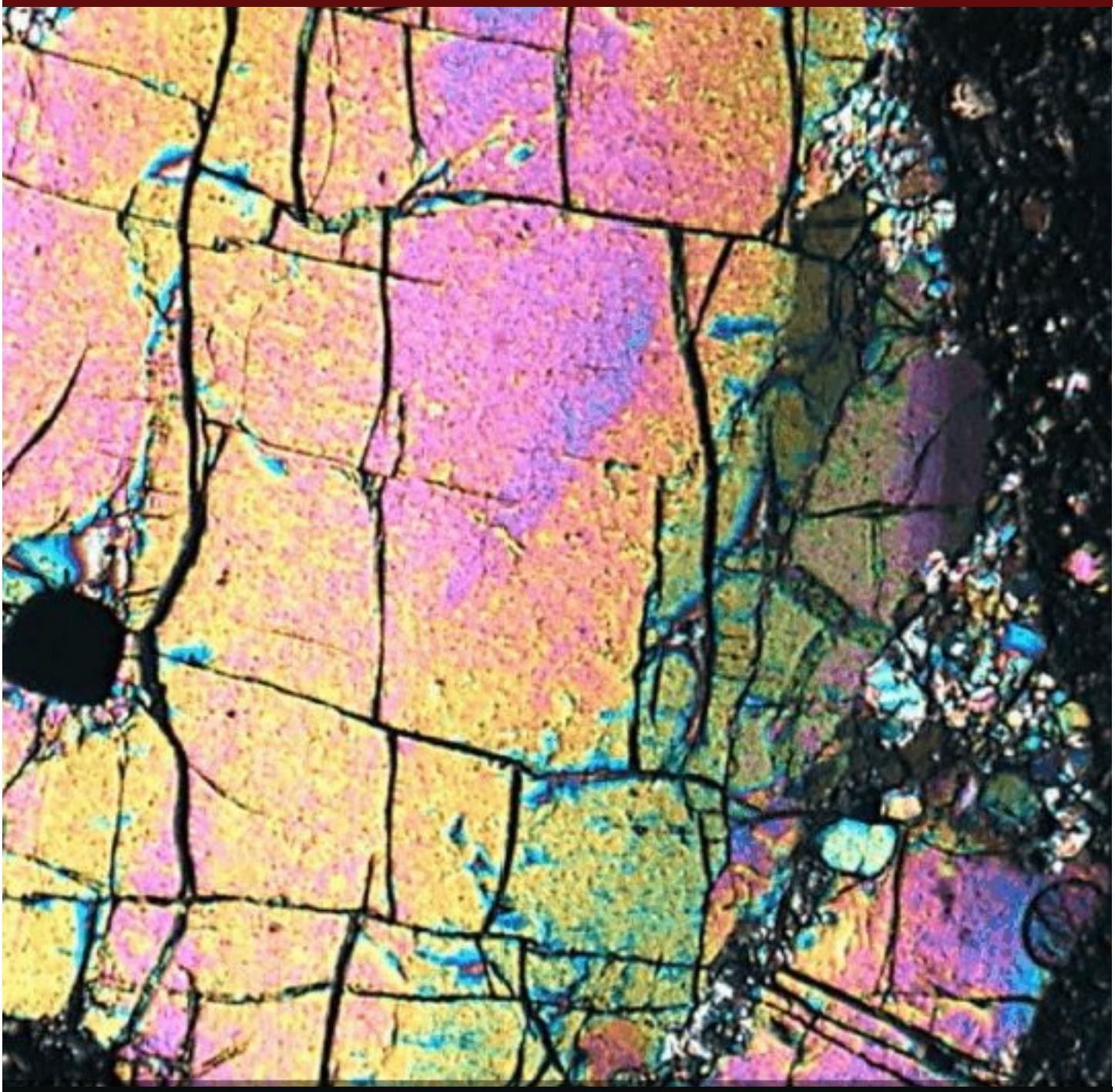
Web-Accessible Training in Thin-Section Petrography of Cultural Material | 2010-05

University of Delaware



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WEB-ACCESSIBLE TRAINING
IN THIN-SECTION PETROGRAPHY OF CULTURAL MATERIALS

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Executive Summary

Thin-section petrography is a technique used to examine small samples of stone, ceramics, or other mineral-containing materials under a polarized light microscope in order to characterize the material and/or fabrication technology and to answer a wide range of questions relevant to issues in historic preservation, conservation, archaeology, or anthropology. Contributing to NCPTT's 2007 *Preserve America* mandate to serve as a national clearinghouse of preservation technologies, this tutorial provides a free interactive web-accessible workshop on thin-section petrography of cultural materials. It includes eleven illustrated chapters with text and audio background, each ending with self-quizzes. These chapters begin with the basics of polarized light microscopy. An introduction explains what petrographic thin sections are and how they are made, then chapters continue on plane polarized light, crossed polarized light, and identifying common rock-forming minerals. The next seven chapters explore how thin-section petrography can be used to better understand and interpret cultural materials. Three chapters focus on stone (igneous, including both volcanic and plutonic; sedimentary, including both detrital and chemically precipitated; and metamorphic). Another three chapters focus on pottery (looking at low-fired pottery; high-fired pottery; and identifying pottery fabrication and decoration methods). The last chapter incorporates other (non-pottery) ceramic materials such as brick and tile, and unfired clay materials such as cuneiform tablets, clay sculptures, and clay core materials inside bronzes. Examples of the use of digital image analysis to replace traditional methods for obtaining quantitative data are incorporated where appropriate. Use of the open-source Python programming language-based Ren'Py visual novel engine permits the tutorial to be freely downloaded by users with files readable in Windows, Mac, or Linux platforms.

Introduction

In thin-section petrography, a small sample is taken from an object or building material made of stone, ceramic, or other mineral-containing material. The sample is mounted onto a glass slide using an epoxy with a refractive index similar to that of quartz, the most common mineral found in almost all earth-based materials. The sample is then ground down to a thickness of 30 microns, giving minerals a standard appearance in polarized light. Published tables and descriptions of mineral optics help the researcher to identify the minerals that are present, and to study many other characteristics of minerals and earth-based materials.

Many research and treatment projects for stone and ceramic cultural materials could be improved by use of thin-section petrography. Although many other analytical methods are also useful, thin-section petrography remains a significant tool with a long history of proven applications, capable of providing unique information helpful for identifying minerals, textures, materials, fabrication technology, and possible object function; conducting provenance or deterioration studies; and assessing the effects of preservation strategies or conservation treatments. It is a relatively inexpensive technology, requiring primarily a polarizing light microscope. However, specialized expertise is required in order to use the technique effectively.

Introductory books on polarized light microscopy are available, as are reference works and atlases of geological materials in thin section. However, without background training it is difficult to learn the technique independently, especially when working with cultural materials. Many university geology departments offer courses in mineralogy and petrography that incorporate laboratory training. However, these are often restricted to students in departmental programs, are focused on geological problems, and require extensive in-class time.

This goal of this project was to develop a tutorial that could serve as an additional aid to preservation professionals trying to gain expertise in thin-section petrography. The tutorial consists of a set of interactive web-accessible training chapters providing some practical experience in viewing petrographic thin sections of a variety of cultural materials. The primary audience consists of preservation and conservation professionals and archaeologists. We assume that users need to quickly learn enough of the basics to be able to apply their knowledge, and that they are interested specifically in cultural materials and preservation problems. We focus on stone, ceramic, and clay materials in this tutorial. Cementitious materials, while also important to many preservation and archaeological research questions, are a highly specialized subject beyond the scope of this tutorial and are deserving of their own dedicated tutorial.

The chapters include images of some of the objects and buildings sampled for thin sections. Many images of thin sections are shown in plane and crossed polarized light, often dissolving from one into the other, to provide a virtual laboratory experience. A character designed for this tutorial (named Crystal) points out specific features in the thin sections that are discussed in the accompanying text, and is intended to maintain interest and attention. An audio sound track, with music selected for each chapter that gives some of the feeling of the type of material covered in that chapter, is intended to provide interest and mood. Short self-quizzes at the end of each chapter test whether or not some of the main information has been retained.

The tutorial is freely accessible as a download via the web from the Center for Historic Architecture and Design's Laboratory for Analysis of Cultural Materials web site, and can also be posted by NCPTT, to contribute to it's 2007 *Preserve America* mandate to serve as a national clearinghouse of preservation technologies. The open-source Python programming language-

based Ren'Py visual novel engine provides files readable in Windows, Mac, or Linux environments. The ability to download the tutorial for use on any personal computer is preferable to a tutorial that must be run on the web (since links often disappear) or which require a program such as Flash that cannot be run on all platforms. No proprietary products must be purchased by users in order to run the tutorial.

Thin-section petrography is a widely-used technology with applications that cut across many NCPTT research priorities. This web-accessible training in practical use of the technique has the potential to serve a large number of individuals, not just those who can afford to travel to in-person workshops. Users will be able to work through the material at their own pace, varying the time they spend on any particular topic according to their own needs or interests. This tutorial will help to fill a current gap in training materials for cultural heritage professionals or students who want to make use of thin-section petrography in their work.

Methods and Materials

Thin Sections Selected

Chandra Reedy wrote the text for all of the chapters and selected the images to use. Many of the thin section images came from a comprehensive book she published with Archetype Publications in London, titled *Thin-Section Petrography of Stone and Ceramic Cultural Materials* (2008). The 288 page book is accompanied by a CD-ROM of interactive images (viewable at http://www.udel.edu/CHAD/petrography/). Those images and that text together provided a good background and base of material for the training chapters, which then build on and leverage those products.

In addition, she has published over twenty-five journal articles and book chapters that include thin-section analysis of cultural materials. Some of these papers are review articles that discuss methodological advances and the range of research questions in cultural heritage studies that thin-section work can address; examples are "Petrographic Analysis of Casting Core Materials for Provenance Studies of Copper Alloy Sculptures," in *Archeomaterials*, Volume 6, Number 2, pages 121-163 (1991) and "Thin Section Petrography in Studies of Cultural Materials," in *Journal of the American Institute for Conservation*, Volume 33, Number 2, pages 115-129 (1994). Thin section images and case studies were also included from many of those projects, including stone, terracotta, and clay materials analyses reported in Reedy 1987, 1992, 1996, 1997a, 1997b, 1997c, 2006a, and Boxt and Reedy 1985.

In 2000 she began to explore the potential of new methods of digital image analysis to thin-section petrography. Her work in this area has resulted in a series of papers that focus on image analysis applications for a variety of specific research problems with cultural materials. She conducted research on the many image analysis packages available, analyzing them for suitability with research problems in our field as well as for ease of use and widespread utility for addressing questions in archaeology, conservation, and preservation. Some of the results of that work are incorporated into this tutorial as examples of situations where digital image analysis is appropriate for obtaining quantitative information from petrographic thin sections. Among the papers she authored on this subject is "Review of Digital Image Analysis of Petrographic Thin Sections in Conservation Research," *Journal of the American Institute for Conservation*, Volume 45, Number 2, pages 127-146 (2006b), as well as Goins and Reedy 2000, Reedy and Kamboj 2003, and Reedy and Meyers 2007; the tutorial also draws on that work.

Educational Approach

Chandra Reedy brought extensive teaching experience to help her in designing the education approach used for the web-accessible training chapters, in order to convey the basic principles of polarized light, thin-section petrography, and applications to cultural materials. She became an Assistant Professor at the University of Delaware in 1989, was promoted to Associate Professor with tenure in 1994, and to full Professor in 2001. Currently her primary appointment is in the Center for Historic Architecture and Design, where she teaches students in the M.A. and Certificate programs in Historic Preservation.

She also has experience developing and teaching short-term workshops, which are more similar to this tutorial than are full-semester classes. She was the instructor or co-instructor for fifteen workshops on various topics in cultural heritage and preservation research for the American Institute for Conservation, National Park Service, National Center for Preservation Technology and Training, Colonial Williamsburg Foundation, Washington Conservation Guild, Image Permanence Institute, and the Library of Congress; and, most relevant, in summer 2009 offered a workshop on thin-section petrography of cultural materials at the Freer Gallery of Art in Washington, DC. For this workshop for the Freer, she developed and tested much of the text used in this tutorial, tested the image sequences to use, and identified features to be pointed out and discussed as part of a virtual laboratory learning experience.

As a Professor at the University of Delaware, she has taught thin-section petrography of cultural materials. Most recently, she offered a course cross-listed in Art Conservation, Anthropology, and Museum Studies on “Technology of Cultural Materials: Ceramics and Glass.” As part of that course, she introduces the basic methodology of thin-section petrography,

identification of minerals in plane polarized and crossed polarized light, and ceramic petrography. The course included an online web-based virtual laboratory experience. Thin-section petrography for identification of stone and for studying its weathering characteristics is a primary focus in her course "Science and the Detection of Art Forgeries" which is taught completely online. Other courses where she has incorporated thin-section petrography include a graduate course in "Traditional Architectural Materials" for the Center for Historic Architecture and Design, and lectures on science for objects conservation for the Art Conservation Department. All of these courses provided additional background material, case studies, and teaching approaches that were used in designing this tutorial.

Dr. Reedy also brought extensive experience developing and using educational technology, much of which was applied to the development of this tutorial. As a UD Online faculty member, she has taught online courses for over nine years. She is the winner of the Exemplary Application of Teaching Technology Award from University of Delaware's IT-User Services (2005) and winner of the Innovative Teaching Award in Distance Education from the university (2004). Since 1997 she has used a web-based learning management system for face-to-face courses as well as for online classes, designing and incorporating a wide range of interactive tutorials and other multi-media chapters, including those that incorporate Flash, and Captivate tutorials. She also developed an interactive CD-ROM to accompany her forthcoming book, "Thin-Section Petrography of Stone and Ceramic Cultural Materials." Utilizing Flash technology, the CD enables users to view all of the materials discussed in the book in both plane polarized and cross polarized light. All of these experiences were drawn on for decisions about how to best present material in this tutorial.

Ren'Py Visual Novel Engine

Ren'Py is a free, cross-platform visual novel engine designed to incorporate words, images, and sounds into computer-based stories or simulation games (www.renpy.org). It uses a script with tutorials and other support to help non-programmer users to be able to make their own visual novels. Its Python support (www.python.org) permits more complex simulation games as well. Hundreds of novels and simulation games have been made using Ren'Py, and are available at www.games.renpy.org.

While Ren'Py has been used often for visual storytelling, simulation games, and has even been used as a museum kiosk platform called the Storytelling Station (Oppenneer 2010), it has not been used before for this type of specialized educational tutorial. Therefore, for creative enhancements of the Ren'Py tool in applications specific to the material of this tutorial, Python programmer Dr. Terry J. Reedy was important to the success of the project. He has wide experience in delivering products for the cultural heritage field, as co-author with C. Reedy on two books published by the Getty Conservation Institute (*Statistical Analysis in Art Conservation Research*, 1988, and *Principles of Experimental Design for Art Conservation Research*, 1992), as well as papers in journals such as *Archaeometry*, *World Archaeology*, *American Anthropologist*, and in several *Materials Issues in Art and Archaeology* volumes. He is currently writing a book titled *Exploring Algorithms, Recursion, Iteration, and Inductive Structures* using Python as the algorithm language. As a result, he brought expertise with Python programming and also strong familiarity with the subject matter of the tutorial project.

Images, Graphics, and Music

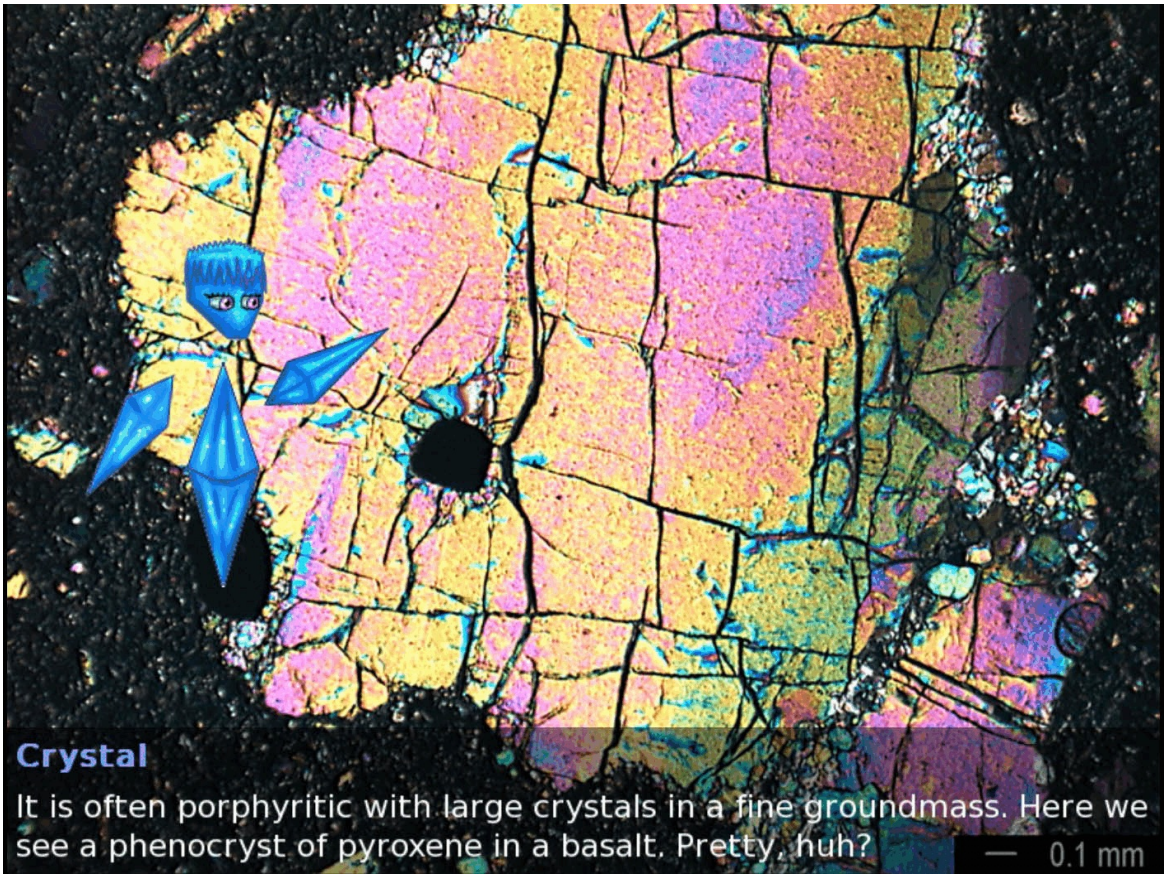
All thin section images were taken by Chandra L. Reedy using a Nikon Labophot transmitted light polarizing microscope with a Polaroid digital microscope camera system. All images were taken as three separate photographs, each focused on a different area of the thin section (usually at the center, at one corner, and mid-way between center and corner). Then, using Image-Pro Plus image analysis software (www.mediacy.com), a depth-of-field correction was applied, and the three photographs were merged into one photograph with improved focus over the entire field of view. Most of the photographs of objects and buildings were also taken by Chandra L. Reedy; additional images were taken from Wikimedia Commons (http://commons.wikimedia.org/wiki/Main_Page), selecting images that have been released to the public domain.

To most appropriately follow the spirit of the Ren'Py format, we decided to develop a character, named Crystal, to lead the user through the tutorial, point out features of interest in thin sections, and conduct self-quizzes at the end of each chapter. Crystal was designed and drawn by Cara L. Reedy, using a Wacom pen tablet and digitizer, in conjunction with Adobe Photoshop software. In many cases, plane polarized and crossed polarized light images needed to be more perfectly aligned in order to smoothly dissolve from one to other; she also used Photoshop to re-align such thin section images as needed. She identified music in the public domain that would fit the mood of each chapter, and used Audacity to equalize the volume for the music of each chapter in the tutorial.

Results and Discussion

The Finished Tutorial

Each chapter incorporates text with visual elements, including photographs of objects and buildings, and thin section photomicrographs. Often plane polarized light images dissolve into crossed polarized light images of the same thin section, so users can compare the information available with each type of analysis. The character named Crystal is often used to point out features of interest on thin sections.



The finished tutorial consists of eleven chapters as follows:

(1) Petrographic Thin Sections

Definition of thin-section petrography

How petrographic thin sections are prepared

Background Music: Tchaikovsky, Souvenir De Florence, 1st movement (www.musopen.com)

(2) Plane Polarized Light

Explanation of polarized light, and of plane polarized light

Mineral properties of thin sections viewed in plane polarized light

- Transparency versus opacity
- Color and pleochroism
- Refractive index (relative to quartz)
- Relief (how well the mineral stands out in the thin section)
- Morphology (size and shape)
- Cleavage (how the mineral breaks)
- Textures

Self-quiz: Identifying minerals in plane polarized light

Background Music: Holst, The Planets, 2nd movement Venus, The Bringer of Peace (commons.wikimedia.org)

(3) Crossed Polarized Light

Explanation of crossed polarized light

Isotropic versus anisotropic minerals

Mineral properties of thin sections viewed in crossed polarized light

- Interference colors
- Quantitative measurement of birefringence and the Michel-Levy color chart
- Extinction
- Undulous extinction
- Extinction characteristics in relation to morphological features
- Extinction angle
- Twinning
- Zoning
- Quartz textures in crossed polarized light

Self-quiz: Identifying minerals in crossed-polarized light

Background Music: Ockeghem, Ma bouche rit (commons.wikimedia.org)

(4) Identifying Common Rock-Forming Minerals

Definitions of minerals, rocks, rock-forming minerals, and accessory minerals

Silicate minerals

- Framework silicates
  - Quartz
  - Feldspars
- Sheet silicates
  - Micas
  - Clay minerals

Ring silicates

Chain silicates

Pyroxene group minerals

Amphibole group minerals

Non-silicate minerals

Carbonate minerals

Sulfate minerals

Self-quiz: Identifying common rock-forming minerals in thin section

Background Music: Tchaikovsky, Souvenir De Florence, 1st movement (www.musopen.com)

(5) Igneous Stone Materials

Volcanic rocks

Obsidian

Scoria

Tuff

Rhyolite

Dacite

Trachyte

Andesite

Basalt

Plutonic rocks

Granite

Granodiorite

Diorite

Gabbro

Self-quiz: Igneous rocks in thin section

Background Music: Balbastre, Joseph est bien marie (commons.wikimedia.org)

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(6) Sedimentary Stone Materials

Detrital sedimentary rocks

Shale

Siltstone

Sandstone

Congolomerate

Breccia

Chemically precipitated sedimentary rocks

Limestone and dolomite

Sedimentary silicates

Evaporites

Self-quiz: Sedimentary rocks in thin section

Background Music: Brahms, Klavierstucke,Op18, II Intermezzo (www.musopen.com)

(7) Metamorphic Stone Materials

Describing metamorphic rocks

Slate

Phyllite

Schist

Gneiss

Marble

Quartzite

Self-quiz: Metamorphic rocks in thin section

Background Music: Beethoven, Symphony #9, 1st movement (commons.wikimedia.org)

(8) Low-Fired Pottery

Low-fired wares (earthenwares)

Characterizing inclusions

Sand

Lithics

Calcium carbonates

Organic matter

Grog

Micas

Other inclusions

Self-quiz: Low-fired pottery in thin section

Background Music: anon, Worldes bliss ne last no throwe (medieval melody, www.pbm.com/~lindahl/vladislav/filk/)

(9) High-Fired Pottery

Stoneware

Porcelain

Hard-paste

Soft-paste

Bone ash porcelain (Bone China)

Stonepaste/Fritware

Self-quiz: High-fired pottery in thin section

Background Music: anon, Sakura Sakura (Japanese folk song, daisyfield.com/music/index.htm)

(10) Identifying Pottery Fabrication Methods

Describing the clay matrix and identifying clay processing choices

Reconstructing forming methods

Inferring firing conditions

Deducing intended functions

Interpreting voids and porosity data

Decoration and surface/clay body interfaces

Slip, glaze, paint and enamels, opacifiers, natural ash glazing, salt glazing, transfer prints

Self-quiz: Identifying pottery fabrication methods in thin section

Background Music: anon, Mo Li Hua (Chinese folk song) (commons.wikimedia.org)

(11) Other Ceramic and Clay Materials

Sculptures and molded or stamped objects

Bricks

Tiles

Casting core materials

Self-quiz: Other ceramic and clay materials in thin section

Background Music: anon, Bracmo Oro (Macedonian folk song, sakura.canvas.ne.jp/spr/marucho/media/midi_e.htm)

The final two sections include a Help menu, and the Credits.

Working with Ren'Py

The Ren'Py engine was relatively easy to work with in developing this tutorial. We would definitely use it again, and have so far only touched on the full range of capabilities. We would recommend it to other educational technology developers, as it has great potential.

We first downloaded it from www.renpy.org. We then greatly simplified the menu system to remove the game elements (for example, the functions of saving and loading, etc., are not needed for our tutorial). We also made a quiz function; this permits having a different response resulting for correct or incorrect answers; we could have chosen to keep a score if this were being used as a required element in a class.

Otherwise, the main work was devoted to defining images and text, and designing a menu for selecting chapters. Once all of the content was defined, it took only a few minutes to build the

compressed files for free distribution that can be downloaded and used on all three platforms (Windows, Mac, and Linux). No proprietary software is required either for development or for running a Ren'Py product. Finally, with Ren'Py, it will be easy to make regular updates and modifications to the tutorial.

Conclusions

The final tutorial has been published on the web site of the Laboratory for Analysis of Cultural Materials, Center for Historic Architecture and Design, University of Delaware, at: http://www.udel.edu/CHAD/tutorial.html. Within the tutorial, we invite emailed comments, and will use that input to periodically update and improve the tutorial, perhaps adding additional didactic materials, images, video clips, case studies, or other additions suggested by users. With the Ren'Py platform, such modifications are easy to accomplish. Since the open source Ren'Py engine is constantly maintained and updated by a community of users, it is likely to always be freely available and usable by the major computer platforms, unlike many propriety software products. It is simple and fast to rebuild an edited or modified product for the three platforms. The web page where the tutorial download is located will include information about the date when the tutorial was last modified, so users can check to make sure they are using the most current version. There is no substitute for hands-on practice with thin sections under the microscope. However, this tutorial should provide a virtual laboratory experience that will function as a training tool in an intermediate space between reading about thin-section petrography in a book, and working at a microscope.

Acknowledgments

Chandra L. Reedy wrote the tutorial text and photographed thin sections (with the aid of the extended depth-of-field tool in Image-Pro Plus), and photographed some of the objects and buildings shown in the tutorial; additional object and building photos came from commons.wikimedia.org, selected from images that have been released to the public domain. Terry J. Reedy programmed the tutorial using the Ren'Py Visual Novel Engine (renpy.org), which in turn uses the Python programming language (python.org) and other open-source software. Cara L. Reedy adjusted photos and drew artwork with Photoshop, selected music from among pieces that have been released to the public domain, and adjusted volumes with Audacity. The National Center for Preservation Technology and Training (NCPTT) provided funding for this project. Thin sections used in the tutorial are mainly from collections in the Laboratory for Analysis of Cultural Materials, University of Delaware. Other materials for sampling and/or thin sections were generously provided by Pamela B. Vandiver, University of Arizona; the Freer Gallery of Art Conservation and Scientific Research Laboratory; and the University of Delaware Anthropology Department.

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