A PROPOSAL TO THE OHIO UNIVERSITY RESEARCH COUNCIL

TITLE OF PROJECT: ____Constraining the timing of the Great Ordovician Biodiversification Event (GOBE) in North American brachiopods______________________

NAME OF APPLICANT: ___Alycia Stigall_____________________________

STATUS: _____ Asst. Prof. _X__Assoc. Prof. _____Prof. _____ Administrator

DEPARTMENT: ____Geological Sciences_____________________________
CAMPUS ADDRESS: ___316 Clippinger Lab___________________________
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RE-SUBMISSION: ___ YES (Original Submission Date _______)
_x_ NO

BUDGET: Total Request _____$7980_________
(May not exceed $8,000)

IRB AND IACUC APPROVAL:
To ensure that the University is in compliance with all federal regulations, complete the checklist below. Note: your proposal can be approved prior to IRB or IACUC approval, but funding will be withheld until notification of approval or exemption.

Yes	*No*	*Office of Research Compliance*	*Policy #*
	X	Human Subjects in Research (including surveys, interviews, educational interventions): Institutional Review Board (IRB) Approval #: Expiration Date:	19.052
	X	Animal Species: Institutional Animal Care & Use Committee (IACUC) Approval #: Expiration Date:	19.049

SIGNATURES:

Applicant's Signature		**Chair/Director's Signature**	
Signature	Alycia L Stigall	Signature	D. L. López
Name	Alycia L. Stigall	Name	Dina L. Lopez
Dept/School	Geological Sciences	Unit	Geological Sciences
Date	9/22/2014	Date	9/22/14
Dean's Signature			
Name	Brian C. McCarthy	Signature	Brian C. McCarthy
College	Arts and Sciences	Date	9/22/2014

x **Optional:**
If selected for funding, I give permission to the Office of the Vice President for Research and Creative Activity to use my proposal as an example during training and workshop exercises.

Signature: Alycia L Stigall Date: ____9/22/2014________________

Ohio University Research Council Proposal Checklist

Applicants **must** complete and sign the checklist. The checklist should be included as the second page of the application (following the cover page).

☑ Cover Page	use OURC form
☑ Checklist	use OURC form
☑ Abstract*	1 double-spaced page
☐ Introduction *(for resubmissions only)**	1 double-spaced page
☑ New Project Description *(for established applicants only*[†]*)**	1 double-spaced page
☑ Discussion	10 double-spaced pages
☑ Glossary/Definition of Terms* *(not required)*	2 double-spaced pages
☑ Bibliography *(not required)*	3 pages
☑ Biographical information *(applicant(s) and key personnel)*	3 pages per person
☑ Other Support *(applicant(s) and key personnel)*	1 page per person
☑ Budget and Justification	no limit specified
☑ Appended Materials	10 pages; no more than 10 minutes of footage
☑ Recommended Reviewers	5 required
☑ Electronic copy of proposal	Single Acrobat file, containing entire proposal and required signatures

* These sections should be written in language understandable by an informed layperson to assist the committee in its review. Established applicants (*†)* are faculty members who have tenure **and** have been at the university at least three years or administrators who have been at the university at least five years.

****Please note: The committee has the right to return without review any proposals that do not conform to these format requirements.****

Applicant signature: Alycia L Stigall

3. Abstract

The Ordovician Period records an extraordinary biodiversification event known as the Ordovician Radiation or Great Ordovician Biodiversification Event (GOBE). The GOBE is characterized by the sustained radiation of marine animal life that resulted in a three to four times increase in generic diversity from start to finish. The basic outline of this dramatic rise in marine diversity is widely appreciated; however, different regions of the globe were characterized by different diversity trajectories that are less well understood. Because each region carries its own unique component of the GOBE that is related to local environmental changes and paleoecology, it may be possible to unravel a series of causal factors that progressed around the globe in the Ordovician. However, the details and timing of diversity increase within North America are poorly known at present. The lack of North American data hinders the ability of researchers to fully test oceanographic and biogeographic hypotheses to explain the causes of the GOBE.

If funded, this project will support the collection of detailed diversity data from a key series of strata from the North American midcontinent, which would allow the first detailed study of biodiversity patterns on this continent during the GOBE. This project will develop diversity curves for brachiopods, a key component of the Paleozoic fauna that flourished during the GOBE, at fine temporal resolution through new field work and analyses of museum specimens. Field work in May will focus on Middle Ordovician succession in the Arbuckle Mountains of Oklahoma. Previously collected specimens from these strata in the Smithsonian Institution and Sam Noble Museum (Oklahoma University) will also be studied in March and May, respectively. The diversity curves generated will be compared with those of the Baltic region and China to determine the relative timing of radiation between North America and these paleocontinents. Constraining the timing of diversification will provide key data for evaluating the multiple hypotheses proposed to explain the causes of the GOBE.

5. New Direction and New Project Description

This proposed research represents a new direction for the PI as it will investigate a set of scientific questions, an interval of geologic time, and a geographic location that differ from her previous work. Stigall's prior research has focused on investigating the role of ancient invasive species in mediating *biodiversity decline*, specifically how the spread of taxa from one geographic region to another can impact the formation of new species. These analyses have focused on two specific intervals of geologic time: the Late Devonian mass extinction and the Late Ordovician Richmondian Invasion. In both of these studies a series of *biogeographic, ecological, and evolutionary analyses* were conducted. Geographic regions examined focused on *New York, Iowa, Montana, and the Tri-State area (OH, IN, KY) surrounding Cincinnati*.

This new project builds on the knowledge gained in those studies (such as expertise in fossil brachiopods and macroevolutionary theory). However, this project will employ those skills to examine a completely different scientific question: how did *species and genus diversity increase* during an interval of global *biodiversity increase*. The project proposed herein will generate data on *diversity patterns*, use *chemostratigraphic correlations* to compare the newly documented diversity changes to other regions of the globe—including comparisons between *Oklahoma, Estonia, and south China*. Further, the interval of geologic time to be analyzed precedes the Late Ordovician interval previously studied by Stigall by ~20 million years. Therefore, the set of fossils to be studied in this project belong to *species and genera that are mostly different* from those previously studied. Thus, this project represents a significant new direction in research questions, hypothesis testing tools, geographic locations, and taxa, albeit a direction that the PI has sufficient background from other research to be able to successfully undertake.

6. Discussion

A. Specific Aims

The core research questions driving the proposed project are: "What was the timing and pattern of **diversification** within shallow marine animals of North America (=**Laurentia**) during the Great Ordovician Biodiversification Event?" and "How does that pattern compare to other regions around the world at the same time?" Thus, the primary goal of this project is to develop temporally constrained diversity curves for **brachiopod** species and genera from the midcontinent of Laurentia during the GOBE. The resulting diversity curves will be correlated with previously established diversity curves from other paleocontinents (e.g., **Baltoscandia**: Rasmussen et al. 2007 and South China: Zhan and Harper 2006) using **biostratigraphy** and **chemostratigraphy**. This approach will provide the data required to test a series of specific hypotheses: (1) Diversification began at the same time in Laurentia as other paleocontinents; (2) Diversification began earlier in temperate regions (e.g., Baltoscandia) than in tropically situated Laurentia; (3) Diversification rate was higher in tropical vs. temperate regions. Some of these hypotheses has been proposed in the literature (ex., Harper et al. 2013), but none can be fully tested without the detailed data collection proposed in this project. The data collected in this project, while significant in their own right, will also form the basis for a large National Science Foundation proposal to incorporate additional aspects of diversity (e.g., phylogenetic relationships, paleobiogeographic analyses) and highly detailed chemostratigraphy (including new analyses by NSF proposal co-PI Matt Saltzman (Ohio State) to produce a comprehensive study aimed at understanding the core Earth system drivers of the GOBE.

B. Significance

Ordovician age rocks record an extraordinary increase in the diversity of animal life

(Fig. 1), which recently has gained the acronym GOBE as short for Great Ordovician Biodiversification Event (Webby et al. 2004; Harper 2006; Servais et al. 2010). Although a monotonic increase appears within data sets analyzing all taxa globally, finer scale analyses have demonstrated that different regions of the world are characterized by different diversity trajectories (Miller 1997, 2012; Harper et al. 2013). If in fact each region carries its own unique component of the GOBE that relates to local environmental changes and **paleoecology** (e.g., Novack-Gottshall and Miller 2003; Zhan and Harper 2006; Botting and Muir 2008), then it may be possible to unravel a series of causal factors that progressed around the globe in the Ordovician. These local factors could have worked in association with global changes such as temperature (Trotter et al. 2008), asteroid impact (Schmitz et al. 2008), or oceanic oxygenation (Pruss et al. 2010; Saltzman et al. 2011) to produce the net diversity increase throughout the GOBE.

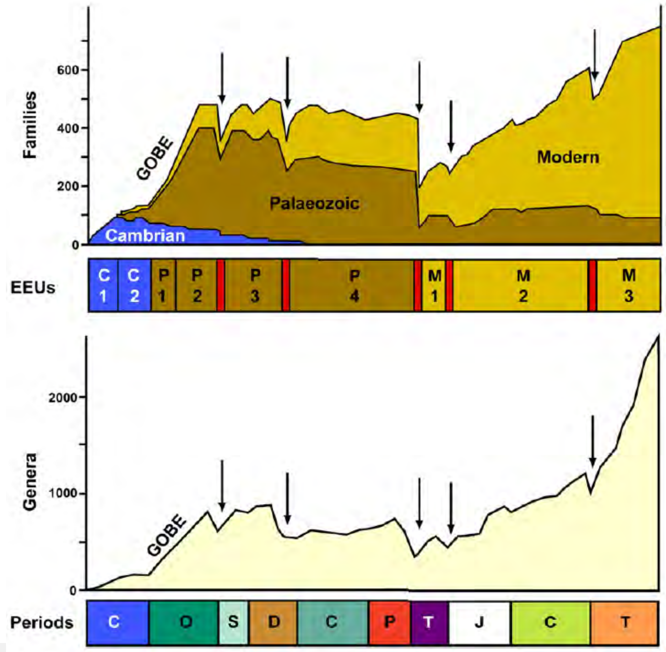


Fig. 1. Top panel shows the classic 'Sepkoski' diversity curve of marine invertebrate families through Phanerozoic time, documenting the Cambrian, Paleozoic and Modern Evolutionary Faunas, the Great Ordovician Biodiversification Event (GOBE) (from Servais et al., 2010), and the 'Big Five' mass extinctions of marine invertebrates. Lower panel shows the diversity curve of the Paleobiology Database (Alroy et al., 2008). The GOBE stands out in both datasets as one of the major increases in biodiversity in the Phanerozoic. Ecological-Evolutionary Units (EEUs) after Sheehan (1996): C1–C2: Cambrian; P1–4: Palaeozoic; M1–3: Modern. Geological periods, from left to right: C: Cambrian, O: Ordovician, S: Silurian, D: Devonian, C: Carboniferous, P: Permian, T: Triassic; J: Jurassic, C: Cretaceous. T: Tertiarv.

Because brachiopods are a key component of the **Paleozoic fauna** that flourished during the GOBE, analyzing patterns of diversification within this clade can provide key insights into the nature and controls on biota during the GOBE (Harper et al. 2013). The geographic dissection of brachiopod diversification during the GOBE has previously been examined on various timescales for regions including Baltoscandia (e.g., Hammer 2003; Rasmussen et al. 2007), North America (e.g., Droser and Finnegan 2005), Argentina (Waisfeld et al. 2003), and China (Zhan and Harper 2006). These studies point to important regional **tectonic** or **oceanographic** factors controlling local diversity, but timing or radiation and potential faunal exchange between these areas is unclear.

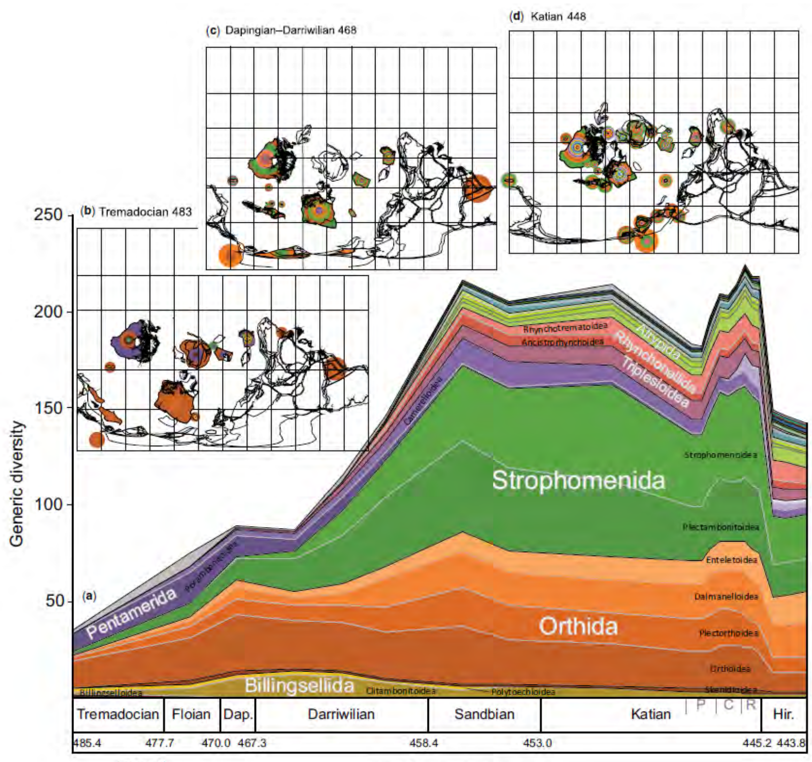
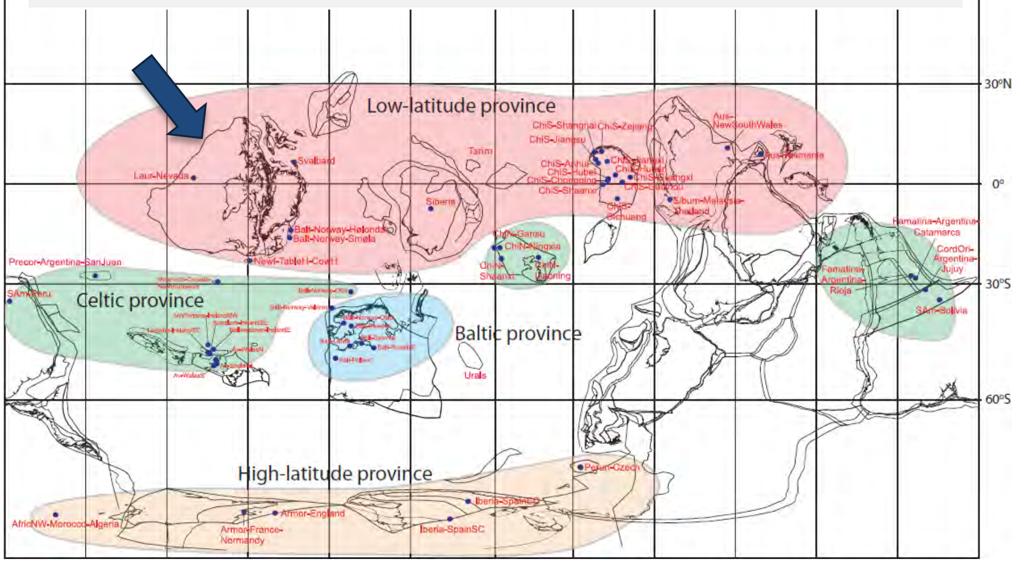


Fig. 2. From Harper et al. (2013): Ordovician generic brachiopod diversity and phylogeographic distribution through the Ordovician Period. Generic diversity increases throughout the Darriwilian stage and reaches a maximum in the early Sandbian. Genera are grouped into superfamilies. Radial colorings indicate dominance of each superfamily in a given region, going from least dominant (center of circles) to most dominant (outermost part of circles). Note substantial geographic shifts in phylogenetic composition of areas between time slices. The focus of the proposed research is on the Dapingian-Darriwilian and Sandbian time slices.

The Middle Ordovician **Dapingian-Darriwilian** stages and the Late Ordovician **Sandbian** stage represent critical intervals in the history of brachiopod evolution during the GOBE (Fig. 2; Harper et al. 2013). Most of the localities that make up the diversity curve of Harper et al. (2013) are from Baltoscandia and other continents, with the epicontinental seas of Laurentia poorly represented. Because Laurentian faunas are so incompletely known, assessing the role that this major continent played in the overall development of diversity rise during the GOBE has not yet been possible. Most analyses of the timing and impact of Ordovician radiation within Laurentia have emphasized either paleoecological or sedimentological patterns (e.g., Li and Droser 1999; Finnegan and Droser 2005; Pruss et al. 2010) or have examined the GOBE from the standpoint of aggregated taxa within large databases (e.g., Miller and Foote 1996). Currently, genus or species level diversity data for the epicontinental seas of Laurentia is lacking or highly limited for most taxa in both the literature and in online resources [hence the lack of data within the Harper et al. 2013 compilation in Fig. 3]. The key exceptions to this are the trilobites, which have been examined in detail by Adrain et al. (1998). Their analyses determined that a subset of trilobite lineages, the Whiterock Fauna, diversified in concert with the GOBE, but the stage-level resolution of their analyses is too course to develop detailed comparisons with other regions.

Fig. 3. Palaeogeographical map for the Dapingian–Darriwilian time slice (~468 million years ago) showing locations with known brachiopod assemblages from Harper et al. (2013). Note the lack of representation from central North America (indicated by arrow, rotated nearly 90° clockwise from present orientation). A major goal of this project is to increase the number of localities during these time intervals in North America.



In order to test the hypotheses about relative timing and rate of diversification among regions during the rapid biodiversity increase of the Dapingian to Sandbian stages, detailed faunal data, explicitly tied to a highly resolved timescale are necessary. In this project, I will rectify this problem by *developing a detailed dataset of brachiopod diversity patterns,* correlate these data with a newly developed high-resolution chemostratigraphic framework for the midcontinent of North America and Baltica, and compare these data to compatible Baltic or

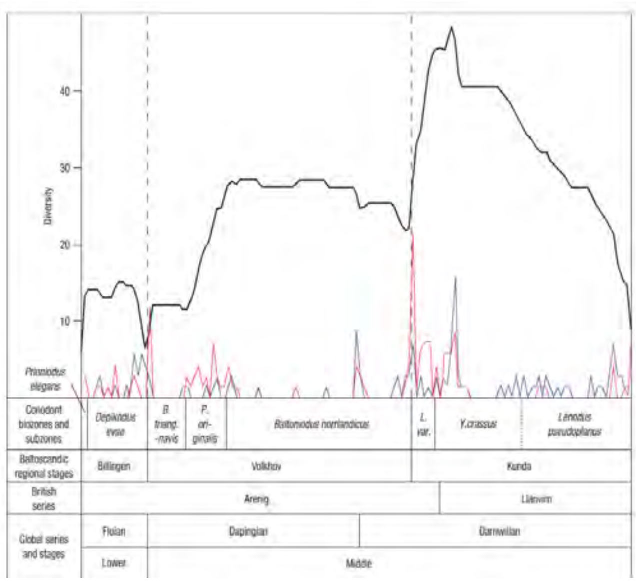
Chinese data sets of Rasmussen et al. (2007) or Zhan and Harper (2006). Results of these analyses will be of substantial importance to the community of Ordovician geoscientists and will disseminated via presentations at international and national meetings (e.g., Geological Society of America and International Geoscience Programme 591 annual meetings), published in peer-reviewed journals, and data will be contributed to large database efforts, such as the PaleoDB (paleodb.org). This research will expand the PI's areas of expertise to include intervals of diversification, additional field areas, and additional taxa beyond her previous work.

Developing a more complete understanding of mechanisms that promote biodiversity increase is an important component for understanding ecosystem functions and planning for biodiversity preservation in the modern world. At the present time, most analyses of conservation biology focus on extinction mechanisms, but it is also critical to determine the factors that can promote and retain biodiversity (Stigall 2010, 2012). Biodiversity retention and protection of **speciation** processes is likely to become especially important over the next few decades. Extinction levels have already reached that of ancient mass extinctions (Barnosky et al. 2011), and biodiversity can only be restored to the planet via origination. Consequently, identifying key aspects of ancient biodiversification events, such as the GOBE, is crucial.

C. Preliminary Studies of Applicant

Although the analysis of the GOBE diversification patterns represents a new research direction for Dr. Stigall, skills developed during her prior work with Late Devonian and Late Ordovician brachiopod **systematics** and paleoecology in eastern North America can be readily applied to this new project. Specifically, Stigall's recent research has incorporated significant field work which analyzed species occurrence data within detailed **stratigraphic frameworks** (ex., Brame and Stigall 2014; Malizia and Stigall 2011; Walls and Stigall 2012) and utilized brachiopod specimens housed in museum collections at the United States National Museum and other institutions (ex., Wright and Stigall 2013a, 2014). Much of her work has considered how ecology and biogeography mediate speciation processes (ex., Stigall 2012a, 2012b, 2013) and the role of tectonic and oceanographic factors in promoting geographic differentiation (ex., Wright and Stigall 2013b). This combination of previous research skills provides a solid foundation on which to build a new field and museum based study of brachiopod diversification during the GOBE.

Proof of concept data was gathered for this project from online records of museum collections (Figure 4b). Within the course resolution of this data, it appears the brachiopod radiation in North America occurred later than in Baltoscandia. However, these data are preliminary are represent a biased result compared to data that could be obtained from new fieldwork as proposed herein.



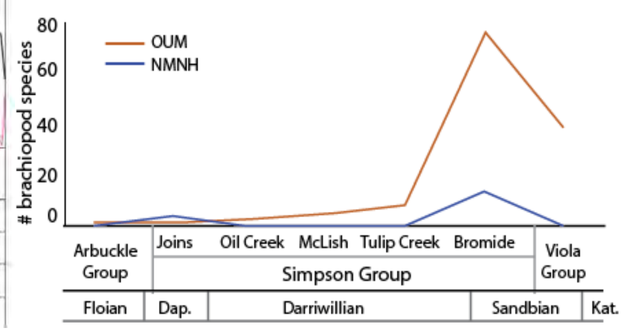


Fig. 4. Comparison of regional diversification patterns. (A) From Schmitz et al. (2008): Total diversity of brachiopod species (number of species) through part of the Lower and Middle Ordovician in Baltoscandia based on bed-by-bed collections at eight localities. Note the dramatic increase in biodiversity (black line) during the early Darriwillian. (B) Preliminary diversity data based on brachiopod species housed within the collections at the Sam Noble Oklahoma Museum of Natural History (OUM) and US National Museum of Natural History (NMNH). Based on the preliminary data, radiation occurred earlier in Baltoscandia than in the Simpson Group, but this pattern is sampled at a course scale.

D. Methods

This project will focus on developing detailed brachiopod diversity curves for the tropical, epicontinental seas of Laurentia during the GOBE through targeted field research and museum collection analyses. Both types of analyses will focus on gathering diversity data from the same focal strata, the Simpson Group, which is exposed in Oklahoma.

Study area: Arbuckle Mountains, Oklahoma.—

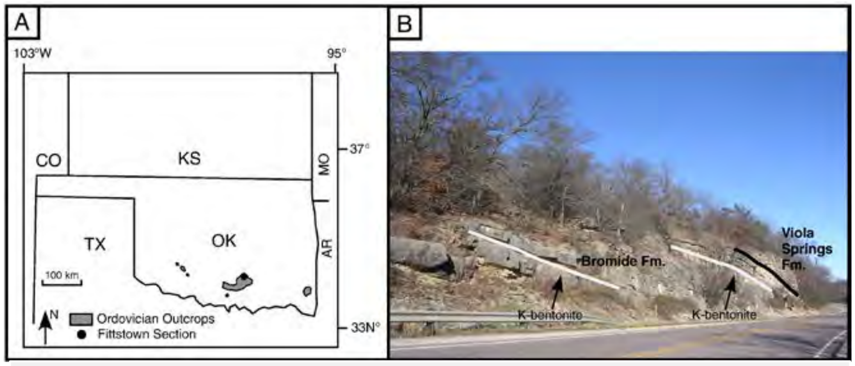


Fig. 5. Schematic map of study area. A) Locality map showing Ordovician outcrops in Oklahoma (after Rosenau et al., 2012). B) Photograph of exposure illustrating the nature of the outcrops in the Arbuckle Mountains.

Data collection will focus primarily on the shallowly buried Ordovician sections in the Arbuckle Mountains of Oklahoma (Figs. 5, 6). The proposed study will focus in detail on the Simpson Group succession spanning the key interval for brachiopod evolution of Dapingian-Darriwilian to early Sandbian stages. The Simpson Group has been well-dated using conodont biostratigraphy (ex., Derby et al., 1991, Bauer et al. 2010) and new studies of chemostratigraphy provide additional temporal constraints (Bergström et al. 2009; Saltzman et al., 2014). This is also one of few regions in North America with relatively continuous sedimentation during this interval and thus represents a key reference section for the Paleozoic sea level curve (Haq and Schutter, 2008). The Simpson Group contains fossiliferous strata, including over 90 named brachiopod species (Cooper, 1956). The combination of excellent exposure, continuous sedimentation, excellent bio- and chemostratigraphic control, and diverse brachiopod assemblages make the Simpson Group strata outstanding units in which to test hypotheses about timing and rate of diversification of brachiopod in North American seas.

Generating diversity data for Simpson Group brachiopods.— Rhychonelliform brachiopods of the Simpson Group were primarily described by G.A. Cooper in his 1956 monograph on Chazyan brachiopods of North America. With only a few exceptions (ex., revision of

Lepidocyclus by Amsden, 1983), these brachiopods have not been re-examined taxonomically and there have been no detailed analyses of the stratigraphic ranges of species within the Simposon Group. Thus both detailed field collection and systematic revision must be competed in order to develop a dataset compatible with contemporaneous basins of other regions.

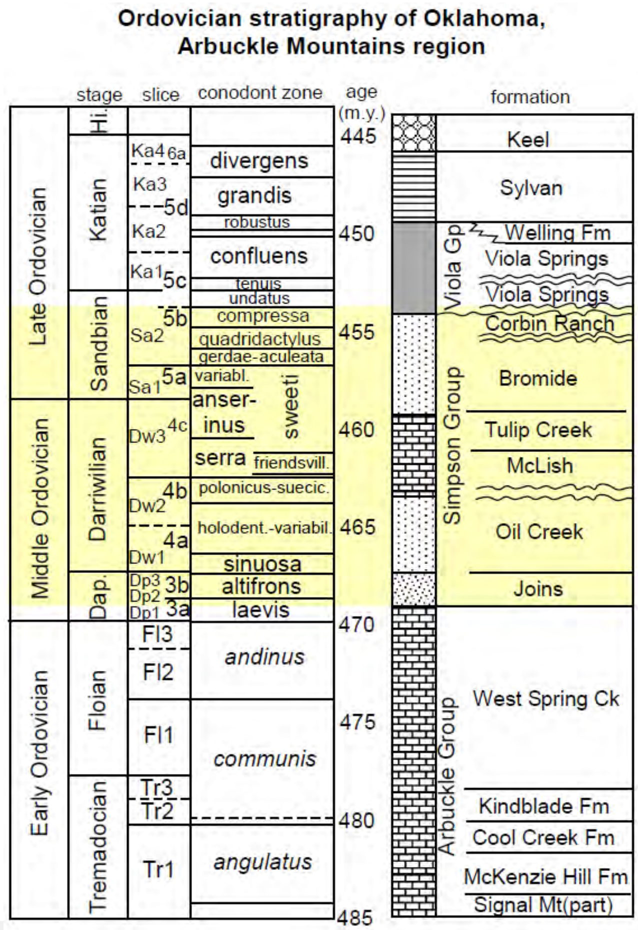


Fig. 6. Ordovician stratigraphy of Oklahoma. The proposed study will investigate the Simpson Group succession spanning the key interval for brachiopod evolution of Dapingian-Darriwilian to early Sandbian. The Simpson Group has been well-dated using conodont biostratigraphy (see Derby et al., 1991). Sections are well exposed in the Arbuckle Mountains region.

<u>*Museum work*</u>: The initial phase of data collection will occur at the National Museum of Natural History (USNM) in Washington, DC. This institution houses Cooper's type specimens, and thus holds a critical collection of specimens for understanding and revising the taxonomy of the Simpson Group brachiopods. The PI and grad student (Sarah Trubovitz) will travel to the USNM and spend three days becoming familiar with the taxa and collecting stratigraphic and geographic distribution data for specimens in the type and non-type collections. The full research team (PI, grad student, and undergrad student researcher) will conduct a similar analysis at the Sam Noble Oklahoma Museum of Natural History (OUM) before beginning the Arbuckle Mountains fieldwork to familiarize the group with the focal species and collect diversity data available from the museum collections. The PI has excellent working relationships with curators at both institutions (see

attachment for OUM letter of collaboration).

Fieldwork: Although museum specimens are critical for systematic work, most specimens lack the detailed bed-by-bed level of stratigraphic precision required to construct the detailed diversity curves necessary for this study. Thus, data collection via new fieldwork is required to generate the detailed data necessary to fully test the hypotheses outlined herein. Thus, the PI, grad student, and undergraduate research assistant will undertake fieldwork within the well-exposed units of the Simpson Group, collecting or documenting brachiopod specimens on a bed-by-bed basis as applicable. Two weeks of fieldwork are anticipated to be sufficient to gather high quality species occurrence data due to the easy accessibility of the outcrops. In addition to species presence data, ecological data (abundance, taphonomic condition, orientation, and accessory fauna) will be collected on the outcrop and representative specimens will be returned to the lab for comparative analysis. Sampling and sedimentological biases will be mitigated following recommendations of Patzkowsky and Holland (2012).

Diversity curve generation: Diversity curves will be produced using rarefaction and analyzed for ecological correlates. A preliminary dataset compiled from existing museum collections (Fig. 4) reflects a diversity increase through the Simpson group with a peak in the Sandbian Bromide Formation, the veracity of this peak will be ascertained in this project.

Regional comparisons: Using biostratigraphy (based on conodonts and other microfossils) and chemostratigraphy (based on isotopes), the Simpson Group will be correlated with contemporaneous strata around the world. Following correlation, the timing and pattern of brachiopod diversification within the Simpson Group will be compared with other sections, such as the Baltic sections of Rasmussen et al. (2007).

Results and research products: Results of this research will provide insight into how dramatic diversity increases can be accomplished and will be of wide interest to geologists and paleontologists. Anticipated research products include at least 2 journal articles, a more competitive NSF grant proposal, a MS thesis, and 2-4 presentations at scientific conferences.

Table 1: Project timeline

Task	Date
Museum work at the National Museum of Natural History (Smithsonian)	March-April 2015
Field and museum work in the Arbuckle Mountains and Sam Noble Museum of Natural History	May 2015
Compilation and analysis of North American brachiopod diversity data	June-Sept. 2015
Students and PI present preliminary results at the Annual Geological Society of America Meeting [funding from other sources]	October 2015
Correlation of North American diversity data with Baltic and Chinese diversity patterns	Nov.-Dec. 2015
Grant period ends; Submission of NSF proposal using OURC data	Jan. 2016
Master's thesis defended	April 2016
Submission of journal articles	May-June 2016

E. Collaborations: The proposed work will be performed by the PI, one MS student, and an undergraduate geology major. The PI and grad student will participate in all phases of the project, with the student developing the diversity curve analyses into her MS thesis project. The undergraduate will assist with data collection in the field and museum in Oklahoma, thereby gaining valuable skills in stratigraphic and paleontologic analysis. Dr. Steve Westrop of OUM will assist us with orientation to the strata of the Arbuckle Mountains (see Appendix). The data generated from this project will be used to enhance a NSF proposal that was previously declined due to limited pilot data (see "Other Support").

F. Summary: This project will generate a key set of data on diversification of marine animals during the GOBE. These data will provide— for the first time—the ability to test hypotheses about rate and timing of diversification of Laurentian faunas compared to other paleoplates. The enhanced understanding of regional diversification will provide additional constraints for selecting among the competing causal hypotheses for dramatic diversification during the GOBE.

7. Glossary

Baltoscandia: Paleocontinent comprised of landmasses of the modern Baltic and Scandinavian regions.

biostratigraphy: Correlation of rock units between disparate geographic locations based on the presence of one of more short-lived species. In the Ordovician, conodont and gratpolite fossils are commonly used for biostratigraphy.

brachiopod: Marine invertebrates belonging to the phylum Brachiopoda, characterized by two bilaterally symmetrical valves. These animals superficially resemble clams and were the dominant shellfish of the Ordovician seas.

chemostratigraphy: Correlation of rock units between disparate geographic locations based on the chemical signatures in the rocks that reflect global chemical signatures. Chemostratigraphic markers include stable isotopes, such as $\delta^{13}C$ and radiogenic isotopes, such as $^{87}Sr/^{86}Sr$.

Dapingian: First age of Middle Ordovician epoch, see **Ordovician** entry.

Darriwillian: Second age of Middle Ordovician epoch, see **Ordovician** entry.

diversification: Increase in the total number of taxa (species or genera) over time.

Laurentia: Ordovician paleocontinent comprised of modern North America and Greenland.

Oceanographic factors: Ocean circulation, temperature, oxygenation, nutrient content or other aspects of the oceanic realm of the Earth system.

Ordovician: A period of the Paleozoic Era covering the timespan of approximately 488 to 444 million years ago. The Ordovician is divided into the series and stages indicated below.

Period	Epoch	Age		Age (Ma)
Ordovician	Late Ordovician	Hirnantian		446 - 444
		Katian		456 - 446
		Sandbian	GOBE interval	461 - 456
	Middle Ordovician	Darriwillian		468 - 461
		Dapingian		472 - 468
	Early Ordovician	Floian		479 - 472
		Tremadocian		488 - 479

paleoecology: Area of inquiry related to analyzing fossils as living animals within communities.

Paleozoic fauna: Dominant organisms during the Ordovician to Permian periods (488-521 Ma) characterized by brachiopods, byrozoans, crinoids, blastoids, etc.

Sandbian: First age of Late Ordovician epoch, see **Ordovician** entry.

speciation: The formation of new species.

systematics: The study of the relationships and classification of species.

Stratigraphic framework: The temporal/rock system in which a fossil occurs. Each fossil occurs within a specific layer of rock. The stratigraphic framework describes this position. Higher details results in greater temporal precision.

Tectonic factors: Mountain building, basinal accommodation, intracratonic arch formation and other aspects of the Earth system controlled by plate tectonic motions.

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9. Biographical Information: Alycia L. Stigall, PhD (Univ. Kansas, 2004)

Professional Positions

2009-present	Associate Professor, Ohio University, Department of Geological Sciences
2004-2009	Assistant Professor, Ohio University, Department of Geological Sciences
2006-present	Member, OHIO Center for Ecology and Evolutionary Studies
2014-present	Affiliate faculty member, Women's, Gender, and Sexuality Studies Program
2005	Visiting Researcher, Yale University, Department of Geology and Geophysics
2004	Post-doctoral Researcher, The Ohio State University, Department of Geological Sciences

Accomplishments

1. ***Educational Outreach:*** (A) Co-leader of "Scaffolding Inquiry through Literacy and Assessment Strategies (SILAS)" 5-day workshop (2013) for twenty in-service science teachers from Appalachian Ohio. Content focus on Tectonics and Earth History, including development of three state education standards aligned modules, two on Ordovician fossils (B) Leading workshop for Cincinnati area teacher in October 2014 to train these modules and the effective use of fossils in their classrooms.

2. ***GIS Methods Development/promotion:*** Developed procedure for using GIS to analyze species ranges over time intervals approximating 0.5 million year intervals. To date, the protocol has been presented to the paleontological community in numerous meetings and publications detailing the methods developed. Students at 5 universities in the USA and China have been trained in these methods; and data assembled is uploaded into the Paleobiology Database (www.paleodb.org).

3. ***Community Outreach:*** (A) Developed website for identification of key Cincinnatian fossils: www.ordovicianatlas.org (ongoing addition of taxa); (B) Guest speaker in local middle and elementary schools and public libraries including presentations on basic geology, paleontology, oceans, and careers in geological sciences; (C) Speaker for Annual Women in Science and Engineering Program for 5th to 8th grade girls, at Ohio University; (D) Presenter for Ohio University Science Café, (E) Speaker for Cincinnati Dry Dredgers, Amateur Paleontology Club, promoting interaction between amateur and professional scientists. In my visits with and presentations for students in the rural Appalachian region of southeast Ohio, most students do not anticipate attending college; therefore, I focus on career and travel opportunities (including my Antarctic field work) for geologists to help motivate those students to exceed expectations and consider college as a potentially viable option (ongoing).

Key Professional Service Roles and Awards (past 5 years)

2014	Symposium convener, "Paleobiogeography: The Importance of Fossil Data to Species Biogeography Past, Present, and Future" at the International Biogeography Society 7th Biennial Conference, Bayreuth, Germany
2014	Nominating Committee, International Palaeontological Association
2014	Outstanding Faculty Research and Scholarship Award in the Natural Sciences, College of Arts and Sciences, Ohio University
2014, 2013, 2012, & 2006	Outstanding Research Award, Department of Geological Sciences, Ohio University

2011, 2009, 2008, & 2006	Outstanding Teaching Award, Department of Geological Sciences, Ohio University
2013, 2010	NSF Panel Review, Sedimentology and Paleobiology
2012-2013	International Biogeography Society, Conference Program and Abstract Committee
2012, 2008, 2007, & 2004	Chair for technical sessions at Geological Society of America meetings
2012-present	Participant in the International Geosciences Programme (IGCP) Project 591: The Early and Middle Paleozoic Revolution
2010	Transformative Faculty Award, College of Arts and Sciences, Ohio University
2010	Grasselli Brown Faculty Teaching Award in the Natural Sciences, College of Arts and Sciences, Ohio University
2008-2011	Paleontological Society Nominating Committee

Select Peer reviewed publications (past 5 years)

**I have published 29 peer-reviewed articles since 2010, those listed here focus on the Ordovician or diversity patterns*

Stigall, A.L. 2014. When and how do species achieve niche stability over long time scales? Ecography, Early View online. doi: 10.1111/ecog.00719

Wright, D.F., and **Stigall, A.L.** 2014. Species-level phylogenetic revision of the orthide brachiopod *Glyptorthis* from North America. Journal of Systematic Palaeontology, 12: Early View online. doi:10.1080/14772019.2013.839584

Stigall, A.L., and Brame, H-M.R. 2014. Relating environmental change and species stability in Late Ordovician seas. GFF: A Scandinavia Journal of Earth Sciences, 136:249-253. doi:10.1080/11035897.2013.852619

Brame, H-M.R., and **Stigall, A.L.** 2014. Controls on niche stability in geologic time: Congruent responses to biotic and abiotic environmental changes among Cincinnatian (Late Ordovician) marine invertebrates. Paleobiology, 40(1): 70-90. doi:10.1666/13035

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Stigall, A.L. 2010. Invasive species and biodiversity crises: Testing the link in the Late Devonian. PLoS ONE, 5(12): e15584. doi:10.1371/journal.pone.0015584.

Stigall, A.L. 2010. Using GIS to assess the biogeographic impact of species invasions on native brachiopods during the Richmondian Invasion in the Type-Cincinnatian (Late Ordovician, Cincinnati region). Palaeontologia Electronica, 13: 5A, 19 p. http://palaeo-electronica.org/2010_1/207/index.html.

Select Abstracts of Scientific Meeting Presentations (past 5 years)

**I have published 33 abstracts related to meeting presentations since 2010,*

Stigall, A.L., †Bauer, J.E., Brame, H.-M.R., †Lam, A.R., Dani, D.E., Helfrich, S.R., and Sickel, A.J. 2014. Oceans of Ohio: opportunities for engaging K-16 students via local geology. Geological Society of America, Abstracts with Programs, 46 (3): 25.

Brame, H.R., **Stigall, A.L.** and †Bauer, J.E. 2013. Creating an online invertebrate paleontology museum: turning fossils into digital data. Geological Society of America, Abstracts with Programs, 45 (7): 324.

Stigall, A.L., and Brame, H.R. 2013. Environmental change and niche evolution: Which types of change promote adaptive response? Geological Society of America, Abstracts with Programs, 45 (7): 90.

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Stigall, A.L. 2013. Expanding the Role of Biogeography and Niche Evolution in Macroevolutionary Theory. American Associated for the Advancement of Science Annual Meeting 2013, Abstract Volume, A30.

Stigall, A.L. 2013. When and how do species achieve niche stability over long time scales? *In* Conference program and abstracts. International Biogeography Society 6th Biennial Meeting – 9-13 January 2013, Miami, Florida, USA (ed. by J. Hortal, K. Faller, K. Fee-ley, R. Field, C. Graham, F. Guilhaumon and D. Gavin), *Frontiers of biogeography* Vol. 4, suppl. 1, p. 67. International Biogeography Society.

Wright, D.F., and **Stigall, A.L.** 2012. Using phylogenetic biogeography to link tectonics, speciation, and biotic invasion in Late Ordovician Laurentia. Geological Society of America, Abstracts with Programs, 44 (7): 396.

Stigall, A.L. 2010. Using ecological niche modeling to evaluate niche stability in deep time: Analyzing Late Ordovician brachiopods of Eastern North America across an invasion event. In: Programme & Abstracts, 3rd International Palaeontological Congress, 365.

10. Other Support

A. Previous University Funding (2012-2014):
No active OURC or Baker fund awards within the past 3 years.

The PI has successfully sought Ohio University Program to Aid Career Exploration (PACE) funding to support undergraduate research.

2014-2015 "Paleontology website content and media developer" $2385
2013-2015 "3D imaging of fossil specimens" $2385 per year
2013-2014 "Paleontological curatorial assistant and media developer" $2355
2012-2013 "Paleontology Field Assistant" $2230
2012-2013 "Research Assistant in Invertebrate Paleontology" $2230

Outcomes of this funding include development of the www.ordovicianatlas.org website, and assistance with field work of two MS theses. A PACE proposal will be submitted in Spring 2014 that, if funded, would provide assistance in the field for this project.

The College of Arts and Sciences and the Department for Geological Sciences provide funds for conference travel but do not offer financial support for faculty research in the sciences and Research Challenge awards are no longer available.

Limited funds are available within the PI's Research Incentive account. However, the PI has historically reserved those funds to support student travel to scientific conferences, as the Geological Sciences Department does not have funds to fully support student travel. For this project, RI funds will support travel by grad and undergrad students to the Geological Society of America's Annual Meeting in Baltimore, MD in October 2015.

B. External Funding (2012-2014):

"Collaborative Research: From biodiversity epicenter to species pump: Brachiopod evolution in Baltoscandia and North America during the Great Ordovician Biodiversification Event (GOBE). " $204,896 (to OU), collaborative with M.R. Salzman (Ohio State), NSF, 1/2014, *declined* (1 excellent, 2 very good, 1 good, panel summary: excellent potential). This proposal is for a larger project that expands on this OURC proposal. The data produced in the OURC project would enhance fundability of this proposal on planned resubmission of this proposal.

"Digitization TCN: Collaborative Research: Digitizing Fossils to Enable New Syntheses in Biogeography - Creating a PALEONICHES-TCN" $952,437 ($194,462 to OU), NSF, 7/2012-6/2015, PI with Bruce Lieberman (KU) and Jon Hendricks (SJSU), and Co-PI's Brenda Hunda (CMC), Kendall Hauer (MUGM), Una Farrell (KU), James Beach (KU), Roger Portell (FMNH). This project is unrelated to the current proposal. Work on this project has funded 3 MS students and resulted in 1 journal article, 4 data-rich websites, and 6 presentations at 5 scientific meetings (3 international, 1 national, 1 regional).

"Collaborative Research: Assembling the Cephalopod Tree of Life. " $553,295 (to OU), collaborative with 8 institutions, NSF, 3/2012, *declined.* This program has been terminated by NSF (1 excellent, 3 very good, 1 good).

C. Sustainability:
The project will develop a key set of diversity data that can serve as a critical "proof of concept" data set that will improve the probability of securing NSF funding for the larger, multi-year project incorporating evolutionary and chemostratigraphic analyses (i.e., the first proposal part B).

11. Budget and Justification

<u>Budget:</u>

A. Consumable Supplies	
Field collection bags	$ 75
Field notebooks	$ 35
Specimen storage trays	<u>$ 150</u>
	$ 260
B. Travel	
Museum analysis in Washington, DC	
Round-trip airfare from Columbus to Washington, DC: 2@$200	$ 400
Transportation within DC	$ 50
Hotel room: 1 room for 2 nights @ $150/night	$ 300
Per diem: 2 people x 3 days @$71/day	<u>$ 426</u>
	$1176
Field collection/museum analysis in Oklahoma	
Roundtrip airfare from Columbus to Oklahoma City: 3@$350	$1050
Rental car for 18 days	$ 750
Rental car fuel	$ 250
Hotel room: 2 rooms for 4 nights @ $83/night	$ 664
Camping fees: 14 nights @ $25/night	$ 350
Per diem: 3 people x 18 days @$46/day	<u>$2480</u>
	$5544
C. Student wages	
Graduate student stipend	$1000
D. Equipment: none requested	
E. Faculty Stipend: none requested	
F. Other: none requested	
G. <u>Total Requested</u>	**<u>$7980</u>**

<u>Budget justification:</u>

Primary needs: The bulk of the funds requested will directly fund data collection and, consequently, are critical to the success of this project. Funds are requested to support visits to significant museum collections, conduct field work to collect new data and specimens, and provide a limited stipend to the graduate student involved with data collection. Limited funds for field supplies are also requested.

Consumable supplies: Basic field supplies are required for fossil and sedimentology data collection and processing for this project including sample bags, field notebooks, and acid-free trays for fossil storage. Cost estimates are based on previous purchases via Forestry Supplies (for sample bags and field notebooks) and Gaylord Brothers (for specimen trays).

***Travel*:**

Museum analysis at the National Museum of Natural History (Smithsonian Institution), Washington, DC: $1176

The vast majority of the Middle Ordovician brachiopod species were formally described by G. Arthur Cooper of the Smithsonian Institution, and the type specimens are still housed there. The PI and graduate student will travel to Washington, DC to examine the type specimens in order to train on identifying these taxa during the subsequent field work and the collect diversity data to the degree possible. Funding is requested for a three day trip to Washington. The student and PI will travel to DC on the earliest possible flight and will fly back to Athens in the late evening of the third day, which will provide nearly 3 full days to analyze the fossil collections. On similar collections visits, the PI has arrived at the museum by 9am and been collecting data by 10am on the first day. Costs include one shared hotel room for two nights (estimated at $150/night) and per diem of $71/day for 6 people days. Limited funds are requested for public transport between the hotel, museum, and airport.

Field and museum work in the Oklahoma: $5544

Data must be collected by visiting outcrops of the Middle Ordovician strata throughout the Arbuckle Mountain outcrop region. Additional data will be collected at the Sam Noble Oklahoma Museum of Natural History. Field work and museum analysis will be conducted by the PI, the graduate student, and an undergraduate research assistant. The research team will fly to Oklahoma, then rent a car to provide transportation in the field. The cost is approximately the same as mileage for personal vehicles on this trip and the rental provides additional protection should breakdowns occur. The team will stay in hotels during museum work in Norman, OK (estimated at $83/night for two rooms) and will camp during the field work (estimated at $25/night). Per diem is calculated at $46/day for 54 people days.

The Sam Noble Museum has the largest collection of Middle Ordovician fossils from the focal strata. Three days will be spent examining specimens within the Sam Noble Museum at the beginning of the trip to Oklahoma. Museum work will provide an increased assessment of diversity when combined with the Smithsonian collections data and provide taxon training for the undergraduate field assistant. Field work will focus on bed-by-bed collection of diversity data. This is time and labor intensive, thus requiring two weeks and the assistance of an undergraduate assistant.

Student Wages: Funding is requested to provide a $1000 stipend to the graduate student who will be conducting the research and analyzing the data for her MS thesis. The graduate student will collect data at both museums and will spend two weeks in the field followed by data processing in the PI's laboratory for the remainder of the summer term. This stipend level provides compensation for the summer field season and is approximately 1/7th of a full semester TA stipend in our department. Currently the target graduate student is enrolled in her first year of the MS program in the department of Geological Sciences. Since the graduate student has already begun her degree program, funding of this proposal in the current cycle is of utmost importance for project success.   Funding for to support the undergraduate research assistant will be requested via the PACE program.

Sam Noble Museum

September 12th, 2014

Dr. Alycia Stigall,
Department of Geological Sciences
Ohio Center for Ecology and Evolutionary Studies
Ohio University
316 Clippinger Laboratories
Athens, Ohio 45701

Dear Alycia,

This letter will confirm that the Department of Invertebrate Paleontology at the Sam Noble Museum offers its enthusiastic support for your studies of Simpson Group brachiopods in southern Oklahoma, which will be part of your latest proposal. The brachiopods are abundant and diverse, but have languished without study for more than half a century. It is good to see that they will be part of an active research program.

We will give you and your students full access to our collections, and we will make loans for study as necessary. We have a digital imaging lab that may also be helpful to you when you visit the museum. My students and I are well advanced in our studies of the trilobites, sedimentary facies and sequence stratigraphy of the upper Simpson, and there may well be scope for paleoecological and evolutionary comparisons with the brachiopod faunas.

Good luck with the proposal.

Best regards,

Steve

Dr. Stephen R. Westrop
Curator of Invertebrate Paleontology
Oklahoma Museum of Natural History, and
W.L. Miller Professor
School of Geology & Geophysics and
University of Oklahoma

13. List of Recommended Reviewers

Dr. William I. Ausich
Department of Geological Sciences
The Ohio State University
155 South Oval Mall
Columbus OH 43210
phone: (614) 292-3353
email: ausich.1@osu.edu
Expert on Ordovician fossils of North America, benthic communities, paleoecology, and quantitative methods. No prior professional collaboration.

Dr. Stig M. Bergström
Department of Geological Sciences
The Ohio State University
155 South Oval Mall
Columbus OH 43210
phone: (614) 292-4473
email: stig@geology.ohio-state.edu
Expert on Ordovician stratigraphy including North America, Baltica, and China. No prior professional collaboration.

Dr. Jisuo Jin
Department of Earth Sciences
University of Western Ontario (Canada)
1151 Richmond Street N.
London, Ontario, Canada, N6A 5B7
phone: (519) 661-2111
pmail: jjin@uwo.ca
Expert on Ordovician brachiopods of North America and China. No prior professional collaboration.

Dr. David L. Meyer
Department of Geology
University of Cincinnati
505 Geology-Physics Building
Cincinnati, OH 45221-0013
phone: (513) 556-4530
email: david.meyer@uc.edu
Expert on Ordovician fossils and strata as well as modern and ancient marine ecosystems. No prior professional collaboration.

Dr. Peter Sheehan
Milwaukee Public Museum and University of Wisconsin-Milwaukee
800 West Wells Street
Milwaukee, WI 53233
phone: (414) 278-2741
email: sheehan@mom.edu
Expert on Ordovician brachiopods and faunal dynamics, including both Laurentia and Baltica. No prior professional collaboration.