POSTPONED PAPER.

On the GEOLOGY of MALAGA and the SOUTHERN PART of ANDALUSIA.

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[Read June 17, 1857*.]

Introduction.—The south coast of Spain has been frequently the subject of geological description; but many most essential points have hitherto been left unnoticed, and the general relations of the different groups of rocks, as well as the special characteristics of the various deposits, still remain very imperfectly known, although they are likely to prove of sufficient importance to justify a complete revision of the existing views concerning the geology of the western part of the Mediterranean. I propose in the present memoir to give the result of a somewhat minute investigation in various parts of the district, dwelling particularly on the rocks in the neighbourhood of Malaga, where I first obtained the clue that seems likely to clear up the difficulties and obscurities hitherto felt with regard to other parts.

The Spanish geologists who have described the tract of country under consideration are (1) Don Ramon Pellico and Don Amalio Maestre, in a memoir in the second volume of the 'Anales de Minas' of Madrid, 1841; (2) Don Amalio Maestre in the 'Revista Minera' of Madrid; and (3) Don Antonio Linera, the present Inspector of Mines of the province of Malaga, in the same publication (vol. ii. pp. 161 & 193). There is also a notice of the geology of the neighbourhood of the town by Don Pablo Prolongo, published in the 'Topografia Medica' of Dr. Martinez, and dated 1852. Some notice of particular points in the immediate vicinity of Malaga will be found in the 'Bulletin de la Société Géologique de France' of 1852 (deux. sér. vol. x.), in a memoir by M. de Verneuil. Others are mentioned by M. d'Archiac in the 'Histoire des progrès de la Géologie,' vol. iii. p. 11, and others in vol. vii. of the same work. Col. Silvertop described the geology of the whole district, in a general manner, in two memoirs read before this Society† in 1830 and 1833, and afterwards published in the 'Edinburgh Philosophical Journal' for 1833 (vol. xv. p. 364); and I was informed at Malaga of a notice of a hurried journey by Dr. Conybeare from Malaga to Granada and back. A notice of the Sierra de Gador by Capt. Cook will be found in the Proceed. Geol. Soc. vol. i. I am not aware of other notices‡ of more

* For the other communications read at this evening-meeting, see Quart. Journ. Geol. Soc., vol. xiv. p. 84.

† Proceed. Geol. Soc. vol. iii. pp. 216, 234, 485.

‡ I may remind the reader that the bibliography of Spanish geology is given in some detail in the memoir by M. de Verneuil already cited.

than special isolated facts ; and in none of these does there appear anything more definite than a doubtful reference of the limestones to different geological periods, some being supposed to be Silurian, others Carboniferous, others Jurassic, others Cretaceous, and some Tertiary. Except by M. de Verneuil, in the geological sketch of a map of Europe recently published, in conjunction with Sir R. Murchison*, there has not been any attempt to generalize or to connect the various rocks with each other by actual sections, while, unfortunately, fossils are so extremely rare as to have been almost useless in the identification of deposits widely removed from each other.

Metamorphic Rocks.—The oldest rocks of Andalusia appear to be the highly metamorphosed micaceous schists, loaded with garnets, of which the Sierra Nevada is chiefly composed. With these mica-schists are some good specimens of chlorite-schist, and others of clay-slate. They are interpenetrated with bands of quartz, and occasionally covered with thick beds of argillaceous iron-ore. Veins of copper-ore, argentiferous copper-ore, argentiferous lead-ore, and impure antimony-ore have been discovered and worked at various times and at several points, chiefly on the south flanks. The veins are frequently large and strongly marked, but the deposits of ore hitherto proved are bunchy and irregular. Gold has been obtained by washing the sands of the rivers proceeding from the western side of the Sierra ; and cinnabar is known to exist on the north side.

The eruptive rocks that have lifted the mica-schists of the Sierra Nevada to their present great elevation of nearly 13,000 feet are very rarely, if anywhere, to be seen at the surface. Serpentine, however, has been found at various points, and was at one time largely quarried near Granada ; and, in riding along the north side of the Sierra, I have observed in more than one place tolerably large fragments of basaltic rock rolled down from above, chiefly from near the lofty peak of Muley Hassan. Not having visited either this peak or the Veleta, I cannot speak positively as to their composition ; but it is described as schistose by the few travellers who have climbed to the summit and given an account of their trip. The two annexed diagrams, figs. 2 & 3, show the relative position of the limestones, underlying shales, argillaceous shales, and mica-schists in two sections, one (fig. 2) at the eastern, and the other (fig. 3) at the western end of the Sierra de Gador. The tertiaries are seen irregularly covering all the rocks.

Schists of a somewhat similar kind, but less micaceous and chloritic, and more argillaceous, form a large part of the coast-range between Almeria and Malaga, appearing at distant intervals still further to the west. These pass into metamorphic rocks of other kinds, which are more modern. I have not been able hitherto to obtain proof of the exact order of succession of these newer rocks ; but on the left bank of the Rio de Adra, which comes down from the Sierra Nevada, I observed that the black shales (which elsewhere intervene between the black limestones of the Sierra de Gador and the argil-

* Geological Map of Europe, by Sir R. I. Murchison and Prof. James Nicol, 1856.

laceous shales of the coast) were absent, and the limestone reposes on other pale shaly beds, conformable in position, and occasionally containing gypsum in large quantities. The regular argillaceous shales come in below, and continue as a coast-range, varying but little in appearance towards the west, and not reaching far back into the country, except under a thick cover of newer formations. The stratified character of this schist is not easily traceable. It seems to have undergone many elevations; the latest being on a north-east and south-west axis, tending to produce a dip towards the north-west.

Fig. 2.—Section at the Eastern End of the Sierra de Gador.

Besides these general remarks, I have also to give a particular notice of the schists as they occur near Malaga. They there consist chiefly of clay-slates, of whitish, dark-red, or brown colours, varying a good deal in appearance in different parts of the district. They

Fig. 3.—Section at the Western End of the Sierra de Gador.

are everywhere very close to the surface, and have been subjected to numerous local disturbances. In some places their dip is very distinct; but it is more generally confused by jointed structure to an extent which renders it very difficult to make out the details. The most ordinary form here is a kind of grauwaacke-schist, rather hard, but easily disintegrated on exposure. Next in abundance are more shaly varieties, passing from imperfect micaceous schist to an impure clay-slate; and I have observed that the nature of the schist often bears a very marked relation to that of the overlying rock,—this being more especially the case where the harder schists are overlaid by compact conglomerates, composed of quartz-pebbles, cemented by a quartzose paste with sand. Wherever this happens (and it is by no means uncommon) the contact is difficult to deter-

mine, as the conglomerates pass downwards into a kind of quartzite by insensible gradations, and this soon becomes a sandy grauwacke-grit, passing into more regular schists. It has often happened that I have been unable without much difficulty to draw the line between conglomerates regularly bedded and the metamorphic rock. The diagram, fig. 4, illustrates the relative position of the rocks in these cases.

Fig. 4.—Section taken about one mile east of Malaga.

N.

S.

1. Tertiary sands and gravels. (Pectens and Oysters.)
2. Jurassic limestones, without fossils.
3. Gypsiferous sands with lignite. (Equisetite-beds.)
4. Altered conglomerates, passing into schists.
5. Argillaceous shales and slaty beds.

No indications whatever of organic remains have, I believe, been observed in any of these schists. As shown in the map, fig. 1, they occur at frequent intervals in every part of the country near Malaga, at the foot of some, and at the summits of others of the hills, and, where not covered up or complicated by newer deposits, they may be studied with great facility. They do not, for the most part, exhibit the more striking and interesting phenomena of cleavage, and generally (here as elsewhere) the stratification indicates a great complication of disturbances.

Quartz-veins occur in the schists, some of them containing unmistakeable indications of copper. One of these crops out on a hill close to the city of Malaga, bearing N.N.E.—S.S.W., and dipping apparently towards the S.E. A quartz cross-vein appears to have met the principal vein a little above the present level of the surface; and at the junction, which took place above the present hill-top, there seems to have been formed a bunch of ore, which has been undermined and has fallen down on the side of the hill in a manner alluded to in another part of this memoir. There is nothing to justify the expectation of any important result from this lode, although it is more than likely that other bunches of ore would be found, were they sought for by regular mining-operations. I examined two other cupriferous veins in the schists near Malaga; but in neither case was there much promise of any result beyond small bunchy deposits of ore leading to nothing.

The schists are generally covered up near the coast in the vicinity of Malaga, either by regular deposits or raised beaches; but they occupy the highest points of the mountain-chains a short distance to the north. The higher of these are from 3000 to 4000 feet, and they enclose the tertiary and secondary rocks in a semi-basin, the bottom of which is of the most irregular and broken form. Considerable masses of similar rock are seen in the hill near Malaga, on which the castle (Gibralforo) is built, and others to the north near the

Granada road, forming a continuation of these and the margin on the eastern side of the Malaga basin. Others, but of lower elevation, are seen on the Antequera road; and these, as well as the Sierra de Cartama, further west, rise directly out of the plain, being surrounded entirely by the tertiary sands. The slate-hills are generally, but by no means always, capped with secondary rock.

Although I have more than once ridden across the country, I have had no opportunity of determining the character of these metamorphic rocks in the country to the west of Marbella; nor am I aware of the places where they appear before reaching Gibraltar. Near San Roque, and also near Algeciras, they may be observed at various points at low levels. I noticed them again at Tangier, and was informed that they extend on the African coast from that point eastwards at least as far as Tetuan.

Eruptive rocks, consisting entirely of serpentines, and not very largely developed, are known to occur at various points along the coast. One of the most interesting is traceable from near Marbella towards the north and east, passing through Caratraca (celebrated for its sulphur-waters), and there containing considerable quantities of kupfer-nickel and chromate of iron in nodules irregularly dispersed. These have been partly worked, but the mines are not at present profitable. Near the point where this outburst of serpentine commences on the coast is a gigantic band of magnetic iron-ore and other rich peroxides of iron (hæmatites), extensively worked by open cuttings, and supplying several furnaces in connexion with two foundries at Malaga. Close to this vein of iron a mine has been opened on a vein containing lead and antimony with a little silver; but hitherto no profit has been divided, nor is the prospect very encouraging.

On the whole, there is as yet but little made out in a satisfactory manner with regard to the true age of these metamorphic rocks. They are altogether without organic remains; and the mica-slates appear to be generally unconformable with them, as well as with other rocks that may be adjacent. On the other hand, as already shown, there are several places where the contact of these doubtful schists with the overlying rocks, whether limestone (as on the south side of the Sierra de Gador, near Berja) or conglomerate (as near Malaga at various points), is unmistakeably conformable. The enormous amount of local disturbance, often reversing the dip many times within a few hundred or thousand yards, and preventing the possibility of showing any constant strike on a map, tends greatly to add to the difficulty of identifying the shales; but, no doubt, future observers may be enabled by actual sections to connect some portions of them with less altered rocks concerning which more positive knowledge may be obtained.

Palæozoic Rocks.—Many of the limestones and some of the sandstones and shaly rocks of the district under consideration have been referred to the Palæozoic period, chiefly from their metamorphic character, and from their occurring in immediate contact with the shales and slates already described. With the exception of some fossiliferous limestone-bands in Murcia, described by M. de Verneuil,

and possibly some part of the slates and schists, the age of which is undetermined, there is little probability of palæozoic rocks of old date being found. I have observed, however, in the immediate vicinity of Malaga a small development of magnesian limestone, which, from its position, I am inclined to refer to the Permian series, whilst the group of conglomerates and obscurely stratified grits overlying the schists may probably be of the same or a more ancient date.

The divisions of this group, as shown near Malaga, appear to agree very well with the most usual development of the Permian series elsewhere. At the bottom are conglomerates consisting of quartz-pebbles, perfectly rounded, passing from an extremely compact grit-stone, of which the cementing medium is harder than the pebbles, into a coarser pudding-stone, the fracture of which shows the rounded pebbles projecting above the broken cement. The colour of this deposit is usually dark red, but sometimes dark brown; and iron is abundantly present in various parts of it. The conglomerates generally repose on the schists near the bottoms of the hills behind Malaga, the character of the schist being in these cases greatly modified, and showing a very gradual transition without any abrupt change from conglomerate to shale. The thickness of the conglomerates is irregular, but nowhere very considerable, and seldom more than from 10 to 20 feet.

Above the conglomerates, where they are best exhibited, is found a hard compact quartzite, very much indurated and of a dark red colour; its thickness varies from 50 to 60 yards, and is sometimes greater. This bed has only been remarked by me *in situ* near Malaga up some of the water-courses near the base of the hills; but it probably has a wider range, as fragments of the rock are found amongst the débris in most of the dry river-beds.

At one spot, only about two miles from Malaga, on the shore, and just beyond the ravine of the Caleta, I noticed a black fetid limestone, strongly dolomitic, resting on the shales, which are there brought up by a fault, and immediately covered up by the red rocks of newer date, which I regard as Triassic (see fig. 5). This magne-

Fig. 5.—Section on the coast about two miles east of Malaga.

1. Jurassic limestones.
2. Marly sandstones with gypsum, overlying other sandstones with lignite.
- 3, 3. Fetid magnesian limestone. (The upper part covered by detritus and fragments of No. 2.)
4. Clay-slates and shales.

sian limestone is quite unlike all the other limestones of the district, and also unlike the dolomites of the Sierra de Mijas, further to the

west. From its position, decidedly underlying the Triassic sandstones, I can hardly place it elsewhere than amongst the Permian series; but I could not discover any indication of organic remains in the various fragments which I examined, nor was I able to find a similar rock along the coast.

The pure white dolomite of the Sierra de Mijas, which abounds in lead and occupies an important position on the coast, comes in to the east of the serpentine already mentioned, but is separated from the rocks east of Malaga by the Tertiary basin. It may possibly be of the same age as the very different black dolomite to the east, above described; but I am inclined (in the absence of positive proof) to refer it to the newer limestone series of the Jurassic period, which it resembles in containing bunches of galena, and to which it appears to belong by its position. It reposes on sandy beds, which are also highly metamorphosed, and probably correspond with the equisetite-grits to the east of Malaga.

Secondary Rocks.—Above the magnesian limestone, and occupying a very distinct and important position near the coast between Malaga and Velez Malaga, there occurs a series of sandstones and marls, with occasional lenticular masses of gypsum and some bands of lignite, which belong to the older part of the Secondary period. The exact identification of these deposits is a matter of some importance.

The lowest of these beds in the neighbourhood of Malaga consist of hardish sandstones and marls (white or cream-coloured), passing into dark red grits, quarried for building-material. These immediately overlie the black dolomite already described, and are widely distributed in the neighbourhood of Malaga. Near the magnesian limestone, as shown in fig. 5, there are about 30 or 40 feet of this sandstone, much disturbed by the fault which has brought up the dolomite and shales; and it here abounds with obscure vegetable markings and fragments of fossil wood. It also contains several species of *Calamites* or *Equisetites*, the presence of which marks the age of the deposit—and these are amply sufficient to prove that the rocks are not older than Triassic*. A little beyond the spot where the dolomite is brought up, a band of lignite, of small magnitude and quite valueless, was being opened as a coal-mine during the winter of last year (1856). The lignite is associated with marls, and overlies a grit.

In the upper part of this series, as shown in several places near Malaga, large lenticular masses of gypsum occur, which are extensively worked for plaster of Paris. The diagram, fig. 6, illustrates the relative position of the divisions of the sandstone series near the quarries of San Telmo; and the conditions are nearly the same on

* The following note on the subject of these plant-remains has been kindly communicated by Mr. C. J. F. Bunbury:—"I have examined the fossil stems from Malaga. They are in a bad state of preservation, but have a great resemblance to the *Equisetites columnaris*, much more than to any *Calamites* properly speaking. I think it most probable that they belong to that species; but they are not in a condition to admit of accurate determination." [The *E. columnaris* ranges from the keuper to the inferior oolite, and has been found in England and Germany, and near Richmond, Virginia, U.S.]

the west side of the tertiary basin of Malaga at a distance of several leagues. The deposits of gypsum worked near Malaga are five in number, and below them are springs of salt water.

Near the town of Berja, in the vicinity of the great lead-producing district of the Sierra de Gador, I observed several places where the limestones of that Sierra were reposing on marls and shaly beds,

Fig. 6.—Coast-section, near San Telmo, east of Malaga.

- 1, 1. Jurassic limestone.
- 2, 2. White grit, with lenticular masses of gypsum.
3. Marls and grits with lignite and gypsum.
- 4, 4. Red sandstone.
- 5, 5. Shales and schists.

often very arenaceous and abounding with gypsum. In other places the black limestones rest on blacker shales, and these again immediately overlie shales and schists resembling those of the coast-range. There are not many places where the contact is very clearly seen, but in one or two of these there was every appearance of conformable stratification. All the rocks, however, in this vicinity are much disturbed, and have assumed a highly metamorphic character.

At the western extremity of Andalusia the pale-blue limestones of the Rock of Gibraltar repose on irregular masses of shales. Sandstones and marls, alternating with shaly beds, are seen in Gibraltar Bay, between the towns of Algeciras and Tarifa, while older shales come out on the shores of the bay near San Roque. On the north side of the Sierra Nevada, a few hours' ride from Granada, there has recently been found a development of highly crystalline blue limestone, closely resembling in appearance the dark limestones of the Sierra de Gador, and containing, like them, large bunches of galena in irregular fissures. These pass downwards by shaly beds quite distinct from the mica-schists of the Sierra Nevada.

The limestones that overlie the red and white sandstones near Malaga, and the corresponding rocks that extend eastwards and westwards, occupying a somewhat similar position for nearly 100 miles in each direction, vary much in their character. Towards the Sierra Nevada, on both sides of the central ridge, they are highly metamorphosed, of very dark-blue or black colour, and traversed by innumerable white crystalline veins, besides larger fissures, some of which are more or less open, and others entirely filled with limestone-breccia. It is these fissures that contain the deposits of galena and carbonate of lead for which the Sierra de Gador is so famous; and all the limestones of the adjacent sierras to the west partake of the same character. The bottom beds of limestone are generally shaly and often black; and hard shaly bands are not uncommon throughout the series, alternating with the limestones. The shales rarely

contain lead-ore. Fossils are either altogether unknown, or at least exceedingly rare in this limestone. I have only heard of two or three specimens, said to have been found near the village of El Fondon in the Alpujarras (the valley between the Sierra de Gador and the Sierra Nevada); and, although I have made inquiries at Madrid, whither they are said to have been sent, I have not yet succeeded in obtaining information concerning them*.

At and near Gibraltar the limestones, which probably correspond with those of the Sierra de Gador and La Peza, are almost as crystalline, but are of a pale-blue colour, and fossils, though rare, are not unknown. A sufficient number of good specimens have been obtained, and forwarded to me by Mr. Frimbley, to justify the hope that the exact position of these rocks in the series may now be determined. There is no doubt as to their Jurassic character; but whether belonging to the upper or the lower division remains still to be determined†.

Near Malaga the limestone overlying the sandstone series is in all probability not very different in age from that of the Gibraltar Rock; but the character of the limestone is distinct, the beds being yellow and much less crystalline, but still without fossils. Although these beds have been frequently quarried on a large scale near Malaga, I have not been able to hear even of a single specimen of organic remains of any kind having been found in them. There are three tolerably well-marked differences of condition of the limestone; but these differences do not seem to extend far, and have failed hitherto in yielding any satisfactory indication. The diagram, fig. 6, shows the position of these limestone-beds near the coast at San Telmo, about two miles from Malaga.

The marly limestones are the lowermost of those seen near Malaga; and these are occasionally overlaid by a semicrystalline limestone, which, at the summit of the hill of San Anton (1440 feet), passes into a fine red marble, which has been quarried and is well adapted for ornamental purposes. In this red marble have been found several specimens of the alveolus of a Belemnite, considered to be of Cretaceous age. Near San Telmo the marly limestones repose directly on schists, without the intervention of red rock. Close by, the red rock is developed to some thickness, and is covered by the pale-yellow marly limestones as usual. It would be impossible without great labour and detailed mapping to count the number of hills in the immediate neighbourhood capped with these marly limestones. There can be no doubt that the soil derived from the admixture of decomposed rocks of this kind with the red sandstones and underlying

* Since the above was written, I have heard from my friend Don José de Monasterio, Professor at the Mining School of Madrid, and formerly Mining Inspector of the Province of Almeria, who informs me that the fossils in question, forwarded by one of his colleagues, consisted of remains of a *Clypeaster*, perhaps Jurassic, but more probably Tertiary.—[Sept. 1859.]

† The examination of these fossils (an Ammonite and some *Terebratulæ*) by M. de Verneuil and M. Deshayes led to no important result. They confirmed the view already entertained of the Jurassic age of the rocks, but added no new species to those already known.—[30th Sept. 1859.]

shales, together with the close vicinity of gypsum, must be peculiarly adapted for the cultivation of the vine, and has had much to do in the production of the grapes for which Malaga is renowned.

The limestones connecting those of Malaga with those of Granada to the north-east, and Gibraltar to the west, partake of the different characters of those peculiar to the two extremities. They are generally bluish, semicrystalline, and compact, and they rarely resemble in external character the marly yellow beds just described. When, however, they are followed, the passage from one to another part of the series seems very obscure.

The limestones of San Telmo are those mostly worked near Malaga, and they are chiefly valuable for burning. Fair building-stone (good in such a climate) is readily obtained from several other parts of the deposit at no great distance from Malaga, both to the north and west, particularly at some points on the Antequera road.

To the west of the tertiary basin of Malaga, from Torre Molinos along the coast to Fuengirola, and still further west to near Marbella, the character of the limestone is considerably changed. At Marbella a large vein of serpentine is seen traversing the country; and on the east side of this vein the limestones are converted into a beautiful white dolomite. Lead-mines have for some time been worked in these altered limestones, especially in the Sierra de Mijas. Away from the influence of the serpentine, the limestone resumes its ordinary character, and ceases to bear lead.

Near Gibraltar there are marly limestones alternating with sandstones and shales. The country is much disturbed; and it seems not unlikely that these beds are thrown into their present position by an anticlinal axis in the direction of the longer axis of Gibraltar Bay. (See diagram, fig. 7.)

Fig. 7.—Section on the shore of Gibraltar Bay, west of Algeciras.
E.N.E. W.S.W.

1. Sandstone overlying shales.
2. Bands of marly limestone.
3. Shaly beds.

Tertiary Rocks.—Of these there is considerable variety; and the result of a careful and minute investigation would be of the highest interest. Many of the beds are highly fossiliferous; and, as I have been enabled to add much to the lists of fossils from localities in the southern part of the Peninsula, there can be little doubt of valuable results when these beds shall have been properly examined. At present I content myself with a brief statement of the descriptive geology.

The oldest beds are undoubtedly those in the neighbourhood of Malaga, where a portion of the Nummulitic limestone series of the South of Europe overlies a peculiarly beautiful white oolitic marble,

itself reposing irregularly on a limestone-breccia, composed of angular fragments of the adjacent Jurassic rocks, cemented into a hard rock. Annexed is a section showing the position of these beds and their relations with the rocks above and below. (Fig. 8.)

Fig. 8.—Section through the Tertiary Series in the country east of San Telmo and near the Arroyo de Jabonero.

The extent to which these older tertiaries are developed is not very considerable, at least in thickness, as neither of the deposits referred to is more than a few yards thick in ordinary cases. The Nummulitic limestone, however, with its characteristic fossils*, is readily traceable for several miles both to the east and west of Malaga, and undoubtedly connects itself with the great deposit of the same age well known elsewhere in the South of Europe. The oolitic marble is quarried to some extent, and forms an admirable building-material. I have not seen any large slabs polished; but the grain is fine, and large blocks could easily be obtained. I observed in some cases that both the oolitic and other Tertiary limestones were here superimposed directly on the schists; but elsewhere, and more usually, they rest on the Jurassic rock or the sandstones. The belt of all these rocks is much broken, and the deposits consist rather of detached outliers than continuous strata. At one point near San Anton there are two beds, one being parallel to the other for a little distance.

I have not as yet been able to obtain any section showing the Upper Tertiary deposits resting on those of the Nummulitic period. While, however, the newest of the latter belong certainly to the older part of the Eocene series, there seems no probability of the oldest of the former being more ancient than Older Pliocene. The oldest of them are, I believe, the blue clays which are worked for various fictile purposes in several places in the Vega or plain of Malaga, but chiefly near the cemetery on the left and near the convent now used as a quarantine establishment on the right bank of the Guadalmedina River. These clays contain a considerable quantity of marl, and some sand. They extend pretty generally over the space occupied by the Vega, being seen in many small ravines; but they are generally concealed by newer and less argillaceous beds. They are highly fossiliferous, abounding with shells, both univalves and bivalves;

* The fossils of which this limestone is made up are not indeed Nummulites, but *Alveolina*. They belong, however, to the Nummulitic period.

but they are still more remarkable for the enormous multitude of foraminiferous shells which they contain, and the large size and great variety of form that the individuals of several species exhibit. In this respect the clay-beds of the Tejares, or tile-pits, are perhaps unrivalled.

In the basin of Malaga the blue clays of the Tejares are covered with whitish marls, also highly fossiliferous; and these gradually become more sandy towards the edges of the basin, until, a few miles up the Guadalmedina, where they are exposed, they are mere sands, and contain few fossils except fragments of *Pectines*. At the tile-pits (shown in the annexed diagram, fig. 9), however, the fossils are numerous; and they are of much the same character about a mile to the west, where they are again well shown in an artificial cutting.

Fig. 9.—Section at the Tejares or Brick-pits close to Malaga.

1. Gravel and sands.
2. White marl, with bones of land-animals and some shells.
3. Blue clay of the Tejares.

The thickness of blue clay shown in these cuttings is in some places as much as 40 feet; and the fossils are distributed in groups, so that at one time numerous specimens of a particular species abound, and others previously abundant are extremely rare. The shells are generally found perfect, even the most delicate spines and processes being quite uninjured. The *Foraminifera* are particularly well preserved.

Above the blue clay are paler and more marly beds (figs. 1, 2), with similar fossils, at the top of which is a deposit containing marine shells of different character and in different conditions. With these are associated some freshwater shells, the bones of land-animals, and cones of several species of coniferous trees. The mammalian bones hitherto discovered are two remarkably fine fragments of the jaw of a *Rhinoceros*, a portion of the axis-vertebra of a *Rhinoceros*, probably the same species, the horn-core, with part of the left frontal bone, of a Ruminant (considered by Dr. Falconer to be a species of *Capra*), and the vertebræ and other bones of at least one species of large

Cetacean*. There are also several teeth of Sharks, of species common in the Mediterranean tertiary deposits of Malta. Over these are gravels of comparatively recent date. It may be added that these newer tertiary deposits have all been affected by the elevatory movements to which the undulating form of the ground behind Malaga is almost entirely due.

The exact relation of the deposits occupying the basin west of Malaga with those of the adjacent small basin of the Caleta, and those still further east of the Jabonero, are not very clearly made out. Each possesses a series of its own, and there appears to have been at one time a communication from one to another on the upper or north side as well as towards the sea. A reference to the map (fig. 1) will show the reasons which render it probable that such communication once existed, as there will be seen two small patches of tertiary deposits between the Caleta beds and the Tejares,—one a little further up the Arroyo of the Caleta, and the other in a hollow space between two hills which separate the main deposits. The distance between the Caleta and Tejares outlying deposits is thus rendered extremely small, not exceeding indeed 100 yards.

Fig. 10.—Section of the beds in the Arroyo Caleta.

1. Gravel and detritus.	5. Jurassic limestone.
2. Calcareous incrustations, with Pectens.	6. Red sandstones.
3. Sands. (<i>Pectines</i> and <i>Terebratulæ</i> .)	7. Schists.
4. Sands. (<i>Pectines</i> , <i>Terebratulæ</i> , and <i>Foraminifera</i> .)	

The Caleta beds occupy a small tongue of land in the valley, and range also along the hills on the right or western side of the river-course. The diagram, fig. 10, shows the nature of these deposits, which are, for the most part, coarse gravelly beds, abounding with fragments of *Ostreæ*, *Pectines*, and other shells, including several species of *Terebratulæ* and some *Foraminifera*. These beds are covered by a peculiar calcareous incrustation, which also spreads over part of the secondary rocks. It appears to belong to a much more modern period, and contains a few shells of species common in the adjacent seas. The highest point at which I observed this incrustation was about 40 feet above the sea. Gravel is occasionally found on the top of all these deposits.

The Jabonero beds correspond much more nearly with those (just described) of the Caleta than with those of the Malaga basin. They are shown in fig. 8 as overlying the older tertiary deposits, and they consist of sands and pebble-beds with *Pectines* and *Ostreæ*, lying on a regular bed of Oysters, with Pectens accumulated in it. These repose, in doubtful conformability, on the Nummulitic rocks. The

* See Appendix.

thickness of the newer tertiaries is here about the same as in the Caleta series, but the breadth of country over which they extend is much greater. Further to the east the tertiary beds do not, I believe, reappear until we reach the neighbourhood of Velez Malaga.

The tertiary beds of Almeria are better known than those of Malaga, but their fossils have not yet been described. The deposits are sandy and highly fossiliferous. They are of great thickness, and reach an elevation of several hundred feet above the sea. I have not yet had an opportunity of examining their relations with the other tertiaries, or of making a collection of the fossils.

Raised beaches are observable at various points along the coast where the old rocks come near the existing sea-line. These consist generally of fragments of slate, for the most part angular, and often of large size. Near Malaga I took the elevation of two well-marked cases, and found their height above the sea to be about 40 feet. The uppermost deposits of angular gravel, seen a few miles up on the banks of the Guadalmedina, occupy nearly the same, or a somewhat higher, level, but contain a smaller proportion of angular material. I have not observed any shells or fragments of shells in those raised beaches on the coast which consist of large angular fragments; but in one instance, about a mile east of the pier, a considerable quantity of copper-ore, of fine quality, has been removed from amongst detritus of this kind. The mineral vein from which this ore had fallen is seen cropping out on the hill above; but the ore appears to have been confined to a small bunch, and is no longer to be found in the vein in sufficient quantity to be worth working.

Proofs of recent elevation are not wanting in various places near Malaga. These consist partly in a considerable breadth of land actually gained from the sea within the historic period, and partly in the existence along the coast of remains of Roman and Moorish architecture, connected with marine operations, now inland and at such a distance from the sea as to destroy altogether the uses for which they were intended.

APPENDIX.

THE collection of tertiary fossils, chiefly from the Tejares or tile-pits, already referred to (p. 597) has been carefully examined since the preceding memoir was read. It includes (1) a highly interesting series of *Foraminifera*, which have been submitted to Mr. Rupert Jones and Mr. W. K. Parker; (2) a series of shells of *Mollusca*, referred to MM. de Verneuil and Deshayes; (3) a few bones and teeth of Fishes; and (4) some remarkably interesting Mammalian remains, described by Dr. Falconer*.

* For collecting a fine series of the largest of the *Foraminifera*, I am greatly indebted to Mrs. Saurin, at that time resident in Malaga. I have also to thank Don Pablo Prolongo for allowing me to bring to England, for comparison, the jaw of *Rhinoceros* and some other specimens.

1. *Foraminifera*.—The blue clay of the Tejares consists in great part of the remains of these minute animals. Although the number of species is not very large, the collection includes a vast variety of forms, mostly mere modifications of known species, and all tending to connect by numerous intermediate links species and varieties already described. The following remarks are supplied by Messrs. T. RUPERT JONES and W. K. PARKER, who examined the specimens collected in Spain, and obtained a still larger quantity by washing several pounds of the clay.

“This is a rich Rhizopodal fauna. In the Mediterranean, from the shore to a depth of 100 fathoms, we have a similar group of Rhizopods, though the *Nodosariæ* and *Cristellaræ* do not approach the size of those of Malaga. The Malaga fauna under notice is almost the exact counterpart of that of the clays of the Vienna Tertiary basin. The Tertiary sands of Turin contain a similar fauna, but not so rich in species and varieties, although the individual *Nodosariæ* and *Cristellaræ* are very fine near Turin. The Tertiary beds of Sienna contain all that Malaga affords, and more, the additional forms being chiefly Nodosarian and Cristellarian varieties.

There is considerable resemblance between the *Rhizopoda* of the Malaga clay and those of the Tertiary clays of San Domingo*; but the latter clays are rich in *Amphistegina*. As some of the more shelly beds of the Sienna deposits also abound with *Amphistegina*, perhaps further research may reveal a bed at Malaga rich in the same species, which in our collection from this locality we find to be represented by a single specimen.

The Malaga clay has but few forms in common with the Crag, the Faluns, and the Calcaire grossier, which are all shelly sands.

The London clay contains in its rich Rhizopodal fauna many of the forms found at Malaga, but it is without several of those which occur in the later Tertiary deposits.

In the following list are enumerated the *Foraminifera* of the Malaga deposits, mostly under their best-known names (whether varietal or specific):—

No. of typical
species.

1. <i>Lagena sulcata</i> , Walker, and 2 varieties	... ..	rare.
2. <i>Nodosarina</i> † <i>Raphanus</i> , Linn. (34 varieties)	... ..	common.
<i>Nodosaria</i> <i>Raphanus</i> , Linn. and 6 varieties	... ..	common.
<i>N. dentalina</i> , Lam. and 7 varieties	... ..	common.
<i>Vaginulina</i> <i>Badenensis</i> , D'Orb.	... ..	common.
<i>Fronicularia planata</i> , DeFrance	... ..	common.
<i>Cristellaria</i> <i>Calcar</i> , Linn. var. <i>Cassis</i> , Fichtel and Moll, and 15 other varieties	... ..	common.
3. <i>Orbulina</i> <i>universa</i> , D'Orb.	... ..	rather common.
4. <i>Globigerina</i> <i>bulloides</i> , D'Orb.	... ..	rather common.
5. <i>Rotalia</i> (<i>Planorbulina</i>) <i>farcata</i> , F. & M. and 6 varieties	... ..	common.
6. — <i>repanda</i> , F. & M. (3 varieties)	... ..	common.
7. — <i>Beccarii</i> , Linn. and 1 var.	... ..	rather common.

* Quart. Journ. Geol. Soc. vol. vi. p. 40, and vol. ix. p. 132.

† See Annals Nat. Hist. 3 ser. vol. iii. p. 477.

8. <i>Rotalia trochidiformis</i> , <i>Lam.</i> (small var.)	... ..	common.
9. <i>Nonionina sphaeroides</i> , <i>D' Orb.</i>	... ..	rather rare.
10. <i>N. asterisans</i> , <i>F. & M.</i> (2 varieties)	... ..	common.
11. <i>Sphaerodina bulloides</i> , <i>D' Orb.</i>	... ..	common.
12. <i>Polystomella crispa</i> , <i>Linn.</i> and 1 variety	... ..	common.
13. <i>Amphistegina vulgaris</i> , <i>D' Orb.</i>	... ..	rare.
14. <i>Bulimina obtusa</i> , <i>D' Orb.</i> (4 varieties)	... ..	common.
15. <i>Uvigerina pygmaea</i> , <i>D' Orb.</i> and 2 varieties	... ..	common.
16. <i>Verneuilina tricarinata</i> , <i>D' Orb.</i> (4 varieties)	... ..	common.
17. <i>Textularia agglutinans</i> , <i>D' Orb.</i> (3 varieties)	... ..	common.
18. <i>Miliola seminulum</i> , <i>Linn.</i> (4 varieties)	... ..	rather rare.
19. <i>Lituola nautiloidea</i> , <i>Lam.</i> (1 var.)	... ..	rather common."
- T. R. J. & W. K. P., July 1859.

2. *Mollusca*.—These include a considerable number of species distinctly Pliocene, and most of them identical with those described by Brocchi amongst the Subapennine fossils. They are from the Tejares beds, and are associated with the *Foraminifera*, being found buried in the same peculiar blue mud, or in the marly sands above. There are also some of more modern date from the Caleta.

The following list has been forwarded by M. DE VERNEUIL.

Tejares Clays (Subapennine).

<i>Vermetus arenarius</i> , <i>Linn.</i>	<i>Pleurotoma dimidiata</i> , <i>Br.</i>
<i>Dentalium elephantinum</i> , <i>Brocchi.</i>	— <i>rotata</i> , <i>Br.</i>
<i>Conus antediluvianus</i> , <i>Br.</i>	<i>Turritella vermicularis</i> , <i>Br.</i>
<i>Natica.</i>	— <i>subangulata</i> , <i>Br.</i>
<i>Scalaria clathra</i> , <i>Br.</i>	<i>Mitra scrobiculata</i> , <i>Br.</i>
<i>Rostellaria pes-graculi</i> , <i>Br.</i>	<i>Buccinum semistriatum</i> , <i>Br.</i>
<i>Triton apenninicus</i> , <i>Lam.</i>	<i>Columbella nassoides</i> , <i>Bellard.</i>
— <i>subcinctus</i> , <i>Lam.</i>	<i>Cassidaria.</i>
<i>Ranella gigantea</i> , <i>Lam.</i>	<i>Turbo</i> , spec. nov.
<i>Murex brevispina</i> , <i>Br.</i>	<i>Pectunculus glycimoris</i> , <i>Lam.</i>
— <i>fistulosus</i> , <i>Br.</i>	<i>Venus umbonaria</i> , <i>Lam.</i>
<i>Fusus longiroster</i> , <i>Br.</i>	<i>Ostrea navicularis</i> , <i>Br.</i>
<i>Pleurotoma brevirostrum</i> , <i>Sow.</i>	<i>Nucula placentina</i> , <i>Lam.</i>
— <i>cataphracta</i> , <i>Br.</i>	<i>Arca diluviana</i> , <i>Br.</i>
— <i>turricula</i> , <i>Br.</i>	<i>Leda.</i>

Tejares Sands.

<i>Ostrea Boblayei</i> , <i>Desh.</i>	<i>Pecten jacobæus</i> , <i>Linn.</i>
— <i>Virleti</i> , <i>Desh.</i>	— <i>pleuronectes</i> , <i>Lam.</i>
<i>Hinnites.</i>	— <i>varius</i> , <i>Linn.</i>

The following species are in great abundance in the Rio Caleta, and form beds little mixed with sand or other remains,—*Pecten pusio*, *Lam.*, *Terebratula sinuata*, *Riss.*, *Purpura hæmastoma*, *Gm.*, and *Balanus tintinnabulum*, *Linn.*

3. *Pisces*.—The remains of fishes consist of a few vertebræ and teeth, chiefly of sharks. They have not yet been referred to known species.

4. *Mammalia*.—The only Mammalian remains hitherto found consist of several fragments of a large Cetacean animal, the teeth and bones of a *Rhinoceros*, and some remains of a *Capra* (see p. 597). The first were met with since this paper was read; they are in too

imperfect a state for identification, but were originally found so nearly complete that, had any naturalist been present, the skeleton might have been secured. As it was, the greater part was wilfully destroyed by the workmen.

The remains of *Rhinoceros* are of much interest: besides portions of vertebrae, there is a jaw-bone; and concerning this Dr. FALCONER has obligingly favoured me with the following remarks:—

“The specimen consists of the greater part of a right upper maxillary bone, comprising *in situ* the second and third premolars, and the three true molars. The last premolar (p.m. 4) is wanting. The specimen has been fictitiously repaired with cement, placing all these teeth in series, without allowance for the missing premolar, and it is in consequence deceptive at first sight. The outer border of the crown is more or less damaged in most of the teeth. Together with Mr. Waterhouse, to whom I referred the fossil, I was at first led to believe that it belonged to the miocene *Aceratherium incisivum* of Kaup, from its close general resemblance to the specimen figured by De Blainville in the ‘Ostéographie,’ *Rhinoc.* pl. 12, under the name of *Rhinoceros incisivus d’Auvergne*. But I have since arrived at the conclusion, after a fresh examination of the Tuscan Collections, that the Malaga Rhinoceros is the *Rhinoceros Etruscus*, so named by me from its prevalence in the Pliocene deposits of the Upper Val d’Arno. This form has hitherto been confounded, on the one hand with *Rhinoceros tichorhinus*, and on the other with *R. leptorhinus* of Cuvier. It had a bony nasal septum, as in the Clacton form, described in the ‘British Fossil Mammalia,’ under the designation of *Rhinoceros leptorhinus*, from which, however, it is essentially distinct in every detail throughout the construction of the skeleton.

“The true *Rhinoceros leptorhinus* of Cuvier, founded upon the Cortesi cranium, had no ossified nasal septum, and is distinct alike from the species here called *Rhinoceros Etruscus*, and from the fossil Rhinoceros of Clacton. I have ascertained that the character of an ossified nasal septum was common to three European fossil species of *Rhinoceros*, of the Pliocene and Newer Pliocene periods; and that there is only one known species of this category in which it was wanting. The characters of these species, and their distribution over the European area, will be described in detail, in a separate essay.”—H. F., Oct. 1859.

Dr. FALCONER has also obliged me with the following note on the Ruminant horn-core from Malaga:—

“The specimen comprises part of the left frontal bone, including a portion of the orbit and of the cerebral cavity, together with the entire horn-core borne upon the frontal. The base of the core is situated immediately over the orbit, and occupies the whole width of the left frontal from the rim of the orbit to the sagittal suture. The core is thick, cylindro-conical with an obtuse apex, erect, but slightly curved backwards, and concave vertically along the posterior side, as in the species of the subgenus *Ibex*. The section of the core

is oval in the antero-posterior direction, with the greatest width in front. In its general form, the core agrees very closely with that of the fossil species named *Ibex Cebennarum* by Gervais ('Paléontol. Française,' pl. 10. figs. 1 & 2), from the Cavern of Mialet (Dép. du Gard); but, from the relation of the core to the sagittal suture, it is manifest that the horns were more approximated at their base, more erect, and much less divergent in the Malaga form than in the latter. The same characters distinguish the fossil from *Antilope* and *Ovis*. The principal dimensions are :—

	Inches.
Greatest thickness of the frontal between the horns	1·3
Length of the horn-core	6·5
Antero-posterior diameter of the horn-core at base	2·3
Transverse diameter at the base	1·9

"The materials are too scanty and imperfect to warrant an exact specific determination; but, so far as they go, they indicate a species of *Capra* of the section *Ibex*, and probably extinct. So far as I am aware, no species of this genus has hitherto been met with in any of the Lower Pliocene beds of Europe; and the occurrence of the Malaga form along with the fossil *Rhinoceros* characteristic of the 'Sabbione' of the Val d'Arno is a fact of considerable interest."—H. F., Oct. 1859.

I append a short notice of the economic geology of the neighbourhood of Malaga.

Specimens of rich sulphuret of copper have been obtained at various places from the metamorphic schists along the coast. A few years ago a quantity of good ore was discovered amongst detritus close to the English cemetery to the east of the lighthouse; and on further examination, a strong quartz-vein was found, with indications of copper-ore, cropping out on the hill above and traversing the country from N.N.E. to S.S.W. A branch comes into it near the place where the deposit was found; but no result was obtained from mining-operations carried on with a view to cut this lode by an adit. None of the deposits yet made out are of more than very limited dimensions; and no regular mining seems likely to be undertaken.

Marbles, of various kinds and of good quality, are obtained from San Anton and up the Arroyo de Jabonero; and one vein, of a rich red colour, was partly worked some years ago. Specimens of it are to be seen in the British Cemetery, and they promise well; but the quarry is not very accessible. The oolitic marble might be used for decorative purposes; and both it and the Nummulitic limestone are employed to some extent for building. The brecciated limestones are hard, and are used in Malaga for steps. Building-sandstone, of fair quality and adapted to the climate, is found with the "Equisetite-grit" near San Telmo, and is there worked. It is of good quality and even grain, but not very hard. White sands for glass-making and other purposes are found in the Caleta Valley among the triassic beds. Excellent limestone for burning is obtained from

San Telmo, where the marly character of some of the beds renders the mortar hydraulic. For agricultural purposes, the magnesian limestones are available. Gypsum, which is greatly used in Spain for various purposes, is found in several large lenticular deposits in the upper triassic sandstones, and is remarkably free from impurities. Other beds, less pure, occur in sands with tertiary rocks in the valleys to the west of the river. The pliocene clays are extremely pure and admirably adapted for pottery-ware of the finest kinds. They are free from grit, and are very plastic; but they would probably melt readily in the furnace, as they contain much carbonate of lime. Among the clays there is one bed used in the manufacture of small terra-cotta figures, for which Malaga has long been famous. The pottery of the district is very primitive, but of excellent quality.—D. T. A., July 1, 1859.