MICROMORPHOLOGY IN ARCHAEOLOGY: AN ANALYSIS OF EOLIAN AND ALLUVIAL SITE FORMATION PROCESSES IN THE MIDDLE RÍO NEGRO VALLEY, NORTHERN PATAGONIA, ARGENTINA

By

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July, 2022

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ABSTRACT

Based on the results of a previous geoarchaeological study that reconstructed the landscape history of the Middle Río Negro Valley in Northern Patagonia, Argentina, this thesis analyzes previously collected sediments to confirm their depositional context (i.e., eolian or alluvial processes, as well as their depositional forms: alluvial floodplain deposits, eolian loess mantle, or eolian dune), and assess the impacts of eolian and alluvial site formation processes on the preservation of the archaeological record. To determine if the samples are consistent with their previously proposed depositional context a micromorphological analysis was conducted to identify the main characteristics (e.g., mineralogy, texture, shape/rounding, sorting, presence of organic matter, etc.) observed in thin section. The results of this analysis have concluded that the samples are consistent with their previously proposed depositional context. Due to the highly dynamic processes present in the Middle Río Negro Valley, the preservation potential of Late Pleistocene to Middle Holocene archaeological sites is moderate and sites are likely to be located on the older alluvial terraces, either deeply buried by eolian dunes or in the alluvial floodplain deposits. The preservation potential of Late Holocene archaeological sites in the Middle Río Negro Valley is excellent and deposits are likely to be found in the eolian loess mantle and

alluvial floodplain deposits. Large parts of the Río Negro Negro Valley have yet to be systematically surveyed, providing a unique opportunity to further study these environments and to locate previously unidentified archaeological sites.

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A Thesis

Presented To the Faculty of the Department of Anthropology

East Carolina University

In Partial Fulfillment of the Requirements for the Degree of

Master of Arts in Anthropology

by

Victoria Elizabeth Schwarz

July, 2022

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In loving memory of

Nelson Roman, Sr.
(1945-2020)

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CHAPTER 1: INTRODUCTION

1.1 Introduction

Flowing from the western Andes across the northern Patagonian province in Argentina is the Río Negro. Although over 150 years of archaeological research has been conducted in the region, large parts of the valley have not been systematically surveyed. In the Middle Río Negro valley systematic studies began in the early 2000s as part of a US-Argentine collaborative geoarchaeological-archaeological study with the goals of conducting a landscape history and a cultural chronology of pre-Hispanic occupation in the river valley (Luchsinger, 2006; Prates, 2007). The geoarchaeological study found that during the Middle to Late Holocene, the Río Negro abruptly shifted its course across the middle valley three times – through the process of channel avulsion – leaving behind three abandoned channels (i.e., paleochannels) (Luchsinger, 2006). Based on the stratigraphic analysis and correlations with radiocarbon and OSL dating of archaeological sites, Luchsinger (2006) claimed that the abandoned channels were occupied by prehistoric hunter-gatherer groups in two phases: (1) pre-avulsion and (2) post-avulsion.

In addition to the detailed and comprehensive reconstruction of the landscape, Luchsinger (2006: 118) also makes several claims about how the landscape history would have impacted the archaeological site preservation in the valley: (1) Of the 200+ surface archaeological sites identified during fieldwork, all sites date to the Late Holocene, indicating the preservation potential of Late Holocene sites is excellent; (2) the archaeological materials from the Late Holocene sites are likely to be found in alluvial (i.e., transported by water) and eolian (i.e., transported by wind) sediment deposits; and (3) for the Late Pleistocene through Middle Holocene, the preservation of the archaeological record is good, but sites are likely to be buried deeply in alluvial terraces and the eolian mantle.

Sediment samples from a wide variety of stratigraphic contexts were collected during the previous study and processed into thin sections for micromorphological analysis but were never analyzed. In fact, none of the previous studies in this region have incorporated the high-resolution analysis of sediments from these depositional environments (e.g., eolian and alluvial sediments) using micromorphology. Although the analysis of the micromorphological samples was not vital to Luchsinger's 2006 research, the importance of this data should not be undervalued.

1.2 Research Statement and Expectations

This thesis aims to conduct a micromorphological analysis of these samples from landforms in the Middle Río Negro Valley to conclusively identify the depositional sediments as either eolian or alluvial and to revisit the conclusions regarding the preservation potential of archaeological sites in the Middle Río Negro Valley originally proposed by Luchsinger (2006). Specifically, the following two questions will be addressed. *First, what are the main characteristics (e.g., mineralogy, texture, shape/rounding, sorting, presence of organic matter, etc.) of the sediments observed in thin section and are they consistent with their previously proposed depositional context (i.e., referring to either the eolian or alluvial processes, as well as their depositional forms: alluvial, eolian loess mantle, eolian dune)? Second, what implications do natural site formation processes along the Middle Rio Negro Valley have for the preservation of archaeological sites?*

To achieve these objectives, I will be conducting a micromorphological analysis of the thin section sediment samples collected during previous field seasons (Luchsinger, 2006). In the past, soil micromorphology was typically geared towards pedology, but its application in geoarchaeology has grown in the past 40 years, contributing to a number of topics (Goldberg & Aldeias, 2018). Geoarchaeology is the interdisciplinary relationship between the geosciences and archaeology that applies the concepts and methods of the geosciences to archaeological research. Waters (1992) identifies three fundamental objectives in geoarchaeology: The first objective is to place sites and their contents in a relative and absolute temporal context through the application of stratigraphic principles and absolute dating techniques. The second objective is to understand the natural processes of site formation. The third objective is to reconstruct the landscape that existed at a site during its occupation.

This thesis addresses the second objective related to understanding site formation. For example, microstratigraphic analysis of thin sections can be used to determine if the sediment is geogenic or anthropogenic, distinguish between original depositional aspects of the sediment and post-depositional processes, as well as determine large and small-scale human activities (e.g., trampling, sweeping, stabling, agriculture, etc.) (Goldberg & Aldeias, 2018; Goldberg & Macphail, 2006; Macphail & Goldberg, 2018). Minor shifts in sedimentation, subtle traces of soil formation, and evidence of migration or stability of cultural materials can be detected on the microscale.

As discussed in Chapter 2, the stratigraphic contexts from which the samples were taken suggest that three main types of depositional environments were responsible for site burial along the Middle Rio Negro Valley. These include eolian processes in the form of the eolian loess mantle or eolian dunes, and alluvial floodplain processes. Micromorphology is particularly useful in identifying each process based upon the observation of individual grain morphology, sorting, and texture in the thin section. Sediment minerology defined in thin sections can also indicate sediment sources (i.e., local vs. extra-regional). Expectations for each of the processes is outlined below (from Brown, 1997; Goldberg & Macphail, 2008; Luchsinger, 2006; Schiffer, 1987; Waters, 1992).

Eolian Loess Micromorphology: It is expected that the eolian loess mantle sediments will be composed of quartz, feldspar, and mica minerals. They can also include clay minerals and carbonate grains. Grain size is positively skewed, meaning the proportion of grains will include more larger grains and less smaller grains (i.e., the proportion of silt sized grains would be greater than clay sized grains). The average grain size of loess sediments are silt-sized grains (20-40 µm) but may also contain varying proportions of clay (< 4 µm) and sand (>63 µm) sized grains. Intact loess sediment deposits are expected to be well sorted but this can vary if they sediments were disturbed by other depositional processes (e.g., fluvial interference from flooding episodes). The roundness of the grains is expected to exhibit a greater degree of angularity.

Eolian Dune Micromorphology: While both eolian dunes and loess are the result of wind-blown processes, eolian dunes are composed primarily of quarts-rich sands (>63 µm) and quartz grains are typically subrounded, with larger quartz grains increasing in their degree of rounding. Although the dune sediments will be composed primarily of quartz, feldspars are also expected to be present. Grain size is negatively skewed, meaning that they will contain more finer grains and less coarser grains, but variations are possible. Finer sand and silts (<100 µm) can be expected but they will be more subangular. Dune sediments tend to be more well sorted than alluvial river sediments.

Alluvial Floodplain Micromorphology: Fluvial sediments can range in grain size, from large boulders to clay, depending on the location of the stream system. However, in the meandering-anastomosing stream system present in the Middle Río Negro Valley, there is a fining upward sequence from gravel, sand, and finer silts. It is expected that the alluvial floodplain sediments will be composed of moderately sorted, angular to subangular, sands and silts (< 2 mm). The mineral composition of these sediments is expected to contain quartz, the most resistant grain to weathering, and feldspar minerals.

1.3 Thesis Structure

The remainder of the thesis is structured as follows. Chapter 2 includes the background literature relating to the physiographic setting (e.g., geological history, regional biological characteristics, and climate) and previous archaeological research conducted in the region. Chapter 3 details the methodology that guides the micromorphological analysis of the materials (i.e., eolian loess mantle, eolian dune sands, and overbank sand thin sections). Chapter 4 presents the results of the thin section analysis. Chapter 5 discusses the micromorphological interpretations of the results for each thin section and a response to the thesis objectives, and Chapter 6 provides the conclusions.

CHAPTER 2: BACKGROUND

2.1 Introduction

In the first part of this chapter, the geomorphological evolution of the Pampa-Patagonia transition in Argentina is presented to provide a broad understanding of quaternary environmental processes present in the study region (Section 2.2). This section includes a discussion of the geological history of the region (i.e., tectonics, geology, topography, and geomorphology), a brief introduction to the regional biological characteristics (i.e., vegetation and fauna), followed by a discussion of the climate (i.e., modern and paleo). The main objective of Section 2.2 is to present the geomorphological features that influence the Middle Río Negro valley. These factors are important to the interpretation of the micromorphological analysis and the implications these factors have on the preservation of prehistoric archaeological sites in this region.

The second section presents a brief review of the archaeological research conducted in the Pampa-Patagonian transition (Section 2.3). The goal of this section is to describe what is known about the prehistoric human presence in the region and specifically in the Middle Río Negro Valley.

2.2 Physiographic Setting

The geography of Argentina is divided into four sub-regions: the North, the Andes, the Pampas, and Patagonia. The North encompasses the northern most part of the country, from the eastern boundary of the Andes toward the edge of Uruguay. The Andean region extends along the western edge of the country. In central Argentina, the Pampas or grasslands extend southward to the Colorado River and eastward to the Atlantic Ocean. Patagonia begins South of the Pampas; it is a cold, windy region that stretches to the tip of South America into Tierra del Fuego. The zone where the Pampas and Patagonia meet includes five provinces: Río Negro, Neuquén, Mendoza, la Pampa, and Buenos Aires (**Figure 1**). In the Río Negro Province, southeast from Choele Choel, is the Middle Río Negro Valley and represents the location of the study region where the current micromorphological samples analyzed for this thesis were collected during the 2004-2005 geoarchaeological investigations (**Figure 2**). The project area from this previous study included both sides of a 150-kilometer segment of the Río Negro (Luchsinger, 2006).

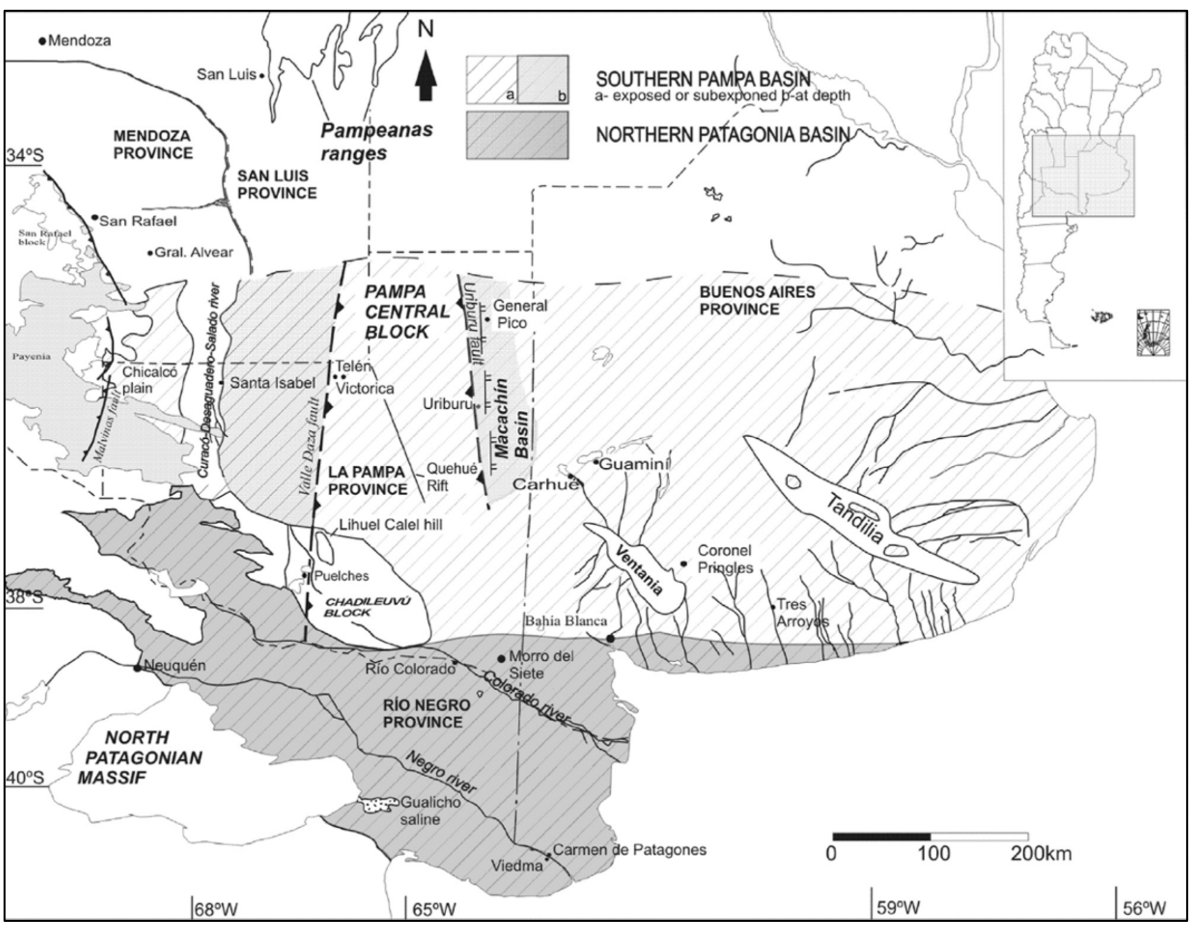


Figure 1. Distribution of the southern Pampa basin and the northern Patagonia basin in the extra-Andean region (Folguera et al., 2015).

Figure 2. Map of South America showing location of the Middle Río Negro Valley and survey location. Modified from Luchsinger, 2006.

2.2.1 Geological History

Tectonics

There are many influencing factors that shape a landscape, but at the core of every factor is tectonics. These internal driving forces, plate tectonics, determine what the surface lithology will be. These source rocks are eroded and weathered to eventually become the sediments explored in thin sections in this thesis. The complex assemblage of different rock formations that make up the South American plate have been evolving for more than three billion years. These ancient rocks were part of the Pangea supercontinent until large-scale rifting and crustal separation in the Mesozoic Era split South America from Africa and other continents (Clapperton, 1993). During the last 160 Ma (i.e., million years), tectonic and denudation processes (i.e., erosion, weathering, mass movement, transportation, and deposition) have constantly shaped the structure, relief, and drainage of South America.

Over the past 15 Ma, the Andes were uplifted which led to the beginning of a vast network of fluvial systems that transported rock waste from the mountains to the adjacent basins (Clapperton, 1993). To the west of the Pampa-Patagonian transition is a typical orogen caused by subduction of oceanic crust beneath the South American plate forming a volcanic system: The Andean Cordillera (Folguera et al., 2015; Ramos, 1999). Folguera et al. (2015) concluded that there are two separate foreland basins, the southern Pampa basin, and the northern Patagonian basin, with infill composed of late Miocene and Pliocene sedimentary units (**Figure 1**). These two main foreland basins of the Andes are located between 34° and 41° South. The northern Patagonian basin extends from the Colorado-Curacó fluvial system to the North Patagonian massif, 38° to 41° South, and is comprised of the northern part of the Río Negro province, eastern Nequèn province, the southern part of la Pampa province, and the Buenos Aires province. While the southern Pampa basin is located at 34° to 38° South and is comprised of two provinces: the Buenos Aires and la Pampa province (Folguera et al., 2015).

Physical Geology

In this region, the deepest strata that has been investigated is a Pre-Cretaceous crystalline-metamorphic bedrock (Kaasschieter, 1965, 1967; Zambrano, 1972 as cited in Luchsinger, 2006). Gypsiferous claystones of the Pedro Luro formation, dated to the Danian period (66 – 61.6 Ma) overlay the Pre-Cretaceous bedrock. The Pedro Luro is then covered by a greenish-grey glauconitic sandstone, intercalated with greenish clay and fine gravels (Paleocene-Oligocene, 61 Ma-23.03 Ma). The next layer is from the Miocene (23.03 – 5.33 Ma) and is composed of

Sandstones with pelitic intercalations with microfossils. This is followed by the Pliocene (5.33 – 2.58 Ma) Río Negro Formation, which includes a medium fine grained bluish-gray sandstone (**Figure 3**). Next is the Rodados Patagonicos, or Patagonian Gravels, that date to the early or middle Pleistocene (2.58 Ma – 129 ka [i.e., thousands of years ago]), sands and clasts with eolian polish (Angulo et al., 1979 as cited by Luchsinger 2006). The late Pleistocene (129 ka – 11,700) alluvial and eolian sediments were deposited in the valley and Patagonian Plateau was elevated and the basins across the plain were formed (Suriano et al., 1999). Holocene (11,700 – present) deposits include alluvial fine-coarse sands with gravel and eolian sediments of fine-medium sand (Luchsinger, 2006). The alluvial and eolian sediments of the Holocene are the proposed depositional origins of the samples examined in this study. A summary of the geological history is presented in **Table 1**.

(A) *(B)*

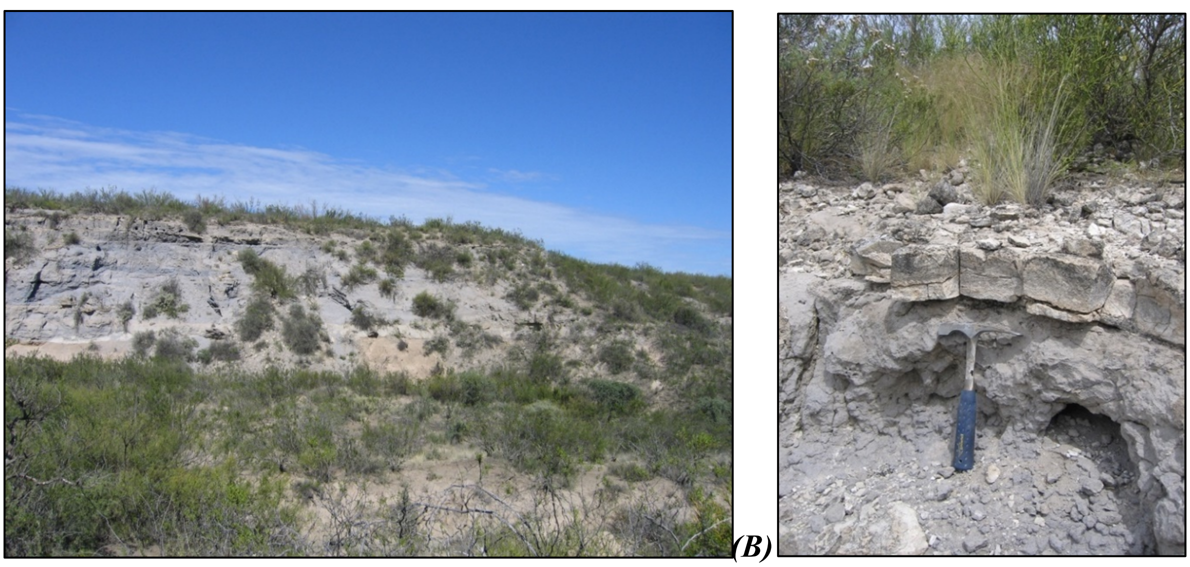


Figure 3. (A) Overview of blueish-gray sandstone outcrop and (B) close-up of outcrop, from the Río Negro Formation (Pliocene: 5.33 – 2.58 Ma) (copyright permission of H. Luchsinger).

Table 1. Miocene-Holocene Geological History Summary

Geologic Time Scale			Strata	Composition
Quaternary		Holocene (11,700 – present)	Alluvial and eolian sediments within the valley	Alluvial fine-coarse sands with gravel; eolian sediments of medium-fine sand
			Alluvial, colluvial, and eolian sediments in the basins on the modern plateau	Basins consist of sands, silts, sparse fine gravel (alluvial-colluvial on basin slopes) and pelitic deposits, clayey-silts, and evaporates along the basin bottom.
		Late Pleistocene (129 ka – 11,700)	Alluvial and eolian sediments within the valley	Alluvial and eolian sediments were deposited in the valley and plateau after the plain was elevated and the basins across the plain were formed
		Plain elevation: 1) Initial incision of the modern Río Negro valley. 2) Formation of the basins across the plain (present meseta).		
		Early to Middle Pleistocene (2.58 Ma – 129 ka)	Rodados Patagonicos	Sands and clasts with eolian polish.
Tertiary	Neogene	Pliocene (5.33 – 2.58 Ma)	Río Negro Formation	Medium-fine grained bluish-gray sandstone with sporadic intercalations of pinkish and cream siltstones and claystones. The sandstones have a volcanic matrix with plagioglase (labradorite and andesine), magnetite, hypersthene, hornblende, quartz, feldspars, and some heavy minerals.
		Miocene (23.03 – 5.33 Ma)	Barranca Final Formation	Sandstones with pelitic intercalations (clayey-silt) with microfossils in the pelitic levels.
	Paleogene	Paleocene to Oligocene (61.6 – 23.03 Ma)	-	greenish-grey glauconitic sandstone, intercalated with greenish clay and fine gravels
		Beginning of Paleocene: Danian Period (66 – 61.6 Ma)	Pedro Luro Formation	Gypsiferous claystones
Pre-Cretaceous			-	Crystalline-Mettamorphic Bedrock

Note: Modified from Luchsinger, 2006 (Angulo et al., 1979; Clapperton, 1990; Kaasschieter, 1965, 1967; Luchsinger, 2006; Suriano et al., 1999; Zambrano, 1972.)

Topography

The underlying surface uplift from tectonic activity and the accompanying denudation processes (i.e., erosion, weathering, mass movement, transportation, and deposition) shape the land surface. In turn, the topography drives the pace and spatial patterns of geomorphological processes across the landscape. The general topography of the Pampa-Patagonia region is composed of low-lying plains and elevated plateaus.

The Pampean region, north of the Patagonian plateau, is often divided into several areas based either on the sedimentary surface cover (e.g., pampa arenosa or sandy pampas) or on the climatic conditions (e.g., dry pampa vs. humid pampa). At the transition zone, the Pampean region is characterized by the dry and sandy eolian cover, the Dry Pampa (Zarate & Tripaldi, 2012). Two river valleys, the Río Negro and Colorado River, follow the Pampa-Patagonia transition zone from east to west (**Figure 2**). The headwaters for each river begin in the western Andes, flowing east across the continent before finally reaching the Atlantic Ocean (Seitz et al., 2018; Soldano, 1947). The western Andes were extensively glaciated in the late Pleistocene from 30,000 to 14,000 BP. The subsequent deglaciation in 14,000 – 13,000 BP resulted in an influx of glacial-fluvial discharge into both fluvial systems (Rabassa & Clapperton, 1990; Zarate & Blasi, 1993).

During the Pleistocene, the glacial systems in the Andes played a major role on the morphology of the fluvial networks in the Pampa-Patagonia region (Clapperton, 1990; Rabassa & Clapperton, 1990; Quatrrocchio et al., 2008). The rapid influx of sediment and water discharge from snow melt caused a rapid incision across the northern Patagonian plateau (Luchsinger, 2006; Zarate & Blasi, 1993). In the wake of this topographic change, the Río Negro started to erode the alluvial plain, carving a complex set of alluvial terraces across the floodplain (**Figure 4**).

Figure 4. Pleistocene alluvial terraces in the foreground cutting across the valley (copyright permission, H. Luchsinger).

In the Middle Río Negro Valley project area, Luchsinger (2006) conducted a landscape study to reconstruct the landscape history of the valley. A geomorphic map and generalized stratigraphic cross section of the Middle Río Valley is available in **Figure 5**. The study concluded that during the Late Pleistocene, the Río Negro was a large braided stream that created two gravel terraces (T3 and T2). A period of landscape surface stability, in the Late Pleistocene, allowed for the formation of two paleosols on each terrace. During either the end of the late Pleistocene or early Holocene, the second Pleistocene terrace (T2) experienced a drop in base level. In other words, the level below which incision cannot occur dropped and changed due to sea level drop or tectonic uplift (Harvey, 2012). The base level drop caused a deep incision across the floodplain, creating terrace T-1. From the early to middle Holocene, a gravel terrace

(T1) covered by fine alluvial sand was deposited by the Río Negro and then covered by the Rafael paleosol (Luchsinger, 2006). By the end of the middle Holocene the Río Negro shifted from a braided fluvial system to a meandering-anastomosing stream system.

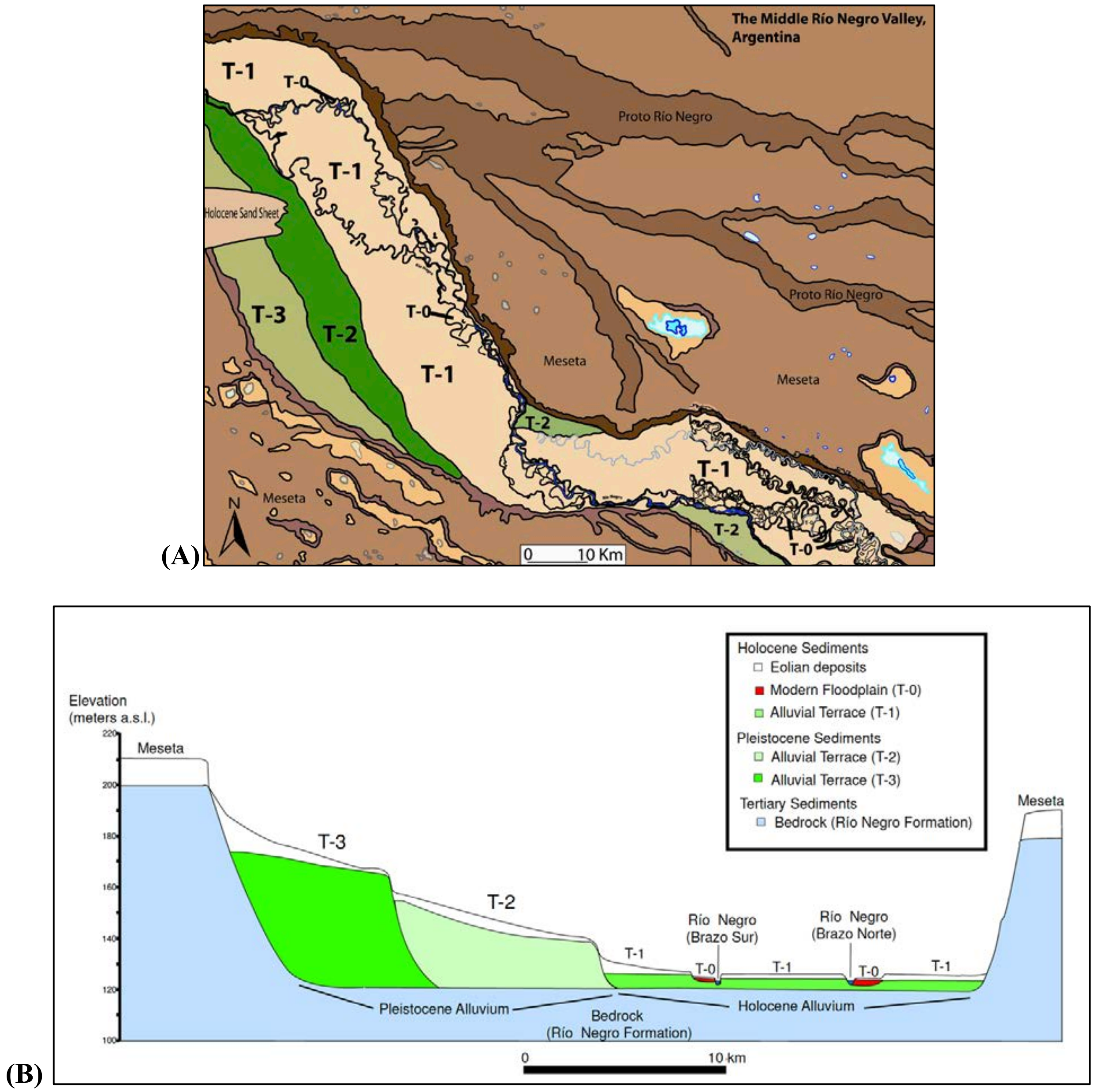


Figure 5. From Luchsinger (2006: 56-57), (A) geomorphic map of the Middle Río Negro Valley. Pleistocene alluvial terraces are in western portion (T-3 and T-2) and the Holocene alluvial terraces (T-1 and T-0) lie to the east of these deposits. (B) Generalized cross section of the Middle Río Negro Valley where Pleistocene alluvial terraces are preserved. The thin section sample were collected from T-1 and T-0.

Geomorphology

As a meandering-anastomosing stream system, the Río Negro is composed of a unique set of geomorphic elements or features, as illustrated in **Figure 6**. Deposition of sediments occurs through lateral and vertical growth (i.e., accretion). A laterally migrating meandering stream system typically produces a fining upward sequence (i.e., the grain size will decrease towards the surface). During normal conditions, the flow is restricted to the channel and sediment deposition occurs on the channel floor or along point bars. However, deposition is not uniform across the channel. A point bar is a low ridge of sediment attached to the riverbank on the inside of a meander bend. The inside of the meander bend has a lower flow velocity allowing for the lateral accretion of sediments and formation of point bars (**Figure 7**). The thalweg, the deepest part of the stream, is located along the outside of the meander bend. It is in this part of the river where flow velocity is highest, causing a greater amount of erosion forming a cut bank (**Figures 7 & 8**).

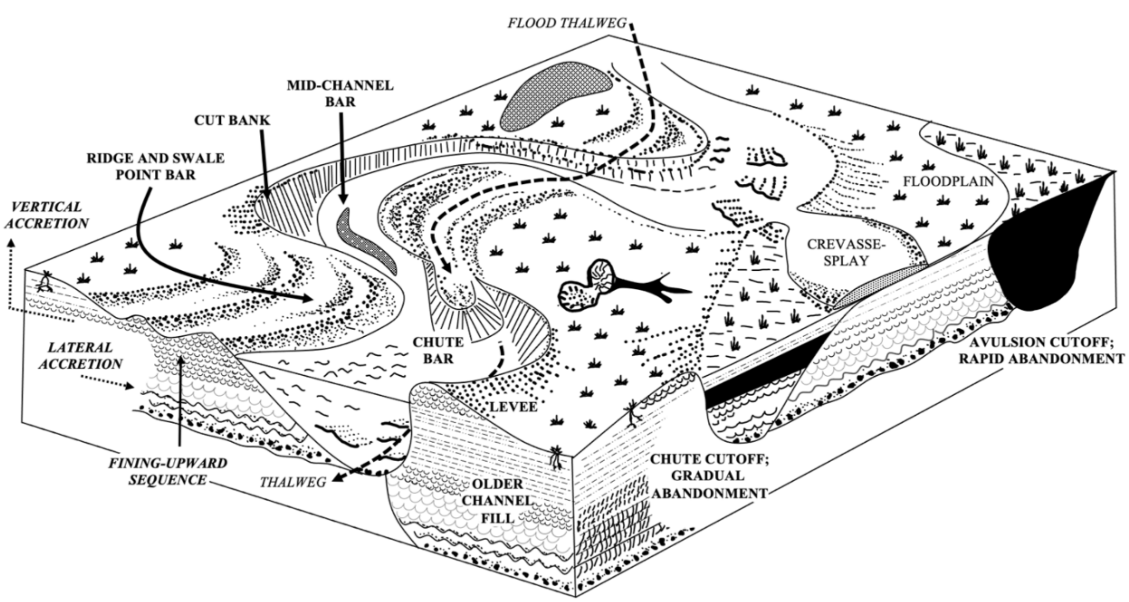


Figure 6. Block diagram showing major geomorphological elements and floodplain aggradation in a meandering system. Modified after Walker & Cant, 1979.

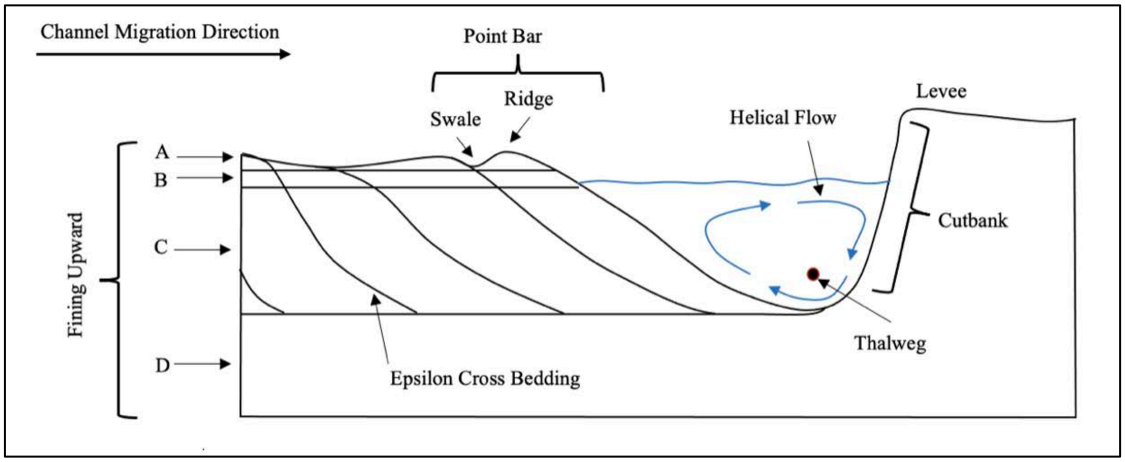


Figure 7. Schematic diagram of the cross section of a point bar depositional sequence, showing the location of the helical flow that erodes sediment off the cutbank and deposits sediment on the point bar. Sediments exhibit a fining upward vertical sequence.

Figure 8. Alluvial Terrace (T1) incised by the modern channel of the Río Negro. This is an example of a river cutbank. The undercutting caused by the river is exposing the fluvial gravels. From Luchsinger, 2006: 54.

Conditions can also fluctuate due to periods of drought or even high intensity events like flooding. During high intensity flooding episodes, over bank deposits consisting of fine grain sediments will be deposited over the levees, point bars, and floodplains. In **Figure 9**, the result of multiple flooding events is observed in the profile from paleochannel 2 (i.e., avulsion channel 2) near waypoint 498.

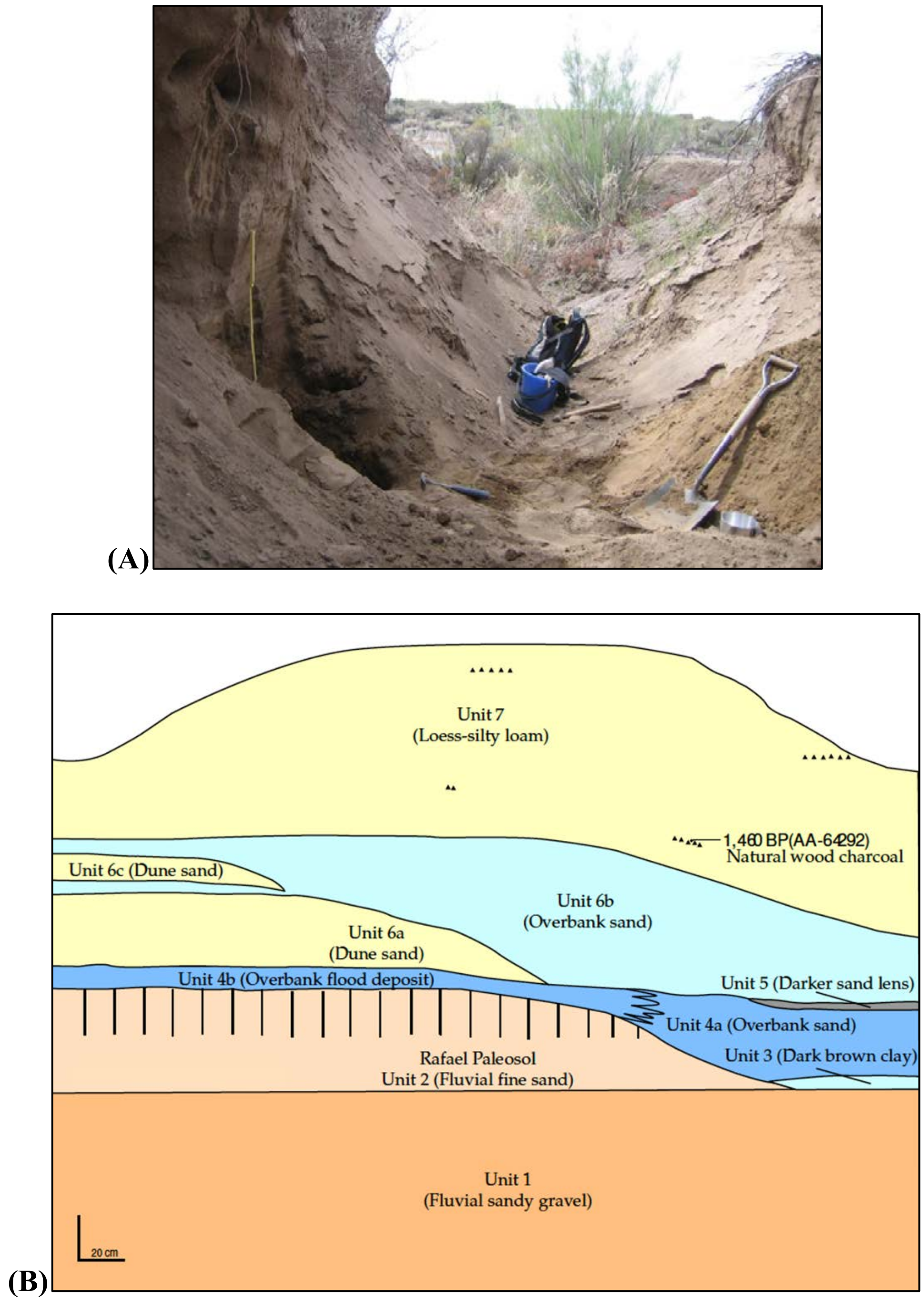


Figure 9. From Luchsinger, 2006: 64. (A) Gully perpendicular to an abandoned channel; (B) stratigraphic profile at Location 1 (S39°48.197', W64°56.222), waypoint 498.

In the Middle Río Negro Valley during the late Holocene, the river underwent three separate channel avulsions. Channel avulsion is the process by which the flow is diverted out of an established river channel into a new course on the adjacent floodplain (Slingerland & Smith, 2004) (**Figure 10**). During periods of high rainfall and flooding events, the abandoned channels (i.e., the channels that underwent channel avulsion) flood and the deep parts of the channel – typically the meander bend of the channel – will fill with flood waters, creating pools (**Figure 11**).

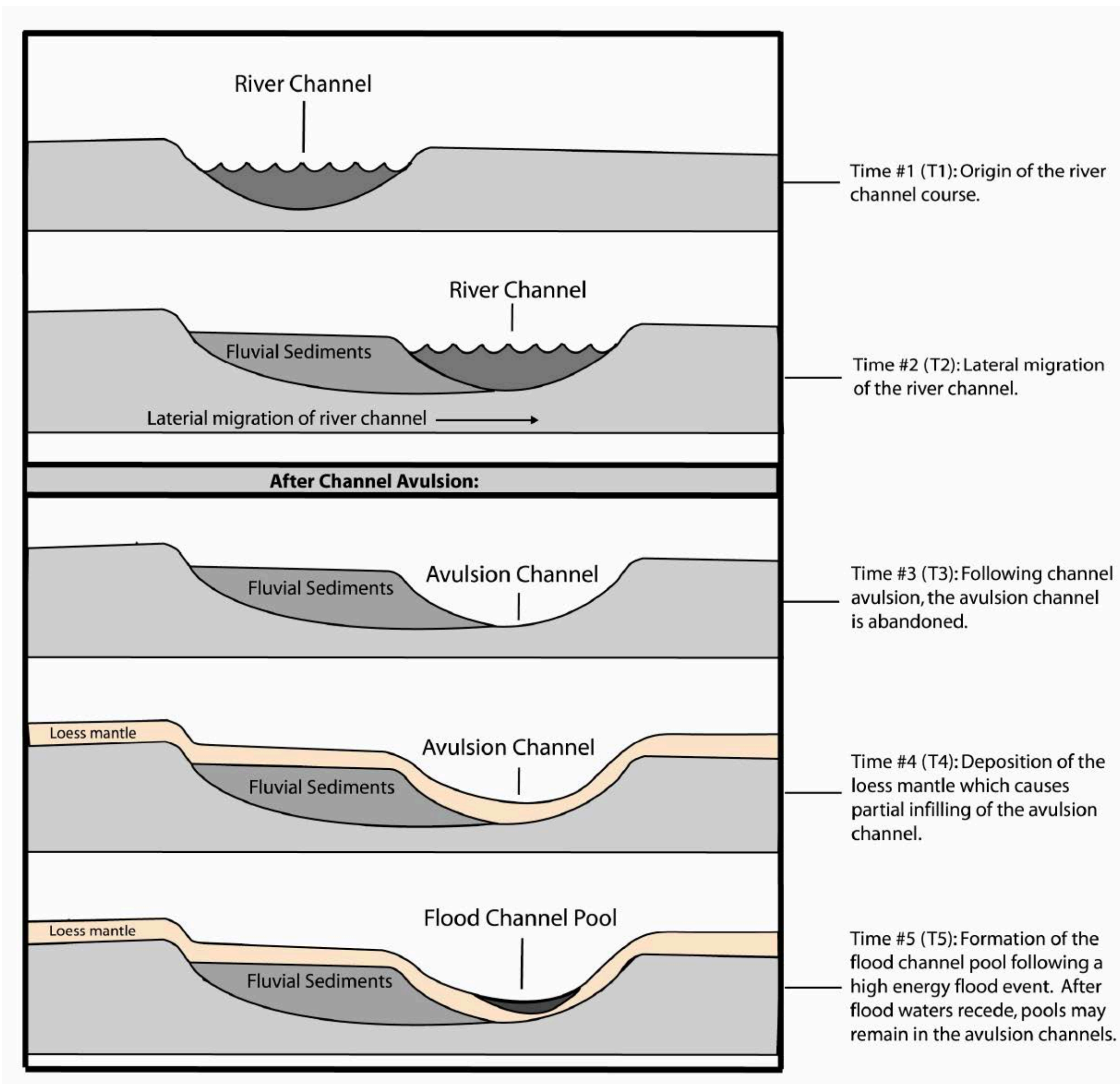


Figure 10. Probable sequence of channel avulsion, loess (i.e., eolian mantle) infilling, and pool formation proposed by Luchsinger, 2006.

Figure 11. Flooded avulsion channel (i.e., paleochannel) with grazing flamingos, in the Middle Río Negro Valley (copyright permission, H. Luchsinger).

Understanding the chronology of the channel avulsions, was a key factor contributing to Luchsingers (2006) landscape reconstruction. Based on the uncalibrated radiocarbon dates from archaeological sites in Avulsion Channel 2, Avulsion Channel 3, and along the banks of the main channel, Luchsinger (2006) was able to estimate the period during which each avulsion channel served as the main channel for the Río Negro (**Figure 12**). Avulsion Channel 2 served as the main river channel until about 2500 - 2000 years 14C BP when it avulsed 8.5 km to the south to form Avulsion Channel 3. Based on this chronology, it is suggested that Avulsion Channel 1 served as the main channel for the Río Negro prior to 2500 - 2000 years 14C BP before it shifted 2 km northeast to Avulsion Channel 2. More testing would need to be completed on Avulsion Channel 1 to provide additional support for this hypothesis. This chronology indicates that the Río Negro was highly dynamic during the Holocene, experiencing environmental changes that caused rapid movement back and forth across the valley. A schematic cross section of the valley reconstruction with results from the radiocarbon dating is available in **Figure 13**.

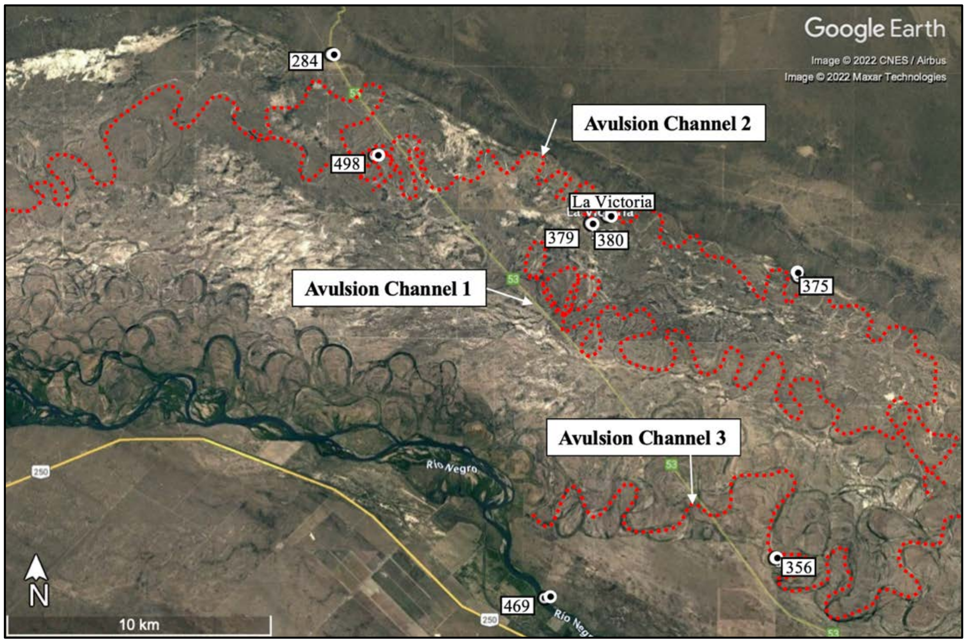


Figure 12. Google Earth image of the eastern Middle Río Negro Valley, location of the three avulsion channels (i.e., paleochannels) (Google Earth Imagery copyright 2022, Maxar Technologies). The points marked on the map indicate the waypoint number where samples were collected for radiocarbon dating.

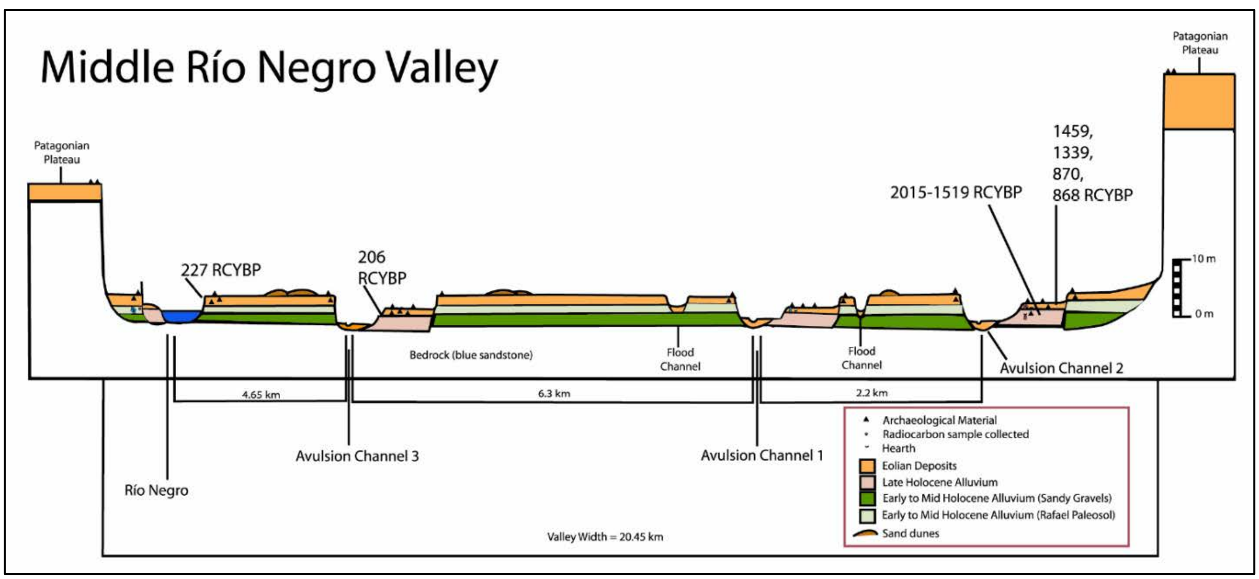


Figure 13. Schematic stratigraphic cross section of the Middle Río Negro Valley, showing the three avulsion channels (i.e., paleochannels), modern Río Negro channel, chronology of sediment deposition, and the results from the radiocarbon dating of archaeological sites. From Luchsinger, 2006: 82.

On top of the alluvial deposits is a series of eolian deposits. Eolian deposits (i.e., the eolian loess mantle and eolian dunes) are formed by high flow velocity transport and deposition, via wind. Dunes migrate across interdune flats, causing the surface of the flats to be eroded and topped by new dune formations (**Figure 14**). This process occurs when sediment is transported up the stoss side of the bedform to the crest before it rolls down the lee side (**Figure 15**). This process is repeated continually until the dune begins to migrate laterally.

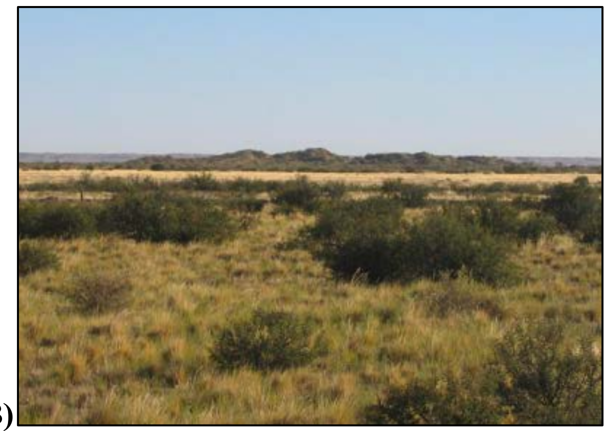
(A)  **(B)** 

Figure 14. From Luchsinger (2006: 54), (A) eolian blowout zone on surface of eolian mantle between avulsion channels 1 and 3; (B) sand dune complex, background in center of horizon, located between avulsion channels 1 and 2.

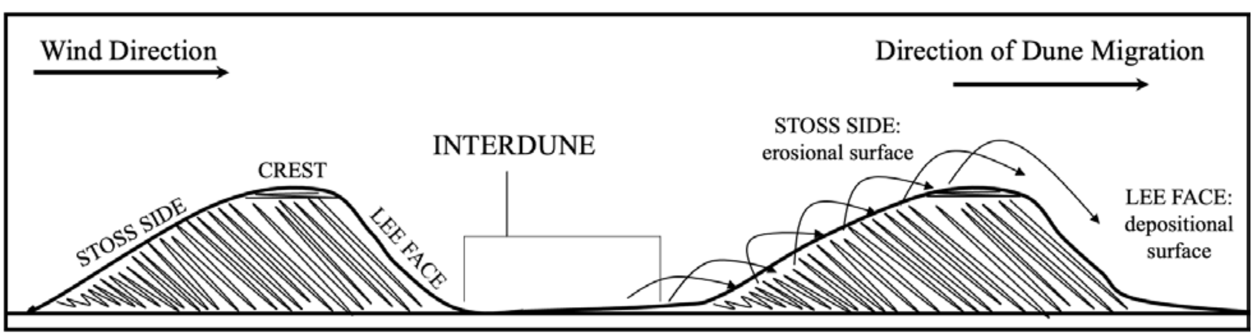


Figure 15. Schematic diagram of eolian dune cross section and eolian dune formation.

The eolian mantle deposits (**Figure 16**), also known as loess, are fine grained sediments that are eroded by wind from areas poorly protected by vegetation and are then transported great distances before being deposited (Waters, 1992). When wind velocity is reduced the grains settle to the ground and are kept in place by vegetation, this results in a sheetlike mantle deposit. Loess is primarily composed of silt-sized particles, with minor amounts of clay and very fine sand grains. Once the loess grains are deposited, they cannot be easily resuspended by wind like sand dunes due to their cohesiveness (i.e., grain size and shape). A study by Zarate and Blasi (1993), claims that the fine grained eolian deposits (i.e., loess mantle) within the eastern segment of this transitional region, as well as the dune fields of central Argentina, originate from the alluvial plain arc of the Río Negro and Río Colorado systems.

Figure 16. Gravel terrace and overlying eolian mantle sediments. From Luchsinger, 2006: 63.

2.2.2 Biological Characteristics

Vegetation

In the west, the Pampa borders a xerophytic woodland vegetation, called the "Espinal", that forms a broad ecotone (Cabrera, 1976 as cited in Quattrocchio et al., 2008; Luchsinger, 2006; Prates, 2007). The "Espinal" is dominated by trees (*Prosopis flexuosa* and *P. caldenia*) and thorn shrub woodlands. This characteristic steppe environment, observed in **Figure 17**, includes the dominant *Stipa papposa* and *Bromus brevi* grasses, along with herbs and shrubs (*Cynodon hirsutus, Baccharis ulicina, Parthenium hysterophorus, Verbesina enceliodes* and *Solanum eleagnifolium*). The vegetation is a reflection of the climate; from a grass prairie in the northeast to xerophytic woodland and shrubs southwest (Cabrera, 1971 as cited by Zarate & Tripaldi, 2012; Prieto, 1996). At present, a large part of the vegetation is thoroughly modified and disturbed by modern agriculture (Zarate & Tripaldi, 2012).

Figure 17. Steppe environment observed in the Middle Río Negro Valley, near an abandoned avulsion channel (i.e., paleochannel) (copyright permission, H. Luchsinger).

Fauna

In the Pampa-Patagonian transition, the characteristic ecotone continues to present itself through the abundance of fauna that is found in the vicinity of the active rivers but that do not appear on the plain (Cabrera, 1976; Prates, 2007; Ringuelet, 1961). Many of the modern species native to this region were important food resources for prehistoric hunter-gatherers. Some of the common species found in the archaeological record at various sites in the Middle Río Negro Valley include the guanaco (*Lama guanicoe),* big hair armadillo (*Chaetophractus villosus),* greater and lesser rhea (*Rhea americana* and *Rhea pennata)* (**Figure 18**)*,* chaco tortoise (*Chelonoidis chilensis)*, as well as native fish and mollusks.

Figure 18. The nandu, also known as the greater or lesser rhea (i.e., *Rhea americana* or *Rhea pennata*), in the Middle Río Negro Valley (copyright permission, H. Luchsinger).

2.2.3 Climate

Modern

In Patagonia the climate is characterized as semi-arid, arid, and cold (Clapperton, 1993; Mancini et al., 2008). In most of the Pampa-Patagonia transition, the modern climate is arid to semi-arid, but in the western region, near southern Buenos Aires province, the climate is humid (Zarate & Blasi, 1993; Zarate & Tripaldi, 2012). Regionally, wind conditions are controlled by subtropical high-pressure cells, the intensity of the quasi-stationary low in the Gran Chaco province, and the westerlies of the middle latitudes (Zarate & Tripaldi, 2012: 402). The modern climate in the Middle Río Negro Valley is arid and dry winds blow from the west and southeast (Acevedo, 1981; Luchsinger, 2006; Prates, 2007).

Paleoclimate

The paleoclimate during the late Pleistocene and the late Holocene was not much different than the present-day climate; arid conditions prevailed. Prior to 12,000 BP, before the end of the Pleistocene, it is suggested that the climate was drier and colder, at least 10°C lower than current average temperatures (Zarate & Blasi, 1993). A recent sedimentological study in the eastern Pampa-Patagonian transition by Quattrocchio et al. (2008), concluded that the transition from Late Pleistocene to Early Holocene was marked by climatic fluctuations between intervals of arid-cold and warm-humid. This was determined by the alternating sequences of loess and paleosol units; loess deposition during the arid-cold periods and paleosol development during the warm-humid intervals. Schäbitz (1994), reconstructed the paleoenvironment from the Middle to Late Holocene. The results of this analysis concluded that the Mid-Holocene climate was primarily arid and eolian processes prevailed. In the late Holocene, the climate shifted to semi-arid. With an increase in precipitation and seasonality there was also greater fluvial influence during this period and therefore an increase in alluvial sediments in the valley.

2.3 Archaeology of the Pampas-Patagonia Transition

The Río Negro Valley in the Argentine province of Patagonia, has attracted archaeological investigations since the early 1800's. From 1831 to 1836, the HMS Beagle embarked on an expedition to survey South America that included explorations along the Río Negro in northern Patagonia, Argentina (Darwin, 1878). In the 1878 Journal detailing the expedition, Charles Darwin recalls a soldier striking fire with a piece of flint that resembled the tip of an arrow. The soldier informed Darwin that the flint was found near Cholechel [Choele Choel, Argentina] in an area where "arrowheads" were frequently found (Darwin, 1878: 105). Darwin hypothesized that the stone tools, found near Choele Choel, were artifacts left behind by prehistoric peoples that inhabited the area long before the introduction of the horse into South America in the 16th century.

Nearly 100 years after Darwin's observations in Choele Choel, Junius Bird excavated some of the earliest evidence for human occupation in South America at Fell's Cave or Cueva Fell, Chile, roughly 900 miles south of Choele Choel (**Figure 19**) (Bird, 1938; Bird, 1988). Bird discovered artifacts and hearth features, including stemmed and fluted points (i.e., Fishtail points), associated with the burned remains of the extinct ground sloth and horse. In the 1960's, radiocarbon samples from the hearth features were dated to 11,000 ± 170 14C years BP (Bird, 1988). Bird's 1936 discovery at Fell's Cave was groundbreaking for Paleo-American archaeology because it clearly established the presence of modern humans in southern South America during the late Pleistocene. Recent radiocarbon dating from the hearths has provided further justification for Bird's discovery by placing the occupation at Fell's Cave from 12,750 to 12,200 cal BP (Waters et al., 2015). In addition, based on the chronology and radiocarbon dating of sites across southern South America, human populations would certainly have been mobilizing in northern Patagonia between 14,000 and 13,000 years ago, well before the end of the late Pleistocene (Borrero, 2003; Dillehay et al., 2015; McEwan et al., 1997; Nami, 2019; Prates et al., 2013).

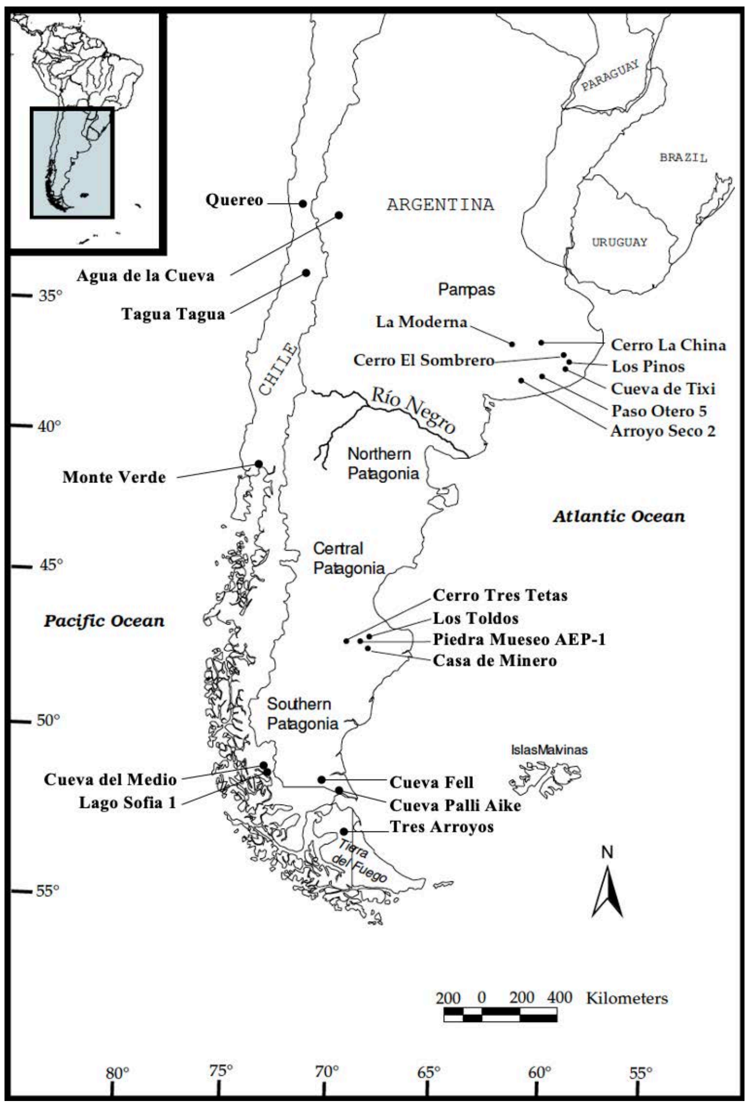


Figure 19. Prehistoric archaeological sites in southern South America. Mentioned in this thesis is Cueva Fell, Arroyo Seco, Paso Otero, Cerro La China, Cerro El Sombrero, Cueva de Tixi, and Los Pinos. Modified from Luchsinger, 2006: 25.

In the Pampas, the earliest dated site is Arroyo Seco (Gutierrez, 2004). Uncalibrated radiocarbon dates from modified bone have dated the occupation of the open-air campsite from 12,240 to 10,500 BP. Northeast of Arroyo Seco is the Paso Otero 5 site (**Figure 19**). Based on radiocarbon dates from bone and other organic material, this megafauna processing site was first used around 10,440 BP (Martínez et al., 2004). It should also be noted the presence of two Fishtail points, similar to the ones found at Fell's Cave, and flakes were found among the burnt megafauna remains.

Northeast of the Arroyo Seco and Paso Otero 5 site is a series of hills and valleys known as the Tandilia range (Martínez et al., 2013). Most of the archaeological sites in this region are rockshelters and their uncalibrated radiocarbon samples date between 11,000 to 10,000 BP. This mountain range represented an optimal environment for the early Pampas hunter-gatherers during the late Pleistocene-Holocene transition. It's possible that these cave sites were most likely occupied by the same hunter-gather groups that utilized open-air sites like Arroyo Seco and Paso Otero in the intermountain plains (Politis & Barros, 2006). Donadei (2022) concluded that the cave sites in the eastern Tandilia range, were the result of a logistical mobility system in which small human groups circulating through the valley would search for natural mountain resources, such as raw lithic materials and fresh water. The results found that the patterns of occupation in the cave sites were short-term.

In the Pampa-Patagonia transition, systematic investigations in the Middle Río Negro Valley first began in 2003. Prates (2008) focused on creating a prehistoric chronology based on the archaeological record through systematic pedestrian surveys and excavation of select sites. Simultaneously, Luchsinger (2006) reconstructed the Late Pleistocene-Holocene landscape history of the middle valley, analyzed its impact on Holocene human settlement patterns, and evaluated the preservation potential of the archaeological record in various depositional environments. These early studies identified a clear human presence in the Middle Río Negro Valley by the late Holocene.

Luchsinger (2006) identified middle-late Holocene patterns of occupation that corresponded with three abandoned channels that were produced by the repeated episodes of large-scale channel avulsion during this period (Section 2.2.1). The model proposed was a two-phase occupation of the avulsed channels: pre-avulsion and post-avulsion (**Figure 20**). The first phase occurred when the channel served as the principal or main channel of the Río Negro prior to channel avulsion; these archaeological sites were located within or on the surface of alluvial sediments and subsequently were buried by the overlying eolian deposits. Following the channel avulsion, after the river shifted its course, there was a period of abandonment when the channels remained unoccupied allowing for the deposition of the eolian sediments. The second phase is linked to archaeological sites that are buried within or on the overlying eolian mantle and represented prehistoric groups returning to the abandoned channels. The reasons why these abandoned channels were revisited was not immediately clear. Continued research by Prates (2008; Prates & Di Prado, 2013), and more recently by Mange (2019), confirms the use of these abandoned channels for their raw materials and diversity of renewable food resources. These more recent studies also confirm a mainly late Holocene presence in the Middle Río Negro Valley, with residential bases and burial sites located on dunes (Mange, 2019; Prates, 2008; Prates & Di Prado, 2013).

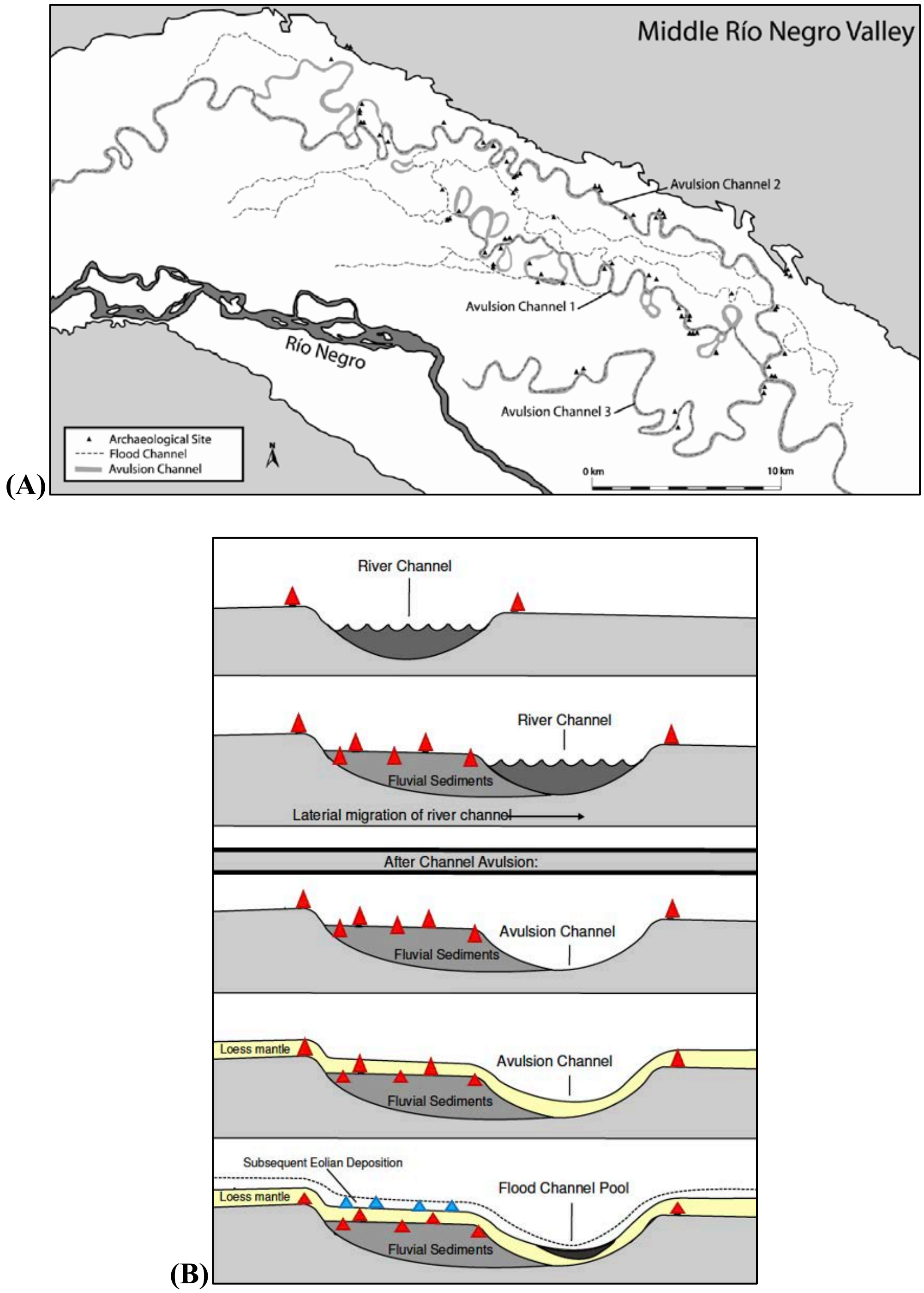


Figure 20. (A) Map of the three avulsion channels (i.e., paleochannels) and locations of archaeological sites observed in the eastern segment of the study region. (B) Two-phase occupation of the avulsion channels proposed by Luchsinger, 2006. Sites located within or on the surface of alluvial sediments and subsequently buried by the overlying eolian mantle are Phase 1 (pre-avulsion). Sites buried within the overlying eolian deposits which were deposited after the river channel had avulsed to another location are Phase 2 (post-avulsion). The pre-avulsion archaeological sites are marked by the red triangles and the blue triangles represent post-avulsion sites. Modified from Luchsinger, 2006.

Prates (2008) presented a broader model for the procurement of faunal resources across the valley based on different mobility strategies. Near the main channel camps, groups would have access to otters, fish, and clams. In the valley, daily foraging parties would have captured various species (e.g., medium sized birds, small deer, armadillos, etc.) before returning to the main channel camps. In the adjacent plateau, larger animals (e.g., rhea and guanaco) would have been hunted by small groups and the abandoned channels would have served as temporary camps before returning to the main channel camps.

Further studies in the Middle Río Negro valley have attempted to establish the chronologies of the indigenous peoples who inhabited the Río Negro Valley during pre-Hispanic times. Mange (2019) focused on analyzing the spatial distribution of the archaeological record, chronology, subsistence strategies, characterizing the technology, and investigating the mobility based on the characteristics of the sites. Mange (2019) synthesized all the available radiocarbon dates (**Table 2**) in the Middle Río Negro Valley and concluded that 76% of the sites date to the late Holocene and 23.4% of the sites correspond to the early Holocene. This synthesis revealed that there are gaps in the dates, some spanning up to 500 years. This could be due to the small sample size and the need for further investigations in the valley.

Table 2. Dates available for archaeological sites in the Middle Río Negro Valley

Site	**Context**	**14C Age (year BP)**	**14C Cal. BP**	**Sample #**	**Citation**
LV5	Residential	2015 ± 38	2006-1861	AA64294	Luchsinger, 2006
LV5	Residential	1519 ± 50	1485-1296	AA64288	Luchsinger, 2006
LV5	Residential	1459 ± 41	1379-1271	AA64292	Luchsinger, 2006
LV5	Residential	1339 ± 48	1299-1155	AA64290	Luchsinger, 2006
LV5	Burial	928 ± 39	909-727	AA70563	Prates et al., 2011
LV5	Burial	868 ± 48	667-804	AA64293	Prates et al., 2011
NM	Residential	398±46	497-319	AA62794	Prates, 2008
NM	Residential	483±43	546-445	AA62795	Prates, 2008

A1	Residential	405±46	499-321	AA62793	Prates, 2008
A1	Residential	938±45	917-730	AA2551	Prates, 2008
LM	Burial	2088 ± 46	2114-1899	AA81827	Prates et al., 2010b
LM	Burial	3027 ± 48	3272-2995	AA81828	Prates et al., 2010b
LM	Burial	2718 ± 47	2879-2732	AA81829	Prates et al., 2010b
LM	Residential	520 ± 90	574-322	LP2005	Prates et al., 2010a
LM	Residential	2156 ± 39	2164-2001	AA90950	Prates & Di Prado, n.d.
NM2	Burial	1586 ± 47	1536-1345	AA89359	Serna & Prates, 2012
NM2	Burial	1637 ± 48	1583-1372	AA91545	Serna & Prates, 2012
NM2	Burial	1283 ± 44	1271-1064	AA91546	Serna & Prates, 2012
NM2	Residential	2057 ± 38	2061-1885	AA90953	Prates & Di Prado, n.d.
NM3	Residential	1430 ± 30	1352-1270	LP3219	Mange et al., 2016
NM3	Residential	1110 ± 33	999-924	AA106437	Mange et al., 2016
NM3	Burial	1091 ± 35	1001-906	AA105420	Prates et al., 2019
LT	Burial	750 ± 50	728-623	LP-3465	Flensborg et al., 2018
M	Burial	1020 ± 50	961-773	LP-3469	Mange, 2019
Fa	Burial	1170 ± 50	1113-933	LP-3455	Mange, 2019
Po	Burial	983 ± 36	924-773	AA90955	Mange, 2019
Po	Residential	1070 ± 43	988-896	AA94709	Mange, 2019
Po	Residential	1011 ± 38	937-790	AA93602	Mange, 2019
Co1	Residential	790 ± 50	761-633	LP-3493	Mange, 2019

Site Abbreviation: NM= Negro Muerto; A1= Angostura 1; LM= Loma de los Muertos; LV=La Victoria; M= Malalvaca; Fa= Fábrega; Po= Pomona; Co 1= Colforta 1; LT= LA Toma.
Note: Table modified from Mange, 2019: 349. Calibration was performed with the *Calib* 7.0 program.

Mange (2019) identified three types of archaeological sites in their study region: quarries located on high Pleistocene terraces, human burials, and residential areas both found on the middle Holocene terrace. The residential sites and burials were located on dunes near ponds in the fluvial channels. Mange (2019) comes to the same conclusion as Luchsinger (2006) regarding the re-occupation of the abandoned channels being related to resource procurement. The location of the residential sites, near the fluvial channels, provides access to drinking water, vegetation, and fauna. Activities at these residential sites includes creating stone tools, making pots, consumption of local animal resources, bead production, and bone instrument production.

The raw materials found at these sites would have been obtained in the valley from the banks of the current channel, as well as from the paleochannels (**Figure 21**), and in the upper terraces of the valley (Mange, 2019). Sandstones, obtained for grinding activities, would have been collected 10-15 kilometers from the camps on the edges of the valley. Foreign materials are limited and found mainly in association with mortuary contexts (e.g., as personal decoration at the La Toma site). Mange (2019) also proposes that depending on the seasonal increases in flow rates, the Río Negro would have been impassible, creating a barrier between groups occupying the valley north of the channel and groups to the south. Archaeological sites found north of the main channel exhibit similarities in artifact assemblages with archaeological sites found in the Colorado River Valley to the north, suggesting that there was movement between these two groups (Mange, 2019; Prates, 2008).

Figure 21. Lithics observed in the avulsion channels (i.e., paleochannels). Raw materials found in the channel lag of the paleochannels are excellent for stone tool production. Copyright permission, H. Luchsinger.

In summary, the Patagonia-Pampas region is largely dominated by the alluvial processes from the Río Negro. These fluvial environments are great locations to find archaeological sites because they would have been excellent locations within an arid landscape to collect a diversity of natural resources, resources that would not have been available outside of this zone. The local resources were utilized by groups of hunter-gatherers in the Middle-Late Holocene. The groups occupied the dunes adjacent to the main channel of the Río Negro, establishing open-air residential camps. Small groups would travel to the higher terraces and abandoned paleochannels to collect raw materials for lithic production. These small groups would also hunt guanaco and rheas on the adjacent plateau, setting up small open-air camps in the abandoned channels before returning to the main channel residential areas.

Not only is the sample size in the Middle Río Negro Valley limited, but it also only presents data from archaeological sites dating from the Middle to Late Holocene. To the north and south, there is a clear presence of Late Pleistocene archaeological sites but not within the Río Negro Valley. If the Middle Río Negro Valley presents a mecca within an arid landscape, with the abundance of fresh water, food, and tool resources, then it calls into question why there is an absence of Late Pleistocene sites within the valley. The gap could be due to the highly dynamic landscape destroying older archaeological deposits or due to environmental changes that made this area less favorable.

CHAPTER 3: MATERIALS AND METHODS

3.1 Introduction

In the 2004-2005 field season, Luchsinger collected several hundred bulk and intact block sediment samples for both particle size analysis and micromorphological analysis. These samples were collected from various geomorphic features, as supplemental to the regional landscape reconstruction. The particle size analysis data was presented in Luchsinger's 2006 dissertation; however, the thin section samples were never analyzed or included in the original report. In total, 59 thin sections were processed from these samples, and they were grouped based on the geomorphic environment in which they were found. For the scope of this thesis, 15 of the 59 samples were selected for analysis based on their potential to yield a generalized description of the proposed eolian and alluvial processes occurring in the Middle Rio Negro Valley.

3.2 Field Sampling

Samples for micromorphological analysis are typically extracted from the soil profile as undisturbed natural blocks of sediment, as well as unconsolidated bulk samples, from the specific sedimentological units/soil horizons, using a large field knife. Once removed from the soil profile, the vertical orientation of the undisturbed sample is preserved by carefully inserting several flathead metal thumbtacks into the top of the soil-sediment block. The soil-sediment blocks are then carefully wrapped in thin tissue, followed by a tightly wrapped layer of clear packing tape to keep samples protected. The field samples were labeled by their way point number (e.g., waypoint 593), unit number if applicable (e.g., unit 2), and proposed context (e.g., Top EOL. /SURFACE EOL. [i.e., eolian deposits]; DUNE; SOSG [i.e., sand over sandy gravel]).

3.3 Laboratory Processing of Thin Sections

The soil-sediment samples were then shipped to Spectrum Petrographics, Inc. (Vancouver, WA), for processing into thin sections. This process involves drying the soil-sediment blocks to remove all water, followed by complete saturation with resin, which will harden and consolidate the soil-sediment block. The blocks are then cut down to size and mounted on a glass slide. The final state involves the samples being ground down to a uniform thickness of 30 microns (µm) which is necessary for identification and analysis of mineral, natural, and archaeological features under plane polarized light (PPL) and cross-polarized light (XPL), using a petrographic polarizing microscope.

3.4 Micromorphological Analysis

The discipline of micromorphology concerns the qualitative description of soil-sediment blocks at a microscopic level. Thin sections for micromorphological analysis are investigated at several levels of magnification and types of light: 1) thin sections are examined by hand in natural light with a hand lens (10X) and without magnification, 2) thin sections are scanned on a flatbed scanner producing a set of images which are then analyzed, and 3) thin sections are analyzed with a petrographic microscope at various magnifications (i.e., 40-200X) under both plane polarized light and cross-polarized light. Under low magnification, each thin section is systematically scanned from top to bottom along 4 "transects" each in PPL and XPL in order to observe the majority of natural and archaeological features preserved in thin section. Both types of light are necessary because certain characteristics are more visible under a specific type of light (e.g., organic matter is very clear in PPL but often obscured in XPL).

Terminology of Bullock et al. (1985) and Courty et al. (1990) are the standard handbooks for micromorphological analysis at archaeological sites (see Appendix A for diagrams and guides used for describing thin sections). More recently, Stoops (2021) produced an updated edition of his Guidelines for Analysis and Description of Soil and Regolith in Thin Sections. This edition provides a summary of the key terminology from previous handbooks and has been a suitable companion in the analysis of the presented data. A systematic approach was adopted to analyze the thin sections and organize the data they generated. Descriptions for each sample are presented in Chapter 4.

All phases of observation are focused on determining the qualitative description of thin sections in terms of composition (mineral and organic), size, sorting, shape, roundness, frequency, and distribution. The universally accepted Udden-Wentworth grain size scale is divided into four major class sizes: gravel, sand, silt, and clay (Appendix A, **Figure A-001**). Each class can be further subdivided into fine sand, medium sand, coarse sand, etc. The variation in grain-size within a sample is defined as sorting (Appendix A, **Figure A-002**). The distribution of grain sizes and sorting varies between different types of geomorphic features (i.e., sand dunes, loess mantle deposits, point bars, overbank deposits, etc.) and provides an insight into the processes responsible for the transportation and deposition of sediments (i.e., eolian or alluvial).

CHAPTER 4: RESULTS

4.1 Overview of Thin Sections

This overview includes a brief description of 15 thin section samples collected during the 2004-2005 fieldwork. The sediment samples were collected at various geomorphic locations across the Middle Río Negro Valley (**Figure 22)**. The following descriptions are intended to explain the qualitative characteristics observed during the micromorphological analysis. The results of this analysis are summarized in **Tables 3** and **4**. A glossary of micromorphological terms and descriptive diagrams is presented in Appendix A. Flatbed scans and photomicrographs of all thin sections are included in Appendix B.

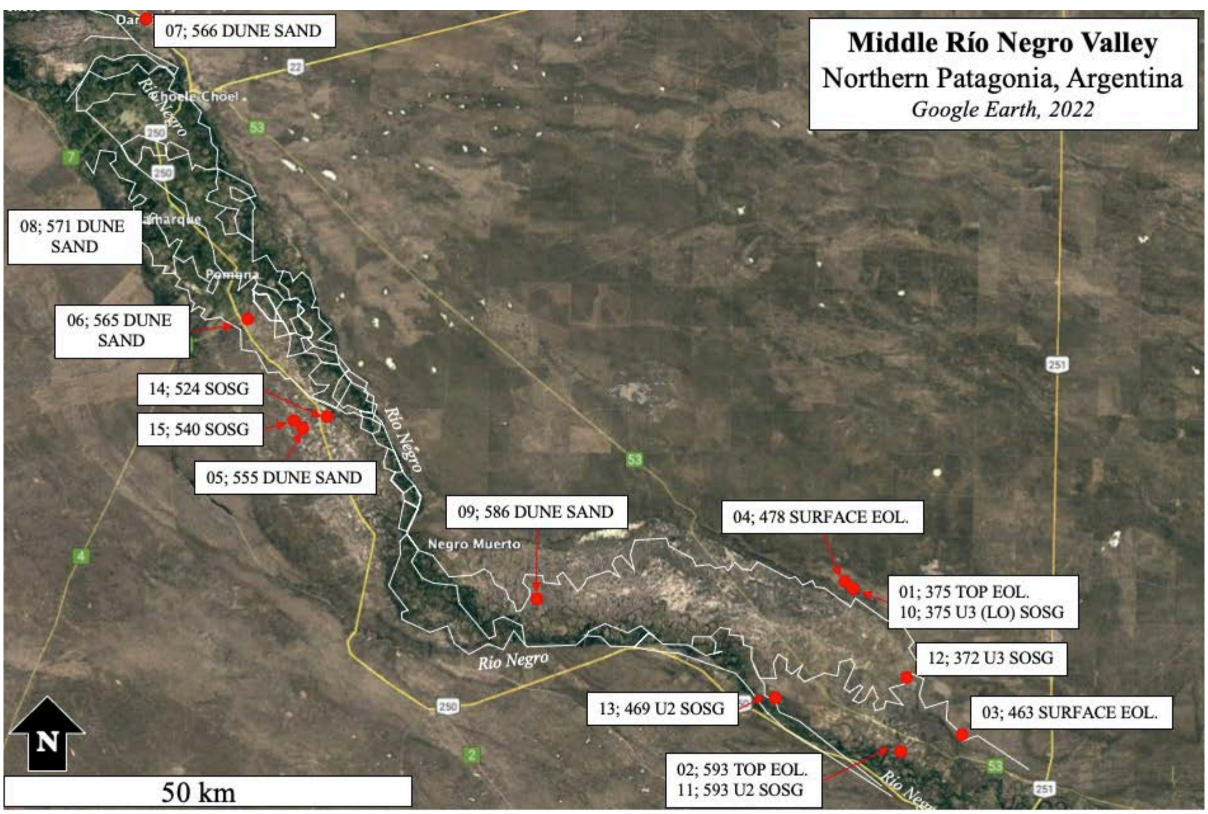


Figure 22. Google Earth image showing locations where samples were collected for thin section analysis in the Middle Río Negro Valley in northern Patagonia, Argentina (Google Earth Imagery copyright 2022, Maxar Technologies).

4.2 Proposed Eolian Loess Mantle

The sediment for samples 01 and 04 were collected from the proposed eolian loess mantle deposits in Paleochannel 2 (i.e., avulsion channel 2). Samples 02 and 03 were collected from along the main Río Negro channel, also from the proposed eolian loess mantle.

Sample 01 (375 Top EOL.)

Sample 01 was collected at waypoint 375, in paleochannel 2, from the deposits that overlay the gravel deposits in Unit 4. Sample 04, waypoint 478, was also collected nearby from the loess eolian mantle. Sample 01 contains well sorted, very fine to fine sands of different compositions. Quartz grains are dominant in frequency and very fine to fine in grain size. Quartz grain shape is smooth subangular to subrounded. Feldspar mineral grains are very fine in size and their frequency across the sample is very few. The frequency of mica (e.g., biotite and muscovite) is also few and ranges from large columnar-rodlike grains to very fine columnar-rodlike grains. Feldspar and mica grains are subrounded. Sample 01 also contains a noticeable presence of organic matter. This includes very few bone fragments, very few charcoal fragments, and few fragments of unidentified plant matter. See Appendix B; **Figures B-001 – B-011**.

Sample 02 (593 Top EOL.)

Sample 02 was collected at waypoint 593, along the main channel near waypoint 463 (sample 03), from the deposits that overlay the gravel deposits. Sample 02 contains poorly sorted, very fine to coarse sands. Quartz grains are frequent across the sample and range in size from very fine to coarse grains, with most of the grains being subangular fine grains. Feldspar mineral grains are very fine, and their frequency is few. Very few feldspar grains exhibit class 1, cross linear (C2) alteration. Micas are less frequent but also very fine in size. Feldspars and mica grains are subrounded. The frequency of organic matter is few and includes bone fragments, charcoal, and unidentified plant remains. See Appendix B; **Figures B-012 – B-023**.

Sample 03 (463 SURFACE EOL.)

Sample 03 was collected at waypoint 463, along the main channel nearby sample 02, from the surface deposits that overlay the gravel deposits. Sample 03 contains poorly sorted, fine to medium sands. Quartz grains are frequent across the sample and range in size from fine to medium subangular grains. The frequency of feldspar mineral grains is very few. Grains range from fine to medium and are undulating subangular. The mica mineral grains are also subangular and very few in frequency, but grains are much finer in size. The frequency of organic matter is few and is composed primarily of unidentified plant remains. No distinguishable bone or charcoal was observed during the thin section analysis. See Appendix B; **Figures B-024 – B-029b**.

Sample 04 (478 SURFACE EOL.)

Sample 04 was collected at waypoint 478, in paleochannel 2 near sample 01, from the loess eolian mantle unit that covers the gravel deposits. Sample 04 contains poorly sorted, very fine to coarse sand. Quartz grains are common and range in size from medium-coarse subrounded grains to fine subangular grains. Also ranging in size are the feldspar mineral grains: very few coarse and frequent fine-medium subangular grains. Very few feldspar grains exhibit class 1-2 cross linear (C2) alterations. Mica mineral grains are very fine, subangular, and their frequency is very few. Sample 04 also contains few, medium to coarse, subrounded compound mineral grains. The frequency of organic matter, in the form of unidentified plant remains, is very few. No distinguishable bone or charcoal was observed during the thin section analysis. See Appendix B; **Figures B-030 – B-033**.

4.3 Proposed Eolian Dunes

The following five samples were collected from the proposed eolian dune sands along the main channel in the northwest segment of the project area.

Sample 05 (555 DUNE SAND)

Sample 05 was collected at waypoint 555 from the dunes along main channel 3. This sample contains moderately well sorted, very fine to fine sands. Quartz grains are fine, subangular, and are common across the sample. Feldspar and mica mineral grains are very fine to fine in size, subrounded, and their frequency across the sample is few. Sample 05 contains very few organic matter (e.g., plant remains) and no distinguishable bone or charcoal was observed during the thin section analysis. See Appendix B; **Figures B-034 – B-038**.

Sample 06 (565 DUNE SAND)

Sample 06 was collected at waypoint 565 from the dunes along main channel 2. This sample contains moderately sorted, fine to medium sand. Quartz grain size ranges from fine to medium, subrounded to subangular, and is dominant across the sample. The feldspar minerals are fine to medium subrounded grains. The frequency of feldspar grains that exhibit class 0-1, cross linear (C2) alteration is very few. Mica mineral grains are fine in size and subrounded. Feldspar and mica grains are very few across the sample. Very few organic matter (e.g., plant remains) is observed in sample 06 and no distinguishable charcoal or bone was observed during the thin section analysis. See Appendix B; **Figures B-039 – B-041b**.

Sample 07 (566 DUNE SAND)

Sample 07 was collected at waypoint 566, north of sample 08, from the dunes along main channel 1. Sample 07 contains moderately sorted, fine to medium sands of different compositions. Quartz grains are fine to medium in size and frequency is common across the sample. Grains are mostly subangular and very few of the grains are subrounded. Sample 07 contains a common frequency of compound mineral grains. The compound mineral grains are medium in size and are subrounded to rounded. The frequency of feldspar minerals is few. Feldspar mineral grains are smooth, subrounded, and fine to medium in size. The frequency of mica minerals is very few. Mica mineral grains are smooth, subrounded, and fine in size. Very few organic matter (e.g., unidentified plant remains) is present in this sample. No distinguishable charcoal or bone was observed during the thin section analysis. See Appendix B; **Figures B-042 – B-043**.

Sample 08 (571 DUNE SAND)

Sample 08 was collected at waypoint 571 from the dunes along main channel 1. This sample contains poorly sorted, fine to coarse sands. Quartz grains are dominant across the sample. Grains are subrounded to rounded and are mostly medium in size, although some larger coarse fragments and small fine fragments are present. The larger quartz grains exhibit a greater degree of rounding compared to the finer grains. Sample 08 also contains a higher, common, frequency of compound mineral grains that are smooth, subrounded, and coarse in size. The frequency of feldspar minerals is few, and grains range from medium to coarse in size. Mica minerals are very few in frequency and medium to fine in grain size. Feldspar and mica mineral grains are subrounded. The frequency of organic matter (e.g., unidentified plant remains) is very few and no distinguishable charcoal or bone was observed during thin section analysis. See Appendix B; **Figures B-044 – B-047**.

Sample 09 (586 DUNE SAND)

Sample 09 was collected at waypoint 586 from the dunes along main channel 4. This sample contains moderately sorted, very fine to medium sands. Quartz grains are common across the sample, with sizes ranging from fine to medium, subangular to subrounded smooth grains. The frequency of feldspar and mica grains is few. Feldspar mineral grains are fine to medium in size, undulating, and subrounded. Mica mineral grains are also fine to medium in size, smooth, and subrounded across the sample. The frequency of organic matter (e.g., unidentified plant remains) is very few and no distinguishable charcoal or bone was observed during thin section analysis. See Appendix B; **Figures B-048 – B-053**.

4.4 Proposed Alluvial Floodplain Deposits

All samples were collected from the sandy layer between the eolian mantle top unit and the underlying alluvial gravel deposits. Sample 10 was collected from paleochannel 2 and sample 12 was collected from paleochannel 3. The remaining four samples were collected from along the main Río Negro channel.

Sample 10 (375 U3 (LO) SOSG)

Sample 10 was collected from the same waypoint as Sample 01, waypoint 375, in paleochannel 2. This sample was collected from the thin sandy layer between the loess (eolian) surface cover and the gravel deposits in Unit 3. Sample 10 contains moderately sorted, very fine to medium sands. Quartz is common across the sample and ranges in size from very fine to medium sand. Quartz and feldspar grains are subangular to subrounded. The frequency of feldspar minerals is few, and grains are very fine to fine in size. Mica minerals are also few in frequency, but grains are subangular and fine in size. The frequency of organic matter (e.g., bone, charcoal, and plant remains) is very few but consistent across the sample. See Appendix B; **Figures B-054 – B-056b**.

Sample 11 (593 U2 SOSG)

Sample 11 was collected from the same waypoint as Sample 02, waypoint 593, along the main channel in Unit 2. This sample was collected from the thin sandy layer between the eolian surface cover and the gravel deposits. Sample 11 contains well sorted, fine to medium sands of different compositions. Quartz is dominant across the sample and grain size ranges from fine to medium, roundness is angular to subangular. The frequency of feldspar minerals is frequent and mica minerals are few. Feldspar and mica exhibit subangular rounding. Sample 11 contains a frequency of very few, medium sized, subrounded compound mineral grains. Organic matter (e.g., unidentified plant remains) is very few and no distinguishable bone or charcoal was observed during thin section analysis. See Appendix B; **Figures B-057 – B-059.**

Sample 12 (372 U3 SOSG)

Sample 12 was collected from waypoint 372, in paleochannel 3 from the thin sandy layer between the eolian surface cover and the gravel deposits in Unit 3. This sample contains moderately well sorted, very fine to fine sands. Quartz is common across the sample. Grains are angular to subangular and range in grain size from very fine to fine. The frequency of feldspar and mica minerals is few, with both minerals exhibiting subangular rounding and very fine to fine grain size. Very few compound mineral grains are present in the sample. Organic matter (e.g., bone and plant matter) has a frequency of very few, and no distinguishable charcoal was observed in the sample during the thin section analysis. See Appendix B; **Figures B-060 – B-063**.

Sample 13 (469 U2 SOSG)

Sample 13 was collected from waypoint 469, along the main channel from the overbank deposits in Unit 2. This sample was collected from the thin sandy layer between the eolian surface cover and the gravel deposits. Sample 13 contains moderately sorted, very fine to fine sand of different compositions. The quartz is subangular, ranges from very fine to fine in size, and is common across the sample. The frequency of feldspar minerals is frequent, grains are also subangular, and grain size ranges from very fine to fine. The mica minerals are few in frequency, mostly very fine in size, and subangular. The frequency of organic matter across the sample is very few, but includes fragments of bone, charcoal, and plant remains. See Appendix B; **Figures B-064 – B-067b**.

Sample 14 (524 SOSG)

Sample 14 was collected from waypoint 523, near the main channel from the thin sandy layer between the eolian surface cover and the gravel deposits. This sample contains moderately sorted, very fine to medium sands. Subangular quartz grains are common across the sample, with grains ranging in size; most grains are fine in size, but some medium grains are present. Feldspar minerals are few in frequency, and grain sizes are mainly fine and subangular. Mica is frequent and grain sizes range from very fine to fine, subangular grains. The frequency of compound mineral grains is very few and grains are subrounded, and medium in size. Organic matter is present; very few unidentified plant remains and no distinguishable bone or charcoal was observed during thin section analysis. See Appendix B; **Figures B-068 – B-070**.

Sample 15 (540 SOSG)

Sample 15 was collected from waypoint 540, near the main channel from the thin sandy layer between the eolian surface cover and the gravel deposits. This sample contains poorly sorted, very fine to medium sand. Quartz grains are frequent across the sample and grains range in size from very fine to medium subangular grains. The frequency of feldspar and mica is very few. These mineral grains also range in size and are predominately subangular. Organic matter is present in the sample, its frequency is very few and includes charcoal and unidentified plant matter. No distinguishable bone fragments were observed during the thin section analysis. See Appendix B; **Figures B-071 – B-076**.

The results from this analysis are summarized in the following tables. **Table 3** presents the frequency of the coarse mineral components observed in the thin sections (i.e., quartz, feldspar minerals, mica minerals, and organic matter). **Table 4** presents a summary of the grain sizes observed in the thin section, degree of rounding between different mineral grains, and observed sorting. The interpretation of the samples and a discussion of site formation processes are presented in the next chapter.

Table 3. Frequency of Coarse Mineral Components Observed in Thin Section

Sample Number	Sample Name	Coarse Mineral Components						
		Quartz	Feldspar	Micas	Compound Mineral Grains and Rock Fragments	Bone	Charcoal	Plant Matter
01	375 Top EOL.	+++++	+	++		+	+	++
02	593 Top EOL.	+++	++	+		+	+	++
03	463 SURFACE EOL.	+++	+	+				+
04	478 SURFACE EOL.	++++	++	+	++			+
05	555 DUNE SAND	++++	++	++				+
06	565 DUNE SAND	+++++	+	+				+
07	566 DUNE SAND	++++	++	+	++++			+
08	571 DUNE SAND	+++++	++	+	++++			+
09	586 DUNE SAND	++++	++	++				+
10	375 U3 (LO) SOSG	++++	++	++		+	+	+
11	593 U2 SOSG	+++++	+++	++	+			+
12	372 U3 SOSG	++++	++	++		+		+
13	469 U2 SOSG	++++	+++	++		+	+	+
14	524 SOSG	++++	++	+++	+			+
15	540 SOSG	+++	+	+			+	+

Frequency refers to observable percentage on area of thin section (After Bullock et al. 1985 and Stoops, 2021)
+ = very few (<5%), ++ = few (5-15%), +++ = frequent (15-30%), ++++ = common (30-50%), +++++ = dominant (50-70%

Table 4. Overview of Grain Size, Shape, and Sorting Observed in Thin Section

Sample Number	Sample Name	Size (µm)	Roundness	Sorting
01	375 Top EOL	very fine to fine sand	subangular – subrounded (qtz), subrounded (fs, mic)	well sorted sand of dif. compositions
02	593 Top EOL.	very fine to coarse sand	subangular (qtz), subrounded (fs, mic)	poorly sorted
03	463 SURFACE EOL.	fine to medium sand	subangular (qtz, fs, mic)	poorly sorted
04	478 SURFACE EOL.	very fine to coarse sand	subangular – subrounded (qtz), subangular (fs, mic), subrounded (CMG)	poorly sorted
05	555 DUNE SAND	very fine to fine sand	subangular (qtz), subrounded (fs, mic)	moderately well sorted
06	565 DUNE SAND	fine to medium sand	subangular – subrounded (qtz), subrounded (fs, mic)	moderately sorted
07	566 DUNE SAND	fine to medium sand	subangular – subrounded (qtz), subrounded (fs, mic), subrounded to rounded (CMG)	moderately sorted
08	571 DUNE SAND	fine to coarse sand	subrounded – rounded (qtz), subrounded (fs, mic, CMG)	poorly sorted
09	586 DUNE SAND	very fine to medium sand	subangular – subrounded (qtz); subrounded (fs, mic)	moderately sorted
10	375 U3 (LO) SOSG	very fine to fine sand	subangular – subrounded (qtz, fs), subangular (mic)	moderately sorted
11	593 U2 SOSG	fine to medium sand	angular – subangular (qtz), subangular (fs, mic), subrounded (CMG)	well sorted sand of dif. compositions
12	372 U3 SOSG	very fine to fine sand	angular – subangular (qtz), subangular (fs, mic)	moderately well sorted
13	469 U2 SOSG	very fine to fine sand	subangular (qtz, fs, mic)	moderately sorted
14	524 SOSG	very fine to fine sand	subangular (qtz, fs, mic)	moderately sorted
15	540 SOSG	very fine to medium sand	subangular (qtz, fs, mic)	poorly sorted

Grain Size: Fine clay (< 0.2 µm), Clay (< 2 µm), Silt (2-20 µm), Very Fine Sand (20-100 µm), Fine Sand (100-200 µm), Medium Sand (200-500 µm), Coarse Sand (500-2,000 µm) (After Stoops, 2021)
Mineral Abbr.: qtz = Quartz, fs = Feldspar, mic = Mica, CMG = Compound Mineral Grains and Rock Fragments

CHAPTER 5: DISCUSSION

5.1 Introduction

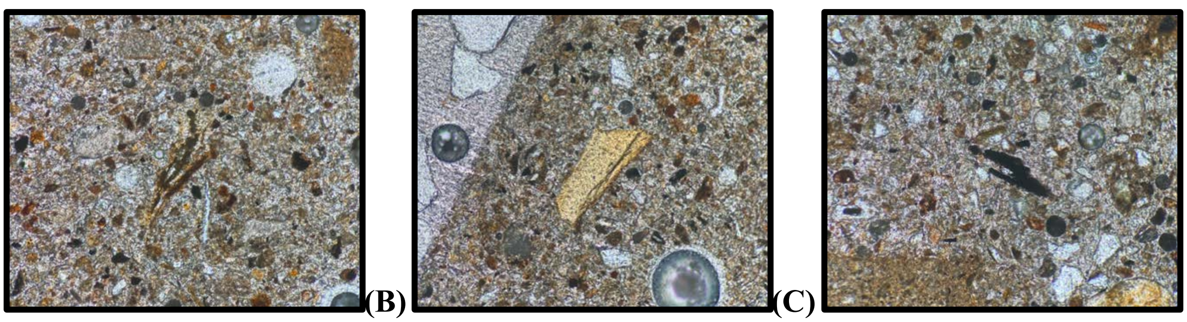
The environment is a frame of reference that needs to be considered when studying prehistoric human populations. In the Middle Río Negro Valley, prehistoric groups would have needed a vast knowledge of the environment and the ability to adapt to environmental changes. The environment is also what determines how the archaeological record is preserved. Therefore, our ability to interpret the archaeological record will depend on our knowledge of the environment and its dynamic landforms. Among these dynamic landforms are the river and dunes present in the Middle Río Negro Valley. This first part of this chapter reviews the interpretations from the micromorphological analysis (Section 5.2). Followed by a discussion in section 5.3 about the site formation processes in the valley and the expected preservation of the archaeological record in these environments.

5.2 Micromorphological Interpretations

The results of this analysis revealed that all samples consist primarily of quartz-rich sands, with feldspar and mica minerals also present, and grain size ranged in from very fine to coarse sand. The interpretations of the samples connected to their proposed depositional context is presented below.

5.2.1 Proposed Eolian Loess Mantle Deposits

Samples 01, 02, 03, and 04 were collected from four different mantle units overlying alluvial gravels in the eastern segment of the study region (**Figure 22**). Samples 01 and 04 were collected from paleochannel 2 and samples 02 and 03 were collected near the modern Río Negro channel. Grain sizes ranged from very fine to coarse sand across the samples, and grain sizes were poorly sorted in samples 02-04. Sample 01 contained very fine to fine, well sorted sand of different compositions. Grain shape is primarily subangular, but some grains exhibit a greater degree of rounding. Sample 04 contains coarse subrounded compound mineral grains and rock fragments. Each sample contains less than 5% observable plant matter, while samples 01 and 02 also contain small bone and charcoal fragments (**Figure 23**). The noticeable presence of bone and charcoal is consistent with the samples being collected from the archaeological deposits at waypoints 375 (sample 01) and 593 (sample 02).



(A) (B) (C)

Figure 23. Photomicrographs showing <5% organic matter observed in eolian mantle samples 01 and 02: (A) organic plant matter in sample 01 (Appendix B, Figure B-009, x100/PPL); (B) bone fragments observed in sample 01 from waypoint 375 (Appendix B, Figure B-013, x100/PPL); (C) charcoal fragments observed in figure 02 from waypoint 593 (Appendix B, Figure B-035, x100/PPL).

Samples 01-04 were collected from unconsolidated surface eolian loess mantle deposits overlying alluvial gravels. In some locations the distinction between the top deposits and lower deposits was clear due to the harsh erosional surface and thick top mantle (**Figure 24**); however, in some locations this distinction was not as clear, and the top unit was thin (**Figure 25**). The grain size, shape, and degree of rounding confirms that these sediments are eolian deposits, from the eolian loess mantle that was deposited during the Late Holocene.

Figure 24. Harsh erosional base between the alluvial gravels and overlying eolian unit (copyright permission, H. Luchsinger).

Figure 25. Profile of Early-Middle Holocene gravel terrace near the main channel of the Río Negro (S 39 46.529', W 65 24.558'). Dark sediment is coarse sand which is mixed with fine gravels. A very thin layer of eolian sediment (2-3 cm) preserved at the top of the profile. From Luchsinger, 2006: 62.

5.2.2 Proposed Eolian Dune Deposits

Samples 05 through 09 – five samples in total – were collected from surface dunes along the main channel spanning across the entire northwestern segment of the study region from Choele Choel to Negro Muerto (**Figure 22**). All dune samples, except sample 08, exhibited moderate grain sorting with grain sizes ranging from very fine to medium sand (**Figure 26**). Sample 08 was poorly sorted and contained grain sizes ranging from fine to coarse. The degree of rounding observed in the eolian dune samples is subrounded. The quartz grains ranged from subangular to subrounded and in most samples – in sample 08 quartz was subrounded to rounded – while the feldspar and mica minerals are all subrounded. Compound mineral grains are present in samples 07/08 and range from subrounded to rounded. Each sample contained less than 5% plant matter and no identifiable bone or charcoal was observed during the thin section analysis.

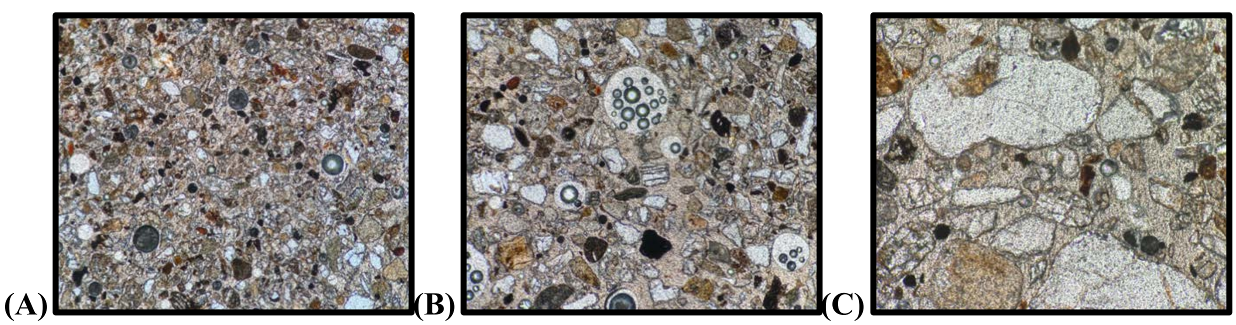


Figure 26. Eolian dune thin section photomicrographs. (A) Sample 05 exhibits moderately well sorting, and grain sizes range from very fine to fine sand (Appendix B, **Figure B-059**, x50/PPL); (B) Sample 06 contains fine to medium grain sizes and exhibits moderate sorting (Appendix B, **Figure B-064**, x50/PPL); (C) Sample 08 is poorly sorting with grain sizes ranging from fine to coarse sand (Appendix B, **Figure B-070**, x50/PPL).

Samples 05-09 were collected from unconsolidated surface dune deposits. The grain size, shape, and degree of rounding confirms that these sediments are eolian dune deposits. Based on the morphological characteristics observed in the thin sections, the dunes sediments are likely to originate from the alluvial channel sediments. A meandering fluvial system typically records a fining upward sequence, with larger grain size deposits at the base and grain sizes gradually decreasing in size at the top. The finer sediments typically belong to point bar or overbank (i.e., flood) deposits. In the Middle Río Negro Valley, there is a harsh erosional base between the alluvial gravels and the overlying unit (**Figure 24**). The finer grains from the point bars are carried into suspension by the wind to form the dunes, where they are reworked and become more rounded in shape.

The more angularity a grain exhibits, the closer it is to its source; therefore, it is likely that the eolian dunes, located in the northwest Middle Río Negro Valley, originated from the eastern segment of the study region where the paleochannels are located. The dune sediments would have been eroded from the paleochannels. This would also explain why there is such a harsh contrast between the eolian mantle and the underlying alluvial deposits.

5.2.3 Proposed Alluvial Floodplain Deposits

In only a few sample locations, a fine layer of sandy deposits was found between the alluvial gravel deposits and overlying mantle deposits (**Figure 27**). The final six samples, samples 10 through 15, were collected from these deposits along the main channel spanning across the entire northwestern segment of the study region from Choele Choel to Negro Muerto (**Figure 22**). Grains from these samples are mainly very fine to medium sand and exhibit moderate sorting (**Figure 28**). The degree of rounding among these samples ranged from angular to subrounded, with most samples being subangular. Each sample contained less than 5% plant matter. Samples 10, 12, and 13 contained identifiable bone fragments and samples 10, 13, and 15 contained identifiable charcoal fragments. The presence of identifiable bone and charcoal in samples 10 and 13 is consistent with the samples being collected from the known archaeological deposits at waypoints 375 and 469. The grain size, shape, and degree of rounding confirms these sediments of an alluvial origin. They are likely the overbank or point bar sediments that have not been eroded away between the eolian mantle and the underlying alluvial gravel deposits.

(A)  (B) 

Figure 27. (A) Location 2 (S40°01.211', W64°34.486) where fluvial sand was found preserved overlying sandy gravel deposit and (B) sandy gravel unit at base of profile (Unit 1). From Luchsinger, 2006: 66.

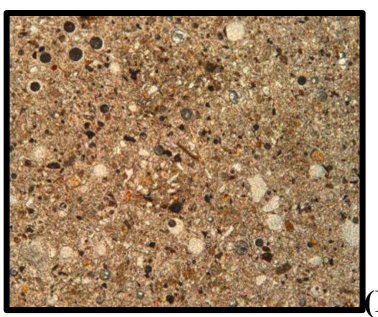
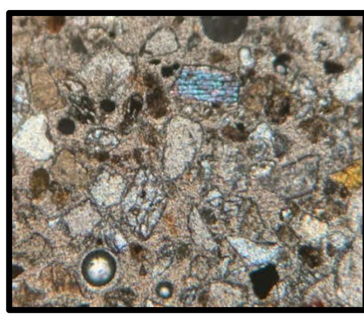
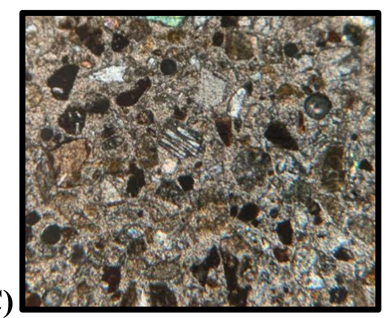
(A)  (B)  (C) 

Figure 28. Photomicrographs of thin section samples exhibiting increased angularity and moderate sorting. (A) Subangular to subrounded, high frequency of very fine sand grains observed in sample 10, from waypoint 375 (Appendix B, Figure B-084, x40/PPL); (B) Angular, subangular, and subrounded, high frequency of medium sand observed in sample 11, from waypoint 593 (Appendix B, Figure B-088, x40/PPL); (C) Angular to subangular, high frequency of fine sand grains observed in sample 12 (Appendix B, Figure B-092, x40/PPL).

5.5 Site Formation Processes and Preservation in the Middle Río Negro Valley

Luchsinger (2006) came to four conclusions regarding archaeological site preservation in the Middle Río Negro Valley. This includes the proposed two-phase occupation of the abandoned avulsion channels (*Section 2.3*), the preservation potential of Late Holocene sites in the alluvial and eolian deposits is excellent, and for the Late Pleistocene through Middle Holocene, the preservation of the archaeological record is good, but sites are likely to be buried deeply in the alluvial terraces and eolian mantle deposits. Based on the previous archaeological research conducted in the Middle Río Negro Valley, most archaeological sites do, in fact, date to the Late Holocene but there is a lack of data to support the presence of Late Pleistocene archaeological sites. In surrounding regions, there is a clear presence of older Late Pleistocene through Middle Holocene archaeological sites but there is a gap in the Río Negro Valley. An explanation for the lack of older archaeological deposits can be explained by the site formation processes occurring in the valley. The micromorphological analysis has confirmed the originally proposed depositional context of the sediment samples and now the site formation processes related to alluvial and eolian sediments is discussed below.

The Río Negro was characterized as a braided stream during the Late Pleistocene, and it shifted to a meandering-anastomosing stream by the Middle Holocene. The alluvial floodplains are the result of the erosional and depositional processes of these stream systems. The Late Pleistocene braided stream is connected to a period of high energy flow that was caused by the deglaciation after the Last Glacial Maximum. Archaeological sites are expected to be situated on the bars and banks of the braided river system. Unfortunately, high energy flows are unlikely to the preserve archaeological sites. In a braided system sites are typically eroded by episodes of high intensity flooding where archaeological remains are swept from the surface and transported downstream into a secondary alluvial setting. These artifacts can still provide valuable data, but their context is lost.

By the Middle Holocene, the Río Negro shifted from a braided to a meandering-anastomosing stream system. The site formation processes in a meandering-anastomosing and braided stream system are similar. They are also highly dynamic river environments; however, archaeological sites are more likely to be preserved through the lateral (e.g., channel deposits) and vertical accretion (e.g., floodplain deposits) of sediments. Archaeological materials found in the channel deposits (e.g., point bars) are typically out of context because they have been eroded from previously buried sites on the outside of the meander bend (i.e., the cutbank). Archaeological remains can also be resuspended by high energy channel flow and transported and deposited downstream.

Undisturbed archaeological sites found in this fluvial environment are likely to be found in floodplain sediments (i.e., upper point bars, levees, flood basins, etc.) formed from vertical accretion. After the sites are abandoned, they become buried by fine grained sediments from flooding events. The flow of these flooding events is low enough to allow the fine grains to settle and for there to be minimal site erosion from the water flow. Following these events there is a period of landscape stability and possible formation of paleosols, such as the Rafael Paleosol discussed in *Section 2.2.* Although these archaeological sites can remain intact, they also risk being destroyed by channel avulsions or high velocity overbank floods. Both of which have occurred in the Middle Río Negro Valley.

There are two types of eolian site formation processes present in the Middle Río Negro Valley, they correspond to dunes and loess deposits. Archaeological materials are commonly found buried in or beneath sand dunes. Well preserved archaeological deposits in the dunes can only occur when a site is rapidly buried after site abandonment and the dunes are stabilized by vegetation. Fluctuating climactic periods can cause this vegetation to change and dune stabilization to also change. The archaeological sites located in the dunes are likely to be deeply buried and because of the highly mobile nature of dunes and eolian blowout surfaces, the context of these sites is likely to be disturbed.

The loess mantle sediments are less dynamic than dunes and they typically provide better preservation of sites because they form a sheet-like mantle that has limited mobility once deposited. Depending on mantle thickness and distance from the river, fluvial processes might influence site preservation. Based on the radiocarbon dating by Luchsinger (2006) any archaeological sites found within the eolian mantle are likely to date to the Late Holocene. Therefore, any archaeological sites buried by the eolian mantle could potentially pre-date the Late Holocene.

In summary, the thin section analysis conducted in this thesis supports the eolian and alluvial site formation processes, which would likely lead to the preservation of archaeological sites proposed by Luchsinger (2006). The preservation potential of Late Holocene sites associated with pre- and post-avulsion is great; these sites are likely to be found in the alluvial floodplain and eolian loess mantle deposits. The preservation potential of the Late Pleistocene archaeological record is likely to be found in a secondary context due to the high flow velocity and dynamic nature of the braided river channel that likely redeposits most archaeological sites. Early and Middle Holocene sites might contain more intact archaeological deposits if they are within the alluvial floodplain sediments, or deeply buried by the eolian dunes.

CHAPTER 6: CONCLUSION

6.1 General Conclusion

In this thesis the results of a micromorphological analysis of sediments from landforms in the Middle Río Negro Valley was conducted to test the interpretations of depositional sediments as either eolian (i.e., loess or dunes) or alluvial floodplain deposits, and to revisit the conclusions regarding the preservation potential of archaeological sites. This study has identified the main characteristics (e.g., mineralogy, texture, shape/rounding, sorting, and presence of organic matter) of the sediment samples observed in thin section and found that they are consistent with their previously proposed depositional contexts (e.g., eolian or alluvial). By confirming the sediments as eolian or alluvial, this study has also been able to investigate the site formation processes associated with these types of deposits to make inferences about the preservation of archaeological sites in the Middle Río Negro Valley. The conclusions from this study are as follows:

- The six samples collected from the sandy layer between the top eolian mantle and underlying alluvial gravels are consistent with the characteristics of alluvial sediments, likely deposited by the overbank floods.
- The five samples collected from the eolian dunes are consistent with the characteristics of eolian sediments that are likely to have originated from the eroded alluvial floodplain sediments in the paleochannels.
- The four samples collected from the surface and top mantle are consistent with the characteristics of eolian loess sediments. These eolian sediments are capable of traveling greater distances due to their smaller grain size, therefore, it is possible that these

sediments originate from the paleochannels outside the Middle Río Negro Valley or from the adjacent river valleys, such as the Río Colorado.

- The preservation potential of Late Holocene archaeological sites in the Middle Río Negro Valley is excellent and deposits are likely to be found in the eolian mantle and alluvial floodplain deposits on Terrace T-1.
- The preservation potential of Late Pleistocene to Middle Holocene archaeological sites in the Middle Río Negro Valley is moderate. Sites are likely to be found in the T-2 or T-3 Terraces, either deeply buried by eolian dunes or in the alluvial floodplain deposits.

6.2 Future Considerations

The Río Negro is part of a highly dynamic fluvial system. Groups of prehistoric hunter-gatherers from this region would have participated in cooperative activities in large open-air sites near the main channel of the Río Negro. They would also have relied on the abandoned paleochannels for raw lithic materials and the diversity of natural resources available at pools found in the paleochannels. The available research on Late Holocene groups in this area has increased in the last two decades, but the sample size is small. Surrounding this region there are very few Late Pleistocene sites that have been identified and the ones that have been investigated are generally located in regions with good preservation, such as rock shelters or cave sites. The lack of Late Pleistocene sites within the Middle Río Negro Valley is likely due to the geomorphology impacting the preservation of the archaeological record and limited sample size. By studying the landforms in this region, we can assess the preservation potential and probability of locating Late Pleistocene archaeological sites. Still, archaeological survey designed to locate potentially deeply buried sites is needed to confirm their presence.

For future geoarchaeological landscape studies, it is recommended that the researcher employs a more systematic sampling strategy and increased sample size to add to a broader understanding of the processes in question. In addition, when studying grain size averages and sorting, this researcher suggests employing a particle size analysis for a more statistical approach to this study that was not available at the time of this thesis. Large parts of the Río Negro Valley have yet to be systematically surveyed. This provides a unique opportunity to further research the Late Pleistocene through Early Holocene presence of prehistoric hunter-gatherer groups in this region to better understand how they interacted and adapted to a highly dynamic environment.

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APPENDIX A: Handbook for Thin Section Description

SIZE RANGE (mm)	WENTWORTH SIZE CLASS	
>256 mm	boulder	
64-256 mm	cobble	
32-64 mm	gravel	very coarse gravel
16-32 mm		coarse gravel
8-16 mm		medium gravel
4-8 mm		fine gravel
2-4 mm		very fine gravel
1-2 mm	sand	very coarse sand
0.5-1 mm		coarse sand
250-500 µm		medium sand
125-250 µm		fine sand
63-125 µm		very fine sand
3.9-63 µm	silt	
< 3.9 µm	clay	

Figure A-001. Wentworth grain size table (modified from Macphail & Goldberg, 2006, and Wentworth, 2006).

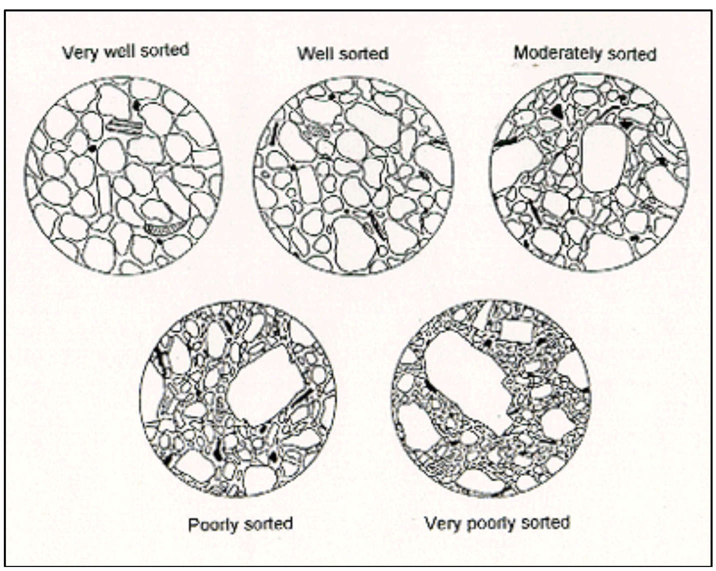

Figure A-002. Diagram showing examples of the grain sorting scale. The degree of sorting components in a thin section is an expression of the variation in particle size (Bullock et al., 1985).

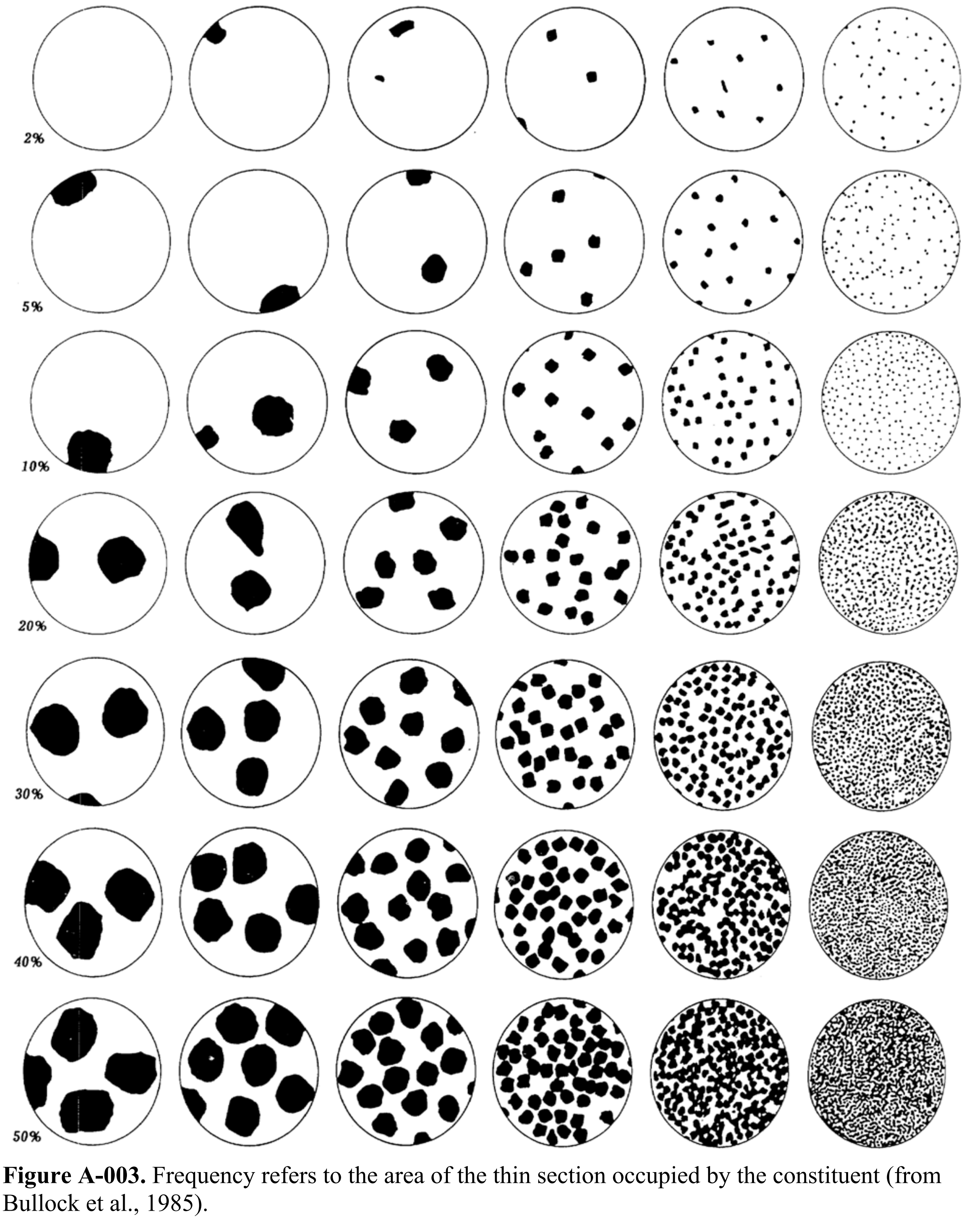

Figure A-003. Frequency refers to the area of the thin section occupied by the constituent (from Bullock et al., 1985).

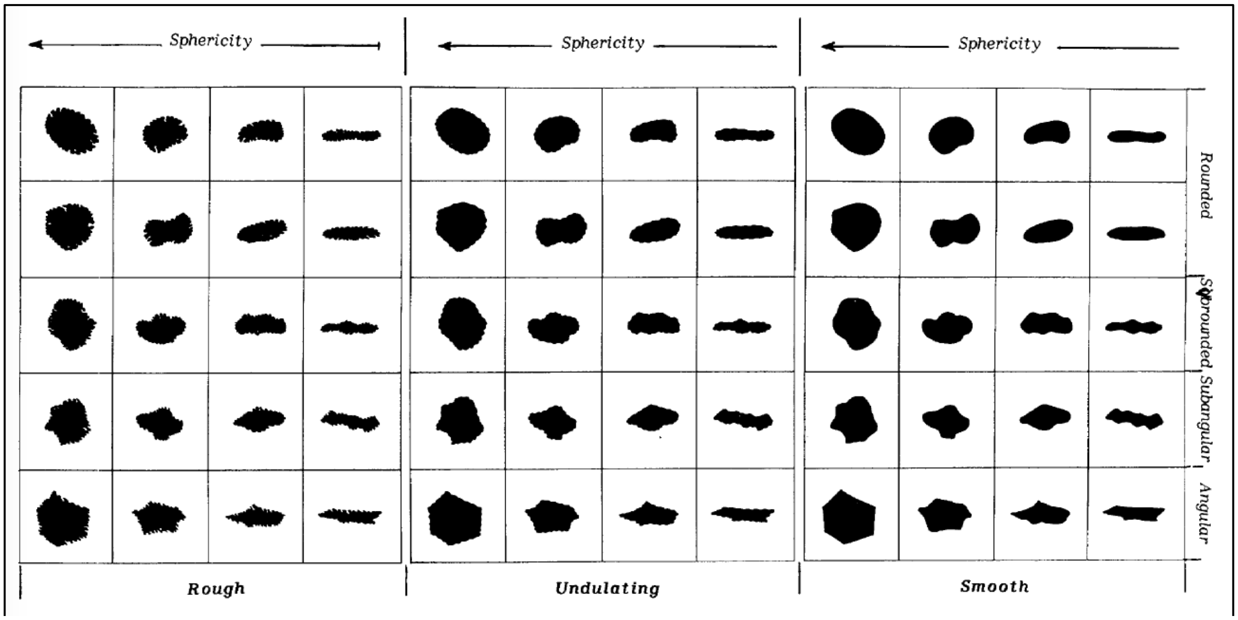

Figure A-004. Grain sphericity and roundness charts combined with roughness/smoothness grades (from Bullock et al., 1985). Roundness is defined as the relative sharpness of the particle corners (Pettijohn, 1957, as cited in Bullock et al., 1985).

APPENDIX B: Flatbed Scans and Photomicrographs of Thin Section

Figure B-001. *Sample No. 01, 375 Top EOL. Flat Bed Scan.*

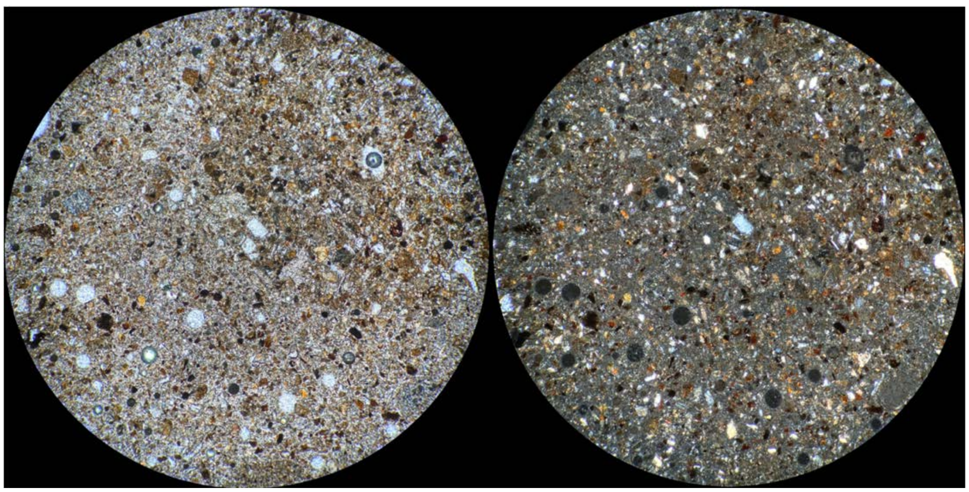

Figure B-002a. *Sample No. 01, 375 Top EOL. x50. PPL/XPL.*

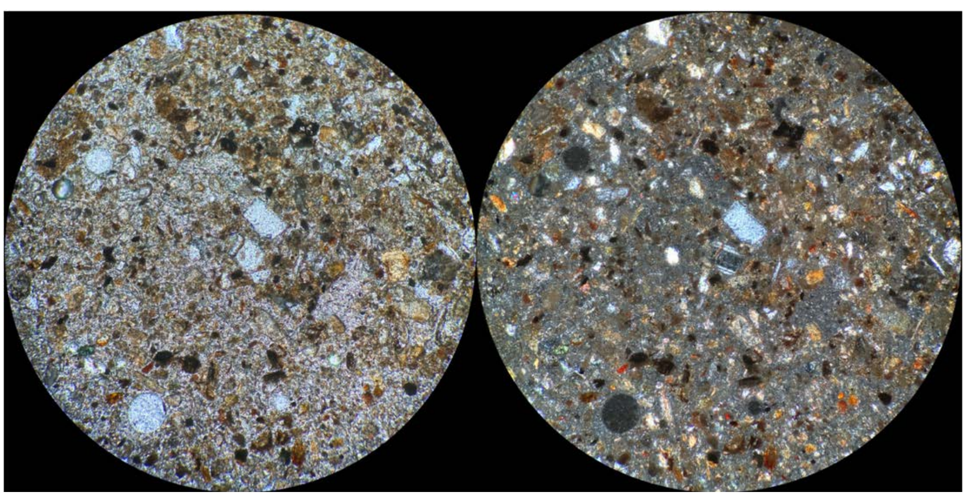

Figure B-002b. *Sample No. 01, 375 Top EOL. x100. PPL/XPL.*

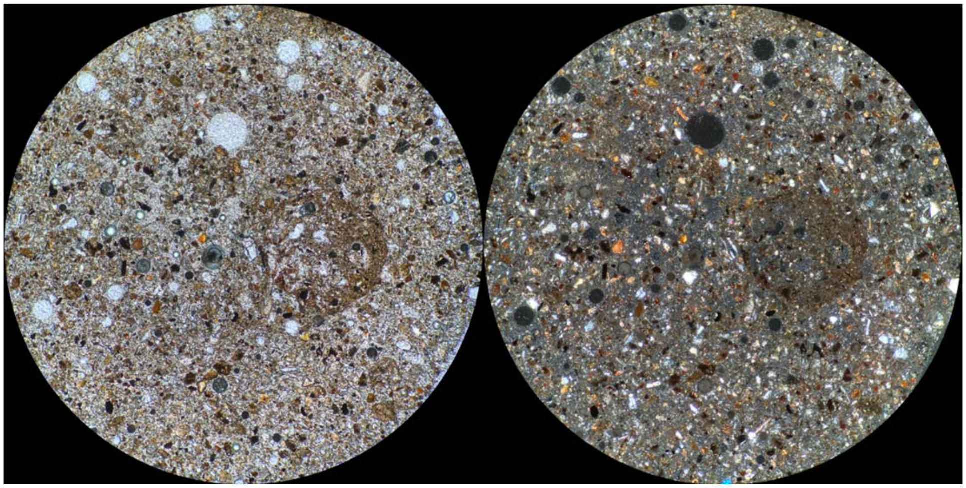

Figure B-003a. *Sample No. 01, 375 Top EOL. X50. PPL/XPL.*

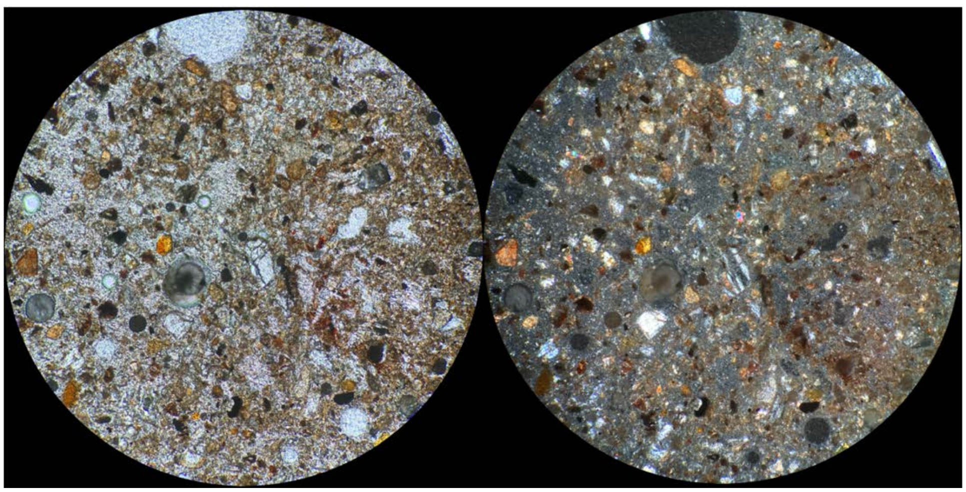

Figure B-003b. *Sample No. 01, 375 Top EOL. x100. PPL/XPL.*

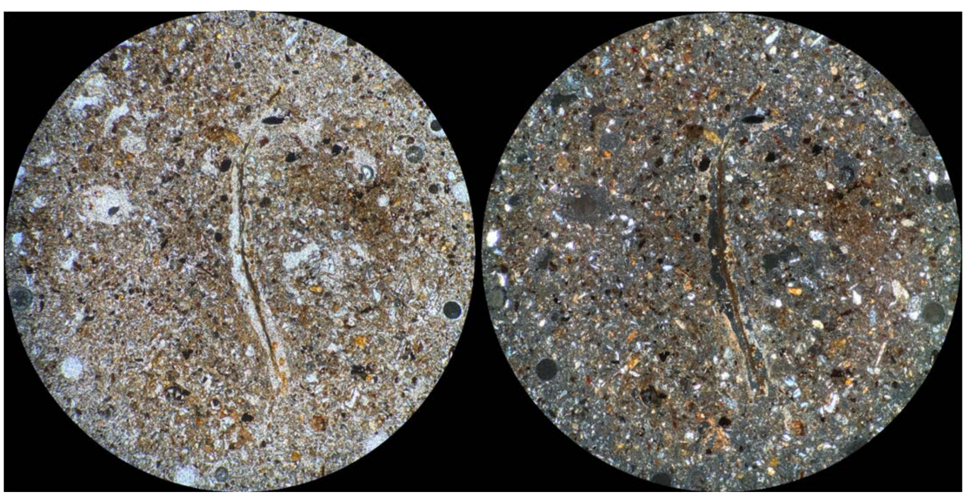

Figure B-004. *Sample No. 01, 375 Top EOL. x50. PPL/XPL.*

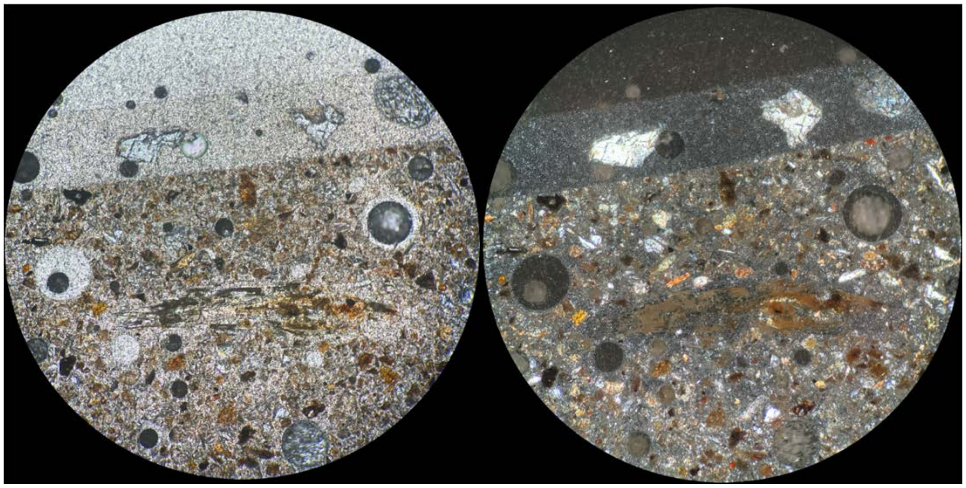

Figure B-005. *Sample No. 01, 375 Top EOL. x100. PPL/XPL.*

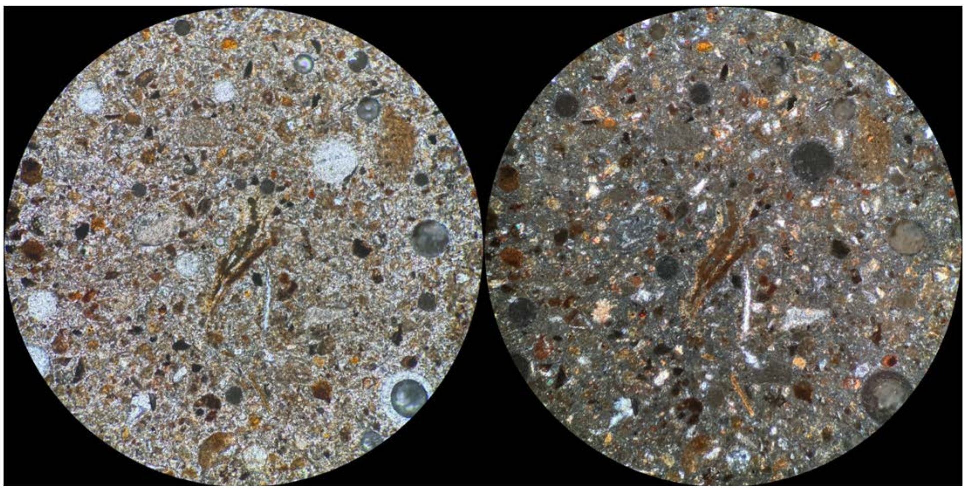

Figure B-006. *Sample No. 01, 375 Top EOL. x100. PPL/XPL.*

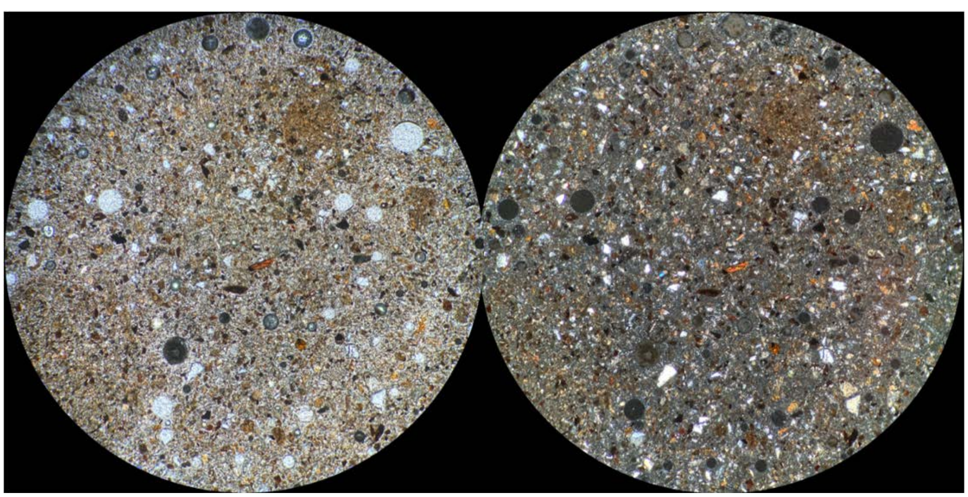

Figure B-007. *Sample No. 01, 375 Top EOL. x50. PPL/XPL.*

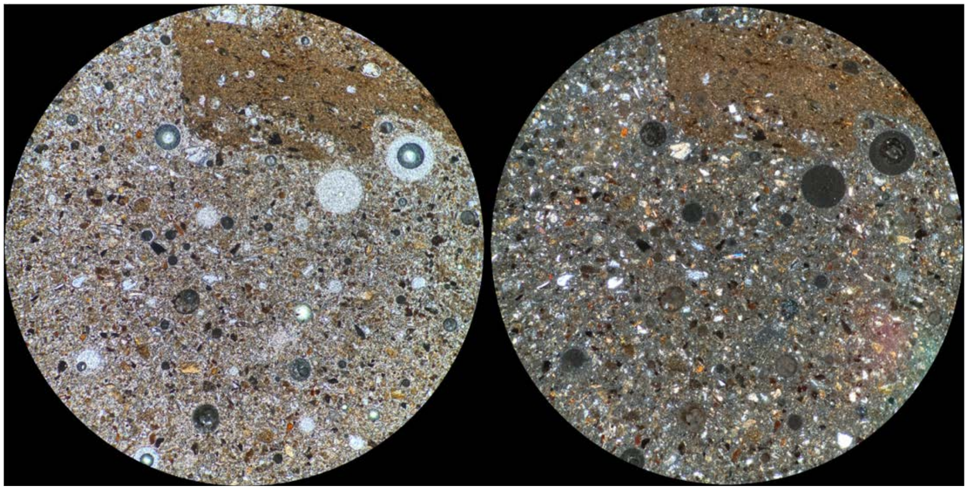

Figure B-008a. *Sample No. 01, 375 Top EOL. x50. PPL/XPL.*

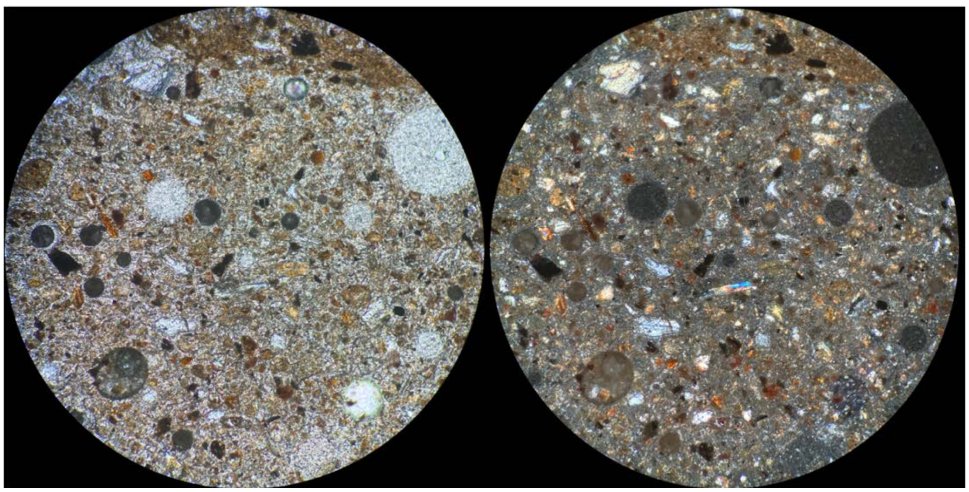

Figure B-008b. *Sample No. 01, 375 Top EOL. x100. PPL/XPL.*

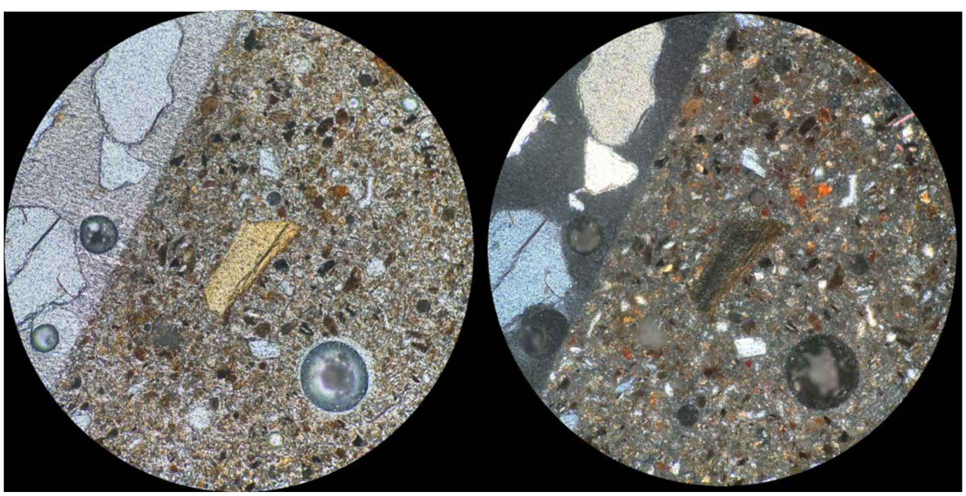

Figure B-009a. *Sample No. 01, 375 Top EOL. x100. PPL/XPL.*

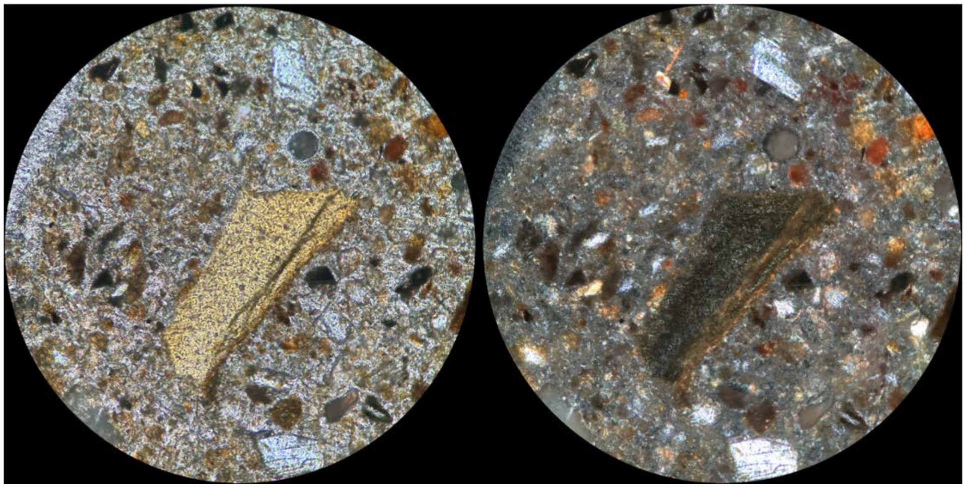

Figure B-009b. *Sample No. 01, 375 Top EOL. x200. PPL/XPL.*

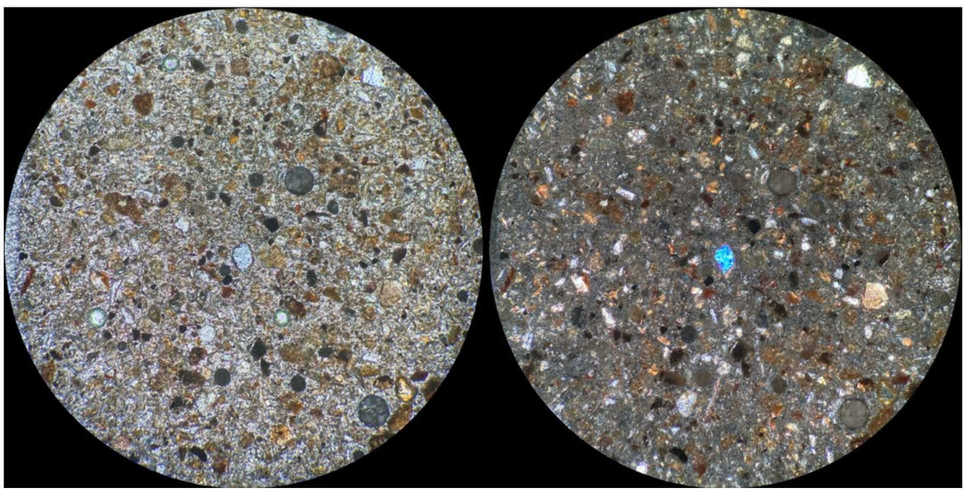

Figure B-010. *Sample No. 01, 375 Top EOL. x50. PPL/XPL.*

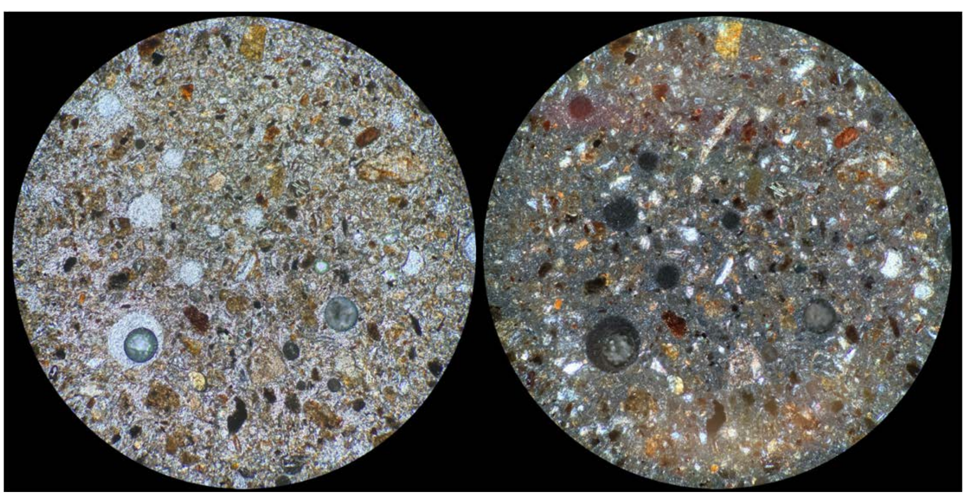

Figure B-011. *Sample No. 01, 375 Top EOL. x100. PPL/XPL.*

Figure B-012. *Sample No. 02, 593 Top EOL. Flat Bed Scan.*

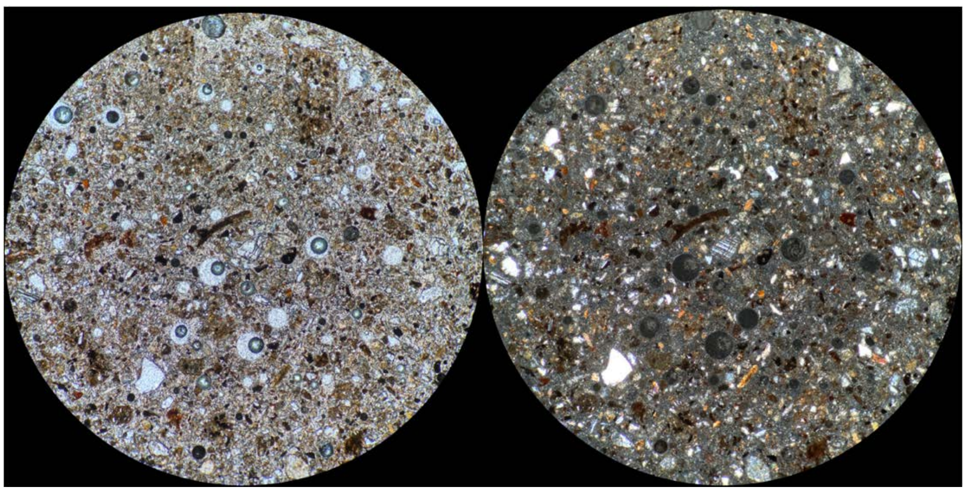

Figure B-013a. *Sample No. 02, 593 Top EOL. x50. PPL/XPL.*

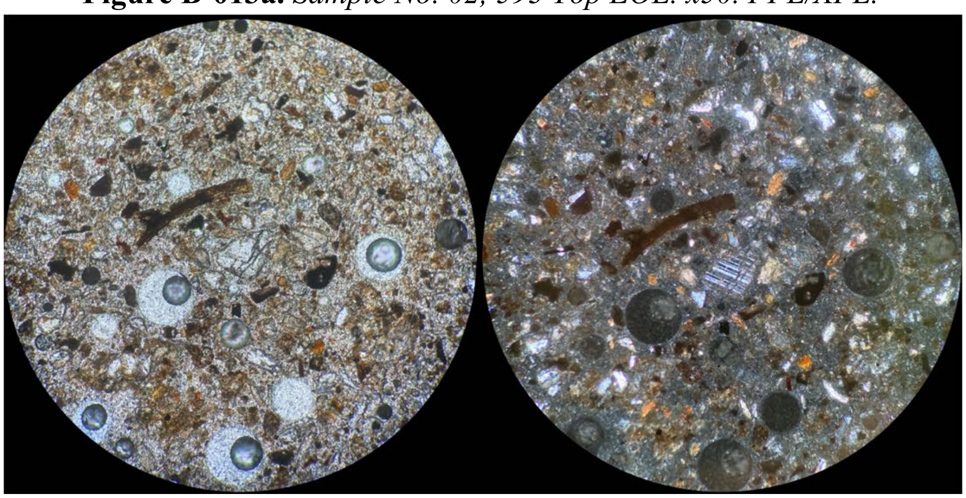

Figure B-013b. *Sample No. 02, 593 Top EOL. x100. PPL/XPL.*

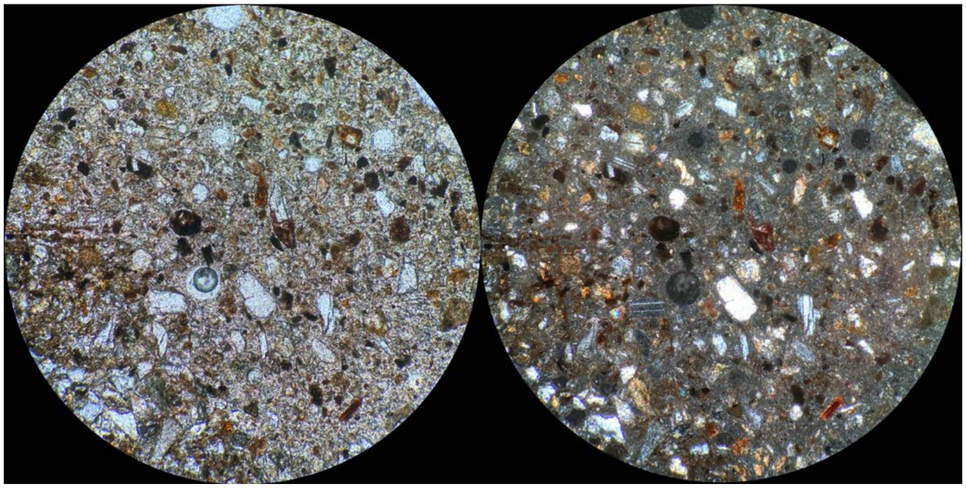

Figure B-014. *Sample No. 02, 593 Top EOL. x100. PPL/XPL.*

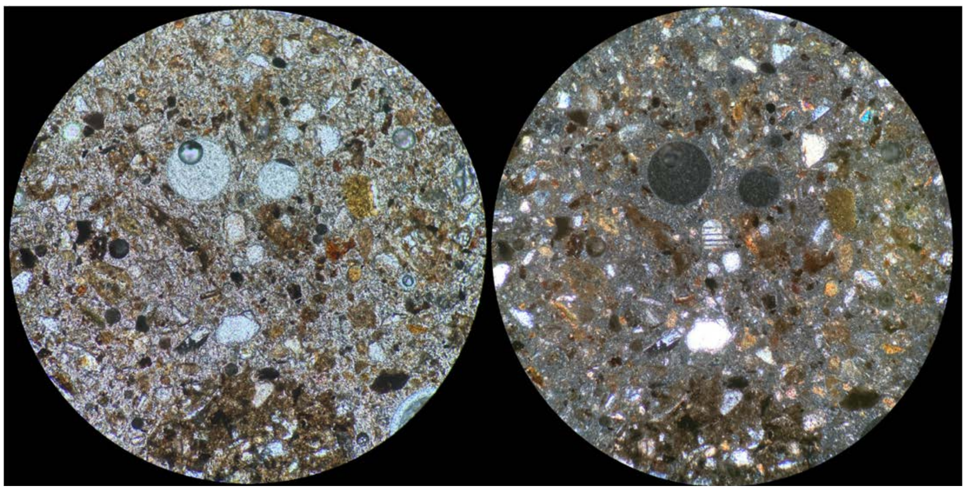

Figure B-015. *Sample No. 02, 593 Top EOL. x100. PPL/XPL.*

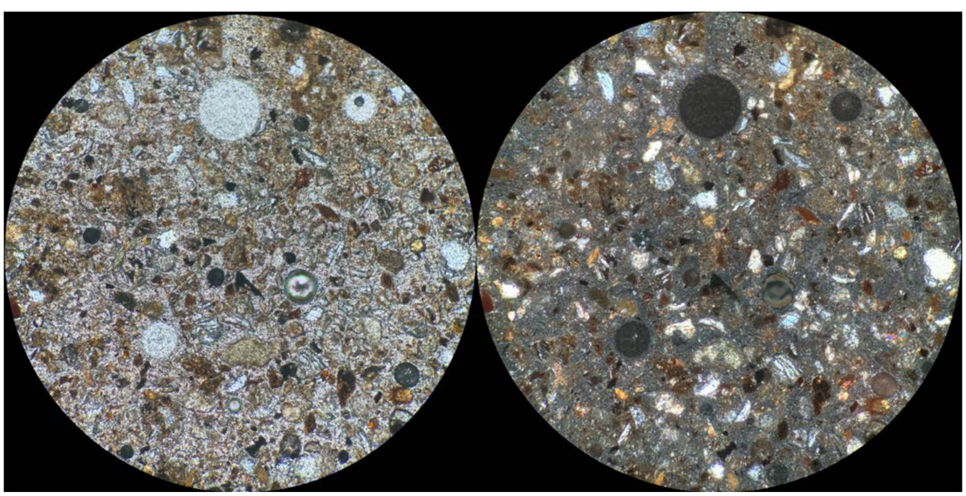

Figure B-016a. *Sample No. 02, 593 Top EOL. x100. PPL/XPL.*

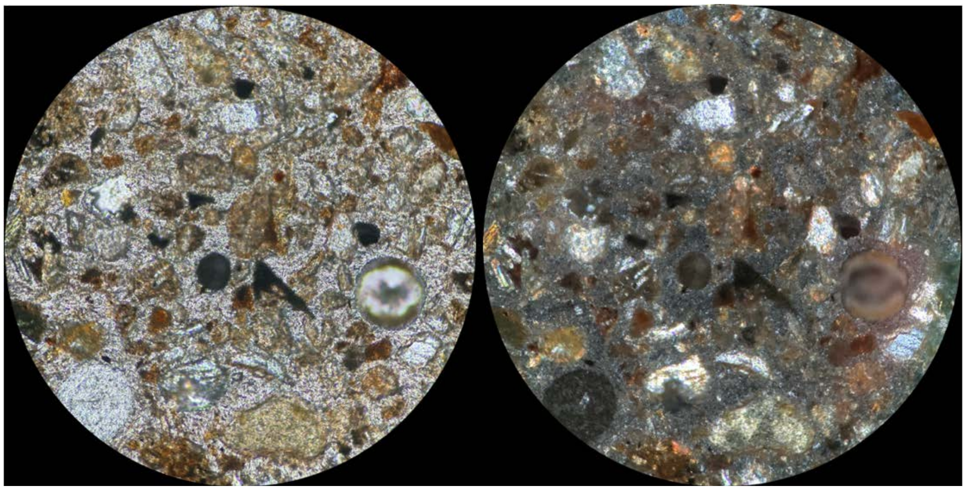

Figure B-016b. *Sample No. 02, 593 Top EOL. x200. PPL/XPL.*

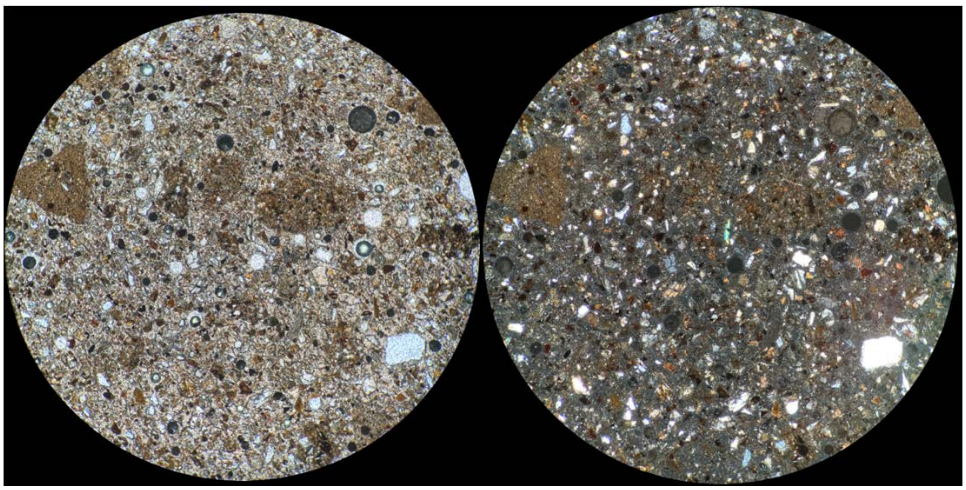

Figure B-017a. *Sample No. 02, 593 Top EOL. x50. PPL/XPL.*

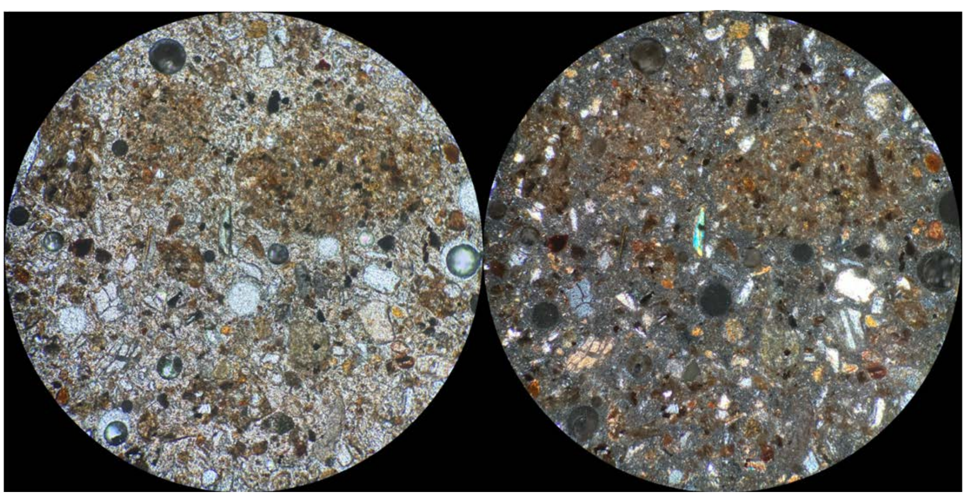

Figure B-017b. *Sample No. 02, 593 Top EOL. x100. PPL/XPL.*

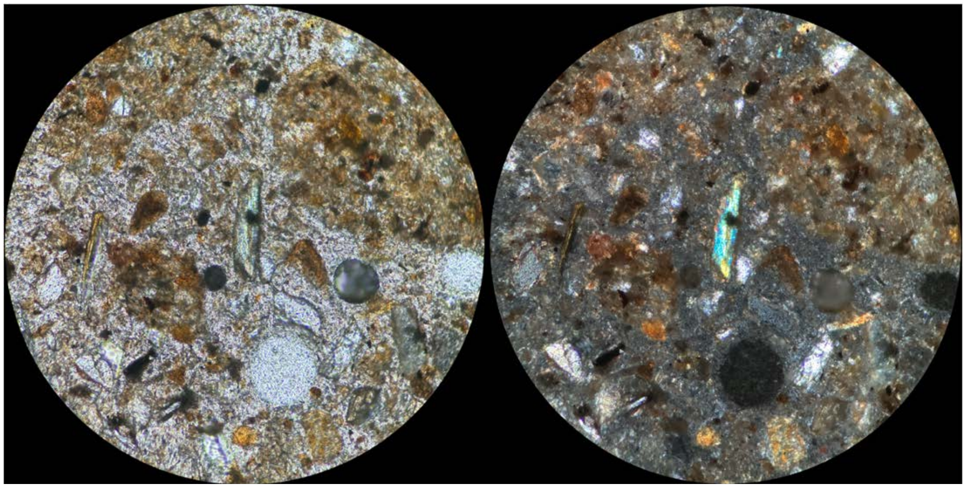

Figure B-017c. *Sample No. 02, 593 Top EOL. x200. PPL/XPL.*

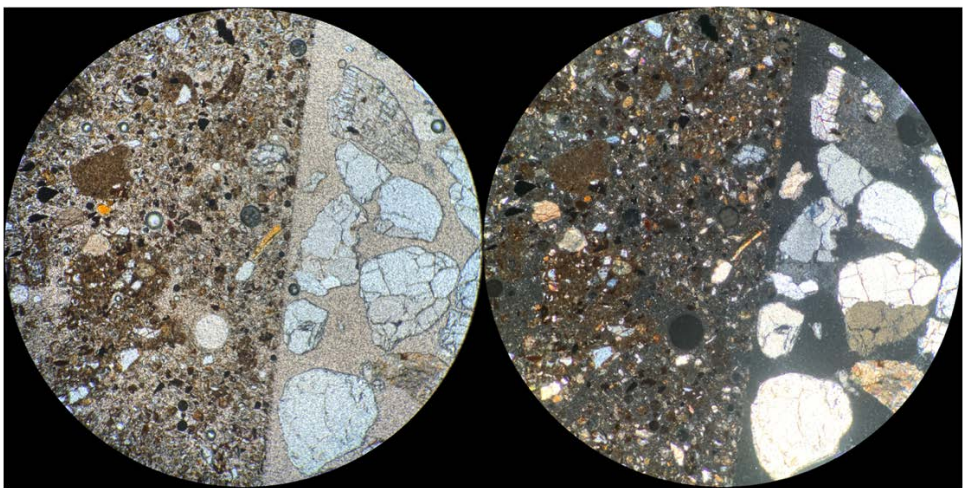

Figure B-018a. *Sample No. 02, 593 Top EOL. x50. PPL/XPL.*

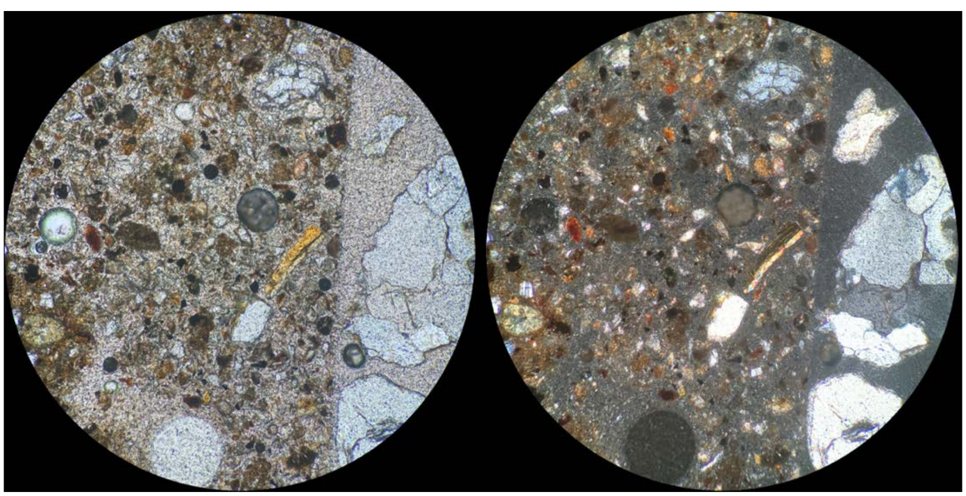

Figure B-018b. *Sample No. 02, 593 Top EOL. x100. PPL/XPL.*

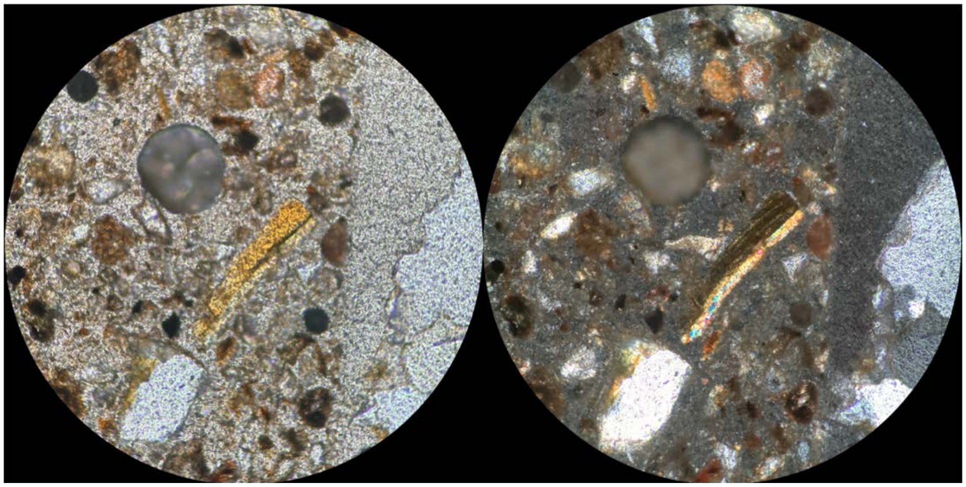

Figure B-018c. *Sample No. 02, 593 Top EOL. x200. PPL/XPL.*

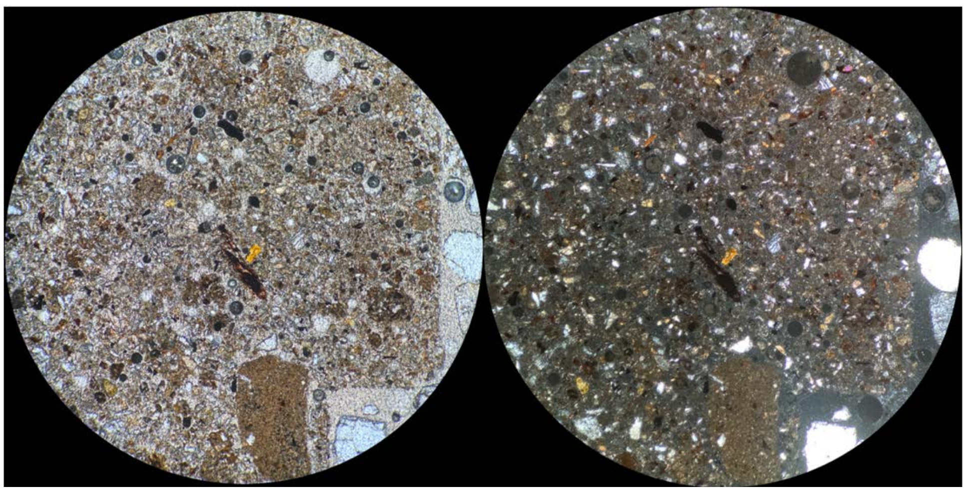

Figure B-019a. *Sample No. 02, 593 Top EOL. x50. PPL/XPL.*

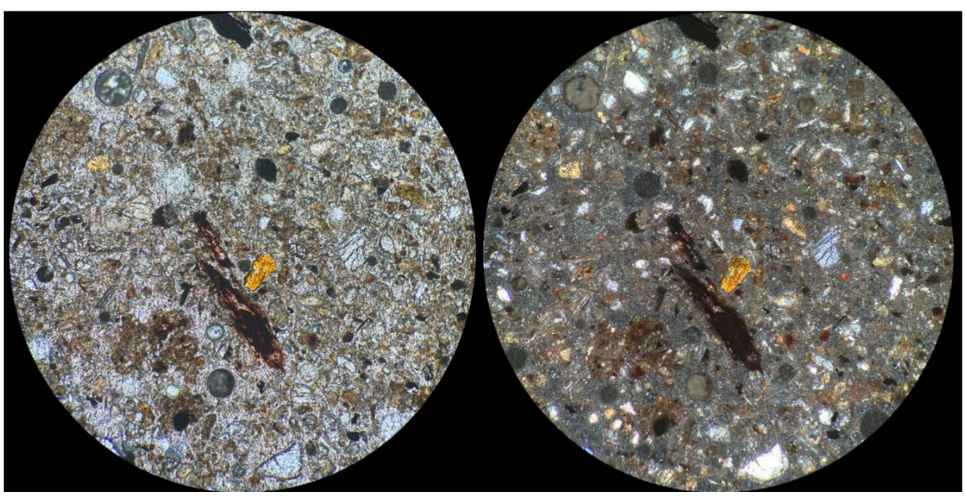

Figure B-019b. *Sample No. 02, 593 Top EOL. x100. PPL/XPL.*

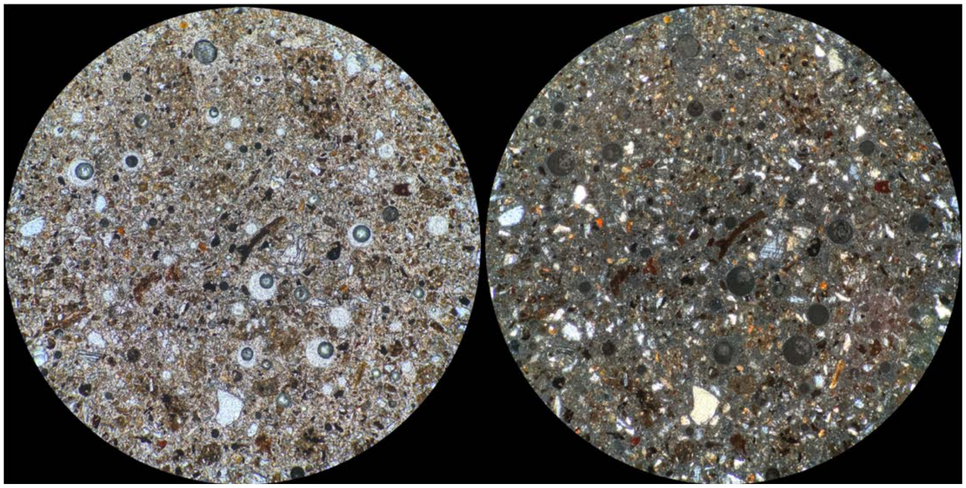

Figure B-020a. *Sample No. 02, 593 Top EOL. x50. PPL/XPL.*

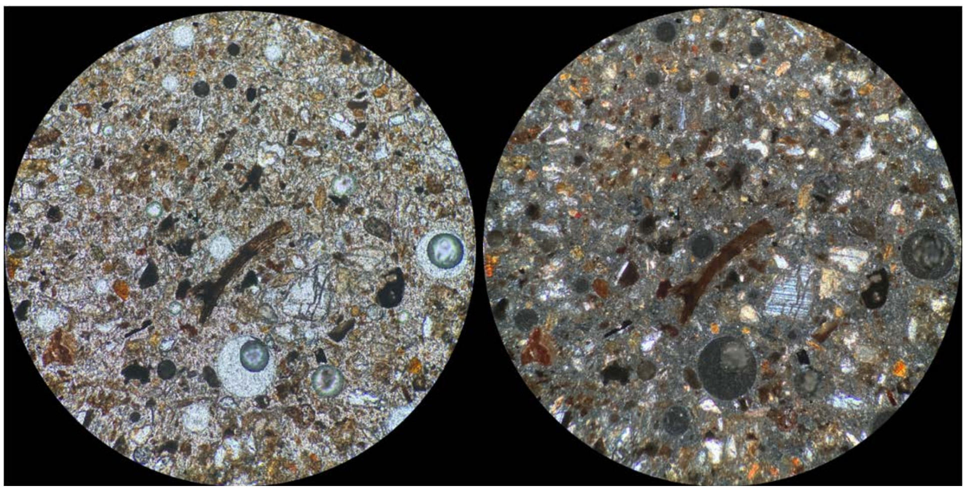

Figure B-020b. *Sample No. 02, 593 Top EOL. x100. PPL/XPL.*

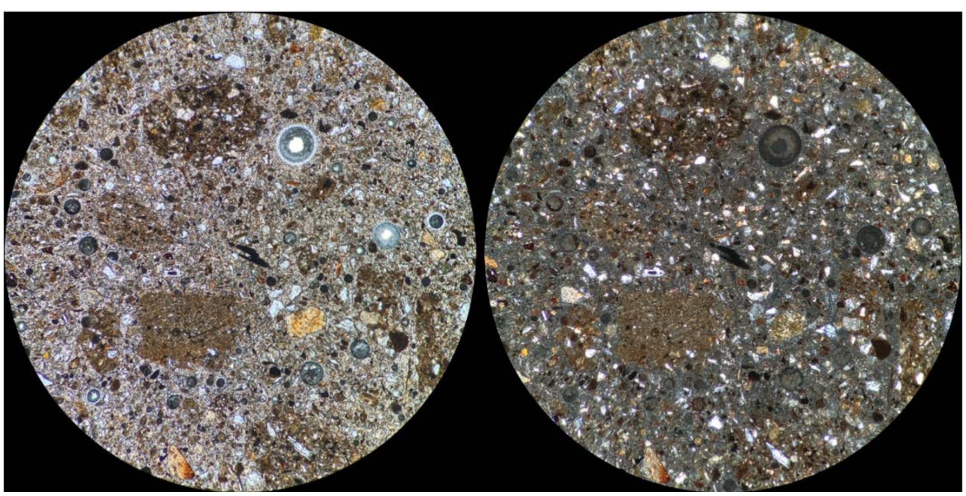

Figure B-021a. *Sample No. 02, 593 Top EOL. x50. PPL/XPL.*

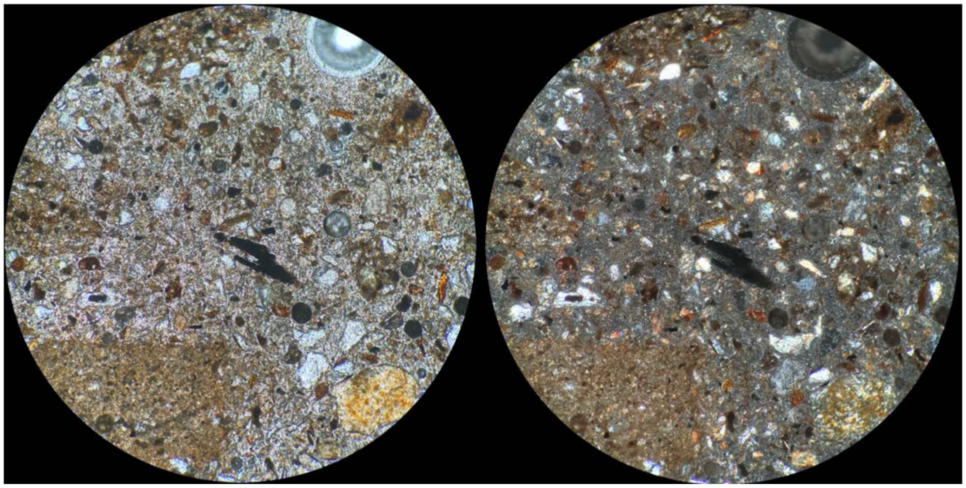

Figure B-021b. *Sample No. 02, 593 Top EOL. x100. PPL/XPL.*

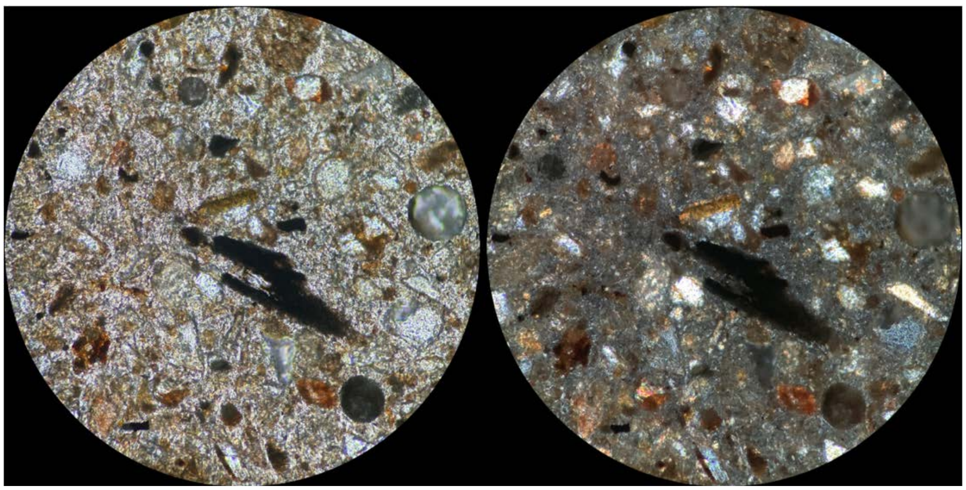

Figure B-021c. *Sample No. 02, 593 Top EOL. x200. PPL/XPL.*

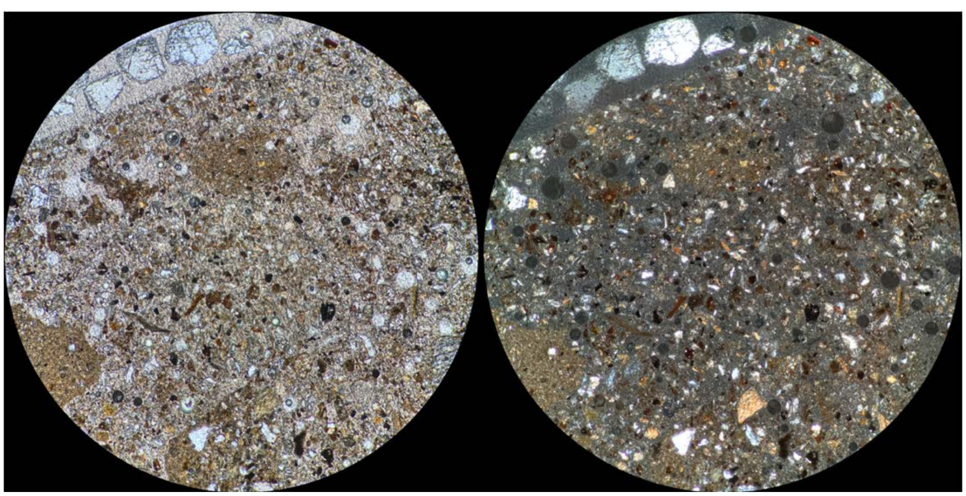

Figure B-022. *Sample No. 02, 593 Top EOL. x50. PPL/XPL.*

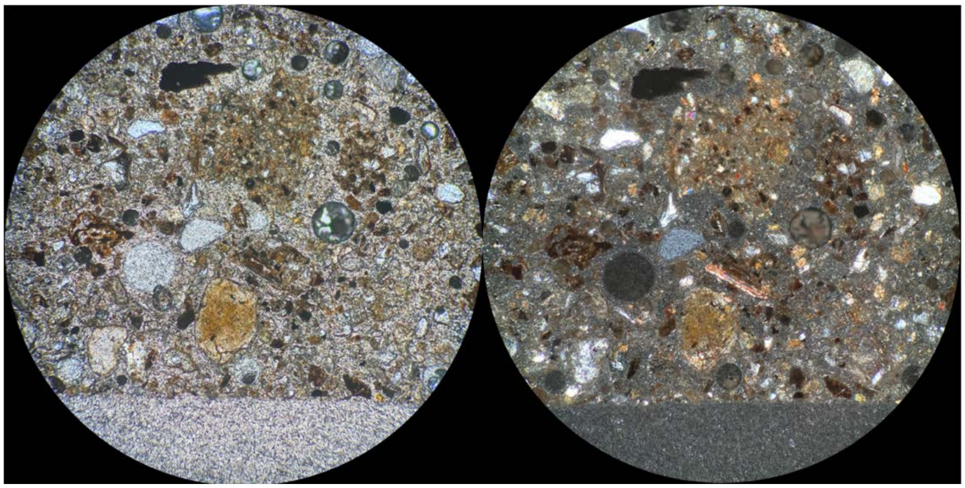

Figure B-023. *Sample No. 02, 593 Top EOL. x100. PPL/XPL.*

Figure B-024. *Sample No. 03, 463 SURFACE EOL. Flat Bed Scan.*

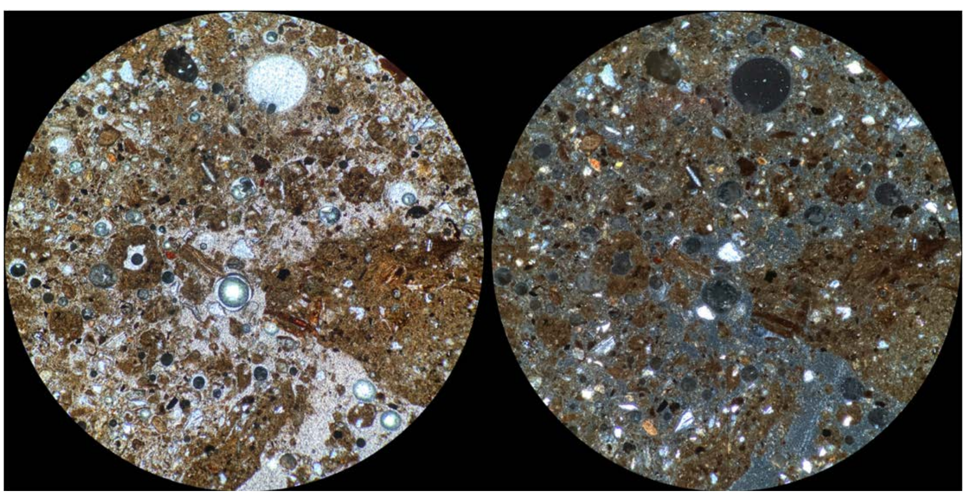

Figure B-025a. *Sample No. 03, 463 SURFACE EOL. x50. PPL/XPL.*

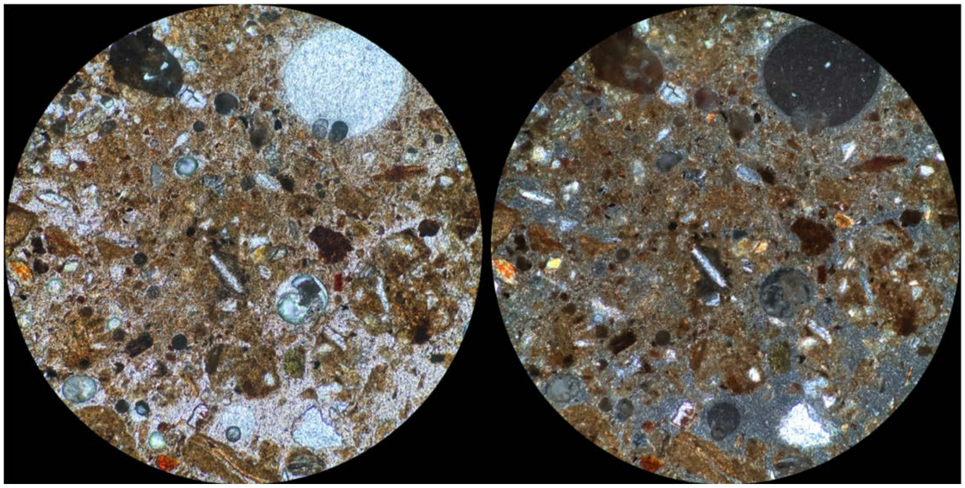

Figure B-025b. *Sample No. 03, 463 SURFACE EOL. x100. PPL/XPL.*

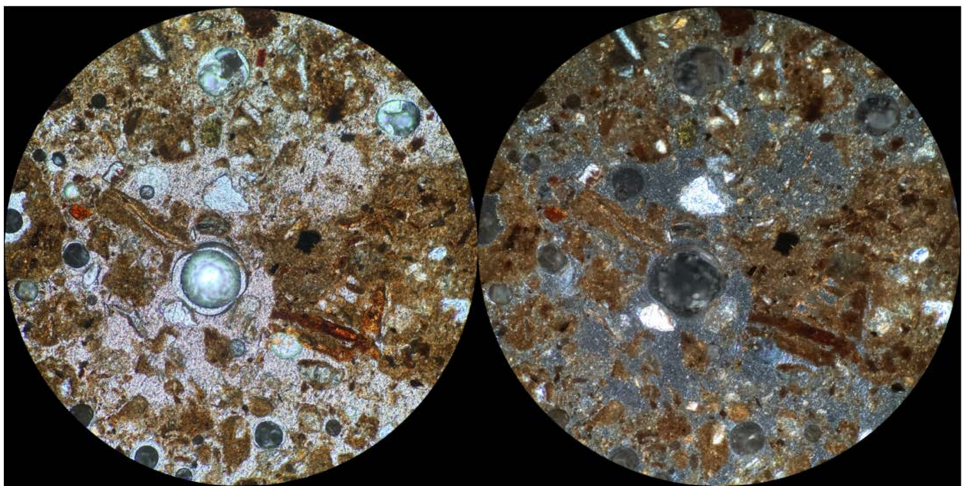

Figure B-025c. *Sample No. 03, 463 SURFACE EOL. x100. PPL/XPL.*

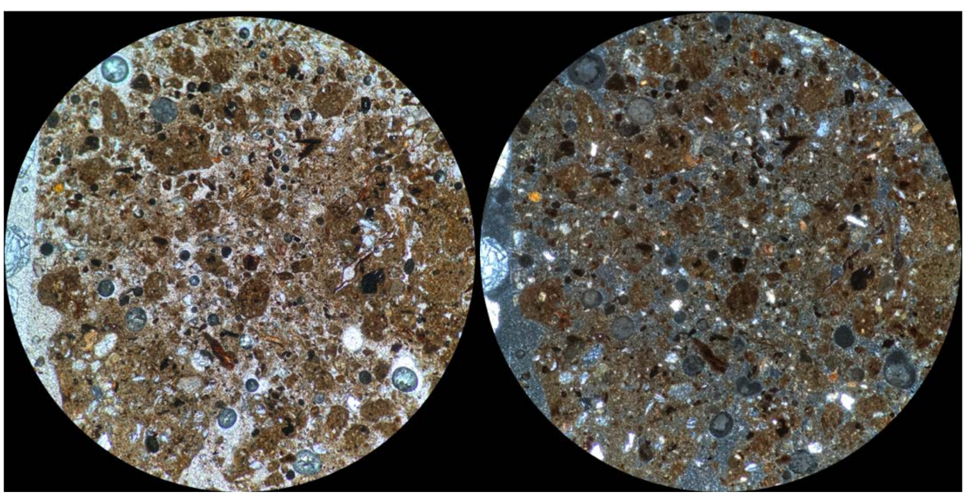

Figure B-026. *Sample No. 03, 463 SURFACE EOL. x50. PPL/XPL.*

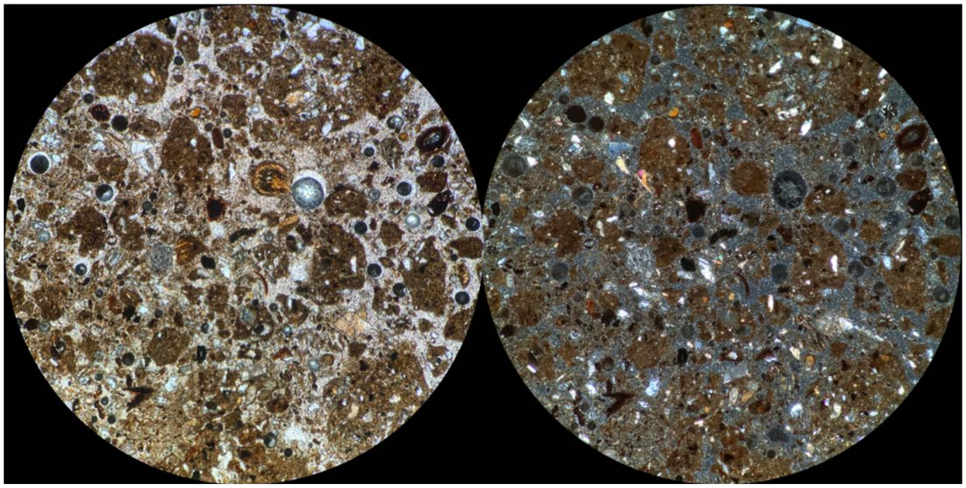

Figure B-027. *Sample No. 03, 463 SURFACE EOL. x50. PPL/XPL.*

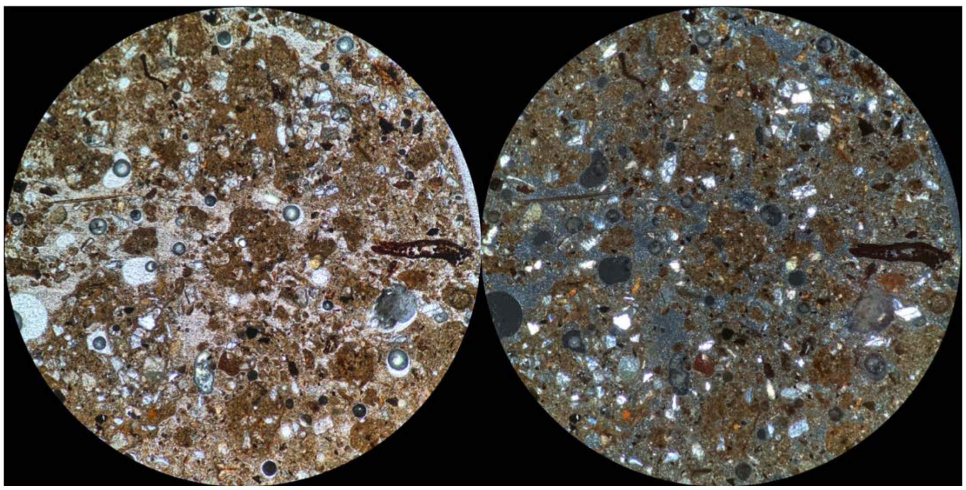

Figure B-028a. *Sample No. 03, 463 SURFACE EOL. x50. PPL/XPL.*

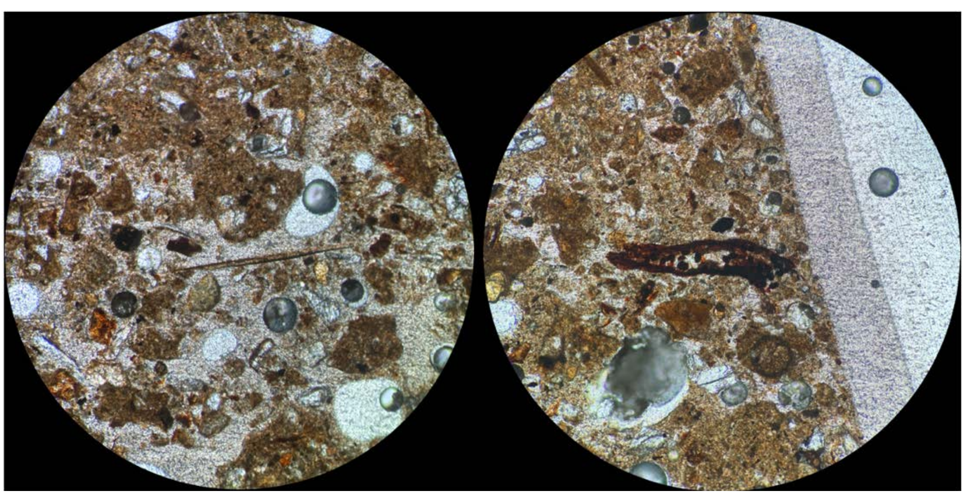

Figure B-028b. *Sample No. 03, 463 SURFACE EOL. x100. PPL.*

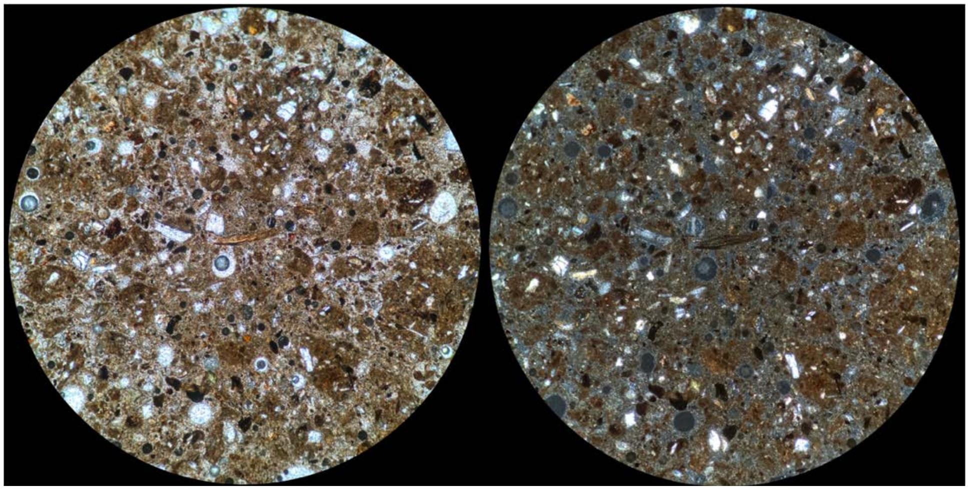

Figure B-029a. *Sample No. 03, 463 SURFACE EOL. x50. PPL/XPL.*

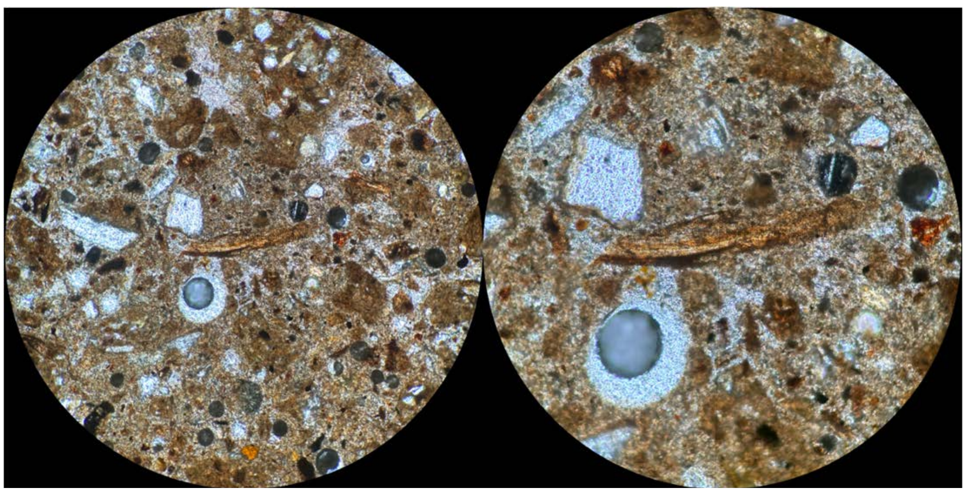

Figure B-029b. *Sample No. 03, 463 SURFACE EOL. x100/x200. PPL/XPL.*

Figure B-030. *Sample No. 04, 478 SURFACE EOL. Flat Bed Scan.*

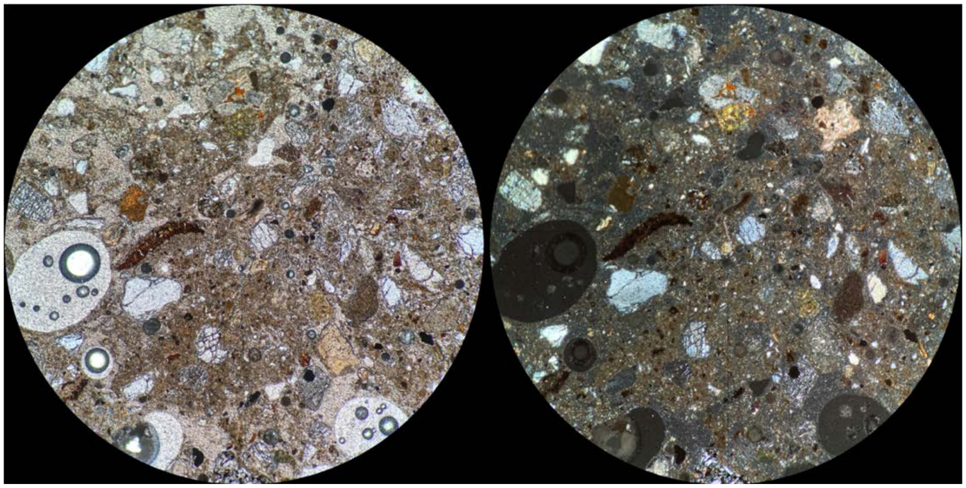

Figure B-031a. *Sample No. 04, 478 SURFACE EOL. x50. PPL/XPL.*

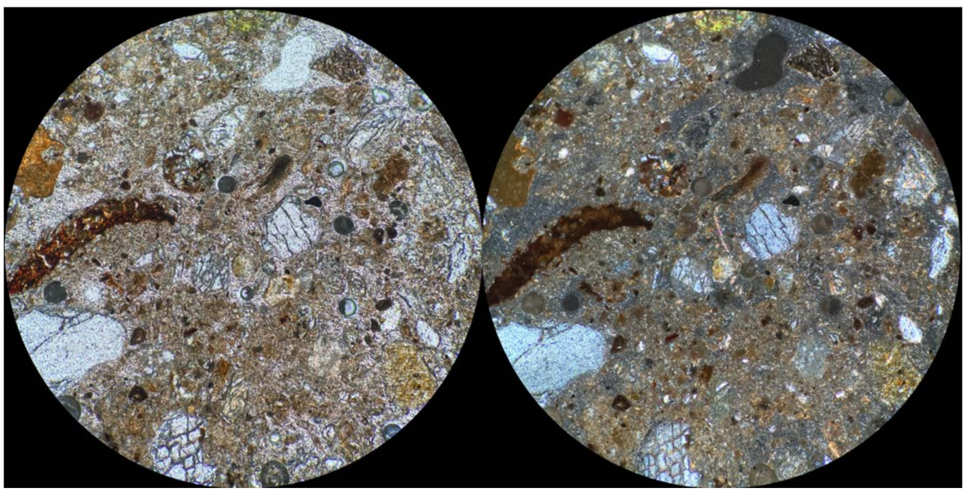

Figure B-031b. *Sample No. 04, 478 SURFACE EOL. x100. PPL/XPL.*

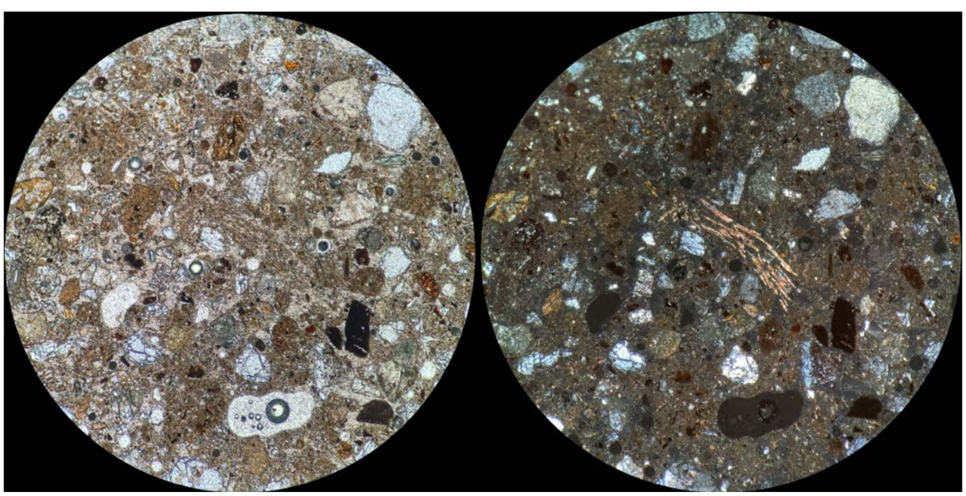

Figure B-032a. *Sample No. 04, 478 SURFACE EOL. x50. PPL/XPL.*

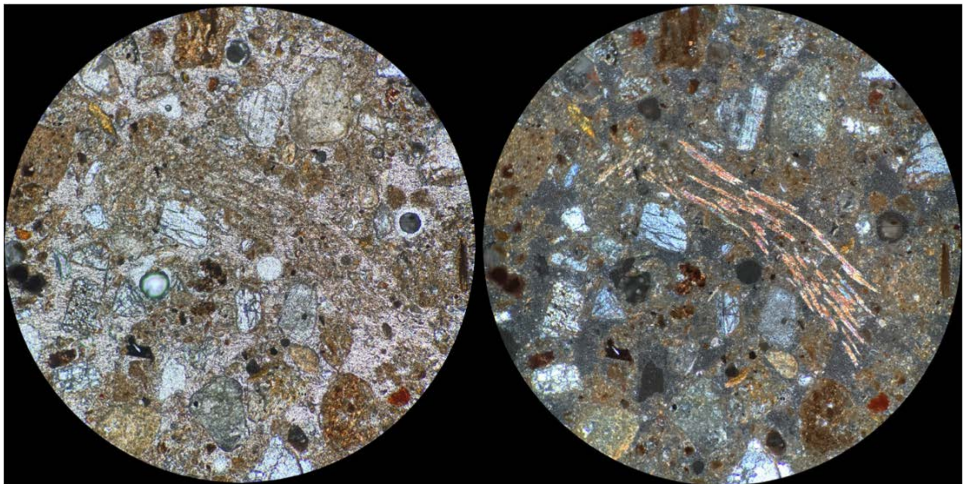

Figure B-032b. *Sample No. 04, 478 SURFACE EOL. x100. PPL/XPL.*

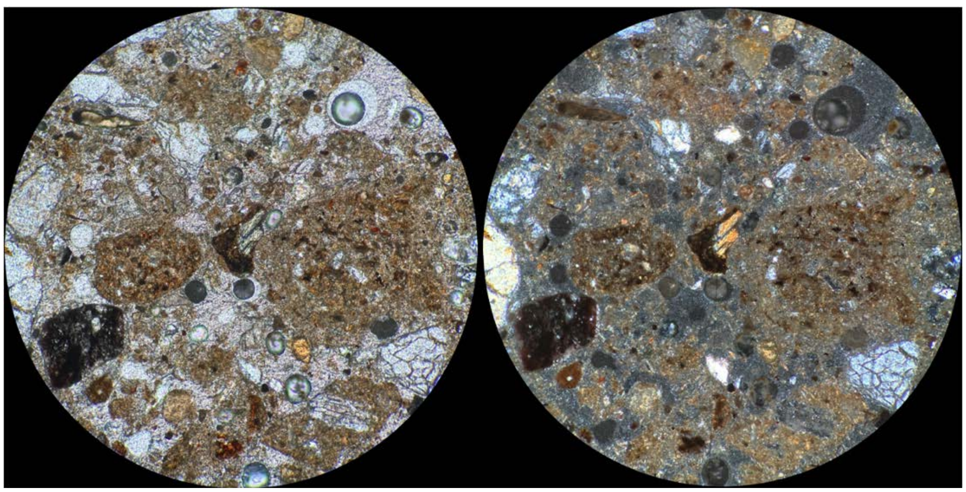

Figure B-033. *Sample No. 04, 478 SURFACE EOL. x100. PPL/XPL.*

Figure B-034. *Sample No. 05, 555 DUNE SAND. Flat Bed Scan.*

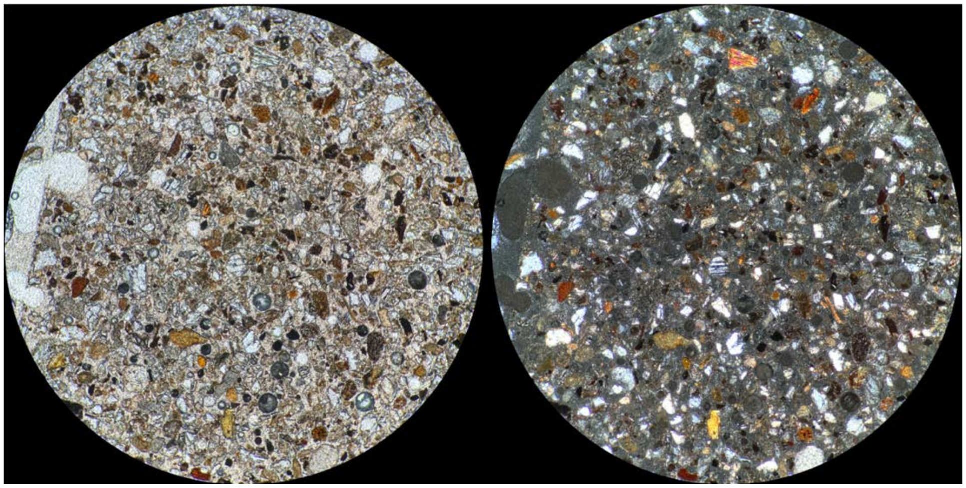

Figure B-035a. *Sample No. 05, 555 DUNE SAND. x50. PPL/XPL.*

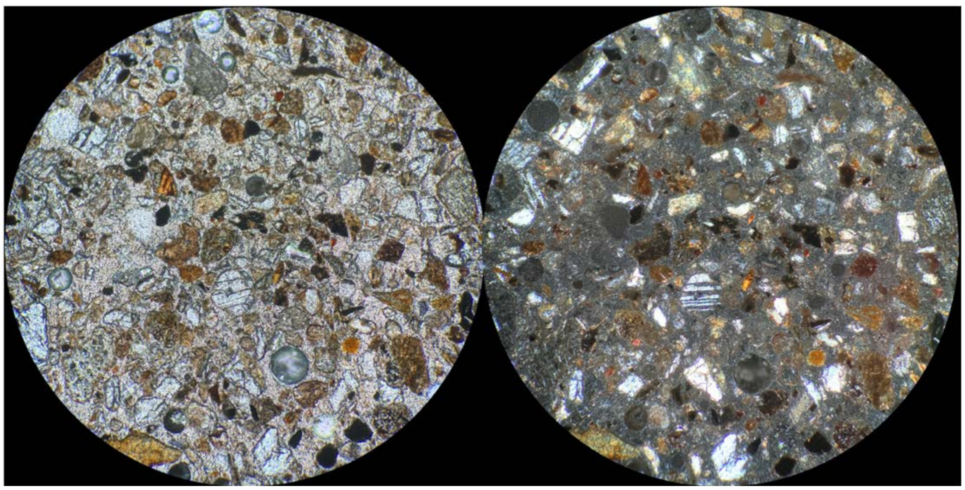

Figure B-035b. *Sample No. 05, 555 DUNE SAND. x100. PPL/XPL.*

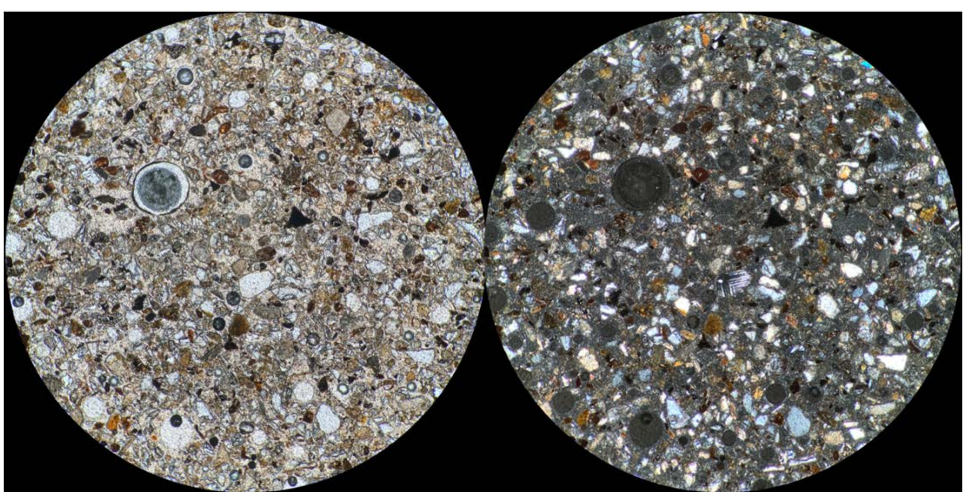

Figure B-036a. *Sample No. 05, 555 DUNE SAND. x50. PPL/XPL.*

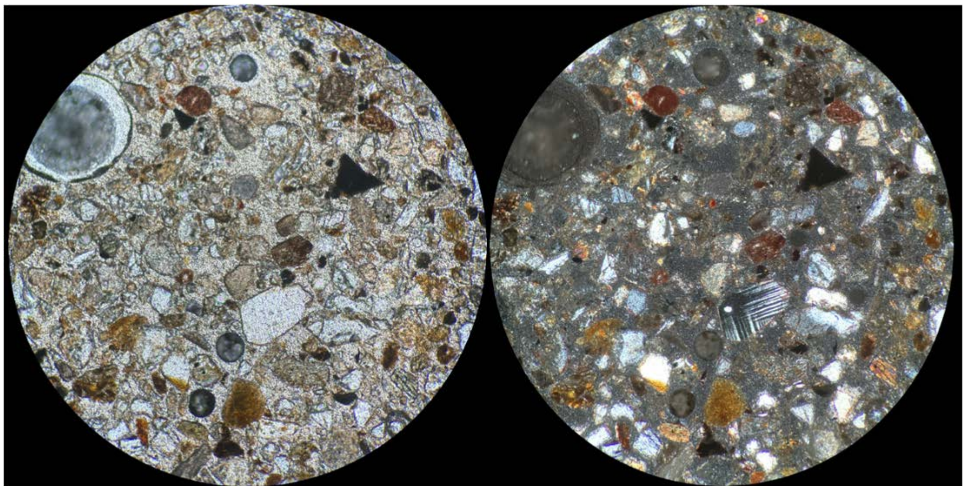

Figure B-036b. *Sample No. 05, 555 DUNE SAND. x100. PPL/XPL.*

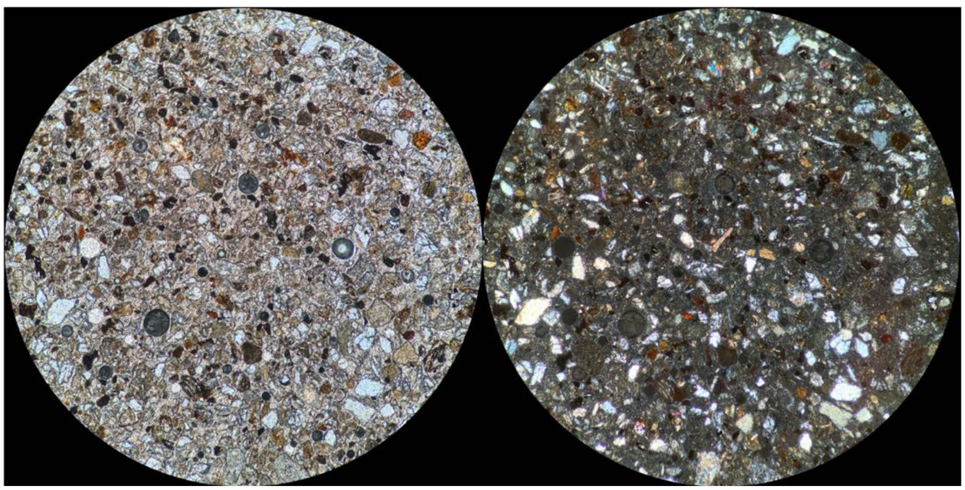

Figure B-037. *Sample No. 05, 555 DUNE SAND. x50. PPL/XPL.*

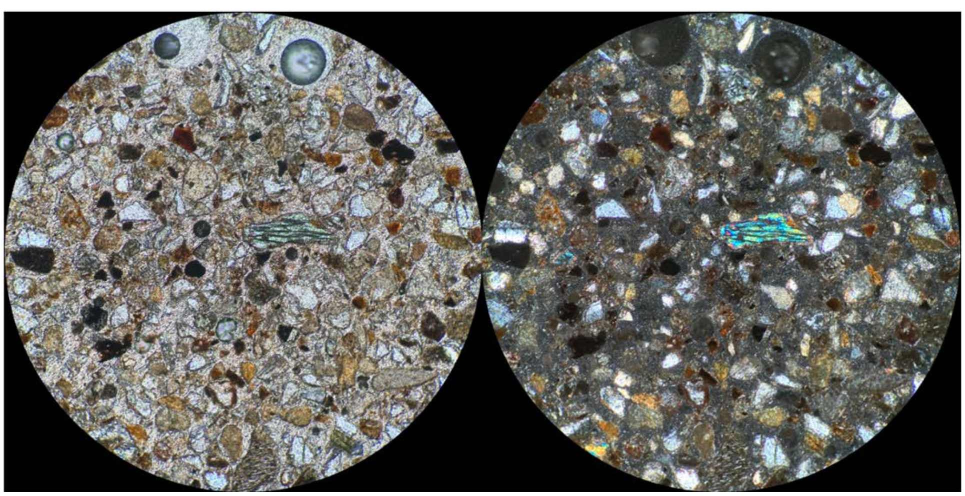

Figure B-038. *Sample No. 05, 555 DUNE SAND. x100. PPL/XPL.*

Figure B-039. *Sample No. 06, 565 DUNE SAND. Flat Bed Scan.*

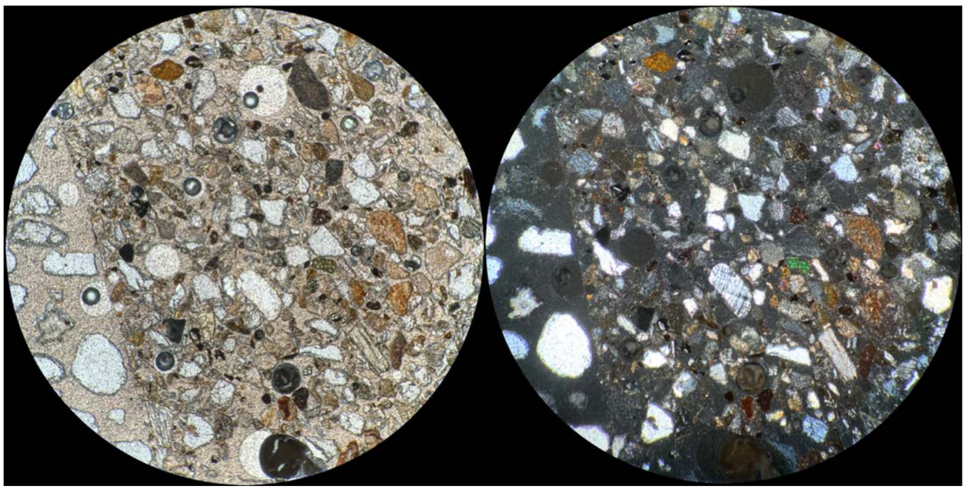

Figure B-040a. *Sample No. 06, 565 DUNE SAND. x50. PPL/XPL.*

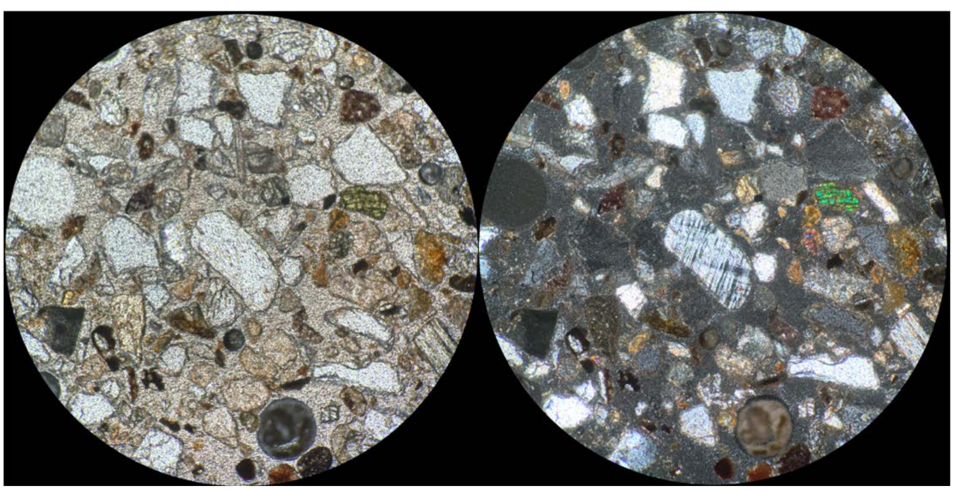

Figure B-040b. *Sample No. 06, 565 DUNE SAND. x100. PPL/XPL.*

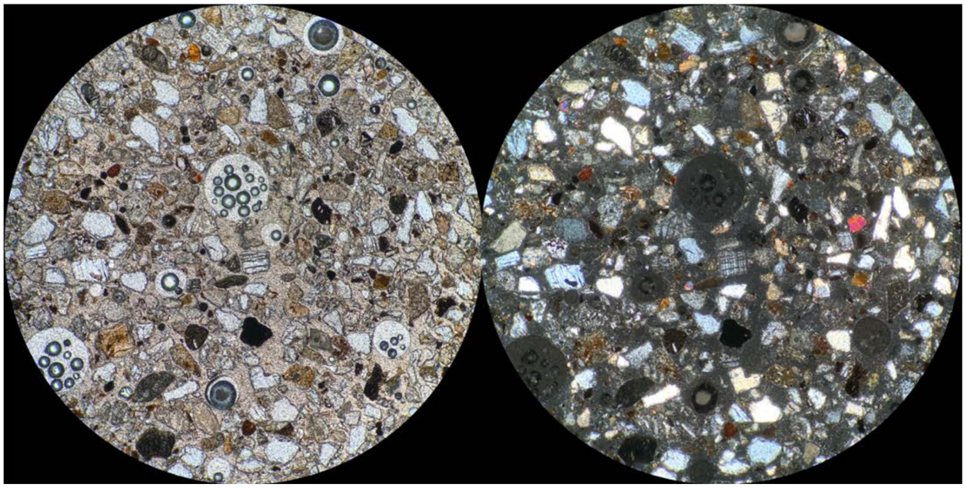

Figure B-041a. *Sample No. 06, 565 DUNE SAND. x50. PPL/XPL.*

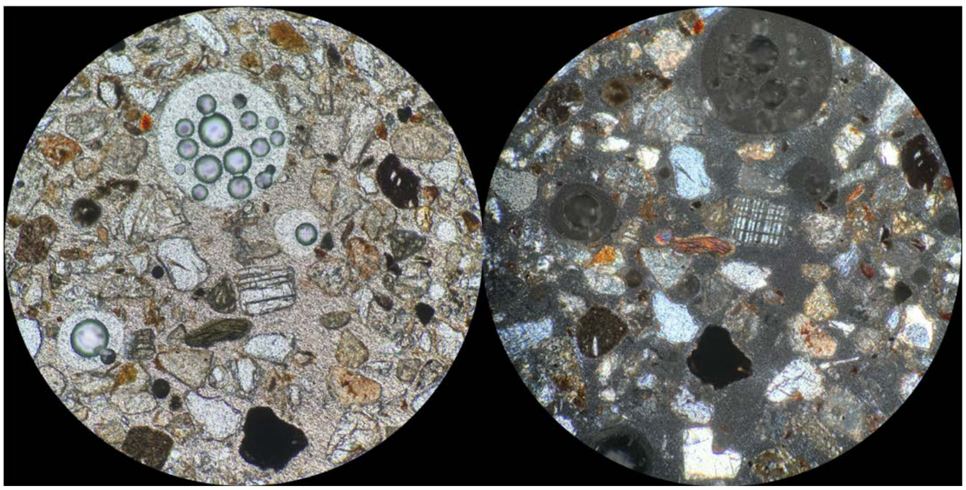

Figure B-041b. *Sample No. 06, 565 DUNE SAND. x100. PPL/XPL.*

Figure B-042. *Sample No. 07, 566 DUNE SAND. Flat Bed Scan.*

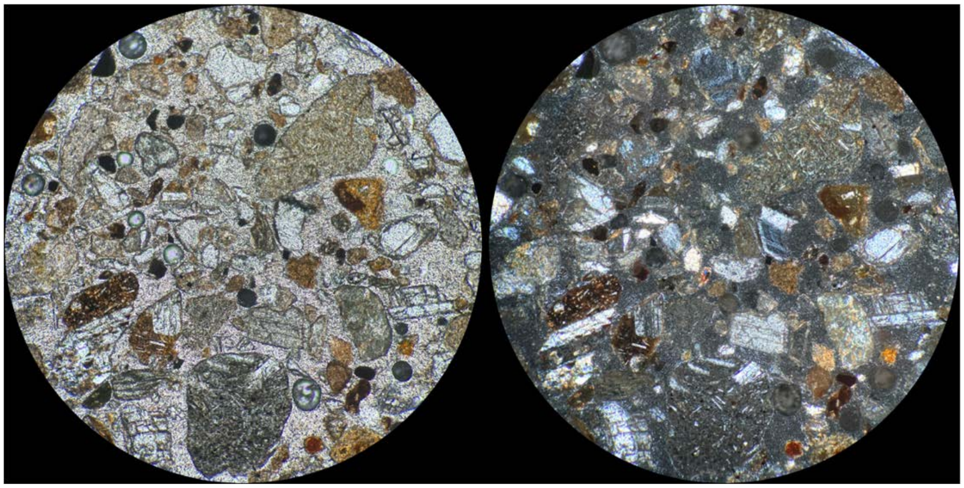

Figure B-043. *Sample No. 07, 566 DUNE SAND. x50. PPL/XPL.*

Figure B-044. *Sample No. 08, 571 DUNE SAND. Flat Bed Scan.*

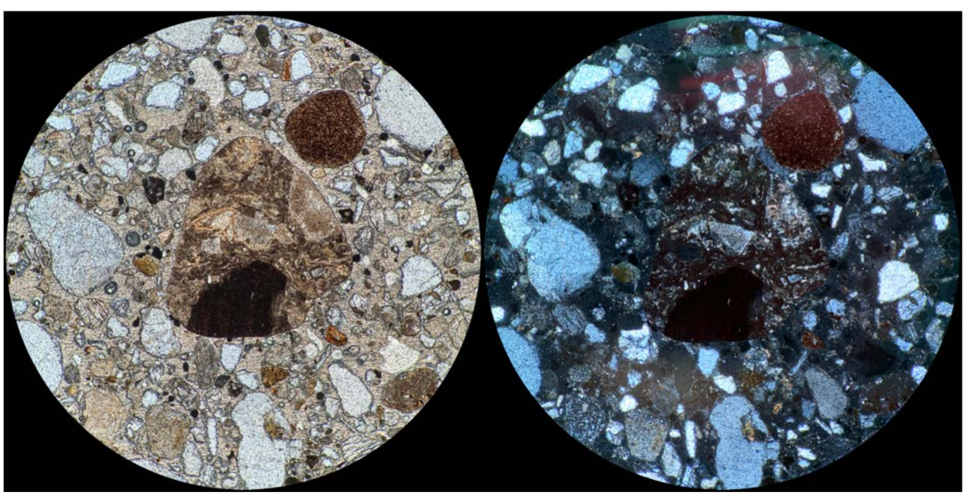

Figure B-045. *Sample No. 08, 571 DUNE SAND. x50. PPL/XPL.*

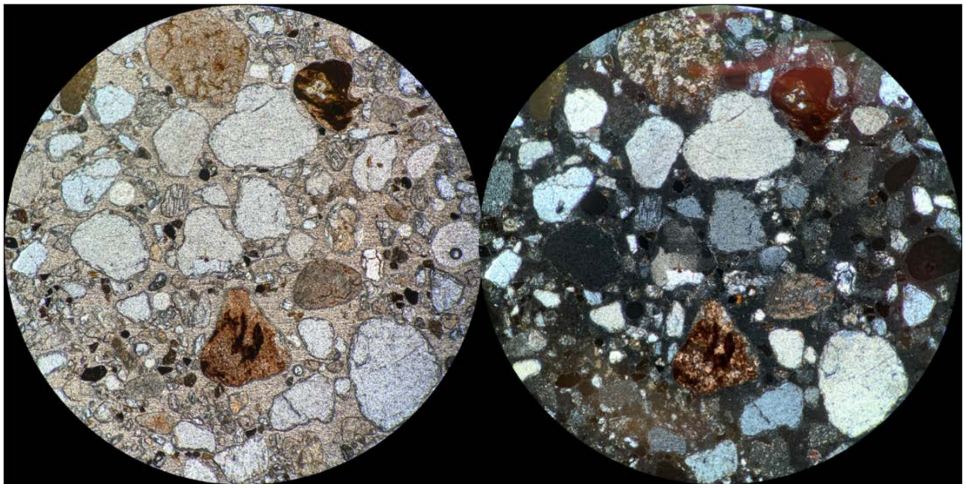

Figure B-046. *Sample No. 08, 571 DUNE SAND. x50. PPL/XPL.*

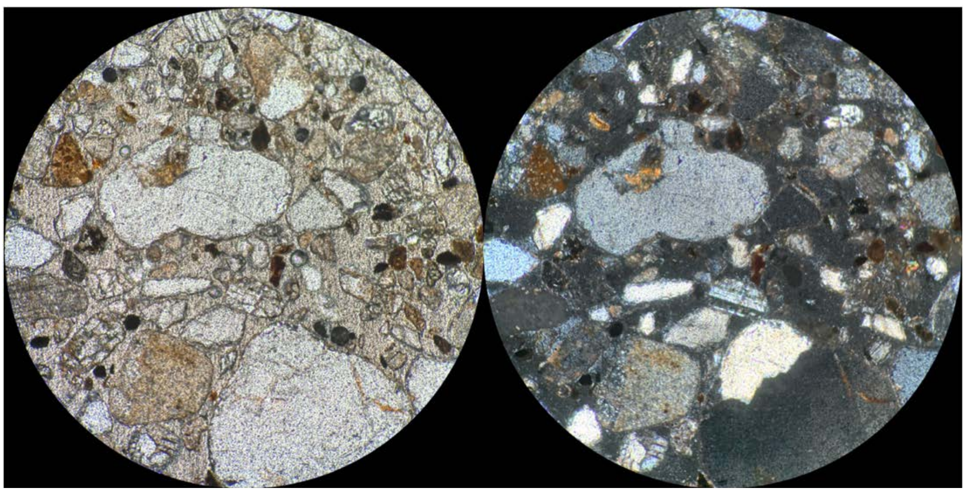

Figure B-047. *Sample No. 08, 571 DUNE SAND. x100. PPL/XPL.*

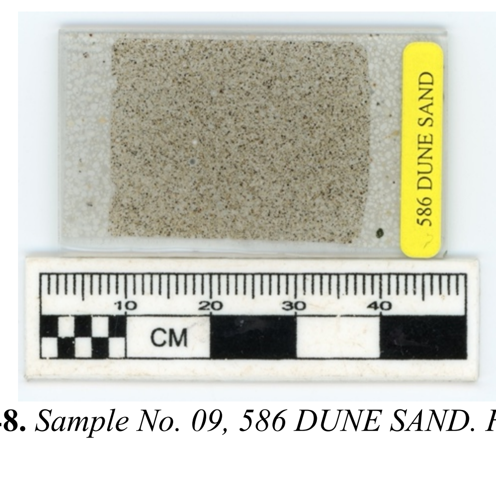

Figure B-048. *Sample No. 09, 586 DUNE SAND. Flat Bed Scan.*

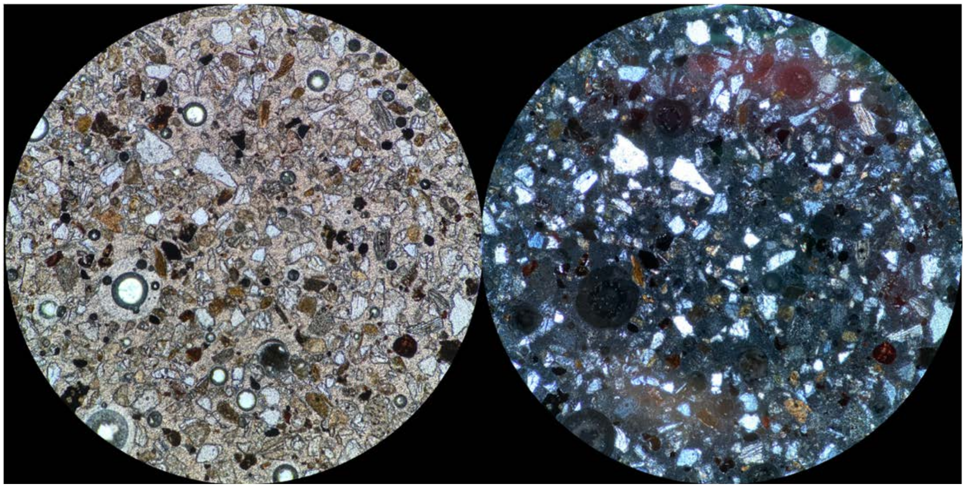

Figure B-049. *Sample No. 09, 586 DUNE SAND. x50. PPL/XPL.*

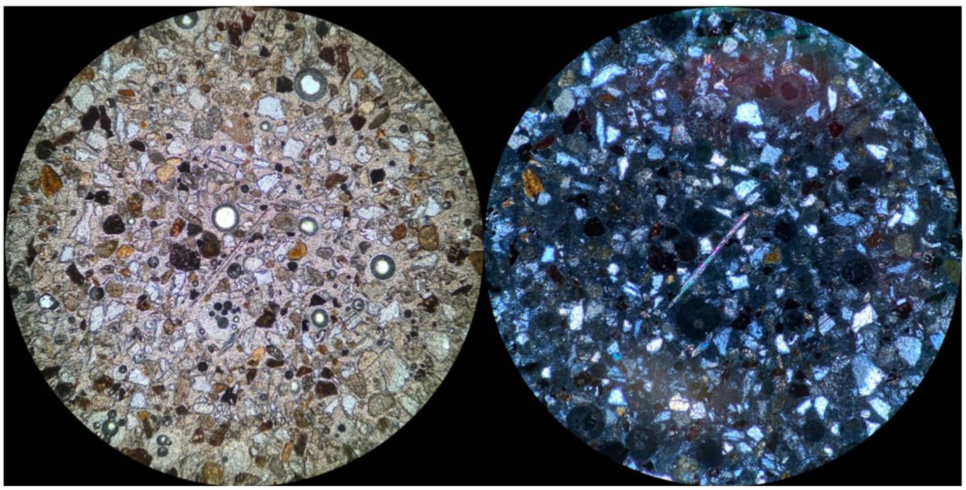

Figure B-050a. *Sample No. 09, 586 DUNE SAND. x50. PPL/XPL.*

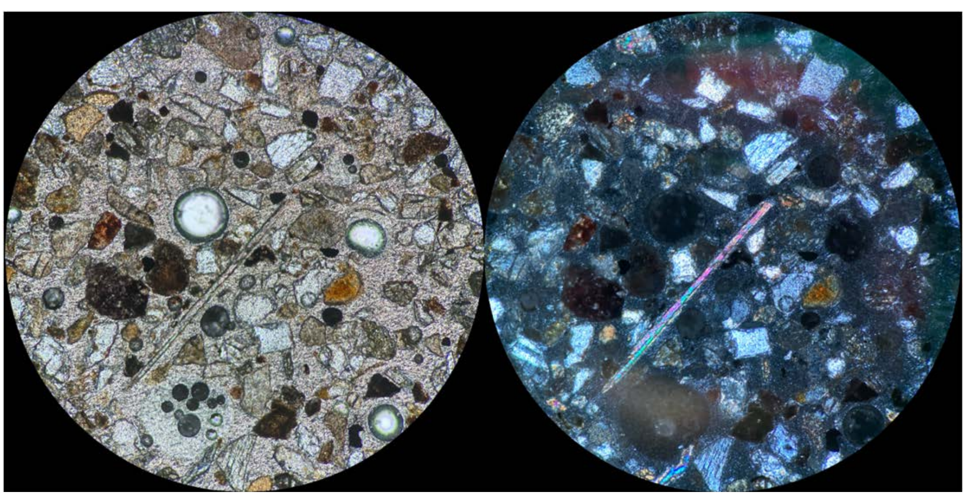

Figure B-050b. *Sample No. 09, 586 DUNE SAND. x100. PPL/XPL.*

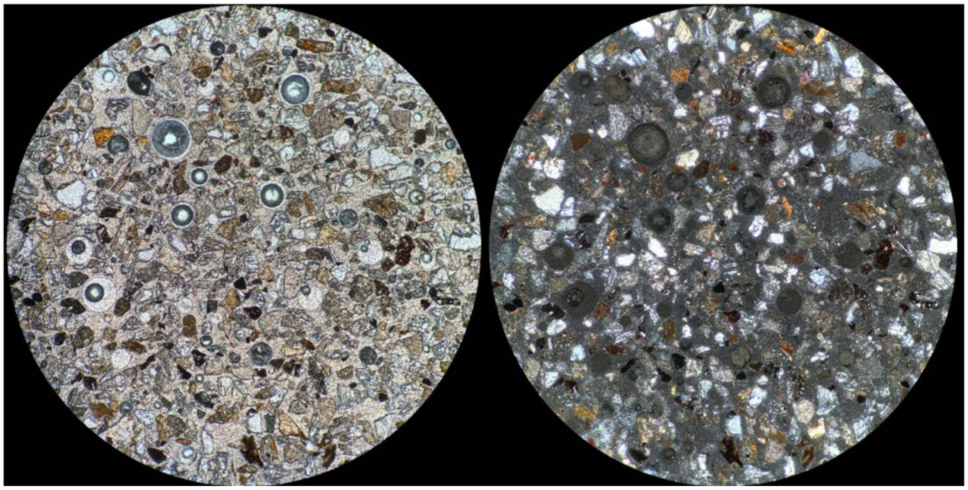

Figure B-051a. *Sample No. 09, 586 DUNE SAND. x50. PPL/XPL.*

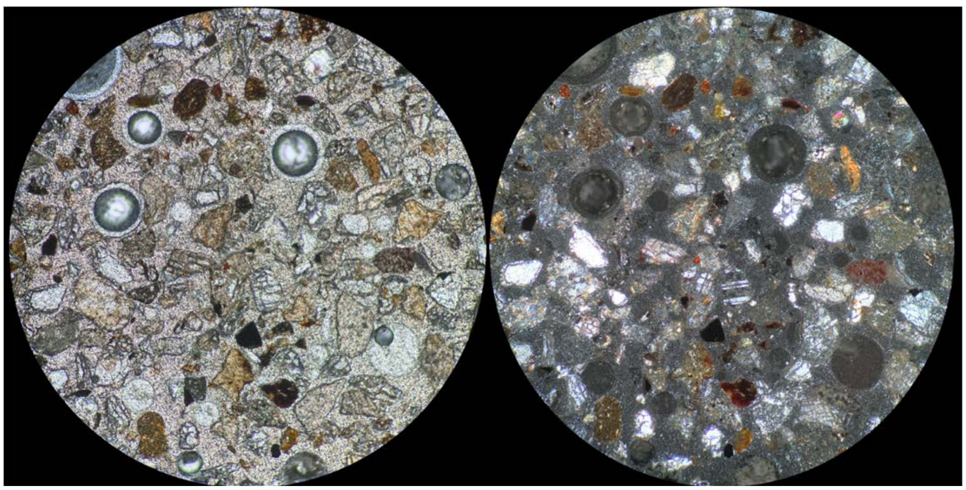

Figure B-051b. *Sample No. 09, 586 DUNE SAND. x100. PPL/XPL.*

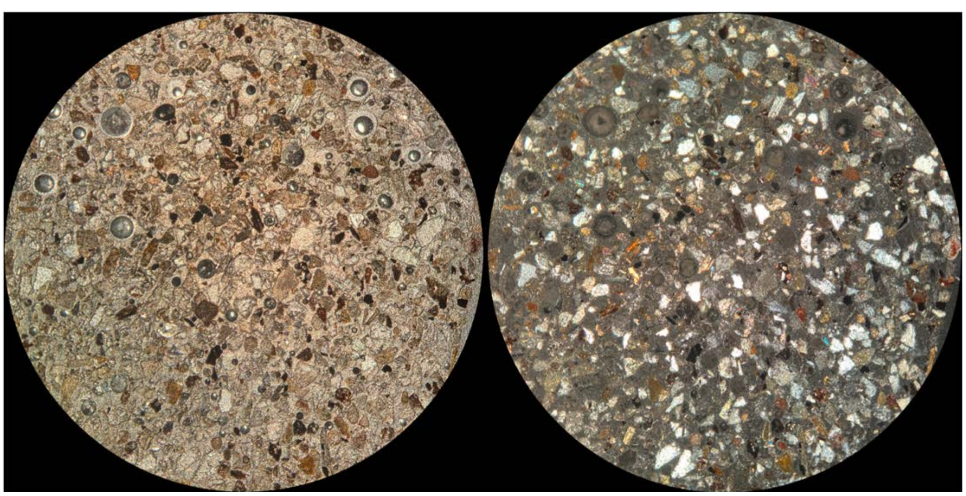

Figure B-052a. *Sample No. 09, 586 DUNE SAND. x50. PPL/XPL.*

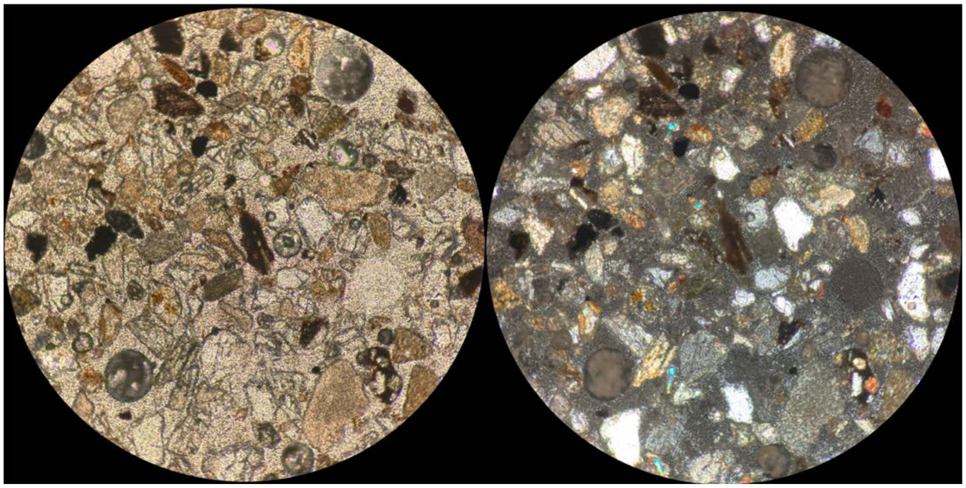

Figure B-052b. *Sample No. 09, 586 DUNE SAND. x100. PPL/XPL.*

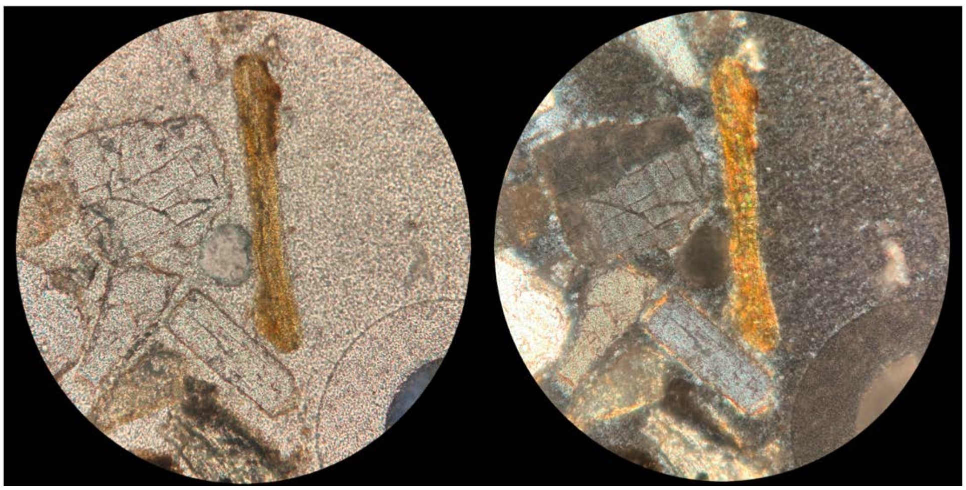

Figure B-053. *Sample No. 09, 586 DUNE SAND. x200. PPL/XPL.*

Figure B-054. *Sample No. 10, 375 U3 (LO) SOSG. Flat Bed Scan.*

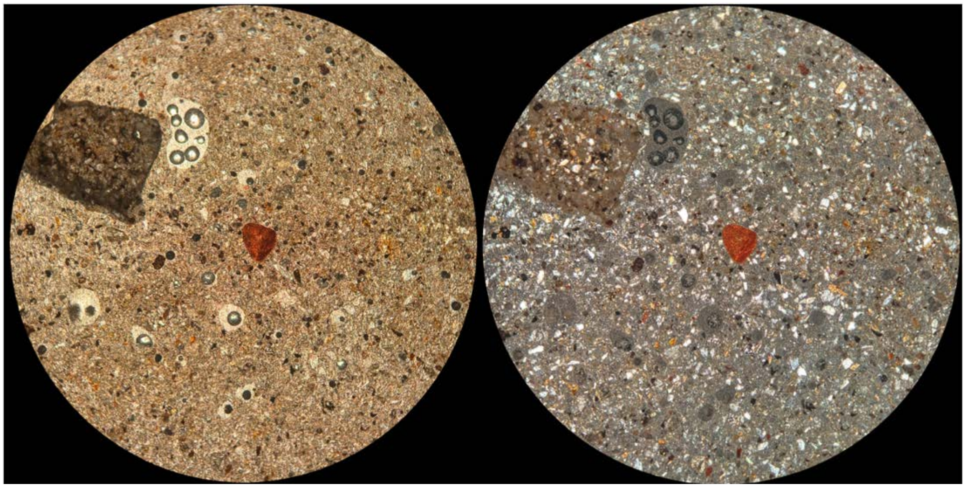

Figure B-055a. *Sample No. 10, 375 U3 (LO) SOSG. x40. PPL/XPL.*

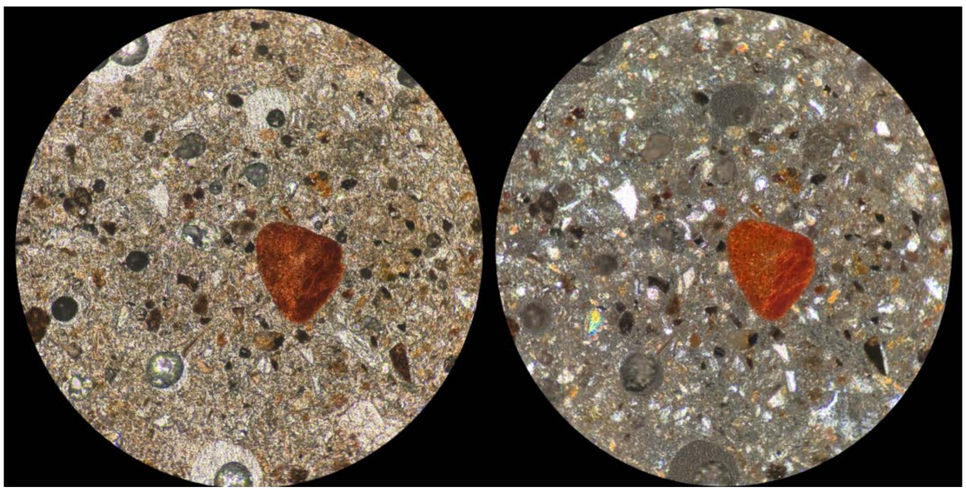

Figure B-055b. *Sample No. 10, 375 U3 (LO) SOSG. x100. PPL/XPL.*

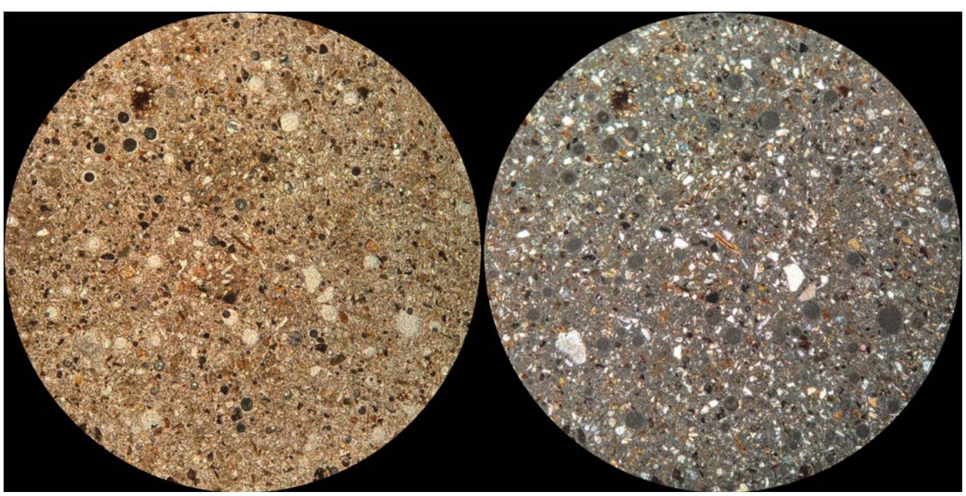

Figure B-056a. *Sample No. 10, 375 U3 (LO) SOSG. x40. PPL/XPL.*

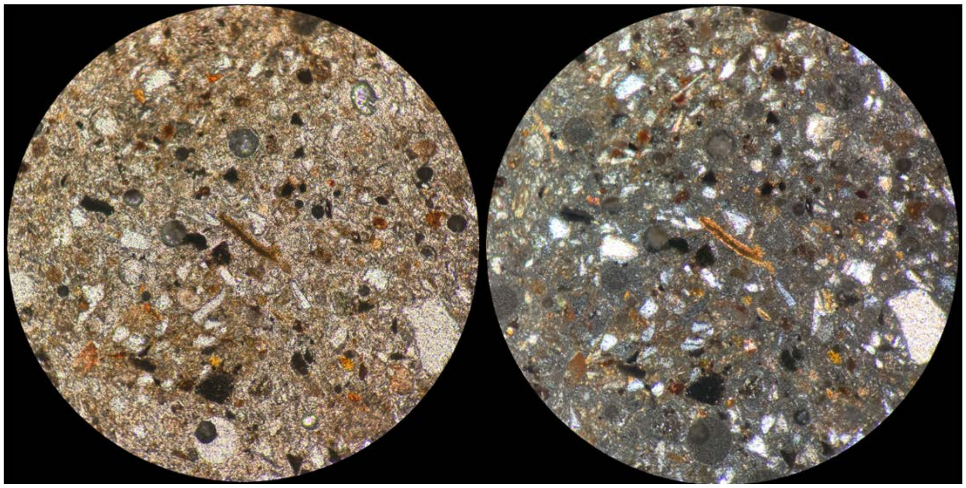

Figure B-056b. *Sample No. 10, 375 U3 (LO) SOSG. x100. PPL/XPL.*

Figure B-057. *Sample No. 11, 593 U2 SOSG. Flat Bed Scan.*

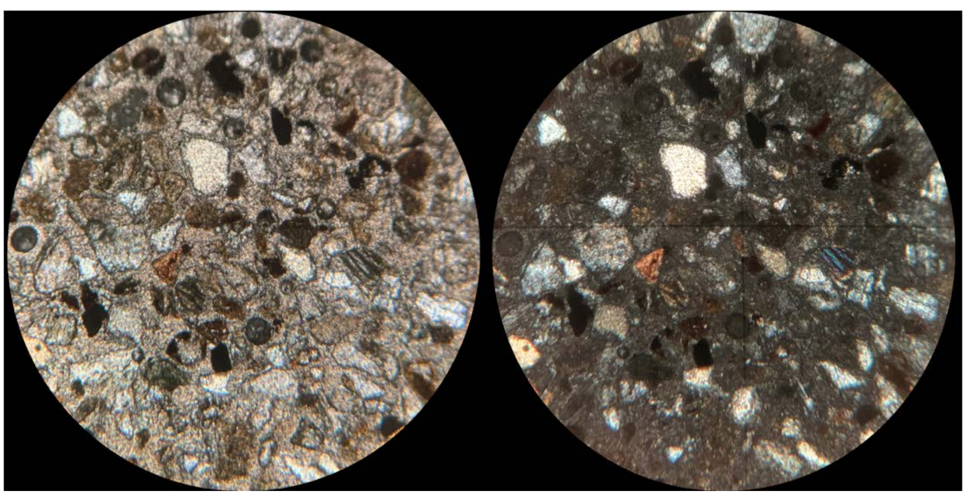

Figure B-058. *Sample No. 11, 593 U2 SOSG. x40. PPL/XPL.*

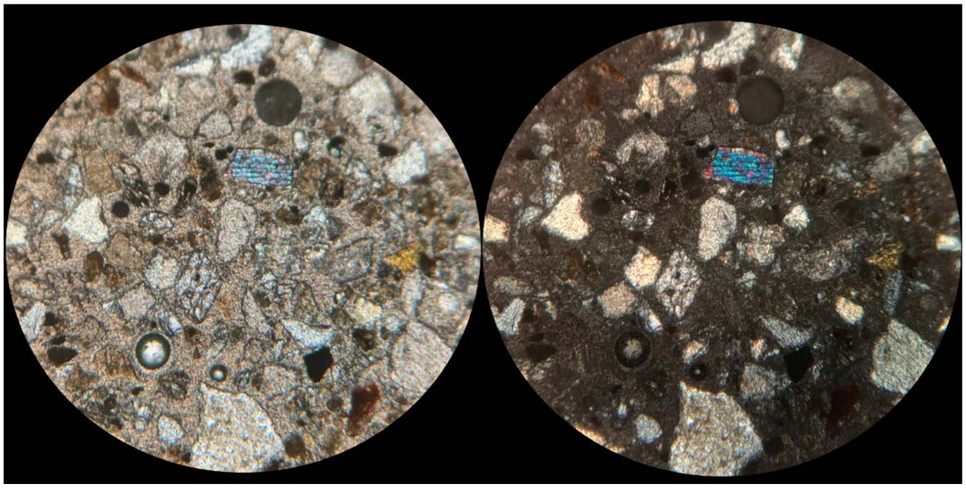

Figure B-059. *Sample No. 11, 593 U2 SOSG. x40. PPL/XPL.*

Figure B-060. *Sample No. 12, 372 U3 SOSG. Flat Bed Scan.*

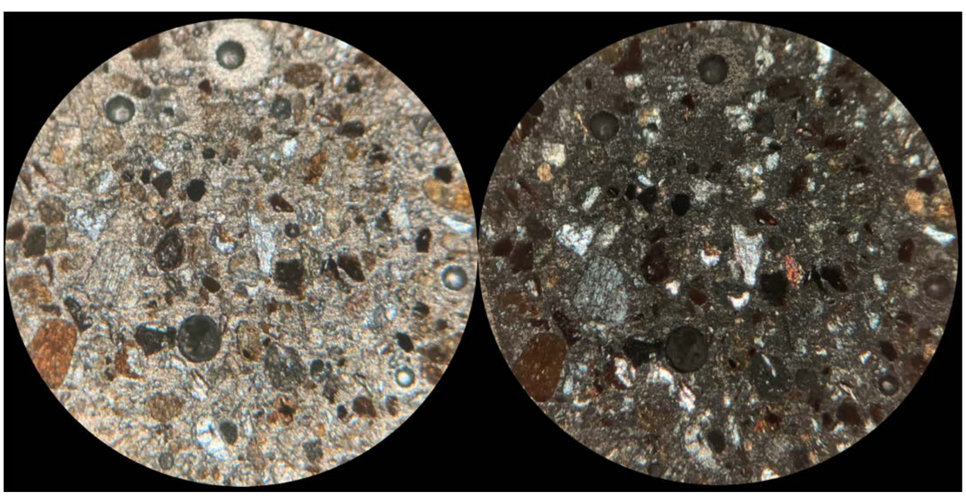

Figure B-061a. *Sample No. 12, 372 U3 SOSG. x40. PPL/XPL.*

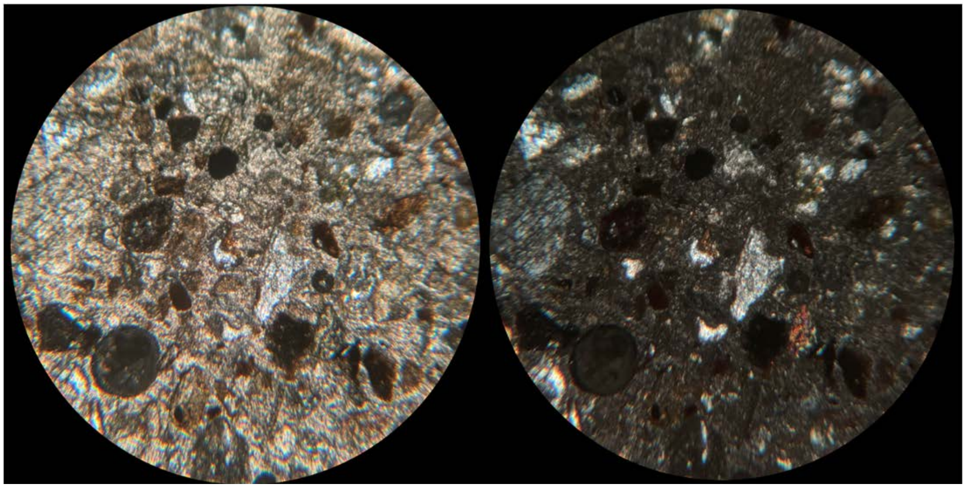

Figure B-061b. *Sample No. 12, 372 U3 SOSG. x100. PPL/XPL.*

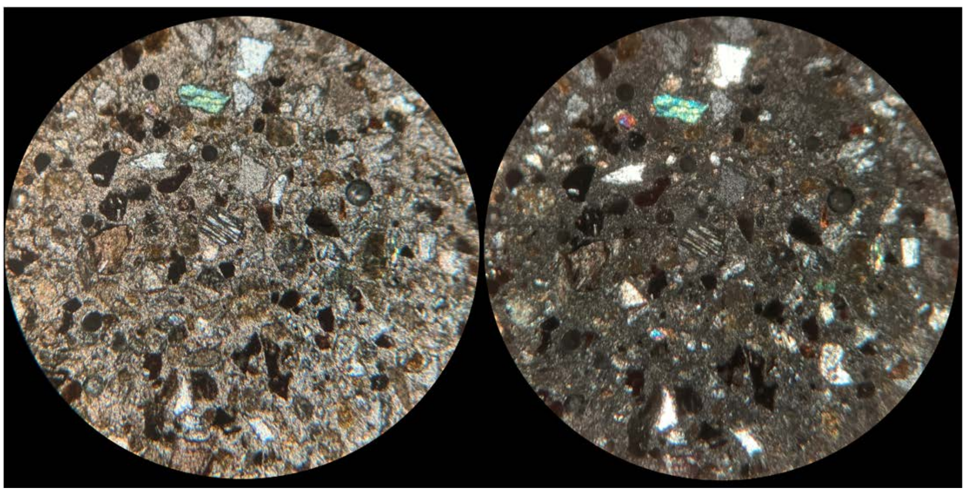

Figure B-062. *Sample No. 12, 372 U3 SOSG, x40. PPL/XPL.*

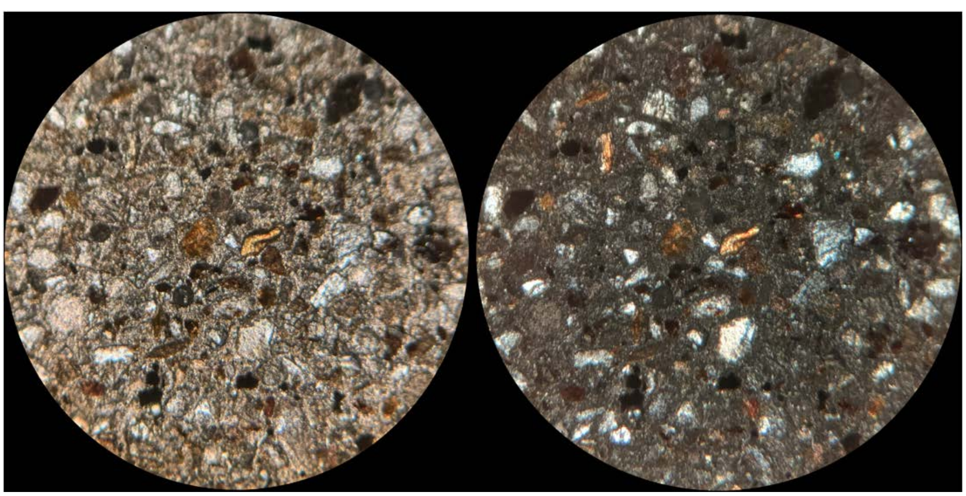

Figure B-063. *Sample No. 12, 372 U3 SOSG. x40. PPL/XPL.*

Figure B-064. *Sample No. 13, 469 U2 SOSG. Flat Bed Scan.*

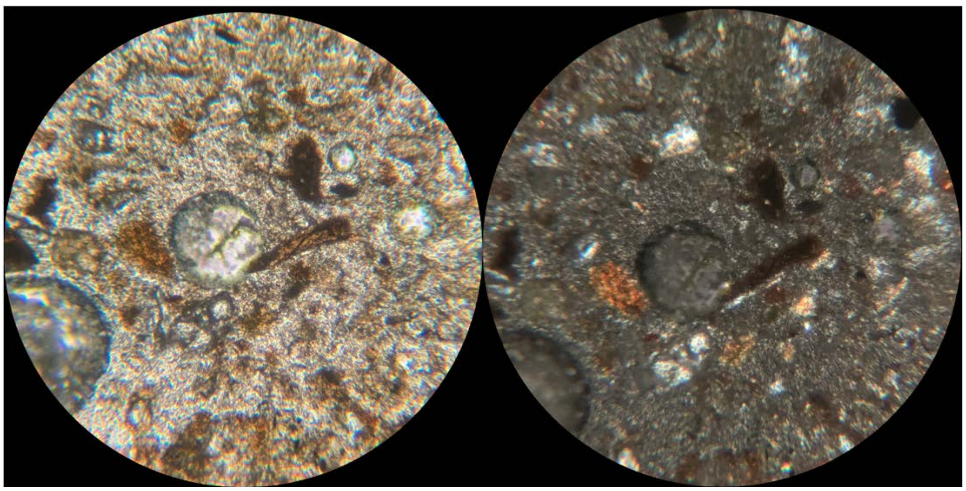

Figure B-065. *Sample No. 13, 469 U2 SOSG. x40. PPL/XPL.*

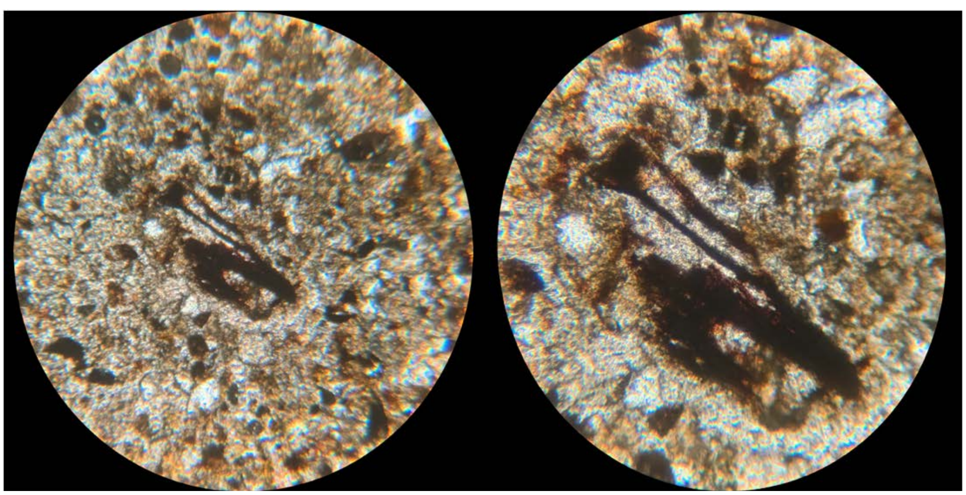

Figure B-066. *Sample No. 13, 469 U2 SOSG. x40/x100. PPL.*

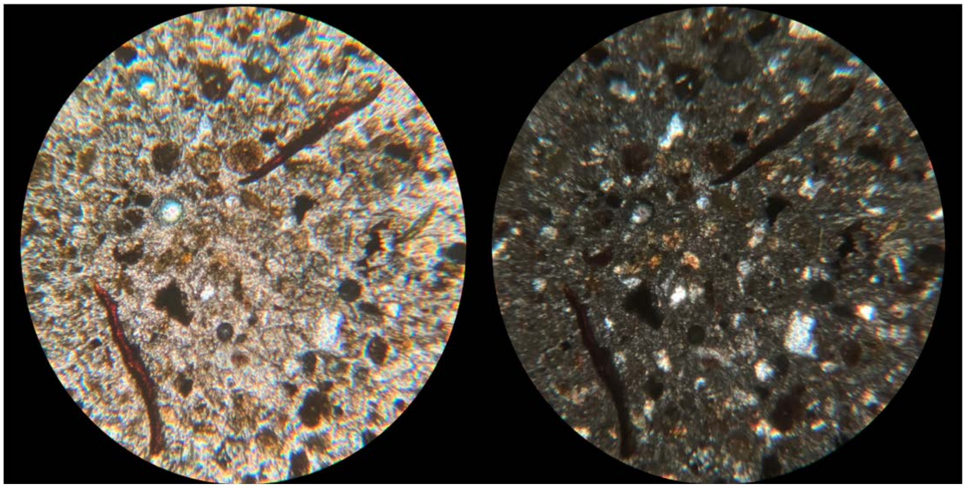

Figure B-067a. *Sample No. 13, 469 U2 SOSG. x40. PPL/XPL.*

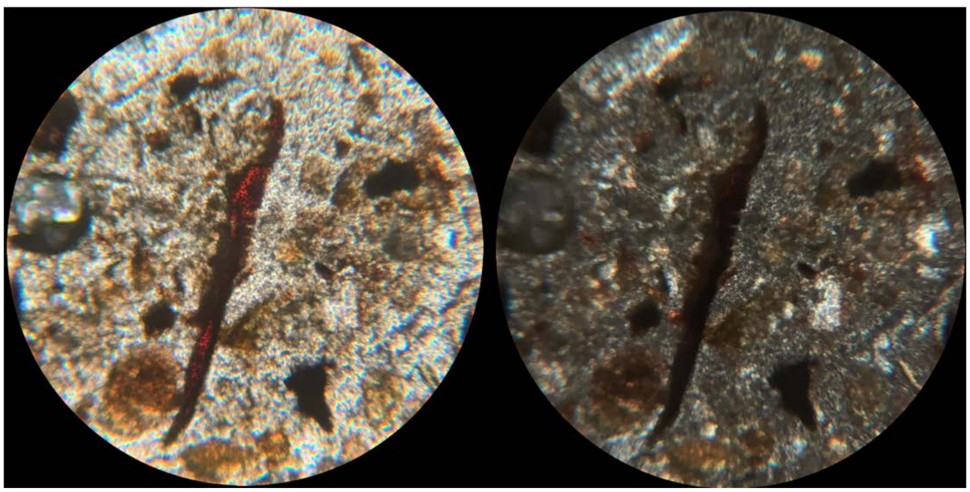

Figure B-067b. *Sample No. 13, 469 U2 SOSG. x100. PPL/XPL.*

Figure B-068. *Sample No. 14, 524 SOSG. Flat Bed Scan.*

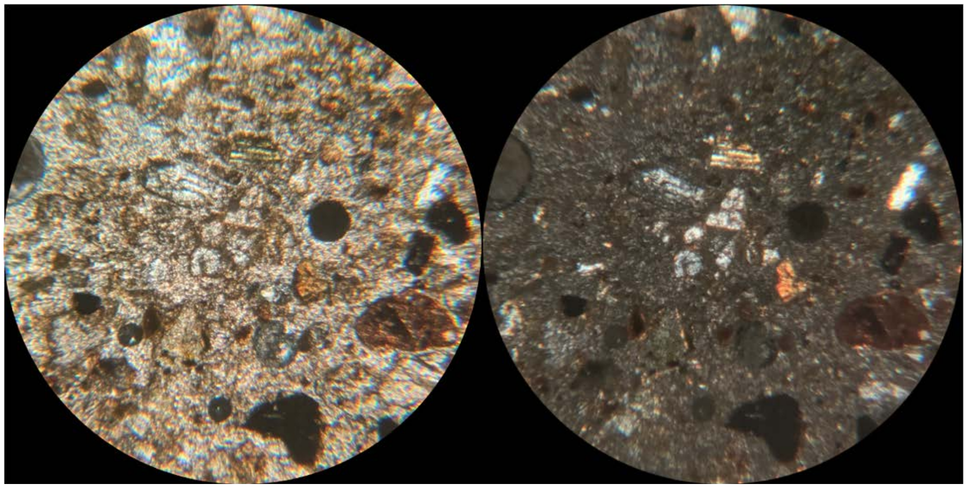

Figure B-069. *Sample No. 14, 524 SOSG. x40. PPL/XPL.*

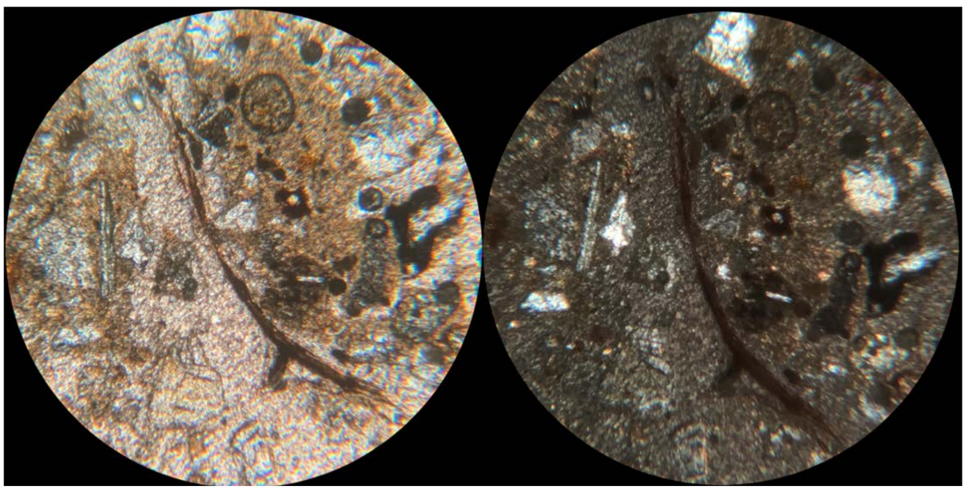

Figure B-070. *Sample No. 14, 524 SOSG. x40. PPL/XPL.*

Figure B-071. *Sample No. 15, 540 SOSG. Flat Bed Scan.*

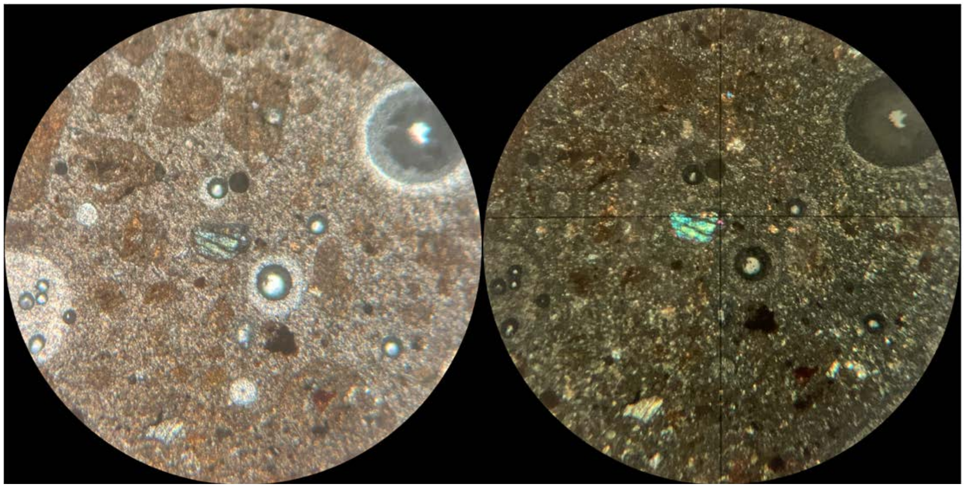

Figure B-072. *Sample No. 15, 540 SOSG. x40. PPL/XPL.*

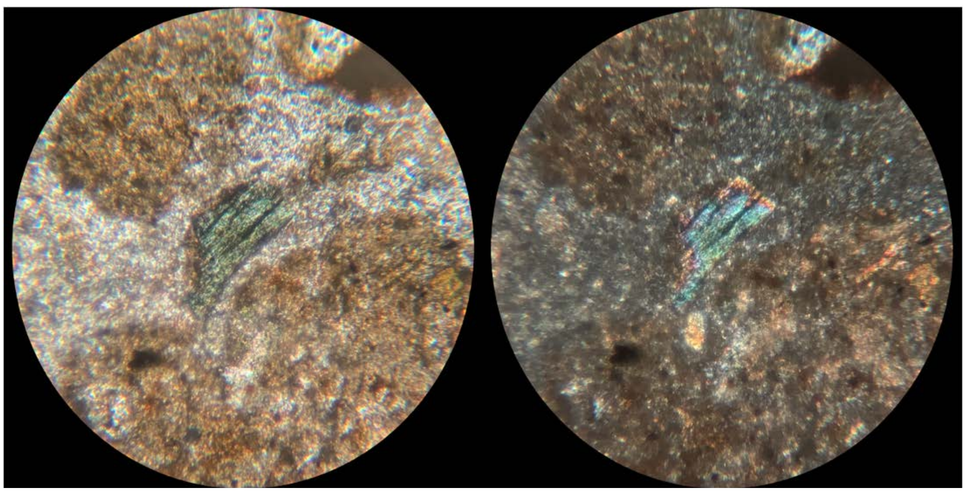

Figure B-073. *Sample No. 15, 540 SOSG. x100. PPL/XPL.*

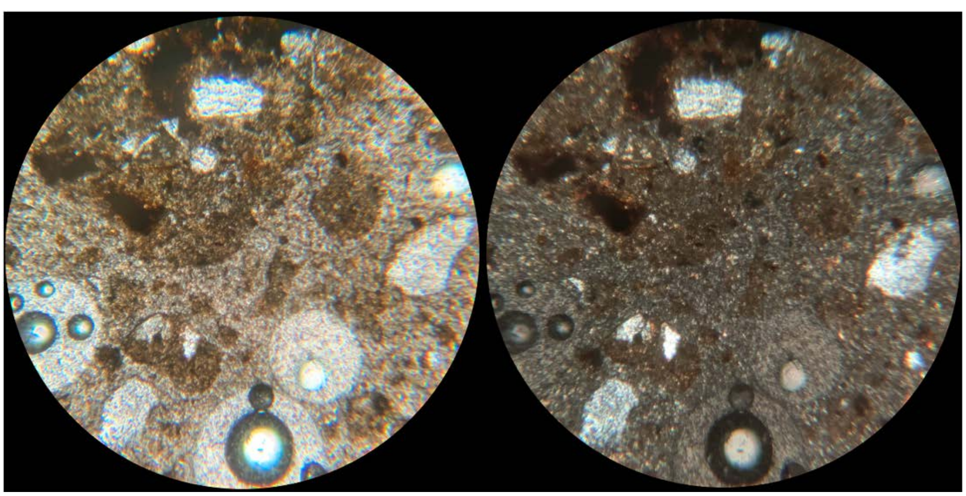

Figure B-074. *Sample No. 15, 540 SOSG. x40. PPL/XPL.*

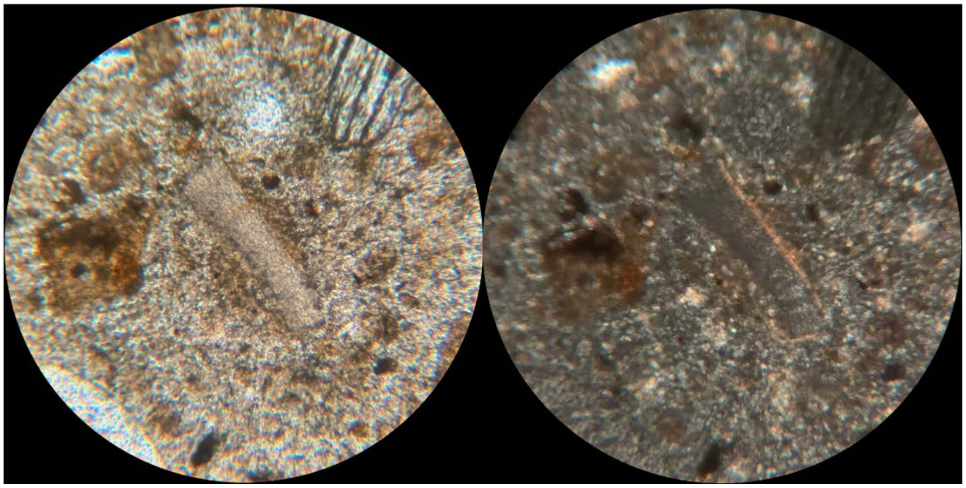

Figure B-075. *Sample No. 15, 540 SOSG. x100. PPL/XPL.*

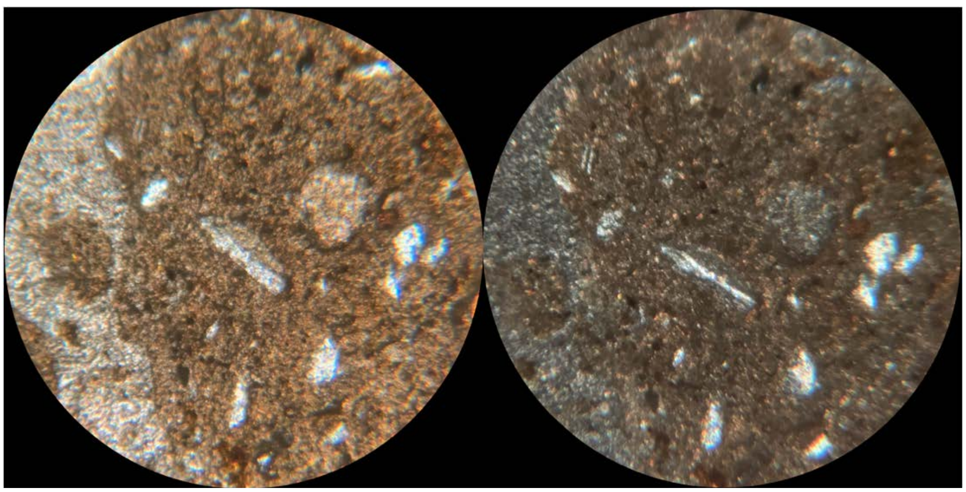

Figure B-076. *Sample No. 15, 540 SOSG. x100. PPL/XPL.*