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MICROSCOPIC PETROGRAPHY

OF THE

Drift of Central Ontario.

BY

A. P. COLEMAN, PH.D.,

COBOURG, ONTARIO.

[*Trans. Roy. Soc. Canada.*]

VII.—*Microscopic Petrography of the Drift of Central Ontario.*

By A. P. COLEMAN.

(Communicated by Dr. T. S. Hunt, May 25, 1887.)

Microscopic petrography is being so eagerly studied, and affords such interesting results in all lands at the present day, that no apology is necessary for the present contribution toward a subject hitherto but little cultivated in Canada. Where so much of the region is petrographically *terra incognita*, perhaps no better beginning could be made than with the materials so profusely supplied by the drift of Ontario, which offers specimens of an immense variety of rocks derived from various distances to the north and east, and especially representing the Laurentian region. By way of foundation, and for the sake of comparison with the results brought out by the masterly works of Rosenbusch, Zirkel, von Lasaulx, and a host of other enthusiastic students of this most recent of the sciences, a somewhat comprehensive discussion of the microscopic characters of our rocks may be permitted; so that much that is well known will be briefly sketched, while special attention will be paid to features that appear to be new or unusual. It should be stated that the specimens examined have been collected at various points in Central Ontario, but chiefly in the vicinity of Cobourg; and it may be added that the merely mechanical work of preparing the 150 rock sections required has been by no means inconsiderable.

I.—GENERAL DESCRIPTION OF THE DRIFT.

As exposed along water-courses and lake shores, the drift is seen to consist of clay, sand, gravel and boulders, the finer materials often laminated, sometimes obliquely, with a false bedding resulting from the action of shifting currents. In other cases there is no stratification, and clay, sand and gravel, with intermixed boulders, lie pell-mell where dropped by the melting of ice. The underlying Silurian limestone is polished and striated, the striations near Cobourg running nearly east and west (S. 80° or 85° E., magnetic), with the thrust from the east. "Soled" boulders with one or more flat striated surfaces shew the tools with which the work was done.

Sands.—Examined with the microscope, the sands prove to contain, in addition to sharp-edged particles of quartz, a large amount of calcareous matter and small fragments of plagioclase, perhaps, also, orthoclase and green or brown hornblende—shewing their origin in the massive and schistose rocks.

Gravel.—Imbedded in the sand and clay, or forming independent strata, are subangular or rounded pebbles, more than half of them limestone, the rest of various Laurentian rocks. The shape of the pebbles is determined by the cleavage of the parent rock, massive rocks giving pebbles with their various diameters not far from equal, while laminated or schistose rocks afford flattened ovoid forms.

Boulders.—The boulders are of all kinds and sizes, from larger pebbles to masses of several tons, which the farmer must blast or undermine and bury to get rid of them from his fields. They are usually more or less rounded, and are very unequally distributed. More than half of the smaller boulders are of Lower Silurian limestone, with the usual fossils, and sometimes nodules of chert, which is not found in Silurian outcrops near Cobourg.

No further notice of the common limestones of the drift, or of the other clastic rocks, such as slate or sandstone, which are very rare, will be necessary in this paper, which will be devoted to the crystalline rocks. The crystalline limestones will be referred to briefly first, and afterward the massive and schistose rocks will be treated more at length.

II.—Crystalline Limestones and Dolomites.

Macroscopic.—These rocks vary in grain from very coarse to compact, and in color from the pure white of saccharine marble to yellowish and bluish greys. They shew no traces of fossils, but yet are more or less evidently stratified, and no doubt are metamorphosed sediments.

Microscopic.—Under the microscope they are found to consist, of course, of calcite or dolomite, more or less pure, and present the usual rhombohedral cleavage and dull colors with polarised light. As accessory minerals, quartz is the commonest, and may be present to the extent even of one-third, while biotite sometimes occurs in so large an amount as almost to form a calcite schist. In addition, pyrite, muscovite and hornblende are found sparingly. Tremolite and actinolite, or intermediate varieties of hornblende, make up an important part of the rock in a few cases, the tremolite in grey radiating prisms, and the actinolite as handsome sea-green prisms. In one such specimen there are portions of quartz containing fluid cavities and cubes of salt.

It is perhaps worthy of mention that, in one specimen, the outer layer of calcite proved to be pierced by a network of the rhizoids of lichens. The boring power of these delicate thread-like cells is remarkable, and must depend on the presence of carbonic or some organic acid dissolved in the cell sap.

III.—Chalcedony.

A few small masses of chalcedony are found in the drift, derived probably from veins. One specimen is of a pale turquoise blue, fading on exposure, and contains scales of talc and small fragments of other minerals; while a second specimen is so impregnated with yellow oxide of iron as to approach jasper.

Microscopic.—Thin sections display with polarised light the usual microcrystalline structure, varied by radially fibrous parts in which a black cross may be seen.

IV.—Massive and Schistose Rocks.

In the treatment of these rocks, the line between massive and schistose cannot be drawn so closely as in the study of rocks *in situ*, where the broad structural lines are easily seen. Rocks which, on the small scale of a boulder, shew no trace of parallelism in their constituents, will be considered "massive"; but in the case of the granites and gneisses, where most of the difficulty occurs, the distinction is perhaps not vital; since, in many places, as, for instance, in the Thousand Islands, the two seem to run into one another.

In general, for the massive rocks, the arrangement of Rosenbusch[1] will be followed, while, for the schistose rocks von Lasaulx[2] will be taken as guide.

These rocks may be divided broadly into an acid and a basic series, and we shall commence with the acid series, which is characterised by the presence of one or more species of potassium felspar. It may be subdivided into a subseries containing quartz as an essential mineral, and a subseries devoid of quartz, or nearly so.

ACID SERIES.

A.

MASSIVE.

(1.) Those containing Quartz.

The Granites.

The admirable description of the granites and their constituent minerals given by Rosenbusch[3] holds for the most part when applied to the granites of the drift of Ontario, though one exception should be made in the case of orthoclase, which Rosenbusch makes an essential element, while in some of our granites it is almost wholly replaced by a triclinic orthoclase felspar, microcline.

We shall define granite as "a rock composed chiefly of quartz, orthoclase or microcline, and some sodium-calcium-felspar, with more or less biotite, muscovite or hornblende." Taking up the minerals in this order, we have:—

Quartz.—This never shews crystalline faces, so far as my observations go, but always forms irregular masses and fragments, consisting, as shewn by polarised light, sometimes of but one individual, sometimes of a number clustered together. It is always fresh and transparent, unless rendered turbid by cavities and inclusions, which are often very numerous. The cavities may contain a liquid (water or carbonic acid), a moving bubble, and often also a cube of salt. Solid inclusions of various kinds also occur, slender and hair-like, or interrupted like telegraphic characters, or cut up into rows of dots, or scattered as dusty particles. Hexagonal plates of a drab color, partly covered with red oxide

[1] Mikroskopische Physiographie der massigen Gesteine, 1878.
[2] Einführung in die Gesteinslehre, 1886.
[3] Mikros. Phys. der mas. Gest., pp. 7, etc.

of iron, are sometimes numerous, and slender, transparent prisms of apatite; in fact, almost all of the substances mentioned by Zirkel,[1] Hussak and others.

Orthoclase.—Of the felspars orthoclase may be described first, though in our rocks microline is usually more abundant. It is one of the least satisfactory minerals to diagnose, since its crystalline form is rarely evident, and the cleavage angles of 90°, so distinctive for macroscopic determinations, are seldom seen in microscopic sections, and in general the characters of the mineral are negative. When badly weathered, one is often in doubt whether a given felspar is not a plagioclase, in which the striations have been obliterated. The orthoclase is generally flesh-colored or red, probably from the separation of ferric oxide, though this is not always evident under the microscope. Near fissures, where, from the decay of plants, organic matter is present in solution, deoxidation sometimes takes place, and the rock is bleached grey. Inclusions similar to those of quartz are found, though in smaller numbers as a rule. Cavities containing a liquid have not been certainly observed by me in orthoclase from from the drift.

Microperthite.—By far the most common inclusions in orthoclase are thin lamellæ of a transparent mineral, differing optically from orthoclase, and described by Hussak and others as albite. These lamellæ are arranged in a roughly parallel way, and in cross-section remind one of a shoal of slender fish. They do not swarm equally in all parts of the crystal, but vary much in numbers as well as in size. This variety of orthoclase (microperthite) is very common. In a few instances combinations of orthoclase and plagioclase of a different kind occur, in which an individual of each penetrates the other, so that in polarised light an intermingling of cloudy patches, with twin striations and without, may be seen. (Plate II, fig. 4.)

Microcline.—A triclinic form of the potassium felspar, microline, is rarely absent from the drift granites examined by me, and in many cases it surpasses orthoclase in amount. The difference between the two is best brought out by polarised light. Moderately thick sections present the most gorgeously colored tartan pattern imaginable, in which scarlet and orange and blue are mixed in an extraordinary way. The imperfect twin lamellæ, which are supposed to give this structure, cross nearly at right angles, and are sometimes woven as warp and woof into a singular cloth-like texture, though generally more loosely put together. Sometimes the structure described is distinct at the edges, but fades out to a uniform color in the middle, reminding one of the effects of strain in modifying the optical properties of bodies. (Plate I, fig. 3.) Microline is very apt to contain the inclusions previously mentioned as forming microperthite. Micropegmatite, a regular intergrowth of orthoclase or microcline with quartz, is seen in a few of the sections. All these varieties of felspar are very apt to weather, usually becoming turbid from the formation of kaolin, while in other cases a dirty, yellowish green substance of a fibrous nature forms along the cleavage lines and fills patches of the crystal. Epidote in pale yellowish, faintly dichroic, grains or crystals is frequently found as a product of the decomposition of orthoclase.

Plagioclase Proper.—The sodium-calcium felspars are more variable in amount than the the potassium felspars, and, when not too much weathered, are readily distinguished by

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[1] Zirkel, Mikr. Besch. der Mineralien und Gesteine, 1873, pp. 64, etc.; Rosenbusch, Mikr. Phys. der petrographisch-wichtigen Mineraliēn, 1873, pp. 222, etc.; Eugen Hussak, Gesteinbildenden Mineralien, 1885, pp. 105, etc.

their polysynthetic structure, which is well brought out by polarised light. The twin lamellæ are often developed in two directions nearly perpendicular to one another, forming a cross-barred structure quite unlike that of microcline. The general habit, inclusions and decomposition products of the plagioclases are very much like those of the potassium felspar, and need no special notice. No attempt has been made in this investigation to divide up the plagioclases of the acid rocks into subspecies.

Biotite.—Of the basic silicates biotite is the commonest, though closely followed by hornblende. This mica is usually brown, though sometimes green, and in sections not parallel to the chief basal cleavage is known by its enormous absorption when its cleavage is parallel to the section of the lower nicol, the upper nicol having been removed. The optical axes, which are seen in basal sections, usually include so small an angle as to give the idea of a hexagonal mineral, though sections of a hexagonal outline are rare in the granites. Except small brown or black scales wedged in between the cleavage lamellæ, inclusions are uncommon. Biotite appears to weather to a confused fibrous substance of greenish or brownish color, with oxides of iron. In one case fragments appear to be included in epidote, as though remnants of metamorphosed crystals.

Muscovite is much rarer than biotite, and from its colorlessness or faint color, and hence want of dichroism, is less obvious under the microscope. A peculiar *moiré* lustre in polarised light is characteristic.[1] In habit it is much like biotite, with which it is frequently found intergrown. In some instances the muscovite seems to have originated by the decomposition of potassium felspar, as shewn by its position within orthoclase crystals.

Hornblende.—This often accompanies or replaces biotite, and is readily known by its cleavage and optical properties. It is usually green, but sometimes brown, with strong pleochroism. It often weathers to dirty greenish or brownish chloritic substances, with the separation of magnetite or other oxides of iron. In one specimen it has changed to pale greenish epidote, which forms a perfect pseudomorph, with the exception of an unchanged remnant of hornblende in the centre. In one section small fibres of glaucophane occur, having intense pleochroism (indigo blue, drab, colorless).

Accessory minerals are numerous, such as magnetite, which occurs with rectangular cross-sections or in irregular grains. In some cases the magnetite is probably of primary origin; in others it is formed, often with brown or red oxides of iron as well, by the decomposition of hornblende or other minerals rich in iron. It is occasionally titaniferous, as shewn by an aureole of greyish leucoxene. Titanite also occurs in brown slightly dichroic cross-sections of the usual sharpened oval shape. Apatite is very common, but in minute amounts. Its slender needles must have been the earliest crystallisations, since they transfix the other minerals impartially. Pyrite and other metallic sulphides are occasionally found in disseminated grains or crystals. As products of decomposition we find secondary quartz, epidote, various serpentinous and chloritic minerals, oxides of iron and (rarely) calcite.

The varieties of granite so lucidly described by Rosenbusch[2] are found in our drift:—

Biotite-hornblende-granites are commonest.

Hornblende-granites, mica being replaced by hornblende, come next in frequency.

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[1] Von Lasaulx, Einf. in die Gesteinslehre, p. 52.

[2] Mikr. Phys., pp. 18, etc.

Muscovite-granites are uncommon.

Granite Proper, consisting of quartz, orthoclase, plagioclase, biotite and muscovite, seems rarest of all.

Our granites vary in grain from rocks with the individual minerals an inch or more in diameter to very fine-grained ones; and in color from flesh-red, which is common, to light or dark grey, or even light greenish grey, the prevailing felspar usually giving the tone. In relative amounts of their ingredients, also, they differ very much, some of the muscovite granites, as observed by Rosenbusch in Europe, being very rich in quartz, while biotite-hornblende-granites, by increase of these two minerals and diminution of quartz, form a transition toward syenite. In a few pegmatitic specimens mica is almost wanting.

Felsite.

Macroscopic.—Quartz porphyries seem to be unrepresented in the drift of this region, unless by a few felsites. These are massive and compact flesh-coloured rocks in which a few quartz blebs and crystals of orthoclase and plagioclase may be recognised with a lens or the naked eye.

Microscopic.—The bulk of the rock is composed of a micrograņitic magma of quartz and felspar, or else a microfelsitic one, giving a wandering play of light and shade between crossed nicols without distinguishable minerals. The minerals found in these rocks are the same as those of the granites, but generally differing in habitus. No cavities have been observed in the quartz of the magma, though these are common in the porphyritic blebs, and then contain a liquid with a moving bubble and often a cube of salt. In one section a plagioclase crystal has a portion broken out and shifted a little to one side, indicating motion after the formation of this crystal and before the solidification of the magma. No glass or other istropic substance was observed.

(2.) Massive rocks free from Quartz or nearly so.

Syenite.

This rock is comparatively rare in our drift, and the specimens examined all belong to the biotite-syenites of Rosenbusch. They are coarse or medium grained, reddish or reddish grey in color, and are composed of orthoclase, microcline and ordinary plagioclase, with much biotite and a little hornblende. Apatite, magnetite and titanite occur as secondary minerals. The descriptions of the constituents of the granites apply fully to those of syenite.

B.

SCHISTOSE.

The acid schistose rocks regularly contain quartz, so that the subdivision "free from quartz," which would correspond to the syenites among the massive rocks, is absent. To this rule a solitary exception has been found in a single specimen of felspar rock in which quartz was wanting.

Gneiss.

Gneiss differs from granite only in the parallelism of some of its constituents, generally the mica and hornblende, but sometimes also the quartz. When indistinctly schistose, it is often indistinguishable from granite when occurring as boulders. Gneiss is probably the commonest material of our boulders, with the exception of limestone, but needs no special description, since almost everything said of granite applies here also. To the varieties described under the head of granites we may add two more for the gneisses, garnetiferous gneiss and tourmaline gneiss.

Garnetiferous Gneiss contains flesh-coloured garnet in so great an amount as to be no longer an accessory mineral. The garnets generally accompany hornblende and seem partially to replace orthoclase in a few cases. In one specimen from Bowmanville the crystals of garnet are sometimes as much as an inch in diameter, but are far from handsome.

Tourmaline Gneiss.—In a few instances black tourmaline (schorl) replaces the mica, having its nine-sided prisms arranged with their longer axes all in the same direction. The dichroism (light brown and black) is very characteristic.

The gneisses vary exceedingly in structure, some being scarcely at all schistose and others almost as much so as mica schist. Some are porphyritic (orthoclase porphyroide) and contain large felspar crystals, often Carlsbad twins. The *augengneiss* structure prevails now and then, large individuals or masses of felspar of a lenticular shape wedging apart the ordinary schistose layers.

Of Clastic Origin.—A few specimens give hints of a clastic origin in the granular look of the quartz; and one small boulder coming from Marmora is very evidently clastic, since it contains large, well rounded pebbles of quartzite and gneiss, recalling the *augen* mentioned before. The layers of true gneissic quartz, felspar and mica, adjust themselves in quite the same way as around the *augen*.

Hälleflinta.

By a diminution of the grain, so that the individual minerals are undistinguishable by the eye, gneiss may pass into hälleflintas, compact rocks shewing traces of schistose structure or evidences of stratification in layers of slightly varying color. The hälleflintas have the same relation to gneiss that felsite bears to granite. Where there is a tendency to the separation of larger masses or crystals of quartz and felspar they approach the group of orthoclase porphyroides; but true porphyroides seem scarcely to occur in our drift.

Macroscopic.—These rocks are in general flesh-coloured or reddish grey and exceedingly hard. They form a considerable part of the smaller boulders.

Microscopic.—Under the microscope their structure is either that of a micro-gneiss or resembles that of felsite but usually with great variations in the grain. When the minerals can be distinguished, they appear to be quartz, orthoclase or a little microline and plagioclase. Magnetite also is almost constantly found. A little biotite, muscovite or hornblende may occur also, but not at all with the constancy of these minerals in gneiss. As accessory minerals we may mention garnet occurring as minute but perfectly formed rhombic dodecahedra, black tourmaline which occurs in one specimen as tiny prisms, and pyrite. Except in porphyritic blebs of quartz, no fluid cavities were observed in the hälleflintas. These obscure rocks vary much in composition, and transitional forms connecting them with gneiss and felsite are easily found. Some specimens, containing minute particles of hornblende in large numbers and but little felspar, are hard to separate from the compact varieties of hornblendic schist.

Felspar Rock.

A specimen of pale flesh-colored rock, consisting of plagioclase and probably orthoclase, with scarcely anything else, may be mentioned here, as the rock seems schistose. The felspar individuals are ill defined and badly weathered to a granular substance of doubtful nature.

The other schistose rocks, such as mica schist, quartzite, etc., have not been observed by me in the drift of this region.

BASIC SERIES.

A.

MASSIVE.

The rocks are characterised by the presence of a plagioclase other than microcline and hornblende or augite, almost invariably accompanied by magnetite or titanic iron ore.

The massive rocks of the series may be divided into diorites, containing hornblende or biotite as an essential mineral; and diabases and gabbros, in which hornblende is mainly or wholly replaced by some species of augite.

The Diorites.

Most of these rocks are badly weathered, so that their constituents are not easy to determine. Some specimens collected as diorites have proved to be diorite-schists on the one hand, or diabases on the other, so that the group appears to be comparatively small.

Macroscopic.—These rocks are in general medium grained, rarely coarse, and of a dark green-grey color.

Microscopic.—Quartz is found occasionally, but not in sufficient quantities to constitute it an essential mineral. Secondary quartz is more common than primary.

Felspar.—It is doubtful if orthoclase is present, but if so, only in small quantities, and microcline has not been observed. On the other hand, the ordinary plagioclases make up a considerable portion of the rock. They are usually turbid and much weathered. The variety seems to vary much, the angle of extinction from the twin plane ranging from 3° to 20°. This would indicate oligoclase and labradorite with intermediate varieties. Two systems of twin lamellæ are commonly found, inclined to one another at an angle of about 86°.

In some of the felspars (probably plagioclase), the centre of the crystals differs from the margin in its angle of extinction, the light or shade beginning in the centre and flowing wave-like to the circumference on revolution between crossed nicols. This probably results from a vague zonal structure, the centre differing chemically from the exterior.

Hornblende.—In the specimens examined, this mineral is generally in tolerably compact crystalline masses. It is highly pleochroic, changing from blue-green or brownish-green to yellow or yellowish-green. Occasional twins are seen, having the orthopinacoid as twin plane.

Biotite.—A little biotite usually occurs, generally brown or dark green, sometimes with parallel plates of light grass-green mica on the outside, perhaps a result of weathering.

Magnetite is uniformly present, unless replaced by titanic iron ore or ilmenite with a wide rim of leucoxene. Titanite is sometimes found, and in a few cases, augite is suspected. Epidote and other decomposition products of the felspar and hornblende are of course very often met.

With few exceptions, the drift rocks of this group belong to the diorites proper. In one specimen, however, the biotite is important enough in amount to warrant us in setting off the rock as biotite-diorite. Another may be named diorite-porphyrite, since reddish and greenish plagioclase crystals are thickly disseminated through a dark green magma, consisting of minute strips of plagioclase and hornblende, with grains of magnetite. This rock is decidedly handsome.

Diabase.

The rocks in which some species of augite is an essential ingredient are not very numerous in the drift, but are interesting from the variety of minerals they contain.

Macroscopic.—These are generally rather coarse-grained rocks, differing from the diorites in having a darker, often purplish, grey colour, and in wanting the light-colored felspars, which are apt to give a spotted look to the latter when weathered.

Microscopic.—Quartz is rare in the drift diabases, having been found with certainty in only two of the sections examined. Orthoclase is found, more or less doubtfully, it is true, in about half the sections studied, but in small amounts.

Plagioclases.—These are found in considerable quantities in almost all sections. The twin structure is characteristic, and there are frequently two systems of striations crossing at an angle of 86°. In addition to this Carlsbad twins are sometimes found.

In composition they appear to belong chiefly to the varieties rich in calcium. The angle of extinction on each side of the twin plane was found in a few cases to be about 7°, corresponding to andesine. It was generally, however, in the neighborhood of 19°. In a few crystals, where the angle could be read for both sets of twins 24½° and 31° or 32° were observed, indicating labradorite.

Most of the larger crystals are rendered more or less greyish by innumerable fine dots and minute dashes, often arranged in rows, sometimes so as to look curiously like the short hair of an animal. These inclusions may be arranged in two or even three planes, forming triangles in the latter case by their intersections. Oblong brown plates with clean-cut angles and others of round or oval forms are also seen. Apatite crystals are common as inclusions, and also sharp-edged crystals of epidote gleaming like jewels in polarised light. The latter may be secondary, but their complete outline and the want of other evidence of extensive change in the plagioclase, seem to suggest a primary origin.

Augite.—At least three species of augite appear in these rocks. In addition to the common augite we have diallage and a rhombic species, probably hypersthene.

The first variety is colorless and transparent, or greyish or green, when moderately fresh. It is apt to take on irregular shapes, filling up the interstices between the crystals of plagioclase. It has the usual rough surface, two not very perfect cleavages inclined about 90° to one another, brilliant coloring with polarised light, and an angle of extinction of 35° or 40°. It tends to weather into hornblende, uralite, or greenish chloritic substances, slightly, if at all, pleochroic and magnetite.

Diallage occurs chiefly as irregularly terminated prisms, with longitutinal fibres or striations. It is usually dull greenish or brownish grey, only faintly pleochroic, and faintly colored in polarised light. It very commonly encloses regularly oriented scales of a brownish color, sometimes two sets at right angles to one another. Edgewise, these scales look like delicate dashes (Plate II, fig 3). The diallage weathers to the same products as common augite.

Hypersthene, or possibly sometimes bronzite, resembles diallage, but is rhombic, as shewn by the extinction when the striations are parallel to the chief section of either nicol. It should be mentioned, however, that extinction is only faintly marked as a rule, and that some fibres seem to be always light.

Inclusions similar to those of diallage are found in hypersthene, but generally in much greater numbers, so as even to determine the color. The hypersthene is quite pleochroic, yellow and blue in crystals cut so as to show the edges of the inclusions; red-brown and drab where the flat sides are presented. Patches of hypersthene are often enclosed in diallage crystals. (Plate II, fig. 3). The glints of bronze or copper reflection caught from rocks of this group come from crystals of hypersthene or diallage.

Hornblende is sometimes to all appearance primary, but generally secondary and uralitic in look. The irregular masses of hornblende have at times a spattered appearance, spreading from a centre, and greatly mixed with other minerals. Their color is generally green, but sometimes brown and almost red. Hornblende often forms a margin around the augites, the two minerals having their chief axis in common. (Plate II, figs. 1 and 2).

Biotite occurs in small amounts, and, as a rule, apatite is found in the same specimens. Magnetite seems universal, but titanite is rare. Scapolite is found in one or two sections.

Following Rosenbusch, these rocks may be divided into :—

Proterobase, containing primary hornblende.

Diabase Proper, containing only secondary hornblende.

Gabbro, in a few specimens where diallage replaces common augite entirely.

Hypersthene Diabase, where much rhombic augite accompanies the monoclinic species.

It should be stated, however, that the general habitus is very constant, and the varieties are united by transitional forms.

One specimen of diabase proper is worthy of separate mention for its remarkable mode of weathering. The plagioclase, which is in long prisms, has a comparatively clear margin, but in the centre is so crowded with brownish or greenish particles arranged in rows parallel to the longest axis of the crystals as to be almost opaque even in the thinnest sections.

The augite is surrounded by a double zone of decomposition products, the outer one dull grey, the inner one transparent and made up largely of fibres (perhaps of quartz and hornblende) arranged radially around the kernel of sound augite (Plate I, fig. 2). Similar zones surround almost all the other minerals, such as biotite, apatite, and even plagioclase. Some crystals which appear to be augite are crossed by irregular bands of magnetite in a way suggestive of olivine, and even the optical characteristics sometimes resemble those of a rhombic mineral. Unless these are really olivine, that mineral seems to be wanting in our diabases.

B.

SCHISTOSE.

Turning now to the schistose basic rocks, we find very few specimens belonging to the augitic group.

Diabase Schist.

But one example was studied under the microscope. This is very fine grained, light green-grey, and composed of minute grains of quartz, probably some felspar, a little green hornblende, and much badly weathered augite in dirty grey fragments or prisms. Its cleavage and optical characters make its nature certain. A little titanite is found as an accessory.

Scapolite-Diorite-Schist.

Before considering the hornblendic schists proper, an interesting group of rather doubtful position may be described. As they present an unusual combination of minerals, they will be treated somewhat in detail.

Several handsome coarse-grained rocks of green-black hornblende, intermingled with violet-grey portions, shewing here and there the striations of plagioclase, were collected as diorites. They are massive in appearance, but often shew traces of a rough parallelism of their constituents, so that they should probably be referred to the schists.

Microscopic.—Under the microscope, the hornblende proves to be of the usual dark green, non-fibrous kind, and needs no particular mention.

Plagioclase.—The lighter portions are found to consist partly of plagioclase of a type resembling that of the diabases. It is slightly dusty in appearance, and of varying composition, as suggested by the angle of extinction from the twin planes. A variety ranging near $4\frac{1}{2}°$ is not very plentiful; another with about 21° is the most frequent; though a third of 31°, perhaps from twin planes according to another law, is not unusual. This indicates albite or andesine and labradorite. The plane of the twin striations, as in the diabases, is often bent, and there is a tendency for a crack to appear at the apex of the bend, possibly evidence of some strain or movement in the rock since its formation.

Scapolite.—In addition to the plagioclase, and often largely replacing it, is a mineral which appears to be one of the scapolites. It forms irregularly shaped masses, wedged in between the hornblende and plagioclase; or else oval portions are massed together, with their longer axes nearly in the same direction. Sections not at right angles to the chief axis, nor nearly so, shew a decided longitudinal cleavage, sometimes with hints of another cleavage perpendicular to it. These sections shew bright red and green hues in polarised light, and are bordered with strips of rainbow colors. Extinction is very perfect parallel to the cleavage.

Other sections nearly at right angles to the chief axis have a rather imperfect rectangular cleavage or no definite cleavage at all. Such sections give faint coloration or none between crossed nicols, and observed thus with the eyepiece removed, display a black cross which does not separate into hyperbolas on revolution. The mineral is quadratic and optically negative. The only specimens that could be examined macroscopically were from a veinlike portion of rather weathered rock. They have a yellowish color, waxy lustre, and hardness of about three. A portion examined by blowpipe methods by Dr. Haanel was pronounced "wilsonite", a modified scapolite. A less weathered portion obtained with difficulty gave hardly a trace of moisture in the matrass; so that probably the clear sections observed under the microscope may be considered scapolite (Plate I, fig. 4).

In most sections, the mineral appears quite fresh and free from inclusions. The plagioclase beside it is of the ordinary type and but little weathered, so that the scapolite must be considered an original constituent of the rock. Since it makes up in most cases at least a quarter of the whole (as estimated under the microscope), it cannot be looked on as an accessory mineral.

Magnetite is common in the rock, while ilmenite and titanite are much less so. A little quartz occurs in perhaps half the sections, and orthoclase is suspected in a few. Biotite is seen now and then, but in very small quantities. The rock, which is not uncommon in the drift, may be named :—

Scapolite-diorite-schist, or possibly, since the schistose character is rather undecided, it may prove to be scapolite-diorite.

One specimen proved on examination to contain beside much hornblende and scapolite, a considerable amount of microcline and quartz, the latter with fluid inclusions and moving bubbles. In addition to the minerals mentioned, a large quantity of sea-green augite was found, often bordered with hornblende, the two minerals having their chief axis in common. This rock seems to connect scapolite-diorite-schist with gneiss on the one hand, and diabase on the other, certainly a wide range of affinities.

Diorite and Hornblendic Schists.

Coming now to the undoubtedly schistose hornblendic rocks we find a most extensive and varied, but not specially interesting, group of rocks. They fill the same position in reference to the diorites as the gneisses occupy toward the granites. They range from compact to coarse grained. In color they are chiefly dark grey, verging on green. In structure they are usually distinctly schistose, sometimes exceedingly so, the cleavage being determined by the parallelism of the hornblende individuals. In some cases where this mineral forms slender parallel prisms, the rock has two very perfect cleavages and splits into long, roughly prismatic slabs.

Microscopic.—In the composition of these rocks, hornblende almost invariably plays the chief part, regularly accompanied, however, by a considerable amount of quartz and magnetite in small grains. In most cases also more or less plagioclase is found. Accessory minerals are tolerably common, such as biotite, ilmenite and pyrite or some other sulphide. As products of decomposition, chloritic minerals, oxides of iron, calcite and epidote are of frequent occurrence. These rocks may be classified as :—

Gneissoid-diorite-schists, when there is comparatively little hornblende.

Quartz-diorite-schists, which are by all means the most common.

Quartz-diorite-porphyroides, or perhaps better, plagioclase porphyroides. The third group is quite common and embraces rocks with a microgranitic or microfelsitic magma, formed, so far as the constituents can be determined, of fine fibres or grains of hornblende, with particles of quartz and magnetite. This magma encloses crystals of plagioclase, less frequently hornblende, and now and then clusters of epidote or chloritic masses with calcite and magnetite, representing some completely metamorphosed mineral.

Hornblendic Hälleflintas.

There is a not insignificant group of compact rocks much resembling hälleflintas, but with darker, greenish tones. They may be joined almost as appropriately to the hälleflintas as to the hornblendic porphyroides. The name "hornblendic hälleflinta" may be proposed for them. They are microgranitic or microfelsitic, but scarcely porphyritic, and they differ from the hälleflintas simply in the large number of particles of hornblende and magnetite mingled with the quartz and felspar.

V.—Conclusion.

We have passed in brief review the various rocks of the drift of Central Ontario, especially as found near Cobourg, and as we may suppose that farther investigation over a wider range of country would add largely to the list of varieties, it is evident that our drift presents a very interesting and extensive lithological collection. With the exception, however, of loose aggregations, such as clay, sand and gravel, and the very numerous fossiliferous limestones of Lower Silurian origin, all the rocks examined are crystalline and apparently of Archæan age. The almost complete absence of rocks of the later Archæan, such as quartzites, slates and mica schists, may be noticed as a negative characteristic of our drift.

Among positive features may be remarked the large number of transitional forms, intermediate varieties being found between the majority of the main groups of rock. This is the less surprising, however, when we remember that rocks, unless composed of a single substance, have in no sense the individuality of minerals; for, by gradual additions and subtractions, one often passes into another. This carries with it the disadvantage of making clean-cut definitions difficult or impossible; but also the advantage of bringing to view the grand unity that underlies variety.

DRIFT ROCKS OF CENTRAL ONTARIO.

	Acid Series.		Basic Series.	
	I.—Containing Quartz.	II.—Free from Quartz.	I.—Hornblendic.	II.—Augitic.
A MASSIVE.	*Granites.* 1. Biotite-hornblende-granite. 2. Hornblende (or amphibole)-granite. 3. Muscovite-granite (including pegmatites.) 4. Granite proper. *Felsites.*	*Biotite-Syenite.*	*Diorites.* 1. Diorite proper. 2. Biotite-diorite. 3. Diorite-porphyrite.	*Diabases.* 1. Proterobase. 2. Diabase proper. 3. Hypersthene-diabase. 4. Gabbro.
B SCHISTOSE.	*Gneisses.* 1. Biotite-hornblende-gneiss. 2. Hornblende-gneiss. 3. Muscovite-gneiss. 4. Gneiss proper. 5. Garnetiferous gneiss. 6. Tourmaline-gneiss. *Halleflintas.*	*Felspar Rock.*	*Diorite-Schists.* 1. Gneissoid-diorite-schists. 2. Quartz-diorite-schists. 3. Scapolite-diorite-schists. 4. Plagioclase-porphyroide. 5. Hornblendic hälleflinta.	*Diabase-Schist.*

So far as special constituents are concerned, it is noticeable how prevalent the mineral hornblende is in our rocks, forming an essential ingredient in the great majority of basic rocks and in fully half of the acid ones. The only series in which it is rare is the small one of the limestones and dolomites.

The widespread occurrence of microline is also worthy of remark. That this is true of other parts of the Dominion is shewn by sections of granite and gneiss in my collection from the Selkirks in British Columbia. Though differing much in habitus from those of Ontario, they almost all contain large quantities of the mineral.

The presence of a considerable group of rocks containing scapolite as an essential mineral seems worthy of special notice. The writer is informed that similar rocks have been described by Michael-Levy, Brögger and others; and that Mr. F. D. Adams contributed at the Montreal Meeting of the British Association a paper on Canadian rocks of the kind, an abstract of which was published in the Proceedings of the Association. Unfortunately the literature on the subject is not at my command, so that it is impossible at present to compare the scapolite rocks of our drift with those described by the distinguished petrographers mentioned.

For the convenience of reference there will be found on the opposite page a tabular list of the massive and schistose rocks described in this paper.

EXPLANATION OF PLATES.

Plate I.

(All between crossed nicols and magnified 85 diameters.)

Fig. 1.—Augite with zones of decomposition products.

Fig. 2.—Epidote in weathered plagioclase.

Fig. 3.—Transition from orthoclase to microline.

Fig. 4.—Scapolite, longitudinal section red and green, cross section dark grey,

Plate II.

(Figs. 1, 2 and 3 with the lower nicol only; fig. 4 between crossed nicols. All magnified 85 diameters.)

Fig. 1.—Cross section of bluish green augite and hornblende with chief axis in common; also brown titanite.

Fig. 2.—Augite and hornblende as in fig. 1, but longitudinal section.

Fig. 3.—Diallage (yellow) enclosing bluish hypersthene and brown hornblende.

Fig. 4.—Intergrowth of orthoclase and plagioclase (microperthite?)

Fig. 1.

Fig. 2.

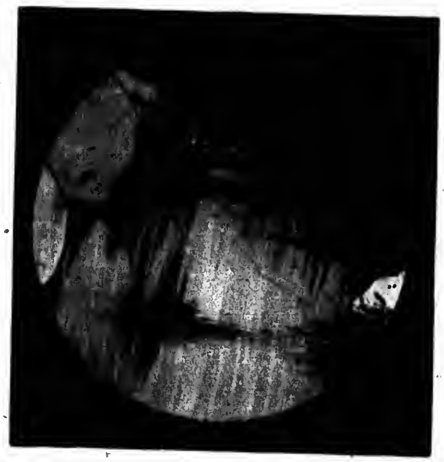

Fig. 3.

Fig. 4.

To illustrate Prof. Coleman's Paper upon Microscopic Petrology.

Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

To illustrate Prof. Coleman's Paper upon Microscopic Petrology.

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