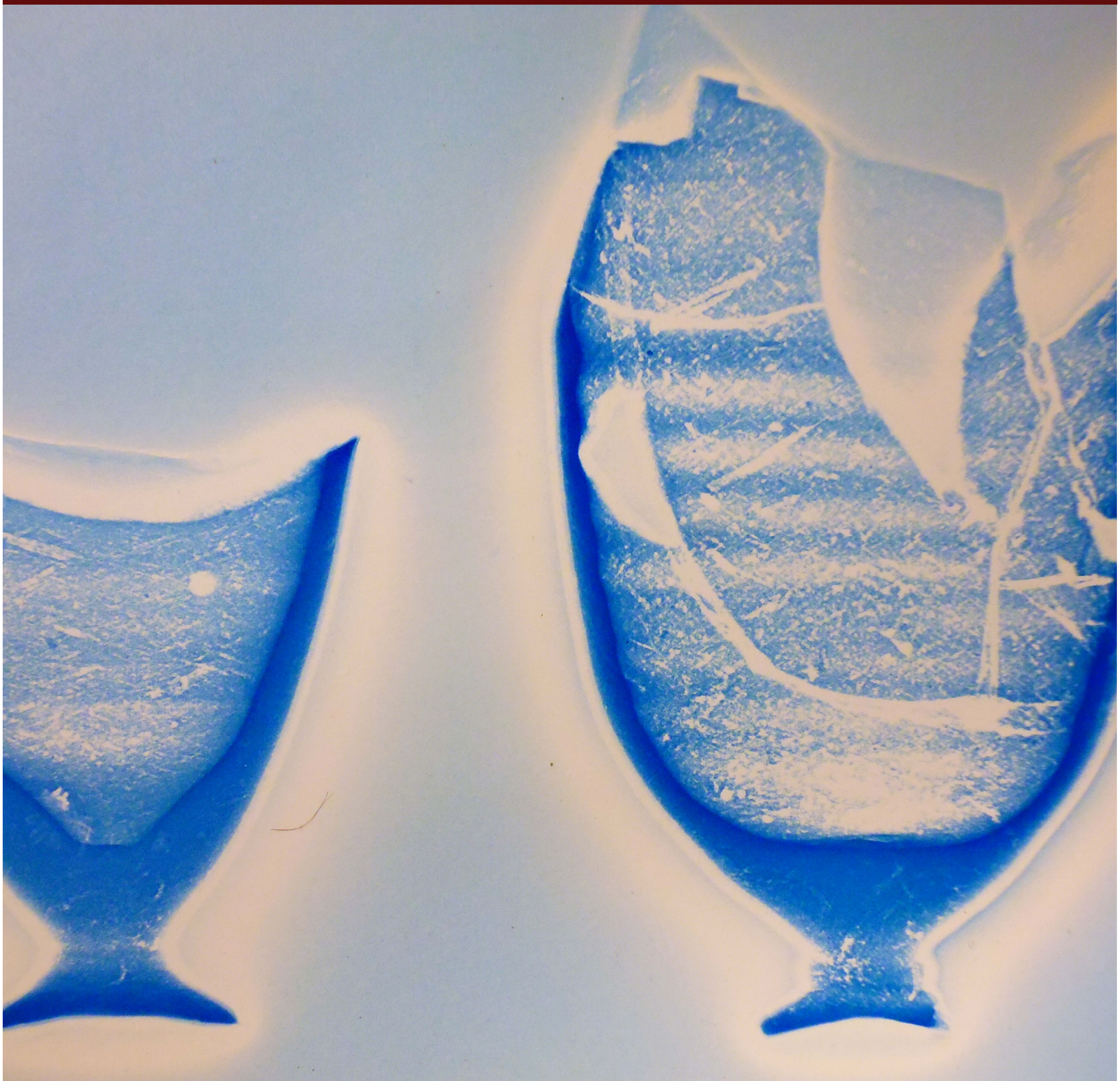
NCPTT

Equipment for Xeroradiography Center at the University of Arizona | 2014-06

University of Arizona



National Park Service
U.S. Department of the Interior

National Center for Preservation Technology and Training

Narrative Final Report Format (Attachment C)

NCPTT 2010 Grant MT-2210-10-NC-11

Equipment for Xeroradiography Center at the University of Arizona

Laboratory for Cultural Materials,

Department of Materials Science and Engineering, College of Engineering, University of Arizona

Pamela B. Vandiver, Professor of Materials Science and Engineering, Adjunct Professor of Anthropology/ Archaeology

1235 E James Rogers Way, Tucson, Arizona, 85721

Cell 520-400-2270, Email vandiver@mse.arizona.edu

6 April 2014

Table of Contents

Executive Summary

Xeroradiography is an electrostatic x-ray technique developed in the 1980s by Xerox Medical Systems-- one that enhances edge-contrast, porosity and phase-contrast because of capacitive discharge on a charged selenium plate at density gradients in or at the edges of an object that has been irradiated by an x-ray source. Several researchers have found the positive or negative images quick to produce, easy to read and superior to traditional film radiography and modern digital x-radiography, especially for ceramics, baskets, wood and many other complex, constructed or repaired art and archaeological objects. The funding support given to us by the NCPTT grant has be instrumental is preserving the analytical technique of xeroradiography for use by the museum, conservation and archaeological communities. The facility is open for collaborative projects with the National Park Service, other museums and interested researchers and students, currently at no charge.

We confirmed the conclusion that xeroradiography offers high dynamic range, high contrast, edge-enhanced images that are easily interpreted, rapid to produce and that offer easy recognition of textures and details of manufacture that are not possible with traditional film or digital radiography. Usually no processing subsequent to the three minutes it takes to make the image is required. The processing is dry with no darkroom required, but the limits of paper size are 24.5 by 34.5 cm. However, film and digital radiography have higher spatial resolution of 2-5 microns, compared to 20 microns for spherical particles that are sintered to form the xeroradiographic image. Currently the image, printed in blue on paper, can be scanned and digitized. The electrostatic discharge often produces multiple halos that formed at edges and other large features. These dark and light patters cause problems with traditional image processing programs that we cannot overcome.

Scanning the charged plate before image transfer to paper was investigated and, although possible, was not achieved for several reasons. The charge gradients can be observed visually on the plate after exposure, but the reproducibility of the process is limited by problems of light, static electricity and humidity that make the image degrade in a short time to become diffuse usually with loss of the darker areas. The plate can be shielded from light, but still needs to be illuminated when scanned. High relative humidity, however, poses a more

serious problem of image deterioration in that degradation is not predictable and probably depends on movement of moist air across the plate, leading to the conjecture that the humidity problem perhaps cannot be overcome. Currently, I am searching for funding for a 5-member senior engineering design team to take on the problem for a one semester investigation and evaluation of design and a second semester period of constructing and testing scanning devices.

Introduction

The proposal requested an x-ray unit to support research that is keeping alive the electrostatic imaging technique of Xeroradiography. This technique is used for nondestructive evaluation and imaging of the macrostructure, internal structure and textural variation of objects. Xeroradiography has lower contrast and wider dynamic range than film radiography, but differs in that images have enhanced edge contrast at density gradients. Xeroradiography is an electrostatic x-ray technique developed in the 1980s by Xerox Medical Systems that enhances edge-contrast, porosity and phase-contrast because of capacitive discharge at density gradients in or at the edges of an object. The images are easier to read than traditional radiographic ones, but they require a larger radiation dose than currently suitable for people.

The facility at the University of Arizona is the only laboratory with xeroradiographic-imaging capability that is available to the museum and archaeology research communities. Xeroradiography was developed for mammography, but has been used primarily for nondestructive evaluation of flaws in industrial devices and composite products. Currently, about 400 units are being used and maintained in military laboratories that are not accessible to civilian researchers, and these are being used to assess flaws in fiber-reinforced composites and various electronic components and systems. These cannot be used for museum collections because the objects would have to be turned over to military personnel for imaging without oversight or presence of a conservator or researcher responsible for the objects.

In museum labs, xeroradiography has been used to determine techniques of manufacture and sequence of assembly of archaeological artifacts and artistic and historically significant objects. Some materials and objects that have been tested include ceramics, stone, metal, baskets, Victorian constructed-paper Valentines, world maps made as parchment covered globes, astronauts gloves and space suits, and instruments, such as violins and guitars that have internal insect damage, among other objects. In the stringed instruments, imaging allows exact determination of the extent of damage such that the damaged wood is removed, and not more.

The NCPTT funding completed the instrumentation required to operate a radiography facility at the Laboratory for Cultural Materials in the Department of Materials Science and Engineering that is being used as part of a doctoral program in Heritage Conservation Science at University of Arizona in collaboration with the Arizona State Museum. This facility is accessible to students and researchers with projects that can be furthered by this unique technology.

We attempted unsuccessfully to develop a digital capability for this technique by investigating scanners and conditions that allow digitization of the exposed and powdered electrostatic plate. We were able to digitize, but not image-process, the images by traditional digital image-processing techniques. The reasons for this failure are set out in the results and discussion section.

Methods, Materials and the Team

The Department of Materials Science and Engineering at the University of Arizona has acquired two Xeroradiograph 126 plate conditioners and two image processors, along with extensive supplies, from the Smithsonian Institution's Museum Conservation Institute and the British Museum. As with most museum labs in the U.S.A. and Europe, the Xeroradiographs are being replaced by digital instruments, even though these instruments lack the same high-contrast, high-dynamic range image quality. However, our equipment did not include the excitation x-ray source and cabinet for exposure. To test and make operable the Xeroradiograph instrument, a sealed x-ray source, electronic controls and lead-lined imaging cabinet were required that are placed adjacent to the Xeroradiograph unit, as the latent image on the plate has a retention time of only about 15 minutes.

The principal investigator, Pamela Vandiver, during her eighteen years at the Smithsonian was one of several pioneers in the use of xeroradiography in museums and believes a need exists for digital xeroradiography (Refs. 1-20). Vandiver is a Professor of Materials Science and Engineering at the University of Arizona, an Adjunct Professor in Anthropology and Co-Director with Nancy Odegaard of the only doctoral program in Heritage Conservation Science in the United States. The other director, Nancy Odegaard, is Head of Conservation at the Arizona State Museum and former head of the American Institute of Conservation. We have 9 graduate students in the program who were eager to learn, and who now know, about and practice xeroradiography. The third collaborator is Robert Bingham, head of BlueRad X-ray Systems, the successor to Xerox Medical Systems, and he wishes to develop a digital xeroradiographic unit for museum and other applications. He hoped to provide the expertise to digitize the technique. He currently maintains and rebuilds units that are still in use at companies and labs doing NDE, and his company has over 400 new Xeroradiographs stored in a warehouse.

To begin the project, Odegaard and Vandiver rented a Hewlett-Packard Faxitron, and imaged 11 sandals, dating from 8,000 BP to 400 AD., that have been excavated over several decades from dry archaeological sites in Arizona. This collection, some of which was excavated by National Park Service personnel, is currently housed at the Arizona State Museum. Information about construction and internal damage and wear was recorded that could not be seen with film radiography or optical microscopy, and one of the images using the new equipment was used at the Arizona State Museum in a basketry exhibition in 2013. The Faxitron we rented had a 12-inch length between object and aperture, giving distortion due to parallax. A longer path-length between source and object of about one meter, as we had at the Smithsonian lab, was indeed necessary to produce measurable images of anything much larger than a one-centimeter bead and to avoid distortion of internal features.

Results and Discussion

A total of $9113 was spent on an x-ray generator, Torrex 150 X-ray Inspection System (Torr X-ray Corporation, Los Angeles, CA), with 1 meter distance from source to object and a sealable and lead-lined cabinet, that cost $8600, and shipping that cost $688. The installation cost was $825 for the electrical service to power the x-ray source. The plan was to purchase and have shipped and install the x-ray unit in one month, but it took several months, as problems developed at the university with the location of the NCPTT funds. As soon as the unit was working, 20 pounds of recently sherds excavated near Mound F, Casa Grande Ruins National Monument, were borrowed from Rebecca Carr and radiographed in conjunction with the undergraduate class, MSE/ANTH/ENGR257b, Materials Science of Art and Archaeological Objects. The sherds were small (4 cm or less in maximum dimension) and heavily weathered, some with evidence of trampling, such that the surface textures were as significant as the presence of pores and aplastic inclusions and the alignment of porosity. The conclusion was that two or three fabric textures are present and that probable basal sherds were slab-built; whereas, wall sherds were made in smaller elements with some overlapping or beveled joints.

The next task was to re-radiograph the ancient sandals to investigate the internal evidence for construction, wear and possible damage. This met with success. Other materials, such as wood, basketry, glass and pottery, were imaged, and the graduate students were trained in the use and interpretation of the electrostatically produced images.

The tasks that we hoped would produce a digital scanner for the charged selenium plates at BlueRad worked somewhat. Charge gradients on the plates, when scanned, were barely visible in the humid California air.

Thus, humidity was a limiting factor. We did not try to integrate a scanner into xeroradiograph cabinet to prevent light impinging on the image. We could potentially try again at the UofA and use this problem as a topic for a collaborative senior engineering design project.

Results and their interpretation were reported in theses and presentations (Ref. 21), at the MRS 2013 Fall Meeting, at the 2012 SAA, but no articles are yet in press. Results were reported at the SAA conference in 2011, and one article is included in an edited volume on object structure that is being reviewed for publication.

Conclusions

The deliverables that were achieved consist of development of a facility, a unique center for the preservation of and training in xeroradiography that was established and sustained because of the NCPTT grant. The comparison of xeroradiography with other radiographic methods was conducted with the same results as reported in several articles (Refs. 11 and 15, and in the book on radiography of cultural materials by Janet Lang and Andrew Middleton, Ref. 20). Our graduate students were trained in the technique and evaluation of radiography, and they have tested a variety of materials and objects that have associated conservation, historical or archaeological problems of interest to the museum and archaeology communities. Professional presentations have been made, and classes and seminars of students have been exposed to xeroradiography. Conference papers are in the process of being turned into journal articles.

Lastly, we now know what we do not know about digital technique development, and that is that the charged and discharged selenium plate is sensitive to humidity and that low RH is necessary. In the paper processing of xeroradiographic images, low RH is maintained by the heater that sinters the blue "ink" particles to the paper and heat generated by the various motors that move the plate and the paper through the cabinet.

Acknowledgments

I wish to thank Mary Striegel of the NCPTT for this grant, as it enabled the Xeroradiography Center to be established. Without this grant, the technique of xeroradiography would have disappeared from museum labs. Acknowledgment is also expressed to Robert Bingham of BlueRad for his technical expertise in setting up and maintaining the equipment, Joseph Simmons for DMSE support, the University TRIP Award in Imaging and the Medical School for their support, the Smithsonian Museum Conservation Institute for the donation of their Xeroradiographic equipment and supplies, and Nancy Odegaard and Rebecca Carr for their enthusiasm and effort to apply the technique to their problems. I also thank the many students at the University of Arizona who have helped organize, image and analyze the archaeological materials we have studied.

References

1. MaryFran Heinsch and P.Vandiver (2006), "Recent Xeroradiographic Analyses of Kura-Araxes Ceramics," in D.L. Peterson, L.M. Popova and A.T. Smith, eds., Beyond the Steppe and the Sown: Proc. of the 2002 Univ. of Chicago Conf. on Eurasian Archaeology, Brill, Colloquia Pontica vol. 13, pp. 382-394.
2. P.B. Vandiver (2008), "A Ceramic Plaque Representing a Part of the Moses Panel by Lorenzo Ghiberti in the East Baptistry Doors (Florence, Italy)," Materials Issues in Art and Archaeology VIII, ed. P.B. Vandiver et al., MRS Symp. Proc. vol. 1047, pp. 71-88.
3. M.Yang, A.M. Winkler, J.K. Barton, and P.V. Vandiver (2009), "Study of Optical Coherence Tomography Applied to Chinese Glazes," Eighth Int'l Symp. on Ancient Ceramics, March 2009, Luo Hongjie, et al.,eds., Shanghai Inst. of Ceramics, Chinese Academy of Sciences, Shanghai, China, China Science Press, pp. 469-475, and in vol. 50 of Archeometry.
4. P.B. Vandiver, A. Underhill, Cai F., Yu H., Luan F., Fang H. (2002), A Longshan Pottery: Its Manufacture at Liangchengzhen in Southeast Shandong Province (ca. 2600-2000 B.C.), International Symposium on Ancient Ceramics, Shanghai Inst. of Ceramics, Chinese Academy of Sciences, Shanghai, China, Nov. 2002, pp. 574-586, and in Chinese in Wenwu, Fall 2007.
5. P.B. Vandiver (2001), The Role of Materials Research in Ceramics and Archaeology, in Annual Review of Materials Research, vol. 31, pp. 373-385.
6. P.B. Vandiver and S. Chia (1997), "The Pottery from Bukit Tengkorak: A 3,000-5,000-Year-Old Site in Borneo, Malaysia", in Materials Issues in Art and Archaeology V, P. Vandiver, et al., eds., Mat. Res. Soc. Proc., V. 462, pp. 269-277.
8. P.B. Vandiver and V. Chaussonnet (1995), "Ceramic Technology at the Crossroads", in Materials Issues in Art and Archeology IV, P.B. Vandiver et al., eds., Symp. Proc. V. 352, Mat. Res. Soc., pp. 687-699.
9. D. Barbour, and S. Sturman and P.B. Vandiver (1994), "The Technology of Saint Porchaire Ceramics" in Western Decorative Arts: Part I, Medieval, Renaissance and Historicizing Styles, Including Metals, Enamels and Ceramics, National Gallery of Art systematic collections catalog, R. Distelberger, A. Luchs, P. Verdier and T. Wilson, eds., Cambridge University Press, Cambridge, pp. 264-279.
10. M.J. Blackman, G.J. Stein and P.B. Vandiver (1993), "The Standardization Hypothesis and Ceramic Mass Production: Technological, Compositional and Metric Indexes of Craft Specialization at Tell Leilan, Syria", Am. Antiquity, vol. 58(1), pp. 60-80.
11. P.B. Vandiver, W.A. Ellingson, T.K. Robinson, J.J. Lobick and F.H. Sequin (1991), "X-Radiographic Imaging Technologies for Archaeological Ceramics,"

Archeomaterials, vol. 5 (2), pp. 185-207.
12. W.D. Kingery, P.B. Vandiver and Tamar Noy (1992), "An 8500-Year-Old Sculpted Plaster Head from Jericho," MRS Bulletin, vol. 17 (1), pp. 46-52.
13. P.B. Vandiver, O. Soffer, B. Klima and J. Svoboda (1990), "Venuses and Wolverines: The Origins of Ceramic Technology at Dolni Vestonice (Czechslovakia), ca. 26,000 B.P.", in High Tech Ceramics: Past and Present, Ceramics and Civilization series vol. 5, W.D. Kingery, ed., American Ceramic Society, Westerville, OH, pp. 13-82.
14. P.B. Vandiver (1987), "Sequential Slab Construction: Conservative Southwest Asiatic Ceramic Tradition, ca. 7000-3000 B.C.," Paleorient, vol. 13/2, pp. 9-35.
15. P.B. Vandiver, W.A. Ellingson, T.K. Robinson and J.J. Lobick (1988), "Radiographic Imaging Technologies for Archaeological Ceramics", Materials Issues in Art and Archaeology, op.cit., pp. 25-32.
16. P.B. Vandiver and Peter Lacovara (1985-86), "An Outline of Technological Changes in Egyptian Pottery Manufacture", Bulletin of the Egyptological Seminar, New York, vol. 7, pp. 53-85.
17. P.B. Vandiver (1988), "The Implications of Variation in Ceramic Technology: The Forming of Neolithic Storage Jars in China and the Near East," Archaeomaterials, vol. 2 (2), spring, pp. 139-174.
18. P.B. Vandiver and W.D. Kingery (1987), "The Manufacture of an Eighteenth Dynasty Egyptian Faience Chalice", Conference on the Early History of Vitreous Materials (1984), M. Bimson and I.C. Freestone, eds., British Museum Occasional Paper No. 56, Early Vitreous Materials, pp. 79-90.
19. W.D. Kingery and P.B. Vandiver (1986), Ceramic Masterpieces: Art, Structure and Technology, Free Press, New York (339 p.), where xeroradiography is technique of choice.
20. Vandiver was one of many pioneers of the xeroradiographic technique for ceramic analysis during her doctoral dissertation on southwest Asian Neolithic period ceramics and for several projects when she was senior research scientist in inorganic materials for eighteen years (1985-2004) at the Smithsonian Institution's Conservation Analytical Lab. With others she evaluated radiographic techniques, in "New Applications of X-Radiographic Imaging Technologies for Archaeological Ceramics," Archeomaterials 5:185-207 (1991), and has continued using the technique in 19 other publications. When receiving the Archaeological Institute of America's Pomerance Award for Scientific Contributions to Archaeology in 2006, her use of the technique to discover ceramic production techniques using xeroradiography was cited. She introduced the technique to researchers at the British Museum and other laboratories that acquired the equipment. At the British Museum, Ian Freestone and David Gaimster used the xeroradiography technique exclusively in their book, Pottery in the Making, and eventually Janet Lang and Andrew Middleton used it for images in the book, Radiography of Cultural Material, that is still a standard in the field. Patrick McGovern included xeroradiography in a review of analytical methods useful in archaeological investigations that he edited for the A.I.A.'s American Journal of Archaeology. The article, "Science in Archaeology: A Review, A.J.A. 99 (1995) 79-142, with the "Xeroradiographic Imaging" article by Vandiver and C.S. Tumosa, pps. 121-124.

21. Xeroradiography is and has been used in theses by MaryFran Heinsch at the University of Chicago, and at the University of Arizona by Fumie Iizuka and Dana Rosenstein, in Anthropology, and by Lesley Frame, Elyse Canosa, Brunella Santorelli, and Caitlan O'Grady and currently Dustin Moorhead in Heritage Conservation Science in the Dept. of Materials Science and Engineering. A presentation using xeroradiography was made at the MRS 2014 Fall Meeting on pottery with some Greek shapes from a farming village, 400 BCE – 100 CE in Kazakhstan about 400 years before the Silk Road is thought to have started. The paper has been accepted. At the SAA meeting in 2011 in St. Louis a presentation on Neolithic pottery from the country of Georgia was made that has been included in an edited volume that is being reviewed for publication. At the 2012 SAA meeting a presentation on the earliest pottery from Panama, known as Monagrillo, was given, and it also is being reviewed for publication. However, no papers are published yet that employed results from our new equipment.