

## II.—THE OPHIOLITHIC GROUPS OF THE LIGURIAN APENNINES.

### II. EASTERN LIGURIA.

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#### GENERAL FEATURES.

THE three principal ophiolitic groups of this region are those of Levanto, Monte Bianco, and Monte Penna, about midway between Spezia and Genoa, viz. north of Levanto, Sestri Levante, and Chiavari, at average altitudes of 300, 800, and 1,600 metres respectively. Like the Eocene ophiolitic group of Sestri Ponente and Isoverde, west of Genoa, they lie in the upper horizon of that formation, that is, in the fossiliferous (fucoids) albarese limestones and the argillaceous schists which rest on the Middle Eocene macigno sandstone as the lowest member of the Ligurian Eocene. The sedimentary and infolded ophiolitic groups consecutively aligned from the coast to the crest of the Apennines form a series of anticlines north to south, dipping west, with some transverse folds. The whole region is greatly contorted and brecciated; it is, moreover, profoundly eroded by torrents charged with calcium carbonate which has accelerated erosion and at the same time re-cemented breccia. Although the three groups are now separated, they are, together with the scattered islands north of the crest of the Apennines towards Piacenza in the Po Valley, only the remnants of an originally continuous formation of no less than 1,500 square kilometres or 600 square miles.

The principal ophiolitic rocks of the three groups are serpentine, euphodite, and diabase, with their varieties. The serpentine is both compact and schistose, and often of porphyric structure. There is no passage from serpentine to the other two rocks, but there are frequent transitions between the latter; serpentinous schist or pseudo-serpentine, often in transition to argillaceous schist, is also much in evidence. Associated rocks are the semi-crystalline schists known as *flauti* and *diaspri*, viz. silico-calcareous, reddish and green schists, harder than limestone, indurated by taking up silica at the expense of lime, and containing radiolaria. Both, and notably the more highly indurated diaspri, form bands on the margin of ophiolitic rocks in proximity to calcareous masses.<sup>1</sup> It is a noteworthy feature that metalliferous deposits are found only in euphodite and diabase, never in serpentine, though often near the contact of the latter; again, manganese occurs, not in the ophiolitic rocks proper, but in the diaspri masses, though in the vicinity of the former.

#### I. THE LEVANTO GROUP. (Figs. 1 and 5.)

This extends along the coast from Monterosso to Levanto, Bonassola, and Framura for about 10 kilometres, and inland about 20 kilometres to north of La Baracca on the high-road from Sestri Levante to Spezia. The precipitous, craggy outcrops along the coast are composed chiefly of greenish and dark reddish serpentine and of

<sup>1</sup> Indurated, silico-argillaceous schists are known as *galestri*, yellowish, red, or green in colour; *ardesia* are tegular, silico-argillaceous-calcareous schists; and *resinite* is a white or yellowish siliceous, semi-opaline variety.

euphodite alternating with argillaceous schist all more or less decomposed, except the euphodite with felspathic base and smaragdite of Bonassola, which, though it exhibits secondary minerals, is comparatively fresh.<sup>1</sup> The principal outcrops inland are exposed along the road from Levanto to La Baracca (600 m.), where the ophiolitic series may be conveniently studied in the numerous quarries of the beautiful and well-known "green marble of Levanto", largely used for ornamental purposes. It is essentially compact serpentine, greenish and rusty red, with clear white veins which are fissures filled with calcite. The rock passes to a more crushed and brecciated variety, re-cemented by calcium carbonate as opicalce. Another variety is the so-called *ranochiaia* or frog-coloured, which in a greenish yellow groundmass exhibits fine, black, arborescent tissues of opacite. The compact serpentine also passes to schistose, fibrous, and steatitic, is often spheroidal, and, when it contains enstatite, diopside, bronzite, and notably diallage, is porphyric in structure. Along the same road serpentine often alternates with euphodite more or less altered, and with intermediate strips of pseudo-serpentine. The ophiolitic rocks are normally intercalated between argillaceous schists as the lower, and limestones as the upper strata, with occasional intervening claret-coloured diaspri. North of the Sestri and Spezia road occurs the cluster of serpentine and euphodite masses of Tavarone between Castiglione and Maissana, of Velva, Carro, Baracchino, and Matterana (Bracco), in all of which the euphodite is largely gneissiform and, notably north of La Baracca, forms a considerable area. Another interesting mass is that near Pignone, about 10 km. east of Levanto and the same distance north of Spezia, which constitutes, in the Eocene strata, a band of about 8 by 1 km. of serpentine and euphodite, like those of the Levanto group.<sup>2</sup> It runs north-west to south-east, parallel to the latter and to the coast towards the Cretaceous, Liassic, and Rhætian strata of the Porto Venere or western arm of Spezia Bay, and forms the link between the ophiolitic groups of Eastern Liguria and those 15 km. further east of Sarzana, Lunigiana, and Garfagnana in the Magra and upper Serchio Valleys along the northern margin of the Apuan Alps.

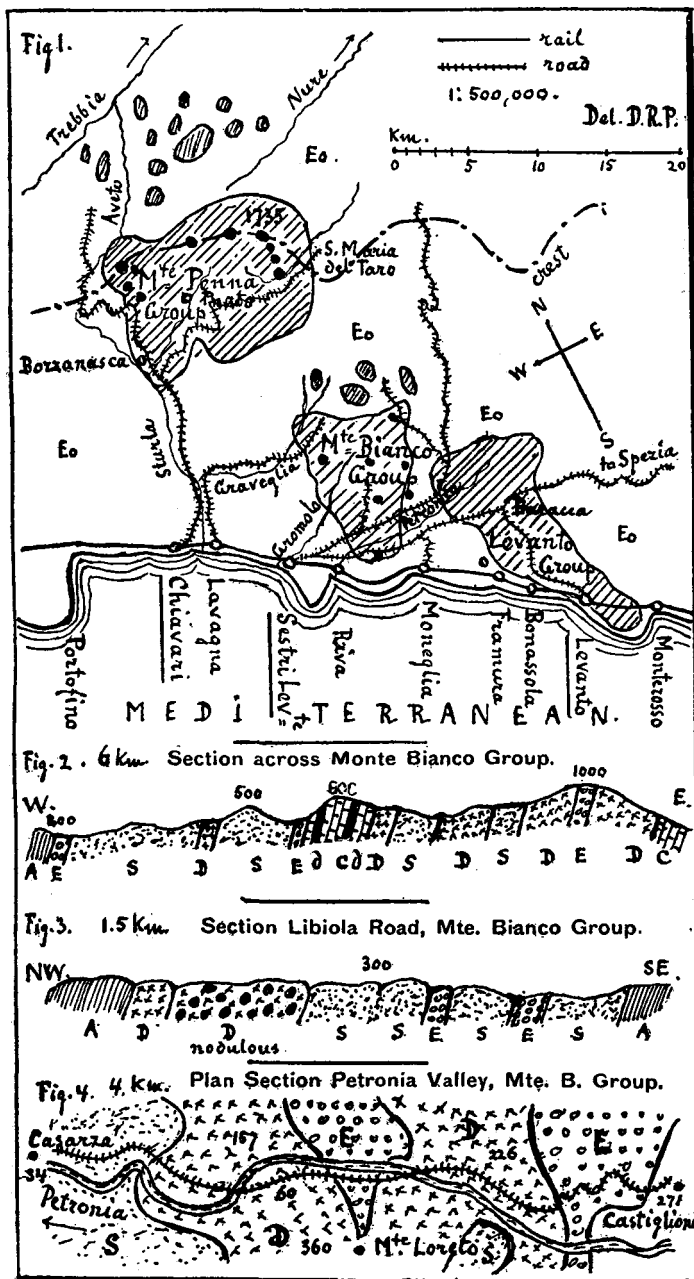
## II. THE MONTE BIANCO GROUP. (Figs. 1-4 and 6.)

This ophiolitic and remarkably metalliferous area is situated north-west of the Levanto group; its lower end, touching the Sestri and Spezia road near Bracco (448 m.), lies about 6 kilometres north of the former town. It covers about 10 by 5 kilometres, and is crossed north-east to south-west by the deeply eroded ravines of the Graviglia, Gromolo, and Petronia torrents in its northern, middle, and southern part respectively. It is traversed north to south by three more or less parallel ridges, viz. anticlinal folds dipping west, the highest

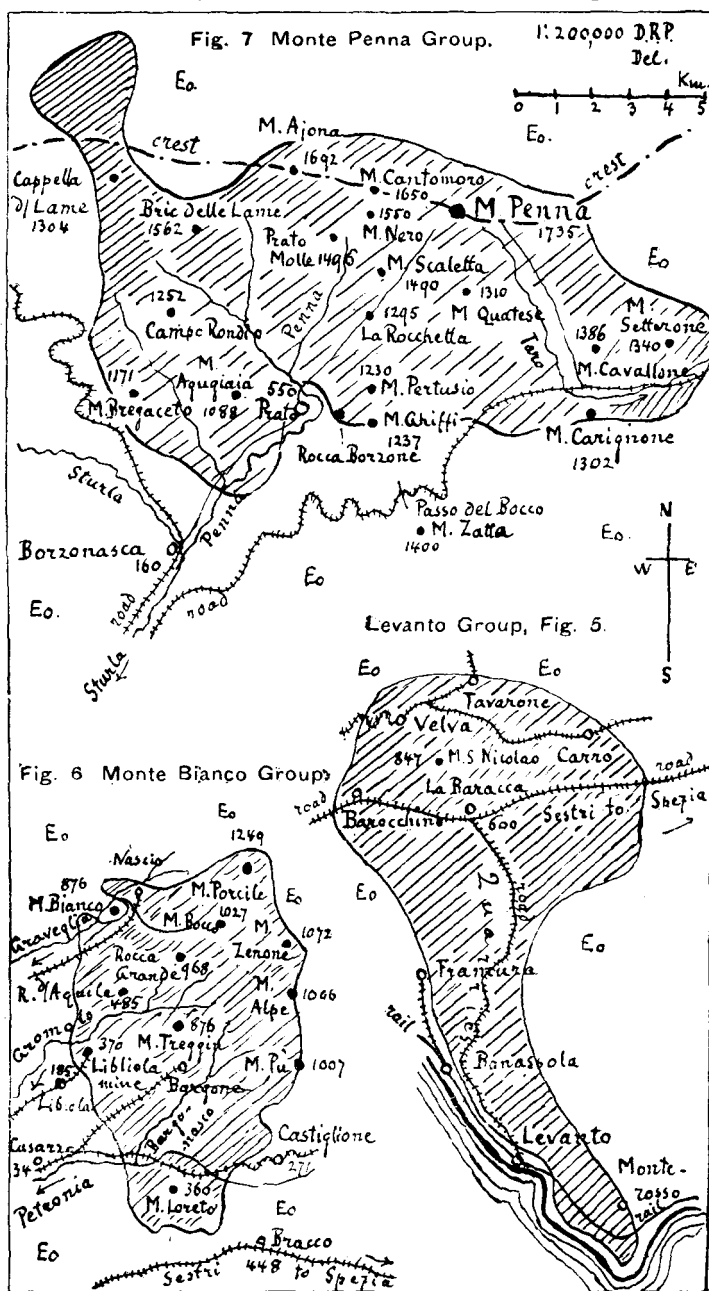
<sup>1</sup> Some of the rocks near Levanto were described by Professor Bonney in op. cit., *GEOL. MAG.*, 1879, p. 362 et seq.

<sup>2</sup> Specimens of the Pignone group were examined microscopically by Professor A. Cossa of Turin, who also gives analyses of the same in comparison with some of the similar Ligurian and Tuscan rocks (*Boll. R. Com. geol.*, 1881, p. 246 et seq.).

Sketch Map of Ophiolitic Groups, Eastern Liguria



### Sketch Map of Ophiolitic Groups, Eastern Liguria.



or eastern of which includes Mte. Porcile (1,249 m.), Zenone (1,072 m.), Alpe (1,096 m.), and Pù (1,007 m.), while the middle one comprises Mte. Bianco (876 m.), Rocca Grande (968 m.), Mte. Treggin (876 m.), and Mte. Loreto (360 m.), and the western descends to 400 and 300 m. altitude.

The ophiolitic rocks are infolded in the usual Eocene sedimentary strata, notably fine-grained, bluish-white, nodulous, and banded limestone, and argillaceous schists, frequently tilted almost vertically. Serpentine predominates more especially in the eastern, diabase and euphodite in the western and central part; their proportion may be roughly estimated as being  $2/5$ ,  $2/5$ , and  $1/5$  respectively. The northern margin of the group is, between the ophiolitic rocks on one side and the calcareous rocks on the other, fringed by bands of claret-coloured diaspri up to one kilometre in width, which crop out on some of the highest points of the middle and eastern ridges such as Mte. Bianco, Rocca Grande, Mte. Treggin, Porcile, and Alpe. The principal roads leading from the coast up into the hills are those from Sestri to Casarza and Castiglione (271 m.) along the Petronia Valley in the southern, and from Lavagna along the Graveglia Valley to Nasco (390 m.) in the northern part of the area, as also the roads up the Gromolo Valley to the Libiola mine (380 m.), and from Casarza to Bargone in the centre of the area. The first of these more especially crosses in succession the serpentine, diabase, and euphodite masses in a natural section west to east of about 4 kilometres, along the Petronia Valley between Casarza and Castiglione. This section is very similar to a larger, parallel one across the widest and central part of the group from the Gromolo Valley to Rocca dell'Aquila, Rocca Grande, and Monte Zenone, cutting the three anticlinal folds and the synclines between them. These sections and another interesting one along the Libiola road, showing nodulous diabase, and euphodite veins in serpentine, are represented in Figs. 2, 3, and 4.<sup>1</sup> Throughout these sections the euphoditic masses more than the other rocks are greatly altered, and often decomposed; the contact with serpentine is always distinct, while euphodite and diabase constantly merge into each other.

The euphoditic and diabolic masses throughout the area contain considerable nodules of copper pyrites which are worked in a number of mines, some of whose approach-tunnels afford interesting exposures. One of these is notably the Libiola mine above the hamlet of that name and in the Gromolo Valley on the western margin of the area at about 350 metres altitude, in a diabolic island of a serpentine mass. The green and reddish diabase here is not only compact but forms laccolitic aggregations in which nodules of pyrite are embedded and separated from the encasing rock by thin strips of white resinite. In another mine on the left of the Gromolo torrent nodulous euphodite appears encased in serpentine, which is completely altered to steatite. Manganese is found only in the diaspri bands, while serpentine throughout is devoid of metalliferous deposits, as previously stated, though they often appear in close proximity to it.

<sup>1</sup> These sections are deduced from L. Mazzuoli's in "Formazioni ophiolitiche della Riviera di Levante, Liguria": Boll. R. Com. geol., 1892, p. 2 et seq.

It was urged at one time as a remarkable phenomenon that in Eastern Liguria serpentine always appears superposed on euphotide and diabase, whereas in other parts of Italy, e.g. in Tuscany, the reverse is the case.<sup>1</sup> The former phenomenon is, however, apparent rather than real, being due not only to the effects of erosion which sometimes expose the outcrops at abnormal levels, but more especially to faults and inverted folds in connexion with the greatly disturbed stratigraphical condition of the whole region. Of this condition a striking example is afforded in the very centre of the area by Monte Treggin (870 m.), a sharply pointed, rugged peak, which is not only surrounded by chaotic masses of breccia and rock-débris, but is itself a confused agglomeration of the ophiolitic and sedimentary rocks of the area, strangely brecciated, crushed, intermixed, and contorted. This phenomenally disturbed condition extends from Mte. Treggin north to the serpentine mass of Mte. Bocco (1,027 m.), and south to the ophiolitic masses near Bargone and Mte. Loreto across the Bargonasco and Petronia Valleys; it constitutes, in fact, an eminently cataclastic zone which runs north to south midway of the area and also from La Baracca along the western margin of the Levanto group down to the coast near Bonassola.

### III. THE MONTE PENNA GROUP. (Figs. 1 and 7.)

This extensive ophiolitic area, the most northern of the three groups, lies north of Chiavari, whence Monte Penna, the highest point of the Ligurian Apennines (1,735 m.), forms a conspicuous object, distant about 25 kilometres. The group comprises a series of mountains disposed, on the crest of the Apennines, in a semicircle facing west and about 15 kilometres in length. In the centre of this semicircle, at 550 metres altitude, or nearly 1,200 metres below the crest, lies the village of Prato, one of a cluster of hamlets called *Sopra la Croce*, which possesses a mineral spring. About 900 metres above Prato, on Prato Molle, rises the Penna torrent, which, together with its numerous affluents, collects the drainage of the southern watershed of the Monte Penna group and discharges into the Sturla torrent at Borzonasca (160 m.). This village, about 15 kilometres from Chiavari, is the starting-point for the western and central part of the group, while the eastern part and Mte. Penna itself are also reached from S. Maria del Taro (700 m.). From west to east the group comprises Mte. Ajona, Cantomoro, Nero, Penna, Scaletta, Rocchetta, Pertusio, and Ghiffi, with the western lower spurs of Mte. Agugliaia, Campo Rondio, Mte. Bregaceto, and Mte. delle Lame, while Rocca Borzone forms a spur at the eastern extremity.

The ophiolitic rocks, chiefly composed of peridotite, lherzolite, serpentine, diabase, and their breccia, are, like those of the Levanto and Monte Bianco groups, infolded in Eocene argillaceous schists, limestone, and sandstone, and follow, with the latter, the same general direction north to south, dipping west, although the folds and alternations of both series are often so brecciated as to defy delimitation. Between Borzonasca and Prato the sedimentary strata give place in

<sup>1</sup> See an earlier memoir by L. Mazzuoli & A. Issel, "*Studi sulle masse ophiolitiche della Riviera di Levante*": *ibid.*, 1881, p. 313 et seq.



the upper part to brecciated limestone and diabase, whose repeated alternations are followed by a mass of diaspri wedged between diabasic breccia, and then by large masses of spheroidal diabase. From Prato, which lies in normal sedimentary strata, to Mte. Agugiaia (1,088 m.) the outcrops again disclose brecciated alternations with spheroidal and variolitic diabase, then a large mass of reddish bastitic peridotite which forms the cupola of Campo Rondio, and is surrounded by diabase and an outer fringe of argillaceous schist. Diabase is again in evidence on Mte. Bregaceto (1,171 m.) and extends to Mte. delle Lame (1,304 m.), which, though covered with plantation, exhibits that rock on its lower flanks.

From Mte. delle Lame the crest is reached on Mte. Ajona (1,692 m.), on whose comparatively broad and flat surface appears a very hard, dark-red, and rusty-coloured peridotitic rock in superposed layers like flagstones, with reticular ribs and wrinkles evidently due to atmospheric denudation. This rock, which is strongly magnetic and extends considerably north of the crest, obviously passes to serpentine on the southern flank, where serpentinous and limestone breccia appear infolded in argillaceous schist. The crest of Mte. Nero towards south-east of Mte. Ajona exhibits the same peridotitic rock passing to serpentine, and so does the remarkable outcrop of Pria Borgheise, a boss on Prato Molle (1,496 m.), below Mte. Nero, which was first noticed by Mazzuoli and, thanks to Professor Cossa's microscopic examination, was recognized as the first example of lherzolite in the Ligurian Apennines. East of Mte. Ajona rise Mte. Cantomoro and the peak of Mte. Penna, both composed of diabase, which also applies to Mte. Scaletta south-west of Mte. Penna. These three mountains obviously form a central mass of diabase between the peridotitic and serpentinous masses on the west and those of Mte. Pertusio on the east. Mte. Scaletta and Mte. Pertusio are separated by the argillaceous schist and limestone breccia of Mte. Rocchetta. The semicircular group is completed by Mte. Ghiffi, on whose northern flank appear limestone and breccia, the contact of these rocks and the serpentine of Mte. Pertusio being exposed in the saddle between the two mountains. On the descent from here by Rocca Borzone the hard diabasic breccia with associated diaspri appear again, being evidently connected with those already noticed above Prato. A notable feature of the Mte. Penna group is the absence of superficial outcrops of euphodite, though that rock probably occurs in places below the surface where the latter is covered with vegetation or detritus, in association with diabase and serpentine as it does in the other ophiolitic areas of Eastern Liguria. North of the Mte. Penna group, about a dozen ophiolitic, chiefly serpentinous, islands crop out in the Trebbia, Aveto, and Nure Valleys, near Bobbio, S. Stefano, and Ferriere respectively, towards Piacenza in the Po Valley; they are obviously a continuation of the Ligurian groups.<sup>1</sup> The diabasic masses

<sup>1</sup> L. Mazzuoli, "Formazione ofiolitica nella Valle del Penna": *Boll. R. Com. geol.*, 1884, p. 384 et seq. A. Cossa, "Intorno ad alcune rocce della Valle del Penna nell'Apennino ligure": *Rendiconti R. Accad. Lincei*, Roma, 1886, pp. 502 and 643 et seq. Professor Cossa, of Turin, also first examined

of Mte. Cantomoro, Penna, and Scaletta extend south-east, towards Varese-Ligure, to Mte. Quatese, Cavallone, Setterano, and Carignone, all at about 1,300 metres altitude, in three more or less parallel zones with intervening strata of argillaceous schist containing abundant lenticular intercalations of diabasic breccia, of which extensive agglomerations also appear on the northern flanks of Mte. Penna. The diabasic zones obviously represent original submarine lava streams flowing in the planes of the plastic sedimentary strata in which the débris became infolded and cemented to breccia.

#### CONCLUSION.

The phenomena presented by the ophiolitic and sedimentary groups of Eastern Liguria are substantially the same as those of the Triassic Voltri and the Sestri and Isoverde Eocene groups west of Genoa. Both regions afford striking evidence of intense folding, crushing, contortion, and brecciation which the sedimentary and the ophiolitic rocks of submarine eruptive origin during their contemporaneous uprise and subsequent settling experienced alike. There is no tangible evidence of these groups being transported areas, while everything points to their emergence and location in situ.<sup>1</sup> The effects of repeated earth-movements, including those of a seismic character, are strikingly evidenced by the frequently cataclastic condition of the Ligurian littoral from the coast to the crest of the Apennines, and the compression of the region during its uprise and settlement must have been all the greater considering that it lies in the contracted semicircular curve of the Gulf of Genoa.

### III.—ON THE CLASSIFICATION OF THE TEREBRATELLIDÆ.

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#### INTRODUCTION.

THE observations presented by Mr. J. Wilfrid Jackson (1916)<sup>2</sup> on my paper on "Brachiopod Morphology", published in this Magazine in 1915, are very welcome as furnishing many important details omitted by Davidson and other writers in the description of species. The error into which I fell as regards the types of folding of *Dallina* and *Dalinella* illustrates the danger of relying on figures when specimens are not available, but it was worth while making such an error when the correction of it brought forward so many useful observations on other points, particularly on the prevalence of

microscopically some of the ophiolitic rocks on the north of the Apennines: "Sopra alcune rocce serpentinosi dell'Apennino Bobbiese," Boll. R. Com. geol., 1881, p. 58 et seq.; also D. Zaccagna, Relazione, 1902; *ibid.*, 1903, p. 39.

<sup>1</sup> Further east towards Spezia the Mesozoic and Tertiary sedimentary strata exhibit an abnormal superposition which has always been regarded as an extensive inverted fold, but may be the effect of an overthrust. In the ophiolitic areas of Eastern Liguria, on the other hand, the Eocene sedimentary sequence is normal.

<sup>2</sup> References are given in the list of papers at the end of this article, and are indicated in the text by the author's name and date.