# APPLICATION CHECKLIST
## Research, Scholarship, and Creativity Grant

**Deadline February 12th**

Please print and complete this checklist and attach it as the cover page of your grant application.

## Faculty information

Name: __Julie Bartley____________________ Dept: ______Geology________________

Email: __jbartley@gac.edu_________________ Rank: ___Associate Professor__________

## Checklist

**X Description of previous projects (and outcomes) funded by RSC grants**
*Not applicable – no previous projects*

**X Complete project description, including separate statements of:**

1. **Purpose.** What are the intellectual, conceptual, or artistic issues? How does your work fit into other endeavors being done in this field?
2. **Feasibility.** What qualifications do you bring to this project? What have you done/will you do to prepare for this project? What is the time period, i.e. summer, summer and academic year, academic year only? Is the work's scope commensurate with the time period of the project?
3. **Project Design.** This should include a specific description of the project design and activities, including location, staff, schedules or itineraries, and desired outcomes.

**X RSC Budget Proposal Form attached as last page of application**

**X Nine (9) copies of completed application and budget (including this checklist) to be submitted to the John S. Kendall Center for Engaged Learning (SSC 119)**

**If successful, my proposal can be used as an example to assist future faculty applications. This decision will not in any way influence the evaluation of my application. Yes (please circle one)**

## Research, Scholarship, and Creativity Grant
## BUDGET INFORMATION

**Faculty Stipend**
**($500 professor; $600 associate professor; $700 assistant professor)**

**Expenses**
Faculty may apply for up to **$1500** to pay for the cost of equipment, materials, personnel, and travel associated with the project to be funded by the RSC Grant. All expenses must be necessitated by the project to be funded by the RSC Grant.

| ITEM | | AMOUNT |
|---|---|---|
| Equipment (e.g., transcription machine, camera, cassette recorder—but not to include computer hardware) | | $0 |
| 1: | Cost: | |
| 2: | Cost: | |
| 3: | Cost: | |
| Materials (e.g., books, printing, software, lab supplies): | | $500 |
| 1: Field Supplies[1] | Cost: $200 | |
| 2: Laboratory Supplies[2] | Cost: $300 | |
| 3: | Cost: | |
| Personnel (e.g., typist, transcriptionist, student assistant) | | $0 |
| 1: | | |
| 2: | | |
| Travel Costs (cannot include conference travel, see http://gustavus.edu/finance/travel.php for allowable travel expenses) | | $795 |
| Airfare: | | |
| Mileage: Number of miles_900____ @ $0.55/mile ($495) | | |
| Lodging: 5 nights @ $30/night (camping/hostel fees) ($150) | | |
| Meals: 5 days @ $30/day ($150) | | |
| Other Expenses | | $80 |
| 1: shipping - archived samples | Cost: $80 | |
| 2: | Cost: | |
| 3: | Cost: | |
| | | $0 |
| | | |
| TOTAL EXPENSES | | $1375 |
| | | |
| AMOUNT REQUESTED (not to exceed $1500 + stipend commensurate with rank) | | $1975 |

[1]Field supplies include sample bags and boxes, GPS base map updates for Canada, topographic and geologic maps

[2]Laboratory supplies include saw blades, thin section materials, drill bits, acids and standards for geochemical analyses, and lab consumables (plasticware, etc.).

Have you applied for, or received funding from, another source to help support this project? No

# The Gunflint Formation: Early modern environment or echo of an archaic Earth?

## Purpose

The Gunflint Iron Formation (GIF), a 1.88 billion-year-old succession of sedimentary rocks exposed in the Lake Superior region, preserves a diverse assemblage of microorganisms. This succession was deposited at a time in Earth's history when an oxygen-containing atmosphere was first being established. It was, in fact, the initiation of an oxygen-containing atmosphere that produced the massive, economically important iron deposits of the upper Midwest. The GIF caught the attention of the geologic community in 1954, when fossilized microscopic organisms were reported for the first time (Tyler and Barghoorn, 1954), at long last dismissing Darwin's (1859) century-old concern that the fossil record began a mere 0.5 billion years ago, with the sudden appearance of megascopic animals. Since then, both older and younger assemblages of microbial fossils have been discovered, but the Gunflint microbiota remains one of the oldest complex assemblages, containing both abundant fossils and a diversity of form. Subsequent work has constrained its age (Fralick et al., 2002), further delineated the microfossil communities (Barghoorn and Tyler, 1965; Hofmann, 1971; Awramik, 1976; Awramik and Barghoorn, 1977; Moore, 1993), and examined the rocks that house them (Sommers et al., 2000; Planavsky et al., 2009). These studies, taken together, establish that the Gunflint Formation was deposited in shallow to mid-shelf depths (0-200m of water) and that this ancient ocean (called the Animikie Basin) and seafloor hosted a diversity of microbial forms, including groups that lived on the seafloor and those that inhabited the water column. Published work, however, does not yet paint a clear picture of the overall environment of the Animikie Basin, nor do we understand the ecology of the preserved ecosystem(s). Because the age of the Gunflint places it at a crossroads between the archaic, anoxic environments of the Archean Eon (4.0-2.5 billion years ago) and the modern-style, oxygen-containing environments of the later Proterozoic Eon (<1.6 billion years ago), understanding the nature of the early Proterozoic Eon (2.5-1.6 billion years ago) is key in deciphering the history of oxygen in the atmosphere-ocean system.

In this study, I propose to examine key localities of the Gunflint Formation to answer three main questions:

(1) How do the ecology and environment of the Gunflint microbiota in the GIF compare to assemblages in younger and older successions?

(2) What is the origin of silica in the Gunflint cherts (sedimentary rocks made of finely crystalline silica), and how are these cherts related to the carbonates (sedimentary rocks made of calcium-magnesium carbonate) also present in the GIF?

(3) What does the geochemistry of the GIF sedimentary rocks indicate about ancient ocean chemistry, and specifically about the concentrations of oxygen in the Animikie basin, 1.8 billion years ago?

## Feasibility

### *Qualifications —*

- PhD in geology.
- Research experience related to interpretation of microfossils and microbial ecology (Bartley 1996; Bartley et al., 2000), mechanism of sedimentary rock deposition (Bartley et al., 2000; Kah et al., 2006; Kah et al., in press), and geochemistry of Proterozoic carbonate rocks (Bartley et al., 2001, 2007; Bartley and Kah 2004).
- Significant field experience in Proterozoic successions, including fieldwork in arctic Canada, Siberia, the Ural Mountains, Mauritania, and western Montana.

### *Preparation —*

I have been in contact with Dr. Toby Moore, who conducted several field seasons in the Gunflint Iron Formation in the late 1980s and early 1990s. He is enthusiastic about renewing his interest in the Gunflint microbiota and brings significant experience to the collaboration, as well as detailed knowledge of the field sites, much of it unpublished. He has agreed to share his archived samples with me (see budget for sample shipment costs), so that I can select promising field sites. His assistance will substantially shorten the fieldwork required, as I will not have to do reconnaissance prior to initiating sample collection.

I have also contacted Dr. Russell Shapiro (former GAC geology department member), who collaborated on the work published in Planavsky et al. 2009. He has active ongoing research in the Biwabik Iron Formation (an iron formation equivalent in age to the Gunflint, exposed in Minnesota), and we both believe that our projects have the potential to be complementary.

### *Likelihood of Success —*

This proposal builds on recent work in the Gunflint Formation and coeval iron formations exposed in Minnesota (Biwabik Formation) that suggests these questions are tractable. Importantly, recent geochemical analyses suggest that the iron-bearing cherts of the GIF and Biwabik were deposited under low-oxygen conditions, and that the iron present in the chert was incompletely oxidized, suggesting that the dominant ecology of these assemblages was iron-oxidizing, rather than photosynthetic (Planavsky et al., 2009). These conclusions are consistent with the morphologies of microfossils from the cherts; however, other work (e.g., Moore, 1993) concludes that the overall diversity of the Gunflint microbiota is better explained by invoking a modern-style ecology, with photosynthesis forming the base of the foodweb. The proposed work will take an approach that integrates traditional paleontological inquiry with newly developed geochemical techniques to assess competing hypotheses about this ecosystem.

Similarly, the origin of the silica in Gunflint chert remains a matter of some debate. Maliva and coworkers (2005) suggest that chert older than 1.6 billion years old typically precipitated directly from seawater. It is well-established (e.g., Kah and Knoll, 1999; Bartley et al., 2000) that younger chert formed by replacement of pre-existing carbonate rock, from silica present in near-surface pore waters. Sommers and coworkers (2000) closely examined chert samples from the Gunflint Formation and found evidence that at least some chert formed by replacement of carbonate. Given the excellent preservation of microfossils in many parts of the Gunflint, I expect that petrography of a larger set of samples will be able to resolve the question of the origin of chert, using the methods of Sommers et al. (2000) and Bartley et al. (2000).

Recent work in the Gunflint also concluded that marine conditions in the Animikie basin were, at least sometimes, very different from the oxidized oceans of later units (Planavsky et al., 2009). Furthermore, this study suggests that even within the Animikie basin, oxygen levels varied dramatically. As a result of this potential variability, the third question is most difficult to answer, but will yield potentially useful data. A few earlier studies (Kamber and Webb, 2001; Kamber et al., 2004) have successfully evaluated redox-sensitive elements in sedimentary rocks older than 1 billion years and have been able to make inferences about ancient seawater chemistry. I have a separate, ongoing project (funded by a recent NSF grant) that will evaluate the range of rock types amenable to this analysis. It is my hope that the Gunflint carbonates are well-preserved enough to extract meaningful geochemical data. The chances are good, though, that only a subset of sampled rock will be amenable to this approach. Because of the relative novelty of these techniques applied to rocks of this age, it is likely that even negative results will be of use to the community. Fortunately, it is relatively simple to tell whether the measured geochemistry likely reflects seawater, or whether poor preservation has scrambled the chemistry – seawater has a distinctive pattern of elemental concentrations, and sedimentary samples that lack such a pattern do not preserve primary marine chemistry. (e.g., Kamber and Webb, 2001). Gunflint cherts analyzed by Planavsky et al. (2009) *do* show such a pattern, but Planavsky and coworkers did not examine all cherts and their study omitted carbonates entirely.

## Project Design

The field and laboratory work proposed here will simultaneously address all three questions posed above. It is critical to the success of the project that I sample the full range of well-preserved rocks present in the study area. Moor's PhD dissertation (Moore, 1993) contains excellent information about outcrop location and quality. I have been in contact with the author of this dissertation, and he has agreed to share samples collected during his fieldwork (1988-1991). This will allow me to preview the rocks present at various localities, assessing the fossil preservation and lithologic information. Moore's samples were collected with the intention of examining microfossils alone, so the sample set will not be complete enough to launch a geochemical study, or a comprehensive analysis of preserved environments. His work will, however, provide a much-needed context to guide the fieldwork.

During a short (5-7 day) field excursion, I will examine the stratigraphic relationships within the Gunflint, evaluating the field evidence for ancient environments. Two or three localities will be extensively sampled, with an eye toward sampling the full range of rock types.

Upon return to the laboratory, samples will be cleaned and cut (microfossils and sedimentary fabrics) or powdered (for geochemical analyses). I will use a light microscope to evaluate microfossils and sedimentary fabrics in thinly cut sections of chert and carbonate. Rock powders will be dissolved using geochemical methods successful in other very old sedimentary rocks (e.g., Kamber and Webb, 2001; Planavsky et al., 2009).

*Proposed timeline for work —*

June 1-20 – receive and examine archived samples of Toby Moore
June 20-30 – plan and organize details of fieldwork based on evaluation of archived samples
July 5-15 – execute fieldwork
July 20-August 10 – process samples (cut sections; powder rocks for geochemical analysis)
August 10-31 – complete analyses

*Anticipated outcomes —*

- Reestablishment of a collaborative relationship with Dr. Toby Moore, who has studied the Gunflint microbiota in detail.
- Establishment of a research agenda in a relatively accessible area, opening the door for future collaborations with students seeking to complete either field- or laboratory-oriented research projects.
- Development of experience in novel geochemical techniques using the newly-acquired ICP-MS (inductively coupled plasma – mass spectrometer).
- Publication of an article detailing microfossil morphology and the relationship of fossil assemblages to the environments they inhabited (as inferred from field and sedimentary rock data). Possible journals include *Palaios, Canadian Journal of Earth Science.*
- Publication of an article discussing the origin(s) of chert in the Gunflint Iron Formation, relating the mechanism of chert formation to original mineralogy, water depth, source of silica, and post-depositional factors. Possible journals include *Journal of Sedimentary Research, Precambrian Research.*
- Compilation of a body of geochemical data from the Gunflint that will either stand alone as a publishable dataset or will inform future grant proposals for work in the area. As mentioned above, this third piece of the research plan is least likely to produce publishable results from an exploratory study, but forms an important foundation for future work.

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