

as at Bourg d'Oisans, has been noted by other writers. Here, too, the mineral so abundant in the green veins of Penmaenmawr, which Schaub has determined as prehnite,¹ is at times seen to be intimately associated with the axinite. It has a lower refractive index and higher birefringence than the latter, and where cleavage-traces are developed it extinguishes parallel thereto (001). A genetic relationship between the two minerals appears to be indicated.

In all the cases which I have seen recorded hitherto the gaseous boron-bearing emanations leading to the production of axinite have followed the intrusion of a granite magma. At Penmaenmawr the magma was of intermediate calc-alkalic character. It is assumed that here, too, the hot gases charged with boron-compounds reacted on the original lime-bearing minerals of the veins, releasing the silica and forming new combinations with the lime and other constituents, and that thus the secondary mineralization of the axinite veins was essentially effected. In the Cornish greenstones the production of axinite is usually accompanied by "one or more of the following minerals, pyroxene, epidote, hornblende, garnet, quartz, and feldspar, while zoisite, zinblende, sphene, and fluor-spar are sometimes present".² With the exception of quartz, a soda-lime feldspar, and a little epidote, none of these minerals has been observed in the axinite veins of Penmaenmawr.

The green and other veins, which are so abundant at Penmaenmawr and have been previously described, as mentioned above, consist predominantly of micropegmatite and orthoclase, with subordinate plagioclase, augite, ilmenite, biotite, and apatite. It may perhaps be assumed that the axinite veins, which appear to be of very limited distribution, were originally filled with predominantly basic material, rich in lime; and that this took place at some other period, probably earlier in the course of the intrusive episode, than that which saw the production of the more acid veins. Somewhat confirmatory of this suggestion is the fact that in the same neighbourhood, viz. the most easterly Graig Lwyd Quarry, an interesting vein or patch was recently exposed, consisting essentially of calcite and talc, largely intergrown with each other.

IV.—THE PERMIAN FORMATION IN THE ALPS OF PIÉMONT, DAUPHINÉ, AND SAVOY.

By C. S. DU RICHE PRELLER, M.A., Ph.D., M.I.E.E., F.G.S., F.R.S.E.

I. INTRODUCTORY.

IN a recent paper on the Marble District of the Apuan Alps or Carrara Mountains³ I showed that the gneissose schists which form the nucleus of that range, and upon which rests the Triassic marmiferous formation, are, not of Archæan, but, upon irrefutable palæontological evidence, of Palæozoic age, and that, upon equally

¹ *Neues Jahrbuch für Mineralogie*, Abh., p. 110.

² *The Geology of the Country around Bodmin and St. Austell* (Mem. Geol. Surv.), 1909, p. 53.

³ *GEOL. MAG.*, December, 1915, pp. 554-65.

conclusive lithological and stratigraphical evidence, they must be assigned to the later part of that period, that is, to the Lower Permian. The former conclusion was first arrived at in the course of the geological survey of the range by Lotti and Zaccagna and upon the palæontological authority of the late Professor Meneghini; the latter conclusion was chiefly the result of the striking analogy, first pointed out by Zaccagna, between the stratigraphical sequence and lithological characteristics of the Apuan Alps and the Montgioie range of the Maritime Alps which forms the divide between Southern Piémont and the Western Italian Riviera.

The geological survey of the Montgioie range, carried out in the 'eighties, was subsequently extended to a revisionary survey of the Italian side of the Cottian, Grajan, and Pennine Alps for the completion of the new geological map of Italy then in course of preparation and published in 1896; but the latter survey, by Zaccagna and Mattiolo, revealed such fundamental differences between the Italian interpretations and the existing maps of the French side of the Alps that it had, in its turn, to be extended to the French border districts.¹ In the result Zaccagna's conclusions, fortified by his experience in the Apuan and Maritime Alps, were fully confirmed, not only as regards the continuity of the Permian formation from the Maritime Alps to the Western Alps on the French side, but also in relation to the pre-Palæozoic formations, a great part of which was until then regarded by French geologists as of much more recent, that is, of later Mesozoic age.

Having visited the Piémontese, Dauphiné, and Savoy Alps on several occasions, both then and more recently, I propose to succinctly review the main features of the Permian formation in the principal localities, and also to refer briefly to some of the other important points elucidated by the Italian revisionary survey on the French side of the Alps. (See sketch-map, p. 10, and plan and sections, p. 11.)

II. THE PERMIAN IN THE MARITIME ALPS.

As shown in the sketch-plan (Fig. 1, p. 11), the Italian Maritime Alps, embracing the Ligurian and the Montgioie ranges, extend from Savona west to the River Tanaro, and thence to the Col di Tenda, beyond which lie the Mercantour gneiss and granite massif and the Cottian Alps. The Montgioie range, in which the Permian formation reaches its maximum development, comprises in a length of about 50 kilom. between the Tanaro—an affluent of the Po—and the Col di Tenda road a remarkable series of rugged and peaked mountains

¹ These surveys, accomplished in four consecutive short summer seasons, and embracing the Maritime and the whole of the Western Alps, including the Mont Blanc massif on both sides, constituted on Zaccagna's part a veritable *tour de force*, enhanced by his exhaustive reports in the *Bollettino R. Com. Geol. d'Italia* of 1887, pp. 346–417, and 1892, pp. 173–244 and 311–404, with maps and sections. He also compiled, with Issel and Mazzuoli, an excellent geological map 1 : 200,000 of the Ligurian and Maritime Alps for the Italian Alpine Club in 1887. The circular examination of the Mont Blanc massif was carried out by Zaccagna himself, while a section from the Arve (Chamounix) Valley across Mont Blanc by the Col du Géant to the Dora Baltea (Aosta) Valley was taken by Mattiolo.

of an average elevation of 8,000 feet, separated by passes up to 3,000 feet above sea-level. The highest mountain is Montgioie, 2,630 metres altitude, situated practically in the centre, but both on the north and the south the crest-range is flanked by a parallel range of somewhat lower elevation.

The Permian formation occupies, in a width of about 40 kilometres, the greater part of the central and also of the northern subsidiary range, the declivities of both being deeply eroded by the Tanaro and its tributary torrents. On the east the formation thins out towards the hills above Savona, and on the west crosses the Stura Valley, whence it passes into Dauphiné. The southern subsidiary range comprises Monte Abisso, Monte Rocchetta (2,473 metres altitude), and some deposits south of Col di Tenda, as part of the Permian formation, but is chiefly composed of Triassic and Liassic strata bordering on a large area of Eocene albaese limestone and macigno sandstone which reaches to the Riviera seaboard of San Remo. Besides Rocchetta and Montgioie, the most remarkable Permian mountain is Monte Besimauda, 2,404 metres altitude, which is entirely composed of that formation and with its double-peaked summit is a conspicuous object as part of the northern subsidiary range, being situated about 20 kilometres south of Cuneo and 10 kilometres east of the Col di Tenda road. The Permian formation, overlying the Carboniferous, may be conveniently studied in the outcrops of those and other mountains, more especially in the deep and narrow valleys of the upper Tanaro and its affluents, one of the most interesting and accessible of which is that of the Negrone torrent on the southern flanks of Montgioie, where the sequence of strata can be distinctly traced on both sides. Another instructive locality is that of the ravines of the Bormida torrents east of the Tanaro and south of Monte Settepani, where the contact of the Carboniferous and the Permian is well exposed at several points.

Up to the 'eighties the principal authority on the Maritime and Western Italian Alps was Gastaldi, who, besides his well-known studies on the crystalline and pietra verde rocks and an unpublished map of the latter Alps, left a memoir on the former.¹ He was at first disposed to class the gneissose schists of the Montgioie range with the Archæan gneiss of the Western Alps; but the Montgioie schists, owing alike to their "deficient crystallinity" and to their stratigraphical location, presented so puzzling a phenomenon that, pending further definition, he designated them as of indeterminate age under the name of 'apenninite', as being akin to the Apennines rather than to the Alps. As this formation does not extend east beyond the Savona hills, and is in no sense characteristic of the Apennines proper, the name was obviously a misnomer, and hence Zaccagna, who was the first to recognize its true stratigraphical position, chose the name of besimaudite, from Monte Besimauda already referred to, as typically representative of the gneissiform schist, which has its equivalent facies both in the Apuan and the Western Alps, and also in the so-called Suretta gneiss of the Splügen Pass.

¹ "Fossili Paleozoici Alpi Marittime": *Atti R. Acad. Lincei*, 1877.

THE PERMIAN FORMATION IN THE MARITIME ALPS.



FIG. 1.—Sketch-plan. Scale 1 : 1,000,000.

M = Miocene. P = Permian.
Eo = Eocene. C = Carboniferous.
L = Lias. CS = Cale-schist } Archæan.
T = Trias. G = Gneiss }

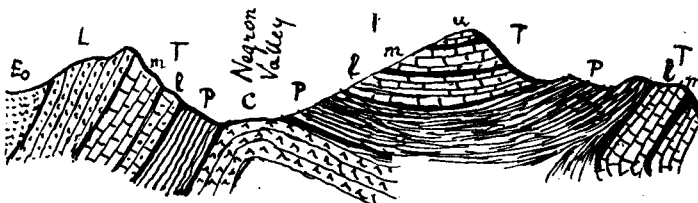


FIG. 2.—Section of Montgras (2,631 m.), S. to N. Scale 1 : 1,000,000.
T, l, m, u = Lower, Middle, and Upper Trias.

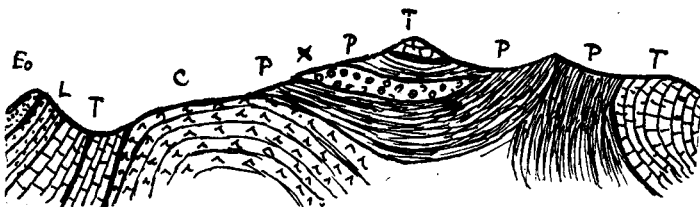


FIG. 3.—Section of Cime de Rochette (2,476 m.), S. to N.
x = porphyritic mass.

D. R. P. del.

The Permian formation reaches a thickness of at least 1,000 metres, and rests directly and conformably upon the fossiliferous Carboniferous strata, which attain about half that visible depth and constitute the lowest zone of the Montgioie range. The latter strata are, as usual in the Alps, composed in the main of blackish carbonaceous and grey micaceous schists, graduating into talcose greenish calc-schists, which become felspathic and then pass into quartzose schist, which forms the base of the Permian formation. The Carboniferous age of the strata underlying the Permian, and consequently the Permian age of the besimaudite zone itself, was definitely established by fossils found in the Negrone Valley near Viozène, on the southern flank of Montgioie, by Zaccagna, and determined by Professor Portis of Pisa. Soon afterwards this discovery was confirmed independently by Squinabol and by Mazzuoli, both of whom found indubitably Upper Carboniferous fossils in the Bormida valleys already mentioned, where the Carboniferous strata are, moreover, anthracitic.¹

The distinguishing feature of the besimaudite zone, like that of the equivalent schists of the Apuan Alps, is its gneissiform character, but it also comprises, in upward progression, a variety of associated rocks. Thus, from a granular quartzose schist it passes into greenish-grey compact rock of porphyritic texture with large elongated felspar crystals up to 2 centimetres in length. Again it passes into nodulous gneissiform schist without felspar, or again into sericitic schist, and in places also assumes a granitoid structure, notably above Savona. There are also hornblende-bearing intercalations, simulating the aspect of *pietra verde*. In Monte Rocchetta occurs a large mass of reddish porphyritic quartzose rock with white mica crystals, which Zaccagna regards as intrusive porphyry, and which also occurs in Monte Abisso, close to the Col di Tenda Pass; but I am disposed to regard both these masses, which, moreover, lie in a zone, rather as Upper Permian, very similar to the red verrucano or *sernifite* of the Glarus Alps, a clastic rock which often has all the appearance of porphyry.

The besimaudite zone is directly and conformably overlain by, and graduates into, a coarse conglomerate with white and reddish pebbles in a greenish, talcose matrix. This conglomerate or 'anagenite' is of considerable depth in the Montgioie range, and also occurs sparsely in the same position in the Apuan Alps. It represents the Upper Permian or Verrucano formation, and marks a transition from the latter to the Lower Trias. In my opinion, the porphyritic masses of Monte Rocchetta and Abisso already mentioned form part of it. It graduates, in its turn, into the conformably overlying Triassic series of quartzite, grey subcrystalline limestone, and calcareous schists, and these are overlain by banks of blackish, brecciform, marmiferous limestone with white calcite crystals, which is quarried near Villanova, at the northern base of the range, and is conspicuous in

¹ A. Portis, *Boll. R. Com. Geol.*, vol. xviii, p. 417, 1887; L. Mazzuoli, *ibid.*, p. 6; S. Squinabol, *Giornale Scient. Genova*, Fascie. Giugno, 1887. The survey of the Ligurian Alps eastward from the Montgioie range, surveyed by Zaccagna, was carried out concordantly by Mazzuoli and Issel, *Boll. R. Com. Geol.* 1884 et seq.

the columns and ornamental architecture of the churches and palaces of Turin. The Triassic series, about 400 metres in thickness, crowns Montgioie and most of the other principal mountains of the range, on the southern base of which occur also some Juraliassic and Cretaceous outcrops, followed by a large area of Eocene lime- and sandstone, while on the north it is bordered by an equally extensive area of Miocene marl and molasse.

Thus the stratigraphical sequence of the range, illustrated in the two typical parallel cross-sections of Montgioie and Rocchetta (p. 11, Figs. 2 and 3), exhibits a close analogy to that of the Apuan Alps from the Permian formation upwards. In the Montgioie range the flexures are inclined to the west, where the strata abut unconformably against the gneiss and granite massif of Mercantour; in both the Montgioie and the Apuan range there is considerable folding, but no faulting or unconformity, and their uniformity of age, sequence, and general lithological character is abundantly demonstrated.

III. THE PERMIAN IN THE WESTERN ALPS.

From the Montgioie range the Permian formation extends in a westerly direction to the Cottian Alps, and thence continues N. and N.N.E. to the Grajan Alps and the base of Mont Blanc. As the limits of this paper do not admit of a detailed description of the different localities, suffice it to indicate briefly the alignment of this extension of the Permian zone.

1. *In Dauphiné.* From near Boves at the north-western extremity of the Montgioie range, the Permian, skirting the Monte Viso massif on the right and that of Mercantour on the left, crosses the Stura Valley, and from here forms an uninterrupted zone about 60 kilometres in length and 2 to 5 kilometres wide to the Ubbaye Valley and Mont Chambeyron (3,388 metres altitude) on the Italo-French frontier. Thence it reappears further north on the south-eastern side of Briançon, near Mont Genève, and, skirting the frontier, continues for about 15 kilometres to Mont Chaberton (3,135 metres), this zone being about 2 kilometres in width.¹

2. *In Savoy.* The next outcrop occurs about 20 kilometres north of the last point, near Modane, below the northern end of the Mont Cenis tunnel, in the Arc Valley, at an altitude of about 1,000 metres, whence it extends in a belt 5 kilometres in average width to St. Bon, Bozel, and Champagny in the Doron Valley east of Moutiers.²

¹ The Mont Genève group and Mont Chaberton have been dealt with at length in the interesting papers respectively by Cole and Gregory, *Q.J.G.S.*, 1890, p. 305 et seq., and by Davies & Gregory, *ibid.* 1894, p. 307 et seq.

² Near Moutiers are the two geologically famous localities of Petit Cœur and Mont Jovet in the Tarantaise district of the Isère Valley. Near Petit Cœur, about 6 kilometres north of Moutiers, the long-debated phenomenon of a Carboniferous, fossiliferous stratum being wedged between two strata of Jurassic fossiliferous limestone was interpreted, among others by Lory, as due to a fault, whereas Zaccagna explained the Carboniferous strip more naturally as the remnant or denuded extremity of a synclinal fold, the other end of which appears in a somewhat larger outcrop at Hautecour, some 6 kilometres east of Moutiers. In Mont Jovet (2,303 metres), on the other hand, the puzzling feature was its being capped by a considerable mass of calc-schist with *pietra*

It then reappears—

3. In Northern Piémont above Courmayeur, at the foot of Mont Blanc, in the two well-known mountains Chétif and La Saxe (2,343 and 2,358 metres), separated by the Dora Baltea, and again, some 5 kilometres lower down the Dora Valley, in the Pian d'Arp, an eminence near Pré St. Didier.

Throughout this more or less continuous belt from the Maritime Alps to Mont Blanc the Permian exhibits the besimaudite and verrucano characteristics already described, and runs parallel with, and in normal sequence between, the Carboniferous and the Triassic series, so much so that the three zones, with the addition of a narrow Jurassic zone, all bifurcating at Col de Bonhomme, the south-western spur of Mount Blanc, form a belt, more or less interrupted by denudation, round that massif.

Of the Permian outcrops, those of Modane and Courmayeur are of special interest: (1) that of Modane, because Lory and other French geologists included it in their great zone of crystalline metamorphosed Triassic schists, whereas its interposition between Carboniferous and Triassic—both fossiliferous—strata clearly proves its Permian age; and (2) that of Courmayeur, because Chétif and La Saxe were regarded as granitic spurs of the Mont Blanc massif,¹ whereas Zaccagna recognized them as the northern extremity of a Permian synclinal fold, which is conformably overlain by the Triassic series, and whose southern extremity is the outcrop of Pian d'Arp near St. Didier, already mentioned. It appears again in the St. Mary Mountain near Aosta, some 20 kilometres down the Dora Valley.

In Savoy the Permian zone from the Arc Valley at Modane to the Doron Valley south-east of Moutiers has more recently been considerably enlarged by Termier, more especially in the Vanoise region and in the Doron Valley itself.² In Dauphiné the crystalline schists of Mont Genève near Briançon have also been assigned to the Permian, whereas this formation only skirts the western base of that group, and is overlain by dark, indubitably Triassic limestone corresponding to the grezzoni of the Apuan Alps, while the crystalline schists with their diabasic and serpentinous (pietra verde) intercalations are clearly Archæan.³

verde or *vert des Alpes* intercalations, surrounded by a Triassic belt. The former outcrop was regarded by Bertrand as Liassic, while Professor Lory included it in his Triassic metamorphosed *schistes lustrés*, and lastly, Zaccagna recognized it as *schistes lustrés* but of Archæan age, the *pietra verde* intercalations being conclusive evidence by analogy with Mont Genève, Susa, etc. Professor Gregory, in his searching analysis of all the evidence (Q.J.G.S., 1896, pp. 1-16), concludes in favour of the pre-Carboniferous age of the Mont Jovet schists, viz. in the absence of the Lower Palæozoic, virtually in favour of their Archæan age.

¹ The Val Veni depression between these two mountains and the granite massif of Mont Blanc is filled with Liassic limestone resting conformably against the Permian of the former but unconformably against the latter.

² "Étude sur la constitution géologique du massif de la Vanoise": Bull. Carte géol. France, vol. ii, No. 20, 1891.

³ A sketch-section of part of the Mont Genève group is given in Professor Bonney's paper, "Two Traverses of the Crystalline Rocks of the Alps": Q.J.G.S., 1889, p. 80. The limestone at the western end is marked Jurassic, probably on the strength of Lory's map as *Lias compacte* or *calcaire Briançonnais*. It is now included in the Trias.

IV. THE PERMIAN IN RELATION TO ARCHÆAN AND MESOZOIC SCHISTS.

Intimately connected with the stratigraphical position of the Permian is the demarcation of the Archæan and Mesozoic schists. As is well known, both Elie de Beaumont in the French map (1860) and Sismonda in the Italian map (1862) of the Western Alps divided the crystalline rocks into two great zones—a lower one, comprising indiscriminately the Archæan gneiss, and the Palæozoic and Mesozoic series, as the “metamorphosed Jurassic area”; and an upper one, embracing the Archæan granite and all the *pietra verde* rocks, as intrusive and post-Jurassic. The later maps of Lory and Favre of the French, and of Gastaldi of the Italian side, to some extent disentangled that strange confusion: Lory and Favre by assigning the gneiss, granite, and the “*vert des Alpes*” to the Archæan and all the mica- and calc-schists indiscriminately to the Trias as “*schistes lustrés*”, while Gastaldi separated all the *pietra verde* rocks into a zone *per se* as overlying the primitive gneiss and granite zone, and labelled it and the mica- and calc-schists as crystalline rocks, more recent, but pre-Palæozoic. The Permian did not figure in any of those maps.

Such was the position in the 'eighties when Zaccagna's revisionary survey showed those more or less arbitrary classifications to be obsolete and untenable. Accordingly he defined the Archæan as composed of two zones—a lower, comprising exclusively the primitive gneiss and granite rocks, and an upper, embracing the mica-schists (*schistes lustrés*) and the small-grained tabular gneiss; the calc-schists and crystalline limestone; and the great masses of *pietra verde* as a contemporaneous part.¹ From the Carboniferous formation, till then held to be the only representative of the Palæozoic in the Maritime and Western Alps, he separated the Permian *besimaudite* and *verrucano* zone directly overlain by the indubitably Triassic series in which he included Lory's “*Lias compacte*” or Briançonnais limestone. This clear definition of the Lower and Upper Archæan, the Upper Palæozoic, and the Lower Mesozoic formations harmonized the two sides of the Western Alps, and was embodied in the new geological map of Italy of 1896, a preliminary sketch of the earlier results in the Maritime and Cottian Alps having been already exhibited at the Berlin Geological Congress of 1885. These were largely, if with variations, adopted by Vasseur and Carez in their geological map of France of the same year.² Zaccagna's conclusions were thus, in the main, signally vindicated.

¹ The small-grained tabular gneiss (*gneiss minuto tabulare*) is extensively quarried in the Susa, Chisone, and Pellice Valleys for building purposes in Turin.

² Vasseur and Carez assign the crystalline schists west of Monte Viso on the Italian side to the Palæozoic (Cambrian), for which, however, there is no warrant, the absence of the Lower Palæozoic in the Western Alps being, on the contrary, an important feature as marking a long interval of erosion which led up to the Carboniferous formation, composed of the sedimentary and calcareous products of that erosion in which were engulfed the vast debris-accumulations of a luxuriant vegetation. The Archæan age of the crystalline schists was, after Zaccagna's publication in 1885, affirmed also by Professor Bonney (1886 and 1889), in relation to the Alps generally.

In so far as the degree of crystallinity, being the effect of metamorphism under pressure and high temperature, is a test of age, the Archæan highly crystalline schists differ from the gneissiform Permian schists as much as do the latter from the still less crystalline Triassic schists, e.g. those of the Apuan Alps as part of the marmiferous zone, albeit both those younger schists often simulate a gneissose aspect. As regards the Archæan schists, the presence of igneous rocks, whether primary or altered, is, of course, no absolute criterion of age, but in Piémont the enormous *pietra verde* masses of Monte Viso, of the Dora Riparia Valley, and of Val d'Aosta are by alternation, graduation, and lenticular intercalations, or again as irregular, obviously eruptive deposits, so closely associated with the mica- and calc-schists that their inclusion in the Upper Archæan zone appears perfectly legitimate. As in the younger schist-formations, so also in that Archæan zone the mica-schists always form the lower part of the zone, gradually passing into calc-schists which predominate in the upper part, with intercalations of saccharoidal limestone, quarried e.g. in the Susa Valley. It is with the upper parts of the mica- and the lower parts of the calc-schists that the *pietra verde* masses are more especially associated, and the intermediate position of the latter therefore points to their original subaqueous or superficial eruption in the corresponding period.¹

V. CONCLUSION.

In the necessarily small sketch-plan (p. 11, Fig. 1) I have traced the Permian zone from the Ligurian Alps near Savona through Southern Piémont, Dauphiné, and Savoy to Mont Blanc, a distance of 250 kilometres. It is seen that the curved alignment of that zone, which would equally apply to the concomitant Carboniferous and Triassic zones, runs, in the main, between and parallel to the two great primitive gneiss and granite belts indicated by dotted lines, the outer belt comprising the Mont Blanc massif and the Pelvoux group in Dauphiné, while the inner, more continuous one extends from Monte Rosa to Gran Paradiso and Mercantour in Southern Piémont.² A third, smaller, but continuous inner belt may be said to lie between the Dora Riparia and the Maira Valleys, with Monte Viso midway

¹ In Piémont alone the crystalline schists, lying between the Mercantour massif in the south and Monte Rosa in the north, cover an area of 200 by 30 kilometres, or roughly 2,400 square miles, of which the three principal *pietra verde* masses represent about one-fifth. These masses are all composed of basic rocks, more especially of diorite, diabase, gabbro, serpentinous and hornblending rocks. The white marble of Susa is, as shown above, Archæan, in contrast to the Triassic marble of the Apuan Alps, but both attest the process of the deposition of coarse calcareous material being followed by that of gradually finer to very fine material purified by solution and precipitation. The majestic triumphal arch at Susa shows that the marble of that locality, as that of Carrara, was quarried already by the Romans. Similar saccharoidal limestone intercalations are also worked in the Pellice, Upper Po, and Varaita Valleys. I propose to refer to these and the *pietra verde* areas, as also to Franchi's recent divergent views as to their age, in a subsequent paper.

² C. Diener outlines a similar series of belts in his *Gebirgsbau der Westalpen*, 1891, but embraces in his generalizations the entire chain of the Alps.

but outside the western edge, albeit this third belt forms more obviously part of the second one.

The surface-level of the Permian zone varies between 2,000 and 1,000 metres altitude, the highest being at Montgioie and Chétif (Courmayeur) and the lowest near Modane and in the Doron Valley, while the parallel Archæan zones vary in altitude between 4,000 and 3,000 metres. It is therefore obvious that the Permian and concomitant zones must have been deposited in a longitudinal trough at a time when the Archæan groups had already experienced a first partial raising, followed by a long period of erosion in the Lower Palæozoic interval. The marked unconformity at the points of contact between the Archæan and the Palæozoic and Mesozoic formations warrants the same inference of a long intervening period of erosion. A further uprise, which also affected the secondary formations, appears, on similar grounds of unconformable superposition, to have taken place in post-Liassic,¹ and a third occurred in Miocene times, which last-named movement, proceeding, like the preceding ones, mainly in a radial sense from the south-east, viz. from the Mediterranean, probably imparted to the Maritime and the Western Alps, as also to the Ligurian and Apuan ranges, their present general alignment and configuration.

The initial emergence of the Montgioie and Apuan ranges as ellipsoidal groups probably occurred before that of the Apennines; but it is during the third and last great movement that the final uprise of the Permian schists, already more or less subjected to metamorphism and overlain by the younger formations, must have taken place in the Apuan Alps as the nucleus of that range, and as its average surface-level of about 1,500 metres above the sea is the same as that of the analogous zone in the Maritime and Western Alps, it follows that the Permian formation in all the three ranges must have been raised to its present level simultaneously in Miocene times.

V.—A CHEMICAL EXAMINATION OF THE ST. BEES SANDSTONE OF WEST CUMBERLAND.

By SIDNEY MELMORE.

THE following analyses were made to ascertain the magnitude of local variations in the St. Bees Sandstone of West Cumberland. It will be convenient for this purpose to consider the district as follows:—

The area south of St. Bees, as far as Calder Bridge.
The area north of Maryport, as far as Wigton.

1. THE AREA SOUTH OF ST. BEES.

In view of its basin-shaped character, the observed dips in this area vary considerably in value and direction. On the whole, however, there is a constant dip to the south.

¹ Of this post-Liassic uprise, followed by a period of erosion, evidence is afforded by a general and marked discordance between the strata of the Upper Lias and the Tithonian, and, again, between the Neocomian and Senonian both in the Western and in the Apuan Alps.