XXXI.—On the Geology of the Island of Zante.

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The observations detailed in this paper are the result of a few days' residence in the Island of Zante, during which I was enabled to take a general view of its geological features; but a complete survey of this and the other Ionian islands is still to be desired. Such an investigation would be a work of labour, for though there is little variety in the rocks, there is much complexity in their arrangement. The structure of Zante, more simple than that of the other islands, presents an epitome of their component rocks in an almost unbroken succession; and it may, therefore, be selected as a type to which the phenomena of the other islands may be referred.

The geological phenomena of Zante may be arranged under the three heads of, 1. Apennine Limestone; 2. Tertiary Deposits; and 3. Mineral Springs. (See Map, Plate XXXIII.).

1. Apennine Limestone.—This is perhaps the most convenient appellation for that deposit of compact white or grayish limestone, which is so largely developed in the south of Europe, and especially on the shores of the Adriatic. It has an uniform character throughout many thousand feet of vertical thickness, and many hundred miles of horizontal extent. The few fossils it contains agree with those of the cretaceous, and in part also of the oolitic series of northern Europe. It constitutes, in Zante, an anticlinal ridge, extending in a N.N.W. and S.S.E. direction along the south-western coast, from Point Skinari to Point Cheri, and this ridge is continued through the island of Cephalonia. Along the eastern side the prevailing dip of the strata is from 30° to 45° to the E.N.E. ; west of Point Skinari an opposite dip commences, and continues, with few exceptions, to near Point Cheri, where the strata again dip to the eastward.

The tertiary beds occur only on the east of this ridge. On the west we find a series of cliffs, upwards of 600 feet high and almost perpendicular, the sea-worn caves and fir-clothed crags of which present highly picturesque scenery. This steepness is continued to a great depth beneath the surface of the sea, as is proved by the deep soundings along this coast.
The Apennine limestone, of which these cliffs are composed, is nearly white, and less compact than usual, often resembling the hard chalk of the north of England. No beds of flint were noticed here, though in Corfu they are not unfrequent. Organic remains are by no means abundant, yet Nummulites, fragments of Hippurites, and indistinct traces of other fossils, may frequently be detected by searching.

From its compact, inflexible, and brittle texture, the Apennine limestone generally abounds with faults and fractures, which give rise to numerous caverns, (catavothra), subterranean rivers, and thermal and mineral springs. In these respects, no less than in its mineral structure, it presents a close analogy to the Carboniferous Limestone of northern Europe, for which it has often been mistaken by observers, who paid no attention to its fossils.

The frequency and violence of earthquakes in many parts of the south of Europe, may perhaps be accounted for by the unyielding texture of this rock, the vibrations being propagated to much greater distances, than in countries composed of more loosely aggregated or more elastic materials.

In Zante the Apennine limestone presents numerous faults, one or two of which will be alluded to in a subsequent page.

2. Tertiary Beds.—These occupy the greater part of the island of Zante. Reposing on the eastern flank of the Apennine limestone, they extend to the coast: they rise also in several detached hills through the alluvial plain which forms the centre of the island. They have evidently yielded to the same disturbing force as the limestone range; and they dip from this rock to the eastward. The upper portion is the counterpart of the beds, described by Mr. Hamilton and myself, as occurring near Lixouri in Cephalonia*. In Zante, they are best displayed in the Castle Hill above the town, and in the cliff which extends thence to the eastern coast. (See Plate XXXIII., Sect. 1.)

The upper strata near the Lighthouse consist of a porous, calcareo-arenaceous stone, of a pale yellow colour, and easily worked. Fossils are rare in it, except on the east coast, where one or two of the strata contain numerous casts of Cerithia and other mollusca.

These strata are succeeded by a thick deposit of blue clay and marl, forming the height on which stands the citadel of Zante. The shells found in it are principally Pectunculus auritus, Broch., Buccinum semistriatum, Broch., and Natica glaucina, Lam. All these species occur also in the middle portion of the Lixouri section, but more abundantly, and associated with many others.

The gypseous beds, which at Lixouri succeed the argillaceous strata, are not visible in this part of Zante, but on the south coast they form the com-

* See Geological Proceedings, No. 51, and postea.
of the Island of Zante.

mencement of a section which carries us much further down in the series than the lowermost beds examined at Lixouri. (Pl. XXXIII., Section 2.) The gypsum also occurs in white and conspicuous patches on the hill at the S.E. extremity of the island. The rest of this hill consists of sand and clay belonging to the upper part of the series; but the beds are much disturbed, and not easily reducible to the regular arrangement seen in Sections 1 and 2.

The uppermost beds in Section 2 consist of gypseous marls and gypsum, sometimes fine-grained and saccharine, but sometimes only a coarse aggregate of selenitic crystals like that at Lixouri. The stratification is occasionally preserved, though in others it appears to have been obliterated by the action of crystallization. Angular fragments of a black marlstone, imbedded in the gypsum, seem to have been derived from strata of stone, broken up by the force of the crystallizing process.

The strata of yellow limestone above the gypsum, exhibited in Section 1, and at Lixouri, clearly belong to the Pliocene epoch, many of their fossils being identical with those of the Subapennine hills. The strata which underlie the gypsum in Section 2, consist of a series of brown sandy clays and marls, but whether they also belong to the Pliocene or to a prior epoch, it is not easy to determine. They extend for about two miles along the coast, and dip about 25° to E.N.E., with a few local interruptions. Fossils are very rare in these beds, and in general they are too much crushed to allow the species to be determined. They were noticed only near the middle of the argillaceous series and near its base. At the former spot are crushed fragments of echini and obscure bivalves; and at the latter, is a bed of indurated bluish marl containing an abundance of the shells of Hyalæa and Creseis, but they are larger than those of the species now living in the Mediterranean (Hyalæa cornea and Creseis spinifera), and are therefore probably distinct species.

The argillaceous beds are succeeded by yellowish calcareous sandstone and loosely aggregated limestone. A great subsidence appears to have taken place between that point and the range of secondary limestone, about a mile distant. This tract forms the marshy plain of Port Cheri, towards which the tertiary strata dip on both sides. There is consequently no traceable sequence between the argillaceous beds above described and the calcareous strata, which we are now considering. The latter dip about 18° S.W., and extend along the east side of the marsh, forming some hillocks at its upper end. They consist in general of calcareous particles, interspersed occasionally with pebbles of secondary limestone; but some of the beds approach the texture of Portland stone. Minute Foraminifera are abundant in it, and the only other fossils noticed were two species of small Pectens.
These calcareous rocks seem referable to a distinct epoch, and may perhaps eventually prove to be of the Meiocene or even of the Eocene age. The fine-grained limestone, extensively quarried near Lixouri in Cephalonia, belongs probably to this part of the tertiary series.

On the west side of Port Cheri is a low cliff of blue marl and clay, the beds of which abut against the secondary or Apennine limestone, and dip about 18° north-east. The only fossils noticed in it, were a few scales and vertebrae of fish, and a species of Vermiculum, Mont. (Quinqueloculina, D'Orb.)

This small, argillaceous mass has been probably derived from a higher part of the tertiary series, and brought down to its present position by the subsidence, which seems to have formed the valley and bay of Port Cheri. Of this depression, there is further proof in a remarkable fault, which occurs in the Apennine limestone, and is marked by a smooth surface of the rock descending to the sea. It may be traced inland in a direction W,N,W. for half a mile or more, rising like a wall above the downcast portion on the north-east side. At the point where it joins the sea the surface is nearly a plane, inclined about 55°. It is scored with numerous striae, inclined at an angle of 65° to the horizon, the dip of the strata being about 25° N.E.

The enormous friction and pressure of the descending mass have imparted to the surface of rock, a remarkable degree of hardness, and a darker colour than usual. This change of character penetrates to the depth of about two or three inches from the surface; the rock below being softer and white, and resembling the compact chalk of Yorkshire.

The tertiary beds range from Port Cheri northwards along the foot of the limestone, and reappear on the north shore about two miles beyond the village of Castashi; they are shown in Section 3, which is in some respects a counterpart of Section 2, but presents differences which it is not easy to explain. The porous yellow limestone, which at Port Cheri intervenes between the argillaceous beds and the secondary rocks, is here wholly absent, and the tertiary clay appears to pass gradually into the secondary limestone. The highest beds in the section, consisting of blue marl with shells of Creseis and Hyalæa, are the precise equivalents of that which contains these fossils near Port Cheri; and we are thus furnished with a common point of departure in our comparison of Sections 2 and 3. They are succeeded (Section 3) by numerous beds of blue clay and marl, apparently destitute of fossils, becoming more calcareous in the lower part, and ultimately passing into a white limestone resembling hard chalk. A stratum of conglomerate, used for millstones, occurs here, and consists of rolled pebbles of compact Apennine limestone; beneath this are other strata of compact limestone, undistinguishable from that
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of the secondary mountain range. The beds above described are conformable throughout, and seem to pass downwards into the secondary limestone; whether this is really the case, cannot, however, be determined from the section before us, for the sequence is again interrupted by an extensive fault, (seen at the left hand of Section 3). It is therefore possible, that the limestone beds below the conglomerate may be considerably above the true base of the tertiary series, and that an hiatus may exist between them and the real secondary limestone, which they so much resemble. A careful survey of the line of junction between the secondary and tertiary formations throughout the island, would perhaps solve the difficulties, presented by this section.

§ 3. Mineral Springs.—The springs of bitumen, for which Zante has been celebrated from the time of Herodotus, rise in the marsh at Port Cheri, (see Pl. XXXIII., Section 2.). The principal one is a well about five feet deep; the bitumen oozing up from the bottom; and above it the well is filled by clear, cool, and tasteless water, which is probably only an accidental accompaniment of the bitumen. Some travellers (Walsh, Chandler, &c.,) state that bubbles of gas are given out by the bitumen, but in two visits which I made to the spot, nothing of the kind was observed. The produce has been stated at forty barrels annually*. Bitumen also rises in the Bay of Cheri, some hundred yards from the shore. (See Map.) This circumstance proves, that the bitumen is not derived from the peaty soil of the marshy plain, and there is nothing in the composition of the rocks around, to induce us to refer its origin to them; we must therefore suppose, that this substance is derived from that region of volcanic action, which may be almost demonstrated to underlie the Ionian Islands. This supposition derives farther probability from the fact before noticed, that the spot, where the bitumen rises, has been the site of a vast dislocation.

On the northern coast is another remarkable mineral spring, which seems to have escaped the notice of previous observers. It occurs about half a mile to the north of the junction of the tertiary and secondary rocks shown at the left hand of Section 3, Pl. XXXIII. The Apennine limestone here forms a low cliff descending abruptly to the sea. A spring of turbid water, resembling diluted milk, gushes out at the foot of the cliff beneath the sea level, and rising to the surface, from its less specific gravity, flows away above the sea-water in a stratum a few inches thick; flakes of a slimy white substance (probably Glairine) abound in this water, and are seen in the surrounding sea for a considerable distance; a strong smell of sulphuretted hydrogen is diffused.

* For further details relative to the "tar-springs," see Hawkins in Walpole's Travels in the East, Chandler's Travels, vol. ii. ch. 79, &c.
around, but no bubbles of gas rose in the water, nor was there any appearance of inflammable gas, on the application of a lighted taper.

On the 30th of May, 1836, the temperature of the air in the shade being 82° Fahr., of the adjoining sea at the surface 73°, and at the bottom in 4 fathoms, 69°, the spring indicated a temperature of 65°. This is so near the mean temperature of the latitude of Zante, that the mineral spring cannot be regarded as thermal. A bottle of the water is now in my possession, but I have not yet ascertained its chemical ingredients; from its close resemblance, however, to the mineral waters of many volcanic regions, as those of the "Aquæ Albulae" near Rome, we must refer its origin to some analogous cause. Of this we have a further proof in the fact, that this spring rises on the line of a considerable fault which has affected the Apennine limestone at right angles to its strike. The upcast is on the south, and presents a smooth and almost polished surface of rock, rising like a wall at an angle of about 80°, and running in a straight line for about a quarter of a mile inland. (See the Plan, Pl. XXXIII.) It projects some distance into the sea, and the spring above described rises in a recess a few yards to the south. Two smaller springs of similar turbid water issue at the base of the smooth face of rock. There can be little doubt, that the outburst of these springs is owing to this fault, which has opened a passage from the abyss in which they originate.

We have, then, in this mineral spring, an additional indication of the existence of a region of volcanic action, at some vast depth beneath the Ionian Islands,—of which there is already much presumptive evidence in the springs of bitumen, the frequent earthquakes, and, above all, in the current of seawater absorbed into a chasm in the neighbouring island of Cephalonia*. It is, however, somewhat remarkable that no rocks of igneous origin exist, as far as is known, throughout these islands.

I cannot conclude this imperfect contribution to the geology of the Ionian Islands, without expressing a wish that some competent geologist would undertake an accurate survey of them. Such an undertaking would be well worthy the attention of our Government, and would form an important appendix to the splendid survey, which has been already effected by the French Government in the Morea.

Postscript to the Paper on the Geology of Zante, by H. E. Strickland, Esq.

Since the printing of the paper on the Geology of Zante, I have been favoured by Dr. Daubeney with the following analysis of the mineral spring described at p. 407:

Specific gravity, 1.020.
Solid contents in one pint, 174 grains.
Ferrocyanite of potash produced no effect, proving the absence of iron.
Barytic salts produced a cloud, proving the presence of sulphuric acid.
Nitrate of silver produced a dense cloud, proving much common salt.
Oxalate of ammonia produced a cloud, proving presence of lime.
Phosphoric test caused evident indications of magnesia.

From the above analysis it appears that the water of this spring differs but little from ordinary sea-water. Indeed, from the manner in which it rises in the sea, a large quantity of sea-water must unavoidably become mixed with it. At the same time, its inferior specific gravity, its milky colour, the flocculi of Glairine, and the strong smell of sulphuretted hydrogen, all serve to characterize it as a mineral spring analogous to those of volcanic regions.

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