UNIVERSITY OF SÃO PAULO
INSTITUTE OF GEOSCIENCES

# Investigation of luminescence signals of quartz and their application for provenance analysis and extending dating range of Brazilian fluvial sediments

**Pontien Niyonzima**

Project Supervisor: Prof. Dr. André Oliveira Sawakuchi

Doctoral Thesis

Program of Post-Graduate in Geochemistry and Geotectonics

São Paulo

2022

UNIVERSITY OF SÃO PAULO
INSTITUTE OF GEOSCIENCES

# Investigation of luminescence signals of quartz and their application for provenance analysis and extending dating range of Brazilian fluvial sediments

**Pontien Niyonzima**

Thesis submitted to the Institute of Geosciences, University of São Paulo, in fulfilment of the requirements of the degree of Doctor (Ph.D.) of Science in Geosciences.

Area of concentration: Geochemistry and Geotectonics

Supervisor: Prof. Dr. André Oliveira Sawakuchi

São Paulo

2022

**Dedication**

This thesis is dedicated to my wife

Belyse Ingabire Niyonzima,

My Daughters

Belinda Shami Niyonzima,

Abby Liz Hayla Niyonzima

Gabby Julia Kayla Niyonzima

Serviço de Biblioteca e Documentação do IGc/USP

Ficha catalográfica gerada automaticamente com dados fornecidos pelo(a) autor(a)via programa desenvolvido pela Seção Técnica de Informática do ICMC/USP

Bibliotecários responsáveis pela estrutura de catalogação da publicação: Sonia Regina Yole Guerra - CRB-8/4208 | Anderson de Santana - CRB-8/6658

Niyonzima, Pontien
Investigation of luminescence signals of quartz and their application for provenance analysis and extending dating range of Brazilian fluvial sediments / Pontien Niyonzima; orientador Andre Oliveira Sawakuchi. -- São Paulo, 2022.
94 p.

Tese (Doutorado - Programa de Pós-Graduação em Geoquímica e Geotectônica) -- Instituto de Geociências, Universidade de São Paulo, 2022.

1. Radiofluorescence. 2. Optically stimulated luminescence. 3. Violet stimulated luminescence. 4. Ironstones. 5. Fluvial sediments. I. Sawakuchi, Andre Oliveira, orient. II. Título.

UNIVERSIDADE DE SÃO PAULO

INSTITUTO DE GEOCIÊNCIAS

# Investigation of luminescence signals of quartz and their application for provenance analysis and extending dating range of Brazilian fluvial sediments

**PONTIEN NIYONZIMA**

Orientador: Prof. Dr. André Oliveira Sawakuchi

Tese de Doutorado

**Nº 643**

COMISSÃO JULGADORA

Dr. André Oliveira Sawakuchi

Dra. Priscila Emerich Souza

Dra. Sonia Tatumi

Dr. Carlos Conforti Ferreira Guedes

Dr. Daniel Rodrigues do Nascimento Junior

SÃO PAULO

2022

# Acknowledgement

I would like to express my gratitude to the Almighty God for the gift of life and his guidance during this journey of four years of doctoral studies.

First and foremost, I would like to thank my supervisor Prof. Dr. André Oliveira Sawakuchi, who has been a tremendous support, since the first time I contacted him to start this project. Despite André´s busy and hectic work life, he has always prioritised finding the time for me, regardless of importance of the issue at hand. I owe a debt of gratitude to André, but I do not have any idea of how I will pay but for sure I pay it on the due time. André, thank you for being such a good supervisor for me, Almighty God bless you abundantly.

I would also like to thank Raquel for all help I have received from you since my first day in Brazil, particularly your support in the struggles for my visa registration, looking for accommodation. I will cherish all your support during this period of my PhD studies.

I also wish to express my gratitude to Dr. Naomi Porat (Luminescence Dating Laboratory, Israel Geological Survey) for her support throughout this entire work. I am very grateful for her willingness to share with us her knowledge in revising, commenting, suggesting on the articles in this thesis for them to meet the publication standards.

Grateful acknowledgement is made the my colleagues of Luminescence and Gamma Spectrometry Laboratory (LEGaL), Institute of Geosciences, University of São Paulo, for the warm manner by which they welcomed me there. I thank them for the many useful discussions and suggestions, and for the great time before, in between and after scientific sessions. Acknowledging and thanking everyone that have helped and supported me during the last four years.

I am very grateful to National Council for Science and Technology Development (CNPq), The World Academy of Sciences (TWAS) (CNPq/TWAS grant 154507/2017-2) and The São Paulo Research Foundation (FAPESP grant 2019/04059-6) for funding my PhD fellowship at the University of São Paulo.

# Abstract

This work investigates the feasibility of applying quartz radiofluorescence (RF) as provenance proxy, carried out experiments to evaluate if violet stimulated luminescence (VSL) of quartz is able to extend the dating age range of fluvial sediments in Brazil, and performed optically stimulated luminescence (OSL) dating to establish formation ages of ferruginous deposits (ironstones) of the Xingu River in Eastern Amazonia. The focus on luminescence properties of quartz from fluvial deposits is motivated by their widespread occurrence across Brazil, land of large rivers, thus, representing the most important continental record of landscape changes during the Quaternary.

Firstly, the work examines RF emissions in quartz from parent rocks (igneous plutonic and volcanic) and sediments of different provenances. After deconvolution of RF spectra into its emission bands, emission band intensities were plotted versus OSL (first 1s) and 110°C thermoluminescence (TL) peak sensitivies to investigation whether RF emission band intensity can be used as sediment provenance. It has been shown that ultraviolet (UV) RF intensity correlates with both OSL and TL sensitivities of quartz from sediments. This correlation supported the suggestion that both 110°C TL peak and OSL of quartz use the same recombination centers rather than the same electron trap and that sensitization processes in nature of two signals might be due to the changes in recombination probability instead of changes in charge trapping probability. It is concluded that UV-RF intensity measured using X-ray sources can also be used for provenance analysis of sediments in the same way as the OSL and TL sensitivities.

Characteristics of VSL signals of quartz from major fluvial systems from Western Brazil (Pantanal), Southeastern Brazil (Paraná River basin) and Central and Eastern Amazonia were investigated to assess if the VSL signal is suitable to extend the age range of luminescence dating of fluvial sediments. Single-aliquot regenerative dose (SAR), multiple aliquots regenerative dose (MAR) and multiple aliquots additive dose (MAAD) protocols were used to estimate the maximum dose that can be estimate by VSL signals for Brazilian sediments. Quartz VSL was found to significantly increase the dating limit to the Early Pleistocene (~800 ka to 1.6 Ma for the $2D_0$ MAAD) even with the relatively lower characteristic doses ($D_0$) observed in dose response curves of the studied samples. Despite the improvement in luminescence age range of Brazilian fluvial sediments using VSL dating

relative to the conventional OSL dating, the behavior of VSL appears to be sample dependent, with natural VSL signal missing in samples from Amazonian settings.

In the estimation of formation ages of ironstones from the Xingu River, ages between ~60 ka and 3 ka were obtained using the SAR OSL dating protocol. This indicates that ironstones of the Xingu River result from a Late Pleistocene and Holocene surface geochemical system able to precipitate goethite and cement fluvial sediments under transport. The high dose rates (2.7-12.3 Gy $ka^{-1}$) of these fluvial deposits limits the OSL dating to the last ~60 ka, assuming maximum doses of ~200 Gy estimated using quartz OSL applied to fluvial deposits across Brazil.

The performed investigations improve the applicability of luminescence signals (RF, OSL and VSL) to obtain provenance and depositional age data from a variety of fluvial deposits occurring over Brazil. This is a contribution to expand the application of luminescence methods to study fluvial deposits.

**Keywords**: Radiofluorescence; Optically stimulated luminescence, Ironstones; Violet stimulated luminescence; Fluvial sediments.

## Resumo

Este trabalho investigou a viabilidade da aplicação de radiofluorescência (RF) do quartzo como indicador (*proxy*) de proveniência, realizou experimentos para avaliar se a luminescência do quartzo estimulada por luz violeta (VSL, em inglês) é capaz de estender o intervalo temporal da datação de sedimentos fluviais no Brasil e realizou datações por luminescência opticamente estimulada (OSL, em inglês) para estabelecer idades de formação de depósitos ferruginosos (*ironstones*) do rio Xingu na Amazônia Oriental. Assim, esta tese de doutoramento buscou desenvolver aplicações das características de luminescência do quartzo no estudo de depósitos fluviais quaternários. Isto foi motivado pela ampla ocorrência de depósitos fluviais no Brasil, terra dos grandes rios, os quais geraram importante registro continental de mudanças de paisagem e do clima durante o Quaternário.

Inicialmente, o trabalho examinou as emissões de RF em quartzo de rochas fonte (ígneas plutônicas e vulcânicas) e sedimentos de diferentes proveniências. Após a deconvolução dos espectros de RF em suas bandas de emissão, as intensidades das bandas de emissão foram comparadas com as sensibilidades OSL (primeiro 1s) e termoluminescência (TL, pico a 110°C) para investigar se a intensidade da banda de emissão de RF pode ser usada como indicador de proveniência sedimentar. Foi demonstrado que a intensidade de RF ultravioleta (UV) se correlaciona com as sensibilidades OSL e TL do quartzo de sedimentos. Essa correlação apoiou a sugestão de que tanto o pico TL de 110°C quanto o OSL de quartzo usam os mesmos centros de recombinação em vez da mesma armadilha de elétrons e que a sensibilização natural dos sinais OSL e TL pode ocorrer devido às mudanças na probabilidade de recombinação em vez de mudanças na probabilidade de captura de cargas. Conclui-se que a intensidade de UV-RF medida com fonte de raios X também pode ser utilizada para análise de proveniência de sedimentos da mesma forma que as sensibilidades OSL e TL.

Características dos sinais VSL de quartzo dos principais sistemas fluviais do Oeste do Brasil (Pantanal), Sudeste do Brasil (bacia do Rio Paraná) e Amazônia Central e Oriental foram investigadas para avaliar se o sinal VSL é adequado para estender o intervalo de tempo da datação por luminescência de sedimentos fluviais brasileiros . Os protocolos de dose regenerativa de alíquota única (SAR, em inglês), dose regenerativa de alíquotas múltiplas (MAR, em inglês) e dose aditiva de alíquotas múltiplas (MAAD, em inglês) foram usados para estimar a dose máxima que pode ser medida por sinais VSL do quartzo presente em sedimentos quaternários brasileiros. Conclui-se que o sinal VSL do quartzo pode aumentar

significativamente o limite de datação até o Pleistoceno Inicial (~800 ka a 1,6 Ma para $2D_0$ obtida por MAAD), mesmo com doses características relativamente mais baixas ($D_0$) observadas nas curvas de dose-resposta das amostras estudadas, se comparadas com outros estudos da literatura. Apesar da VSL ampliar o intervalo de tempo da datação por luminescência dos sedimentos fluviais brasileiros, em relação à datação OSL convencional, o comportamento do sinal VSL parece ser dependente da origem amostra. Isto é sustentado pela ausência de sinal VSL natural em amostras de quartzo derivadas dos depósitos fluviais amazônicos estudados.

Na estimativa das idades de formação dos *ironstones* do rio Xingu, idades entre ~60 ka e 3 ka foram obtidas por meio do protocolo de datação SAR OSL em alíquotas de quartzo. Isso indica que as rochas ferruginosas do rio Xingu resultam de sistema geoquímico superficial do Pleistoceno Tardio e Holoceno, capaz de precipitar goethita e aprisionar sedimentos detríticos em transporte no canal do rio Xingu. As altas taxas de dose (2,7-12,3 Gy $ka^{-1}$) desses depósitos fluviais limitam a datação OSL para os últimos ~60 ka, assumindo doses máximas de ~200 Gy estimadas a partir da dose característica ($D_0$) das curvas de dose resposta.

As investigações realizadas contribuem para entender a sensibilização natural de sinais OSL e TL, processo ainda pouco compreendido, e ampliam as aplicaçoes dos sinais de luminescência (RF, OSL e VSL) do quartzo para análise de proveniência e geocronlogia de depósitos fluviais no Brasil.

**Palavras-chave**: Radiofluorescência; Luminescência opticamente estimulada, Rochas sedimentares ferruginosas; Luminescência estimulada por luz violeta; Sedimentos fluviais.

# Introduction

## Motivation and purpose

Human excellence is nurtured by inherent curiosity to know about the past (Gould, 1987). The age determination of geological and archeological events in the last ~2.6 million years (The Quaternary period) is critical for understanding past climate and environmental changes, landscape evolution, and human evolution and dispersal. This understanding is important for future predictions of climate, environmental changes and resource planning.

In this connection, the luminescence dating technique, a novel and rapidly developing application in geochronology, has played an important role in age determination of the archaeological and geological events in the Quaternary timespan (Aitken, 1998; Rhodes, 2011; Liritzis *et al*., 2013; Roberts *et al*., 2015; Duller, 1997). In particular, it has proven to be a highly useful and widely applicable technique for obtaining chronologies for the Late and Middle Pleistocene (Buylaert *et al*., 2008; Rittenour, 2008; Cunha *et al*., 2012; Herman *et al*., 2013; Guralnik et al., 2015; Henshilwood *et al*., 2002; Singhvi and Porat, 2008; Fattahi and Walker, 2007; Wallinga, 2002).

Luminescence dating is an interdisciplinary research field based on solid state physics, radiation physics, and Earth and archaeological sciences; all these areas have contributed to the development of the luminescence dating technique. Despite the immense success of the luminescence technique, there are continuous attempts from laboratories across the world to further improve the technique for wider application. Some of the active research areas are: use of luminescence as a sediment tracer and provenance tool (Sawakuchi *et al*., 2018; Gray *et al*., 2019), extending the age range to cover the full Quaternary (Ankjaergaard et al., 2013), investigating the feasibility of luminescence method to shed the light on the formation age of Quaternary rocks (Niyonzima *et al*., 2022), and modelling charge build up in thermally and optically dynamic environments (King *et al*., 2016). Even a slight improvement in the method can have a significant positive impact on the application of the technique in the Geosciences or Archaeology fields, and on the age resolution of the past events.

The researchers rely on the fact that natural minerals such as quartz and feldspar, which are widely used in dating, are rich in luminescent defects and have complex charge transfer processes. It is expected that a better understanding of these defects and processes will give

rise to more robust dating methods, and help to place the existing dating protocols on a solid foundation.

Hence, the first overriding objective of this thesis, therefore, was to investigate luminescence signals of quartz extracted from Brazilian fluvial sediments for better understanding of charge transfer process, and the application of the technique for age resolution and improving of its dating range. This consisted of investigating the variation of the radiofluorescence (RF) emission spectra in quartz extracted from different igneous rocks and sediments of different geological settings. We investigated the difference in RF emission spectra between quartz extracted from igneous rocks and sediments for better understanding the mechanisms involved in thermoluminescence (TL) and optically stimulated luminescence (OSL) sensitivities, properties successfully used in sediment provenance analysis (e.g. Sawakuchi *et al*., 2018; Mendes *et al*., 2019). The possibility of use of RF of quartz for sediment provenance analysis was also investigated by studying the correlation between the ultraviolet (UV) RF emission intensity and sensitivity of both TL and OSL emissions.

Besides the widespread unconsolidated sandy fluvial deposits, some bedrock rivers in eastern Amazonia host sandy and gravelly deposits cemented by goethite. These deposits form rocks over the riverbed and represent unique riverine landscape features. This is the case of the Xingu River draining shield areas in eastern Amazonia. Additionally, it has been reported that the original oxygen isotopes ratio of iron minerals such as goethite and hematite is generally preserved, thereby providing information about weathering and climate conditions at the time of formation (Giral-Kacmarcik *et al*., 1998; Girard *et al*., 2002). The formation ages of ironstones (fluvial sands and gravels cemented by goethite) of the Xingu River are unknown and their formation process is still poorly understood despite their relevance as substrate for the aquatic ecosystem (Fitzgerald *et al*., 2018). Different dating methods of ironstones were applied in Brazilian settings, including (U-Th)/He of goethite (Riffel *et al.*, 2016), electron paramagnetic resonance of matrix kaolinite (Allard *et al*., 2018) and cosmogenic nuclides of trapped quartz grains ($^{10}$Be) (Pupim *et al*., 2015). These methods are suitable to obtain ages in the hundred thousand to million years timescale and dating of ironstones is still challenging for the thousand years timescale necessary to cover the late Pleistocene and Holocene age range. In this thesis, we checked the feasibility of OSL dating on detrital quartz grains within ironstones to shed light on the timing and processes of formation over the riverbed of the Xingu River. This was the second objective of this thesis.

The third objective aimed to extend the age range of luminescence dating to tackle research problems beyond the late Pleistocene, which is usually the age limit for quartz OSL dating. In this way, deposition ages of fluvial sediments have a fundamental role to constrain the landscape changes in Amazonia during the middle and early Pleistocene, when most species representing the modern Amazonian biota appeared (Smith *et al*., 2014). Geochronological methods to determine reliable burial ages for the middle and early Pleistocene fluvial sedimentary record of Amazonia are crucial to understand the role of the physical landscape for the biota diversification (Hoorn *et al*., 2017). So far, most successful dating studies of Amazonian Quaternary sedimentary deposits are based on radiocarbon dating of rare organic material (e.g. Rossetti *et al*., 2005) or quartz optically stimulated luminescence (OSL) (e.g. Rossetti *et al*., 2015). However, the use of quartz for OSL dating is typically limited to the last 100–150 ka due to saturation of the OSL signal around 150-200 Gy (Wintle and Adamiec, 2017). The violet stimulated luminescence (VSL) from quartz, which probes traps deeper than those accessible by blue light, has been observed to grow with doses up to about 1000 Gy (Jain, 2009), ~10 times higher than the OSL from the same grains. Further studies confirmed that VSL signal originates from thermally stable with lifetime of $10^{11}$ years at 10°C (Ankjaergaard *et al*.,2013, 2015) with no athermal loss (Ankjaergaard *et al*.,2013); thus giving the potential to extend the age range of quartz luminescence dating to cover the full quaternary period. Therefore, we explored the VSL single aliquot regenerative dose (SAR), multiple aliquots regenerative (MAR), multiple aliquots additive dose (MAAD) protocols, and investigated the behavior of the VSL signal under different measurement conditions with the aim of extending the dating range of luminescence dating for Brazilian fluvial sediments.

## Thesis outline

The thesis is outlined in five chapters. Chapter 1 introduces the basic concepts of dating based on luminescence methods. The physical basics of luminescence, principal of luminescence, environments suitable for luminescence dating, and explanation of how the phenomenon can be used for dating is presented.

Chapters 2, 3 and 4 describe three manuscripts, where two are published (Niyonzima *et al*., 2020, 2022) and other is in preparation for submission in peer-reviewed scientific journal. Each article is individually understandable. They are structured so that they describe the motivation, experimental procedures, results and discussion. They all address the subject of using luminescence signals from quartz extracted from Brazilian fluvial sediments for provenance analysis and dating.

The work presented in Chapter 2 is based on the article *"Radiofluorescence of quartz from rocks and sediments and its correlation with thermoluminescence and optically stimulated luminescence sensitivities"*, published in *Ancient TL* (Niyonzima et al., 2020). This study investigates radiofluorescence (RF) emissions in quartz from parent rocks and sediments of different provenances and different optically stimulated luminescence (OSL) and thermoluminescence (TL) sensitivities. The correlation of OSL and TL (110°C peak) sensitivities were compared to RF emission peak sensitivities in order to understand the sensitivity variations in terms of charge traps and recombination centers. We investigate the relationships between intensities of RF emission peaks and OSL and TL sensitivities in order to investigate the possibility of RF emission band sensitivity to be used as a provenance proxy as in the way as OSL and TL sensitivities for quartz from sediments.

The work presented in Chapter 3 is based on manuscript: "*Testing the potential of quartz violet stimulated luminescence (VSL) for dating of Brazilian fluvial sediments" (Niyonzima et al., in preparation).* On this chapter, VSL properties of quartz from major fluvial systems in South America, represented by fluvial terraces from western Brazil, southeastern Brazil and central and eastern Amazonia. Firstly, we investigated the presence of VSL signals in quartz from the studied samples under different preheating temperatures. Afterwards, dose recovery test of SAR-VSL protocol and thermal stability test were performed to evaluate dose estimation capacity. We also estimated equivalent dose ($D_e$) and characteristic doses ($D_0$) of samples that showed VSL signal using a single aliquot regenerative dose (SAR), multiple aliquots regenerative doses (MAR), and multiple aliquots

additive doses (MAAD) protocols. Considerations about the use of VSL to extend the age limit of quartz dating beyond the late Pleistocene were addressed in this chapter.

The work presented in Chapter 4 is based on the article "*Luminescence dating of quartz from ironstones of the Xingu River, Eastern Amazonia",* published in Quaternary Geochronology (Niyonzima *et al*., 2022). In this study, OSL dating method was applied for first time in establishing formation ages of ferruginous deposits (ironstones) of the Xingu River in Eastern Amazonia, Brazil. Equivalent doses, environmental dose rates and hence luminescence ages were determined. Equivalent dose distributions were also evaluated in order to inform about how quartz grains are incorporated into ironstones. Additionally, the organic content of some samples was dated by radiocarbon ($^{14}C$) for comparison with quartz OSL ages.

In Chapter 5, we summarize the main conclusions based on outcomes from the thesis. It this chapter also, we clarified the possible work to be done in the future in order to support some arguments raised in this work.

## Summary conclusions

Chapters 2, 3 and 4 of this study provide characteristics of different luminescence signals (RF, VSL and OSL) of quartz from Brazilian fluvial rocks (ironstones) and sediments. All characteristics confirmed the use of the luminescence signals for provenance, first estimation of fluvial ironstones formation ages using existing luminescence method (SAR OSL) and the appraisal of the recently proposed VSL method to extending the dating range of Brazilian sediments using samples dated using existing OSL methods.

The general observation the work presented in chapter 2, is that the RF intensity differs between quartz from rocks and sediments, and among quartz from sediments with different provenances. The observed linear correlation between OSL, TL sensitivities and UV-RF emission intensity improved the understanding that the sensitization processes in nature might be due to the changes in recombination processes rather than changes in the charge trapping probability. From this correlation, this work also suggested for the first time the use of UV-RF emission intensity for provenance analysis in addition to other provenance proxies. It also supports the suggestion that a single process is involved in sensitization of both TL and OSL. However, further studies are recommended using samples from different provenances in order to confirm the use of the UV-RF signal as provenance proxy.

Chapter 3 investigates the characteristics of VSL signals of quartz from major fluvial systems within Brazil and the use of VSL signals in extending luminescence dating range of Brazilian sediments. VSL protocols used in this study showed that VSL signal of quartz could extend the dating range of fluvial deposits in Brazil especially in the cratonic settings where dose rates are relatively low. Here, it is recommended to use more samples as we observed the dependence of VSL signal on samples. In chapter 4, the OSL dating method was found to be feasible in dating ironstones deposits and the OSL ages are between ~60 ka and 3 ka. The estimated OSL ages of quartz improve the understanding of the genesis of ironstones and suggest that they are related with the Quaternary hydrology of the Xingu River. We recommend the use of single grain approach to determine the time of specific grain trapping, minimize the averaging effect and investigate the possible source of high overdispersion observed for same samples

## References


Adamiec G., Duller G. A. T., Roberts H. M., Wintle A. G., 2010. Improving the TT-OSL SAR protocol through source trap characterisation. **Radiation Measurement**, 45: 768-777.

Aitken, M. J., 1985. Thermoluminescence dating. **Academic press, London.**

Aitken, M. J., 1994. Optical dating: a non-specialist review. **Quaternary Science Reviews**, 13(5-7), 503-508.

Aitken, M. J., 1998. An Introduction to Optical Dating. Oxford: **Oxford University Press**.

Aitken, M. J., 1998. An introduction to optical dating: the dating of quaternary sediments by the use of photon-stimulated luminescence. **Oxford University Press**.

Aitken, M. J., Smith, B. M., 1988. Optical dating: Recuperation after bleaching. **Quaternary Science Reviews**, 7, 387-393.

Allard, T., Gautheron, C., Riffel, S. B., Balan, E., Soares. B. F., Pinna-Jamme, R., Derycke, A., Morin, G., Bueno, G. T., do Nascimento, N., 2018. Combined dating of goethites and kaolinites from ferruginous duricrusts. Deciphering the Late Neogene erosion history of Central Amazonia. **Chemical Geology,** 479, 136–150.



Allard, T., Gautheron, C., Riffel, S. B., Balan, E., Soares. B. F., Pinna-Jamme, R., Derycke, A., Morin, G., Bueno, G. T., do Nascimento, N., 2018. Combined dating of goethites and kaolinites from ferruginous duricrusts. Deciphering the Late Neogene erosion history of Central Amazonia. **Chemical Geology,** 479, 136–150.



Ankjærgaard, C., 2019. Exploring multiple-aliquot methods for quartz violet stimulated luminescence dating. **Quaternary Geochronology,** 51, 99–109.

Ankjærgaard, C., Guralnik, B., Buylaert, J-P., Reimann, T., Yi, S.W., Wallinga, J., 2016. Violet stimulated luminescence dating of quartz from Luochuan (Chinese loess plateau): Agreement with independent chronology up to ~600 ka. **Quaternary Geochronology,** 34, 33–46.

Ankjærgaard, C., Guralnik, B., Porat, N., Heimann, A., Jain, M., Wallinga, J., 2015. Violet stimulated luminescence: geo-or thermochronometer? **Radiation Measurement**, 81, 78–84.

Ankjærgaard, C., Jain, M., Wallinga, J., 2013. Towards dating quaternary sediments using the

quartz violet stimulated luminescence (VSL) signal. **Quaternary Geochronology**, 18, 99–109.

Arnold, L. J., Bailey, R. M., Tucker, G. E., 2007. Statistical treatment of fluvial dose distributions from southern Colorado arroyo deposits. **Quaternary Geochronology,** 2, 162–167.

Arnold, L. J., Demuro, M., María, J., Pérez-González, A., Castro, M. B. De, Carbonell, E., Arsuaga, J. L., 2015. Evaluating the suitability of extended-range luminescence dating techniques over early and Middle Pleistocene timescales: published datasets and case studies from Atapuerca, Spain. **Quaternary International**, 389, 167–190.

Arnold, L. J., Roberts, R. G., 2009. Stochastic modeling of multi-grain equivalent dose ($D_e$) distributions: implications for OSL dating of sediment mixtures. **Quaternary Geochronology,** 4, 204–230.

Asiedu, D. K., Suzuki, S., Nogami, K., Shibata, T., 2000. Geochemistry of lower cretaceous sediments, inner zone of southwest Japan. Constraints on provenance and tectonic environment. **Geochemical Journal,** 34, 155–173.

Bahia, R. B. C., Faraco, M. T. L., Monteiro, M. A. S., and Oliveira, M. A. O., 2004. Folha SA.22-Belém. In: Carta Geológica do Brasil ao Milionésimo. Sistema de Informações Geográficas. Programa Geologia do Brasil, edited by Schobbenhaus, C., Gonçalves, J. H., Santos, J. O. S., Abram, M. B., Leão Neto, R., Matos, G. M. M., Vidotti, R. M., Ramos, M. A. B., and Jesus, J. D. A. de, CPRM, Brasilia, CD-ROM.

Bertassoli Jr, D. J., Sawakuchi, A. O., Chiessi, C. M., Schefuβ, E, Hartmann, G. A., Häggi, C., Cruz, F. W., Zabel, M., McGlue, M., Santos, R. A., Pupim, F. N., 2019. Spatiotemporal variations of riverine discharge within the Amazon basin during the Late Holocene coincide with extratropical temperature anomalies. **Geophysical Research Letters,** 46(15), 9013–9022.

Bertassoli Jr, D. J., Sawakuchi, A. O., Sawakuchi, H. O., Pupim, F. N., Hartmann, G. A., McGlue, M. M., Chiessi, C. M., Zabel, M., Schefuß, E., Pereira, T. S., Santos, R. A., Faustino, S. B., Oliveira, P. E., Bicudo, D. C., 2017. The fate of carbon in sediments of the Xingu and Tapajós Clearwater Rivers, Eastern Amazon. **Frontiers in Marine Science**, 4. https://doi.org/10.3389/ fmars.2017.00044.

Bezerra, I. S. A. A., Nogueira, A. C. R., Motta, M. B., Sawakuchi, A. O., Mineli, T. D., Silva. A. Q. Silva Jr, A. G., Domingos, F. H. G., Mata, G. A. T., Lima, F. J. C., Rike, S. R. L., 2021. Incision and aggradation phases of the Amazon River in Central-Eastern Amazonia during the late Neogene and Quaternary. **Geomorphology,** 399, 108073.

Buylaert J. P., Jain M., Murray A. S., Thomsen K. J., Thiel C., Sohbati R., 2012. A robust feldspar luminescence dating method for Middle and Late Pleistocene sediments. **Boreas**, 41(3): 435–451.

Buylaert, J. P., Murray, A. S., Vandenberghe, D., Vriend, M., De Corte, F., 2008. Optical dating of Chinese loess using sandsized quartz: establishing a time frame for Late Pleistocene climate changes in the western part of the Chinese Loess Plateau. **Quaternary Geochronology**, 3(1), 99-113.

Chapot, M. S., Roberts, H. M., Duller, G. A. T., Lai, Z. P., 2012. A comparison of natural and laboratory-generated dose response curves for quartz optically stimulated luminescence signals from Chinese Loess. **Radiation Measurements**, 47, 1045–1052.

Chen, G., Li, S. H., Murray, A. S., 2000. Study of the 110°C TL peak sensitivity in optical dating of quartz. **Radiation Measurements**, 32, 641-645.

Chithambo, M. L., Preusser, F., Ramseyer, K., Ogundare, F. O., 2007. Time-resolved luminescence of low sensitivity quartz from crystalline rocks. **Radiation Measurements**, 42, 205–212.

Chithambo. M., Niyonzima. P., 2017. Radioluminescence of annealed synthetic quartz, **Radiation- Measurements**, 106, 35-39.

Colarossi, D., Chapot, M. S., Duller, G. A., Roberts, H. M., 2018. Testing single aliquot regenerative dose (SAR) protocols for violet stimulated luminescence. **Radiation Measurements,** 120, 104–109.

Cunha, P. P., Almeida, N. A., Aubry, T., Martins, A. A., Murray, A. S., Buylaert, J.P., Sohbati, R., Raposo, L., Rocha, L., 2012. Records of human occupation from Pleistocene river terrace and aeolian sediments in the Arneiro depression (Lower Tejo River, central eastern Portugal). **Geomorphology**, 165, 78-90.

David, B., Roberts, R. G., Magee, J., Mialanes, J., Turney, C., Bird, M., White, C., Fifield, L. K., Tibby, J., 2007. Sediment mixing at Nonda Rock: investigations of stratigraphic

integrity at an early archaeological site in northern Australia and implications for the human colonisation of the continent. **Journal of Quaternary Science,** 22, 449–479.

Duller, G. A. T., 1996. Recent developments in luminescence dating of Quaternary sediments. **Progress in Physical Geography**, 20(2), 127-145.

Duller, G. A. T., 1997. Behavioural studies of stimulated luminescence from feldspars. **Radiation Measurements**, 27(5), 663-694.

Duller, G. A. T., 2003. Distinguishing quartz and feldspar in single grain luminescence measurements. **Radiation Measurements,** 37, 161–165.

Duller, G. A. T., 2014. Luminescence dating of Quaternary sediments: recent advances. **Journal of quaternary science**, 19, 183–192.

Duller, G. A. T., 2015. The Analyst software package for luminescence data: overview and recent improvements. **Ancient TL,** 33, 35–42.

Duller, G. A. T., Wintle, A. G., 2012. A review of the thermally transferred optically stimulated luminescence signal from quartz for dating sediments. **Quaternary Geochronology**, 7, 6–20.

Fattahi, M., Walker, R. T., 2007. Luminescence dating of the last earthquake of the Sabzevar thrust fault, NE Iran. **Quaternary Geochronology**, 2(1), 284-289.

Filizola, N. P., 1999. O fluxo de sedimentos em suspensão nos rios da bacia Amazônica Brasileira. **Publicação ANEEL, Brasília**, 63 pp.

Fitzgerald, D. B., Sabaj Perez, M. H., Sousa, L. M., Gonçalves, A. P., Rapp Py-Daniel, L., Lujan, N. K., Zuanon, J., Winemiller, K. O., Lundberg, J. G., 2018. Diversity and community structure of rapids-dwelling fishes of the Xingu River: Implications for conservation amid large-scale hydroelectric development. **Biological Conservation**, 222, 104–112.

Fleming, S. J., 1970. Thermoluminescence dating: refinement of the quartz inclusion method. **Archaeometry**, 12, 133-145.

Friedrich, J., Fasoli, M., Kreutzer, S., Schmidt, C., 2017. The basic principles of quartz radiofluorescence dynamics in the UV– analytical, numerical and experimental results. **Journal of Luminescence**, 192, 940–948.

Galbraith, R. F., Roberts, R. G., Laslett, G. M., Yoshida, H., Olley, J. M., 1999. Optical dating of single and multiple grains of quartz from Jinmium rock shelter, Northern Australia: part I, experimental design and statistical models. **Archaeometry,** 41, 339–364.

Giral-Kacmarkcik, S., Savin, S. M., Nahon, D., Girard, J.-P., Lucas, Y., and Abel, L., 1998. Oxygen isotope geochemistry of kaolinite in laterite-forming processes, Manaus, Amazonas, Brazil. **Geochimica et Cosmochimica Acta,** 62, 1865–1879.

Girard, J. P., Freyssinet, P., Morillon, A. C., 2002. Oxygen isotope study of Cayenne duricrust paleosurfaces: implications for past climate and laterization processes over French Guiana. **Chemical Geology,** 191, 329–343.

Girard, J.-P., Freyssinet, P., Chazot, G., 2000. Unraveling climatic changes from intraprofile variation in oxygen and hydrogen isotopic composition of goethite and kaolinite in laterites: an integrated study from Yaou, French Guiana. **Geochimica et Cosmochimica Acta,** 64 (3), 409–426.

Gould, S. J., 1987. Time's arrow, time's cycle: Myth and metaphor in the discovery of geological time (Vol. 2). **Harvard University Press**.

Gray, H. J., Jain, M., Sawakuchi, A. O., Mahan, S. A., Tucker, G. E., 2019. Luminescence as a sediment tracer and provenance tool. **Reviews of Geophysics**, 57, 987–1017.

Grögler, N., Houtermans, F. G., Stauffer, H., 1958. Radiation damage as a research tools for geology and prehistory. Convengo sulle dotazioni con metodi nuclear. **5th Internazation Elettr Nucl Sezione Nuclear Roma**: 5-15.

Guedes, C. C. F., Sawakuchi, A. O., Giannini, P. C. F., DeWitt, R., Aguiar, V. A. P., 2013. Luminescence characteristics of quartz from Brazilian sediments and constraints for OSL dating. **Anais da Academia Brasileira de Ciências**, 85, 1303-1316.

Guerin, G., Mercier, N., Adamiec, G., 2011. Dose-rate conversion factors: update. **Ancient TL,** 29, 5–8.

Guralnik, B., Ankjærgaard, C., Jain. M., Murray, A. S., Müller, A., Wälle, M., Herman, F, 2015. OSL-thermochronometry using bedrock quartz: A note of caution. **Quaternary Geochronology**, 25, 37-48.

Guralnik, B., Jain, M., Herman, F., Ankjærgaard, C., Murray, A. S., Valla, P. G., Kook, M., 2015. OSL-thermochronometry of feldspar from the KTB borehole, Germany. **Earth and Planetary Science Letters**, 423, 232-243.

Henshilwood, C. S., d'Errico, F., Yates, R., Jacobs, Z., Tribolo, C., Duller, G.A., Mercier, N., Sealy, J.C., Valladas, H., Watts, I., Wintle, A. G., 2002. Emergence of modern human behavior: Middle Stone Age engravings from South Africa. **Science**, 295(5558), 1278-1280.

Herman, F., Seward, D., Valla, P. G., Carter, A., Kohn, B., Willett, S. D., Ehlers, T. A., 2013. Worldwide acceleration of mountain erosion under a cooling climate. **Nature**, 504(7480), 423-426.

Hernandez, M., Mauz, B., Mercier, N., Shen, Z., 2012. Evaluating the efficiency of TT-OSL SAR protocols. **Radiation Measurements**, 47, 669-673.

Hernandez, M., Mercier, N., 2015. Characteristics of the post-blue VSL signal from sedimentary quartz. **Radiation Measurements**, 78, 1–8.

Hogg, A. G., Heaton, T. J., Hua, Q., Palmer, J. G., Turney, C. S. M., Southon, J., Bayliss, A., Blackwell, P. G., Boswijk, G., Ramsey, C. B., Pearson, C., Petchey, F., Reimer, P., Reimer, R., Wacker, L., 2020. SHCal20 Southern hemisphere calibration, 0–55,000 years Cal BP. **Radiocarbon,** 62(4), 759–778.

Hoorn, C., Bogotá-A., G.R., Baez, M.R., Lammertsma, E.I., Flantua, S.G.A., Dantas, E.L., Dino, R., Carmo, D.A., Chemale, F.Jr. 2017. The Amazon at sea: Onset and stages of the Amazon River from a marine record, with special reference to Neogene plant turnover in the drainage basin. **Global and Planetary Change,** 153, 51-65.

Huntley, D. J., Godfrey, S. D. I., Thewalt, M. L. W., 1985. Optical dating of sediments. **Nature**, 313, 105-107.

Huntley, D. J., Godfrey-Smith, D. I., Haskell, E. H., 1991. Light-induced emission spectra from some quartz and feldspars. **Nuclear Tracks Radiation Measurements**, 18, 127–131.

Itoh, C., Tanimura, K., Itoh, N., Itoh, M., 1989. Threshold energy for photogeneration of self-trapped excitons in Si O 2. **Physical Review B**, 39(15), 11183.

Jacobs, Z., Roberts, R. G., 2007. Advances in Optically Stimulated Luminescence Dating of Individual Grains of Quartz from Archeological Deposits. **Evolutionary Anthropology,** 16, 210–223.

Jain, M., 2009. Extending the dose range: probing deep traps in quartz with 3.06 eV photons. **Radiation Measurements**, 44, 445–452.

Jain, M., Murray, A. S., Bøtter-Jensen, L., 2003. Characterization of blue-light stimulated luminescence component in different quartz samples: Implications for dose measurement. **Radiation Measurements**, 37, 441-449.

Kim, J. C., Duller, G. A.T., Roberts, H. M., Wintle, A. G., Lee, Y. I., Yi, S. B., 2009. Dose dependence of thermally transferred optically stimulated luminescence signal in quartz. **Radiation Measurements,** 44, 132-143.

King, G. E., Herman, F., Lambert, R., Valla, P. G., Guralnik, B., 2016a. Multi-OSL thermochronometry of feldspar. **Quaternary Geochronology,** 33, 76–87.

Krbetschek, M. R., Götze, J., Dietrich, A., Trautmann, T., 1997. Spectral information from minerals relevant for luminescence dating. **Radiation Measurements**, 27, 695–748.

Krbetschek, M. R., Trautmann, T., 2000. A spectral radioluminescence study for dating and dosimetry. **Radiation Measurements**, 32, 853–857.

Kreutzer, S., Schmidt, C., Fuchs, M. C., Dietze, M., Fischer, M., Fuchs, M., 2012. Introducing an R package for luminescence dating analysis. **Ancient TL,** 30, 1–8.

Liritzis, I., Singhvi, A. K., James, K. (2013). Luminescence dating in archaeology, anthropology, and geoarchaeology: an overview; Heidelberg, Germany: **Springer.**

Lü, T., Sun. J., 2011. Luminescence sensitivities of quartz grains from eolian deposits in northern China and their implications for provenance. **Quaternary Research**, 76, 181-189.

Malins, A. E. R., Poolton, N. R. J., Quinn, F. M., Johnsen, O., Denby, P. M., 2004. Luminescence excitation characteristics of Ca, Na and K-aluminosilicates (feldspars) in the stimulation range 5–40 eV: determination of the band-gap energies. **Journal of Physics D: Applied Physics**, 37(10), 1439.

Marazuev, Y. A., Brik, A. B., Degota, V. Y., 1995. Radioluminescent dosimetry of Alpha - quartz. **Radiation Measurements**, 24, 565-569.

Marengo, J. A., 2004. Interdecadal variability and trends of rainfall across the Amazon basin. **Theoretical and Applied Climatology,** 78, 79–96.

Martini, M., Fasoli, M., Galli, A., 2009. Quartz OSL emission spectra and the role of [AlO4]° recombination centres. **Radiation Measurements**, 44, 458-461.

Martini, M., Fasoli, M., Galli, A., Villa, I., Guibert, P., 2012a. Radioluminescence of synthetic quartz related to alkali ions. **Journal of Luminescence**, 132, 1030-1036.

Martini, M., Fasoli, M., Villa, I., Guibert, P., 2012b. Radioluminescence of synthetic and natural quartz. **Radiation Measurements**, 47, 846-850.

Meade, R. H., Rayol, J. M., Conceição, S. C., Natividade, J. R. G., 1991. Backwater effects in the Amazon river basin of Brazil. **Environmental Geology and Water Sciences,** 18, 105–114.

Mehdahl, V., 1979. Thermoluminescence dating: Beta-dose attenuation in quartz grains. **Archaeometry**, 21, 61-72.

Mejdahl, V., Christiansen, H. H., 1994. Procedures used for luminescence dating of sediments. **Quaternary Science Reviews,** 13, 403–406.

Mendes, V. R., Sawakuchi, A. O., Chiessi, C. M., Giannini, P.C. F., Rehfeld, K., Mulitza, S., 2019. Thermoluminescence and optically stimulated luminescence measured in marine sediments indicate precipitation changes over northeastern Brazil. **Paleoceanography Paleoclimatology,** 2019PA003691.

Mineli, T. D., Sawakuchi, A. O., Guralnik, B., Lambert, R., Jain, M., Pupim, F. N., del Río, I. A. G., Nogueira, L., 2021. Variation of luminescence sensitivity, characteristic dose and trap parameters of quartz from rocks and sediments. **Radiation Measurements**, 144, 106583

Moska, P., Murray, A. S., 2006. Stability of the quartz fast-component in insensitive samples. **Radiation Measurements**, 41, 878-885.

Murray, A. S., Wintle, A. G., 2000. Luminescence dating of quartz using an improved single-aliquot regenerative-dose protocol. **Radiation Measurements,** 32, 57–73.

Murray, A. S., Wintle, A. G., 2003. The single aliquot regenerative dose protocol: potential for improvements in reliability. **Radiation Measurements,** 37(4–5), 377–381.

Nathan, R. P., Thomas, P. J., Jain, M., Murray, A. S., Rhodes, E. J., 2003. Environmental dose rate heterogeneity of beta radiation and its implications for luminescence dating:

Monte Carlo modelling experimental validation. **Radiation Measurements,** 37, 305–313.

Nian, X., Zhang, W., Qiu, F., Qin, J., Wang, Z., Sun, Q., Chen, J., Chen, Z., Liu, N., 2019. Luminescence characteristics of quartz from Holocene delta deposits of the Yangtze River and their provenance implications. **Quaternary Geochronology**, 49, 131–137.

Niyonzima, P., Sawakuchi, A. O., Bertassoli Jr. D. J., Pupim, F. N., Porat, N., Freire, M. P., Goes, A. M., Rodrigues, F. C. G. Luminescence dating of quartz from ironstones of the Xingu River, astern Amazonia. **Quaternary Geochronology,** 67101241.

Niyonzima, P., Sawakuchi, A. O., Jain, M., Kumar, R., Minelli, T. D., del Río, I., Pupim, F. N., 2020. Radiofluorescence of quartz from rocks and sediments and its correlation with thermoluminescence and optically stimulated luminescence sensitivities. **Ancient TL,** 38 (1), 11–20.

Nogueira, C., Buckup, P. A., Menezes, N. A., Oyakawa, O. T., Kasecker, T. P., Neto, M. B. R., da Silva, J. M. C., 2010. Restricted-range fishes and the conservation of Brazilian freshwaters. **PLOS ONE,** 5(6), 1–10.

Pickering, R., Jacobs, Z., Herries, A. I. R., Karkanas, P., Bar-Matthews, M., Woodhead, J. D., Kappen, P., Fisher, E., Marean, C. W., 2013. Paleoanthropologically significant South African sea caves dated to 1.1-1.0 million years using a combination of U-Pb, TT-OSL and paleomagnetism. **Quaternary Science Review**, 65, 39–52.

Pietsch, T. J., Olley, J. M., Nanson, G. C., 2008. Fluvial transport as a natural luminescence sensitizer of quartz. Quaternary Geochronology, 3, 365-391.

Porat, N., Duller, G. A. T., Roberts, H., Wintle, A .G., 2009. A simplified SAR protocol for TT-OSL. **Radiation Measurements**, 44, 538-542.

Porat, N., Jain, M., Ronen, A., Horwitz, L. K., 2018. A contribution to late middle Paleolithic chronology of the levant: new luminescence ages for the Atlit railway bridge site, Coastal plain. Israel. **Quaternary International**, 464, 32–42.

Prasad, A. K., Lapp, T., Kook, M. and Jain, M., 2016. Probing luminescence centers in Na rich feldspar. **Radiation Measurements**, 90, 292-297.

Prescott, J. R., Hutton, J. T., 1994. Cosmic ray contributions to dose rates for luminescence and ESR dating: large depths and long-term time variations. **Radiation Measurements,** 23, 497–500.

Prescott, J. R., Robertson, G. B., 1997. Sediment dating by luminescence: a review. **Radiation Measurements,** 27, 893-922.

Pupim, F. N., Sawakuchi, A. O., Mineli, T. D., Nogueira, L., 2016. Evaluating isothermal thermoluminescence and thermally transferred optically stimulated luminescence for dating of Pleistocene sediments in Amazonia. **Quaternary Geochronology,** 36, 28-37.

Pupim, F. N., Bierman, P. R., Assine, M. L., Rood, D. H., Silva, A., Merino, E. R., 2015. Erosion rates and landscape evolution of the lowlands of the Upper Paraguay River basin (Brazil) from cosmogenic $^{10}$Be. **Geomorphology,** 234, 151–160.

Pupim, F. N., Sawakuchi, A. O., Almeida, R. P., Ribas C. C., Kern, A. K., Hartmann, G. A., Chiessi, C. M., Tamura L. N., Mineli, T. D., Savian, J .F., Grohmann, C. H., Bertassoli Jr, D. J., Stern, A. G., Cruz, F. W., Cracraft, J., 2019. Chronology of Terra Firme formation in Amazonian lowlands reveals a dynamic Quaternary landscape. **Quaternary Science Reviews,** 210, 154–163.

Pupim, F. N., Sawakuchi, A. O., Mineli, T. D., Nogueira, L., 2016. Evaluating isothermal thermoluminescence and thermally transferred optically stimulated luminescence for dating of Pleistocene sediments in Amazonia. **Quaternary Geochronology,** 36, 28–37.

Rahimzadeh, N., Tsukamoto, S., Zhang, J., Long, H., 2021. Natural and laboratory dose response curves of quartz violet stimulated luminescence (VSL): Exploring the multiple aliquot regenerative dose (MAR) protocol. **Quaternary Geochronology**, 65, 101-194.

Rhodes, E. J., 2011. Optically stimulated luminescence dating of sediments over the past 200,000 years. **Annual Review of Earth and Planetary Sciences**, 39, 461-488.

Ribeiro, L. M. A. L., Sawakuchi, A. O., Wang, H., Sallun Filho, W., Nogueira, L., 2015. OSL dating of Brazilian fluvial carbonates (tufas) using detrital quartz grains. **Quaternary International,** 362, 146–156.

Riffel, S. B., Vasconcelos, P. M., Carmo, I. O., Farley, K. A., 2016. Goethite (U–Th)/He geochronology and precipitation mechanisms during weathering of basalts. **Chemical Geology,** 446, 18–32.

Rink, W. J., Rendell, H., Marseglia, E. A., Luff, B. J., Townsend, P. D., 1993. Thermoluminescence Spectra of Igneous Quartz and Hydrothermal Vein Quartz. **Physics and Chemistry of Minerals**, 20, 353-361.

Rittenour, T. M., 2008. Luminescence dating of fluvial deposits: applications to geomorphic, palaeoseismic and archaeological research. **Boreas**, 37(4), 613-635.

Roberts, R. G., Jacobs, Z., Li, B., Jankowski, N. R., Cunningham, A. C., Rosenfeld, A. B., 2015. Optical dating in archaeology: thirty years in retrospect and grand challenges for the future. **Journal of Archaeological Science**, 56, 41-60.

Roberts, R. G., Lian, O. B., 2015. Dating techniques: Illuminating the past. **Nature**, 520(7548), 438-439.

Rodnight, H., Duller, G. A. T., Tooth, S., Wintle, A. G., 2005. Optical dating of a scroll-bar sequence on the Klip River, South Africa, to derive the lateral migration rate of a meander bend. **The Holocene,** 15, 802–811.

Rossetti, D. F, Toledo, P. M., Góes A. M. 2005. New geological framework for Western Amazonia (Brazil) and implications for biogeography and evolution. **Quaternary Research,** 63, 78–89.

Rossetti, D. F., Cohen, M. C. L., Tatumi, S. H., Sawakuchi, A. O., Cremon, É. H., Mittani, J. C. R., Bertani, T. C., Munita, C. J. A. S., Tudela, D. R. G., Yee, M., Moya, G. 2015. Mid-Late Pleistocene OSL chronology in western Amazonia and implications for the transcontinental Amazon pathway. **Sedimentary Geology,** 330, 1–15.

Sawakuchi, A. O., Blair, M. W., DeWitt, R., Faleiros, F. M., Hyppolito, T., Guedes, C. C. F., 2011. Thermal history versus sedimentary history: OSL sensitivity of quartz grains extracted from rocks and sediments. **Quaternary Geochronology**, 6, 261–272.

Sawakuchi, A. O., Guedes, C. C. F., Dewitt, R., Giannini, P. C. F., Blair, M. W., Nascimento Jr., Faleiros, F. M., 2012. Quartz OSL sensitivity as a proxy for storm activity on the southern Brazilian coast during the Late Holocene. **Quaternary Geochronology**, 13, 92–102.

Sawakuchi, A. O., Hartmann, G. A., Sawakuchi, H. O., Pupim, F. N., Bertassoli Jr., D. J., Parra, M., Antinao, J. L., Sousa, L. M., Sabaj Perez, M. H., Oliveira, P. E., Santos, R. A., Savian, J. F., Grohmann, C. H., Medeiros, V. B., McGlue, M. M., Bicudo, D. C., Faustino, S. B., 2015. The Volta Grande do Xingu: Reconstruction of past

environments and forecasting of future scenarios of a unique Amazonian fluvial landscape. **Scientific Drilling,** 20, 21–32.

Sawakuchi, A. O., Jain, M., Mineli, T. D., Nogueira, L., Bertassoli Jr, D. J., Häggi, C., Sawakuchi, H. O., Pupim, F. N., Grohmann, C. H., Chiessi C. M., M. Zabel c, Mulitza S., Mazoca, C. E. M., Cunha, D. F., 2018. Luminescence of quartz and feldspar fingerprints provenance and correlates with the source area denudation in the Amazon River basin. **Earth and Planetary Science Letters**, 492, 152–162.

Sawakuchi, A. O., Kalchgruber, R., Giannini, P. C. F., Nascimento, Jr. D. R., Guedes, C. C. F., Umisedo, N. K., 2008. The development of blowouts and foredunes in the Ilha Comprida barrier (Southeastern Brazil): the influence of Late Holocene climate changes on coastal sedimentation. **Quaternary Science Reviews,** 27, 2076–2090.

Sawakuchi, A. O., Mendes, V. R., Pupim, F. N., Mineli, T. D., Ribeiro, L. M. A. L., Zular, A., Guedes, C. C. F., Giannini, P. C. F., Nogueira, L., Sallun Filho, W., Assine, M. L., 2016**.** Optically stimulated luminescence and isothermal thermoluminescence dating of high sensitivity and well bleached quartz from Brazilian sediments: from Late Holocene to beyond the Quaternary? **Brazilian Journal of Geology,** 46(1), 209–226.

Sawakuchi, A. O., Rodrigues, F. C. G., Mineli, T. D., Mendes, V. R., Melo, D. B., Chiessi, C. M., Giannini, P. C. F., 2020. Optically stimulated luminescence sensitivity of quartz for provenance analysis. **Methods and Protocols**, 3(1), 6.

Schilles, T., Poolton, N. R. J., Bulur, E., Bøtter-Jensen, L., Murray, A. S., Smith, G. M., Riedi, P. C., and Wagner, G. A., 2001. A multi-spectroscopic study of luminescence sensitivity changes in natural quartz induced by high-temperature annealing. **Journal of Physics D: Applied Physics**, 34**,** 722–731.

Schmidt, C., Kreutzer, S., DeWitt, R., Fuchs, M., 2015. Radiofluorescence of quartz: A review. **Quaternary Geochronology**, 27, 66-77.

Shimizu, N., Mitamura, N., Takeuchi, A., Hashimoto, T., 2006. Dependence of radioluminescence on TL-properties in natural quartz. **Radiation Measurements**, 41, 831-835.

Singhvi, A. K., Porat, N., 2008. Impact of luminescence dating on geomorphological and palaeoclimate research in drylands. **Boreas**, 37(4), 536-558.

Sioli, H., 1984. The Amazon: Limnology and Landscape Ecology of a Mighty Tropical River and its Basin, **Kluwer Academic Publishers, ed. Dordrecht, Boston**.

Smith, B. T., McCormack, J. E., Cuervo, A. M., Hickerson, M. J., Aleixo, A., Cadena, C.D., Perez-Em an, J., Burney, C. W., Xie, X., Harvey, M. G., Faircloth, B. C., Glenn, T. C., Derryberry, E. P., Prejean, J., Fields, S., Brumfield, R., 2014. The drivers of tropical speciation. **Nature,** 515 (7527), 406-409.

Soares, E. A. A., Tatumi, S. H., Riccomini, C., 2010. OSL age determination of Pleistocene fluvial deposits in Central Amazonia. **Anais da Academia Brasileira de Ciências,** 82, 691–699.

Sontag-González, M., Frouin, M., Li, B., Schwenninger, J. L., 2020. Assessing the Dating Potential of Violet Stimulated Luminescence Protocols. **Geochronometria**, DOI 10.1515/geochr-2015-0115.

Stuiver, M., Reimer, P. J., and Reimer, R. W., 2019, CALIB 7.1 [WWW program] at http://calib.org, accessed 2019-12-18.

Timar-Gabor, A., Vasiliniuc, S¸, Vandenberghe, D. A. G., Cosma, C., Wintle, A. G., 2012. Investigations into the reliability of SAR-OSL equivalent doses obtained for quartz samples displaying dose response curves with more than one component. **Radiation Measurements,** 47, 740–745.

Tsakalos, V., Dimitriou, E., Kazantzaki, M., Anagnostou, C., Christodoulakis, J., Filippaki, E., 2018. Testing optically stimulated luminescence dating on sand-sized quartz of deltaic deposits from the Sperchios delta plain, central Greece. **Journal of Palaeogeography,** 7, 130–145.

Tsukamoto, S., Duller, G. A. T., Wintle, A. G., 2008. Characteristics of thermally transferred optically stimulated luminescence (TT-OSL) in quartz and its potential for dating sediments. **Radiation Measurements**, 43, 1204-1218.

Tsukamoto, S., Nagashima, K., Murray, A. S., Tada, R., 2011. Variations in OSL components of quartz from Japan sea sediments and the possibility of reconstructing provenance. **Quaternary International**, 234, 182-189.

Wallinga, J., 2002. On the detection of OSL age overestimation using single-aliquot techniques. **Geochronometria,** 21, 17–26.

Wallinga, J., 2002. Optically stimulated luminescence dating of fluvial deposits: a review. **Boreas**, 31(4), 303-322.

Wang, X. L., Lu, Y. C., Wintle, A. G., 2006. Recuperated OSL dating of fine grained quartz in Chinese loess. **Quaternary Geochronology,** 1, 89–100.

Wintle, A. G., Adamiec, G., 2017. Optically stimulated luminescence signals from a review. **Radiation Measurements,** 98, 10–33.

Wintle, A. G., Huntley, D. J., 1979. Thermoluminescence dating of deep sea sediments. **Nature**, 279, 710–712.

Wintle, A. G., Murray, A. S., 2006. A review of quartz optically stimulated luminescence characteristics and their relevance in single-aliquot regeneration dating protocols. **Radiation Measurements**, 41, 369-391.

Wittmann, H., von Blanckenburg, F., Maurice, L., Guyot, L., Filizola, N., Kubik, P. W., 2010. Sediment production and delivery in the Amazon River basin quantified by in situ-produced cosmogenic nuclides and recent river loads. **Geological Society of America Bulletin B,** 30317–1.

Zular, A., Sawakuchi, A. O., Guedes, C. C. F., Giannini, P. C. F., 2015. Attaining provenance proxies from OSL and TL sensitivities: coupling with grain size and heavy minerals data from southern Brazilian coastal sediments. **Radiation Measurements**, 81, 39–45.

Zuluaga-Gómez, M. A., Fitzgerald, D. B., Giarrizzo, T., Winemiller, K. O., 2016. Morphologic and trophic diversity of fish assemblages in rapids of the Xingu River, a major Amazon tributary and region of endemism. **Environmental Biology of Fishes,** 99, 647–658.