An Investigation of the Genesis of the Sudbury Breccia

by

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The Ohio State University

Thesis Advisor

[Signature]

Department of Geology and Mineralogy
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Abstract

The Sudbury mining area is very important in the world today. The Sudbury Breccia, near Sudbury, Ontario, is an interesting breccia because of the wide variety of textures. The problem has been deciding a genesis for the breccia.
Acknowledgements

I wish to extend my thanks to Dr. Pride for his guidance on this project, which he suggested to me. I would also like to extend thanks to Mr. David Little for the time spent photographing the hand specimens and help in all laboratory preparations; it was much appreciated. I also wish to thank my fiancee for the constant help and typing she put in on this paper. Most of all I wish to thank my parents, without them I would have never attained this goal. Again thanks to all!
Introduction and Statement of Problem

This paper will discuss the genesis of the Sudbury Breccia, which is located in northern Ontario, Canada (Fig. 1). The Sudbury area has been one of the most important mining areas of the world since the late 1800's (Thompson, 1969).

The accepted origin of this breccia is that it was formed in volcanic pipes by explosion.

The problem concerning this breccia is the elliptical rock fragments included in this breccia which would imply transportation.
Geology of The Sudbury Basin

Two main geologic features are present in the Sudbury district, the Grenville Front and the Sudbury Basin. The Sudbury Basin (Fig. 2) consists of a variety of Precambrian rocks. The Sudbury Breccia and the Onaping Formation are the main concerns of the present paper. The origin and ages of these formations have been of major concern to geologists for years (Hawley, 1962).

Origin of the Sudbury Breccia

The Sudbury Breccia, as perceived by Diety (1963), is a shock breccia, because the breccia occupies fractures that are oriented radially or concentrically to the Sudbury Basin. Deitz also compared the breccia to the pseudotachylite of Shand (1916), which would mean that the rock melting occurred near a sudden, gigantic impact. Thomson (1969) and Speers (1967), agree that the breccia was formed within diatremes, although Thomson suggested the breccias represent "abortive diatremes." Speers further suggested that expulsion of the breccia caused the collapse of the shattered walls and the pipes to be filled with rubble. After the walls collapsed, more fracturing and faulting occurred, thus creating more of the same breccia.

The Onaping Formation is located within the Sudbury Basin (Fig. 2), and according to Thomson (1969), the feeders of the tuff (which in this case is the Onaping Formation), are located around the outer rim of the granophyre. Thomson (1969), Diety (1963) and Speers (1962) agree that the Onaping Formation originated as
glowing avalanche deposits. Up to 5,000 feet of material is present within the Sudbury Basin while none has been found outside the basin.
**Figure 1**

*Location of Sudbury, Ontario*
Portion of The Geological Map of the Province of Ontario

Figure 2.

- Protozoic
  - Basic Intrusives: Gabbron (Diabase) (Keweenawan, may include Matachewan)

- Archean
  - Acid Intrusives: granite, syenite, gneiss-gneiss
  - Sedimentary and derived metamorphic rocks: gneiss, arkose, quartzite, conglomerate, slate, iron formation, (Timiskaming, Sudbury, etc.), some volcanics.
  - Volcanic and derived metamorphic rocks: basalt, andesite, rhyolite, pyroclastics (Kewatin). Includes narrow bands of sediments, minor basic intrusives, and undifferentiated volcanics and sediments.

Key

Ex  - Approximate collection sites for specimens under investigation

Onaping -
Sample Collection

The two types of material that have been used in the present investigation of the Sudbury district were collected in September, 1982. The Sudbury Breccia was collected from a site north of the town of Laveck (Fig. 2), while the sample of the Cnaping Formation was collected about one kilometer south of Laveck.

Laboratory Studies

The laboratory studies were conducted at The Ohio State University during Autumn Quarter 1982. A thirty-six inch diameter oil saw was used to cut clabs for megascopic examinations. The slabs were ground on fourteen inch laps, with gut size from 220 to 1000. Vibration laps coated with TiO₂ were used to polish the specimens prior to microscopic examination.

Following the initial procedures, the long process of making thin sections began. Areas within the cut slabs for which thin section study was needed were selected and a thin slab approximately one-half inch thick was cut from the initial rock. Next rectangular chips approximately 4 mm x 2 mm were cut, and then glued with epoxy to the glass slides. The chips were cut and ground to approximately 0.33 mm and cover slips were applied. Mineralogic identifications and textural studies of the sections were done with a Nikon binocular, polarizing microscope. Important relationships were recorded photographically using a Nikon microscopic camera and Kodak black and white ASA 100 and Kodak Panatomic X color film ASA 100.
Results

The Sudbury Breccia from just south of Levack (Fig. 1 and 2) is present in all scales of magnitude (Dietz, 1963). The rock under examination (Fig. 3 and 4) consists of large fragments ranging from 12 mm to 2 mm of whitish pink granite (see Fig. 2) suspended within a very fine-grained black matrix. A very striking elliptical fragment is evident in figure 4, seen also in figure 3. This fragment, possibly gabbro, has very smooth borders, as do the larger granite fragments. In many cases the smaller fragments are shattered to some degree, with flow textures seemingly present (Fig. 5, also see Appendix B, samples Bx2 and Bx4). Small inclusions of sulfides (pyrite and chalcopyrite) also are present in this specimen (not shown).

The Onaping Formation, represented in this paper by the rock shown in figures 6 and 7, is greyish-blue in color, and contains obvious concentrically banded shards of quartz. Pyrite and chalcopyrite are common in the specimen of Onaping Formation studied and range from a fraction of a millimeter to about 0.5 centimeters, not shown in figures 6 and 7.

Conclusions

The origin of the Sudbury Breccia and the Onaping Formation have been the subject of some dispute over the years by many geologists. The present study supports an origin for the Sudbury Breccia during emplacement of diatreme intrusions, perhaps ejection from the diatremes. Flow textures within the rock, plus the smooth well
rounded borders to fragments, suggest that the fragments were abraided and smoothed during flow of the fluid matrix. The flow textures represent volcanic material, flowing into cracks in the surrounding country rock. The black matrix of the breccia was probably produced after the shock of the meteorite which sent the fluid upwards into the cracks.

The genesis of the Onaping Formation has not been as widely disputed as that of the Sudbury Breccia. The Onaping Formation very likely originated in volcanic activity, as the glass shards, concentric rings and the flow textures in the rock support a volcanic origin for the rock, perhaps as one or more glowing avalanche deposits. This conclusion is supported by the random direction of the existing flow textures.
Figure 3: Cross section of Sudbury Breccia.

Figure 4: Close-up of borders within Sudbury Breccia.
Figure 5: Fragmented granite within Sudbury Breccia with flow textures.

Figure 6: Slab of Onaping Formation
Figure 7: Close-up of shards, flow textures and concentric rings of Onaping Formation.
References Cited


Appendix A

Rock Descriptions
I. Rock Descriptions- Megascopic

A. Sudbury Breccia

This rock actually is composed of three parts: (1) black very fine-grained matrix (Bx4), (2) light pink coarse grained granite (Bx2) and (3) black fine-grained elliptical shaped rock (Bx6), (predominately hornblende plus biotite and quartz).

The matrix is so fine-grained that mineral identification was not possible. The granite fragments are composed of smokey quartz with an average (long dimension) of 2-3 cm, and plagioclase which is pink and average length of 2-3 cm. Biotite is present as anhedral grains and angular to prismatic hornblende with an average long dimension of 0.5-1 cm. Sulfides present in the rock.

B. Onaping Formation

The rock is dark grey, fine-grained and contains angular shards of all sizes (up to 2 cm in diameter). Randomly oriented flow textures are visible in the specimen.

The rock is high (approximately 10%) in sulfide content; the sulfides exist throughout as small fragments (approximately 0.3 cm in both dimensions).
Appendix B

Thin Section Descriptions
I. Thin Section Descriptions
A. Sudbury Breccia
1. Specimen Bx2

<table>
<thead>
<tr>
<th>Constituents</th>
<th>Percentage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quartz</td>
<td>40%</td>
<td>The quartz grains are sub-euhedral and some contain many inclusions of opaque minerals. Some of the grains are mosaics of quartz. Still others existing in a veinlet of biotite appear angular and exhibit wavy extinction, implying some tectonic stress. Photo Bx2-2.</td>
</tr>
<tr>
<td>Plagioclase</td>
<td>20%</td>
<td>Plagioclase is present in rectangular to square cross-sections and display good Carlsbad twinning. The plagioclase is truncated in places by the biotite.</td>
</tr>
<tr>
<td>Biotite</td>
<td>20%</td>
<td>The biotite is present in small veinlets throughout the section. The grains are pleochroic green and contain small inclusions of opaques, that line up length-wise with the biotites cleavage (Bx2-2). Birdseye extinction is also present.</td>
</tr>
<tr>
<td>Hornblende</td>
<td>6%</td>
<td>Hornblende is present as small angular (0.45 mm in length) grains. The grains exhibit good cleavage grains and are pleochroic brown.</td>
</tr>
<tr>
<td>Pyrite</td>
<td>4%</td>
<td>The pyrite is euhedral-subhecral and ranges in long diameter from less than 1 mm to approximately 5 mm.</td>
</tr>
</tbody>
</table>
Bx2-1: Quartz some mosaiced (notice arrow)

Bx2-2: Angular quartz, and the opaques.
2. Specimen Bx3

<table>
<thead>
<tr>
<th>Constituents</th>
<th>Percentage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quartz</td>
<td>50%</td>
<td>Quartz is angular to sub-rounded and ranges in size from 1.0 mm to 0.05 mm. Grains exhibit wavy extinction and often are granulated.</td>
</tr>
<tr>
<td>Plagioclase</td>
<td>30%</td>
<td>Plagioclase ranges in size from 1.0 mm to 0.05 mm and exhibits good twinning.</td>
</tr>
<tr>
<td>Hornblende</td>
<td>10%</td>
<td>Hornblende is anhedral and shows faint cleavage; the grains are approximately 0.45 mm in long dimension.</td>
</tr>
<tr>
<td>Matrix</td>
<td>10%</td>
<td>The matrix is very fine-grained and the mineral constituents and rock fragments are difficult to identify.</td>
</tr>
</tbody>
</table>

3. Specimen Bx4

Percent determinations are not possible in the extremely fine-grained matrix; quartz, plagioclase, biotite and hornblende have been identified. On this slide, the matrix can be seen flowing into the small granite fragment (see also figure 5).
Bx4: Thin section of fragment shown in figure 5.

Figure 8: Location of Bx6-
Thin section is of boundary in center of photo.
4. Specimen Bx6 (see Figure 6 page)

<table>
<thead>
<tr>
<th>Constituents</th>
<th>Percentage</th>
<th>Description</th>
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<tbody>
<tr>
<td>Hornblende</td>
<td>60%</td>
<td>Hornblende is present as anhedral, angular grains typically 0.45 mm in long dimension. The cleavage is very prominant in some grains, as is a green, brown and sometimes yellow pleochroism. Hornblende grains sometimes are truncated by the matrix material (Bx6-2).</td>
</tr>
<tr>
<td>Quartz</td>
<td>35%</td>
<td>Inside the elliptical rock fragments the quartz grains are anhedral and are approximately equal in size to the hornblende grains (0.45 mm in diameter). The quartz grains exhibit wavy extinction. Outside the rock fragment the quartz grains consist of mosaics of smaller grains. (Bx6-1)</td>
</tr>
<tr>
<td>Plagioclase</td>
<td>4%</td>
<td>Subhedral grains of plagioclase approximately 0.2 to 0.4 mm in size long dimension are present. The grains exhibit twinning, and some alteration to sericite is present. (Bx6-3)</td>
</tr>
<tr>
<td>Trace</td>
<td>1%</td>
<td>Biotite and Pyrite</td>
</tr>
</tbody>
</table>
Bx6-1
Outside rock fragment.

Bx6-2
Truncated Hornblende

Bx6-3
Pyrite and Biotite also the Plagioclase
B. Onaping Formation

1. On 1-1; On 1-2

Quartz

The rock is composed dominantly of glass shards that exhibit concentric rings (dark bands in figure On 1-2). Visible quartz is made up of mosaics of smaller quartz grains (On 1-2).
On 1-1
Shows both shards and concentric banding.

On 1-2
Shards with concentric banding
also mosaiced quartz.