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White Paper: Summary of the New World Luminescence Dating Workshop 2018

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Introduction

The 12th annual New World Luminescence Dating Workshop (NWLDW) was hosted by Dr. Regina DeWitt of East Carolina University in Greenville, North Carolina from June 27-30, 2018. This workshop is annually attended by researchers and practitioners from across North and South America (Table 1). Attendees presented current research initiatives and discussed new scientific advances in luminescence dating via oral and poster presentations followed by question and answer sessions. In addition, attendees participated in multiple panel and working group discussions concerning future scientific research, community development, and scientific infrastructure.

Executive Summary

The NWLDW forum serves to gather scientists concerned with luminescence and ESR geochronology and technique development to discuss recent scientific advancements, establish collaborations, further educate students in the field of luminescence dating, and discuss initiatives relevant for the community. As the luminescence or "trapped charge" community expands, and a new generation of enthusiastic scientists enters the field, it has become necessary to formally collect and present the consensus of this community to the wider research community as is done in other fields (e.g., Huntington & Klepeis, 2017). As such, we wish to begin the publication of community-authored white papers, such as this one, stemming from the panel discussions at the 12th NWLDW. The purpose is to secure future educational requirements, and ensure community priorities are communicated to funding agencies, research groups abroad, and the general public. These initiatives include: (1) the development of a trapped-charge professional society, (2) the development of an open-source database to house luminescence age data, (3) a formal laboratory inter-comparison study, and (4) the development of calibration standards for various methods in luminescence dating. These discussions were constructive and fruitful with the conclusions being described in the following sections.

Intellectual Merit

Our knowledge of the scientific basis for luminescence dating, and the insights arising from its application, are expanding at an exponential pace (Nelson et al., 2015). Luminescence dating methods are being applied to a wide array of geologic environments, cultural sites and materials. Resulting ages are used to solve a variety of scientific problems (Rhodes, 2011; Smedley, 2018), and serve as an independent variable in studies requiring multi-level geochronology. Geologic and archaeologic problems in which luminescence dating has been applied range from quantifying rates and timing of surface processes (Rittenour, 2018) to constraining our evolution and origin as a species (Roberts & Jacobs, 2018). In addition to dating, novel applications of

Attendee Name	Title	Institution
Regina DeWitt	Associate Professor	East Carolina University
David Mallinson	Professor	East Carolina University
Zhengye Xiong:	Professor	Guangdong Ocean University
Joel Spencer	Associate Professor	Kansas State University
Vasilis Pagonis	Professor	McDaniel College
William Amidon	Associate Professor	Middlebury College
Michel Lamothe	Professor	University of Quebec - Montreal
James Feathers	Research Professor	University of Washington
Sebastian Huot	Research Scientist	Illinois State Geological Survey
Jose Luis Antinao	Research Scientist	Indiana Geological Survey
Shannon Mahan	Research Scientist	U.S. Geological Survey
Michelle Nelson	Laboratory Manager	Utah State University
Harrison Gray	Post-doctoral Researcher	U.S. Geological Survey
Nathan Brown	Post-doctoral Researcher	U. of California, Los Angeles
Kathleen Rodrigues	Ph.D Graduate Student	Desert Research Institute
Christopher Garcia	Ph.D Graduate Student	East Carolina University
Joel Pogue	Ph.D Graduate Student	East Carolina University
Laurence Forget Brisson	Ph.D Graduate Student	University of Quebec - Montreal
Marisa Schorr	M.S Graduate Student	Indiana University
Amy Cressman	M.S. Graduate Student	East Carolina University
Nina Ataee	M.S. Graduate Student	Kansas State University
Nicholas Kowalski	Undergraduate Student	East Carolina University
Mikaela Rader	Undergraduate Student	Kansas State University

Table 1. Attendee list for the 12th NWLDW meeting.

luminescence physics continue to develop at a rapid pace (Smedley, 2018). Some of these applications arising in the recent decade include thermoluminescence thermometry (Spencer & Sanderson, 2012; Spencer, 2012; Sanderson et al., 2014) low-temperature thermochronology (Brown et al., 2017; Herman & King, 2018), surface exposure dating and hard rock erosion rates (Sohbati et al., 2018; Gliganic et al., 2019), sediment tracing and provenance (Sawakuchi et al., 2018; Gray et al., 2018), and in-situ field measurements of natural luminescence characteristics (Sanderson & Murphy, 2010).

Broader Impacts

Luminescence shows excellent promise as a multi-purpose research tool, but further research and support is needed to maintain this momentum into the coming decade. The NWLDW community identifies the following areas as critical and cutting-edge research fronts:

- Advancement of novel applications of luminescence dating such as Martian deposits;
- An exploration of luminescence dating to new natural materials such as plant phytoliths and evaporites;
- Application of luminescence dating to new problems in geomorphology, climate change, and neotectonics;
- Investigations of the physical mechanisms for luminescence, including tunneling behavior of electrons, effects of impurities in crystal structures, and the effects of light attenuation through solid matter;
- Benchmarking of new luminescence thermochronology against established thermochronometric methods and improving applications to soils and crystalline bedrock;
- Development of theoretical models and collection of field data concerning the application of luminescence as a sediment tracer;
- Application of luminescence properties within soil profiles and at the soil-bedrock interface among other critical zone science matters;
- Utilizing thermoluminescence techniques to understand paleo-wildfires;
- Experimentation of luminescence and luminescence characteristics with doped synthetic quartz.

These topics are of importance to the community in terms of continuing progress and maintaining the momentum of the scientific progress displayed by luminescence science.

Luminescence beyond dating: Broader research goals

The above research fronts have been identified as high-priority by the NWLDW community for their relevance to broader research goals and for improving and expanding the capabilities of luminescence dating. First, the advancement of novel applications of luminescence dating is a logical expansion that builds on the previous successes of the method. One of the key benefits of luminescence is its broad applicability. For example, luminescence dating of Martian sediments (Kalchgruber, 2007), could help answer a broad array of unanswered questions relating to planetary formation and planetary climate change. On a similar note, plant phytoliths could potentially directly date preserved plant matter beyond radiocarbon dating (Rader & Spencer, 2018), and luminescence dating of evaporites could allow direct dating of playa sediments and associated landforms (Fitzgerald et al., 2017), which can act as key climate indicators. Recent dating work on historic attic dust contaminated with heavy metals (Alghamdi & Presley, 2016) is demonstrating the utility of luminescence chronology to very young sedimentary deposits of mm-thickness and is opening up potential application to areas such as environmental hazards, standing buildings, and forensic science (Spencer et al., 2017). Luminescence dating is also well suited to solve problems in climate change and tectonics, two fields of study that encompass a substantial research community. Finally, luminescence dating has been and continues to be a versatile and robust tool for archeological research over the past 20+ years (Feathers, 1997, 2003).

Beyond dating, luminescence is proving to be a useful research tool to directly quantify processes that shape the Earth's surface. Luminescence thermochronometry (Herman et al., 2010; Brown, 2017) allows us to constrain the thermal histories of quartz and feldspar crystals (Spencer, 2012). Luminescence thermochronometry is particularly useful in that luminescence measures a lower temperature range than other thermochronometers (Guralnik et al., 2013; Brown et al., 2017). This has opened the door for exploring new frontiers such as quantifying landscape exhumation rates (Herman & King, 2018), examining the heating of soil by wildfire (Rengers et al., 2017), and evaluating prospects for geothermal energy (Sanderson et al., 2014). However, luminescence thermochronometry is still a new technique and further cutting-edge research is needed benchmarking the technique against other thermochronometric methods. Likewise, luminescence sediment tracing and fingerprinting (Reimann et al., 2017; Portenga et al., 2017; Sawakuchi et al., 2018; Gray et al., 2018; Furbish et al., 2018) is developing as a new method that can quantify the provenance and rates of travel of sand grains in geomorphic environments such as rivers, hillslopes, and mixing soils. Together, luminescence thermochronology and luminescence sediment tracing can reveal information spanning from deep sources in the Earth to final sedimentary sinks on the surface. However, like luminescence thermochronology, luminescence sediment tracing is new and further studies exploring how specific geomorphic processes affect the luminescence of sand grains are needed.

Luminescence phenomena may also be utilized to better constrain events and quantify processes taking place in the soil profile or critical zone. One such example is wildfires, which are becoming more prevalent and covering ever-expanding areas. Cultural sites and materials in these fire-prone areas are at risk of losing their luminescence history if overrun by wildfire (Ideker et al., 2017). Big questions remain regarding wildfire temperature at the soil surface and at depth (Rengers et al., 2017). In general, luminescence is currently underutilized in soil science, and basic research in this unique application is needed to aid the quantification of soil mixing and soil production (Heimsath et al., 2002; Stockmann et al., 2013). These new applications of luminescence show promise but require a solid theoretical grounding. As such, further research on fundamental luminescence physics, such as tunneling of electrons, effects of impurities in crystal structures, and the effects of light attenuation in solid matter is needed.

Overall, the NWLDW community feels that there is significant and exciting potential within luminescence science. The topics above serve as key focal points for future research and the community desires to see progress on these fronts.

Laboratory Inter-comparison, Calibration, and Reporting Standards

The NWLDW community considers the development and execution of a laboratory inter-comparison study to be a key goal. This inter-comparison will help improve the reliability, accuracy, and precision of luminescence dating across the NWLDW community by allowing us to identify sources of dispersion in age estimates that do not appear during analysis by individual laboratories.

Recently, Murray et al. (2015) performed one of the first laboratory intercomparison studies. They noted larger than expected dispersions in ages estimated between laboratories (18% relative standard deviation) than the dispersion expected based on a "well behaved" sample (5-10% relative standard deviation). This additional dispersion arises from the dispersion found for equivalent dose and dose rate from individual laboratories. However, the exact causes of the dispersions in equivalent dose and dose rate determinations (particularly measurements of radiogenic isotope concentrations and water content) remain a rich topic for research.

A North American community wide inter-comparison would provide a robust method to compare individual laboratory results against community averages, which would identify sources of dispersions and help reduce the statistical dispersion in luminescence results between laboratories to that expected from intrinsic sample characteristics. We propose to do this through standardization of method reporting, establishment of community best-practices, and inter-laboratory comparison. Participation in this project would provide funding to obtain lab standardization and community-wide endorsement of luminescence laboratory products. A community wide effort combined with transparent and open access to data used to generate results from a wide set of users as explained below are the key components of building trust between scientists, practitioners and end-users of the technique.

Luminescence database

The rapid expansion of luminescence dating has led to an exponential increase in the number of ages and associated data. An unfortunate consequence of this rapid expansion is the risk of data loss or unavailability due to various factors including non-publication of data or publication behind journal paywalls. One solution is to create an open access luminescence database containing luminescence ages and dose rate chemistry data used to calculate these ages. Discussion by the NWLDW community is in favor of a database. However, it appears that questions remain as to whether the community prefers to develop a new database or to utilize existing web-based infrastructure, such as the new OCTOPUS: Open Cosmogenic Isotope and Luminescence Database (Codilean et al., 2018) or the Utah Geochronology Database (hosted by the Utah Geological Survey, UGS) as a repository for luminescence data. Currently, the OCTOPUS database is under peer review. The USGS has expressed interest in working with our community to make luminescence data available outside the state of Utah. The community is currently monitoring the development of these databases to see which may provide the service the community desires.

Trapped Charge Dating Association

The NWLDW community is in favor of a trapped charge professional association, proposed by the international luminescence community at the Luminescence and Electron Spin Resonance Dating (LED) meeting in South Africa (September 2017). Our community sees the development of the association as a welcome venue to: increase professional recognition and visibility of luminescence science, to develop credibility with large funding bodies such as NSF and NERC, to generate funds that support student research, and to increase interaction and collaboration with the broader international luminescence community. These topics should be incorporated into the mission of such an association. The NWLDW community is in general agreement with conclusions from previous discussions at the international level and with the minutes from the German LED meeting (October, 2017). Our only significant disagreement is that the NWLDW participants are largely in favor of Ancient TL serving as the primary journal for the association. Detailed minutes from the meeting discussions can be downloaded from `http://ancienttl.org/TCDA/TCDA.htm`.

Conclusions and Recommendations for the Future

We strongly encourage other North and South American luminescence laboratories to attend the NWLDW meetings when possible. Participation at these meetings allows for input on community white papers such as this one, which in turn help inform funding agencies on community priorities. Additionally, the NWLDW community strongly encourages student attendance and presentation at our meetings to foster educational growth for future luminescence specialists. As luminescence science is on the verge of a rapid expansion, funding support needs to be directed towards research areas which the community deems impactful. In addition, the creation of scientific infrastructure such as a luminescence database and calibration standards, is needed to streamline research efforts and to ensure maximum impact per research dollar. Finally, continued professional development of the community, through meetings and the creation of a trapped charge association, promotes collaborative and scientific outcomes.

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Editor's Note:

This manuscript is not a research article. It is a white paper based on consense of the New World community. Instead of a peer review, the white paper has been revised based on suggestions by the Editor.