, also a narrative of the events which attended the capture of these islands by the French, and their conquest by the English ; and an Appendix containing authentic State Papers and other Documents ; London.
1831. Bigelow. Ancient and Modern Sicily, with Sketches of Gibraltar in 1827.
1838. Badger. Description of Malta and Gozo.
1842. J. Davy. Notes and Observations on the Ionian Islands and Malta ; London.
1861. W. Tallack. Malta under the Phœnicians, Knights, and English ; London.
1870. H. Seddall. Malta, Past and Present ; London.
[1874.] A. Issel. Malta ; Residuo di una gran terra sommersa. Schizzo geologico, Genoa.
1876. A. R. Wallace. The Geographical Distribution of Animals, vol. i. ; London.
1878. T. C. Brown. Teeth and Vertebræ of Extinct Sharks (Fossils obtained in Malta) ; 2 photos, Cirencester.
1879. H. A. Nicholson. Manual of Palæontology, vol. ii. ; Edinburgh and London.
1882. T. R. Jones. Fossil Foraminifera in the British Museum ; London.

Some interesting information about the so-called "imported earth" will be found in a small pamphlet on Malta, by Mr. Zammit.

EXPLANATION OF THE PLATES.

The reference letters in the plates have the following signification :—

a, *Globigerina;* b, *Orbulina;* c, *Rotalia;* d, *Pulvinulina;* e, *Alveolina;* f, *Truncatulina;* g, *Textularia;* h, *Planorbulina;* i, *Biloculina;* j, *Miliolina;* k, *Carpenteria;* l, *Nummulites;* m, *Heterostegina;* *n*, Calcareous Algæ ; *o*, Mollusc shells ; *p*, Polyzoa ; *q*, Echini spines ; *r*, Ostracode valves ; *s*, Corals ; *t*, Glauconite. Hartnak's No. 4 objective was used in making the drawings.

GEOGRAPHICAL NOTES.

ASIA.

The Merv Oasis.—After the annexation of Merv, a part of that territory, comprising about 386 square miles, was formed into a private estate for the Emperor of Russia. It lies twenty-eight miles from the town of Merv and near the railway station of Baïram-Ali. About forty miles from this station an immense dam has nearly been completed to check the waters of the Murgab, which will be used for the irrigation of the property. Next spring, when the irrigation canals have been constructed, a fifth of the estate will be colonized. For this purpose Mohammedan settlers from Ferghana will be chosen, these being best able to endure the dry and hot climate of the Merv oasis, where the thermometer often stands in summer as high as 112° to 120° F.—*Deutsche Rundschau*, Bd. xii. Heft 11.

Java.—The Italian Consul at Batavia, in a report to his Government (*Boll. del Ministero degli Affari Esteri*, vol. i. fasc. 5) describes the trade and industry of Java as being in a very unsatisfactory condition. The island is undoubtedly the most important part of the Dutch East Indies. Its area, indeed (about 51,300 square miles), is little more than one-twelfth of the total area of those possessions, but it contains a native population of 22,139,624 souls, or over three-and-a-half times the population of all the other Dutch islands taken together. The natives are weighed down by excessive taxation, and their principal occupation, the cultivation of rice, does not bring in enough to pay their taxes and provide them with means of subsistence. The production of coffee has decreased owing to the devastations of the *Hemeleia vastatrix*, and sugar has suffered equally from a disease known as *sereh*. How much the failure of these principal crops has impoverished the people may be judged from the fact, that, last year, gold to the value of about £80,000 was sent from the inland provinces to Batavia, being obtained by the melting down of ornaments. Notwithstanding this melancholy state of things, the Italian Consul, M. Landberg, looks forward to a more prosperous future. The great want is capital to develop new forms of industry. It must also be remembered that the country is still suffering from the effects of the commercial crisis of 1884. (Compare the admirable series of papers by the late Emil Metzger, published in Volume iv. of our Magazine.)

AFRICA.

A Convention between Britain and France has been concluded in regard to their territorial interests in Africa. France, by becoming a party to the recent Anglo-German Agreement, advances her sphere of influence in North-West Africa from her colonies on the Mediterranean to those in Senegambia, thus securing the unity of her territorial possessions in that part of Africa. The frontier between the