# The Digital Atlas of Ordovician Life: digitizing and mobilizing data for paleontologists and the public

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**Abstract.** A new online resource, "The Digital Atlas of Ordovician Life: Exploring the Fauna of the Cincinnati Region" (www.OrdovicianAtlas.org), provides a tool for exploring the diversity, systematics, biogeography and stratigraphy of Late Ordovician fossils of the Cincinnati, Ohio region. This atlas has been developed using georeferenced specimen-based data that have been newly digitized as part of a collaborative project to mobilize species occurrence data for public use. The goals of this project are to digitize specimens of Late Ordovician (Katian) fossils from the type Cincinnatian Series that crop out in the Cincinnati, Ohio, USA region, develop a comprehensive online atlas of the fossils and develop outreach materials for K-16 (grade school through college) education and avocational paleontologists.

**Key words:** outreach, education, systematics, Katian, Laurentia, biogeography, museum collections.

## INTRODUCTION

Museum collections of fossils, along with their associated locality data, provide millions of records of the temporal and geographic distribution of species in deep time. Many of these data, however, are "dark data" (Heidorn 2008) which are inaccessible to most researchers in the absence of on-site visits to the collections. To reach their greatest scientific and educational potential, data from these fossil collections need to be available on-line and in formats accessible to both professional scientists and the public. Recent efforts in our research group have focused on digitizing specimens of Late Ordovician (Katian) fossils from the type Cincinnatian Series that crop out in the Cincinnati, Ohio, USA region, developing a comprehensive online atlas of the fossils and generating outreach materials for K-16 (grade school through college) education and avocational paleontologists. Ultimately, these products are deployed via the www.OrdovicianAtlas.org interface (Stigall 2013). The development of the Ordovician Atlas is part of an NSF-funded project, The Digital Atlas of Ancient Life, which unites collaborators at six institutions to digitize collections data and build digital atlases for three time periods (Late Ordovician of the Cincinnati region, Pennsylvanian of the Midcontinent United States and Neogene of the Southeastern United States) (Hendricks et al. 2013).

## DIGITAL ATLAS PROJECT

### Digitizing fossil collections

The core data for populating the Ordovician Atlas comes from three extensive museum collections of Cincinnatian fossils: the Cincinnati Museum Center, the Limper Geology Museum of Miami University and the Kallmeyer Collection at Ohio University. The basic workflow developed at Ohio University for the Kallmeyer Collection is described here to illustrate the complete digitization processes: from new specimen acquisition to fully digitized data.

The Cincinnatian collections at Ohio University are referred to as the Kallmeyer Collection in recognition of Mr. Jack Kallmeyer, an avocational fossil collector and longtime president of the Dry Dredgers (an association of amateur geologists and fossil collectors; www.drydredgers.org), who collected the ~13 000 specimens that form the basis of the collection and donated them to Ohio University. This collection includes specimens from all taxonomic groups within Cincinnatian strata (Fig. 1). In order to properly curate this collection, a Specify 6.5 (Specify Software Project 2014) database was designed to organize and store the data. Within Specify, information is stored in a series of nested hierarchical trees (e.g., geographic, stratigraphic and taxonomic trees) (Fig. 2). Field guides and published species descriptions were used to identify each specimen

to the species level, when possible. Following identification, each specimen was cataloged, creating a digital record of all geologic, geographic and taxonomic information. Fossils were placed into trays with Specify-generated labels and a unique catalog number was written on each specimen. All collection localities were georeferenced to ensure the Specify database included the most accurate locality data possible. Georeferencing was conducted following best practices and protocols (Chapman & Wieczorek 2006) in order to convert written locality descriptions or sketch maps into precise latitude and longitude values and provide a numerical range of uncertainty for each of the collecting sites. The Specify framework allows additional information to be appended to individual specimen records (e.g., specimen photographs) and locality entries (e.g., PDFs of field notes), when available.

The digitization process produced digital data of species distributions that are highly detailed, stratigraphically constrained and geographically precise. Specimen data are available via the web portals of the three participating museums. Additional plans for integrating these data within overall species occurrence databases, such as the iDigBio specimen portal (https://www.idigbio.org/portal), are ongoing. By

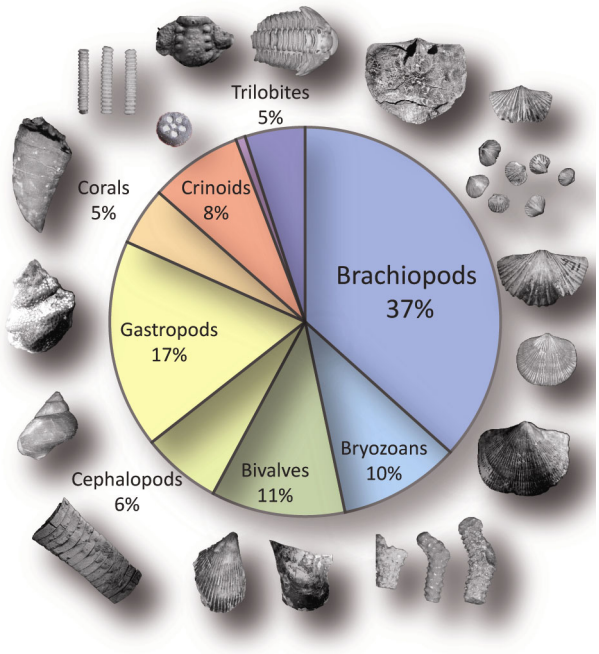


**Fig. 1.** Taxonomic distribution of fossils within the Ohio University Kallmeyer collection. The unlabeled pie slice represents specimens of other taxonomic affinities.

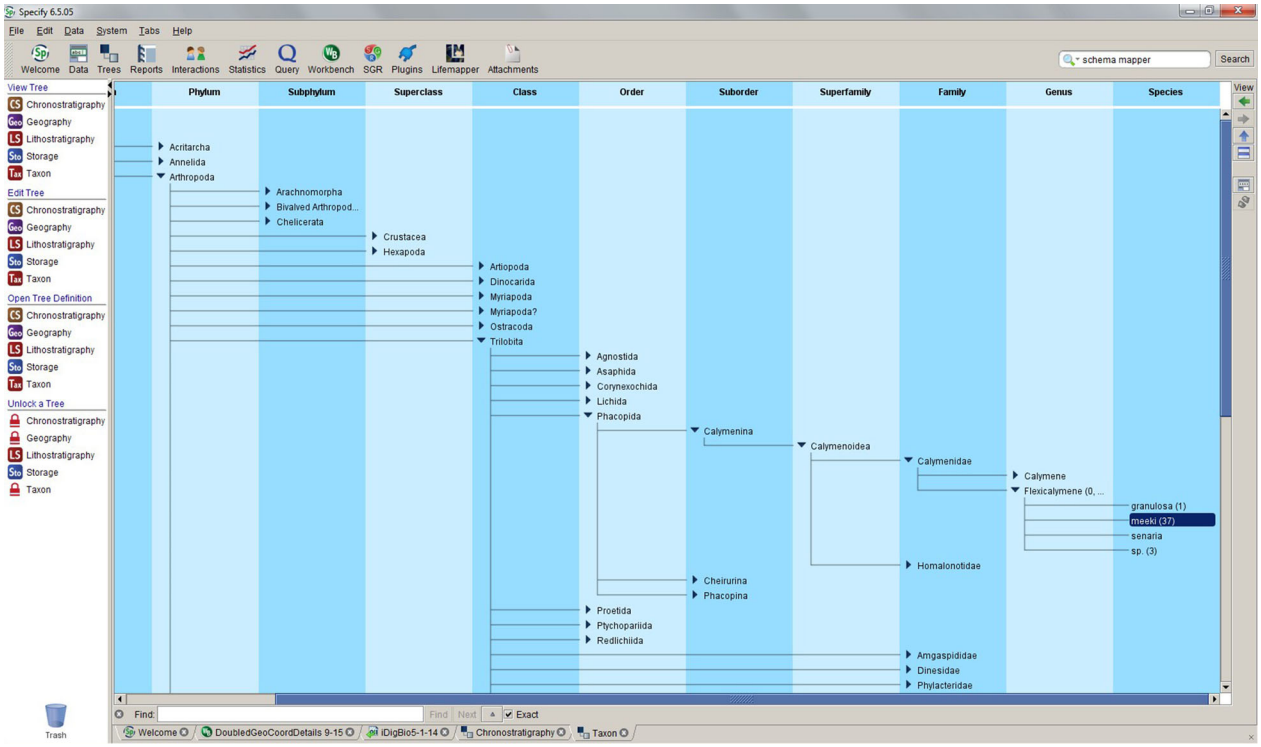


**Fig. 2.** Screen shot from Specify 6.5 illustrating the hierarchical taxonomic structure on which the database schema is constructed. This view illustrates the taxonomic relationship of *Flexicalymene meeki*. Locality and stratigraphic data are stored in similar hierarchical arrays.

attaching accurately georeferenced latitude/longitude coordinates to each specimen, this project has generated thousands of mappable data points that augment previously available digital biogeographic records of Cincinnatian taxa.

**Website organization and development**

A core objective of this project is to develop a website that will serve as a portal to information about identifying and interpreting the fossils of the Cincinnati region for professional and avocational paleontologists, K-16 teachers and community members. The website (www.OrdovicianAtlas.org) was publicly launched in October 2013. The central feature of the website is the "digital atlas", which is an online field guide that illustrates the morphology, taxonomy and stratigraphic and geographic distribution of key fossil taxa within the region. The aim is to provide a resource akin to a printed identification guide, but that can take advantage of digital media (e.g., interactive maps, zoomable photographs, animations) and that can be easily updated as new information or taxonomic determinations are available. By September 2014, the website included over 550 live pages, the vast majority of which are the taxonomic (species, genus, family, etc.) pages that comprise the atlas. In addition to the atlas, supplemental pages include information about geologic setting, stratigraphy, fossil-collecting localities, resources for teachers and a comprehensive reference list.

Development of the website is an ongoing project. We have utilized WordPress architecture (www.wordpress.com) to generate a dynamic site that is responsive, customizable and provides a simple interface that can be effectively modified and operated by the undergraduate and graduate students who input the data. A responsive theme, which optimizes website rendering based on user device (computer, mobile device, phone), was utilized for greater portability and accessibility. Additional features, including interactive geographic maps, interactive 3D images of common species and a mobile app, are planned for development in later stages of this project.

The taxonomically arranged atlas, which provides information about ecology, stratigraphic range and identification information, forms the core of the Ordovician Atlas website. The atlas includes dedicated pages for common species and their associated higher taxa in the Cincinnatian strata. There are currently over 100 species and more than 250 higher taxa pages visible to the public; an additional 50 species are planned for development. Brief biological introductions and illustrated explanations of morphological terms are presented for each phylum. Each species page includes paleoecological data, taxonomic details, stratigraphic occurrences, tips for identification and published descriptions of the species in question (Fig. 3). The project team strives to generate content useful to both professional and avocational paleontologists. Thus, information that is critical for proper systematic treatment of these taxa but is less relevant to avocational paleontologists is included within drop down menus, such as taxonomic details including synonymy lists and common names, additional stratigraphic distribution information and transcriptions of published descriptions for each taxon. Genus and species pages include an "Identification in Hand Sample" section that provides a bulleted list of key diagnostic attributes of the taxon and annotated figures as an identification aid; a feature which is useful for fossil collectors at any level of expertise.

**Curriculum development**

In addition to creating an identification and systematics reference that is of educational value to teachers, we have developed comprehensive lesson plans for K-16 educators. To foster student understanding of observation-based data, lesson plans were developed following the 5E learning cycle construct (Bybee et al. 2006) that integrates scientific inquiry with literacy skills, while leveraging the local fossil record to promote engagement through place-based inquiry (Smith 2007). Lessons were aligned with the Next Generation Science Standards of the United States (NGSS Lead States 2013) and state science standards for Ohio. These lesson plans can be and have been modified for use in grade school to university classrooms as well as in public outreach programs with adults and children (Stigall et al. 2014). Early childhood engagement with fossils and place-based learning are cited as key ways to engage students in STEM (Science Technology and Mathematics) education, and these lesson plans leverage the local marine invertebrate fossils of the Cincinnati Arch region to explore concepts in diversity, ecology and evolution with ties to modern ecosystem functions.

## SUMMARY

The Ordovician Atlas of Ancient Life project provides a framework for transforming "dark" data into publically accessible raw data and information-rich resources via the www.OrdovicianAtlas.org website. When completed, this website will include stratigraphic, geographic and taxonomic information for over 150 of the most common species, representing at least seven animal phyla, preserved in the Late Ordovician formations in the Cincinnati, Ohio region, including members. These resources can

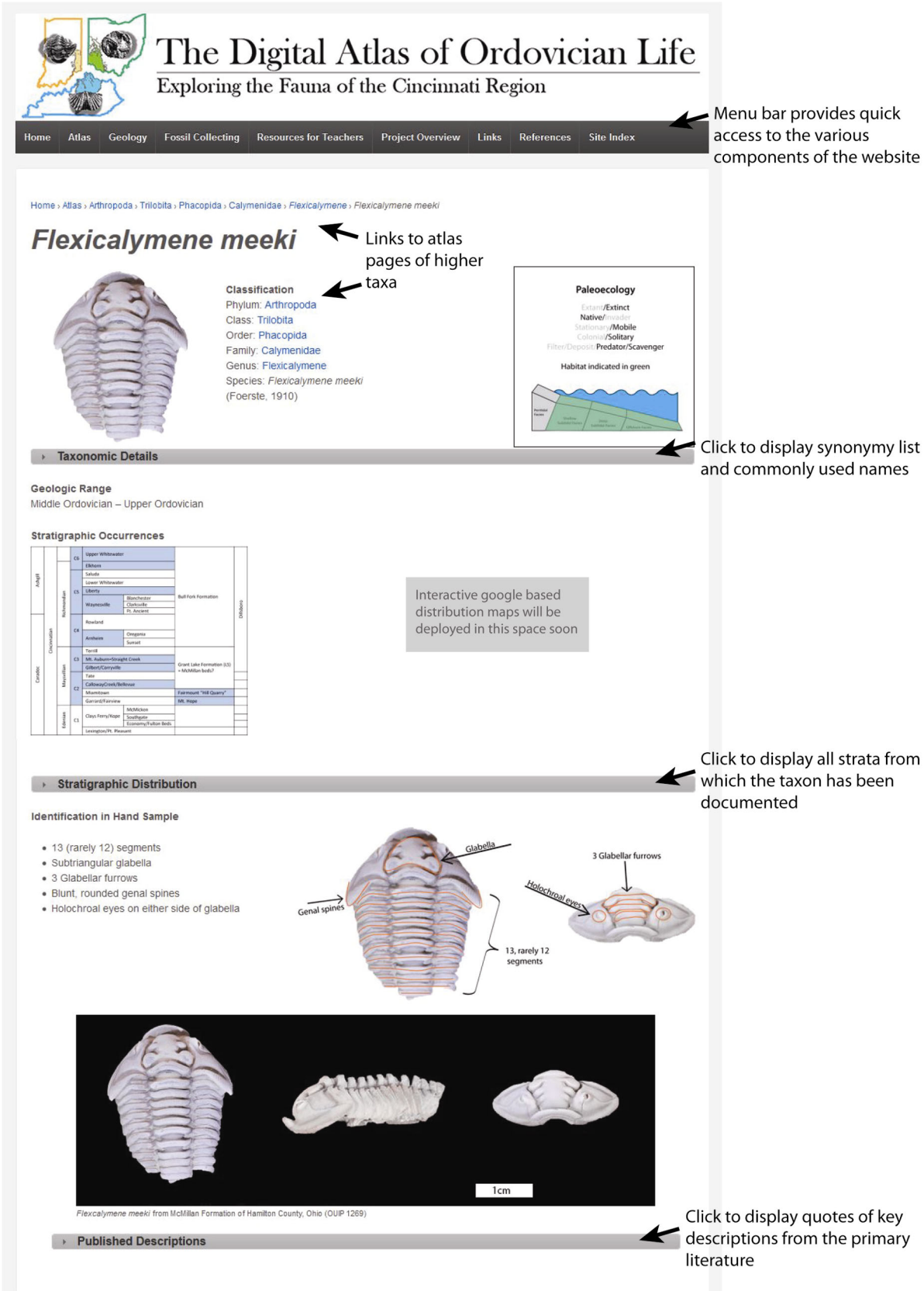


**Fig. 3.** Example atlas page of the calymenid trilobite *Flexicalymene meeki*. Key navigational features are annotated.

be applied to paleontological research, public engagement with fossil enthusiasts and directed educational goals within (and outside of) classroom settings.

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