

Taking a review of the fossil ISOPODA, we may venture to arrange them provisionally as follows:—

- I. BOPYRIDÆ. *Bopyrus*, sp. (parasitic under carapace of *Palæocorystes*), Upper Greensand, Cambridge.
- II. ÆGIDÆ. *Palæga*, 4 species, 2 Cretaceous, 2 Tertiary.
Ægites, 1 species, Oolite, Solenhofen.
- III. ARCTURIDÆ. *Archæoniscus*, 2 species, Purbeck, Swanage, etc.
Præarcturus, 1 species, Old Red, Hereford.
- IV. SPHÆROMIDÆ. *Arthropleura*, 1 species, Coal Measures.
Sphæroma, 4 species, Tertiary, Italy, Calabria, etc.
Eosphæroma, 2 species, Eocene, Isle of Wight.
Eosphæroma (= *Palæoniscus*), 2 species, Eocene and Miocene.
Archæosphæroma, 1 species, Miocene, Bohemia.
Cycloosphæroma, 1 species, Great Oolite, Northampton.
- V. ONISCIDÆ. *Cymodocea*, 1 species, Tertiary.
Oniscus, 1 species, Tertiary (in amber).
Triconiscus, 1 species, Tertiary (in amber).
Porcellio, 3 species, Tertiary (in amber).
Armadillo, 1 species, Miocene, Oeningen.

EXPLANATION OF PLATE XV.

- FIGS. 1-a, b, c. *Cycloosphæroma trilobatum*, H. Woodw., sp. nov., Great Oolite, Northampton.
- FIG. 1a. Specimen natural size (d position of flagellum of antenna).
- FIG. 1b. The same as fig. a, enlarged $1\frac{1}{2}$ times.
- FIG. 1c. The same, front view of cephalon, a antennule; a, part of the antenna; e epistomial plate.
- FIGS. 2a, b, c. *Ceratocephalus Grayanus* (A. White, MS.) living; Bass's Straits (Mus. Brit. collection), about 4 times natural size.
- FIG. 2a. dorsal aspect.
- FIG. 2b. ventral aspect.
- FIG. 2c. frontal aspect of head.
- FIG. 3. *Sphæroma serratum*, Fabr. sp. (length of living specimen about half an inch). English and French coasts, found under stones.
- FIG. 4. *Archæoniscus Brodiei*, Milne-Edwards, Purbeck, Swanage, Dorset (magnified 3 times), now referred to the *Ægida*.

II.—NOTE ON THE EFFECT OF PRESSURE UPON SERPENTINE IN THE PENNINE ALPS.

By Prof. T. G. BONNEY, D.Sc., LL.D., F.R.S., F.G.S.

IN some parts of the Alps serpentine is by no means a rare rock; indeed it is commoner than some geologists (myself included) once supposed, because much that was formerly comprehended under the term 'serpentinous schist' now proves to be true serpentine modified by the effects of pressure.

An Alpine serpentine, when in its most normal condition, so far as I have seen—and my experience is a fairly wide one—varies usually in colour from a dark green to almost black, a red tint being rare. Sometimes it is veined with a lighter green, and the rock that has been affected by pressure is usually of a paler colour, ranging from a fairly rich sage-green to a light greyish-green, the change being no doubt, in part at least, the result of weathering. Small grains of magnetite or chromite may often be detected. Except for this, the structure—apart from the results of mechanical action—is usually compact, though varieties with glittering crystals of bronzite and allied minerals occur. In this case the rock presents a con-

siderable resemblance to the dark serpentine from north of Cadgwith (Lizard), or to those found near Genoa or at Levanto.¹

One of the largest masses of serpentine in the Alps occurs near the watershed of the Pennine Chain in the neighbourhood of Zermatt. In this region mountain-making has taken place on a grand scale, so that good opportunities are afforded of studying the effects of pressure as an agent of metamorphism. But before considering this, a few words of explanation are necessary for the sake of those who are not familiar with the geology of this region. The snowfields in the neighbourhood of Monte Rosa, upon the north-western side of the watershed, descend towards the Visp in two glaciers—the Gorner and the Findelen—which are separated by a huge buttress or spur. This culminates in a rocky ridge which runs parallel (roughly from east to west) with the former glacier. At its western end is a singular craggy tower, named the Riffelhorn (9616 feet); east of this, the ridge after a depression mounts to the well-known Gorner Grat (10,290 feet), from which it undulates upward along the Hochthäligrat (10,791 feet), and finally culminates in the Stockhorn (11,595 feet).

This huge spur to a great extent consists of serpentine; but on its northern shoulder a considerable area (above the Riffelhaus Inn, 8430 feet) is occupied by a tolerably hard fine-grained green schist, apparently bedded, in which a rather acicular hornblende and sometimes epidote are fairly conspicuous.² This mass is completely surrounded by serpentine. The latter rock continues to the summit of the Gorner Grat, where it is succeeded by calc-mica schists, associated with some fissile mica-schists and micaceous gneiss and with a hard white quartz-schist. This group—on the details of which it is, for the present purpose, needless to dwell—is followed, apparently in descending order, by a moderately coarse, rather micaceous, gneiss, of which, so far as I have seen, the remainder of the ridge, up to the peak of the Stockhorn, consists. The annexed section (Fig. 1), which is merely diagrammatic, may serve to render the relation of the rocks, described above, rather more clear.³

The serpentine no doubt forms part of the bed of the Gorner glacier, for of it, on the left bank, not only the rocks of the Lychen-

¹ See *Geol. Mag.* Dec. II. Vol. VI. p. 362; Vol. VII. p. 538. Descriptions of some Alpine serpentines will be found in Mr. Teall's *British Petrography*, p. 109, *et seq.*

² A specimen of one of the harder varieties which I have had sliced consists of a not very characteristic glaucophane (the greater part of the grains being, as has often been described, altered into a dull green hornblende), epidote, garnets (rather small), a little white mica, hematite, etc. It is difficult to offer an opinion as to the origin of these green schists. Some may be modified igneous rocks; others possibly altered tuffs.

³ According to the Swiss Geological Survey there should be some *rauchwacké* interstratified near the base of the quartzite, but I omit this rock as I do not hold it to be a member of the crystalline series. The quartz-schist, green-schists, and calc-mica schists belong to the great group of crystalline schists which in the Alps have such a wide distribution and occur at the top of the Crystalline (probably Archæan) series.

bretter, on which rests the Ober Théodule glacier, but also the peak of the Klein Matterhorn (12,752 feet) consist. It appears again on the south side of the Twins and the Breithorn, in the Val d'Ayas, and patches of the same rock, sometimes of considerable size, occur at intervals about the Val d'Aoste and the Graian Alps. West of the above-named mass of serpentine comes a green schist which is indicated on the Swiss map by a colour different from that assigned to the Riffelberg schist; but to my eye there is no marked distinction between the two rocks. Serpentine also occurs in isolated patches among the schists for a distance of many miles in this direction, while on the north-east a kind of tongue protrudes from the mass forming the Riffelberg towards the base of the Findelen glacier, runs in a broad dyke-like mass on its right bank, and then forms another great patch which culminates in the summits of the Allaleinhorn, Rimpfshhorn, and Strahlhorn, whence it extends even as far as the Fee-alp above the Saasthal. The distribution of the serpentine, as mentioned above, is inexplicable on any other supposition than that it is an intrusive rock of igneous origin, though I have not yet seen it either sending off dykes or cutting distinctly across the bedding of the schists. This negative evidence, however, is of little weight, for in the Alps junctions are very often commonly covered up by débris, and I deemed it unnecessary to spend much time in hunting for them, because evidence already obtained in other localities has fully satisfied me as to the history of an ordinary serpentine.

WNW.

ESE.

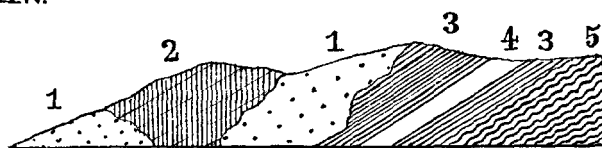


FIG. 1.—Section through Gorner Grät.

- (1) Serpentine. (2) Green schist. (3) Calc-mica schist. (4) Quartz-schist.
(5) Micaceous gneiss.

The main mass of serpentine, described above, together with the enclosed hornblendic schist, measures rather more than $3\frac{1}{2}$ miles from E. to W. and rather less than $2\frac{1}{4}$ miles from N. to S.; but if we measure from the summit of the Klein Matterhorn to the furthest part of the margin, in a direction rather east of north, the distance is more than five miles. Thus the mass of serpentine at the head of the Vispthal is not less important than that of the Lizard in Cornwall.

Some at least of the schists through which the serpentine appears to have broken must be rocks of sedimentary origin. Whatever may be that of the green-schists and certain of the mica-schists and gneisses in this series, it is impossible to doubt that of the quartz-schist and the calc-mica schist. In the latter micaceous and calcareous bands, these sometimes becoming a crystalline marble, so constantly alternate, that they seem only explicable on the hypothesis of an

interstratification of more argillaceous and more calcareous layers. It is also evident that these rocks, after they had assumed a crystalline condition, were modified by a strong pressure, definite in direction. This pressure in many cases appears to have acted at right angles to the planes of the original, or 'stratification-foliation,' and to have superinduced upon it a secondary or 'cleavage-foliation' in the same direction; but sometimes, as for instance may be seen at the very summit of the Gorner Grat, the former structure is folded so as to cross the direction of the latter, which then usually becomes inconspicuous. The bedding in these schists dips roughly to the N.W. or a little W. of this, at an average angle of about 40° , but minor disturbances make a very precise determination almost impossible.

Pyroxenic constituents are generally absent from the serpentine of the Gorner Grat, so far as I have seen, but grains of iron-oxide (magnetite or perhaps chromite) which sometimes attain a fair size are rather common. Thus the rock originally must have been the

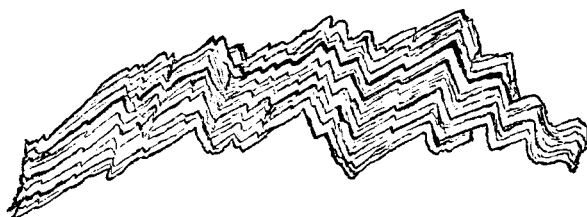


FIG. 2.—Contortions in Slaty Serpentine (natural size).

variety of peridotite called dunite. Occasionally we find specimens of fairly normal serpentine, but the rock commonly is more or less fissile, looking compressed or even crushed. In some places it is converted into a veritable slate, and the mountain is strewn with slabs, which have smooth level surfaces, and exhibit a structure as compact as that of an argillite, so that their true nature might readily be overlooked. But the more normal and only slightly cleaved serpentine can be traced into this slaty kind, which we then see indicates only localities of greater pressure or of less strength in the rock-mass. In some instances (as near the base of the Riffelhorn on its northern side) the serpentine is so fissile that it can be split into films hardly thicker than an ordinary visiting card. I brought away a specimen, perhaps about half a dozen square inches in area (larger could have been easily obtained), which is nowhere thicker than an eighth of an inch, and in not a few parts is actually translucent. Not far from this place I noticed specimens which seemed to indicate that the rock had been twice affected by pressure, for the thin slaty layers were bent into a series of V-like folds, like a row of gables, perhaps half an inch high, and rather less than an inch wide, these bent layers being separable one from another (Fig. 2).¹

¹ A very fine specimen, on a scale about five times that figured above, was found last summer at the top of the Théodule Pass by Prof. W. Ramsay, F.R.S., and given to our Museum at University College.

I have examined microscopically slices cut from a slab (about 6 or 7 tenths of an inch in thickness) of the above described slaty serpentinite, collected from the western slopes of the Gorner Grat. Both were cut at right angles to the flat surface, one along what appeared to be the 'dip' of the cleavage and the other with its 'strike.' The structure in the two slices differs little, but the former is slightly more streaky. The rock¹ consists almost entirely of two minerals. One, forming the matrix, occurs in small translucent flakes or streaky folia of a very pale olive colour; the other, an iron oxide, in rather small black grains (Fig. 3). The former, with crossing Nicols, resembles a streaky felted mass, the folia varying from a rather regular to a lobate or irregular outline. Commonly the flakes lie with their longer axes parallel with the cleavage-planes. Occa-

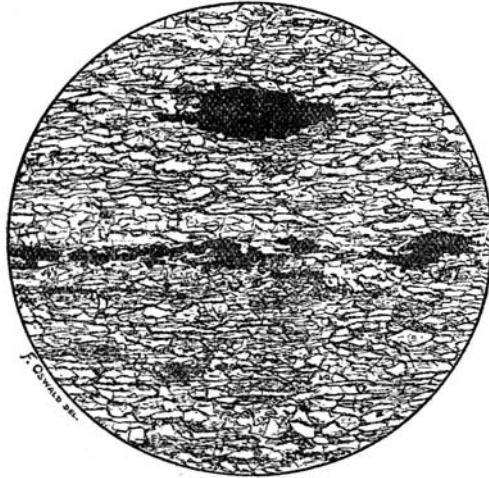


FIG. 3.—Section of Slaty Serpentinite from near the summit of Gorner Grat. $\times 50$.

sionally the mineral exhibits a cleavage like a mica, parallel to which extinction occurs, and these also lie in the above direction. Hence the slide as a whole is darkest when placed with the boundary of the cleavage surface parallel with the vibration plane of either Nicol.² Then a darkish field is speckled by irregular granules of low tints, white, greyish, or yellowish. It is brightest when the same lines are equally inclined to the vibration planes, a yellowish tint (yellow to orange) dominating. In this position the streaky interweaving of the mineral flakes is more conspicuous. This structure bears some resemblance to tapestry work in wool, where the stitches are irregular in length and more or less in one general direction. Difficult, however, as it is to describe the appearance, it is

¹ The hardness of the rock is between 3 and 3.5, and its S.G. = 2.67.

² Possibly the mineral may be (in part at least) antigorite. Cf. the description in Teall's British Petrography, p. 113. The larger flakes in my slides show a faint dichroism, but it is imperceptible in the smaller.

familiar to all students of rocks modified by pressure as one which occurs when a mass, composed of grains of fairly uniform size and strength, has been much compressed. The component grains seem to have been flattened out and squeezed together. The other constituent, the iron oxide, can be readily seen by the unaided eye, forming black lines, up to about $\frac{3}{4}$ inch in length, parallel with the rock cleavage, like strokes made with a thick pen. These, on microscopic examination, are found to be composed of grains or granules, more or less aggregated in regular lines, and usually not exhibiting a crystalline form, but being, so far as can be determined, rather lenticular in outline. Generally they are black and perfectly opaque. Sometimes, however, they appear slightly translucent and of a brownish tint, and the adjoining matrix is stained with the same colour, which penetrates for some little distance in a dendritic fashion. There can, I think, be no doubt that these represent grains of magnetite or possibly chromite, which have been crushed up and arranged by pressure in their present form. Once or twice I note lenticular clusters of larger and more definite flakes of the doubly refracting mineral, but can find no distinct trace of a pyroxenic constituent.

At one spot we find in the low bosses which crop out from among the scattered *débris* two rocks in association, both of which seem to differ from the serpentine. The one is a dark dull-green chloritic rock; the other a talcose rock of a rather pale greyish colour. The hardness of the former is about 2; the latter is still softer, being easily scratched with the finger-nail. The 'chloritic' rock occurs in a series of irregular reef-like masses, and I have no doubt that it is intrusive in the talcose, though both evidently have been modified by pressure and greatly altered from their original condition.¹ The former, when examined under the microscope, is found to consist of a flaky mineral, apparently belonging to the chlorite group, with some flakes and irregular grains of an opaque iron-oxide, and (in the junction-specimens) an occasional grain of a clear rather granular mineral. The chloritic mineral has one well-defined cleavage like a mica; it is moderately dichroic, showing a light dull-green, with vibrations parallel with the cleavage-planes, and a very pale straw colour with vibrations perpendicular to them. The dichroism is more marked in a junction-specimen (where the flakes have a more distinctly parallel arrangement), but this may only be due to a difference in the thickness of the slides. The polarization tints are low, but rather brighter in the latter specimen. Extinction seems generally to take place parallel with the cleavage-planes, but occasionally there is room for doubt on this point, and it appears to be most complete at a very small angle with them. In the junction-specimens the grains of iron-oxide are smaller, and more distinctly linear in arrangement than in the other. In form they resemble hematite. The third mineral has a rather granular structure, is colourless, and gives low polarization tints. I have not seldom seen

¹ I am greatly indebted to Mr. J. Eccles, F.G.S., for verifying the opinion which I had formed, and for much additional information.

What then is this mineral, and what was the rock originally?

I have examined a considerable number of analyses of minerals which have a general resemblance to that dominant in the above described rocks, and are quoted in Dana's "Mineralogy," Heddle's "Chloritic Minerals,"¹ and other works.² Now in the case of the Gerner Grat rock the microscope shows us that it is mainly composed of one mineral. Hence the composition of this must be roughly represented by the bulk analysis of the rock (omitting most of the Fe_2O_3). Therefore the mineral cannot be pennite, ripidolite, or chlorite (clinochlore), *i.e.* not one of the chlorites as defined by Professor Heddle. But this analysis nearly approaches those of chloritoid, given by him (I. and II.) except in the presence of alkalis and the much lower percentage of FeO .

	I.	II.	III. ³	IV. ⁴
SiO_2 ...	24.47	25.36	24.90	24.40
Al_2O_3 ...	41.34	41.74	40.99	42.80
Fe_2O_338	3.89	.55	
FeO ...	18.52	13.93	24.28	19.17
MnO91	.92	—	—
CaO30	.90	—	—
MgO ...	6.80	6.82	3.33	6.17
K_2O ...	—	—	—	—
Na_2O ...	—	—	—	—
H_2O ...	6.98	6.57	7.82	6.90
	99.70	100.41	101.87	99.44

But the hardness of chloritoid is 5.5 to 6, while in this case it is about 2; it has also a higher specific gravity, *viz.* about 3.5. However, there can be little doubt that it is very nearly related to chloritoid and a member of Tschermak's 'Clintonite' group,⁵ which contains this mineral with Ottrelite, Xanthophyllite, etc.

I have not been more successful in endeavouring to ascertain the original nature of the rock. A peridotite is obviously out of the question; the excess of the alumina over the silica is much greater than in any analysis given by Roth. If, however, we suppose that silica has been removed (perhaps with some magnesia and lime), we are perplexed at the percentage of alkalis, which is about that of a normal basalt.

The adjacent schist adds to our difficulty.⁶ Its softness and microscopic structure justify us in regarding it as a talc-schist, and the field evidence is in favour of its being only an altered condition of the slaty serpentine. This was my own opinion at the time, and Mr. Eccles, who kindly undertook to re-examine the question, informs me that though the change from the one rock to the other is abrupt, this conclusion appears the more probable.⁷ To convert

¹ Trans. Royal Soc. Edin. vol. xxix. (1879) p. 55.

² I am indebted to Miss C. A. Raisin for much help in this search.

³ Analysis of Chloritoid, Tschermak and Sipöcz, Sitz. k. k. Akad. Wiss. 1879.

⁴ Analysis of 'Sismondine' from Zermatt, Des Cloiseaux, Bull. Soc. Min. vol. vii. p. 80.

⁵ *Loc. cit.*

⁶ Curiously enough there is a similar association in Anglesey, Q.J.G.S. vol. xxxvii p. 44.

⁷ After microscopic examination of a specimen collected by Mr. Eccles, I think

a schistose serpentine into a talc-schist, either much SiO_2 must be added or much MgO removed. The condition and structure of the rock is not favourable to the former explanation; it seems more probable that the alteration has been by a 'leaching out' of the magnesia. It is therefore difficult to understand the reason of such different changes in two adjacent rocks, unless it be that an aluminous silicate more readily parts with its silica, and a magnesian silicate with its magnesia, in favour of which there is some evidence. At present, however, I think it safer to restrict myself to calling attention to the facts.

Other specimens of slaty serpentine in my collection exhibit a structure like that described above. For instance in one from the western side of the Col di Vallante (Cottian Alps), which is extremely fissile and of a distinctly green colour, the microscopic structure is yet more minute, the rock more fissile (for it splits up in grinding), but the slice gives higher polarization tints. This also exhibits an occasional bending or 'rucking' of the 'foliation,' which sometimes has produced a 'strain-slip' cleavage. Another specimen, from near Verrex (at the opening of the Val d'Ayas), exhibits a like structure, but in it, I think, a little enstatite has been present. In one less conspicuously fissile, from the junction of glens at the head of the Val Malenco, enstatite and augite are certainly present. Sometimes the latter mineral is crushed to a powder, which has a rather dusty aspect, while the larger granules exhibit the bright tints customary in augite. Here and there a characteristic fragment of that mineral can be found, and we may note that, though the pressure has been very great, it remains augite, and has not been altered into hornblende.¹ This variety of serpentine must exist in some part of the *massif* in the region of the Gorner glacier, for I collected several years since a specimen on one of its moraines, of which, as I had some doubt as to the true nature of the rock, I examined a slide. Here the matrix is less completely crushed than in the specimens described above, and there is a large amount of this granular pulverized augite (at least I identify it with this mineral after comparison with the better preserved examples in the last-named slide). Specimens from other parts of the Alps exhibit both varieties of serpentine, and the effects of less severe pressure; but on these it is needless to enlarge.

It has been suggested that the streaky structure which is rather conspicuous in some of the Lizard serpentines (*e.g.* a variety on Goonhilly Downs and a common type at Porthalla²) may be due to pressure.³ Applying the knowledge obtained in the present investigation, I may venture to express the opinion that these Cornish rocks have not been materially affected by pressure since they there can be little doubt the rock is an altered serpentine. The dominant mineral has all the characters of talc, but there are several grains of calcite which, by their mode of occurrence, suggest replacement (? of augite).

¹ There are however not a few minute grains of a honey-brown, somewhat dichroic, mineral which *may* be a variety of hornblende.

² Q.J.G.S. vol. xxxix. pp. 21-23.

³ GEOL. MAG. Dec. III. Vol. IV. p. 137.

became serpentines. It might, however, still be affirmed that they were crushed as peridotites and were afterwards converted into serpentines. I possess only one specimen of a peridotite modified by pressure, but this lends no support to that hypothesis, and the structure of the accidental constituents in the Cornish serpentines does not appear to suggest it, so that I think we must seek for some other explanation.

It results then from this investigation that in a large number of cases the direct effect of 'dynamometamorphism' on a serpentine is not to produce any marked mineral change, but only to reduce the magnitude of the constituents and to impress upon them a linear arrangement, more or less marked. Under ordinary circumstances it does not appear to generate one of the soft unctuous talcose schists, though such a change sometimes occurs. This, however, must be accompanied, as stated above, by considerable chemical alteration, because in olivine or serpentine (and in the rocks mainly composed of these minerals) the silica and the magnesia are nearly equal in amount; while in talc the former is about double that of the latter. There is also a lower proportion of H_2O . Perhaps, in such cases, some local cause may have given to the water a more distinctly solvent action.

III.—A REVISION OF THE GROUP OF *NAUTILUS ELEGANS*, J. SOWERBY.

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OWING to the defective character of Sowerby's description and figure of *Nautilus elegans*, the latter has been variously interpreted, specimens belonging to other species having been frequently referred to it. In the present paper we shall show what is the true *N. elegans*, tracing the history of the type-specimen, which we have been fortunate enough to identify in the collection of the British Museum. This done, we shall proceed to describe three other species, viz. *N. elegantoides*, d'Orbigny, *N. Atlas*, Whiteaves, and *N. pseudoelegans*, d'Orbigny, all evidently allied to *N. elegans*, and forming with it a group of species which may be appropriately called the "Group of *Nautilus elegans*."

The identity of *Nautilus elegans*, J. Sowerby, has hitherto been completely mistaken, owing to the uncertainty existing as to the true character of Sowerby's fossil, the type of which had not been recognized.

The following is Sowerby's description of this species: "Gibbose, umbilicate, with numerous linear, reflexed radiating sulci. About two-thirds as thick as wide; the septa are rather numerous, gently waved; the aperture is obtusely sagittate, with the posterior angles truncated; umbilicus small, perhaps closed." Respecting the type-specimen Sowerby states, "This fine specimen was found in the chalk marl, at Ringmer in Sussex, in 1814, by Mr. Mantell."

It is undoubtedly Sowerby's type-specimen which Mantell figures in his *Fossils of the South Downs*, tab. xx. fig. 1, and which he