THE RELATIONS OF THE GRENVILLE SEDIMENTS AND THE POTSDAM SANDSTONE IN EASTERN ONTARIO

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INTRODUCTION

The Grenville Sub-Province includes that part of the Canadian Pre-cambrian lying in eastern Ontario, extending north and east into Quebec. It also takes in the Adirondack region in the United States.

The major part of the Grenville area is underlain by two main rock series. The oldest, is a series of altered sediments known as the Grenville formation. These rocks are highly metamorphosed and now consist of banded quartzites, gneiss, and schist, interbedded in places with crystalline limestone.

The Grenville series, probably already altered and folded during early Pre-cambrian time, was invaded by a second and younger series of batholithic intrusives, consisting of granite, syenite, and pegmatite. Contemporaneous with this intrusion a further disturbance of the sediments again subjected them to folding and alteration. In places the sedimentary beds were pushed aside by the batholithic masses or dykes. Other and more intimate phases of invasion along the bedding produced the lit-par-lit structure so common in the area. During this movement the sediments were metamorphosed into gneiss, quartzite, and crystalline limestone. The remnants of bedding are still visible. Both the strike and dip vary locally; the series now has a dip of from 70° to 90°. The strike is northeast. Where folding has taken place it is consistent for all phases, the folds of quartzite, limestone, and gneiss being similar in type.

The main phase of the intrusive is a coarse grained red granite, containing milky blue quartz, red feldspar and hornblende. Syenite and pegmatite are other phases common in the area but are less abundant than the granite. The disturbance and alteration are regarded as late Pre-cambrian. An extended period of erosion at the end of Pre-cambrian time has truncated the folds and completed base levelling.

The Potsdam sandstone was formed from the material supplied by this base levelling process, and was laid down on the eroded Pre-cambrian surface. Various Paleozoic sediments followed. Subsequent erosion removed the later formations exposing the base levelled Grenville gneisses in much the same condition as they existed at the close of Pre-cambrian time.

Characteristics of the Heavy Residual Grains of the Potsdam Sandstone

The most striking characteristic of the Potsdam sandstone is its high silica content. Four determinations for silica from samples obtained from widely separated exposures show:

1—SiO_2—99.40 per cent
2—SiO_2—99.14 "
3—SiO_2—99.71 "
4—SiO_2—98.99 " Average SiO_2=99.31 percent.

The sand grains are thus nearly all pure quartz with siliceous cementing material. A small amount of calcium carbonate is found also as a cement, and in places iron oxides perform this function to a minor extent, coating the grains, and supplying the color to the red sandstone found in the district.

Most quartz grains show pronounced wear and the majority show evidence of secondary growth in a direction corresponding to the original orientation. In a general way the abundance of heavy residual grains and the number of mineral types for each sample showed a remarkable lack of variation. The sandstone from Glenburnie road near the Rideau River yielded slightly more heavy grains than the other samples examined. More minerals were identified in it than in any of the others. The grains of this sand are much more angular than in the others, and on the whole suggest less perfect sorting, and perhaps less transportation. In this sample, one flaky mineral of hexagonal outline with good basal cleavage was not determined. It is rather abundant in this one sample, but does not appear in any of the others. It is badly altered, and no pieces free from alterations could be obtained for satisfactory identification. The minerals other than quartz are not abundant nor the number of species large.

The following were identified and are listed in order of abundance (this result was obtained by an attempt at counting the number of mineral grains): Quartz, zircon, magnetite, titanite, tourmaline, apatite, rutile, garnet. Calcite and pyrite were also noted; both are considered to be of secondary origin.

The following arrangement represents the relative amount of rounding and wear exhibited by the grains.

Zircon, extreme wear, grains spherical and ellipsoidal.
Quartz, extreme wear, grains spherical—ellipsoidal, some irregular.
Apatite, extreme wear, grains mostly ellipsoidal, some irregular.
Magnetite, variation from spherical grains to fairly sharp crystal outlines.
Tourmaline, variation: Spherical forms to flat irregular but rounded pieces, some pieces show evidence of crystal outlines.
Garnet, variation: Spherical forms to fairly well preserved crystals.
Rutile, variation: Spherical forms to sharp crystal outlines.

These two lists show zircon to be the most abundant, the most consistently present, and the most rounded mineral occurring among the heavy residual grains. Most of the zircon grains have ellipsoidal or spheroidal forms; more rarely the shape is irregular and distorted. All grains are nearly colorless; some are of a very pale amber shade. They vary in size from a length of 1 mm. to .6 mm. The frosting on the zircon grains is most pronounced and consistent.

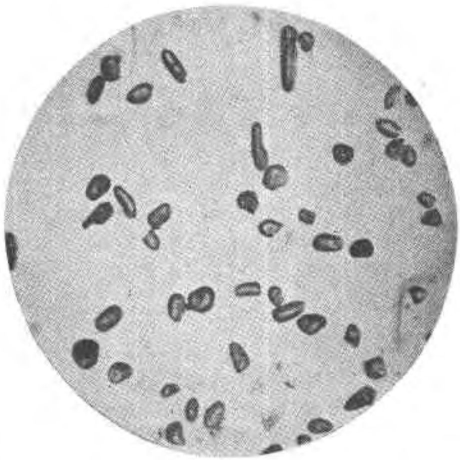

FIG. 1. Rounded sand grains. Potsdam sandstone. Note curved zircon grain above center of picture.

Considering all the heavy grains collectively, pronounced wear is general. In preparation of the samples a relatively small number of grains were split and where such fractured pieces were noted with the remaining part showing a rounded, smooth surface, they were regarded as broken during grinding. No grains of zircon could be found which displayed fresh faces and rarely did any exhibit the remnants of former crystal outline. Many grains, however, show elongation, and in such cases bent grains are not infrequent. (Fig. 1.)

Many of the zircons are so worn that they appear as small spherical grains. The distortion of the zircons is no doubt due to the folding of the host rock before the grains were released by erosion.

The relative amount of wear to which the heavy residuals have been subjected is no less significant than their abundance or persistence. This characteristic is shown best by zircon and to a nearly equal extent by titanite. By far the greater number of quartz grains show evidence of extreme wear, and most grains approach spherical or ellipsoidal form. Irregular shapes partly rounded are less common. The remainder of the minerals occur in both rounded and irregular shapes. The magnetite and the rutile in the Glenburnie road sample show practically all the stages of wear, from fresh crystal shapes to much worn grains. Some quite perfect octahedra of magnetite were recovered from sandstone obtained from Cushendall and from Bass Lake.

Apatite occurs in various worn shapes both rounded and irregular but never as sharp crystal forms. Garnets show a transition in wear between the two extremes of perfect crystals and much worn grains.

The frosting and pitting of the sandstone heavy residual grains is consistent throughout all samples and in general varies directly with the amount of rounding to which the grains have been subjected. For this reason zircon grains show the best examples of frosting.

Heavy Residuals in the Grenville Gneiss

Examinations were made of five samples of the Grenville gneiss. In the method of obtaining samples and of recovering the heavy minerals the same procedure was followed as with the sandstone.

The number of mineral types obtained from the gneiss is decidedly greater than in the sandstone. The minerals recognized are as follows:

Quartz	Garnet	Biotite	Tourmaline
Zircon	Pyrite	Cyanite	Sillimanite
Titanite	Magnetite	Rutile	Andalusite
Enstatite	Hornblende	Microcline	Chlorite
Apatite	Epidote	Andesine	Kaolin
Corundum	Calcite	Oligoclase	

Several other minerals were recovered, but not identified because grains were not obtained which were suitable for determination.

Most of the minerals occur as irregular, angular grains. Zircon and titanite are rounded, apatite less commonly. These three minerals are the only types to show abundance of rounded forms. There are also fresh types having no evidence of wear with well-formed crystal faces (Fig. 2).

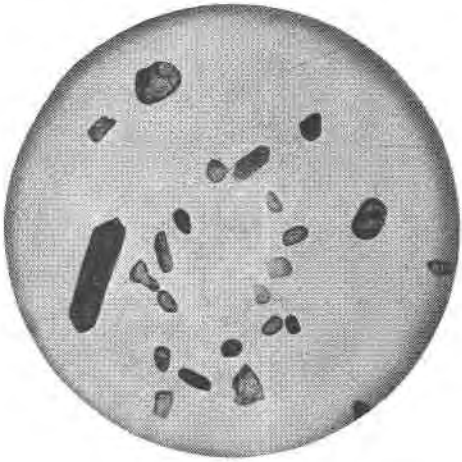

FIG. 2. Sand grains from Grenville gneiss.

INCLUSIONS OF GNEISS IN CRYSTALLINE LIMESTONE

An interesting detail of the Grenville formation is the presence of inclusions of gneiss contained in beds of crystalline limestone. These have been described by M. B. Baker as follows:

> "Of very frequent occurrence is a pseudo-conglomerate, composed of fragments of rusty weathering gneiss in a matrix of crystalline limestone. This might be mistaken as evidence of an unconformity showing the gneiss to be an older series. A close examination of the inclusions, however, shows that they are fragments of beds of para gneisses, which were mashed up with the limestones during their metamorphism—the softer limestone flowed around the pieces of gneiss and these moved like phenocrysts in a porphyry so that they often show a flowlike alignment."[1]

Samples of these inclusions were obtained and the heavy minerals recovered from them. An examination showed the presence of distinctly rounded sand grains (Fig. 3). No doubt these are waterworn grains of the original sediment preserved in the gneiss and retaining their identity. These inclusions of gneiss are not so hard and quartzitic as the main mass from which they were derived. Reactions between the constituents of the gneiss and the

[1] Baker, M. B., Geology of Kingston and Vicinity, *Ont. Bureau of Mines*, Vol. **XXV**, Pt. III.

limestone has resulted in the formation of tremolite, augite, and other calcium silicates. Augite was recovered from these inclusions in the form of rounded grains, evidently the result of alteration, with the retention of the original rounded waterworn forms.

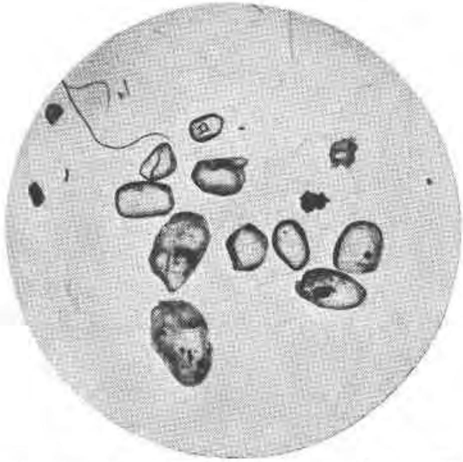

FIG. 3. Sand grains from inclusions of Grenville gneiss in crystalline Grenville limestone.

SOURCE OF THE MATERIAL OF THE POTSDAM SANDSTONE

Every heavy mineral found in the sandstone was also recovered from the gneiss. The garnet in the two formations is of the same type. Also the similarity of the zircon grains in Potsdam sandstone and Grenville gneiss is good evidence that the transportation has not been extensive, and that the sandstone lies on part of the same basement from which its material was derived. Since the Potsdam shows evidence of thorough sorting, and the material is so near its source of origin, it seems reasonable to believe that the gneisses from which in most part the Potsdam was derived are arenaceous sedimentary beds which, having experienced one cycle of erosion, were capable of supplying waste material already high in quartz and low in other minerals.

Climatic conditions in this erosion period are problematical. The presence of frosting on sand grains and the ferric oxide in layers of interbanded red and white sandstone suggest intervals of arid and probably desert conditions with stretches of wind swept coast land between the mountains and the sea.

Undoubtedly worn shapes are the result of abrasion and are therefore also the result of transportation, yet in measuring the extent of transportation, such grains, after having once become well-rounded, would not likely be much altered in shape by further transportation. Daubrée[2] states that from experiments which he performed he could prove that fresh angular sand grains subjected to 15½ miles of average river transportation became so worn that they could not be distinguished from ordinary river-worn grains. This distance seems remarkably short. It seems reasonable to assume, however, that in the initial stages of transportation, rounding may have a ratio to distance which would lose significance once the grains have become well rounded, and therefore could not be relied upon as a means of measuring distance in cases of far-reaching transportation.

The same reasoning applies to frosting. Once a sand grain has been thoroughly frosted, further effects cannot be measured. Under proper conditions, rounding and frosting may be perfected in a very short time. Window panes along sandy seashores lose their transparency in a few days, and in some instances are entirely worn through in a month, due to sand abrasion.[3] Such illustrations are convincing evidence that sand abrasion works rapidly, and that the effects on the grains themselves may result in rounding and frosting during a comparatively short period.

Summary

The examination of the Potsdam sandstone and Grenville gneisses show:

1. A low content of heavy minerals with thorough rounding.
2. A similarity in kind of grains in both gneiss and sandstone.
3. The zircons especially are more perfectly rounded in the sandstone than in the gneiss.
4. The gneisses are undoubtedly sedimentary in origin and originally sandstones, shales, etc. Some igneous material has been introduced in places but commonly this is easily recognized.

Conclusions

The gneisses were sediments formed by normal erosion so that the heavy minerals were fairly well rounded.

The sandstones were formed from the gneisses rather than directly from igneous rocks. This conclusion is based on the small amount of heavy residuals as compared with quartz, and on the perfection of rounding of the zircon.

[2] Daubree, *Geologie—Experimentale*, p. 256.
[3] Pirsson and Schuchert, *Introductory Geology*, p. 13.