UNIVERSIDADE DE SÃO PAULO

INSTITUTO DE GEOCIÊNCIAS

Quartz Luminescence Sensitivity as a Sediment Provenance tracer: Perspectives from the Northern Andes Orogenic basins

CARLOS ANDRÉS ORTIZ BARRIOS

Dissertação apresentada ao Programa de Pós;Graduação em Geoquímica e Geotectônica do Instituto de Geociências da Universidade de São Paulo como requsito parcial para a obtenção do título de Mestre em Ciências.

Área de concentração: Geotectônica

Orientador: Prof. Dr. Maurício Parra

SÃO PAULO

2024

Autorizo a reprodução e divulgação total ou parcial deste trabalho, por qualquer meio convencional ou eletrônico, para fins de estudo e pesquisa, desde que citada a fonte.

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

Ortiz , Carlos Andrés
Quartz Luminescence Sensitivity as a Sediment Provenance tracer: Perspectives from the Northern Andes Orogenic Basins / Carlos Andrés Ortiz ; orientador Mauricio Parra. -- São Paulo, 2024.
94 p.

Dissertação (Mestrado - Programa de Pós-Graduação em Geoquímica e Geotectônica) -- Instituto de Geociências, Universidade de São Paulo, 2024.

1. Quartz. 2. OSL Sensitivity. 3. Northern Andes. 4. Provenance. 5. Source areas. I. Parra, Mauricio , orient. II. Título.

UNIVERSIDADE DE SÃO PAULO
INSTITUTO DE GEOCIÊNCIAS

Quartz Luminescence Sensitivity as a Sediment Provenance tracer: Perspectives from the Northern Andes Orogenic basins

CARLOS ANDRES ORTIZ BARRIOS

Orientador: Prof. Dr. Mauricio Parra Amezquita

Dissertação de Mestrado

Nº 938

COMISSÃO JULGADORA

Dr. Mauricio Parra Amezquita

Drª. Priscila Emerich Souza

Dr. Sebastian Zapata Henao

SÃO PAULO
2024

ACKNOWLEDGMENTS

This research was financially supported by the Fundação de Amparo à Pesquisa do Estado de São Paulo, funded by the São Paulo Research Foundation (FAPESP) grants 2022/16709-8, 2023/07536-5, and by the CAPES PROEX.

I would like to express my sincere and deepest gratitude to my advisor, Prof. Dr. Mauricio Parra, for his unwavering support, invaluable guidance, and insightful feedback throughout all the stages of this Master's. His mentorship has enriched my academic experience and has also contributed to my personal and professional growth. I am deeply grateful for the time and effort he dedicated to this process, especially for thrusting in me from the very beginning.

I would like to acknowledge Prof. Dr. André Sawakuchi, who was for me another advisor in this process. I will always be grateful for his guidance and feedback, and especially, for opening the doors of his laboratory, LEGaL, to me.

I am sincerely thankful to Fernanda Rodrigues and Carolina Barbosa for their collaborative efforts, assistance, and discussions during this research, with a special focus on teaching me the laboratory procedures at LEGaL.

I would like to express my deepest gratitude to Dr. Mayank Jain, Dr. Kristina Thomsen, and Dr. Myungho Kook for their warm welcome to their laboratory at the Technical University of Denmark and the invaluable insights I gained from them regarding single-grain data during my stay in Denmark.

Special thanks go to Dr. Andrés Mora and Dr. Germán Bayona for providing me with sandstone samples from the Eastern Cordillera that were included in this work

My most heartfelt thanks to all of my colleagues and friends at IGc – USP. I thank them so much for their friendship and support.

I extend my deepest gratitude to the land and the people of Brazil for receiving me as one more Brazilian.

Finally, thanks to my family, they are my everything. This stage in my life would have been impossible without their love, support, presence, and blessings

ABSTRACT

In recent years, the luminescence of quartz has emerged as a potential tool for provenance analysis, particularly through the application of optically stimulated luminescence (OSL) sensitivity. While OSL sensitivity in quartz crystals from igneous and metamorphic rocks is typically low, previous findings indicate that OSL sensitivity can vary within five orders of magnitude within Quaternary sediments. These observations imply that quartz sensitization, in natural settings, occurs at some stage between the sediment source areas and the depositional sites. Laboratory experiments have demonstrated that sensitization of the quartz OSL fast component can be prompted by irradiation-bleaching cycles or by heating at temperatures above 300 °C. These sensitization mechanisms could be driven by surface processes that expose quartz grains to ionizing radiation and sunlight or to high temperatures, including sediment reworking, soil mixing, and wildfires. Thus, the longer sediments remain on the Earth's surface, the higher the probability of those grains undergoing sensitization through surface processes. In this way, the extended residence of sediments on the surface increases the opportunities for quartz grains to experience natural irradiation, bleaching by sunlight exposure, and heating, increasing the probability of sensitization. This hypothesis establishes a connection between OSL sensitivity and surface processes occurring mainly in the source areas, ultimately enabling the tracing of the provenance of sediments released from particular source areas characterized by a specific combination of source rock and surface processes.

OSL sensitivity has been effectively utilized for provenance analysis in modern deposits, but its application in ancient basin-fill sequences has been limited. This dissertation aims to address this gap by investigating the OSL sensitivity of pure quartz sand grains extracted from sandstones of a ~10 km-thick exhumed crustal section of the Northern Andes in the Colombian Eastern Cordillera, as well as from one of its adjacent basins. The studied section encompasses rocks from the entire Phanerozoic eon that have a well-established provenance history determined through various methods including low-temperature thermochronology, detrital geochronology, and sandstone petrography. This comprehensive array of information provides a strong foundation to establish a proof-of-concept for the applicability of quartz OSL sensitivity as a sediment provenance tracer. To achieve this, in this work the OSL sensitivity, measured in sandstones from the Colombian Eastern Cordillera, is compared with proxies such as detrital zircon U-Pb geochronology and sandstone petrography. Here, two different scenarios within the same basin in the Northern Andes were tested. Firstly, changes in quartz OSL sensitivity were demonstrated to be correlated with changes in sediment source areas characterized by contrasting conditions related to the residence time that quartz grains spend on the Earth's surface. Low-sensitivity quartz is associated with orogenic source areas experiencing rapid exhumation and denudation, whereas quartz exhibiting higher sensitivity is correlated with stable cratonic source areas. Finally, the highest-sensitivity quartz is linked to the recycling of sedimentary rocks that exhibit enhanced quartz OSL sensitivity. These observations allow for the construction of a hypothetical frame that serves as a basis for using the quartz luminescence sensitivity as a provenance tracer not only on quaternary and modern sediments but also in ancient basin-fill sequences.

Keywords: Quartz, OSL sensitivity, Northern Andes, Provenance, Source areas

RESUMO

Nos últimos anos, a luminescência do quartzo surgiu como uma ferramenta potencial para a análise da proveniência, particularmente através da aplicação da sensibilidade da luminescência opticamente estimulada (OSL). Embora a sensibilidade OSL em cristais de quartzo de rochas ígneas e metamórficas seja tipicamente baixa, descobertas anteriores indicam que a sensibilidade OSL pode variar dentro de cinco ordens de magnitude em sedimentos quaternários. Estas observações implicam que a sensibilização do quartzo, em ambientes naturais, ocorre numa determinada fase entre as áreas fonte dos sedimentos e os locais de deposição. Experimentos laboratoriais já demonstraram que a sensibilização da componente rápida OSL do quartzo pode ser provocada por ciclos de irradiação-esvazeamento ou por aquecimento a temperaturas superiores a 300 °C. Estes mecanismos de sensibilização podem ser provocados por processos superficiais que expõem os grãos de quartzo à radiação ionizante e à luz solar ou a temperaturas elevadas, incluindo o retrabalhamento de sedimentos, a mistura de solos e os incêndios florestais. Assim, quanto maior for o tempo de permanência dos sedimentos na superfície terrestre, maior será a probabilidade desses grãos sofrerem sensibilização através de processos superficiais. Desta forma, a permanência prolongada dos sedimentos à superfície aumenta as oportunidades de os grãos de quartzo sofrerem irradiação natural, esvazeamento por exposição à luz solar e aquecimento, aumentando a probabilidade de sensibilização. Esta hipótese estabelece uma ligação entre a sensibilidade OSL do quartzo e os processos superficiais que ocorrem principalmente nas áreas fonte, permitindo, em última análise, o rastreio da proveniência de sedimentos erodidos de determinadas áreas fonte caracterizadas por uma combinação específica de rochas fonte e processos superficiais

A sensibilidade OSL tem sido efetivamente utilizada para a análise da proveniência em depósitos modernos, mas a sua aplicação em sequências antigas de de bacias tem sido limitada. Esta dissertação visa colmatar esta lacuna, investigando a sensibilidade OSL de grãos de areia de quartzo puro extraídos de arenitos de uma secção crustal exumada com cerca de 10 km de espessura dos Andes do Norte, na Cordilheira Oriental da Colômbia, bem como de uma das suas bacias adjacentes. A secção estudada abrange rochas de todo o éon Fanerozoico, as quais têm uma história de proveniência sedimentar bem estabelecida, determinada através de vários métodos, incluindo termocronologia de baixa temperatura, geocronologia detrítica, e petrografia de arenito. Este conjunto de informações fornece uma base sólida para estabelecer uma prova de conceito para a aplicabilidade da sensibilidade OSL do quartzo como um traçador de proveniência sedimentar. Para tal, neste trabalho a sensibilidade OSL medida em arenitos da Cordilheira Oriental Colombiana é comparada com proxies como a geocronologia U-Pb de zircão detrítico e a petrografia de arenitos. Aqui, foram testados dois cenários diferentes dentro da mesma bacia nos Andes do Norte. Em primeiro lugar, demonstrou-se que as mudanças na sensibilidade OSL do quartzo estão correlacionadas com mudanças nas áreas fonte dos sedimentos, caracterizadas por condições contrastantes relacionadas com o tempo de residência que os grãos de quartzo passam na superfície da Terra. O quartzo de baixa sensibilidade está associado a áreas fontes orogénica com rápida exumação e denudação, enquanto o quartzo com maior sensibilidade está correlacionado com áreas fontes cratónicas estáveis. Por fim, o quartzo de maior sensibilidade está associado à reciclagem de rochas sedimentares que apresentam uma sensibilidade OSL do quartzo mais elevada. Estas observações permitem a construção de um quadro hipotético que serve de base à utilização da sensibilidade da luminescência do quartzo como traçador de proveniência, não só em sedimentos quaternários e modernos, mas também em sequências antigas de bacias.

Palavras-chave: Quartzo, Sensibilidade OSL, Andes do Norte, Proveniência, Areas fonte

INTRODUCTION

The sediment provenance analysis is an important field in sedimentary geology and has been widely used to associate sediment compositional signatures with sedimentary processes, including weathering, erosion, and transport (Haughton et al., 1991). Advancements in the plate tectonics theory and the development of technology to acquire, process, and analyze massive datasets allow for linking sand detrital modes not only to sedimentary processes but also to geodynamic settings, particularly, regarding the evolution of orogens and their associated sedimentary basins (Najman, 2006; Caracciolo, 2020). Meanwhile, provenance analysis has usually been performed employing classic techniques such as sandstone petrography (e.g., Garzanti, 2016) or using accessory mineral phases in sediments such as heavy mineral assemblages (Garzanti and Andò, 2019) and detrital geochronology, especially U-Pb in zircon (e.g., Gehrels, 2014).

Over the last decade, applied dosimetry in earth sciences has witnessed a significant expansion of frontiers beyond sediment dating, including novel applications that rely on luminescence properties to track sediment movement (e.g., Rhodes and Leathard, 2022) and fingerprint provenance (e.g., Sawakuchi et al., 2018; Capaldi et al., 2022). One of these properties is optically stimulated luminescence (OSL) sensitivity, defined as the luminescence response of a material to an applied radiation dose (Mineli et al., 2021). Extensive research for OSL dating purposes has documented substantial variability of luminescence sensitivity in quartz across different geomorphic and geological settings (Hu et al., 2020). Indeed, quartz grains originally released from crystalline rocks tend to exhibit low sensitivity (e.g., Sawakuchi et al., 2011; Guralnik et al., 2015) and are potentially sensitized through multiple bleaching and irradiation cycles by exposing quartz grains to light, heat, and ionizing radiation (Moska and Murray, 2006). As a result, quartz sensitivity from sedimentary deposits can vary at least five orders of magnitude (Mineli et al., 2021). Although it is not completely understood, in natural settings, quartz sensitization cycles could be driven by surface processes such as wildfires (e.g., Zhang et al., 2023), sediment reworking (e.g., Pietsch et al., 2008), and soil mixing (e.g., Gray et al., 2019). Thus, the rates at which those surface processes occur, which modulate sediment generation and production conditions, would link quartz OSL sensitivity with the residence time of sediments on the Earth's surface (e.g., Sawakuchi et al., 2018) and long-term sedimentary recycling (e.g., Fitzsimmons, 2011; del Río et al., 2021) allowing for the capacity to discriminate the sediment provenance from contrasting source regions.

Fingerprinting sediment provenance using quartz luminescence signals offers numerous advantages, highlighting its potential for further research investment and refinement. These advantages lie in the abundance of quartz, a ubiquitous mineral on the Earth's surface and the most common component of sands and sandstones. Consequently, sample preparation requires smaller volumes, and limitations related to source fertility are minimal. Additionally, luminescence measurements offer high analytical sensitivity, are cost-effective, and are easier to conduct compared to other measurement techniques (Sawakuchi et al., 2020). Furthermore, the potential of quartz OSL sensitivity to track changes in sediment production conditions including sediment residence time in source areas and long-term sedimentary recycling, coupled with other provenance proxies, enhances interpretations regarding sediment routing systems.

Quartz OSL sensitivity in provenance analysis has typically been explored in active sediments (e.g., Bartyik et al., 2021; Capaldi et al., 2022) and quaternary deposits (e.g., Liu and Li, 2006; Lü and Sun, 2011; Nian et al., 2019), but it has only been applied a few times in basin-fill sequences (e.g., del Río et al., 2021) and never in orogenic settings. Therefore, no record represents a robust basis for extending the applicability of quartz OSL sensitivity as a provenance tracer in ancient basin-fill sequences. Additionally, the role of the quartz sensitization mechanisms and the sensitization process itself remains unknown over geological time. One natural experiment to address these concerns involves characterizing the quartz OSL sensitivity in basins where multiple physical and geological variables are well-known and other provenance proxies are available. This approach allows for assessing the effects of the addition and depletion of sediments released from contrasting source regions on quartz OSL sensitivity measured in sedimentary basin-fill sequences. Following this line of reasoning, the Colombian Northern Andean basins stand out as a suitable scenario for conducting such an experiment, as (i) its most external mountain range in Colombia, the Eastern Cordillera, is a Mesozoic back-arc basin which underwent moderate tectonic inversion during Andean orogenesis, that resulted in exposure and recycling of abundant siliciclastic sedimentary rocks into foreland basin strata until the present;

and (2) there is robust control over the major shifts in their sediment source regions through geological time from various provenance datasets. In these basins, multiple proxies, including sandstone and conglomerate petrography (e.g., Parra et al., 2010; Bayona et al., 2013), detrital zircon U-Pb geochronology (e.g., Horton et al., 2010; Saylor et al., 2011), U-Th/He thermochronometry in detrital apatites and zircons (e.g., Horton et al., 2010a; Saylor et al., 2012; Odoh et al., 2019), and reworked palynomorphs (e.g., De La Parra et al., 2015), allow for the recognition of different source regions that experienced contrasting sediment generation and production conditions such as the Amazon Craton and the Andean Magmatic Arc.

This work aims to provide a proof-of-concept of the potential of quartz OSL sensitivity for tracing provenance in sedimentary basin-fill sequences by comparing sensitivity data with other well-established proxies for provenance used in the Northern Andes basins. The structure of this dissertation consists of four chapters describing all the work performed during the master's degree including two manuscripts to be submitted to international peer-reviewed journals, which are the core of this work. The first chapter is the introduction of the dissertation presenting the fundamentals of optically stimulated luminescence in quartz and its previous uses in provenance analysis. In the second chapter, the response of quartz OSL sensitivity to documented changes in contrasting sediment source regions (e.g., cratonic vs orogenic) is assessed, providing insights into the potential of this technique as a provenance proxy. The third chapter presents long-term sedimentary recycling as a quartz sensitization mechanism in geological timescales and how this characteristic is useful in the provenance analysis within sedimentary basin-fill sequences. Finally, the fourth chapter summarizes the main conclusions of all the work carried out in the frame of this master's degree, emphasizing the uses of quartz OSL sensitivity in the provenance analysis and the future work to be developed to establish a robust method in different geological settings.

CHAPTER 4: MAIN CONCLUSIONS AND PERSPECTIVES

For the first time, in this work, quartz OSL sensitivity data was acquired in an almost complete supracrustal section spanning rocks from the whole Phanerozoic eon. This dataset represents an archive for assessing changes in this luminescence characteristic over geological time.

In the second chapter, quartz OSL sensitivity is demonstrated to correlate with previously constrained shifts in sediment source areas. In this case, the source area is characterized by being composed mainly of crystalline rocks either orogenic (Andes) or cratonic (Guyana Shield). Therefore, regardless of the source bedrock, low-sensitivity quartz is associated with orogenic source areas, either in extensional or compressional settings, experiencing rapid denudation. Conversely, quartz that exhibits enhanced sensitivity is correlated with distal and stable cratonic source areas. This observation, now supported by other proxies such as detrital zircon U-Pb geochronology, set the base for the use of this technique to study changes in quartz OSL sensitivity in ancient basin-fill sequences and correlate them with changes in contrasting source areas. Thus, this proxy along with other tools can be very useful in tracing sedimentary provenance.

In the third chapter, quartz OSL sensitivity is also demonstrated that varies according to previously constrained shifts in sediment source areas. Nonetheless, the logic here is different, the source bedrock changes from crystalline and volcanic rocks in an orogenic source area, such as the Andean magmatic arc emplaced in the Colombian Central Cordillera to recycled sedimentary rocks that characterize the Eastern Cordillera. In this case, quartz with enhanced OSL sensitivity is correlated with the recycling of rocks triggered by the uplift and erosion of the Eastern Cordillera. One interesting observation is that quartz grains derived from the recycling of the sedimentary rocks that were sourced in the Guyana Shield exhibit significantly higher sensitivity than those derived from the recycling of the Andean first-cycle sedimentary rocks. These observations complement the conclusions obtained in the second chapter and allow for the construction of a hypothetical frame to assess variations in quartz OSL sensitivity not only in modern and quaternary sedimentary covers but also in rocks from the entire phanerozoic eon (Figure 11).

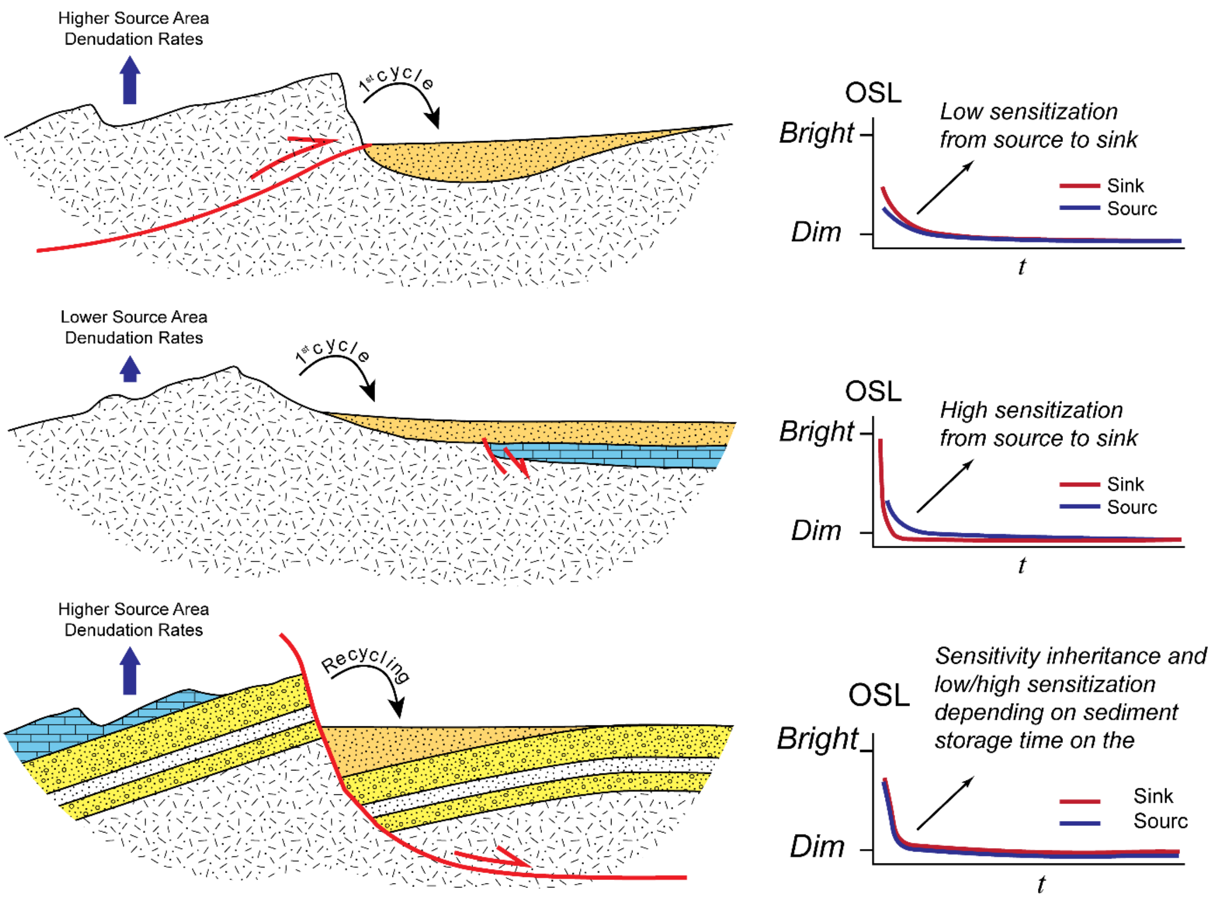

Figure 11. Hypothetical frame to understand changes in quartz OSL sensitivity. Source area denudation rates are correlated with sediment residence time on the Earth's surface (see Sawakuchi et al., 2018).

The first observation to consider in this hypothetical frame is that quartz derived from crystalline and volcanic rocks generally exhibits low-sensitivity fast components (e.g., Alexanderson, 2020 Guralnik et al., 2015; Mineli et al., 2021; Sawakuchi et al., 2011) and that quartz sensitization in natural settings occurs mainly on the Earth surface due to exposure of multiple bleaching and irradiation cycles or by heating induced by wildfires (e.g., Pietsch et al., 2008). Following this line of reasoning, the greater the time that sediments spend on the Earth's surface, the greater the probability of enhancing sensitivity on the surface. This hypothesis correlates with source area denudation rates (e.g., Sawakuchi et al., 2018). Furthermore, quartz grains derived from recycled sedimentary rocks exhibit higher quartz OSL sensitivity when compared with those released from crystalline rocks. Since recycling means that grains go through at least twice on the Earth's surface, they can be potentially sensitized in the subsequent cycles they spend on the surface. All these premises are supported by the dataset studied in this dissertation and previous observations made on quaternary deposits. In this way, sediment source areas characterized by certain types of bedrock (more crystalline or sedimentary) and contrasting denudation rates (slow or rapid) would exhibit a distinctive OSL sensitivity imprint. Therefore, changes in quartz OSL sensitivity can be correlated with changes in these sediment source areas. Instead of tracing provenance using minerals or characteristic ages of a group of rocks, as is the case with detrital zircon U-Pb geochronology or heavy minerals, the sensitivity of quartz allows for fingerprinting the provenance of unique source regions that are differentiated by the type of exposed rock and the processes of sediment generation, production, and erosion that ultimately control the residence time that quartz grains spend on the surface. This perspective opens a new opportunity to establish quartz luminescence sensitivity as a sediment provenance tracer in rocks and sediments.

REFERENCES

Alexanderson, H., 2022, Luminescence characteristics of Scandinavian quartz, their connection to bedrock provenance and influence on dating results: Quaternary Geochronology, v. 69, doi:10.1016/j.quageo.2022.101272.

Amaya López, C., Restrepo Álvarez, J.J., Weber Scharff, M., Cuadros Jiménez, F.A., Botelho, N.F., Ibañez Mejía, M., Maya Sánchez, M., Pérez Parra, O.M., and Ramírez Cárdenas, C., 2020, The Guaviare Complex: new evidence of Mesoproterozoic (ca. 1.3 Ga) crust in the Colombian Amazonian Craton: Boletín Geológico, p. 5–34, doi:10.32685/0120-1425/boletingeo.47.2020.502.

Autzen, M., Murray, A.S., Guérin, G., Baly, L., Ankjærgaard, C., Bailey, M., Jain, M., and Buylaert, J.P., 2018, Luminescence dosimetry: Does charge imbalance matter? Radiation Measurements, v. 120, p. 26–32, doi:10.1016/j.radmeas.2018.08.001.

Bailey, R.M., 2001, Towards a general kinetic model for optically and thermally stimulated luminescence of quartz: Radiation Measurements, p. 17–45, www.elsevier.com/locate/radmeas.

Bailey, R.M., Smith, B.W., and Rhodes, E.J., 1997, PARTIAL BLEACHING AND THE DECAY FORM CHARACTERISTICS OF QUARTZ OSL.:

Bande, A., Horton, B.K., Ramírez, J.C., Mora, A., Parra, M., and Stockli, D.F., 2012, Clastic deposition, provenance, and sequence of Andean thrusting in the frontal Eastern Cordillera and Llanos foreland basin of Colombia: Bulletin of the Geological Society of America, v. 124, p. 59–76, doi:10.1130/B30412.1.

Bartyik, T. et al., 2021, Spatial differences in the luminescence sensitivity of quartz extracted from Carpathian Basin fluvial sediments: Quaternary Geochronology, v. 64, doi:10.1016/j.quageo.2021.101166.

Bayona, G. et al., 2010, Estratigrafía, procedencia, subsidencia y exhumación de las unidades paleógenas en el Sinclinal de Usme, sur de la zona axial de la Cordillera Oriental: v. 35.

Bayona, G. et al., 2013, Onset of fault reactivation in the Eastern Cordillera of Colombia and proximal Llanos Basin; response to Caribbean-South American convergence in early Palaeogene time: Geological Society Special Publication, v. 377, p. 285–314, doi:10.1144/SP377.5.

Bayona, G. et al., 2021, Unravelling the widening of the earliest Andean northern orogen: Maastrichtian to early Eocene intra-basinal deformation in the northern Eastern Cordillera of Colombia: Basin Research, v. 33, p. 809–845, doi:10.1111/bre.12496.

Bayona, G., Cardona, A., Jaramillo, C., Mora, A., Montes, C., Valencia, V., Ayala, C., Montenegro, O., and Ibañez-Mejia, M., 2012, Early Paleogene magmatism in the northern Andes: Insights on the effects of Oceanic Plateau-continent convergence: Earth and Planetary Science Letters, v. 331–332, p. 97–111, doi:10.1016/j.epsl.2012.03.015.

Bayona, G., Cortés, M., Jaramillo, C., Ojeda, G., Aristizabal, J.J., and Reyes-Harker, A., 2008, An integrated analysis of an orogen-sedimentary basin pair: Latest Cretaceous-Cenozoic evolution of the linked Eastern Cordillera orogen and the Llanos foreland basin of Colombia: Bulletin of the Geological Society of America, v. 120, p. 1171–1197, doi:10.1130/B26187.1.

Bøtter-Jensen, L., Andersen, C.E., Duller, G.A.T., and Murray, A.S., 2003, Developments in radiation, stimulation and observation facilities in luminescence measurements, *in* Radiation Measurements, Elsevier Ltd, v. 37, p. 535–541, doi:10.1016/S1350-4487(03)00020-9.

Bøtter-Jensen, L., Larsen, N.A., Mejdahl, V., Poolton, N.R.J., Morrist, M.F., and Mckeever, S.W.S., 1995, Luminescence sensitivity changes in quartz as a result of annealing: Radiation Measurements, v. 24, p. 535–541, doi:https://doi.org/10.1016/1350-4487(95)00006-Z.

Botter-Jensen, L., Mckeever, S.W.S., and Wintle, A.G., 2003, Optically Stimulated Luminescence Dosimetry: Elsevier, http://www.elsevier.com.

Bulur, E., 2000, A simple transformation for converting CW-OSL curves to LM-OSL curves: Radiation Measurements, v. 32, p. 141–145, www.elsevier.com/locate/radmeas.

Bürgl, H., 1960, El Jurásico e Infracretáceo del Río Batá, Boyacá.:

Capaldi, T.N., Rittenour, T.M., and Nelson, M.S., 2022, Downstream changes in quartz OSL sensitivity in modern river sand reflects sediment source variability: Case studies from Rocky Mountain and Andean rivers: Quaternary Geochronology, v. 71, doi:10.1016/j.quageo.2022.101317.

Caracciolo, L., 2020, Sediment generation and sediment routing systems from a quantitative provenance analysis perspective: Review, application and future development: Earth-Science Reviews, v. 209, doi:10.1016/j.earscirev.2020.103226.

Cardona, A., Chew, D., Valencia, V.A., Bayona, G., Mišković, A., and Ibañez-Mejía, M., 2010, Grenvillian remnants in the Northern Andes: Rodinian and Phanerozoic paleogeographic perspectives: Journal of South American Earth Sciences, v. 29, p. 92–104, doi:10.1016/j.jsames.2009.07.011.

Cardona, A., Valencia, V.A., Lotero, A., Villafañez, Y., and Bayona, G., 2016, Provenance of middle to late Palaeozoic sediments in the northeastern Colombian Andes: implications for Pangea reconstruction: International Geology Review, v. 58, p. 1914–1939, doi:10.1080/00206814.2016.1190948.

Cawood, P.A., Hawkesworth, C.J., and Dhuime, B., 2012, Detrital zircon record and tectonic setting: Geology, v. 40, p. 875–878, doi:10.1130/G32945.1.

Cooper, M.A. et al., 1995, BASIN DEVELOPMENT AND TECTONIC HISTORY OF THE LLANOS BASIN, EASTERN CORDILLERA AND MIDDLE MAGDALENA VALLEY, COLOMBIA Telephone (403) 290 2964 E-mail Mark_Cooper@pcp.ca REFERENCES USED TO CONSTRUCT THE CHRONOSTRATIGRAPHIC CORRELATION DIAGRAMS AND PALEOGEOGRAPHIC MAPS OF GROSS DEPOSITIONAL ENVIRONMENTS.:

Cordani, U.G., Sato, K., Sproessner, W., and Fernandes, F.S., 2016, U-Pb zircon ages of rocks from the Amazonas Territory of Colombia and their bearing on the tectonic history of the NW sector of the Amazonian Craton: Brazilian Journal of Geology, v. 46, p. 5–35, doi:10.1590/2317-4889201620150012.

Cordani, U.G., and Teixeira, W., 2007, Proterozoic accretionary belts in the Amazonian Craton, *in* Memoir of the Geological Society of America, Geological Society of America, v. 200, p. 297–320, doi:10.1130/2007.1200(14).

Cunningham, A.C., and Wallinga, J., 2010, Selection of integration time intervals for quartz OSL decay curves: Quaternary Geochronology, v. 5, p. 657–666, doi:10.1016/j.quageo.2010.08.004.

Durcan, J.A., and Duller, G.A.T., 2011, The fast ratio: A rapid measure for testing the dominance of the fast component in the initial OSL signal from quartz: Radiation Measurements, v. 46, p. 1065–1072, doi:10.1016/j.radmeas.2011.07.016.

Fitzsimmons, K.E., 2011, An assessment of the luminescence sensitivity of australian quartz with respect to sediment history: Geochronometria, v. 38, p. 199–208, doi:10.2478/s13386-011-0030-9.

Galbraith, R., 2002, A note on the variance of a background-corrected OSL count: Ancient TL, v. 20, p. 49–51.

Garzanti, E., 2016, From static to dynamic provenance analysis-Sedimentary petrology upgraded: Sedimentary Geology, v. 336, p. 3–13, doi:10.1016/j.sedgeo.2015.07.010.

Garzanti, E., and Andò, S., 2019, Heavy minerals for junior woodchucks: Minerals, v. 9, doi:10.3390/min9030148.

Gehrels, G., 2014, Detrital zircon U-Pb geochronology applied to tectonics: Annual Review of Earth and Planetary Sciences, v. 42, p. 127–149, doi:10.1146/annurev-earth-050212-124012.

Gliganic, L.A., Cohen, T.J., Meyer, M., and Molenaar, A., 2017, Variations in luminescence properties of quartz and feldspar from modern fluvial sediments in three rivers: Quaternary Geochronology, v. 41, p. 70–82, doi:10.1016/j.quageo.2017.06.005.

Gómez, E., Jordan, T.E., Allmendinger, R.W., Hegarty, K., Kelley, S., and Heizler, M., 2003, Controls on architecture of the Late Cretaceous to Cenozoic southern Middle Magdalena Valley Basin, Colombia:, http://pubs.geoscienceworld.org/gsa/gsabulletin/article-pdf/115/2/131/3389039/i0016-7606-115-2-131.pdf.

Gray, H.J., Jain, M., Sawakuchi, A.O., Mahan, S.A., and Tucker, G.E., 2019, Luminescence as a Sediment Tracer and Provenance Tool: Reviews of Geophysics, v. 57, p. 987–1017, doi:10.1029/2019RG000646.

Guerrero, J., Mejía-Molina, A., and Osorno, J., 2019, Detrital U–Pb Provenance, Mineralogy, and Geochemistry of the Cretaceous Colombian Back–Arc Basin, *in* Gómez, J. and Pinilla-Pachón, A.O. eds., The Geology of Colombia, Volume 2 Mesozoic, Bogotá, Servicio Geológico Colombiano, v. 1, p. 261–297, doi:10.32685/pub.esp.36.2019.08.

Guralnik, B. et al., 2015, OSL-thermochronometry using bedrock quartz: A note of caution: Quaternary Geochronology, v. 25, p. 37–48, doi:10.1016/j.quageo.2014.09.001.

Han, K., and Wilson, J.L., 2024, Deciphering the interplay between tectonic and climatic forces on hydrologic connectivity in the evolving landscapes: Frontiers in Water, v. 6, doi:10.3389/frwa.2024.1255883.

Haughton, P.D.W., Todd, S.P., and Morton, A.C., 1991, Sedimentary provenance studies: Geological Society Special Publication, v. 57, p. 1–11, doi:10.1144/GSL.SP.1991.057.01.01.

Horton, B., Parra, M., and Mora, A., 2020, Construction of the Eastern Cordillera of Colombia: Insights from the Sedimentary Record, *in* Gómez, J. and Mateus-Zabala, D. eds., The Geology of Colombia, Volume 3 Paleogene – Neogene, Bogotá, Servicio Geológico Colombiano, v. pub.esp, p. 67–88, doi:10.32685/pub.esp.37.2019.03.

Horton, B.K., Parra, M., Saylor, J.E., Nie, J., Mora, A., Torres, V., Stockli, D.F., and Strecker, M.R., 2010a, Resolving uplift of the northern Andes using detrital zircon age signatures: GSA Today, v. 20, p. 4–9, doi:10.1130/GSATG76A.1.

Horton, B.K., Saylor, J.E., Nie, J., Mora, A., Parra, M., Reyes-Harker, A., and Stockli, D.F., 2010b, Linking sedimentation in the northern Andes to basement configuration, Mesozoic extension, and Cenozoic shortening: Evidence from detrital zircon U-Pb ages, Eastern Cordillera, Colombia: Bulletin of the Geological Society of America, v. 122, p. 1423–1442, doi:10.1130/B30118.1.

Hu, Y., Li, B., and Jacobs, Z., 2020, Single-grain quartz osl characteristics: Testing for correlations within and between sites in Asia, Europe and Africa: Methods and Protocols, v. 3, p. 1–15, doi:10.3390/mps3010002.

Ibañez-Mejia, M., 2020, The Putumayo Orogen of Amazonia: A Synthesis, *in* Gómez, J. and Mateus-Zabala, D. eds., The Geology of Colombia, Volume 1 Proterozoic – Paleozoic, Bogotá, Servicio Geológico Colombiano, v. pub.esp, p. 101–131, doi:10.32685/pub.esp.35.2019.06.

Ibañez-Mejia, M., and Cordani, U., 2020, Zircon U–Pb Geochronology and Hf–Nd–O Isotope Geochemistry of the Paleo– to Mesoproterozoic asement in the Westernmost Guiana Shield, *in* Gómez, J. and Mateus-Zabala, D. eds., The

Geology of Colombia, Volume 1 Proterozoic – Paleozoic, Bogotá, Servicio Geológico Colombiano, v. pub.esp, p. 65–90, doi:10.32685/pub.esp.35.2019.04.

Ibanez-Mejia, M., Pullen, A., Arenstein, J., Gehrels, G.E., Valley, J., Ducea, M.N., Mora, A.R., Pecha, M., and Ruiz, J., 2015, Unraveling crustal growth and reworking processes in complex zircons from orogenic lower-crust: The Proterozoic Putumayo Orogen of Amazonia: Precambrian Research, v. 267, p. 285–310, doi:10.1016/j.precamres.2015.06.014.

Ibanez-Mejia, M., Ruiz, J., Valencia, V.A., Cardona, A., Gehrels, G.E., and Mora, A.R., 2011, The Putumayo Orogen of Amazonia and its implications for Rodinia reconstructions: New U-Pb geochronological insights into the Proterozoic tectonic evolution of northwestern South America: Precambrian Research, v. 191, p. 58–77, doi:10.1016/j.precamres.2011.09.005.

Jain, M., Murray, A.S., and Bøtter-Jensen, L., 2003, Characterisation of blue-light stimulated luminescence components in different quartz samples: Implications for dose measurement, *in* Radiation Measurements, Elsevier Ltd, v. 37, p. 441–449, doi:10.1016/S1350-4487(03)00052-0.

King, G.E., Robinson, R.A.J., and Finch, A.A., 2014, Towards successful OSL sampling strategies in glacial environments: Deciphering the influence of depositional processes on bleaching of modern glacial sediments from jostedalen, southern norway: Quaternary Science Reviews, v. 89, p. 94–107, doi:10.1016/j.quascirev.2014.02.001.

Kreutzer, S., Schmidt, C., Fuchs Helmholtz-Zentrum Dresden-Rossendorf, M.C., Dietze, M., Fuchs, M.C., Fischer, M., and Fuchs, M., 2012, Introducing an R package for luminescence dating analysis:, http://rstudio.org.

Kroonenberg, S.B., 2019, The proterozoic basement of the Western Guiana Shield and the Northern Andes, *in* Frontiers in Earth Sciences, Springer Verlag, p. 115–192, doi:10.1007/978-3-319-76132-9_3.

de la Parra, F., Higuera, C., Ramírez, R., Maya, L., Céspedes, S., Marfissi, N., Carreño, A., Juliao, T., and Forero, S., 2024, Chronostratigraphy of the Upper Cretaceous succession in the Middle Magdalena Valley of Colombia (Northern South America): Cretaceous Research, v. 157, doi:10.1016/j.cretres.2023.105824.

De La Parra, F., Mora, A., Rueda, M., and Quintero, I., 2015, Temporal and spatial distribution of tectonic events as deduced from reworked palynomorphs in the eastern Northern Andes: AAPG Bulletin, v. 99, p. 1455–1472, doi:10.1306/02241511153.

Leal-Mejía, H., Shaw, R.P., and Melgarejo i Draper, J.C., 2019, Spatial-Temporal Migration of Granitoid Magmatism and the Phanerozoic Tectono-Magmatic Evolution of the Colombian Andes, *in* Cediel Fabio and Shaw, R.P. ed., Geology and Tectonics of Northwestern South America: The Pacific-Caribbean-Andean Junction, Cham, Springer International Publishing, p. 253–410, doi:10.1007/978-3-319-76132-9_5.

León, S., Monsalve, G., and Bustamante, C., 2021, How Much Did the Colombian Andes Rise by the Collision of the Caribbean Oceanic Plateau? Geophysical Research Letters, v. 48, doi:10.1029/2021GL093362.

Liu, W., and Li, B., 2006, Thermal equation of state of (Mg0.9Fe0.1)2SiO4 olivine: Physics of the Earth and Planetary Interiors, v. 157, p. 188–195, doi:10.1016/j.pepi.2006.04.003.

López-Isaza, J.A., and Zuluaga, C.A., 2019, Late Triassic to Jurassic Magmatism in Colombia: Implications for the Evolution of the Northern Margin of South America, *in* Gómez, J. and Pinilla-Pachon, A.O. eds., The Geology of Colombia, Volume 2 Mesozoic, Bogotá, Servicio Geológico Colombiano, v. pub.esp, p. 77–116, doi:10.32685/pub.esp.36.2019.03.

Lü, T., and Sun, J., 2011, Luminescence sensitivities of quartz grains from eolian deposits in northern China and their implications for provenance: Quaternary Research, v. 76, p. 181–189, doi:10.1016/j.yqres.2011.06.015.

Mahan, S.A. et al., 2023, Guide for interpreting and reporting luminescence dating results: Bulletin of the Geological Society of America, v. 135, p. 1480–1502, doi:10.1130/B36404.1.

Mineli, T.D., Sawakuchi, A.O., Guralnik, B., Lambert, R., Jain, M., Pupim, F.N., Rio, I. del, Guedes, C.C.F., and Nogueira, L., 2021, Variation of luminescence sensitivity, characteristic dose and trap parameters of quartz from rocks and sediments: Radiation Measurements, v. 144, doi:10.1016/j.radmeas.2021.106583.

Montes, C., Rodriguez-Corcho, A.F., Bayona, G., Hoyos, N., Zapata, S., and Cardona, A., 2019, Continental margin response to multiple arc-continent collisions: The northern Andes-Caribbean margin: Earth-Science Reviews, v. 198, doi:10.1016/j.earscirev.2019.102903.

Mora, A., Casallas, W., Ketcham, R.A., Gomez, D., Parra, M., Namson, J., Stockli, D., Almendral, A., Robles, W., and Ghorbal, B., 2015, Kinematic restoration of contractional basement structures using thermokinematic models: A key tool for petroleum system modeling: AAPG Bulletin, v. 99, p. 1575–1598, doi:10.1306/04281411108.

Mora, A., Gaona, T., Kley, J., Montoya, D., Parra, M., Quiroz, L.I., Reyes, G., and Strecker, M.R., 2009, The role of inherited extensional fault segmentation and linkage in contractional orogenesis: A reconstruction of lower cretaceous inverted rift basins in the Eastern Cordillera of Colombia: Basin Research, v. 21, p. 111–137, doi:10.1111/j.1365-2117.2008.00367.x.

Mora, A., Parra, M., Strecker, M.R., Kammer, A., Dimaté, C., and Rodríguez, F., 2006, Cenozoic contractional reactivation of Mesozoic extensional structures in the Eastern Cordillera of Colombia: Tectonics, v. 25, doi:10.1029/2005TC001854.

Mora, A., Parra, M., Strecker, M.R., Sobel, E.R., Zeilinger, G., Jaramillo, C., Da Silva, S.F., and Blanco, M., 2010, The eastern foothills of the eastern cordillera of colombia: An example of multiple factors controlling structural styles and active tectonics: Bulletin of the Geological Society of America, v. 122, p. 1846–1864, doi:10.1130/B30033.1.

Moska, P., and Murray, A.S., 2006, Stability of the quartz fast-component in insensitive samples: Radiation Measurements, v. 41, p. 878–885, doi:10.1016/j.radmeas.2006.06.005.

Moyano-Nieto, I.E., Prieto, G.A., and Ibañez-Mejia, M., 2022, Tectonic domains in the NW Amazonian Craton from geophysical and geological data: Precambrian Research, v. 377, doi:10.1016/j.precamres.2022.106735.

Murray, A., Arnold, L.J., Buylaert, J.P., Guérin, G., Qin, J., Singhvi, A.K., Smedley, R., and Thomsen, K.J., 2021, Optically stimulated luminescence dating using quartz: Nature Reviews Methods Primers, v. 1, doi:10.1038/s43586-021-00068-5.

Najman, Y., 2006, The detrital record of orogenesis: A review of approaches and techniques used in the Himalayan sedimentary basins: Earth-Science Reviews, v. 74, p. 1–72, doi:10.1016/j.earscirev.2005.04.004.

Nelson, M.S., Eppes, M.C., and Rittenour, T.M., 2022, Quartz luminescence sensitivity from sediment versus bedrock in highly weathered soils of the Piedmont of North Carolina, south-eastern USA: Quaternary Geochronology, v. 72, doi:10.1016/j.quageo.2022.101343.

Nian, X., Zhang, W., Qiu, F., Qin, J., Wang, Z., Sun, Q., Chen, J., Chen, Z., and Liu, N., 2019, Luminescence characteristics of quartz from Holocene delta deposits of the Yangtze River and their provenance implications: Quaternary Geochronology, v. 49, p. 131–137, doi:10.1016/j.quageo.2018.04.010.

Odoh, S., Saylor, J.E., Higuera, C., Copeland, P., and Lapen, T.J., 2019, Discriminating mechanisms for coarse clastic progradation in the Colombian foreland basin using detrital zircon double dating, *in* Andean Tectonics, Elsevier Inc., p. 133–171, doi:10.1016/B978-0-12-816009-1.00008-3.

O'sullivan, G.J., and Chew, D.M., 2020, The clastic record of a Wilson Cycle: Evidence from detrital apatite petrochronology of the Grampian-Taconic fore-arc: Earth and Planetary Science Letters, v. 552, p. 116588, doi:10.1594/PANGAEA.917548.

Paez-Reyes, M. et al., 2021, Assessing the contribution of the La Luna Sea to the global sink of organic carbon during the Cenomanian-Turonian Oceanic Anoxic Event 2 (OAE2): Global and Planetary Change, v. 199, doi:10.1016/j.gloplacha.2021.103424.

Parra, M., Mora, A., Jaramillo, C., Strecker, M.R., Sobel, E.R., Quiroz, L., Rueda, M., and Torres, V., 2009a, Orogenic wedge advance in the northern Andes: Evidence from the Oligocene-Miocene sedimentary record of the Medina Basin, Eastern Cordillera, Colombia: Bulletin of the Geological Society of America, v. 121, p. 780–800, doi:10.1130/B26257.1.

Parra, M., Mora, A., Jaramillo, C., Torres, V., Zeilinger, G., and Strecker, M.R., 2010, Tectonic controls on Cenozoic foreland basin development in the north-eastern

Andes, Colombia: Basin Research, v. 22, p. 874–903, doi:10.1111/j.1365-2117.2009.00459.x.

Parra, M., Mora, A., Lopez, C., Rojas, L.E., and Horton, B.K., 2012, Detecting earliest shortening and deformation advance in thrust belt hinterlands: Example from the Colombian Andes: Geology, v. 40, p. 175–178, doi:10.1130/G32519.1.

Parra, M., Mora, A., Sobel, E.R., Strecker, M.R., and González, R., 2009b, Episodic orogenic front migration in the northern Andes: Constraints from low-temperature thermochronology in the Eastern Cordillera, Colombia: Tectonics, v. 28, doi:10.1029/2008TC002423.

Pietsch, T.J., Olley, J.M., and Nanson, G.C., 2008, Fluvial transport as a natural luminescence sensitiser of quartz: Quaternary Geochronology, v. 3, p. 365–376, doi:10.1016/j.quageo.2007.12.005.

Pimpirev, C.T., Patarroyo, P., and Sarmiento, G., 1992, Stratigraphy and facies analysis of the Caqueza Group, a sequence of Lower Cretaceous turbidites in the Cordillera Oriental of the Colombian Andes: Journal of South American Earth Sciences, v. 5, p. 297–308.

Porat, N., 2006, Use of magnetic separation for purifying quartz for luminescence dating: Ancient TL, v. 24, p. 33–36, http://www.sgfrantz.com/labsep.htm.

Preusser, F., Chithambo, M.L., Götte, T., Martini, M., Ramseyer, K., Sendezera, E.J., Susino, G.J., and Wintle, A.G., 2009, Quartz as a natural luminescence dosimeter: Earth-Science Reviews, v. 97, doi:10.1016/j.earscirev.2009.09.006.

Preusser, F., Ramseyer, K., and Schlüchter, C., 2006, Characterisation of low OSL intensity quartz from the New Zealand Alps: Radiation Measurements, v. 41, p. 871–877, doi:https://doi.org/10.1016/j.radmeas.2006.04.019.

Ramirez-Arias, J.C., Mora, A., Rubiano, J., Duddy, I., Parra, M., Moreno, N., Stockli, D., and Casallas, W., 2012, The asymmetric evolution of the Colombian Eastern Cordillera. Tectonic inheritance or climatic forcing? New evidence from thermochronology and sedimentology: Journal of South American Earth Sciences, v. 39, p. 112–137, doi:10.1016/j.jsames.2012.04.008.

Ramos, V.A., 2018, The Famatinian orogen along the protomargin of Western Gondwana: Evidence for a nearly continuous Ordovician magmatic arc between Venezuela and Argentina, *in* Folguera, A. et al. eds., The evolution of the Chilean-Argentinean Andes, Cham, Springer Earth System Sciences, p. 133–161, doi:https://doi.org/10.1007/978-3-319-67774-3_6.

Ramos, V.A., 2010, The Grenville-age basement of the Andes: Journal of South American Earth Sciences, v. 29, p. 77–91, doi:10.1016/j.jsames.2009.09.004.

Reyes-Harker, A. et al., 2015, Cenozoic paleogeography of the Andean foreland and retroarc hinterland of Colombia: AAPG Bulletin, v. 99, p. 1407–1453, doi:10.1306/06181411110.

Rhodes, E.J., 2011, Optically stimulated luminescence dating of sediments over the past 200,000 years: Annual Review of Earth and Planetary Sciences, v. 39, p. 461–488, doi:10.1146/annurev-earth-040610-133425.

Rhodes, E.J., and Leathard, J.A., 2022, MET-IRSL used to track pre-depositional sediment transport history: Quaternary Geochronology, v. 70, doi:10.1016/j.quageo.2022.101294.

Rink, W.J., 1994, BILLION-YEAR AGE DEPENDENCE OF LUMINESCENCE IN GRANITIC QUARTZ: Radiation measurements, v. 23, p. 419–422.

del Río, I., Sawakuchi, A.O., Góes, A.M., Hollanda, M.H.B.M., Furukawa, L.Y., Porat, N., Jain, M., Mineli, T.D., and Negri, F. de A., 2021, Luminescence signals of quartz and feldspar as new methods for stratigraphic discrimination and provenance analysis of siliciclastic successions: The case of the Parnaíba Basin (Brazil) of West Gondwana: Basin Research, v. 33, p. 2938–2959, doi:10.1111/bre.12590.

Rodriguez-Corcho, A.F. et al., 2022, The Colombian geochronological database (CGD): International Geology Review, v. 64, p. 1635–1669, doi:10.1080/00206814.2021.1954556.

Sarmiento-Rojas, L.F., 2019, Cretaceous stratigraphy and paleo-facies maps of northwestern South America, *in* Frontiers in Earth Sciences, Springer Verlag, p. 673–747, doi:10.1007/978-3-319-76132-9_10.

Sarmiento-Rojas, L.F., Van Wess, J.D., and Cloetingh, S., 2006, Mesozoic transtensional basin history of the Eastern Cordillera, Colombian Andes: Inferences from tectonic models: Journal of South American Earth Sciences, v. 21, p. 383–411, doi:10.1016/j.jsames.2006.07.003.

Sawakuchi, A.O. et al., 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, v. 492, p. 152–162, doi:10.1016/j.epsl.2018.04.006.

Sawakuchi, A.O., Blair, M.W., DeWitt, R., Faleiros, F.M., Hyppolito, T., and Guedes, C.C.F., 2011, Thermal history versus sedimentary history: OSL sensitivity of quartz grains extracted from rocks and sediments: Quaternary Geochronology, v. 6, p. 261–272, doi:10.1016/j.quageo.2010.11.002.

Sawakuchi, A.O., Rodrigues, F.C.G., Mineli, T.D., Mendes, V.R., Melo, D.B., Chiessi, C.M., and Giannini, P.C.F., 2020, Optically stimulated luminescence sensitivity of quartz for provenance analysis: Methods and Protocols, v. 3, p. 1–13, doi:10.3390/mps3010006.

Saylor, J.E., Horton, B.K., Nie, J., Corredor, J., and Mora, A., 2011, Evaluating foreland basin partitioning in the northern Andes using Cenozoic fill of the Floresta basin, Eastern Cordillera, Colombia: Basin Research, v. 23, p. 377–402, doi:10.1111/j.1365-2117.2010.00493.x.

Saylor, J.E., Stockli, D.F., Horton, B.K., Nie, J., and Mora, A., 2012, Discriminating rapid exhumation from syndepositional volcanism using detrital zircon double dating:

Implications for the tectonic history of the Eastern Cordillera, Colombia: Bulletin of the Geological Society of America, v. 124, p. 762–779, doi:10.1130/B30534.1.

Şengör, A.M.C., 2021, Continental Rifts, *in* Gupta, H.K. ed., Encyclopedia of solid Earth geophysics, Cham, Springer Nature, p. 64–78.

Singarayer, J.S., and Bailey, R.M., 2004, Component-resolved bleaching spectra of quartz optically stimulated luminescence: Preliminary results and implications for dating: Radiation Measurements, v. 38, p. 111–118, doi:10.1016/S1350-4487(03)00250-6.

Souza, P.E., Pupim, F.N., Mazoca, C.E.M., Río, I. del, Mineli, T.D., Rodrigues, F.C.G., Porat, N., Hartmann, G.A., and Sawakuchi, A.O., 2023, Quartz OSL sensitivity from dating data for provenance analysis of pleistocene and holocene fluvial sediments from lowland Amazonia: Quaternary Geochronology, v. 74, doi:10.1016/j.quageo.2023.101422.

Spikings, R., and Paul, A., 2019, The Permian – Triassic History of Magmatic Rocks of the Northern Andes (Colombia and Ecuador): Supercontinent Assembly and Disassembly, *in* Gómez, J. and Pinilla-Pachon, A.O. eds., The Geology of Colombia, Volume 2 Mesozoic, Bogotá, Servicio Geológico Colombiano, v. pub.esp, p. 1–43, doi:10.32685/pub.esp.36.2019.01.

Tassinari, C.C.G., and Macambira, M.J.B., 1999, Geochronological provinces of the Amazonian Craton: Episodes, v. 22, p. 174–182, doi:10.18814/epiiugs/1999/v22i3/004.

Thomsen, K.J., Kook, M., Murray, A.S., Jain, M., and Lapp, T., 2015, Single-grain results from an EMCCD-based imaging system: Radiation Measurements, v. 81, p. 185–191, doi:10.1016/j.radmeas.2015.02.015.

Ulloa, C., Arias, A., and Solano, F., 2000, CARACTERIZACION DE UNIDADES GEOLOGICAS Y GEOMORFOLOGICAS DE COLOMBIA: LUTITAS DE MACANAL:, www.ingeominas.gov.co.

Ulloa, C., and Rodríguez, E., 1979, Geología del cuadrángulo K-12, Guateque: Boletin Geológico , v. 20, p. 1–84.

Urueña-Suarez, C.L., Peña-Urueña, M.L., Muñoz-Rocha, J.A., Rayo-Rocha, L. del P., Villamizar-Escalante, N., Amaya-Ferreira, S., Ibañéz-Mejía, M., and Bernet, M., 2019, Zircon U–Pb and Fission–Track Dating Applied to Resolving Sediment Provenance in Modern Rivers Draining the Eastern and Central Cordilleras, Colombia, *in* Gómez, J. and Mateus-Zabala, D. eds., The Geology of Colombia, Volume 3 Paleogene – Neogene, Bogotá, Servicio Geológico de Colombia, v. 1, p. 469–490, doi:10.32685/pub.esp.37.2019.16.

Valencia-Gómez, J.C., Cardona, A., Bayona, G., Valencia, V., and Zapata, S., 2020, Análisis de procedencia del registro sin-orogénico Maastrichtiano de la Formación Cimarrona, flanco occidental de la Cordillera Oriental colombiana: Boletin de Geologia, v. 19, p. 171–204, doi:10.18273/revbol.v42n3-2020008.

Vermeesch, P., 2012, On the visualisation of detrital age distributions: Chemical Geology, v. 312–313, p. 190–194, doi:10.1016/j.chemgeo.2012.04.021.

Villagómez, D., and Spikings, R., 2013, Thermochronology and tectonics of the Central and Western Cordilleras of Colombia: Early Cretaceous-Tertiary evolution of the Northern Andes: Lithos, v. 160–161, p. 228–249, doi:10.1016/j.lithos.2012.12.008.

Villagómez, D., Spikings, R., Magna, T., Kammer, A., Winkler, W., and Beltrán, A., 2011, Geochronology, geochemistry and tectonic evolution of the Western and Central cordilleras of Colombia: Lithos, v. 125, p. 875–896, doi:10.1016/j.lithos.2011.05.003.

Wallinga, J., Murray, A.S., Duller, G.A.T., and Törnqvist, T.E., 2001, Testing optically stimulated luminescence dating of sand-sized quartz and feldspar from fluvial deposits: Earth and Planetary Science Letters, v. 193, p. 617–630, www.elsevier.com/locate/epsl.

Yukihara, E.G., and Mckeever, S.W.S., 2011, Optically stimulated luminescence: fundamentals and applications: John Wiley & Sons.

Zapata-Villada, J.P., Cardona, A., Serna, S., and Rodríguez, G., 2021, Late Cretaceous to Paleocene magmatic record of the transition between collision and subduction in the Western and Central Cordillera of northern Colombia: Journal of South American Earth Sciences, v. 112, doi:10.1016/j.jsames.2021.103557.

Zhang, J., Li, S.H., Sun, J., Tongyan, L., Zhou, X., and Hao, Q., 2023, Quartz luminescence sensitivity variation in the Chinese loess deposits: the potential role of wildfires: Journal of Quaternary Science, v. 38, p. 49–60, doi:10.1002/jqs.3462.