On the so-called Crystalline Schists of Chichibu.

(The Sambagawan Series.)

by

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With plates II, III, IV, & V.

Introduction.

The district of Chichibu is in the Main Island (Honsiū) of Japan lying to the north-west of our metropolitan city of Tōkyō within a day's march. From considerations geological rather than political, Dr. E. Naumann[1] has very appropriately called this region the "alte Bergland von Kwantō"—all the mountainous districts surrounding Chichibu proper being comprehended under this designation. The district now under consideration lies to the east of the so-called great geologic ditch or '*fossa magna*' of E. Naumann,[2] which intersects the Main Island from south-east to north-west through the provinces of Izu, Suruga, Kai, and Sinano, thus separating Northern and Southern Japan. The '*fossa magna*,' or the Japanese mountain-conflexure (Schaarung), as Suess[3] and Harada[4] call it, sends

1) Ueber den Bau und die Entstehung der japanischen Inseln, Berlin, 1885, p. 79.

2) loc. cit. p. 50.

3) E. Naumann, Die Erscheinungen des Erdmagnetismus in ihrer Abhängigkeit vom Bau der Erdrinde, Stuttgart, 1887, p. 17.

4) A letter from T. Harada read in the 'Sitzung der mathematisch-naturwissenschaftlichen Classe vom 7. Juli, 1887.' Vide 'Akademischer Anzeiger,' No. XVII, Wien.

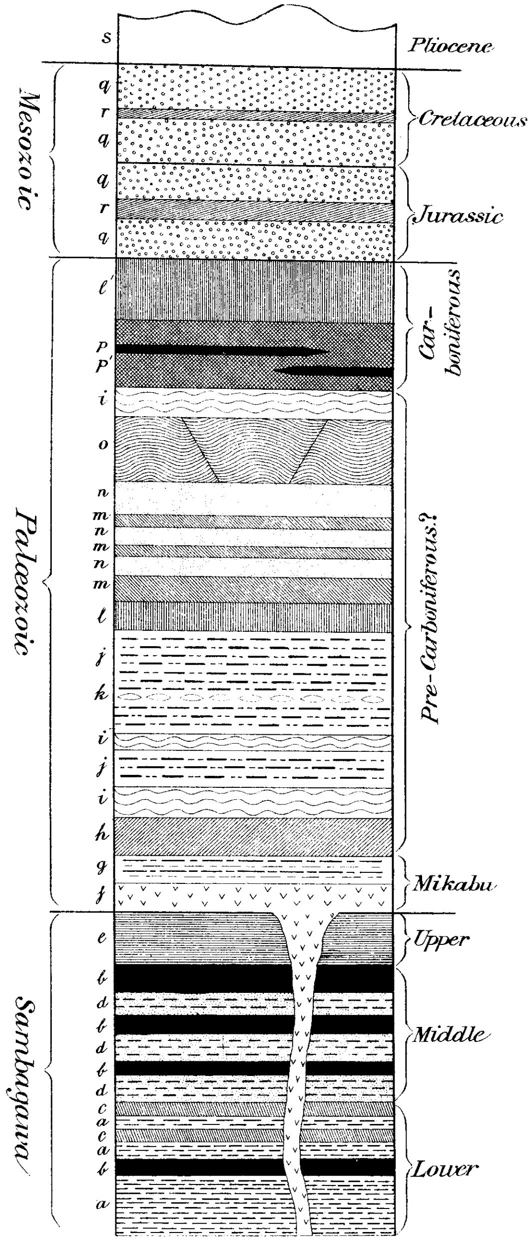

Diagram I. *a.*—Normal sericite schist. *b.*—Green spotted schist. *c.*—Piedmontite schist. *d.*—Black spotted schist. *e.*—Epidote-sericite gneiss. *f.*—Gabbro and gabbro-diorite. *g.*—Pyroxenite, amphibolite and serpentine. *h.*—Red and white, platy quartzite. *i.*—Adinole slate. *j.*—Lower schalstein. *k.*—Limestone (lens-shaped bed). *l.*—Coralline limestone. *m.*—Slate. *n.*—Gray-wacke-sandstone. *o.*—Common hornstone. *p.*—Upper schalstein. *p′.*—Diabase sheets. *l′.*—Fusulina limestone. *q.*—Sandstone. *r.*—Shale. *s.*—Tufaceous sandstone.

out a wing which continues further northward into the Abukuma and Kitakami mountains. This north-easterly wing of the remarkable mountain-conflexure of Japan suffered many, considerable interruptions in its way, especially in the plain of Musasi and Kōzuké; and the district in question is only a part of this wing.

Geologically speaking, this extensive region of Chichibu is in itself a complete one, being bounded on the west and south by high volcanic chains of the well-known Fuji and Yatsugadaké, together with the granite-massives of Kimpōzan and the Mikuni-yama; while the remaining parts are open, and covered by Tertiary and still younger series of the Tōkyō basin, of which a brief account was lately given by Prof. D. Brauns in his "Geology of the Environs of Tōkiō."

Isolated as it is within a

limited area, still the building materials of its geologic edifice are, to the writer's view, those composing nearly all the systems that occur elsewhere in Japan, and therefore the earth's history of Chichibu may indeed serve as a type of our geologic formations.

Mr. Ōtsuka, a graduate of our university, took up, at the writer's request, the district in question for the subject of his thesis, in order to explore thoroughly its geognostic condition. As the result of his study in field and laboratory, he has eventually succeeded in recognizing a certain regular order of sequence of strata younger than the so-called crystalline schists. From various observations taken as far as possible at different points of the Chichibu mountains by the writer and Mr. Ōtsuka, and from the data ascertained by Mr. Ōtsuka,[1] with which the writer's scheme is also incorporated, the latter chiefly referring to the ? pre-Carboniferous and Sambagawan series, we were eventually enabled to recognize the following stratigraphic order of rock series, counting from the very lowest that is ever developed in this region ; it must at the same time be remarked that the names of fossils here given should be taken with reserve, and considered as only of an approximate value, as we can not pretend to any thing more than this at the present state of our knowledge :—

(Compare Diagram I. page 78.)

The Sambagawan series.

1 Normal sericite-schist together with the piedmontite-schist in its upper horizon.
2 Green, and black spotted schist.
3 Lamellar epidote-sericite-gneiss.

4 Amphibole-pyroxene schist, pyroxene-amphibole schist, pyroxene-epidote, and amphibole-epidote schist, together with serpentines, gabbros and the gabbro-diorites.

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1) On the Geology of the Mountain-districts in Chichibu and Kanra, 1887. (Manuscript).

? The pre-Carboniferous.

5 Red, and white, platy quartzite.

6 Adinole-slate overlying the preceding.

7 The lower schalstein, intercalated with the adinole-slate, and also the limestone with crinoidal stems and corals.

8 Graywacke-sandstone and slate, intercalated in their lower horizon with the adinole slate.

9 Siliceous slate or common hornstone overlaid by another series of the adinole-slate.

The Carboniferous.

10 The upper schalstein and the siliceous *Radiolarian* slate.

11 Diabase-sheet sometimes occurs in this horizon.

12 The *Fusulina*-limestone, etc.

The Mesozoic group.

13 The Jurassic subgroup composed of the medium-grained, grayish sandstones and shales.

(*a*) The above-mentioned sandstones afford rich remains of *Cyrena*, *Melania*, *Myacites;* while (*b*) in shales we have found the remains of plants, viz., *Thyrsopteris*, *Nilsonia*, *Dicksonia*, *Podozamites*, *Pecopteris* and *Zamites*.

14 The Cretaceous subgroup consists of thick sandstones and shales with *Trigoniæ* belonging to the section *Scabræ*, *Peteroperna*, *Ostrea (Alectryonia)*, *Patella*, *Exogyra*, an evolute form of *Ammonites*, *Inoceramus*, *Alaria*, *Echinospatangus*, *Arca*, *Cucullaea*, *Solen*, *Anisocardia*, *Nucula*, *Pholadomya*, *Montlivaultia* and *Lucina*.

The Neogene Tertiary.

15 Lastly, the Tertiary basin of Chichibu, being made up of hard sandstones with marly layers, has furnished many fossils, the descriptions of which have lately been given by Dr. D. Brauns in his valuable contribution to the geology of Japan, entitled: 'Geology of the Environs of Tokio.' Mr. Ōtsuka made an addition of other forms to the list of Brauns, viz., *Arca*, *Turritella*, *Voluta*, *Nucula*, and an *Echinoid*.

The same rule holds good with regard to the regular successive order of the geologic series in the other parts of the empire; the Trias, however, which is represented by the *Pseudomonotis*-bearing strata extensively developed in Isadomae in Rikuzen,[1] Nariwa in Bitchiū, and Sakawa in Tosa has not yet been observed in our region.[2]

As to the literature relating to this district, there exists absolutely nothing worthy of a scientific value. A few years ago, the writer travelled through the present geologic terrane, and embodied his preliminary result in a paper "On the Geology of the Southwestern Districts of Kōzuke (manuscript);" this is all we have up to the present. The detailed geological map, Section Maebasi, covers a part of our region; but to his great disappointment, the writer could not derive any profit from it, as the system adopted in the map is too primitive.

During the last winter-holidays, the writer made a fortnight's trip, with the hope of ascertaining, if possible, a certain regular succession of the oldest rock-complexes known in this district, as heretofore no one had ever attempted to follow up the stratigraphical order in detail.

The field of our researches is only a small part of the rather extensive region of the 'Bergland von Kwantō,' being especially confined to the boundary-district of Musasi and Kōzuké provinces, where

1) E. Naumann; Ueber das Vorkommen von Triasbildungen im nördlichen Japan, in the 'Jahrbuch der geologischen Reichsanstalt' in Wien, XXXI Band, 1881, ps. 519–528. Vide also 'Mittheilungen der deutchen Gesselschaft für Natur-und Völkerkunde Ostasiens. Vol. III, p. 205.

2) The Japanese fossil described as *Monotis salinaria* by E. Naumann seems now to be included among the group of *Pseudomonotis ochotica* which, according to Teller, has a wide distribution in the western States, U. S., in New Zealand, New Caledonia, in the Himalaya, and Japan.— M. Neumayr, 'Erdgeschichte,' II Band, p. 266. E. Mojsisovics, 'Arktische Triasfaunen.' Mém. Ac. imp. de St. Petersbourg, Tome XXXIII, No. 6. p. 123.

the so-called crystalline schists[1] are fully exposed to view, and the study of their geognostic condition forms the subject of the present paper. The following gives only a compendium of the writer's notes, and from the nature of the circumstances, much more cannot be expected.

The writer now proposes to treat the subject in the following order:

A.—Petrography of the Sambagawan series.

(*a*) General remarks.
(*b*) The lower division or the normal sericite-schist.
(*c*) The middle division or the spotted graphite-schist, and spotted chlorite-amphibolite-schist.
(*d*) The upper division or epidote-sericite-gneiss.

B.—Architectonics of the Sambagawan series.

(*e*) General remarks.
(*f*) The Lower Sambagawan.
(*g*) The Middle Sambagawan.
(*h*) The Upper Sambagawan.
(*i*) Profiles.
(*j*) Relation of the topography and geology of the Sambagawan terrain.
(*k*) Massive rocks.

C.—Conclusion.

1) It should be here expressly remarked that, when speaking of *crystalline schists* of Chichibu in the present paper, the writer takes them only in the petrographical sense, and does not necessarily imply those of the Archaean group.

A. Petrography of the Crystalline Schists.

(The Sambagawan Series.)

(a) General Remarks.

However simple and monotonous the structure may appear when we travel through a territory of schists, still there are sufficient diversities to be seen even by a casual observer. It is to be deeply regretted that crystalline schists have been regarded with utter indifference by our geologists, so that they have been mapped barely as such and taken heed of no more; but in reality, these old schists can tell more of the history of the past than others, although the events lie hidden by the veil of time. Dissimilarity in structure, in colour, and the fluctuation of relative quantities of mineral components are sufficiently considerable to allow of brief characterization.

The rocks, of which the writer is now speaking, represent those complexes which form the very foundation of the geologic architecture in the Chichibu region, upon which the later formations were built up. E. Naumann[1] says, when speaking of the Archæan group in general, "that the crystalline-schist system in Japan consists of mica-schist, talc-schist, and chlorite-schist etc., together with subordinate layers of serpentines and marbles............Those schists of the 'Bergland von Kwantō' are also characterized by a very complicated mode of occurrence............They describe a deformed are." His statements evidently refer to the region which is now under consideration. But the rocks here developed show many peculiar characters of their own, not observed in the normal types of crystalline schists, and this abnormality

1) loc. cit. p. 9.

has lately induced the writer to make a somewhat closer study of these ancient schists.

The rock-components of the Chichibu schists are of a crystalline nature as in those of normal types; the texture of the rocks is, however, less perfectly developed, some being compact, others thick-banded, while the third is wrinkled and corrugated by mechanical action due to the earth's movement. All our schists in common present a *phyllitic* aspect; but the use of that name should here be guarded against, for to the term phyllite, geologists attribute sometimes a geochronic meaning on account of its usual occurrence in the crystalline schist system; sometimes we understand it petrographically as having green or colourless fibrous scales—the phyllitic constituent, and also as having a schistose structure.

The most characteristic components of our schists are sericite, epidote, and calcite. The presence of these already bespeaks the nature of the rocks in question; for in the genuine crystalline schists, these minerals are often totally absent.

Taken in general, our rocks have a close relation to the so-called 'Casanna Schiefer,' or Studer's 'aeltere graue Schiefer' of the Alps, or to the sericite-gneisses, and sericite-schists of the districts of Nassau, and Taunus, in Germany.

The whole series of the rocks in question may be found along the Sambagawa valley,[1] north-west of a small town Onisi,[2] Kanra district, where it is developed in its full proportions, and where interesting exposures may be seen. The writer proposes now the name of the *Sambagawa series* to the metamorphic schists of this district. It is a name which does not involve any theory, and may be used by any party in the case of a controversy respecting its age. This designation may not be of a mere local value as the same series recurs in other parts of Japan, especially in the Island of Sikoku.

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1) 上野國南甘樂郡三波川村 2) 鬼石町

(b) **The Lower Division.**

Normal Sericite-schist.

It is a grayish-white, thick-foliated rock with a wavy sweep on the sheen surface. Slabs show numerous prominences of a yellowish tinge, owing to the presence of epidote crystals. The cleaved face has a silky lustre, due to the parallel arrangement of fibrous scales of sericite. The rock-ingredients are *quartz*, some *felspars*, *sericite*, *calcite*, a *yellowish-green epidote*, *iron-glance*, *iron-mica*, and lastly, *rutile*; apatite, the most common accessory component in the massive rocks and schists is remarkable by its absence in the rock-series now in consideration.

The greater part of the rock-mass is made up of *quartz-grains*. Their external boundaries are quite irregular, and appear as if one overlapping the other. By a simple macroscopical examination, the part occupied by quartz presents almost an homogeneous aspect, and gives an impression as if it were occupied by solidified masses of the colloid silica of the diagenetic origin. By the use of an upper Nicol, the state of things is found to be quite otherwise; the apparently homogeneous mass resolves itself into an aggregate of quartz grains, each having optically different orientations, and in many cases showing a marked undulatory extinction. The granulation of the quartz is particularly pronounced where the rock-masses have been subjected to minute foldings and flexures, whereby the dismembered parts are more or less pushed further on one side or the other. This complicated condition may be best seen in *fig. 1. Pl. II.* which is drawn from a transverse section of the glaucophane schist from Ōtakisan, Awa,—the rock probably belonging to the same geologic age as the Lower Sambagawan schists. On looking at the figure, it is evident that the sericite (hydromica) was originally arranged in regular order, separated by bands of a homogeneous (but not amorphous) quartz. The so-formed rock has been then subjected to the act of crushing by mountain-making, and that trituration, as it were, must have been secondarily induced, may be proved from the discontinuity of irregular fissures which become very numerous on the upper and lower margins of the quartz-bands, but stop short at the centre. These fissures are particularly numerous at the turning points of the plicature of the rocks, and indeed, the quartz appears there perfectly granular.[1] F. Becke has, in rocks of a similar nature, encountered the quartz-grains arranged in a fan-shaped form; this being shown by the manner in which the extinction-direction of polarized light varies as the grains are examined in succession around the radial centre. He has rightly compared this phenomenon with that in the twisted smoky quartz from the Kreutzlipass in Switzerland.[2] This peculiar fact of which the cause is apparently unknown to him may, as it seems to the writer, be ascribed to the special circumstances under which the rock containing a homogeneous quartz has been granulated. R. Küch,[3] while studying the rocks from Mamanyamatali, Western Africa, seems to have noticed a similar fact, and from this, he formed a hypothesis regarding the clastic nature of the epidote-mica-schist, in which he saw the structure. Some of these grains (apparent) may be a product of secondary infiltrations, and they are distinguished from the rest by weak polarization-colours. Such grains are generally free from interpositions and inclosures, whatever the kind may be, as this quartz is the latest among the rock-components. Slow, insensible, undulatory extinction of light invariably takes place in this variety.

In a schist from Inatsuka, in the Sambagawa valley, we noticed

1) Michel-Lévy calls such quartz masses "Quartz granulitique." Bull. géol. (3) VII. p. 846. 1879.

2) Tschermak; Min. u. petr. Mitth. Band VI. 'Gesteine von Griechenland,' p. 66.

3) ibid. Band VI, p. 102.

the very interesting fact that the quartz here behaves just like an isotropic mineral. As this variety fills up the interstitial spaces of the matrix, it is highly probable that this quartz may be an infiltration-product, and serves as a cement for the other ingredients. Without the use of an upper Nicol, it is hardly recognizable as such, and a slide presents a perfectly homogeneous appearance; but by the help of an upper Nicol, it is soon discovered that the portion apparently homogeneous resolves itself into numerous crystalline grains of quartz cemented by an amorphous variety.

Taken as a whole, the quartz in all varieties of rocks of the Sambagawa series is poor in both liquid-inclosures and gas-pores, and such as are found are exceedingly minute in size. These inclosures are arranged in chains, and run approximately parallel to each other, sometimes terminating at the margin of the grains, or sometimes being continued on to adjacent grains of different optical orientation; sometimes again, these chains begin from contiguous points of the neighbouring grains, especially where the margins end in protuberances and indentations. Bearing in mind the facts just stated, these inclosures seem probably to be of a secondary nature.

The rock now under consideration has possibly assumed the present state through siliceous induration of a graywacke or a volcanic tuff; hence the colloid aspect of quartz in it and the paucity of inclosures. The silica may have been derived from the original rock by molecular rearrangement or in part may have come from other sources as a solution, and after the solidification the quartz may have been granulated by mechanical force due to movements of the earth's crust.

The *felspar* is very variable in quantity. In the normal sericite schist from Sueno near Yorii, it is rare; while in that of Ōboké along the Yosino-gawa, in Awa, it constitutes the main part of the rock at the expense of quartz. The felspar is usually larger in size than the quartz-grains, and never shows any indication of crystallographic faces ; on the contrary, the periphery is exceedingly irregular having deep indentations and sharp projecting points.

It appears to the writer that the felspar grew externally by secondary enlargement, consequently it has tendency to assume more or less a porphyritic habitus. While the exterior of a larger felspar was still undergoing the process of accretion, the imbibed silica, or in part a silicate of sodium or potassium which had served as a solvent, seems to have just begun hardening. Such being the case, the margin of the porphyritic felspar assumes a *quasi*-granophyritic or micropegmatic structure, though by no means a perfect one, when compared with the typical development in granophyres, *fig. 2, Pl. II.*

The felspars often show a corroded appearance. They are of a remarkably vitreous aspect, quite fresh, and often bear evident traces of the basal cleavage ; parallel stripes are few, and there is no polysynthetic lamellar structure. The oblique extinction takes place at about 27° with reference to the vertical stripes. It may be inferred from these facts that the felspars are mainly orthoclase, while some may probably belong to an acidic plagioclase.

The most prominent feature in the felspar is the interposition of opaque, highly lustrous iron-glance; the latter by reflected light shows a slight bluish tinge, especially on the surface of thick lamellæ into which, according to Mügge,[1] the mineral is said to be easily parted, the plane of the lamellæ corresponding to $R = \pi$ $(10\bar{1}1)$ of iron-glance. Thin plates of blood-red iron-mica together with epidote-grains and rutile-needles are also mixed up with the opaque iron-glance in the felspar-substance as in *fig. 3, Pl. II.* All these are localized in the centre, and the periphery of the felspar is fringed with greenish

1) Neues Jahrbuch f. Min. etc. 1884, I Band p. 216.

fibrous lamellæ of sericite. The same structure also occurs in all the rocks belonging to the Sambagawan series, and may be considered as characteristic of these rocks. The same is also typically developed in the graphite-sericite schist, to which we shall have occasion to refer afterwards.

Quartz-grains are frequently found as enclosures in the felspars without any definite crystallographic relation to the latter. In massive rocks, felspars belong to an earlier generation in crystallizing out from the rock-magma, but here a portion of quartz has solidified prior to that of alkali-alumina silicates, so that the physical condition during the formation of the rock must have been a different one.[1)]

The *sericite* is of a yellowish-white, or light grass-green colour with silky lustre. In the latter case, it is pleochroic, showing strong absorptions parallel to the axis of a plication. In some places as in Azuhata in the province of Hitachi, a rock similar to the 'pierre ollaire' or Giltstein of the Alps is found, being essentially made up of sericite with a few admixtures of quartz. This affords us a good material for the study of sericite. It is a light greenish-white mineral with a perfectly smooth surface of cleavage and is extremely thin-lamellar. Its stauroscopic figure shows a tolerably wide axial-angle like that of muscovite. The sericite was isolated by means of the Thoulet solution from a glaucophane-bearing rock occurring in Ōtakisan near Tokusima in Awa, and Mr. Takayama, of the Geological Survey of Nippon, kindly undertook a chemical analysis of the mineral, the result of which is as follows :—

$Si\,O_2$	53.01
$Al_2\,O_3$	34.70

1) Michel-Lévy calls those round quartz-grains irregularly distributed in orthoclase "Quartz de corrosion," and considers them to be of a secondary origin. J. Roth, Allgemeine u. Chemische Geologie, II Band, III Heft, p. 393. 1887.

Fe_2O_3 ...	trace
CaO ...	0.27
MgO ...	0.50
K_2O ...	6.05
Na_2O ...	1.01
H_2O ...	4.67
	100.21

Our sericite differs from the normal type in containing an excess of SiO_2, but less of Al_2O_3 and K_2O.

Bořický's sample also contained potassium, and a small quantity of calcium and sodium.

The flakes of sericite show a minutely folded texture; their appearance closely resembles wrinkled bamboo-paper, and this structure is very characteristic of this mineral. The sericite is commonly heaped around the periphery of felspars and epidote after the manner of a fringe, as if it were produced from both minerals. (*fig. 3, Pl. II*).

A greenish-yellow *epidote* occurs in irregular plates, traversed as usual by numerous, approximately parallel, curved fissures in the direction of the vertical axis. As these transversal rents are probably the contraction-fissures, their course is at right angles to the cleavage-planes (oP,∞P$\bar{\infty}$) of this mineral. The size varies from $^1/_{10}$–1 centim., and seldom sinks into microscopic dimensions ; so that the mineral is macroscopically discernible as yellow spots on the cleaved plane of the rocks.

A characteristic feature of the epidote in this rock is the abundance of micrcscopic interpositions of iron-glance, and rutile-needles. The former is sometimes heaped together in such enormous quantity within the crystal as to give to the epidote almost an opaque appearance, while the periphery is comparatively free from it. Crystals are torn asunder into various parts, each part being joined to the other by fibrous-scaly lamellae of a greenish sericite. Pleochroism is distinct and intense nearly in the direction of the vertical axis. Epidote crystals arrange themselves with the orthopinacoid parallel to the plane of the schistosity of the rock, consequently its transversal section exhibits a vicinal clinopinacoid of epidote as an imperfect rhomboid, tapering at both ends.

Our epidote belongs to a common type in its crystal-form by having M and r or oP and $P\bar{\infty}$ as the predominating faces; consequently the clinopinacoidal section presents a flat rhomboid (M : r=116°); while the manganese-epidote which also makes its appearance in this variety of rock, is of a nearly rectangular rhomboid, when viewed in a similar section as the preceding. This is due to the fact that in the latter, T and i constitute the predominating faces which make with each other an angle of 99° or 81°.

Irregularities of outline mainly result from the neighbouring quartz grains, which push inwards into the substance of the crystals, and when the interior become full of such large, vitreous quartz-crystalloids, the epidote appears not unlike a melilite in basalts in regard to the structure. No evidence of twins can be found.

The rhombohedra of *garnet* occur, without exception, of a light green colour (in the garnet-amphibolite the colour is deep brownish-red, and the crystal becomes a magnetic bead before the blow-pipe). Sometimes the crystals merely make up the external part, while the centre is filled with quartz, and then the garnet-substance is full of fissures proceeding from the contact point with the quartz; rutile-needles are found within the crystal in most confused accumulations, suggestive at times of whirlwinds, and showers of needles occur within the garnet-substance as in *fig. 4. Pl. II.* The garnet is equally distributed throughout the whole of the rock, so differing, in the lack of any special arrangement, from the other mineral components. Optical anomalies are not observed in pure individuals.

Some occurrences are particularly rich in *Calcite* in irregular patches, occasionally, however, in the idiomorphic form of perfect rhombohedral crystals. The latter case seems usually not common in the gneiss of the Archaean group. Calcite-patches often contain quartz- and felspar-grains. Traces of the rhombohedral cleavage appear in bent and zigzag lines, partaking of the plicature of the rock-mass itself. It is highly probable that the calcite in this rock is of a primary nature.

The opaque *iron-glance* and the blood-red *iron-mica* are constant components in this rock as well as in those of the two upper divisions. The opaque iron-oxide has a lamellar structure and exhibits a bluish tinge on the smooth surface, when observed by reflected light. Both varieties of hematite are usually irregular in their distribution, being massed together in one part and remarkably absent in others, and, as has been already said, they are particularly rich in the felspars and epidote.

The *rutile* is the most characteristic component of the Lower Sambagawan Series. It occurs in both types of twins, the one is heart-shaped, being composed of broad crystals, the other knee-shaped. These sometimes occur in trilling according to $P\infty$ and $3P\infty$ at the same time. So far for the description of the component-minerals.

The *normal sericite-schist* has itself a special structure, being caused by an alternation of the quartz-felspar mass with fine layers of sericite together with garnet, and ores of iron-oxides ; and as the consequence of such an arrangement, the rock cleaves into thin plates. A good exposure may be observed at the quarry in Sueno near Yorii.

A peculiar structure has been observed in the course of the study, to which the writer wishes to call special attention. It has already been pointed out on page 85, that the quartz forming the matrix has a colloid appearance, and that the felspar-grains apparently corroded at their edge are imbedded in this homogeneous quartz, as if cemented together by a plaster. It may perhaps be conveniently called the *plastered structure*. This differs, however, from Törnebohm's[1] "Mörtel-Structur," by which we understand a fine aggregate of quartz and felspar containing large allomorphic minerals of the same species.

The upper horizon[2] of the Lower division is characterized by a most peculiar rock, viz., the piedmontite-schist.

The next higher—the Middle division of the Sambagawa series—is essentially formed by an alternation of two distinct types of rocks. These are the *spotted green*, and *spotted black schists*. The *piedmontite-schist* which has just been mentioned commonly occurs in thin bands in the lower *étage* of these spotted schists. Nevertheless the writer considers it to be an integral part of the Lower Sambagawan. It will now be shortly described. So far as the writer is aware, it has not yet been found in other parts of the world, or at least up to the present not recorded in any geological literature he has seen. This fact induced the present writer lately to work it out somewhat in detail, in a separate paper in this journal Vol. I, part III, to which the reader is referred for the details.[3]

This rock is of a purple colour, hence locally called the "Murasaki" or purple rock. It is rather more compact than the normal sericite-schist; but it easily cleaves into thin plates. On a weathered surface, beautiful purple-red crystals of piedmontite or

1) Rosenbusch; 'Massige Gesteine,' 2 te Aufl. p. 42.
2) *See* Note I at the end of the paper.
3) Vide also Quart. Journ. Geol. Soc., 1887, pp. 474 *et seq*.

manganese-epidote[1] are distinctly visible in long needles with unsymmetrical wedge-shaped terminations at both ends, transversally fissured, sometimes pushed asunder into several portions; in other cases the piedmontite is bent like crystals of tourmaline or common epidote. The best exposure is found along the banks of the Ara-kawa river near the village Minano, or near Ōtakisan in Awa. Clusters of needles may often be seen together with quartz-nests as at Miyanosawa near Obata, or at Kamakata near Ogawa. It is not easy, however, to get out a good sample, as they are so intimately imbedded in the quartz-aggregate.

The components of the piedmontite-schist are (besides the manganese-epidote) quartz, sericite, a greenish-yellow garnet, rutile, non-striped felspars, and the blood-red iron-glance. On account of the parallel position of the piedmontite-aggregate with layers of quartz-grains, transverse sections of the rock present a regular banded appearance. The clinopinacoidal section of the mineral is of rhomboidal outline, caused by the predominance of the traces of T and i, and when the face M is at the same time well developed, the section is six-sided. Parallel growth and intergrowth of two or more individuals of different sizes may be found everywhere, and these are the main causes of striation upon the crystal-faces in the direction of the axis of symmetry (ortho-axis). The colour of the piedmontite is deep violet, and often yellowish-brown. A probable explanation of the considerable difference in colours has been given in a separate paper (loc. cit.). Axial colours are:—$\mathfrak{A}$=deep-violet;

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1) Prof. A. Stelzner, of the 'Bergakademie,' Freiberg in Saxony, has favoured the writer with a few lines, dated 30th July, of this year, after receiving my paper on 'Some Occurrences of Piedmontite in Japan,' (this Journal, Vol. I, Part III,) which run as follows: "Die Arbeit ueber Piedmontit interessirte mich um so mehr als Sie das bestätigte, was ich an einem Gesteine vom Gebirgsrücken zwischen Tatsikawa und der Besschi-Kupfergrube, Provinz Iyo beobachtete. Wir hielten das Gestein für einen Thulitschiefer—aber ihre Bestimmung wird wohl die richtige sein."

𝔆 = brownish-red ; 𝔅 = light-violet. The Pleochroism is distinct, the polarization-colours magnificent.

Being of a beautiful rosy-red colour, highly pleochroic and acicular in habit, it has been called by Dr. E. Naumann a tourmaline.[1)]

The piedmontite is capable of undergoing various modifications. On the one side it forms a transition into a greenish-yellow epidote, the same one described in connection with the normal sericite-schist (anté page 90) but with this difference that here the red pigment localizes itself in the centre or in irregular patches. It is a most peculiar fact that the purple piedmontite also graduates into an almost *colourless* epidote. This abnormal, colourless epidote is found in long stalky crystals with rather fibrous terminations at both extremities, and is not unlike a broad column of *Grammatite*. What the chemical nature of this epidote is, the writer cannot at present say. Anyhow he is not disposed to consider it as a variety of zoicite.

The *hematite* is represented by the blood-red hexagonal plates of iron-mica whose minute scales are found abundantly in the greenish-yellow, and also in the colourless epidote ; while another variety (iron-glance) is comparatively rare and occurs in the form of dull, opaque clumps. Thus the habitus of iron-glance deviates somewhat from that of the normal sericite-schist. The presence of iron-mica gives a considerable reddish tinge to this purple schist. In piedmontite, iron-glance is never found as interpositions.

The *felspar* occurs exclusively as grains without any sign of idiomorphic forms, and commonly larger in size than those of the quartz. It is intimately intergrown with the latter as if the felspar served as a cementing medium, thus producing the *plastered structure*. The interposition of quartz-grains is of common occurrence—a fact illustrative of the simultaneous crystallization of both minerals. Simple twins

1) Loc. cit. p. 10.

and a few feeble traces of cleavage alone serve to indicate the presence of otherwise unrecognizable felspar in the rock-mass. The precise nature of the felspar could not be made out, simply because no favourably orientated sections could be seen. Anyhow, the habitus of the mineral coincides with that in the normal sericite-schist (cf. page 88). As in the latter rock, the interposition of iron-glance and iron-mica characterizes the felspar in this schist.

Of the *sericite* the writer has nothing to say, except that it is, as usual, colourless or of a light greenish tinge, and has a fine fibrous scaly structure. Light yellowish-green, rhombic dodecahedra of garnet are tolerably abundant.

In the Island of Sikoku, the piedmontite-schist is accompanied by a blue glaucophane-schist, a brief description of which has been already given in a separate paper.[1] This rock seems to be absent or at least has not as yet been found in the collections from Chichibu.

The piedmontite-schist is characterized by its peculiar outward appearance, of which enough has been already said, and this serves as a good criterion in tracing out the lower division of the Sambagawan series.

(c) The Middle Division.

Spotted graphite-schist, and Spotted chlorite-schist.

The horizon of the piedmontite-schist marks the beginning of the middle division. The rocks are principally of two types, viz., (I) the spotted black schist and (II) the spotted green schist, whose manifold alternations make up a considerable thickness, constituting the

1) B. Kotō, A note on glaucophane. This Journal, Vol. I. Part I. p. 8.

Sambagawan series proper. Their geographical distribution is very wide, consequently they are the commonest rocks which may be noticed even by cursory observers during a flying visit to this district.

What the present writer calls the spotted black schist is—

I.—*The spotted graphite-sericite-schist*, which is essentially made up of felspar, sericite, graphite, both varieties of hematite, quartz, and ? chlorite together with the characteristic accessories of tourmaline, garnet, and lastly rutile. Its outward appearance is not unlike that of the 'Garbenschiefer' of Saxony. The weathered rock has the aspect of a coarse-lamellar, brown mica-schist with prominent black spots (*fig. 5, Pl. II.*). In an advanced stage of decomposition it becomes even talcose in appearance.

These spots are generally of an inflated disk-shaped form with T, l, P, y (*fig. 6, Pl. II.*), the faces being very much blurred by the compression of the rock itself. The inflated side of this deformed felspar lies parallel to the plane of schistosity of the rock; consequently the transversally fractured surface of the rock presents a cleavage-face (P in the figure) of nodules with pearly lustre.

Under the microscope these spots or nodules ($^3/_{10}$–$^1/_2$ centim.) were found to be of a *felspathic* nature. The crystals occur in irregular forms; lustre vitreous; simple twins are often observed by the behaviour of different polarization-colours in the two halves, but with unequal angles on the right and left. A polysynthetic, lamellar structure happens not to have been observed (excepting in a very few cases, if it is really present at all), though traces of cleavage-planes are of common occurrence. Extinction of light usually takes place at about 16°–21° with a trace of twinning-lamellæ. On the rhombic face of the basal cleavage-plane, it makes an angle of −30°, or thereabouts, in the sense of Schuster (*cf. fig. 6, Pl. II.*)

As is shown in *fig. 7, Pl. II.* the central part appears almost black, owing to an enormous accumulation of graphite-particles, rhombohedra of garnet, tourmaline-crystals, actinolite-prisms with the combination of ∞P, $\infty P \grave{\infty}$, and other colourless grains and micro-crystals of an undeterminable nature, together with opaque iron-oxide.

On igniting a thin slice, graphite (possibly identical with the *Graphitoid* of Sauer[1] or Inostranzeff's *shungite*)[2] is partly removed from the felspar-substance, although a dark centre remains as before. A closer inspection with higher powers discloses, besides amorphous coaly dust, some minute inclosures of air and liquid, the latter with movable bubbles. These inclosures are arranged more or less in stripes, and appear under weak powers as black dots. It is their presence that chiefly causes the opacity of the felspar as in the minerals of the hauyne group.

As to the arrangement of the black dust, the fine particles are disposed in the most fantastic manner, thereby producing at the centre a cyclonal, at the margin a fluxional-structure, as shown in *fig. 7. Pl. II.* Dr. A. Sauer[3] has described a similar arrangement of interposition in a felspar contained in the felsparphyllite from Plaue, Saxony; but there the interposed mineral is rutile instead of coaly dust. This peculiar structure has evidently arisen from the squeezing accompanying the movements of the crystals during their formation. Herr Dr. Sauer is rather disposed to think that the structure as of a primary nature, arguing in support of this view that the periphery of the felspar is perfectly pure and free from inclosures of foreign substances, and moreover that the suture of twinning-lamellæ passes straightforward throughout the whole section of crystals irrespective

1) Zeitschrift d. d. geol. Gesselschaft, XXXVII Band, 1885, p. 441.

2) Neues Jahrbuch f. Min. u. Geol. etc. 1880. I Band, p. 97.

3) N. J. f. Min. etc. 1881, I Band, p. 232. 'Rutil als mikroskopischen Gemengtheil in der Gneiss— und, Glimmerschieferformation, sowie als Thonschiefernädelchen in der Phyllitformation.

of the arrangement of the interpositions. The writer is, however, inclined to view the subject from another stand-point; namely, that the clear periphery is due to an accretion of another generation resulting from the *secondary enlargement*, the centre being the primary; the further point in regard to the cleavage, being perhaps explicable as a result brought about by pressure induced afterwards. C. R. van Hise[1] has lately found in the slate-conglomerates of the north shore of Lake Huron what may be enlarged felspar grains, but the evidence there is not sufficiently satisfactory as to the material being of secondary origin, the line of separation between the supposed new material and the nuclei being indistinctly marked. The present case affords better evidence of secondary enlargement, owing to the circumstance that the new material on the clear periphery being free of the above-mentioned interpositions is sharply marked out from the core.

The marginal portion of the felspar nodules is fringed with, or enclosed by a green sericite,[2] which is sometimes coloured brown by the oxidation of iron contained in it; more especially after ignition a slice of it acquires a deep brownish-red colour, becoming not unlike a common biotite, from which we may infer that our green sericite is rich in ferrous oxide. This kind of mica seems to be of a wide distribution in (metamorphic) schists outside the Japanese Archipelago; for the writer has observed the same in a mica-schist from Killin, Perthshire, Scotland, and in all the '*Amphilogit-Schiefer*' from the Zillerthal in Tyrol. In petrographical literature it has been described under various and even self-contradictory names,

1) Bulletin U. S. Geological Survey, Vol. II, p. 44.

2) The present sericite might probably be a modified form of Phengite of Tschermak, for it contains a large amount of $Si\ O_2$, but less of $Al_2\ O_3$, as may be seen from the numbers stated in page 90.

such as green mica, hydro-mica, sericite, green biotite, chloritoid, phyllitic element, etc.

The *tourmaline* forms a very characteristic component of the spotted black schist, especially as regards its quantity and the perfection of its forms. The crystals are slender, being bounded by deuteroprism ($\infty P2$) and protoprism (∞R), and terminate in an acute rhombohedron ($-2R$) at one end, and an obtuse at the other ($+R$); the basal pinacoid not yet observed; but one pole often broken; transversal fissures rare; coaly particles often found as interpositions. The acute pole rhombohedron ($-2R$) is, as a rule, unsymmetrically developed, while the opposite obtuse end is bounded by a rhombohedral face ($+R$) well finished and very regular. And it is a very remarkable fact that the *antilogous* (+) acute pole bounded by $-2R$ is *always deeply coloured;* while the *analogous* (−) obtuse pole ($+R$) is of a *lighter shade* (*fig. 8, Pl. II*). This difference in the tinge of colour should in some way be connected with its pyroelectric properties, which, as Hauy long ago pointed out, have some close connection with the very characteristic hemimorphism of the tourmaline-crystal.

The vicinal section (*fig. 9, b, Pl. II.*) of the base of our tourmaline presents some noteworthy features which may here be briefly noticed. Some basal sections show a nucleus which is marked off clearly by a fine contour, and also by the lighter colour of the centre, while others (*fig. 9, a, Pl. II.*) show an imperfect external shell with half-covered internal parts. Examples of the former are often fcund in various plagioclases known as isomorphic shells (isomorphische Schichtung); while in the latter we have an example of a parallel growth of individuals of the same mineral species, the well-known vertical stripes of tourmaline-columns being due greatly to this special growth. Bearing in mind the facts stated above, we are now forced to believe that the so-called isomorphic shell and the parallel growth do not differ from each other but really mean the same thing.

As to quantity, tourmaline is so abundant that it may be regarded as an essential component.

The quartz, sericite, garnet, the light-green epidote crystals and grains, and lastly, the calcite present no peculiarities worthy of special description.

The *structural modification* of the rock varies within a wide range from a coarse-lamellar rock to a thin-tabular graphite-slate; in the latter the nodules are scarcely visible, unless weathered surfaces are viewed. In the coarse extreme, the nodules attain more than $^1/_2$ centim. in size (*fig. 5, Pl. II.*) and at the same time the rock becomes less graphitic, while the sericite increases proportionally in quantity, and then the colour changes from black to brown. When seen with reflected light, the sericite-lamellae display a nacreous lustre.

In a fine slaty variety a transverse fracture of the rock has a banded appearance through the alternation of quartz-felspar layers with those of the coaly particles. The coarser variety is typically developed near Ōda, while the slaty one occurs at the village of Honnogami.

II.—The *chlorite-amphibolite* or spotted green schist is a thick, imperfectly schistose rock of a grass-green colour with an uneven plane of schistosity. It is full of innumerable white spots ($^1/_2$–2 mm.) on a green ground, presenting an aspect quite similar to currants in a pudding (*fig. 10, Pl. II.*) F. Becke seems to have found a similar structure in a mica-schist and gneiss rich in felspar-nodules from Selitschani in Greece, and has given to it the name *cristhic structure*[1]) from the likeness to cereal grains. Our rock has such a striking

1) Tschermak, Min. u. petro. Mitth, II Band, 1880, p. 43.

resemblance to that of the so-called 'Grünschiefer System' of Saxony, that when hand-specimens from both countries are placed side by side, it is hardly possible to distinguish them, nor are there any special distinguishing features even under the microscope.

Slides show that, under high powers, each spot is nothing but an individual grain of felspar, or composed sometimes of many grains. These felspar-dots are all, without exception, of an irregular outline, and present a characteristic cataclastic structure. They are colourless, showing quite a fresh aspect— only a few stripes ; twins referable to the Carlsbad type occasionally found— polysynthetic twins exceedingly rare.

(1) The writer is of opinion that this rock is a transformed schist from a *tuff* of a felspar-pyroxene rock of an eruptive origin ; and (2) it is an accepted dogma that, when minerals are subjected to a certain pressure, they usually exhibit many traces of cleavage (although all minerals have not as yet been experimentally tested); and lastly (3) a mechanical force can put in motion the molecules of minerals so as to make the particles assume a new position, the result of which is the formation of twins, gliding faces, etc.— it is, indeed, very striking to find only a few such traces of cleavage in our felspar, although the rock bears signs of having been subjected to pressure in the mass-movement.

A probable explanation of these facts may be that the felspars have once been in a condition, in which a long-sustained pressure and moderate heat, with the simultaneous presence of mineral solutions, have made the molecules in the felspars to move easily but only to a *certain extent*. The same reasoning may well be applied with equal force to the formation of schists, which have an appearance as if they were formed by the solidification of an originally gelatinous mass in the diagenetic way (*vide* page 85.)

These felspar-spots seem to have been arranged parallel in accordance with the stratification; and the spots themselves have fine, curved, approximately parallel fissures in the direction of the breadth, probably due to a strain normal to the axis of mountain-flexures, and these minute fissures have been sometimes filled up by calcium carbonate. The felspars already referred to are mainly non-striped, and occasionally a few lines parallel to the basal cleavage are to be seen; still it is not easy to prove optically the nature of the felspar. The extinction-direction with reference to the trace of cleavage is about 12°–19°, and it may probably belong to albite.[1] In saying so, the presence of orthoclase is by no means excluded.

The felspars contain also grains of the same mineral species whose presence is proved by different optical orientations. There seems, however, to be no crystallonomic relation between those grains within, and the enclosing mineral; the latter serves, as it were, as a cementing material; the former may be considered as a product of dynamo-metamorphism.

The spots of felspar are rich in other interpositions of light-yellow epidote-crystals and crystalloids, with a few actinolite-needles, and tourmaline-prisms, arranged in a most confused manner especially in the central part, as viewed in a slide made parallel to the plane of schistosity of the rock. Spots in the transverse section of the rock have a special arrangement of their interpositions, minute needles and crystalloids being disposed more or less after the fashion of streams. These diminutive bodies are not decomposition-products in the ordinary sense of the term; still they might have derived their materials in part from the felspar-substance during a dynamo-metamorphic process.

1) If I rightly remember, Herr Dr. Dalmer made a chemical analysis of a pure felspar from the chlorite-amphibolite of Saxony, which, as has already been pointed out, has a close resemblance to our rock, and he found it to be albite.

the smaller the felspar-grains are, the more interpositions they contain, becoming finally extremely dull so that the felspar-portion is no longer visible, thereby presenting an aspect quite similar to that of a zoicitized felspar of the so-called saussurite-gabbro.

A minuter inspection under high powers resolves the *quasi*-zoicite into a monoclinic epidote. It is found as microliths and round crystalloids. Of the various forms, some have a rhombic outline, or are needle-shaped ; while others are developed in unsymmetrical wings with a twinning-suture at the middle as is seen in *fig. 11. Pl. II.*, The optical investigation of them is made impossible by the interference of the other grains and the enclosing felspars. There are seen frequently actinolite-prisms whose basal sections often met with in slides are of an acute rhombic outline without any trace of the clinopinacoid as is usually supposed to be the case; consequently the prism shows dark longitudinal margins on account of its high refracting power— and the terminations are round and often broken. Rhombic dodecahedra of garnet together with pleochroic, yellowish-green pistacite columns ($^1/_2 - ^1/_4$ centim.) lie also imbedded in the felspars.

The general mass of the rock consists of a grass-green, lamellar-fibrous substance which encircles the porphyritic felspar-grains. This green substance is slightly pleochroic showing a deeper shade of colour when the chief section of nicol is at right angles to the axis of the fibres, and remaining dark between crossed nicols. It transmits only a faint blue light. In a hot solution of hydrochloric acid, the greater part of this green substance is removed from the slides, and the remaining portion becomes almost colourless— it is chlorite.

The minerals found as interpositions in the felspar-nodules occur here again in the *groundmass*, and the green scaly-lamellar mass is interlarded throughout by epidote-needles and grains, and especially actinolite-prisms which are like spicules in the spongy mass.

Calcite with its characteristic rhombohedral cleavage fills up the miarolitic spaces. It is, however, not a constant component. *Iron-pyrites* and *iron-glance* are tolerably plentiful, the latter with margins of blood-red iron-mica. *Quartz* and *rutile*, so abundantly present in the Lower Sambagawan series, are only of a subordinate importance.

We occasionally met with *titanite* as an enclosure in felspar in combination with the clinodome ($n = \infty P\grave{\infty}$), and prism ($l = P\infty$) as in *fig. 12. a Pl. II;* consequently its section in a slide mostly presents a rhombic outline with a deeper shade on the two adjoining sides (*fig. 12. b*) which make with each other an obtuse angle of 134°–137°. This difference in shade arises necessarily from the very form of the crystal itself, and is due to the inclination of the clinodome or prism. Thus the habitus of the microscopic crystal differs from the macroscopic type, as has already been pointed out by v. Foullon.[1]

The *structural modification* of the rock is still more astonishing, ranging from a coarse-lamellar rock to an almost compact schist. A newly fractured surface of the former variety shows felspar-spots of a tolerably large size (more than 2 mm.) with a glittering plane of cleavage. In the compact variety, it differs in no wise from a common chlorite-schist. The weathered surface, however, distinctly tells the presence of countless white spots of felspar-grains.

The compact variety is somewhat more yellowish-green in colour on account of the presence of a considerable quantity of epidote as in the rock of Ōda, $1\,^1/_2$ ri (6 km.) westward from the small town of Kodama. There also numerous clusters of black *tourmaline*-crystals, attaining the size of 1 centim. in length, are found along the plane of stratification of the rock. Slides show that the mineral has a grayish-brown colour with a slight tinge of violet; zonal structure is more

1) Heinrich Baron v. Foullon; Ueber die petrographische Beschaffenheit der Krystallinischen Schiefer, etc. Jahrbuch d. geol. Reichsanstalt, 1883, p. 241.

imperfectly developed than in the crystals of eruptive rocks. The mineral shows the dichroism ; ω = black, ε = violet-brown. The crystals are by no means pure; sagenitic needles, knee-shaped and heart-shaped twins of rutile together with crystals of zircon occur imbedded in them. The tourmaline itself is an unexpected guest in this chlorite-amphibolite, and it is even more striking to find that rutile and zircon which usually belong to the early generation in the order of crystallization, occur exclusively confined in this tourmaline of an apparently secondary origin. The tourmaline characterizes the rocks of the Middle Sambagawan and its true home is, as has been already mentioned, the graphite-sericite schist ; but it is absent in the Upper as well as in the Lower series.

The compact variety of the chlorite-amphibolite is also extensively developed in the Dōzan-gawa near the Besshi mine in Iyo, Island of Sikoku.

(d) The Upper Division.

Epidote-sericite-gneiss.

The Upper Sambagawan is not so extensively distributed as the two preceeding *étages*, and so far as the writer is aware at present, it is mainly confined to the southern side of the Arakawa river.

The rocks belonging to this division overlie directly and conformably the *black* and *green schists* of the middle division, sometimes alternating with the non-spotted graphite-schist in its lower horizon. The characteristic feature of the epidote-sericite-gneisses with their various modifications which constitute the Upper Sambagawan, is a more or less platy structure with an uneven surface on a cleaved specimen. There seems to exist some regularity in their structural modifications ; for the lower horizon consists of a thick-platy, more or less graphitic variety, while as we advance to the higher zone, the rock passes into a very thin, stiff, papery schist.

Beginning now with the lower étage, the thick-platy, grayish-white variety easily cleaves off into slabs of more than $^1/_2$ centim. in thickness. The upper and lower surfaces of the slabs are covered by a thin skin of grayish-green, soft, talcose lamellae which, when viewed by reflected light, shine with a glittering lustre. It is the presence of this layer which allows of the rock being so easily taken off.

A newly fractured surface presents layers of a snowy-white, saccharoidal mass, consisting of a fine admixture of quartz and felspar-grains, the presence of the latter being shown by their pearly lustre. The relative quantity of both minerals could not be easily ascertained on account of the approximate similarity of their optical behaviours. The felspar shows sometimes signs of cleavage; and it as well as the quartz displays an undulatory extinction which in no wise ever comes to total darkness. On the whole, the felspar seems to be the predominating constituent, and usually more porphyritic in its habitus than the quartz-grains.

Thin talcose, wrinkled lamellae were treated with a few drops of HFl, and then evaporated to a concentrated solution, out of which, on cooling, many crystals of potassium-silico-fluoride with the forms belonging to the isometric system, aggregated themselves into perfect, delicate shapes. The angle of the optical axis is as wide as in muscovite. This sericite is either colourless, or light-green, and has fibrillated texture, but is irregularly outlined; smooth lamellae are not rare, in which case it is sometimes almost impossible to discriminate the green sericite from the co-existent chlorite.

The sericite-aggregate is never found in a pure state. In the slides, sericite itself is not abundantly present, being sliced off during the preparation of the sections, and the same holds true of the various enclosures in the sericite. It is better therefore to take off by means of a knife a thin flake of this mineral which, when seen under the microscope, shows various interpositions, especially colourless tremolite in slender prisms, resolving at both ends into tufts of fibres. The extinction-direction of tremolite is insignificant, usually less than 10°; the pleochroism not perceptible. Minute grains and needles of an almost colourless epidote occur associated with the tremolite, within the sericite-aggregate, much as in the manner of spicules in sponges.

A special feature of the minute epidote is its acute rhombic form with sinuating lines along the longer diagonal; and to a cursory view it looks not unlike small crystals of titanite (*fig. 11. b, Pl. II*), It is the common type of twinned epidote whose structure becomes manifest by different optical orientations in the two halves under polarized light. The crystals display vivid chromatic polarization-colours.

Rhombic dodecahedra of garnet occur together with the epidote. but not with the rutile. The enormous accumulation of the above-mentioned microcrystals causes a dull appearance in the otherwise clear sericite-aggregate.

In some specimens, as in that from the Kainita-pass in Chichibu, a few long stalky crystals (1–2 centim) were detected whose longitudinal terminations split into stiff fibres. They are now rusty-brown, although bluish-green where fresh, and their morphological character resembles that of the primary glaucophane from Ōtaki-san in Awa.[1] Taking into account the above-mentioned facts, the writer is rather inclined to consider the tremolite already described, as having been derived either directly or indirectly from the other minerals such as glaucophane.

1) loc. cit.

Somewhat large, pleochroic pistacite-grains are found in isolated patches, but they deserve no special mention. Some specimens are rich in calcite ; its occurrence is, however, not constant.

As we have already pointed out, the more we ascend to the higher horizon, the more papery the rock becomes, and finally this epidote-sericite-gneiss acquires such a structure as to be easily cleaved into thin laminated slabs. The microscopic habitus differs in no way from that of the foregoing variety.

A very characteristic feature of the rocks of the Upper Sambagawan is their papery structure, and also their richness in sericite-scales. Thus the weathered exposures of the rock in any road-cutting present a more or less advanced stage of disintegration, and finally become resolved into tough, slippery, silver-white splinters—a peculiar aspect of road which, if once seen, cannot be easily forgotten.

B. Architectonics of the Sambagawan Series of the Chichibu district.

(e) General Remarks.

The writer has been so far wholly engaged in describing at some length the objective representation of all the rock-varieties which constitute what is called the Sambagawan series; he now turns to another topic—the geotectonic condition of these schists.

The Sambagawan complex forms the very lowest of the long geologic series, that makes its appearance in the Chichibu district, so far as the present state of our knowledge permits us to say. From the analogy of other occurrences, especially in the Island of Sikoku, where thanks to the munificence of our Geological Survey, the writer was placed in a position, last year, to be able to geologize the countries traveled through, and of which he hopes to give some account on another occasion as a continuation of the present study, it is highly probable (but by no means proved) that this series is superposed upon a complex of biotite-mica-schist and biotite-gneiss with great unconformabilities, which indicate a long lapse of time between the formation of the two series.[1]

1) The above supposition has been, to a certain extent, confirmed during a trip this winter (1887-8) to the provinces of Mikawa and Tōtōmi, where coarse-lameller *biotite-schist*, gray, streaked *gneiss* and then dark-gray, fine-lamellar *mica-schist* with the intercalated *quartz-schist*, in all of a considerable thickness, are developed to their full advantage. These typical Archæan rocks, which the writer saw for the first time in this country, form a long belt, beginning from the interior of Sinano, along the upper course of the Tenriū river, through the province of Mikawa, terminating at the Bay of Atsumi.

The general direction of this long, curved belt, with the convex side toward the south-east, is N.E.—S.W.; and this belt represents the western wing of the Japan—"Schaarung" of Suess (Naumann: Die Erscheinungen des Erdmagnetismus, etc., p. 17.). Parallel to the curvature

Granitic eruptions must have taken place through the Archæan group before the Sambagawan was formed; for, along the coast to the north of the city of Imaharu, and especially in the upper course of the Nobusigegawa, east of the city of Matsuyama, both in Sikoku, the granitic bosses have severally intruded on the mica-schist and gneiss-strata; and have, in consequence thereof, produced a well-marked contact metamorphism in the latter; the deep-brown pyrope having been formed thereby in the *hornfels* of the biotite-gneiss.

Endomorphic metamorphism on the part of the intruding rock is also clearly indicated by the formation of fine-grained, aplitic granophyre-facies of granitite, this being indeed the typical biotite-hornblende variety, of which alone are formed almost all the granitic

of this Archæan belt, an extremely coarse-grained hornblende-granite makes its appearance on the south, convex side, where the granite occupies the greater part of what is called the Tsukude district. This rock shows many characters deviating from the common variety; first of all it is remarkable in containing a large, grayish-white plagioclase and the cross-shaped twins of hornblende together with biotite and quartz; the habitus of the granite is dioritic. In some places, as for instance, at the ascent between Hosokawa and Suyama, this Tsukude-granite becomes *gneissoid* in its aspect, due surely to shearing during the mass-movements.

Further to the south-east, this eruptive mass is overlaid by the Sambagawan series, the latter is therefore, no doubt, separated from the Archæan by a wide, geologic gap, and along the geologic boundary between the granite and the Sambagawan terranes, the Toyokawa finds its course. The Sambagawan series of this region appears younger in its whole aspect, when compared with the Chichibu type.

Still further to the south-east, this series is overlaid by the gabbro-derivatives—*tuff-amphibolite* and *tuff-pyroxenite* with intrusive masses of *gabbros* and *serpentines*, i. e. the Mikabu series of the present writer. Again, the tuff series is covered conformably by the ? pre-Carboniferous complexes of *quartzite*, *crystalline limestone*, rusty-brown *schalstein*, *graywacke*, *adinole*, *silicious slate* and, lastly, a *limestone* presumably the Upper Carboniferous—these together making up the boundary-ridge of Mikawa and Tōtōmi.

It is here out of place to give minute details; only suffice it to say that the writer's view is so far corroborated, that the so-called crystalline schists of Chichibu—the Sambagawan series—are not the oldest geologic body in Japan, and they are also not the normal schists of the accepted Archæan group. Therefore it would be a great mistake to make any conjecture as to the general construction of the Japanese Islands from the structural and the choric condition of the so-called Archæan group as understood at present by our geologists, since all the non-fossiliferous rocks of quite unlike origin, but having simply a crystalline, schistose habitus are indiscriminately thrown together under the category of crystalline schists in a narrow sense, and taken as the genuine Archæan. *(Note during the printing).*

mountains of Japan. According to the statements of E. Naumann,[1] the chief granitic eruption occurred at the end of the Palaeozoic, or at the beginning of the Mesozoic era in the Japanese Islands; it seems, however, not unreasonable to suppose that the granites in our country are not the product of a single eruption.

The Sambagawan series has been, perhaps, formed after the first eruption of granite. And the post-granitic schists included in the above-mentioned series are of a considerable thickness probably not less than 300 m.; and these schists in turn have been overlaid discordantly by an equally thick complex of the epidote-pyroxenite, pyroxene-amphibolite, and epidote-amphibolite which the writer is rather inclined to consider as various *modifications of the tuffs* formed in some way in connection with the eruptions of gabbro, diorite and diabase.

The rocks of eruptive origin just referred to can be seen typically developed around the conical-shaped Mikabu peaks, and accordingly the writer designates provisionally the whole complex of gabbro, diabase, the gabbro-diorite, and their derivatives under the name of the *Mikabu series.* The pyroxenites[2] and amphibolites of the above series, usually spoken of simply as chlorite-schists by our geologists, claim our special attention, as they contain an interesting mineral—the secondary glaucophane of which discriptions have been lately given by the author

1) Loc. cit. p. 40.

2) These pyroxenites and amphibolites with their numberless varieties play a not insignificant part in the geologic terrane in Japan, and they have justly full claim to special treatment and independent cartographic representation. To the writer, the above-named rocks seem to be the altered crystal-tuff (in contradistinction to the agglomerate-tuff), originally composed solely of (excepting some few cases) one mineral—the pyroxene which had been thrown up from eruptive vents, just as in the case of ejectamenta of modern volcanoes, and then deposited at the bottom of the once *Universal ocean* of the past, when dry land was comparatively rare. In order to avoid a confusion of the nomenclature, designating rocks of quite unlike origin, or conveying different meanings about the genesis of this class of green, schistose rocks, to which are attached diverse views sometimes diametrically opposite, the writer thinks it advantageous to apply the names of *clasto-pyroxenite* and *clasto-amphibolite* respectively to our rocks, thereby signifying their tufaceous origin, just as Lossen had done long ago for the kindred variety of quartzporphyries. Zeitschrift d. deutschen Geol. Gessel. XXI. 1869.

in another place.[1] To give the detailed geognostic accounts of these is, however, foreign to the scope of the present paper.[2]

(f) The Lower Sambagawan.

The Lower Sambagawan series crops out only in few localities along the banks of rivers and rivulets; the greater part of it is covered by the Middle division, and consequently hidden from our view.

It is, however, not very difficult to ascertain its occurrence through having among its members a characteristic purple-red piedmontite-schist which affords us the surest criterion as to the boundary of the Lower and Middle Sambagawan.

1.—A good exposure, not to mention minor occurrences, may be seen along the winding course of the Tsuki-gawa on a small, isolated island of schists amidst the younger geologic formations, to the east of the village of Ogawa, especially in Tōyama, Simo-sato, and Kamakata, all in the district of Hiki, Musasi province. Here the strata lie almost horizontal with slight dips to the north and east. It is, indeed, very striking to behold the contrast in colour between the overlying chlorite-amphibolite rich in felspar-"eyes" and the purple-red piedmontite-schist. The rosy mangan-epidote, so rare in Europe and America, and much sought after by mineralogists, occurs in rich clusters within quartz-nodules, sometimes attaining 2 centim. or more in length. Lower down we see in thick banks the whitish-gray normal sericite-schist which through weathering acquires a somewhat green colour, while a greenish-yellow pistacite becomes

1) This journal, Vol. I, part I; "A Note on Glaucophane."

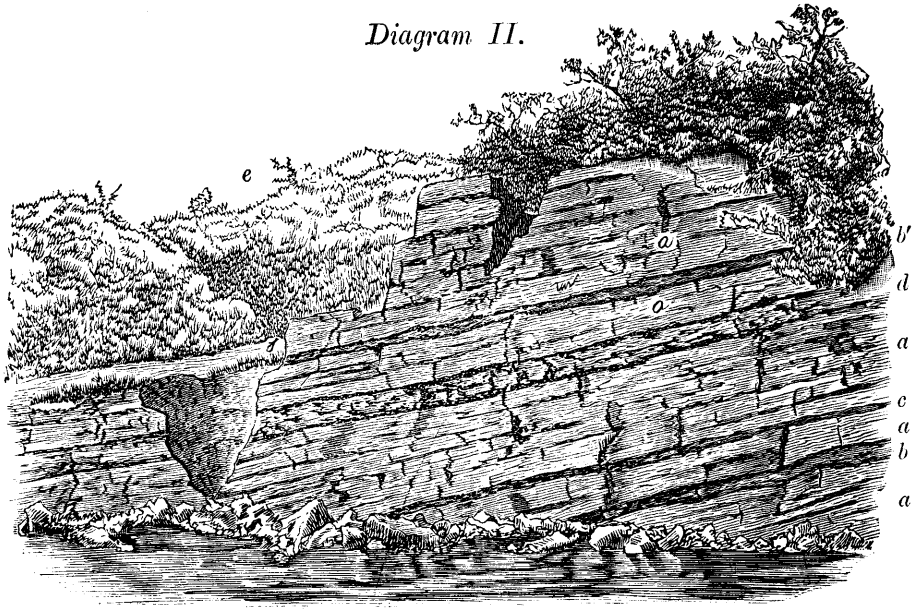
2) Prof. Geo. H. Williams, of the Johns Hopkins University, Baltimore, Md., has lately sent me a chip of a glaucophane-schist from the State of California. Of the Glaucophane of that State, we have as yet only a few records in petrographical literature. Michel-Lévy seems to have been the first to give a short description of it ("4th Annual Report of the State mineralogist of California." p. 182, 1884,—a work which is not accessible to the writer.). F. Becker has mentioned its wide distribution in the Cretaceous metamorphics of that State. (See American Journal of Science, p. 352, 1886).

On examining a slide prepared from a specimen from Berkley, California, the writer was quite surprised at finding a great similarity between the glaucophane-schist of the Kitagawa pass, Tosa (See this journal, Vol. I, p. 92.) and that of the Pacific Coast, U. S.; but our schist is of the ? pre-Carboniferous age instead of being of the Cretaceous. The writer cannot here pass over in the silence the great obligation he is under to Prof. Williams for his gift of a most valuable collection of the typical glaucophanes of Europe, for which he can scarcely find any adequate words to express his deep sense of gratitude.

conspicuously visible in small patches on the plane of schistosity of the rock and characteristically rich in microscopic rutile.

2.—About 4 km. west of Yorii, which is 12 km. south-west from the station of Fukaya on the Nakasendō railway, other good outcrops may be seen in Sueno and Kanaya along the Arakakawa; these exposures are easily accessible to observers as the two villages lie on the main road leading from the Musasi plain to the centre of the Chichibu district. In a stone-quarry in Sueno on the right bank of the river, the normal sericite-schist with abundant lamellæ of a light-greenish sericite is worked in thin slabs, into which the schist may be readily cleaved; the strike is nearly E. 20° S. with high angles of dips to the S. E., and the schist is conformably overlaid by the spotted graphite-schist. Here lies the anticlinal saddle of the Sambagawan series; for, at the Kanao bridge (Tokura bridge), only 1 km. to the north of the quarry already referred to the piedmontite-schist zone is found with its accompanying normal sericite schist, having the strike N. 30° W., but the dip being 40° N. E. Diagram II shows an illustrative exposure near the bridge already mentioned :—

Diagram II.



a.—The normal sericite-schist rich in quartz, abundant in pistacite-patches, the colour light-gray;

b, and *b'*.—the purplish-red piedmontite-schist, only one inch in thickness;

c.—the white, compact quartz-schist making up very thin zones;

d.—the green chlorite-amphibole-schist with its characteristic white "eyes" of felspar; the rock rather compact and imperfectly schistose; yellow, glittering iron-pyrites abundant;

e.—the graphite-sericite-schist with black specks of felspar, showing a thin lamellar structure; spots very promiscuous through weathering; the rock earthy; the soil produced therefrom black and slippery.

The above diagram illustrates well the junction of the Middle and Lower Sambagawan. The cliff about 7 m. in height standing in the foreground represents the latter, while the black graphite-schist of the former lies a little behind covered with grass and consequently not shown distinctly on the drawing. The overlying as well as the underlying Sambagawan rocks dip away from the sight of the observer.

3.—Again about 6 km. up the Arakawa other outcrops come to view at the village of Hon-nogami, and also close by the side of the bridge in Minano. In the latter place two thin zones of piedmontite-schist alternating with the chlorite-amphibolite have been observed in an almost horizontal position with a slight dip to the north-east, just as at Sueno already mentioned.

The occurrence of the red epidote-schist in Hon-nogami, and Minano may be ascribed to the existence of a fault running through the two villages from Kanasaki in the direction of N.20°E along the left side of the Arakawa The vertical displacement being very small, the outcrops found there are very meagre and the underlying normal sericite-schist does not show on the surface to its full advantage. The strike runs approximately N.–S. with a slight dip to the east.

4.—The next locality in which the Lower Sambagawan may be seen, is along the Sambagawa itself, which flows into the Kanna river close to the town of Onisi, in the district of Midono, Kōzuke province. This rivulet has an easterly course with a slight trend to the south, thus harmonizing well with the general strike of the whole series. Along this tectonic valley of about 5 km. in length beginning from Imogaya, just at the foot of the Eastern Mikabu, the entire complex of the Sambagawan series is typically developed; and if any one is desirous of convincing himself of the stratigraphic order of the complex, this is just the place for him.

The general strike is N. 70° W. with variable dips to S.W.; but, where the transversal faults run across the valley (altogether 3 principal ones as in Profile IV), the geotectonic condition is considerably disturbed, and the outcrops of the piedmontite-schist and normal sericite-schist are then laid bare for inspection. As can be seen in Profile IV, two large faults occur in the lower course at Siosawa and Tsukiyosi respectively, causing a depression in the one, while the northern side has been thrown up to a considerable height, forming the fantastic cliff of the Tsubori-iwa (200 ft.). This cliff is composed of chlorite-amphibolite of the Middle division, and at its foot, along a deep ravine, the Lower Sambagawan crops out to day-light.

5.—The last outcrop which the writer has to mention lies at the north-western corner of the geologic territory of the Sambagawan series, being exposed just to the south of Obata, at the entrance of the long valley of Akihata. Here the piedmontite-schist makes a small saddle with the strike N. 50° W., the dip being very steep toward the north (Todoroki), and then vanishes again from sight on the north under the vertical cliff of the Tertiary sandstone and conglomerate of the Chōgonji-yama (str. E. 20 S.) to be seen no more in this region.

(g) The Middle Sambagawan.

This division plays an important rôle among the Sambagawan series, amounting to about 200 m. or $^2/_3$ of the whole thickness, made up of alternate layers of the chlorite-amphibolite and graphite-sericite-schist. The whole middle complex lies conformably upon the Lower division, and occupies the greater part of the area of our geological terrane. As a whole, the green schist predominates in the lower horizon, while the black schist chiefly constitutes the higher part; and both are directly overlaid by rocks of the Mikabu series, when the Upper Sambagawan is wanting.

The chlorite-amphibolite or spotted green schist is extremely rich in the white "eyes" of a *saussuritic* felspar, which become more clearly visible on a weathered surface; but sometimes, nay, indeed very frequently the fresh surface of a rather compact variety does not show any sign of the presence of the "eyes"; and this is the source of a lamentable confusion of this rock with the overlying Mikabu rocks—both being habitually indiscriminately termed *chlorite-schist*, although they are really separated by a wide stratigraphic gap. This green, spotted schist not infrequently comes together with the piedmontite-schist (i. g. in Todoroki near Obata, and Minano), and the former is rather compact and less fissile than the spotted, black schist. The graphite-schist becomes coarse-lameller (Ōda and also in the neighbourhood of Onisi) through the presence of the black "leather-bag-shaped" crystals (*fig. 6*) of felspar; and through weathering the rock acquires a brown colour, presenting an aspect quite distinct from the spotted graphite-schist.

1.—Both the chlorite-amphibolite and graphite-schist occur in an isolated district east of Ogawa, where they overlie the piedmontite-schist, and dip to the north-east, being directly covered on the north by graywacke-sandstone and in part by the Tertiary of the Ogawa basin.

2.—Along the Arakawa from Yorii to Hon-nogami, illustrative examples of the alternation of the spotted black, and green schists are exposed to view with moderate dips variable at times but generally to N.E.

3.—In the other localities, such as, on the road from Kodama to Ōda, in the environs of Onisi, in the lower course of the Sambagawa, in the Hino valley beginning from Kanai to Kami-Hino, or, lastly, in the Akihata valley, these two rocks always occur in multifarious alternations, the higher portion of which consists chiefly of the graphite-schist. The dip is usually very gradual, the prevailing strike harmonizing well with the general axis of the whole series, and it is not uncommon to find them in a perfectly horizontal position in extensive tables.

(h) The Upper Sambagawan.

The upper division is mainly confined to the southern side of the Arakawa and makes its appearance on the higher parts of the hills. This light-gray or dark coloured rock is nothing but the epidote-sericite-gneiss which in the lower horizon is thick-platy, while on the higher zone it becomes a very thin, papery schist. The latter shows on the cleaved surface a silky lustre, and through long exposure to air the rock falls into a soft, talcose, glittering, slippery mass.

The writer has always been confronted with difficulty in assigning the boundary of this and the preceding division, as the spotted graphite-schist of the Middle Sambagawan insensibly blends with that of the Upper Sambagawan forming with it a continuous series. Between the Lower and Middle divisions a well-characterized, red piedmontite-schist serves well for the purpose; while here such reliable means fail entirely. Consequently the writer in this case stands rather on weak footing in establishing the separate existence of the Upper Sambagawan. Nevertheless, the writer believes he is in the right, basing this belief on the general dissimilarity of petrographical characters of the two divisions. Other evidences in favour of his view could be produced from observations made in the Island of Sikoku if required, but the future will decide the whole question.

The task becomes still more serious when we try to fix the boundary between this and the Mikabu series, as the appearances of the rocks of both groups are in the main similar; still the microscope affords a means of discrimination.

The typical exposure of this division may been seen on the Kainita pass between Kaiya and Misawa, where the strata lie nearly horizontal with a slight dip to the east, and the serpentine dykes variously traverse the rocks without causing any considerable disturbances in the adjoining gneiss, and the latter is partially covered by the pyroxenite and amphibolite of the Ōgiri-yama. Where the Upper division fails, the spotted graphite schist of the Middle Sambagawan is directly overlaid by the Mikabu series. These conditions are clearly shown in the following profiles.

(i) Profiles.

Profile I, C D—is taken from Kaiya to Misawa for a distance of about 4 km. through the well-known pass of Kainita; the rocks exposed are in the main various types of the epidote-sericite-gneiss, i. e. the Upper Sambagawan. Just at the foot of the pass near Kaiya, a red schalstein accompanied by a siliceous slate rests unconformably upon the gneiss. This gneiss has a thin-lamellar structure and may be easily cleaved into stiff papery masses. The weathered rock presents a talcose appearance. Half-way up it is covered by a diabase-amphibolite which in turn is intruded into by dykes of a bluish-green serpentine having a shelly structure. On the western flank, the gneiss is considerably disturbed for only a short distance by two dykes of serpentine, but this serpentine by no means constitutes the normal stratified member of the Upper division. It is generally accepted by the geologists of our Geological Survey that all serpentines should form a schistose member of older schists; that is to say, they are derived from olivine-schist and the like. The writer is not able to agree wholly with them in regard to this point. The serpentine occurrences hitherto known in Chichibu always seem to point out that the rock has been derived from the diabasic, and gabbro rocks, although all serpentines in other districts may not necessarily be of like origin.

In this profile, the Upper Sambagawan is developed in its full proportions, and generally speaking, strata are horizontal with a slight dip to the east.

Profile II, EF—is taken from the region, 7 km. to the north of, and parallel to, the preceding, for an extent of about 5 km. between Sueno and Hon-nogami across the village of Fuppu. The strata all dip slightly to the east. The greater part of the section is occupied by the Middle Sambagawan, while the higher horizon is covered at two prominences by the Upper Sambagawan. The whole complex seems to have been greatly disturbed at its middle by numerous dykes of serpentine; the highest part of the pass is capped by the amphibolite of the Mikabu series. Near Sueno on the east, and Hon-nogami on the west along the Kami-Hiradani valley, the graphite-sericite-schist with large nodules is developed in its typical form.

Profile III, GH—presents exclusively the rock-groups of the Middle Sambagawan. It extends from Genda, lying to the west of the town of Kodama to Ōda, along the banks of Minaregawa, for a distance of nearly 6 km. For the study of the Middle Division, the river-banks are worthy of personal inspection in order to get an insight into the mode of arrangement, and the relations of various rock-types which insensibly pass into one another. Near the middle of the profile at Terayama (Kōchi), a serpentine dyke is found considerably disturbing the graphite-schist; at Kōchi an anticlinal fold is clearly traceable. Before the anticlinal the strike is N. 80° W. with the dip of NE; but afterwards it changes to N. 10° E. with the south-easterly dip.

Profile IV, IK—is that of the Samba-gawa, along which all the three divisions are typically represented. In the lower course of the river alternate layers of the spotted black and green schists have a slight northerly dip, while at Siosawa, the strike changes to N. 65° W., dip N.E. The piedmontite-schist layer has strike N. 65° E., dip S. W. All the layers are in the same condition up to Imogaya. After crossing the top to the Hino valley, the strike of the Upper Sambagawan becomes N.–S. with dip to the west.

Profile V, LM—is taken along the Ogawa in Akihata for a distance of 8 km. (2 ris). The rocks exposed are mainly of the Middle division with str. N.50°W., dipping gradually to S.W. Near the Kotōge in Hino, the black schist is traversed by serpentine-dykes, and higher up we encounter the Mikabu rocks which continue far into the interior of the Sanchū valley on the south.

At the north end of the profile (Todoroki), the piedmontite-rock crops out to day-light but only for a short distance, and then again disappears under the Tertiary sandstone of the Chōgonji-yama (str. W. 10° N; dip high to NE.)

Profile VI, AB—represents the section for a distance of 2 km. from Kamagata on the south-east to Ogawa on the north-west. Many instructive exposures may be observed along the winding course of the Tsuki-gawa where the Lower Sambagawan with the normal sericite-schist and piedmontite-schist is conformably overlaid by the Middle Sambagawan complex of the spotted green and spotted black schists. Between Kamagata and Simo-sato, the strike runs N. 15° E. with a gentle dip to S. E., being disturbed by two faults at the village of Tōyama. After passing the anticlinal of Simo-sato in the north-westerly direction, the strike changes to N. 70° W. with a dip to N. E., and then the schistose complex disappears under the greywacke-sandstone and Alluvium near the basin of Ogawa.

(j) Relations of the Orography and Geology of the Sambagawan Terrane.

The axiom, that mountains of older geologic dates are insignificant in their height when compared with those of younger origin, holds true also in the case of Chichibu. The district under question is circumscribed on all sides by mountain-ranges, built up of rocks of various ages, the very centre of which is an extensive geologic basin of the Pliocene-Tertiary of Ōmiya. The north-eastern rim of this caldron-like depression is formed by low hills of the ancient Sambagawan series.

In travelling along the Nakasendo railway, we may notice a very great contrast in the views of different parts. The back-ground is the tremendous escarpment of the Palæozoic hornstone of Ryōkami, while the borderland is a low chain of the Sambagawan series which is limited on the north by the two conical peaks of Mikabu, and on the south the diabasic Ōgiri-yama projects out from the surrounding hills. These heights are built up of the tuff-amphibolite of the Mikabu series which directly overlies the Sambagawan rocks. On account of its compactness of texture, the Mikabu series withstands the atmospheric agencies better than the other, and thus a marked contrast has resulted in the topography of this district.

The hydrographic basin of the Sanchū in the district of Kanra, discharges its waters by Onishi in the form of the Kannagawa; while the waters of the depression of Chichibu find their exit in a narrow channel of the Arakawa by Minano and Yorii. Both rivers run across the Sambagawan series, and no sooner do the rivers enter the region, than they assume a meandering course, being directed against the strike of this series. This district is devoid of forest, and affords only poor soils.

(k) **Massive Rocks.**

Eruptive rocks within the Sambagawan terrane make their appearance as dykes, or more frequently in the form of massive exposures; the boundary between this and the adjacent rocks has become quite indistinct owing to subsequent changes in themselves and also in their mode of occurrence; still it is beyond all reasonable doubt that the eruptive rocks came out after the formation of the Sambagawan schists, as is clearly indicated by considerable tectonic disturbances in the neighboring rocks. The above-mentioned eruptives are *gabbros* and *gabbro-diorites*, both have always an intimate connection with *serpentines*.

Of late, we are acquainted from various sources with the wide distribution of gabbros and the like in our country, and ample materials are ready at hand which can only be treated on another occasion. In the present paper the writer gives the description, for the sake of completeness, of those only which occur within the district under question.

The typical rock is the *gabbro-diorite* found along the Arakawa, on the cliff of Kosaka (Kanasaki) near the (often-mentioned) Minano village. It is a whitish-gray, hipidiomorphic-granular rock of originally massive structure, but now become more or less imperfectly schistose ("grobflaserige"). The grayish mass is speckled with dark brownish, satiny patches (sometimes an inch or more in size) of a lamellar texture. Seen under the microscope these patches consist, for the greater part, of a long, flaky, almost colourless or bluish-green variety of amphibole, a part of which has already changed into a light-green, confused mass of serpentine. The above-mentioned amphibole is ? *tremolite* ($\mathfrak{c} : \mathfrak{c} = 11° - 15°$) of the secondary origin, produced from a diallage-like, greenish-brown pyroxene, the remains of which can frequently be met with in the still fresh cores accompanied with the *dark-brown, highly pleochroic margin of the secondary, compact, basaltic hornblende* ($\mathfrak{c} : \mathfrak{c}$ — always $1° - 2°$ greater than that of the green one). The last variety of amphibole is of a very special interest.

In petrographical works on gabbros, there has been much discussion about the hornblendes which occur in connection with the augite in the gabbro rocks, whether the minerals are of the primary or secondary nature. The hornblendes are principally of 3 kinds which will now be considered—(1) the *green, fibrous, uralitic*; (2) the *compact green*; and (3) lastly, the *brown, compact hornblende* All writers seem so far in accord as to the secondary nature of the first variety ; but the second and the third have in common the *compact* texture, differing from each other only in colour, thus the appearance of both betrays the original freshness. On this account, J. H. Kloos[1] was led to say that, of the hornblende which encircle the core of the intact diallage, "die Annahme einer Umwandlung des Diallags in die compacte Hornblende scheint mir von vornherein ausgeschlossen zu sein......... Die randliche Verwachsung von Diallag und Hornblende würde als einfache Perimorphose zu deuten sein."

Lately, this question became one of paramount importance in petrography, especially in explaining the genesis of amphibole-schists and the "flasergabbros," and has already received much attention

1) Neues Jahrb. f. Mineralogie etc., III Beilage-Band, p. 32.

from various lithologists, such as G. H. Hawes,[2] R. D. Irving,[3] J. Lehmann,[4] Hj. Sjögren,[5] G. H. Williams,[6] and many others; and we are indebted specially to the last author for a detailed account[7] of the paramorphosis of pyroxene to amphibole.

Most American writers adhere, with good reason, to the view of the secondary nature of not only the green compact, but also the brown basaltic hornblende, which Kloos considers a matter of impossibility (op. cit). My study of Japanese gabbros confirms the view entertained by the American lithologists, and the following short account of the hornblendes may prove not to be entirely wanting in interest.

Our rock from Minano contains large porphyritic crystals of *diallage* which is undergoing paramorphosis. The large core is surrounded by a zone of perfectly compact hornblende; the interior boundary of this rim, i. e., the line of contact between it and the diallage-remains, is the most irregular possible. The most delicate tongues and shreds of hornblende extend from the outer rim into the diallage-substance in every direction in a most complicated manner, so that it is impossible either to describe or to portray it adequately. The diallage and hornblende, which are well distinguished by differences in colour and optical orientation, are not really separated by sharp lines of contact. They everywhere shade into one another by insensible gradations. The transition of substance is so gradual that it is not possible to detect the exact points where one begins and the other ends, even under the highest power of the microscope. Nowhere does

2) The Lithology of New Hampshire. Cf. R. D. Irving. (foot-note 3).

3) On the Paramorphic Origin of the Hornblende of the Crystalline Rocks of the North-Western States. Amer. Journ. Science, 1884. II, XXXVIII, p. 166.

4) Ueber die Entstehung der altkrystallinischen Schiefergesteine, etc. p. 190.

5) Geol. Fören. in Stockholm Förh. Cf. Neues Jahrb. f. Mineralogie, etc. 1884, I, p. 81.

6) Bulletins U. S. Geol. Survey, Vol. 4. The Gabbros and Associated Hornblende Rocks, p. 651.

7) On the Paramorphosis of Pyroxene to Hornblende in Rocks. Amer. Journ. Science, XXVIII, 1884, Oct. p. 259. et seq.

the secondary basaltic hornblende exhibit any signs of a fibrous structure. The diallage-core is traversed by fine lines due to its lamellar structure, and these lines sometimes directly proceed into the hornblende-substance. *Pl. III, fig. 1.* is drawn from the polished surface of the rock to half the natural size, and this shows how the marginal black hornblende is related to the diallage. The portion marked (a) between the core and the outer irregular zone is the spot where, when seen under the microscope, the hornblende sends out tongues and shreds of its own substance into the diallage, thus presenting the pseudo-*eutaxitic* structure. The green, compact hornblende of secondary origin is also found in connection with the brown variety, or sometimes developed independently ; and both finally resolve themselves into a fibrous confused mass after passing through an intermediate stage of tremolite.

Now, the question is at once suggested:—Why should the brown, basaltic hornblende described before have all the appearance of a fresh mineral, while the green, compact variety as well as the diallage-core itself show more or less a faded aspect? The keenest observers have hitherto passed over this point in silence. First of all, we may ask ourselves whether the fine lamellar structure present in the diallage before us has existed since the formation of the crystals, or whether it is simply a result of pressure, by the action of which the molecules composing the mineral have been enabled to rearrange themselves in a new position for the production of the polysynthetic lamellæ. Leopold von Werveke[1] thinks it not altogether impossible that these lamellæ could be produced by the influence of mechanical power from outside; but it is not yet decided whether these should be considered as a twinning structure, or only an apparent one. Anyhow, the lamellæ may be regarded as having a pathological significance resulting from the action of external force.

1) Neues Jahrb. f. Mineralogie etc., 1883, II, p. 99.

If such be the case the compact original pyroxene, as it seems to the writer, was paramorphosed to the basaltic hornblende long before the formation of the plane of parting in the former; and by that change the ferrous oxide contained in the pyroxene became in part the ferric oxide, to which the brown colour of the new hornblende appears to be in the main attributable. When once the ferric oxide had been formed, it acted as a preventive to further chemical change in the substance of the hornblende, just as in the case of an iron-rod which, when dipped into nitric acid becomes, by virtue of the thin coating of oxide formed on its surface, passive or indifferent to the acid. The process of oxidation stated above, had advanced gradually from periphery of the pyroxene, while the inner part of it remained quite intact; and at this stage mechanical forces had acted from outside producing the lamellar, polysynthetic structure, very characteristic of diallage; and at the same time lamellæ had been formed in the marginal, brown hornblende, though fewer in number. Judd[1] says; "If lamellar twinning has been already developed in a crystal, then chemical action takes place along the gliding planes in preference to the normal solution-planes." The surface of lamellæ in our diallage therefore afforded new fields for chemical processes, and the mineral ultimately resolved itself into tremolite or serpentine respectively, while the brown, compact hornblende survived the general decomposition. The above supposition is moreover strongly supported by frequent occurrences of sharply defined patches of the basaltic hornblende within tremolite and also in a confused aggregate of serpentine.

The *felspar* of the gabbro-diorite occurs in large allomorphic crystals; its appearance is quite dull, and is of a dirty grayish-white

1) "Nature" Vol. 35, No. 18, March, 1887, p. 416. The Relation between Geology and Other Mineralogical Sciences—Presidential Address to the Geologial Society at the Anniversary Meeting, February, 1887. See also Quart. Journ. Geol. Soc. XLIII.

colour. In spite of its dusky aspect, it displays very vivid, chromatic polarization-colours, uncommon in a partially decomposed felspar. The oblique extinctions upon the faces M and P take place at $-41°$ and $-29°$ to $-33°$ respectively. The positions of hyperbolas seen from M and P are just at the midway between those of hyperbolas of bytownite and anorthite. Along the fissures of the felspar, radiating tufts of stout needles may frequently be seen with vivid chromatic polarization-colours of green and violet tinges. The angle of extinction is oblique, but in no way do they ever come to total darkness; with hydrochloric acid they gelatinize without difficulty. G. H. Williams[1] seems to have found the same mineral in a gabbro of Baltimore, and the writer agrees with him in considering these tufts to be built up of a zeolite (Scolecite). A very similar gabbro-diorite was recently brought from Mine-oka, in the province of Awa. The felspar of that diorite presents exactly the same habitus as that of Chichibu. It may be well here to quote, for the sake of comparison, the result of the analysis of that felspar, which is as follows:—

SiO_2	43.59	
Al_2O_3	31.62	
Fe_2O_3	0.90	(Fe O wanting)
Ca O	17.25	
Mg O	0.27	
K_2O	trace	
Na_2O	1.78	
H_2O	4.51	
	100.42	

Sp. gr. 2.62

The crystals of *epidote* are plentiful in the felspar-substance, especially at the contact between the greenish hornblende and the

1) Bulletins of the U. S. Geological Survey, No. 28, p. 58.

felspar, formed by the mutual reaction of both minerals, the terminated ends of epidote-individuals projecting into the substance of felspar, as described by G. H. Williams.[1]

As has been already stated, a typical exposure of the gabbro-diorite is found at Kanasaki near the village of Minano, along the cliff of the Arakawa. There the rock passes insensibly into *serpentine* which occurs as dykes in the graphite-sericite-schist; and the higher part of the cliff is entirely covered by a mass of the serpentine.

The serpentine is of a bluish colour; the weathered portion of it may be easily parted in shelly masses. Under the microscope in polarized light, the whole rock appears to consist of long, divergent flakes, transmitting a gray or blue light; in short, it looks just like williamsite from Easton in Pennsylvania, although the presence of the nickel oxide in our specimen is not yet proved. Our serpentine may have probably resulted from the decomposition of secondary amphiboles, and up to the present no traces referable to the structure of the olivine-bearing variety has been discerned; the presence of olivine is, however, not absolutely denied, as it seems to be found in other serpentines occurring in the neighbouring districts.

The serpentine is very frequently met with on the southern side of the Arakawa from Nabeyama-Fuppu to the Kainita pass in a long discontinuous chain of a dyke, running from S. 20° E. to N.W. for a distance of 10 km.; and its north-western prolongations may be traced still further at Kōchi in the Minaregawa valley (see Profile III). Its mode of occurrence can be understood clearly by referring to the profiles I and II.

The serpentine rocks lend a peculiar feature to the topography of this region by their compact texture, and they stand out in prominences from the surrounding schists and gneisses. As to its economic

1) op. cit. p. 31.

uses, a small serpentine-quarry was worked until a few years ago, at Yosino-iri in Misawa, for making small ornaments; but it is now entirely abandoned.

The foregoing is only a few, short remarks on the serpentines found within the confines of the Sambagawan series; but the great majority of its occurrences fall in the succeeding or Mikabu period, where ophitic rocks occur in large detached masses within the amphibolite and pyroxenite, accompanied by a very interesting, secondary glaucophane; the treatment of these augite and hornblende rocks lies, however, beyond the scope of the present paper.

(*l*) Conclusion.

The Sambagawan is the lowest of the long geologic series ever found in the Chichibu district, covering an area of about 270 km., and occupying the north-western rim of the central depression of Chichibu. The main anticlinal axis runs from Sueno near Yorii on the south-east to Obata on the north-west, with a trend of N. 70° W. for a distance of 27 km., touching the northern side of the Sambagawa and also the upper course of the Hino valley; and along this line we really find good exposures of the Lower Division, and consequently of the piedmontite-schist. The widest portion of this Sambagawan belt is traversed on the south by the Arakawa river and on the north by the Kanna river, the strata dipping away gradually from the main axis of elevation.

The rock-complex which comes underneath, is probably mica-schist and biotite-gneiss as developed in the Island of Sikoku; but this hypothesis cannot be established until an actual contact is really ascertained; what lies directly above is a thick series of gabbro and diabasic derivatives and serpentines.

To summarize the leading features of the three divisions, the lower one consists of whitish-gray, normal sericite-schist, rich in quartz and sericite with the characteristic rutile and calcite. At the junction of the Lower and Middle divisions a very unique piedmontite-schist[1] makes its appearance, alternating with the spotted black and green schists; the two latter afterwards become the predominant rocks of the Middle division. They are the chlorite-amphibolite with white specks of felspars, and the graphite-sericite-schist with black spots of felspars, these two attaining the great thickness of 200 m. or 2/3 of the whole thickness. The characteristic accessory components are tourmaline and calcite. The Upper Sambagawan consists of a platy or papery epidote-sericite-gneiss rich in felspar, with the never-failing accessory of epidote.

The peculiarities of the Sambagawan rocks are the complete absence of the true muscovite or biotite, the abundance of sericite, the want of the microperthitic structure, the presence of tourmaline and piedmontite. No trace of organic remains has ever been detected. Anyhow, these rocks do not present many of the characteristics so common to the true crystalline schists.

The question now arises as to the real origin of these rocks. It is not altogether safe for an inexperienced student like the writer to advance any view concerning a probable mode of the formation of such rocks as sericite-gneiss, etc., especially in the face of high authorities in Europe. Still the practical lessons learned by personal observation in the field, have forced him utter to his views on the genesis of the Sambagawan rocks, whose nearest relatives are to

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1) This is for the first time we find the piedmontite occurring in such a large quantity as to entitle it to the rank of an essential ingredient of certain rocks. The nearest relative (*thulite*) of this mineral is said to have been found in an eleolite-syenite from the Serra dos Posços de Caldas in Minas Geraes, in Brazil. Its occurrence seemed, however, at first so strange that Rosenbusch was very much astonished on hearing, from Orville A. Derby, of its presence in the syenite, as may be conjectured by his affixing the sign of interrogation to *red epidote* or *thulite*. "Massige Gesteine" 2te Aufl. p. 90.

be found in the "Granulitmittelgebirge" in Saxony, also in the Taunus, and the Ardennes.

To the present writer, it seems highly probable that the whole of the Sambagawan rocks represents a dynamo-metamorphic state of originally different rock-types. The normal sericite-schist may have resulted from a coarse graywacke, while the epidote-sericite-gneiss may have been changed from a fine variety. The chlorite-amphibole-schist might have been derived from a basic tufaceous material of an eruptive rock or rocks, whereas the graphite-sericite-schist may have its origin in a carbonaceous shale.

We have rocks analogous to the Sambagawan series in the higher strata—transition-system—but with quite a dissimilar aspect. Between the Sambagawan and the Upper Carboniferous *Fusulina* limestone in Chichibu, there lies a thick complex of rocks, being made up of alternate layers of arkose graywacke-sandstone, black slate, hornstone, adinole slate, diabase sheets, diabase-tuffs, schalstein, etc.— these are now comprised under the name of the ? pre-*Carboniferous*. To the writer, the Sambagawan rocks seem not materially to differ from these, except that the former have now been changed into apparently unlike rocks. The sericite-gneiss near Döbeln in the 'Granulitgebirge' in Saxony is, according to J. Lehmann,[1] a metamorphosed graywacke. Thus the supposition, that our sericite-gneiss and sericite-schist may have resulted from a felspar-graywacke-sandstone, appears not entirely impossible, and the same may be said of the graphite-sericite-schist which was once a black carbonaceous slate.

One fact should not here be passed unnoticed; i. e. the richness of felspar in our graywacke-sandstones; indeed, that mineral makes up the great bulk of the constituents of the rock. In ordinary sandstones formed by the deposition of washed sands along the shores and river-

1) 'Entstehung der altkryst. Schiefer.' Bonn. 1884.

beds, the felspar-grains are, as a rule, scanty, since that mineral is easily decomposable, when compared with others of the sandstone-components. From this fact, our arkose graywacke seems to differ somewhat as regards its origin from common rocks of the same name. The writer is rather inclined to consider its components to have been derived from the *assorted ejectamenta* of volcanic activity which occurred during the Sambagawan epoch in the same manner as at present, or even on a grander scale. A similar deposit is now being formed along our shores, as may be seen from the samples of sand dredged up from near the Marine Biological Station of the Imperial University at Misaki at the entrance of the Bay of Tōkyō. The younger eruptives near the Station being mostly non-quartzose pyroxene andesite, the dredged samples consist only of grains of pyroxenes, and triclinic felspars, the finer particles of the ejected materials being removed by the sorting action of waves. The normal sericite-schist and epidote-sericite-gneiss already referred to might have been changed from the arkose graywacke-sandstone, the latter having been formed in the manner just described.

Again, the chlorite-amphibole-schist of the Middle Sambagawan, alternating with the graphite-sericite-schist, seems to have been changed from the unsorted, muddy, volcanic ejectamenta deposited in a shallow sea, rather than to have been the product of a crushing *in situ* of zones of the original coarse-grained rock.[1] The result of

1) Association of the gneissic and other schistose rocks with igneous masses and also the similarity of the mineral components in all have often been taken, not with full justice, as proofs, that they were originally of the same rock-variety and have even been said to form the same mass of one geologic age; and this is the current view of lithologists in the modern age of the theory of *dislocation-metamorphism* in geology. This may be partially true. But it is, however, not less reasonable to suppose that the schistose rocks might be tuffs of igneous masses occurring in the vicinity, and they are, of course, respectively most nearly related in mineral composition. The absence or presence of stratification, or *foliation-stratification* can only decide the case; but to ascertain which is really developed in individual cases is a painstaking task, and errors are apt to creep in in such an observation, giving rise sometimes to differences of view, not easily reconcilable.

such a crushing process is said to bring about the formation of an apparently bedded structure called by Bonney *pseudostromatism.*[1]

Of late, Frank Rutley,[2] after studying carefully, under the microscope, the rocks of the much discussed region of the Malvern Hills, classified them into a banded and an unbanded series, the former including the different varieties of gneiss, the latter gabbro, syenite, and diorite, etc.; and he suggested that "*the gneissic rocks of the Malvern Hills may be composed of the detritus of eruptive rocks...... he looked upon them as beds of volcanic ejectamenta.*" At present, some gneiss and schists are considered in Europe as well as in America to have resulted from the deformation of a complex mass of plutonic igneous rocks, and there is an universal inclination to exaggerate the effect of what is called pressure-metamorphism, notably so since the appearance of the work of Lehmann.[3] Rutley's view may serve as a check to this tendency. His observations accord well, on the whole, with those which the writer has made in studying the rocks of the Sambagawan series.

Lastly, as to the age nothing positive can be said. The sericite-gneiss near Döbeln, in Saxony, is said to be equivalent to the Cambrian.[4] In the south-eastern flank of that Granulite-Mountain, the epidote-amphibolite of Hainichen, very similar to that of Japan, is developed as a geologic equivalent of the northern series, which is chiefly made up of phyllite, spotted schist, sericite-gneiss and an earthy graphite-schist; that is, the southern series in part represents the Cambrian rocks. In many parts of the Alps, some of the highly crystalline schists are referred to a special facies of the Palæozoic, or even said to be equivalent to the Triassic.[5] Our

1) Anniversary Address of the President, Quart. Journ. Geol. Soc. Vol. XLII. p. 65.
2) On the Rocks of the Malvern Hills. Quart. Journ. Geol. Soc. for August, 1887. p. 508.
3) op. cit. p. 107. 4) Hermann Credner: Das sächische Granulitgebirge. p. 58.
5) v. Hauer: Geologie. p. 249. Stur: Funde von Untercarbonischen Pflanzen der Schatzlarer Schichten der Centralkette in den nordöstlichen Alpen. Jahrb. Geol. Reichsanstalt, XXXIII. p. 189.

Sambagawan series may, no doubt, be correlated with some of these European types ; it is, therefore, by no means safe to give it now a final resting place in the Archæan group, as has been already done by E. Naumann.

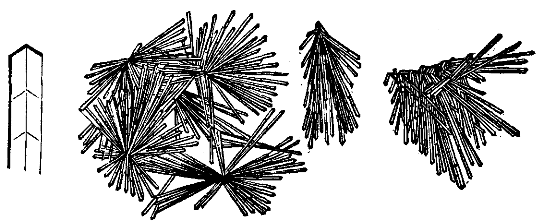
In 1885, Dr. E. Naumann, then Director of the Geological Survey of Japan, laid before the International Geological Congress in Berlin, a reconnoissance-map of the geology of Japan, in which the so-called crystalline-schist system seems to cover a considerable part of the map. But this must now be modified, as the season's works of last year in the Island of Sikoku, and in Chichibu have proved that the greater part of the so-called Archæan rocks in Japan is really represented by the Sambagawan series.

As already mentioned, the age of the Sambagawan series is still uncertain ; therefore it is advisable at present to give it a special position in the cartographical representation of the geology of Japan. With these remarks based upon microscopic and tectonic investigation, the writer concludes now the sketch of the Sambagawan series of Chichibu, by which he hopes to give some impulses to, and some bases for, further observations and studies.

I take here the opportunity of expressing my hearty thanks to Professors Dairoku Kikuchi and C. G. Knott for their kindness in undertaking a laborious and time-wasting work to see the paper through the press, and also in giving many valuable suggestions and additions. I am also largely indebted to Messrs. S. Sekino, M. Ōkawa, and H. Hirauchi for the preparation of the annexed plates. My thanks are lastly due to the Geological Survey of Japan for the free use of the topographical map.

Appendix.

Note 1.—The normal sericite-schist, accompanying the piedmontite-bearing rock, acquires now and then a coarse-lamellar structure; and in some case as that of Yanase near Yorii, a cleaved surface of such a rock shows numerous green patches of a *fuchsite*-like appearance. These patches, after being taken off with a knife-edge and mounted on the object-glass, seem, under the microscope, to consist of sericite-lamellæ, together with a large number of bundles of smaragd-green needles (0.5 mm. in length), beautifully arranged in a radial manner (see the annexed figure).



Studied more in detail, each needle is found to be provided with a median ridge, and extinction of light takes place parallel to, and at right angles with, that ridge. The pleochroism is distinct, and the deepest shade of colour is observed, when the longest extension of the needles is at right angles with the shorter diagonal of the lower nicol. Crystal-individuals are usually broken at a regular distance, and the traces of the planes of fracture meet with each other at the median ridge, making an angle of about 90°; this is probably due to the existence of a plane of cleavage or gliding upon one of the brachydomes. By the addition of a few drops of hydrochloric acid, the green crystals are seen to dissolve readily with vivid effervescence, and from this fact as well as from its form and optical properties, the mineral may be said with certainty to belong to *aragonite* (Eisenblüthe). Cf. foot-note, page 93.

Explanation of Plates II–V.

Plate II.

This plate is devoted to the illustration of some of the most characteristic structures of the rocks and also peculiar habits of the minerals composing the Sambagawan schists.

Fig. 1.—A transverse section of the *glaucophane-schist* from Ōtaki-san near the city of Tokusima, in the province of Awa, Island of Sikoku. This may serve as an admirable example of an internal flexure of schists, in which a quartz stratula of a homogeneous appearance is intercalated between thin layers built up of sericite and glaucophane. The originally horizontal and parallel bands have suffered minute foldings, simultaneous with the mass-motion of the earth's crust; and this movement has brought about the granulation of the homogeneous quartz-bands, as may be seen in the drawing, especially at the turning point of the plicature (page 85).

Fig. 2.—Brings to view, how the periphery of the felspar-nodules in the normal sericite-gneiss has grown together with the quartz grains so as to produce the *pseudo-pegmatic* structure; this figure also illustrates well the simultaneous crystallization of the quartz, and the marginal portion of the felspar (page 88).

Fig. 3.—Gives an instructive example of somewhat porphyritic felspars in a sericite-schist. Felspars are remarkably rich at their centres, in the interpositions of iron-mica, iron-glance and rutile, and are fringed with green, lamellar fibrous scales of sericite. The same interposition and trimming recur in nearly all the felspars of porphyritic habitus throughout the rocks of the Sambagawan series (page 88).

Fig. 4.—A garnet-rhombohedron found in the graphite-sericite-schist. An attempt is made to show a peculiar mode of arrangement of rutile needles within the crystal (page 91).

Fig. 5.—Is an outward appearance of a polished specimen of the typical spotted graphite-sericite-schist, drawn to natural size. A cursory glance at the figure reminds us of the "Garbenschiefer" of Saxony. The interstitial spaces are occupied by black coarsely lamellar-fibrous flakes of sericite. Through weathering, the rock acquires a brown colour, and appears just like a biotite-mica-schist of a common type. Under the microscope, the green mica reminds us of *chloritoid*, but the comparatively low grade of its hardness compels the writer rather to refer it to a green sericite-like mineral (phengite).

Fig. 6.—The flecks of the above schist are the deformed crystals of felspar, in the combination of the faces *T*, *P*, *l*, and *y*, as shown in the figure. The individuals of the felspar lie parallel with the vertical axis to the plane of the schistosity of the rocks. The plane of the basal cleavage shows a pearly lustre; and a few traces of the cleavage apparently parallel to the clinopinacoid are also discernible (page 97).

Fig. 7.—An irregularly outlined crystal of the felspar-dots already referred to in *fig. 5.* The figure brings to view a most peculiar fluidal arrangement of coaly dust; the clear external zone seems to be formed by the *secondary enlargement* of the felspar (page 97).

Fig. 8.—The most common type of the crystals of tourmalines found in the graphite-sericite-schist, showing the acute, deeply coloured pole at one end, while the obtuse termination is of a lighter shade (page 100).

Fig. 9, a.—Represents a case of the parallel growth of two tourmaline-crystals, and *Fig. 9*, *b* an isomorphic layer-structure (page 100).

Fig. 10.—A general appearance of a polished specimen of the spotted green schist, showing numerous "eyes" of felspar (page 100). Drawn to natural size.

Fig. 11.—Crystalloids of epidote in the spotted green schist. Forms are various, some are heart-shaped, while others are almost elliptical. Asymmetry is the prevalent character of these twinned crystalloids. They are exceedingly minute in size and appear under weak powers as colourless dots, rich within the felspar "eyes" and in the general mass of the rock (page 104).

Fig. 12.—Crystals of titanite showing the predominating rhombic character of their crystal-faces (page 105).

Plate III & IV.

In Plates III and IV, an attempt is made to illustrate by means of six profiles the general stratigraphic arrangement of the three divisions of the Sambagawan series, together with the intruded masses of serpentines and the overlying clasto-pyroxenite and clasto-amphibolite complexes of the Mikabu series. The sections are made in various directions, and nearly at equidistant points, and they all give similar profiles, so the general result arrived at as to the stratigraphic order may be considered approximately correct. The genuine crystalline schists and gneisses have so far not yet been observed in this region. Details are given in the chapter on "Profiles" pp. 119 et seq., so that it is not necessary here to append further explanatory remarks.

A few words, however, need be said in regards to *fig. 1*, *Pl. IV*. This is drawn from a polished specimen of an altered gabbro from Minano. The white parts traversed by irregular fissures represent a dull, grayish-white felspar, probably *bytownite;* while the dark-shaded portion gives an approximate idea of the appearance of the paramorphosed portion of the diallage into amphibole. The lightly shaded part (*a* in the figure) is that portion where, when seen under the microscope, the hornblende sends out tongues and shreds of its own substance into the diallage.

Plate V.

The map (as a basis for which the "Middle Section" of the reconnoissance map of topography of Japan, recently published by the Geological Survey has been used) giving the area occupied by the rocks of the Lower, Middle, and Upper Sambagawan, together with the intrusive masses of gabbros, gabbro-diorites and serpentines. The line OP indicates the main axis of the anticlinal ; while those drawn across the Sambagawan belt signify the position of the profiles given in Plates III and IV.

Abbreviations of Geographical Names.

Ki.	= Kita	means	north	as	Ki.-Kaura.
Mi.	= Minami	,,	south	,,	Mi.-Kanra.
Ni.	= Nishi	,,	west	,,	Ni.-Tama.
Hi.	= Higashi	,,	east	,,	Hi.-Ōno.
Y.	= Yama	,,	mount or mountain	,,	Mikuni Y.
S.	= San	,,	,,	,,	Mitsumine S.
K. or g.	= Kawa or gawa	,,	river	,,	Tone-g.

Contents.

Fig. 1.

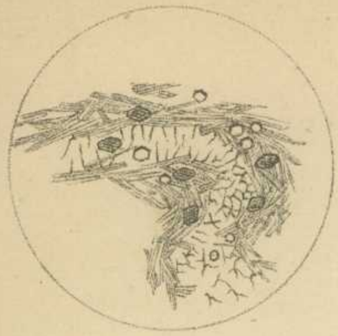
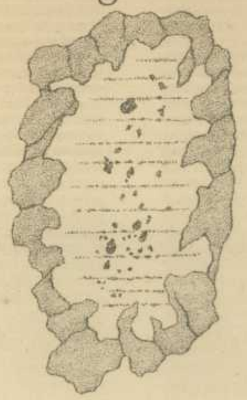


Fig. 2.



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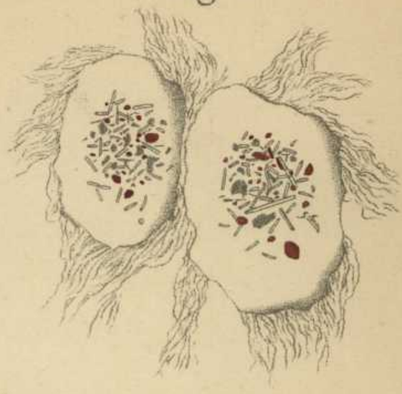


Fig. 4.

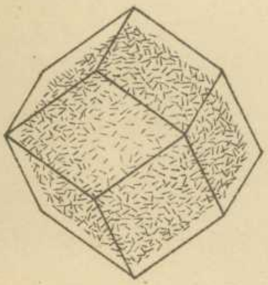


Fig. 5.

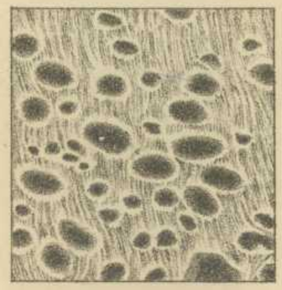


Fig. 6.

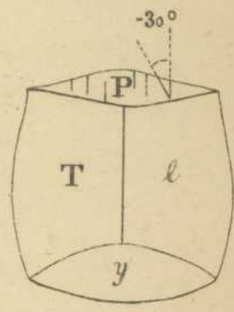


Fig. 7.

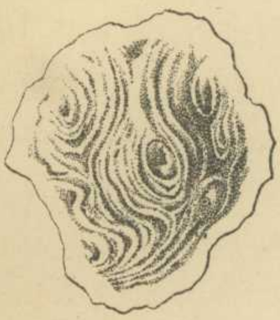


Fig. 8.

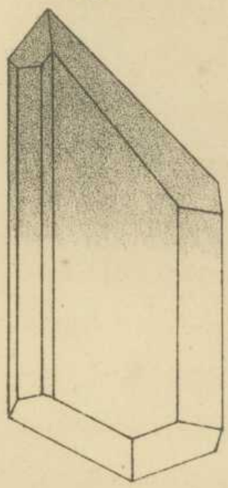


Fig. 9.

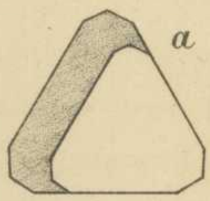


Fig. 9.

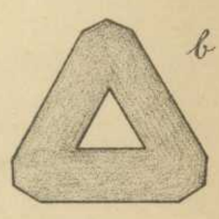


Fig 12.

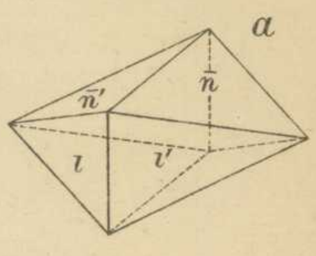


Fig. 10.

Fig. 11.

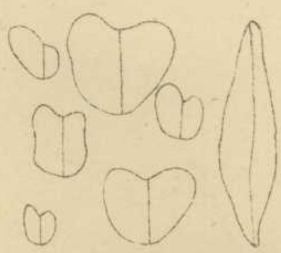
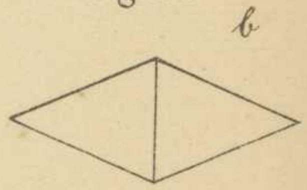
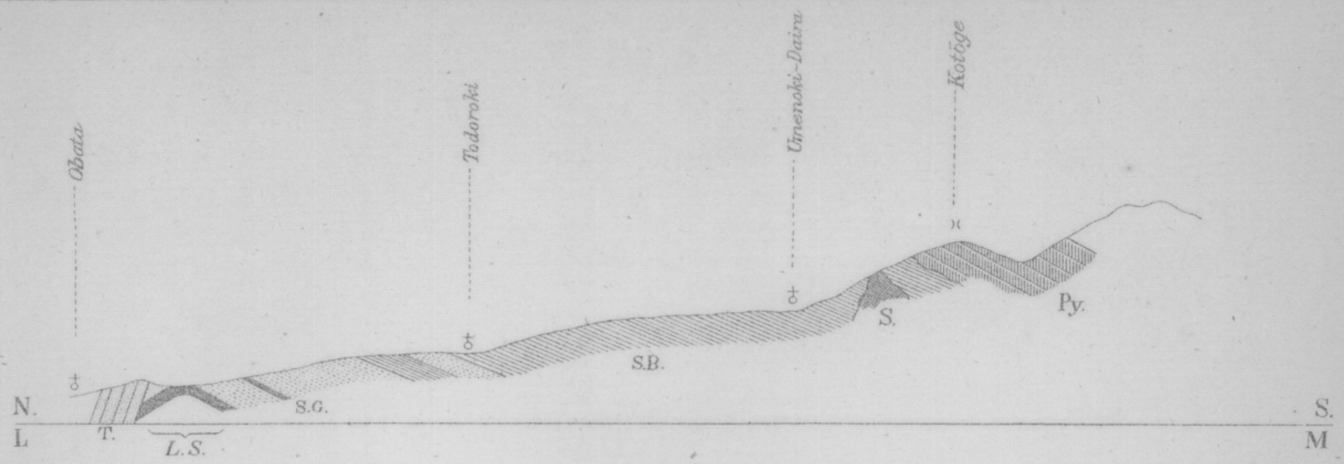


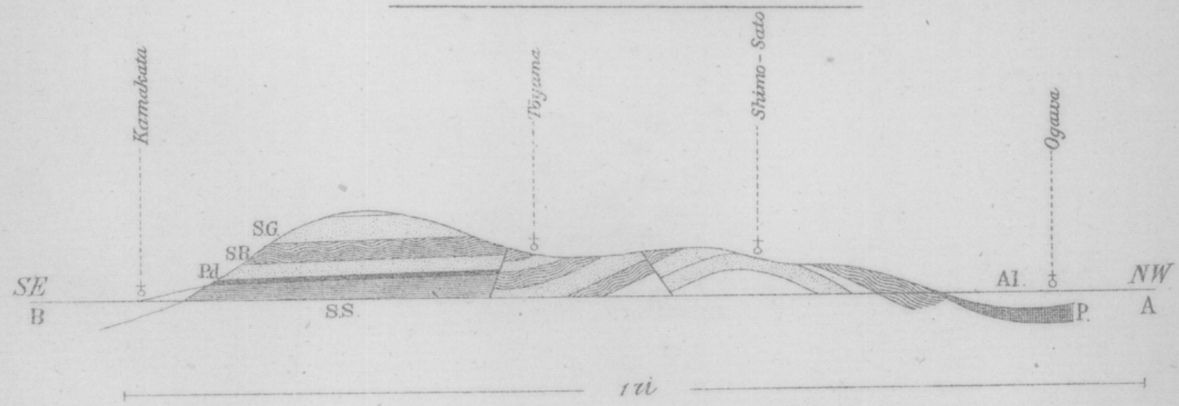
Fig. 12.



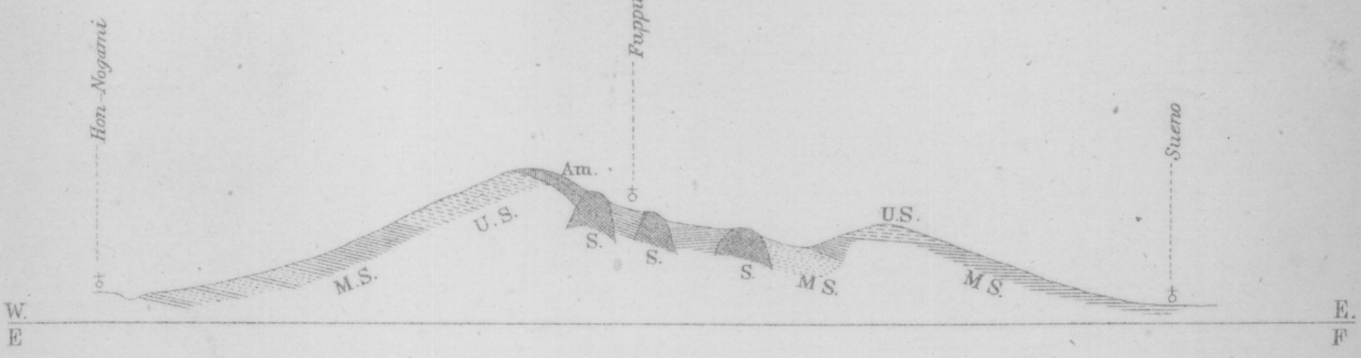
Hirauchi del.



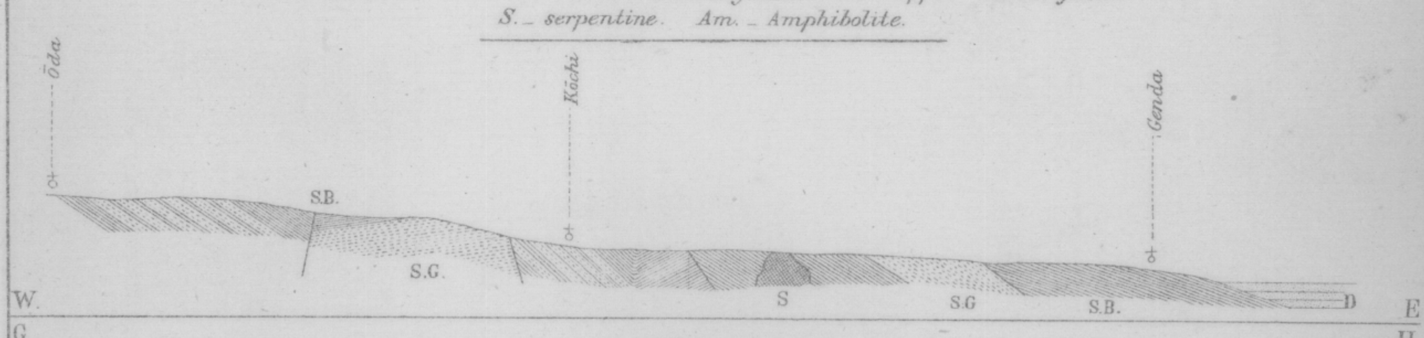
Profile V. _ T. _ Tertiary L.S. _ lower Sambagawan SG. _ spotted green schist.
S.B. _ spotted black schist. S. _ serpentine Py. pyroxenite.



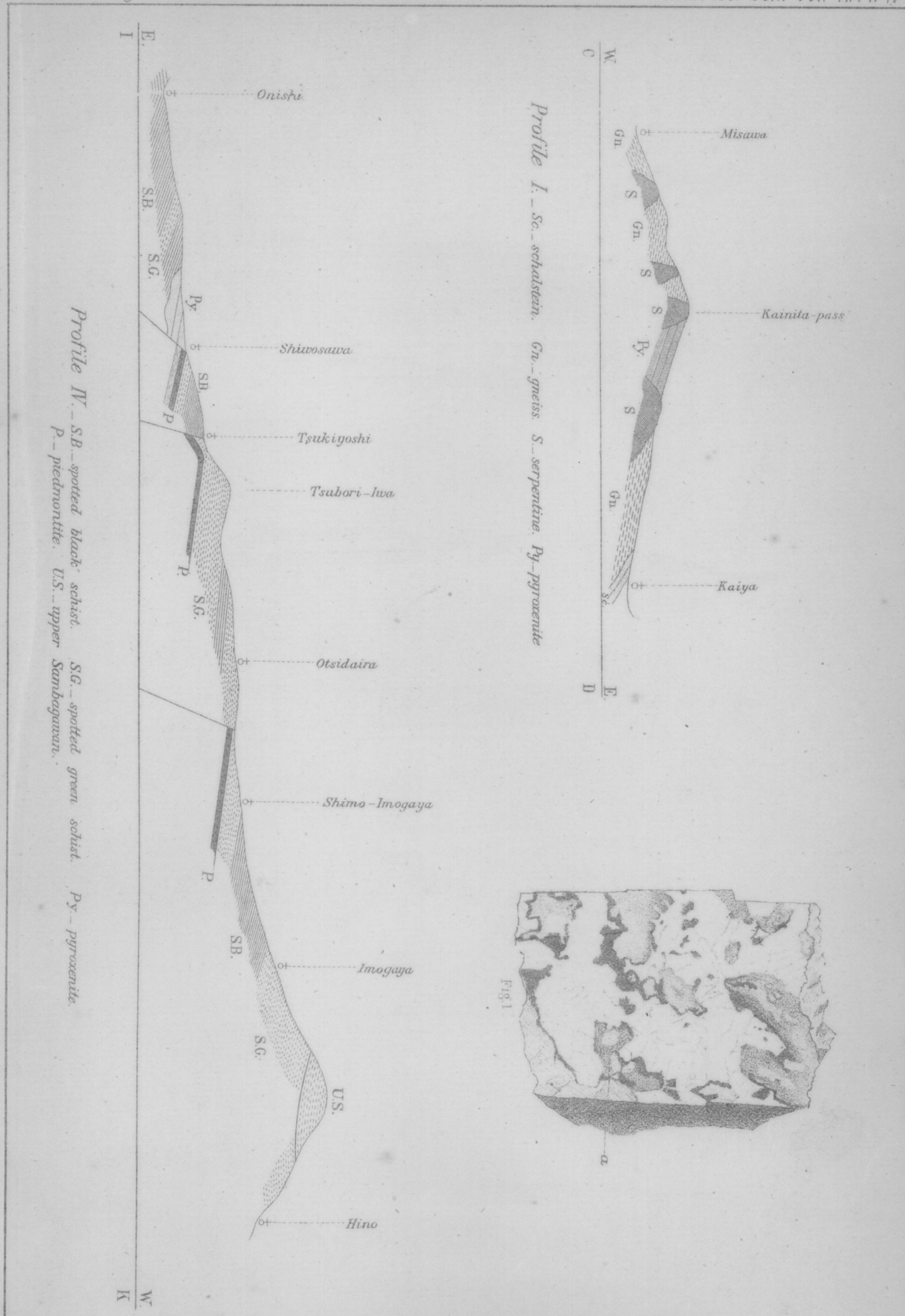
Profile VI. S.S. _ sericite - schist. Pd. _ piedmontite - schist
SG. _ spotted green schist S.B. _ spotted black schist
P. _ Palæozoic. Al. _ Alluvium.

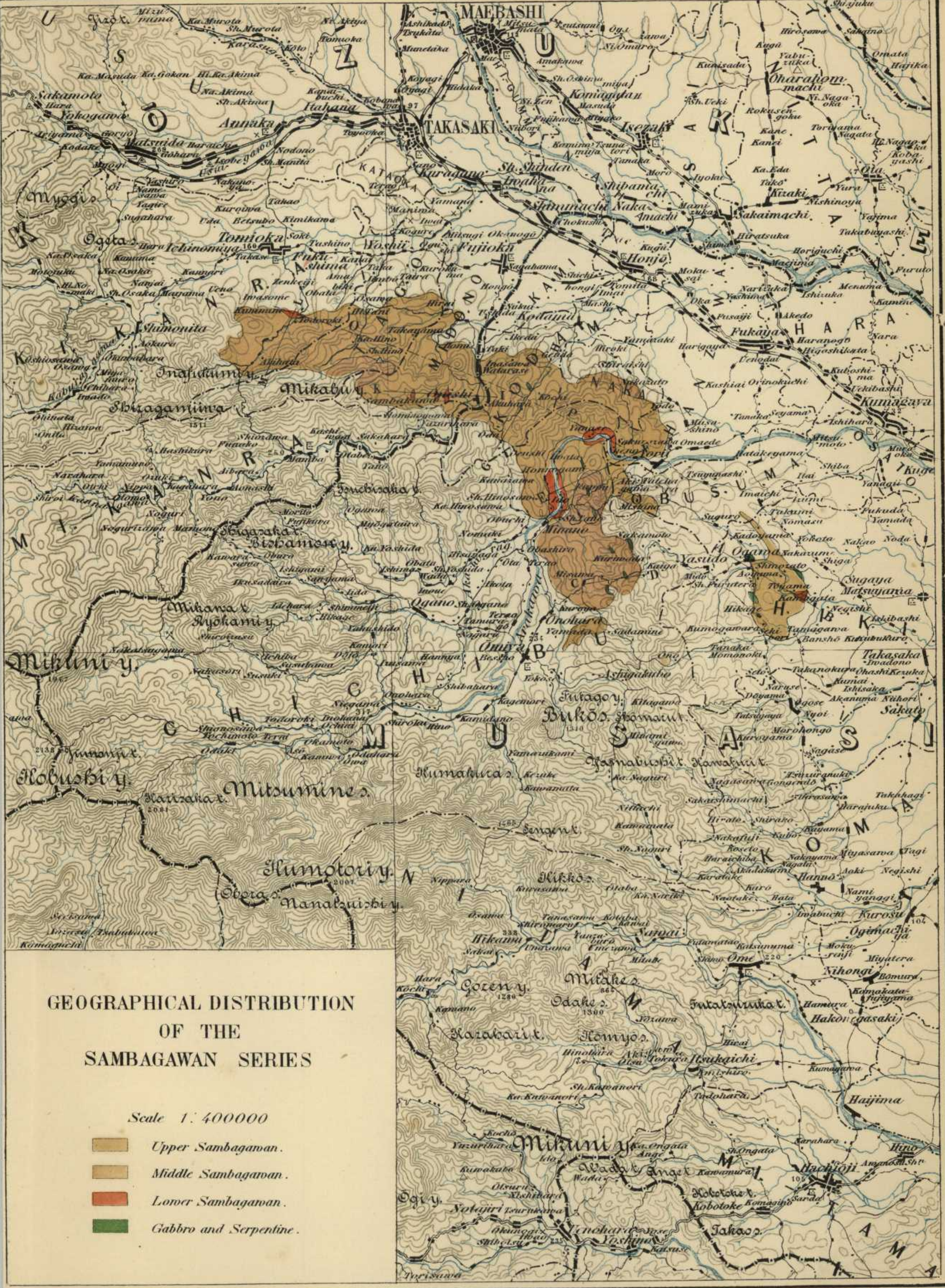


Profile II. _ M.S. _ middle Sambagawan U.S. _ upper Sambagawan.
S. _ serpentine. Am. _ Amphibolite.



Profile III. _ SB. _ spotted black schist. SG. _ spotted green schist.
S. _ serpentine. D. _ diluvium.


W.
C
E.
D
Misawa
Kainita-pass
Kaiya
Gn.
S
Py.
Sc.
Profile I. – Sc. – schalstein. Gn. – gneiss. S. – serpentine. Py. – pyroxenite
E.
I
W.
K
Onishi
Shiwosawa
Tsukiyoshi
Tsubori-Iwa
Otsidaira
Shimo-Imogaya
Imogaya
Hino
S.B.
S.G.
Py.
P.
U.S.
Profile IV. – S.B. – spotted black schist. S.G. – spotted green schist. Py. – pyroxenite.
P. – piedmontite. U.S. – upper Sambagawan.
Fig. 1
a


GEOGRAPHICAL DISTRIBUTION
OF THE
SAMBAGAWAN SERIES
Scale 1: 400000
Upper Sambagawan.
Middle Sambagawan.
Lower Sambagawan.
Gabbro and Serpentine.
139°
36°
MAEBASHI
TAKASAKI
Annaka
Tomioka
Fujioka
Honjo
Fukaya
Kumagaya
Kodama
Onishi
Yorii
Ogawa
Matsuyama
Ogano
Omiya
Mikabu y.
Mitsumine s.
Bukōs.
Hanno
Ome
Hachiōji
Itsukaichi
Mikuni y.
Tōkyō