DIGITIZING COLLECTIONS: EXPERIENCES FROM THE UNIVERSITY OF IOWA PALEONTOLOGY REPOSITORY DIGITIZATION PROJECT

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The University of Iowa Paleontology Repository is the fifth largest university fossil collection in the U.S., holding over 1 million specimens from all geologic ages, worldwide. A digitization project, funded by the National Science Foundation (DBI-0544235; $284,724), has made previously inaccessible collections available to researchers, including the Amoco Conodont Collection, the Paleozoic Coral Collection, the Neogene Coral Collection, the Trilobite Collection, the Amoco South Florida Collection, and the Micromammal Collection. Specimen data are captured using a Specify Biodiversity Collections Database and shared with the Paleontology Portal (www.paleoportal.org). Inventories of new, as yet uncatalogued, collections are available on the Paleontology Repository website (http://geoscience.clas.uiowa.edu/paleo/index.html), including the Crossman Crinoid Collection and the Pope Collection. Ancillary materials have been digitized and made available, including 1,316 Amoco conodont locality folders and 7,000 field photographs (funded in part by a University of Iowa Innovations in Instructional Computing award). Along with specimen samples, cores, and maps, these photographs form the basis for the Tropical America Virtual Field School, an on-line teaching resource drawing on collections made during 30 years of fieldwork in South Florida and the Caribbean. A database of specimen images is being developed, particularly useful for fragile specimens that cannot be loaned. Information for researchers is complemented with information for the public, using different methods of data access and presentation. The Fossils in My Back Yard website provides a user-friendly option for looking at the same specimen data without overwhelming the non-scientist.

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Introduction

Following the introduction of computers into museum collection management in the 1960s (Misunas and Urban 2007), a major goal has been to document or catalogue collections electronically and make that information available to the public and researchers. The importance of digitizing collections is illustrated by the U. S. National Science Foundation's (NSF) October 2010 announcement of a new program, Advancing Digitization of Biological Collections (ADBC), "to create a national resource of digital data documenting existing biological collections and to advance scientific knowledge by improving access to digitized information (including images) residing in vouchered scientific collections across the United States" (NSF 2010). The program was developed in response to community initiatives including the Interagency Working Group on Scientific Collections (National Science Technology Council 2009), The NSF Scientific Collections Survey (Flattau *et al.* 2008) and a 10-year strategic plan produced by the Network Integrated Biocollections Alliance (NIBA) (NIBA 2010). The University of Iowa (UI) Paleontology Repository has recently completed a digitization project funded by the National Science Foundation's Improvements to Biological Research Collections program and now provides over 50,000 electronic records on-line via the Paleontology Portal and various in-house website resources (see the UI Paleontology Repository website at http://geoscience.clas.uiowa.edu/paleo/index.html). This effort can be used to illustrate the type of digitization projects that can be undertaken for a sizeable research collection with a small staff and budget.

The UI Paleontology Repository

The UI Paleontology Repository began as the State University of Iowa Cabinet of Natural History, created by an 1855 Act of Iowa General Assembly to house natural history specimens collected by the early State Surveys of Iowa. Zoology and botany collections formerly in the Cabinet are now under the responsibility of the UI Museum of Natural History and the Iowa State University Ada Hayden Herbarium respectively. The UI Paleontology Repository houses over one-million specimens and is the fifth largest university fossil collection in the U.S (Allmon and White 2000, table 2). The collection focuses on Paleozoic marine invertebrates, microfossils, Quaternary mammals, and Neogene corals, and includes over 25,000 type and referred specimens.

The UI Paleontology Repository is administered and supported by the UI Department of Geoscience in the College of Liberal Arts and Sciences which funds one full-time, permanent, collections manager and provides space, facilities, funds for incidental expenses, and office support. Curatorial supplies, student stipends, outreach materials and professional travel are funded through a quasi-endowment that distributes approximately $2,500 a year. Undergraduate student interns from the Museum Studies Certificate Program support semester-long collection-based projects. Longer-term assistance with larger projects requires additional funding from UI initiatives or external sources. In 2006, the UI Paleontology Repository was awarded a National Science Foundation Grant to digitize priority collections (DBI-0544235 3 yrs., $284,724); "Computerization of the University of Iowa Paleontology Repository" (PI = A. F. Budd, Co-PIs = J. M. Adrain, T. S. Adrain, C. A. Brochu). The goals of this project were to:

- Prioritize collections at risk from losing associated data
- Make collections data accessible on the Internet
- Increase research access to collections
- Make digital images available on-line for researchers and fossil enthusiasts
- Digitally preserve associated printed documentation
- Develop web-based education tools
- Provide training opportunities for undergraduate, graduate and Museum Studies students

Supplementary funding was awarded to create a public-friendly website: "Fossils in My Back Yard" (Research Experiences for Undergraduates Supplement to National Science Foundation Grant DBI-0544235 (1 yr., $13,303)); and to digitize 7,000 field photographs for the development of an interactive educational resource: "Tropical America Virtual Field School" (University of Iowa Innovations in Instructional Computing Award (1 yr., $17,200)).

Digitization: what, why, and how?

A simple definition of digitization is the transcription of information into a digital form so that it can be directly processed by a computer. In a paleontology collection, the data in question include the specimen itself, any recorded or inferred information relating to a specimen (locality, stratigraphy, identification, citations, associated people (collector/donor) etc.), and ancillary materials of archival and or research use, e.g., labels, field notebooks, locality files, photographs, original digital databases or spreadsheets, research data-sets, measurements and analyses.

Like many long-standing collections, the UI Paleontology Repository has a backlog of specimens to catalogue. Of the one-million-plus specimens, 125,996 specimens/lots have been assigned catalogue numbers and either catalogued in a card index system (late 1800s to late 1900s) or in a computer database (since the 1980s). This backlog is due to the large size of the collection and the minimal and intermittent availability of staff associated with collection cataloguing throughout its history. The importance of digitizing paleontology collections is illustrated by the benefits:

- Preservation of associated data at the specimen or lot level
- Documentation of collection knowledge residing with individual staff, reducing its loss on staff turnover
- Development of a collection inventory, allowing staff to become more familiar with the material
- Improved efficiency in searching the collection to answer research and public enquiries
- Increased access to the collection both physically and on-line, which increases research and educational use and development of the collection, and helps justify institutional support and the cost of maintenance

Digitization can take two forms: preservation digitization and digital representation or access. Preservation digitization adheres to recognized standards and procedures for archival quality digitization. For example, preservation digitization of a printed photograph would require the original to be scanned in 8-bit grayscale or 24-bit color, 3,000 to 5,000 pixels across the long dimension, at 100% size,

and saved as a TIFF. An access copy can be 8-bit grayscale or 24-bit color, 150 dpi and 600 pixels across the long dimension, and saved as a JPEG (Western States Digital Standards Group 2003). A general rule is to produce archival-quality digital resources where possible, with lower resolution access formats if necessary. The standard of digitization employed depends on the intended use and available resources. Digitization methods used in the UI Paleontology Repository are outlined below.

1) Recording specimen data in a relational, searchable database including transcribing data from written records such as labels and field notebooks, and editing and reformatting copies of original databases to integrate with the specimen catalogue.

The UI Paleontology Repository currently uses Specify Biodiversity Collections Software (v. 5.2.3) to record specimen data (Figure 1). It is designed by the Specify Software Laboratory at the Biodiversity Research Center, University of Kansas and is distributed free of charge to collaborating non-profit institutions. Specify has free software upgrades and support, and is widely used in natural history collections (274 collections in 16 countries - see http://specifysoftware.org). Specify is adaptable to diverse natural history collections and can be configured for multiple data portals for world-wide access for the scientific community. Specimen data are transcribed from written records such as specimen labels, field notebooks and publications, or, if held in a pre-existing database, edited and reformatted for integration with the Specify collections database. In many cases abbreviated data have to be interpreted, or old stratigraphic terms updated. The digital record is the interpretation of the available data, and this is a major reason for preserving the original documentation in case of error.

2) Making digital images of specimens.

Specimens are photographed using a compact digital Nikon Coolpix 5400. Each taxon is photographed according to standard views in research publications, often from multiple angles to produce a single collage image. Image resolution and format depend on the camera's optical and pixel resolution, but in general the initial image should be an uncompressed, lossless format like TIFF rather than a lossy (compressed) format like JPEG, with a minimum 12M (megapixel) size, e.g. 4000 x 3000 pixels. A digital Single Lens Reflex camera with specific lenses for different image requirements will provide a higher

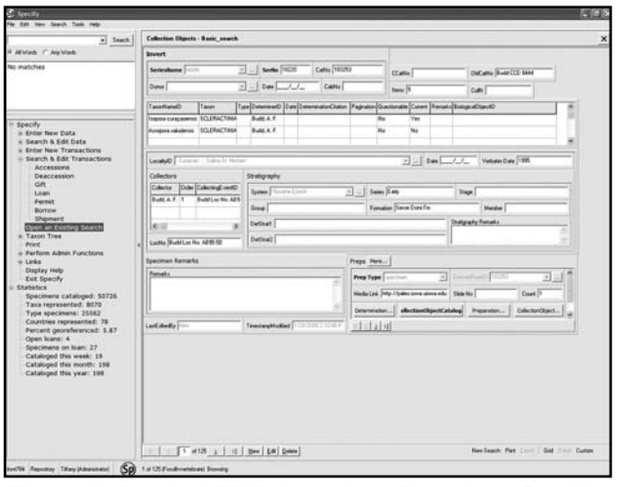

Figure 1. A typical UI Paleontology Repository Specify collections database data entry form.

quality image, but is more expensive than a compact camera. The purpose of the project and available budget will dictate what type of camera is required. In our case the images are intended as digital representations of the specimens to better inform researchers about the collections and their research potential. They are not intended to replace the specimen itself or to substitute for publication quality images.

Digital images are edited in Adobe Photoshop to a consistent format with uniform black background, scale bar and label (Figure 2), and saved as JPEG images of different sizes (150 dpi and 600 pixels

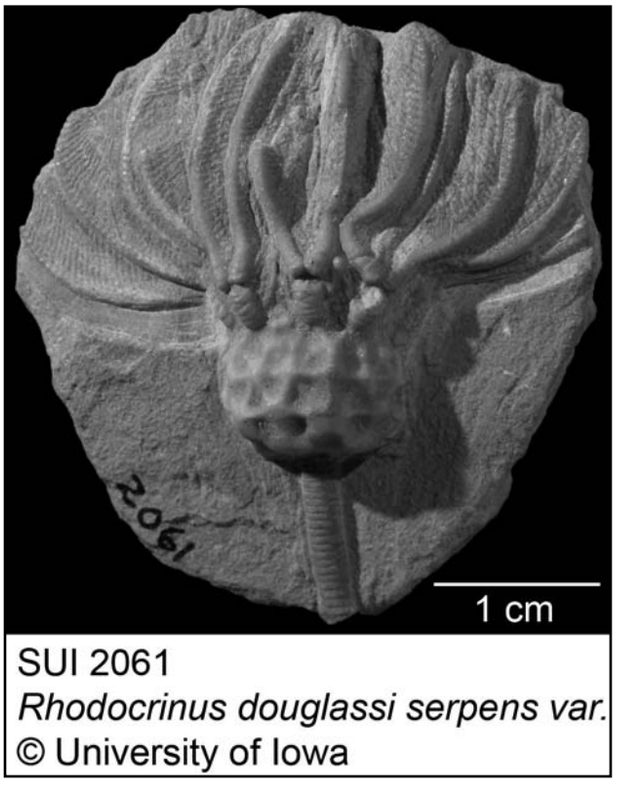

Figure 2. A typical digitized specimen image, (shown in colour on-line).

along the long axis for larger image, and 72 dpi and 150 pixels along the long axis for a thumbnail image). All JPEG images are stored on a server so they can be accessed via the Internet. The original digital image (high resolution, unedited TIFF) is archived on CD-ROM and on external hard drives. Image metadata (specimen catalogue number, taxon, identification, type status, image resolution, camera setting, specimen view, specimen storage location, copyright or use restrictions, date photographed, photographer's name) are recorded for each edited image. The image file name records the specimen catalogue number for easy reconciling and sorting e.g. 009183_tb.jpg. The URL of the image on the server is entered in the associated specimen database record for each image. Researchers who borrow or deposit cited material are encouraged to provide digital images of the specimens.

3) Digitizing photographic prints and written records such as labels and field notebooks.

In general, photographs, handwritten specimen labels and field notebooks are scanned with an Epson Perfection V700 Photo flat bed scanner to preservation standards (Western States Digital Standards Group 2003, FADGI 2010). Some documents, such as the Amoco Conodont Collection locality files (see below) are scanned using a Fujitsu ScanSnap color image sheet feeder scanner for digital representation with the purpose of making them web-accessible. These scanned documents are saved as PDF files, placed on the server, and the URL entered in the relevant specimen records in the Specify collections database. Original photos and documents are cross-referenced with associated specimens and archived, i.e., placed in archival storage media and recorded in an archive finding aid (a simple list of archive box contents) available on-line.

Selecting collections to digitize

With a large uncatalogued backlog, it is more practical to identify discrete sub-collections that can be assessed and prioritized for manageable digitization projects, than to try to tackle the entire collection in one project. At the UI Paleontology Repository, selecting sub-collections begins with a collection survey to determine curation level (Adrain *et al.* 2006) and the amount of work and time needed to prepare for digitization at specimen or lot level. The criteria used to prioritize sub-collections vary and may be numerous according to the digitization project goals. Criteria used to select sub-collections for digitization in the UI Paleontology Repository include:

- Uncatalogued specimens with good quality data available, especially where data are separated from the collection, not easily located, and in danger of becoming disassociated
- Specimens and data unknown to the research community but with potential research value, either new bulk acquisitions or old collections fallen out of research memory
- Specimen data in danger of deterioration, including data in old format databases on obsolete media and historic labels deteriorating physically (for example, due to abrasion from specimens), or chemically (for example, acidic paper becoming brittle)
- Bulk acquisitions including large bequests and field collections that pose a curation challenge beyond normal operating capacity and that are creating a backlog because of their size
- University faculty collections deposited at retirement requiring immediate documentation before the researcher leaves permanently
- Collections with associated data such as digital images or analytical data that would enhance research resources beyond digitizing specimen-based information
- The need to provide access to specimens too fragile to loan, for example silicified trilobites, by making research quality photographs available

Collections selected for digitization

The collections prioritized for digitization can be divided into three categories:

- Bulk donations of large research collections, with continuing research access demand, accompanied by a wealth of data in multiple formats, e.g. Amoco Conodont Collection, Amoco South Florida Collection
- Bulk donations of large private collections of high potential research value, unknown to the scientific community, e.g. Pope Collection of Iowa Pennsylvanian marine invertebrates, Crossman Collection of US Midwest echinoderms
- Previously curated collections that can be enhanced easily for digitization and on-line access, e.g., trilobite, coral, micromammal and type collections

The Amoco Conodont Collection of about 25,000 cavity slides was donated by BP Amoco in 1998, along with a Microsoft Access database, and over one thousand printed files of locality data (Figure 3). Other collections including foraminifera, modern pollen and macrofossils were distributed to various institutions (Groves and Miller 2000), allowing for potential future collaboration. The database was in danger of corruption and/or loss, and the unique

Figure 3. The Amoco Conodont Collection: specimens and ancillary materials.

Figure 4. The Amoco South Florida Collection: specimen samples and ancillary materials.

printed locality files, which pertain also to the other Amoco collections, were routinely sent on loan and stored away from the conodont collection in an "off-site" facility, putting them at risk of loss or disassociation. The collection was made a priority for research and collaboration potential and data capture needs. The locality folders were scanned for web-access rather than archival preservation because of the amount of time and digital space preservation scanning would require. Material was scanned with the sheet feeder scanner on a "normal" quality setting and the contents of each locality folder saved in PDF format and made available on-line. Oversized material (e.g. well log and continuous-sheet computer printouts) was partially scanned with a flatbed scanner and marked with a footnote requesting the researcher to contact the UI Paleontology Repository for more information. Each specimen cavity slide containing one or more specimens was reconciled against the accompanying database which was then edited in preparation for transfer to the Specify collections database.

The Amoco South Florida Collection of Holocene marine invertebrates was collected during 30 years of fieldwork by UI faculty and colleagues as part of the Amoco South Florida Carbonate Seminar. The collection consists of meticulously sorted samples, cores, printed locality and species files, and a wealth of teaching materials, including maps, identification boards, laboratory manuals and 7,000 field photographs including aerial and underwater views (Figure 4). This collection was prioritized for digitization for its potential as a teaching resource and because its multiple components stored in various places could be disassociated over time. Again, accompanying data were in an old format Microsoft Access database on dated media. As well as digitizing specimen lot data in the Specify collections database, research datasets were enhanced with data from lab manuals and transferred to an Oracle database for development of interactive web resources, and the 35 mm slide field photographs were cleaned and scanned commercially to archival quality.

Two large private donations were included in the digitization project so that inventories might be made available before the collections are fully curated. The Pope Collection contains 900 lots of Pennsylvanian marine invertebrates from Iowa localities that are now inaccessible. The Crossman collection consists of 10 tons of US Midwest crinoid material bequeathed by local fossil enthusiast Glenn Crossman in 2002. Much of the material is unidentified making full curation difficult without specialist knowledge. However, it is still important to digitize such collections so that the research community is aware of their existence, either by publishing collection metadata (age, formations, taxa, collector, and localities) or a more detailed, if incomplete, specimen or lot inventory on-line.

Type specimens, although the most well-known and best researched of the UI Paleontology Repository collections, provide excellent material for image digitizing because of good preservation and preparation and existing on-line data access. Holotype specimens were photographed according to staff technical abilities. Two UI researchers (Adrain and Budd) are amassing large trilobite and Neogene coral research collections respectively, accompanied by high quality digital research images. These images are formatted and edited according to UI Paleontology Repository standards outlined above, cross referenced with the specimen's Specify collections database record and made available on-line. Many coral

specimens are figured and cited on the Neogene Marine Biota of Tropical America (NMITA) website (http://nmita.iowa.uiowa.edu/), providing an opportunity to add existing on-line resources to the specimen record. The trilobite specimens are microscopic silicified specimens that cannot be mailed on loan and can only be loaned to researchers experienced in handling silicified material. Making high quality images of these specimens available will enable research access without risk to the specimens. The micromammal collection was also selected for digitization because it was already well curated and described in unpublished site reports, but was not digitally captured or available on-line. The Paleozoic coral collection is an underutilized resource that has been reorganized, assessed by a visiting specialist, and improved under a previous NSF-supported project (DBI-0096768 "Reorganization of the University of Iowa Paleontology Repository," Budd, J. Adrain, J. Golden). Historic labels had been cleaned, scanned and preserved under polyethylene sheets. This was a logical collection to continue curating to the next stage (specimen cataloguing) allowing it to be made accessible on-line. Based on a practice of colleagues at the UI Museum of Natural History, the next goal is to photograph entire drawers of specimens rather than individuals and cross-reference these digital images with specimen records on-line.

Providing access to the digital collections

In addition to capturing data, one of the goals of digitizing these collections was to make them available on the Internet. The variety of digitized material and types of data available enabled several different means of access and use.

The Specify collections database allows users to share data with web-based data portals such as the Paleontology Portal (www.paleoportal.org) and the Global Biodiversity Information Facility (www.gbif.org), where researchers can search collection databases of multiple institutions at the same time, thus increasing exposure of collections data. Specify's web query component also allows the creation of collection/institution-specific on-line queries that can provide images, links to specimen-related documents such as the Amoco locality PDF files, and links to other websites that have relevant specimen information, such as the NMITA website. This type of data access is aimed more towards researchers than members of the public. The UI Museum Studies Program's Collection Care and Management class looks at on-line museum databases as a class assignment and in the last three years has consistently determined natural history collections more difficult to access on-line compared to art museums and social history museums. Usually specific criteria, such as species name, are required to search a natural history collections database, and the result is usually a spreadsheet of data with or without images. Non-specialist members of the public may gain more enjoyment from alternative methods of data presentation.

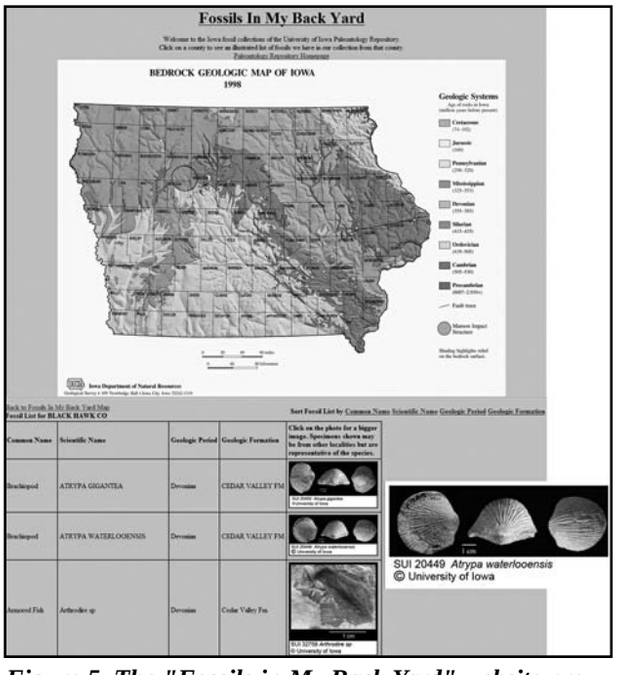

Figure 5. The "Fossils in My Back Yard" website provides public-friendly access to collection data.

A broader impact goal of the UI Paleontology Repository's digitization project was to widen public access to the on-line collections. A website called "Fossils in My Back Yard" was developed to allow visitors to more easily browse fossils from Iowa in the collections. A digital version of the Iowa bedrock map produced by the Iowa Geological and Water Survey invites visitors to click on a county to see an illustrated list of fossil species from that county (Figure 5). Each county is an html hotspot link that runs an XML query based on the county name. A data subset from the Specify collections database was loaded into a very simple Oracle database that can be updated easily using Microsoft Access. Representative species images, usually of the holotype, are used instead of individual specimen images. The query results are an illustrated list of species from individual Iowa counties rather than a list of specimens to avoid repetition and overwhelming the user. Members of the public are using the website to identify their own fossil finds. A future goal will be to expand the website to include more fossils and modern plants and animals found in each county in

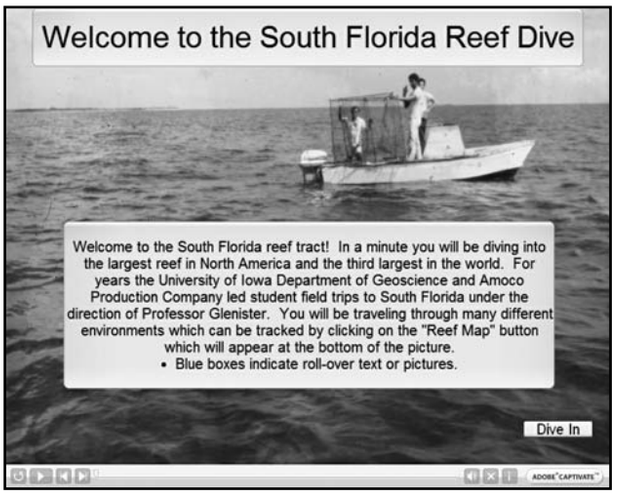

Figure 6. Ancillary materials, in this case field photographs of a reef dive, are used to create a teaching resource.

collaboration with other natural history collections in Iowa.

Materials and data from the Amoco South Florida Collection are being used to develop a new educational resource, the Tropical America Virtual Field School, initially for UI undergraduate classes, but accessible on-line in the future. Some of the 7,000 scanned images are being used to create interactive slideshows or "virtual tours" of a reef dive (Figure 6) and an aerial tour of South Florida where students can navigate through the slideshow and click on various features for information, with a short quiz at the end to evaluate teaching effectiveness. A digitized map of mollusk biofacies and a related query form provide access to specimen sample data using XML protocols. Specimens from the reference collection are being used to illustrate an identification key and exercise.

Key considerations for planning a digitization project

1) State of the existing data

One digitization goal was to reformat existing databases by parsing the data into relevant fields and bulk-migrating the data into the Specify collections database. Unfortunately, both the Amoco South Florida Collection and Amoco Condont Collection databases showed major discrepancies when compared with the physical collections. The Amoco Conodont Collection database contained minimal stratigraphic information requiring essential data to be extracted from the printed locality folders with the possible introduction of human error in interpretation. The dataset contained over 5,000 entries for slides not present in the UI Paleontology Repository collection, which in turn contained over 5,000 slides that were not in the database. Data are now being entered into the Specify collections database manually rather than bulk-migrated and are meticulously checked against each slide and locality folder.

2) People and training

Extensive digitization projects require IT support with experience in writing dynamic queries, installing and maintaining database systems, joining data portals, and creating web interactivity. If necessary, funding should be included for IT support and a dedicated student IT assistant for the project duration. A large digitization project requires a team of assistants competent at entering and interpreting data. Although the UI Paleontology Repository's digitization project funded only one graduate student to assist with data entry, many more undergraduate students were employed - eighteen students in total over four years, in addition to students working on other projects. Student training and supervision became the most time-consuming tasks for collections staff compared to development of collection tasks. Staff management training is recommended for those unfamiliar with working with a large number of students or volunteers. Collaboration with colleagues in other departments or institutions is recommended. The UI Libraries staff provided invaluable advice and assistance with digitizing and preserving archive material. A UI Libraries initiative, the Iowa Digital Library, will provide additional web access to images.

3) Equipment

A team of assistants requires extra computer hardware and software for data entry and image formatting, as well as additional office furniture and workspace. The increased volume of digital material required two servers to be purchased for the Specify database, the images and scanned document files and the UI Paleontology Repository website. Photographic equipment was not high-tech or expensive because of the anticipated wear and tear on the equipment due to the number of users, but it is worth investing in equipment that can provide archival quality digitization if necessary.

4) Physical access to the collections

Physically accessing backlog collections is sometimes an issue. The Pope Collection was still in original containers (Figure 7), and the Crossman Collection had to be relocated to a different building and reorganized. Basic curation issues should be addressed either before the digitization project begins or as part of the project.

Figure 7. The Pope Collection in original storage. Physical access should be addressed before digitization begins.

5) Task analysis and time management metrics

You should be realistic about the time required to complete the digitization project. Research the average data entry time per record and the number of records anticipated, or the time required for scanning or photographing and image processing at different resolutions. Be aware that data entry also involves data gathering and may require more involved research.

Pros and cons of digitizing

There are pros and cons to every digitization project. Digitization is time-consuming, but data-cleaning of existing databases is well-worth the cost in time to make sure that data are in the correct format and are accurate before they are finally entered. With a large team with twice-yearly turnover, data entry consistency can be a problem. Make sure that data entry instructions are clear and readily available. Specify Biodiversity Collections Software provides custom field notes to display data dictionary and terminology control information. Specimen records must be checked for consistency in data entry. Frequently check that procedures for photography and scanning are being followed and metadata recorded as specified. Sometimes accidental changes become permanent. Be aware that the more you interact with a collection, the more your tasks will expand. Determine whether project time management will allow you to tackle collection problems or needs as they arise, or, if they must wait until the end of the project, how you will track tasks that need to be done.

From a collection manager's view, a digitization project is extraordinarily helpful in getting to know the collection and increasing the ability to aid collection users. In addition to providing a collection inventory, a digitization project can include ancillary materials and protect the link between materials often stored apart as well as the link between specimens and associated data. A digitization project can result in the physical preservation of ancillary data as well as the digital preservation, as the value of ancillary materials is revealed. A digitization project should increase collection research use. Currently 6% of UI Paleontology Repository website visitors come via the Paleontology Portal (Google Analytics data). Collection statistics including loan requests and specimen citations will be monitored to gauge project success and the need for further announcements or information dissemination to the scientific community. As well as straightforward specimen data access, digitizing collections can provide a base for multiple spin-off projects like the Tropical America Virtual Field School and Fossils in My Back Yard websites. Finally, digitization can increase public access and encourage interaction and communication.

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