INVESTIGATION OF ALKALI-SILICA-REACTIVITY IN PORTLAND CEMENT CONCRETE

PHASE II – SELECT VERMONT STRUCTURES

Vermont Agency of Transportation
Research, Development and Technology Transfer Project

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Prepared by

James R. Wild, E.I.
Structural Concrete Engineer
Vermont Agency of Transportation
Materials & Research Division
Structural Concrete Unit

Thomas D. Eliassen, P.G.
Transportation Geologist
Vermont Agency of Transportation
Materials & Research Division
Soils & Foundations Unit

Jerry K. McMahan
Chemist
Vermont Agency of Transportation
Materials & Research Division
Materials Unit

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Reviewed By: ____
William Ahearn, P.E. Materials & Research Engineer

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16. Abstract

The Vermont Agency of Transportation (VTrans) has embarked on an evaluation of selected aggregates throughout the state for the potential of alkali-silica-reactivity (ASR) in cementitious concrete used in Vermont's highway structures. This research included two separate phases of investigation. Phase I evaluated aggregate from eleven pre-selected sources utilizing mortar bar expansion (AASHTO T-303) and petrographic analysis (ASTM C295, ASTM C856 and ASTM 294) test methods/techniques. Phase II which is the subject of this current report consisted of evaluating concrete from select bridges in the state utilizing field screening screening, laboratory analysis and petrographic techniques..

Twenty-seven bridges at various locations in the state were selected for ASR evaluation. Concrete in these bridges was found to contain the eleven aggregate sources identified during Phase I during their construction. Concrete core samples were collected from three locations at each bridge for laboratory petrographic analysis. Field screening was also conducted during the core collection activities. Field screening consisted of applying a uranyl acetate solution to prepared concrete surfaces near these same core sample locations and observing these areas under fluorescent light. Thin-sections of each of the core samples were prepared and evaluated under a petrographic microscope for the possible presence of ASR.

Based on field observations, field screening and petrographic analysis, bridges investigated during this study were characterized as being severely, moderately or slightly impacted by the development of ASR. In general, the north-central portion of the state exhibited bridges with the most severe ASR distress while bridges in the upper Connecticut River Valley showed moderate distress and bridges in the southeastern part of the state showed relatively slight impact.

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ABSTRACT

The Vermont Agency of Transportation (VTrans) has embarked on an evaluation of selected aggregates throughout the state for the potential of alkali-silica-reactivity (ASR) in cementitious concrete used in Vermont's highway structures. This research included two separate phases of investigation. Phase I evaluated aggregate from eleven pre-selected sources utilizing mortar bar expansion (AASHTO T-303) and petrographic analysis (ASTM C295, ASTM C856 and ASTM 294) test methods/techniques. Phase II which is the subject of this current report consisted of evaluating concrete from select bridges in the state utilizing field screening, laboratory analysis and petrographic techniques.

Twenty-seven bridges at various locations in the state were selected for ASR evaluation. Concrete in these bridges was found to contain the eleven aggregate sources identified during Phase I during their construction. Concrete core samples were collected from three locations at each bridge for laboratory petrographic analysis. Field screening was also conducted during the core collection activities. Field screening consisted of applying a uranyl acetate solution to prepared concrete surfaces near these same core sample locations and observing these areas under fluorescent light. Thin-sections of each of the core samples were prepared and evaluated under a petrographic microscope for the possible presence of ASR.

Based on field observations, field screening and petrographic analysis, bridges investigated during this study were characterized as being severely, moderately or slightly impacted by the development of ASR. In general, the north-central portion of the state exhibited bridges with the most severe ASR distress while bridges in the upper Connecticut River Valley showed moderate distress and bridges in the southeastern part of the state showed relatively slight impact.

INTRODUCTION

VTrans (Vermont Agency of Transportation) completed a study in 2003 that identified potential ASR (Alkali Silica Reactivity) in mortar bars prepared with coarse aggregate from eleven sources throughout the State. These eleven coarse aggregate sources were selected because they are consistent producers, have been used in the last 10 years by VTrans in bridge structures and produce aggregate containing rock types suspected as possibly ASR susceptible. Coarse aggregate sources were targeted during this study because the VTrans ASR committee members suspected ASR susceptible large aggregate would be a strong contributor to concrete distress. The committee also felt that the geological character of rock material from these locations would be representative of rocks throughout the state. Fine aggregate was not investigated in this study because typically fine aggregate sources are geologically variable in make-up and generally are quickly depleted. Based on the Phase I study, the following conclusions were drawn:

1. Of eleven mortar bar tests, five were found to have expansions equal to or greater than 0.1% and two had expansions equal to or greater than 0.08% but less than 0.1%.

2. Seven of the eleven aggregate sources evaluated exhibited what would be considered moderate susceptibility for the development of ASR. Two samples exhibited the greatest abundance of micro-cracks and ASR gel development.
3. The development of ASR gel and micro-cracks appeared to be evenly distributed throughout the most of the samples and
4. It was suspected that more obvious ASR manifestations would be encountered during Phase II of the study as structures containing potentially reactive aggregates will have had a longer period of time to react with the alkali in the cement.

Based on these conclusions, one of the recommendations was to investigate existing structures built with the potentially reactive coarse aggregate that have been in service for 10 or more years.

OBJECTIVES

The objectives of The Phase II study were to identify the possible presence of alkali-silica reactivity (ASR) in select VTrans structures and recommend remediation actions for existing structures and mitigation options for new concrete. The project tasks were as follows:

1. Identify the set of structures for the study that used the selected coarse aggregate,
2. Review bridge inspection records review to find bridges that showed potential signs of ASR distress and were easily accessible for core sampling,
3. Review construction records review of each structure to confirm that the selected aggregates were used in the concrete,
4. Collect samples from each structure that showed potential for the development of ASR,
5. Perform field screening of each structure using the uranyl acetate fluorescence method for the presence of ASR on the surface of the structure,
6. Examine samples for the presence of ASR utilizing petrographic techniques in the lab and
7. Provide mitigation alternatives and guidance for limiting the potential for ASR development in future VTrans structures.

PHASE II INVESTIGATION

VTrans identified 27 structures throughout the State for evaluation. For this phase of work the structures selected were all bridges. Samples were collected from various parts of each structure, field testing was performed and petrographic analysis was conducted on each of the samples collected. Generally, samples were collected from bridge abutments, piers and curbing. A map showing the locations of the bridges investigated and source areas of aggregate used in these bridges is presented in Appendix A.

STUDY METHODOLOGY

Structure Selection Criteria

The selection of structures to be evaluated was based upon the following criteria:

1. Aggregate used in the structure construction is one of the aggregate sources identified in Phase I,
2. Structures are within a 20 mile radius of batch plants that used each aggregate source and
3. Aggregate sources used for the construction have been in use for a minimum of 10 years.

In order to identify structures meeting the criteria mentioned above, staff contacted concrete plants within the 20 mile radius that currently used those aggregates to confirm their use for the minimum 10 year period. In addition, VTrans Construction records and bridge inspection files were reviewed for each selected structure, when available, in order to confirm the use of the subject aggregate and to determine the top three bridges that showed the most obvious signs of potential ASR distress. This review revealed some incomplete, vague or missing records that made it difficult in some instances to identify the link between certain bridges and aggregate sources used for its construction. The investigators were unable to identify any bridges meeting the selection criteria using aggregate from ASR A020013 and as a result, only ten aggregate sources were evaluated. Assessments were made as to the ease of accessibility for sample collection and screening activities. Only State and U.S. routes within each area were selected. Table 1 lists the aggregate sources and bridges tested during this study.

Table 1 Table Showing Aggregate Source and Bridge Tested

ASR A020020	61	Wolcott	Vt. 15	1985	19
ASR A010594	32	Groton	US 302	1990	14
ASR A010594	35	Groton	US 302	1980	24
ASR A010594	17	Topsham	Vt. 25	1985	19
ASR A020011**	12	Brighton	Vt. 111	1980	24
ASR A020011**	174	Coventry	US 5	1980	24
ASR A020012	71	Hartford	US 4	1986	18
ASR A020012	15	Pomfret	FAS 0166	1983	21
ASR A020012	2	Tunbridge	Vt. 110	1987	17
ASR A020021***	121B	Barnet	US 5	1978	26
ASR A020021***	15	Burke	Vt. 114	1990	14
ASR A020021***	1	Burke	Vt. 5A	1986	18
ASR A010595	7	Andover	FAS 0132	1979	25
ASR A010595	45	Chester	Vt. 11	1983	21
ASR A010595	11W	Windham	FAS 0126	1978	26
ASR A020018	D16	Essex	TH 95	1993	11
ASR A020018	13	Essex	Vt. 289	1993	11
ASR A020018	17	Milton	US 2	1980	24

* Note: Only found one bridge from search criteria that used this aggregate.

** Note: Only sampled 2 bridges because the third was in a railroad right of way.

*** Note: Aggregate used during construction of these bridges is not from the same source tested during Phase I. The Phase I material has only been in use for approximately 7 years, thought to be not enough time for significant ASR reaction to take place. Since the aggregate source selected for Phase II is located in close proximity to the Phase I aggregate,source it is expected that both aggregate sources would be similar in geologic character.

Note: Unable to identify any bridges meeting the selection criteria using aggregate from ASR A020013.

Core Sample Collection

Cores were collected by using a gas powered four stroke 31cc portable core drill. The core bit size was 2 inch outside diameter which resulted in a 1 ¾ inch core. Core lengths were a minimum of 3 inches. The areas to core were selected by the VTrans Concrete Engineer. The core drill was positioned over cracks that typically showed the presence of white gel precipitate as depicted in Figure 1.

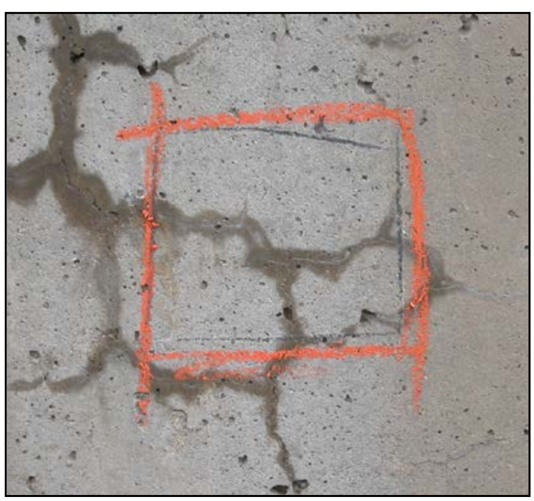

Figure 1 Crack with white precipitate.

Vertical surfaces were generally selected for coring as depicted in Figure 2. Because of poor access to some curbs, horizontal surfaces were also cored, Figure 3.

Figure 2 Coring vertical surface.

Figure 3 Coring horizontal surface.

After the cores were extracted, labeled and tagged, the holes were filled using a VTrans approved concrete repair material.

Aggregate Characterization

Of the ten aggregate sources investigated during this study, four sources consisted of mixed gravel while six sources consisted of crushed stone. The geologic descriptions of the crushed stone sources were taken from geologic descriptions published on the 1961 State of Vermont Centennial bedrock geologic map. These descriptions are:

- Source A020011 - Missisquoi Formation, Coburn Hill Volcanic Member - Actinolite-epidote-chlorite-albite greenstone and hornblende-albite-epidote amphibolite; includes pillow lavas.

- Source A020018 – Two rock types are present at this location.

  Winooski Dolomite - Buff-weathered, pink, buff, and gray dolomite; beds 4 inches to 1 foot thick separated by thin, protruding, red, pink, green, and black siliceous partings.

  Monkton Quartzite - Distinctively red quartzite interbedded with lesser buff and white quartzite and relatively thick sections of dolomite like that of the Winooski.

- Source A010594 - Undifferentiated Granitic Gneiss. This is the well known 'Barre' Granite (which is technically classified as a granodiorite).

- Source A020012 - Ammonoosuc Volcanics, Bimodal volcanic rocks. The specific rock types produced from this quarry are predominantly amphibolite with lesser amounts of aplite.

- Source A020001 – Two rock types are present at this location.

  Clarendon Springs - Fairly uniform, massive, smooth weathered gray dolomite characterized by numerous geodes and knots of white quartz; quartz sandstone and irregular masses of chert are near the top.

  Danby and Potsdam Formations - The Danby is comprised of interbedded quartzite and dolomite; white quartzite beds, more than a foot thick, separated by 10 to 12 feet of dolomite.

- Source A010595 - Bethlehem Granodiorite - Gray, strongly foliated biotite-muscovite granodiorite and associated tonalite and granite.

The gravel sources are made up of a wide range of rock types dependent upon the source areas of the glacial deposits and the direction the glaciers traversed. Generally, gravel from the Champlain and Vermont Valleys consist of carbonate rich rocks; gravel from the Green Mountain and Vermont Piedmont physiographic provinces contain a host of metamorphic rock types and gravel from the Northeastern Highlands are characterized by a high percentage of granitic rocks. Figure 4 shows the physiographic geologic provinces of the State of Vermont.

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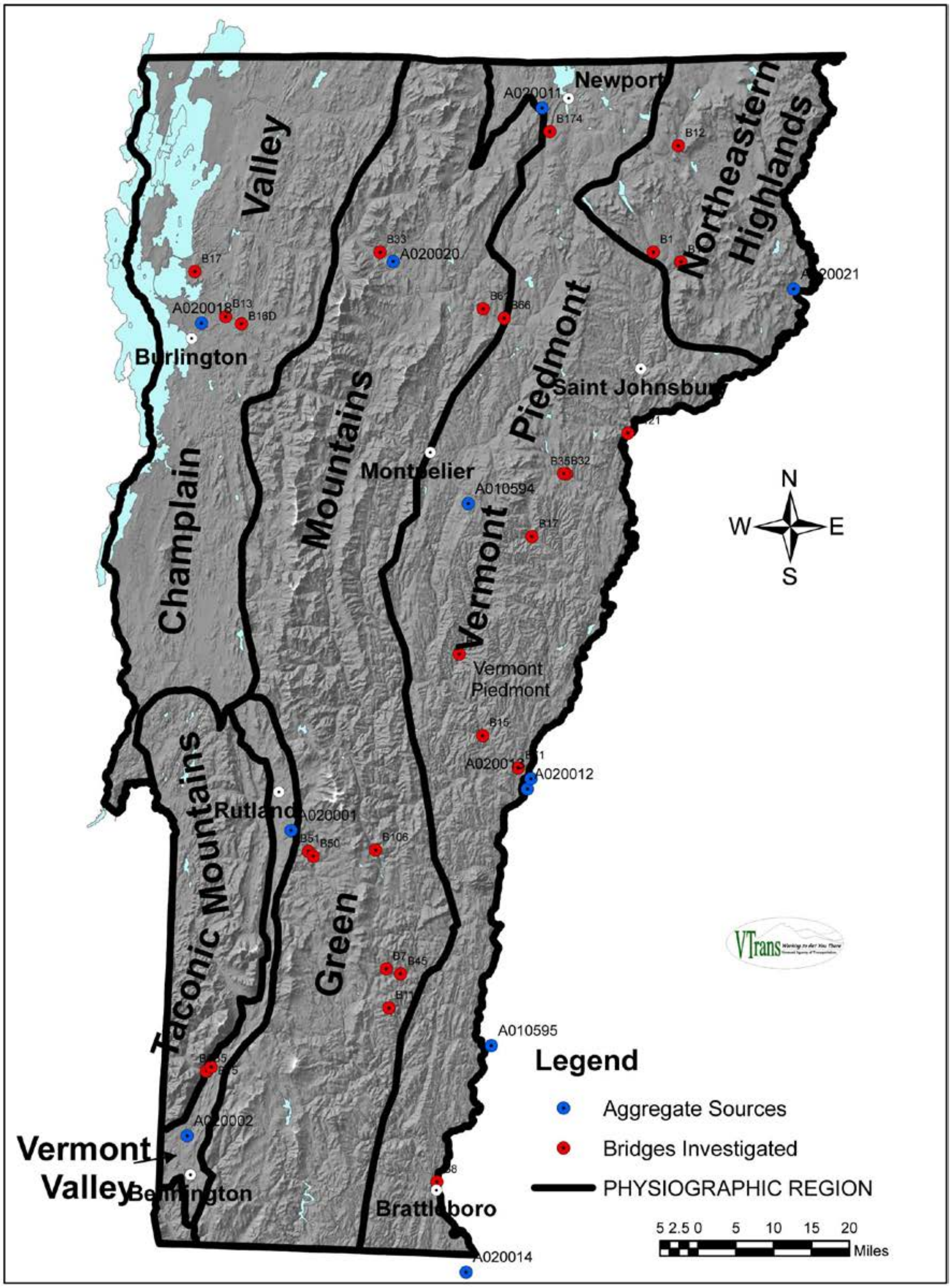

MAP SHOWING VERMONT
PHYSIOGRAPHIC PROVINCES

Figure 4 Physiographic Regions of Vermont.

Appendix A contains a map showing the stone aggregate sources superimposed on a simplified bedrock geologic map of Vermont and a map showing the general distribution of gravel throughout the state along with gravel aggregate sources investigated during this study.

ASR Screening Procedures

Field screening of concrete structures was performed using AASHTO method T-299, 'Rapid Identification of Alkali - Silica Reaction Products in Concrete'. This procedure relies upon the ability of uranium ions in uranyl acetate to replace sodium ions in ASR gel. Uranium ions fluoresce under ultraviolet light, so treated ASR gel is easily detectable. The concrete being screened was abraded to a depth of approximately 1/8th inch to expose a fresh, unweathered surface approximately 4 square inches and wetted with a weak uranyl acetate solution. After several minutes, excess solution was rinsed off and the concrete was examined with a portable UV (ultra violet) lamp. Green fluorescence indicates the presence of ASR gel. Figure 5 shows a core sample under ultra violet light. The bright green areas represent high concentrations of ASR gel. Especially evident are gel filled voids (upper right area of core) and 'reaction rims' around large aggregate particles, where the highly alkaline cement paste has partially dissolved the aggregate.

This procedure has several weaknesses. Carbonated concrete can retain uranyl acetate and falsely indicate the presence of ASR gel. Intense weathering can wash away gel near the surface of the concrete and create a false impression that ASR is not present. Bright sunlight can make visual evaluation difficult (and photography impossible), despite the use of a viewing box designed to exclude daylight. Finally, the presence of ASR gel does not necessarily indicate deleterious expansion, and the amount of gel present is not always proportional to ASR expansion, especially in older structures.

For this study, several locations on each structure were tested. If accessible, each of the four 'corners' of the bridge - northeast, northwest, southeast, southwest abutments were tested. Some curbs, wing walls and piers were also examined. Curbs are under-represented because their geometry makes use of the UV viewing box difficult. If a core sample was taken, the test area was located within one foot of the core. A total of 106 locations were tested, from 27 bridges. Each location was evaluated for general appearance, amount of cracking, overall fluorescence, reacted rims on aggregate particles and gel filled cracks or voids. After examining each test location an estimate was made of the overall effect of ASR on the structure. The surface screening results are not directly comparable to petrographic analysis of the same structure because the extracted core was typically sampled at a depth of several inches and was therefore not affected by surface weathering. The screening procedure is rapid and inexpensive but generally appears to be a less sensitive indicator of ASR than petrographic analysis.

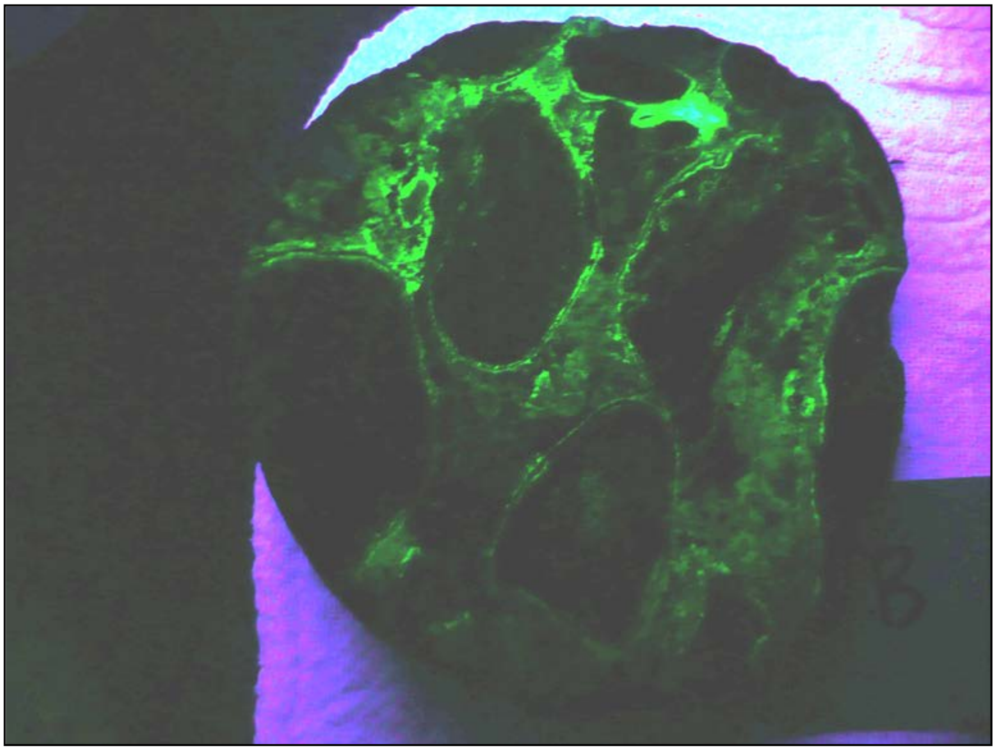

Figure 5 Photograph of core sample under Ultra Violet light showing ASR development.

Petrographic Analysis

Petrographic examination of samples from 27 bridge structures was conducted utilizing petrographic methods in general conformance with methods presented in *ASTM C295-98, Standard Guide for Petrographic Examination of Aggregates for Concrete; ASTM C856-95, Standard Practice for Petrographic Examination of Hardened Concrete* and *ASTM C294-98, Standard Descriptive Nomenclature for Constituents of Concrete Aggregates*. In addition, methods presented in *Petrographic Methods of Examining Hardened Concrete: A Petrographic Manual - Revised 2004* (Hollis N. Walker et al., 2006) were also followed.

As mentioned earlier, samples were collected from three sampling locations at each bridge (two substructures and one curb). This resulted in the collection of 81 samples. Each sample was labeled with a unique laboratory number and petrographic thin sections were prepared for each sample utilizing thin section methods presented in the Phase I study (J. Wild, T. Eliassen, 2003).

Petrographic examinations were conducted by observing possible ASR distress exhibited as gel filled voids and micro and macro cracking. Samples were viewed under 40X and 100X, however, in some instances magnification up to 400X was used.

Photomicrographs of samples that exhibited possible ASR were taken utilizing a Kodak MDS-290 Microscopy Documentation System consisting of a Kodak DC-290 digital camera, specialized phototube and Kodak MDS-290 software plug-in for Adobe Photoshop CS3 version 10.0. Magnification levels are noted on the photomicrographs presented as Appendix C.

RESULTS

Field Screening Results

ASR gel was visible in a large majority of the sites tested. The extent of gel formation varied from microscopic gel filled voids to alteration of all large aggregate particles combined with large gel filled cracks and voids. The amount of ASR is described as follows:

- Very Slight — Gel present in small amounts; visible with difficulty.
- Slight — Gel present but no visible expansion or cracking.
- Moderate — Some cracking and bulging of formerly flat surfaces, but no extensive damage to the structure.
- Severe — Very extensive cracking, pop outs and/or measurable displacement resulting in serious damage to the structure.

The description modifier 'to' in Table 2 is used to describe observations that may relate to either category.

Table 2 shows a summary of field screening results. Refer to Appendix B for a complete reporting of field screening results for all samples.

Table 2 Summary of Uranyl Acetate Field Screening.

TOWNSHIP	HIGHWAY	BRIDGE NUMBER	AGGREGATE SOURCE	OVERALL FLUORESCENCE	REACTION RIMS ON AGGREGATE	GEL FILLED VOIDS	MAP CRACKING	DEGREE OF ASR DISTRESS (VISUAL)
GROTON	U.S.-302	32	A010594	Slight	Slight	Moderate	Slight	Slight to Moderate
GROTON	U.S.-302	35	A010594	Moderate	None	None	None	Slight to Moderate
TOPSHAM	VT-25	17	A010594	Slight	Slight	Moderate	Slight	Moderate
ANDOVER	Weston Rd.	7	A010595	Very Slight	None	None	None	Very Slight
CHESTER	VT-11	45	A010595	Very Slight	None	Very Slight	Very Slight	Very Slight
WINDHAM	VT-126	11	A010595	None	None	None	None	Very Slight
PLYMOUTH	VT-100	106	A020001	Very Slight	None	None	None	Very Slight
SHREWSBURY	VT-103	50	A020001	Very Slight	None	Very Slight	Very Slight	Very Slight
SHREWSBURY	VT-103	51	A020001	Moderate	None	Slight	Moderate	Moderate to Severe
ARLINGTON	VT-7-A	15	A020002	Moderate	Slight	Moderate	Severe	Moderate to Severe
ARLINGTON	VT-313	5	A020002	Slight	Slight	Slight	Slight	Slight
ARLINGTON	VT-313	6	A020002	Very Slight	Slight	None	Very Slight	Very Slight
BRIGHTON	VT-111	12	A020011	Slight	None	Slight	Slight	Slight
COVENTRY	U.S.-5	174	A020011	Slight	Slight	Slight	Moderate	Slight to Moderate
HARTFORD	US-4	71	A020012	Slight	Slight	Slight	Slight	Slight
POMFRET	VT-166	15	A020012	Slight	Slight	None	Slight	Slight
TUNBRIDGE	VT-110	2	A020012	Moderate	Moderate	Moderate	Moderate	Moderate
BRATTLEBORO	US-5	8	A020014	Very Slight	None	Very Slight	None	None
ESSEX	VT-289	13	A020018	Very Slight	None	Very Slight	Very Slight	Very Slight
ESSEX	VT-15	16	A020018	Slight	Slight	Slight	Slight	Slight
MILTON	U.S.-2	17	A020018	Slight	None	Slight	Slight	Very Slight
HARDWICK	VT-15	66	A020020	Severe	Severe	Severe	Severe	Severe
JOHNSON	VT-15	33	A020020	Slight	Slight	Slight	Slight	Moderate to Severe
WOLCOTT	VT-15	61	A020020	Moderate	Severe	Severe	Severe	Severe
BARNET	US-5	121	A020021	Moderate	Moderate	Moderate	Moderate	Moderate to Severe
BURKE	VT-5A	1	A020021	Very Slight	None	None	Very Slight	None

Out of a total of 106 samples, 18 had an overall activity level of ‘moderate’ or 'severe'. Sixty-four occurrences of 'slight', 'very slight' or 'slight - moderate' were noted and 24 sites had no visible ASR activity. In most cases, the observed ASR activity correlated well with the overall physical condition of the bridges. There was one significant exception to this trend. The exceptional structure had severe expansive damage, with cracking and a large displacement, but very little ASR was visible on the surface of the concrete. However, there was abundant ASR gel at depths of 6 inches or more in core samples. It is likely that ASR gel near the surface was removed by weathering. Field screening showed good correlation with ASTM C1260 expansion values from Phase I, with three exceptions. One bridge exhibited virtually no ASR in spite of having the most expansive aggregate tested. It may be speculated that the aggregate source was misidentified in this case, or that concrete additives were successful in preventing ASR. Two other bridges possessed only moderate ASR gel fluorescence despite containing highly expansive aggregate. A third bridge containing the same aggregate displayed very extensive ASR gel. It is possible that surface weathering has removed some of the gel from these two structures.

These results appear to highlight a significant weakness in the field screening method: only the surface of the concrete is checked, so significant ASR may be missed if surface weathering has been heavy. The alkali content of the cement does not appear to be a significant factor. Virtually all cements produced in this area of the country are high in alkali, ranging from 0.6 to 1.2 percent. Also, heavy use of road salt supplies additional alkali to the cement as soon as cracking occurs for any reason. Plants in the Hudson Valley of New York supply slightly lower alkali cement, typically 0.5 to 0.6 percent, but these cements are only used in the Champlain and Vermont valleys, where the local coarse aggregate is nonreactive. There did not appear to be any relationship between condition of the concrete and local moisture conditions or relative exposure to sun or shade.

Petrographic Analysis Results

Analysis of thin sections under the petrographic microscope identified ASR distress in the form of thin, gel filled micro-fractures (generally less than 1μm in width) within the cement paste; wide (greater than 10μm in width) macro-fractures both within the cement paste and within aggregate particles; and, as gel filled air voids. In addition to ASR reaction products some samples exhibited the presence of ettringite filled air voids.

The degree of ASR distress was assigned values of Slight, Moderate and Severe based on the number of cracks, filled voids and also the magnitude of the cracks. Slightly distressed samples showed only few gel filled voids and/or very minor amounts of micro-cracking. Samples labeled as moderate showed numerous gel filled voids and either many thin micro-cracks or isolated zones of distress. Severely distressed samples exhibited ASR distress over much of the thin section sample and in many cases showed mega-cracking that traversed the length of the thin section slide and propagated through aggregate particles. In some cases, based on the relative degree of distress, combined terms were used such as Slight-to-Moderate and Moderate-to-Severe. A photomicrograph of a petrographic thin section slide showing ASR distress is shown in Figure 6. Photomicrographs of petrographic samples from all structures that showed evidence of ASR development are presented as Appendix C.

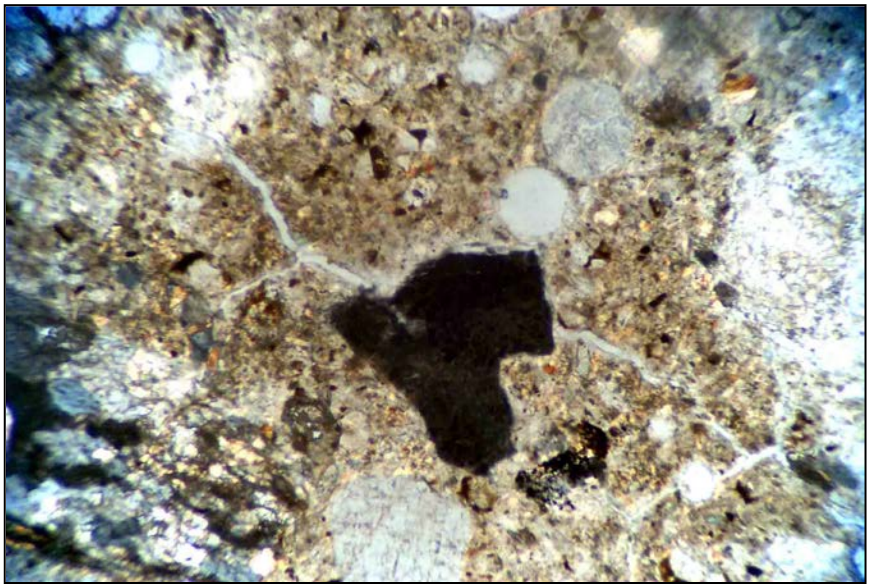

Figure 6 Photomicrograph showing ASR distress in the form of micro cracking.

Based on analysis of eighty-two samples, twenty-six samples from fourteen bridges showed evidence of possible ASR distress. Table 3 presents a matrix of the 27 bridges showing the mode of ASR occurrence and degree of ASR distress observed. Most of the distress was observed as micro-cracking within the cement paste however some of the samples showed ASR gel filled voids, macro-cracking and the possible presence of ettringite filled voids.

Correlation between field screening and petrographic analysis was not strong. There was a tendency for the petrographic analysis to detect more severe ASR than did the field screen. Surface weathering is a possible explanation for this lack of agreement. Petrographic samples were taken from core samples and provided the opportunity to examine unweathered concrete. There was no systematic petrographic sampling scheme and as a result, thin section samples represented various depths from the concrete surface. Since thin section samples collected from sample cores represent a very small fraction of the whole sample (thin section samples measure one-inch square by 30-microns in thickness), petrographic analysis techniques should be considered appropriate tools to help identify and characterize ASR development in Portland concrete but should not be considered a stand alone tool.

Table 3 Summary of Petrographic Analysis Results

TOWNSHIP	HIGHWAY	BRIDGE NUMBER	AGGREGATE SOURCE	MICRO-CRACKING (In Concrete Paste)	MACRO-CRACKING	GEL FILLED VOIDS	ETTRINGITE FILLED VOIDS	AGGREGATE CRACKING	OVERALL ASR DISTRESS
GROTON	U.S.-302	32	A010594	X	X	X		X	Moderate to Severe
GROTON	U.S.-302	35	A010594	X	X	X		X	Moderate to Severe
TOPSHAM	VT-25	17	A010594	X		X	X		Slight to Moderate
ANDOVER	Weston Rd.	7	A010595						None
CHESTER	VT-11	45	A010595						None
WINDHAM	VT-126	11	A010595	X		X			Slight
PLYMOUTH	VT-100	106	A020001						None
SHREWSBURY	VT-103	50	A020001						None
SHREWSBURY	VT-103	51	A020001						None
ARLINGTON	VT-7-A	15	A020002	X	X	X		X	Moderate to Severe
ARLINGTON	VT-313	5	A020002						None
ARLINGTON	VT-313	6	A020002	X		X			Slight to Moderate
BRIGHTON	VT-111	12	A020011	X		X			Slight
COVENTRY	U.S.-5	174	A020011	X	X	X	X	X	Moderate to Severe
HARTFORD	US-4	71	A020012						None
POMFRET	VT-166	15	A020012	X		X			Slight
TUNBRIDGE	VT-110	2	A020012						None
BRATTLEBORO	US-5	8	A020014						None
ESSEX	VT-289	13	A020018						None
ESSEX	VT-15	16	A020018	X		X		X	Slight to Moderate
MILTON	U.S.-2	17	A020018	X		X			Slight to Moderate
HARDWICK	VT-15	66	A020020	X	X	X		X	Moderate to Severe
JOHNSON	VT-15	33	A020020	X	X	X	X	X	Severe
WOLCOTT	VT-15	61	A020020	X	X	X		X	Severe
BARNET	US-5	121	A020021						None
BURKE	VT-5A	1	A020021						None
BURKE	VT-114	15	A020021						None

The degree of ASR distress observed in thin sections were assigned the following designations:

- None — No mega or micro-cracks, gel filled voids, or other evidence of ASR distress.
- Slight — Very minor amount of micro-cracking and/or few gel filled voids.
- Moderate — Many gel filled voids and/or micro-cracks or isolated zones of distress.
- Severe — Exhibits ASR distress over much of the thin section sample. Sample may contain mega-cracking that traverses the length of the thin section sample and propagation of cracks through aggregate particles.

The description modifier ‘to’ in Table 3 is used to describe observations that may relate to either category.

The degree of ASR distress listed in Tables 2 and 3, along with other information gathered during this study were evaluated and overall ASR distress designations were assigned to each bridge (Figure 7). This Figure shows a pattern that suggests severe to moderately severe ASR distress centered in the north-central portion of the state. Moderate ASR distress of bridges was noted in the upper Connecticut River Valley while slightly moderate to no ASR distress were observed in bridges in the Champlain Valley, Vermont Valley and southern portions of the state.

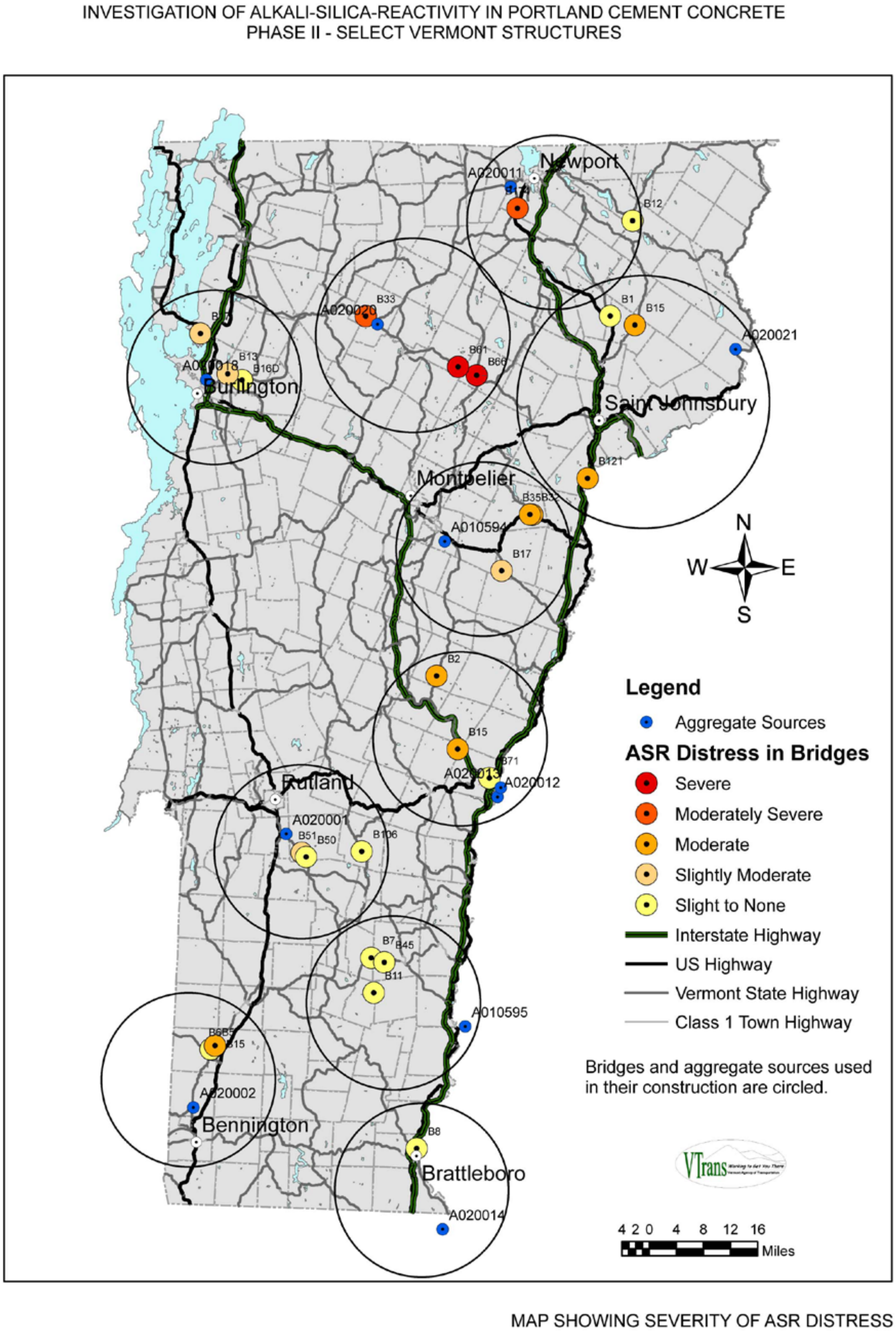

Figure 7 Map showing ASR distress in the bridges investigated during this study.

CONCLUSIONS

Based upon recommendations made in Phase I of the Investigation Of Alkali-Silica Reactivity In Portland Cement Concrete, Phase II was conducted consisting of the identification, sampling and testing of concrete from various parts of selected structures for the presence of ASR. The following conclusions were made:

- Twenty-seven bridges meeting the selection criteria were located. The selection criteria considered whether an aggregate came from a reactive source identified during Phase I, and whether the bridge was ten or more years old. Construction records were reviewed and, when possible, three bridges meeting the criteria were chosen for each aggregate source.
- Core samples were collected from horizontal and vertical surfaces at various locations on substructures and superstructure curbs. Coring proved difficult at some bridges due to access issues and limitation of the core drill machinery.
- Field screening results appeared to be influenced by the surface weathering of the concrete. This may have resulted in the underestimation of ASR development in the structures investigated.
- Based on visual observations and uranyl acetate screening techniques, three bridges were identified as being severely affected by ASR. Another two bridges were ranked as moderate, resulting in five bridges considered to be affected.
- Petrographic analysis identified five bridges as being severely affected by ASR and four others as moderate. These findings corroborated the visual observations.
- Based on a ranking from slight to severe ASR observed during field and laboratory testing, and visual observation of the general condition of the structures, a pattern has emerged showing affected structures in the north central portion of the state. Moderately severe ASR potential can be expected from the northern Connecticut Valley while other areas of the state do not appear to represent a strong potential for the development of ASR.
- The correlation between the level of ASR distress observed in Phase II with expansion results and observations in Phase I appears weak. The lack of a strong correlation may be due to the fact that screening locations and petrographic samples represent an extremely small portion of the structure. Another possible explanation is that ASR is dominantly influenced by fine aggregate properties. An increase in the number of sampling/testing locations may allow for a more representative assessment and provide sufficient data for statistical analysis.

RECOMMENDATIONS

- Use a concrete that mitigates ASR for all new VTrans transportation structures that may contain moderate and highly ASR reactive aggregate by:

  1. Using low alkali cement, typically 0.5 or lower.
  2. Supplementing a portion of the high alkali cement with mineral admixtures to lower the contributing alkali from the cement with fly ash, slag, silica fume or a combination of them.
  3. Test a lithium admixture mixed in with the fresh concrete for further consideration.

- Restrict moisture in all new and existing VTrans transportation structures. Three conditions are needed for the reaction to happen: moisture, alkali and reactive silica in the aggregate. By keeping the moisture out, the ASR reaction is prevented. This may mean waterproofing all accessible concrete surfaces, an example of which would be the back side of an abutment prior to backfilling.
- Possibly adopt a total alkali loading threshold, similar to Texas DOT, to help determine if and when mineral admixtures or lithium admixture would need to be used.
- Restrict use of reactive aggregate determined by AASHTO T 303 unless mitigation is included with mix design.
- Possibly use some sort of lithium treatment for existing structures affected by ASR. This may not be practical because there are no definitive studies or data that prove lithium topical treatments stop or slow the ASR development. A screening program would need to be developed to decide which bridges would benefit from it and the method used to topically apply the lithium. (PUBLICATION NO. FHWA-HRT-06-133 Chapter 5. Use of Lithium to Treat Existing ASR-Affected Structures 5.1 Laboratory Studies).
- In rehabilitation projects, use lithium treatment on old concrete prior to applying contiguous new concrete. ASR levels at the interface between old and new concrete should dictate lithium requirements.
- Consider an ASR screening program for all existing and new coarse and fine aggregates to be used in structural concrete.

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APPENDIX A

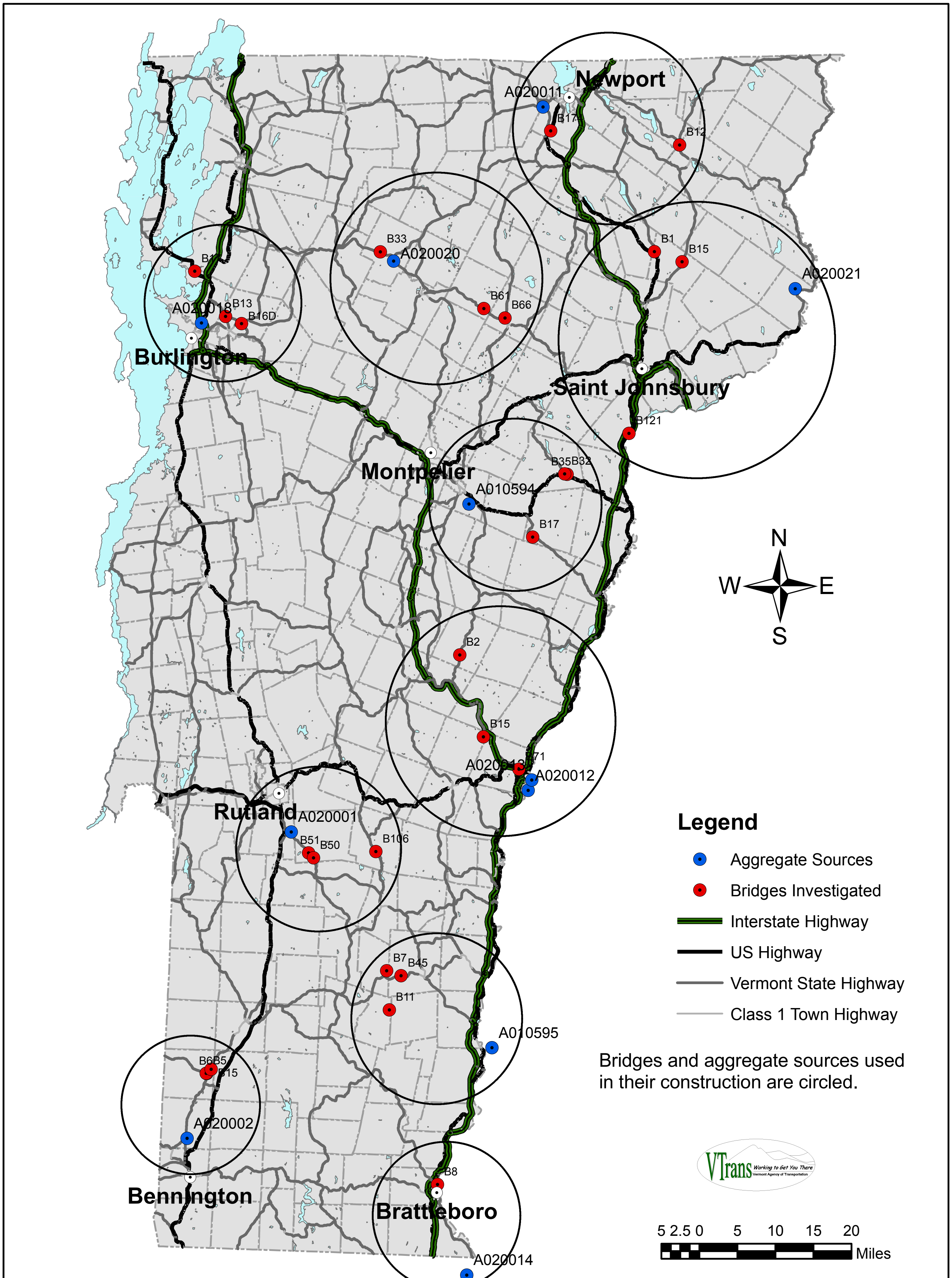
MAPS

Map Showing Aggregate Sources and Bridges Investigated During this Study

Map Showing Bedrock Geology of the State and Stone Aggregate Source Locations

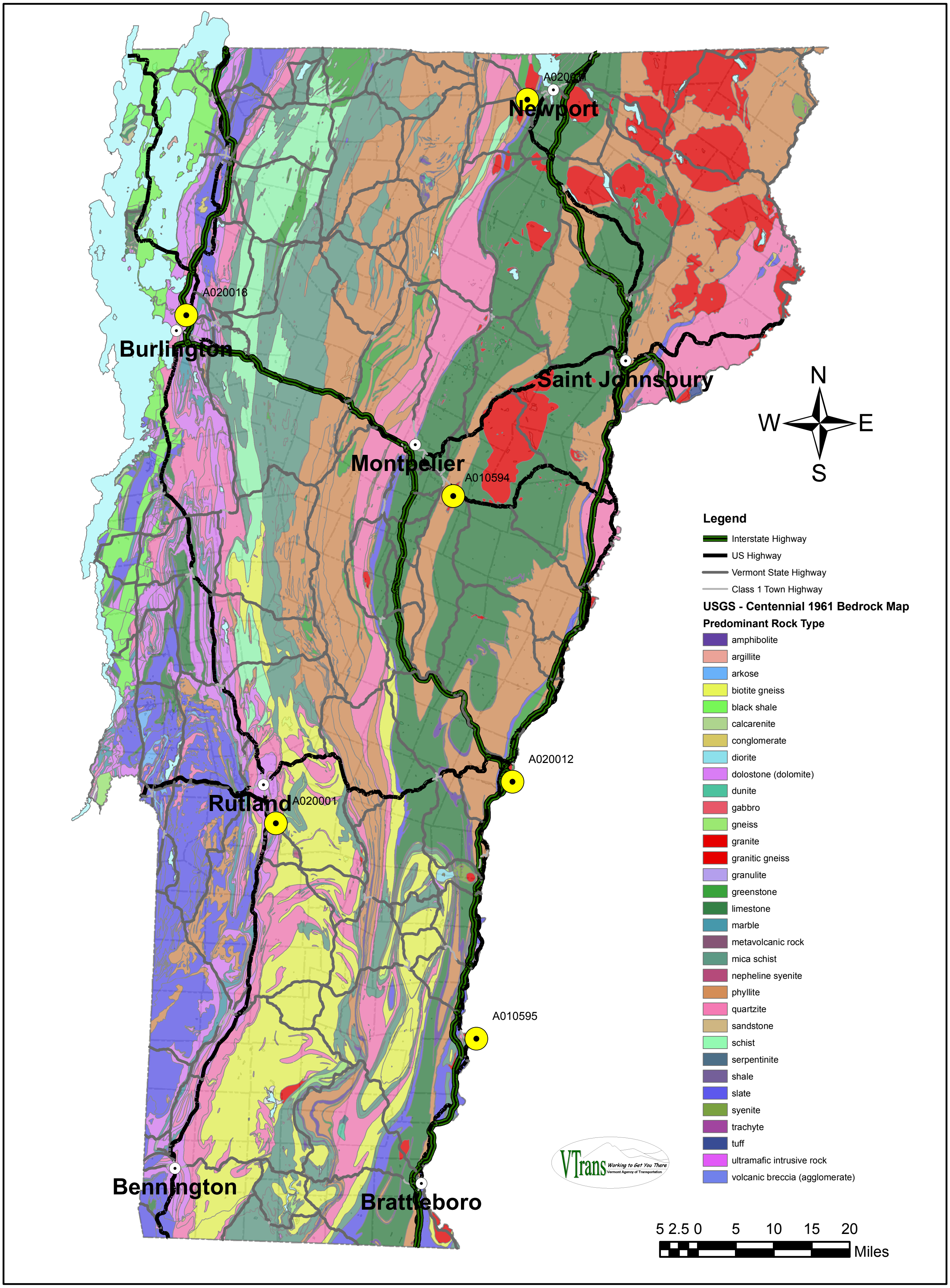
Map Showing Bedrock Geology of the State and Gravel Aggregate Source Locations

INVESTIGATION OF ALKALI-SILICA-REACTIVITY IN PORTLAND CEMENT CONCRETE
PHASE II - SELECT VERMONT STRUCTURES



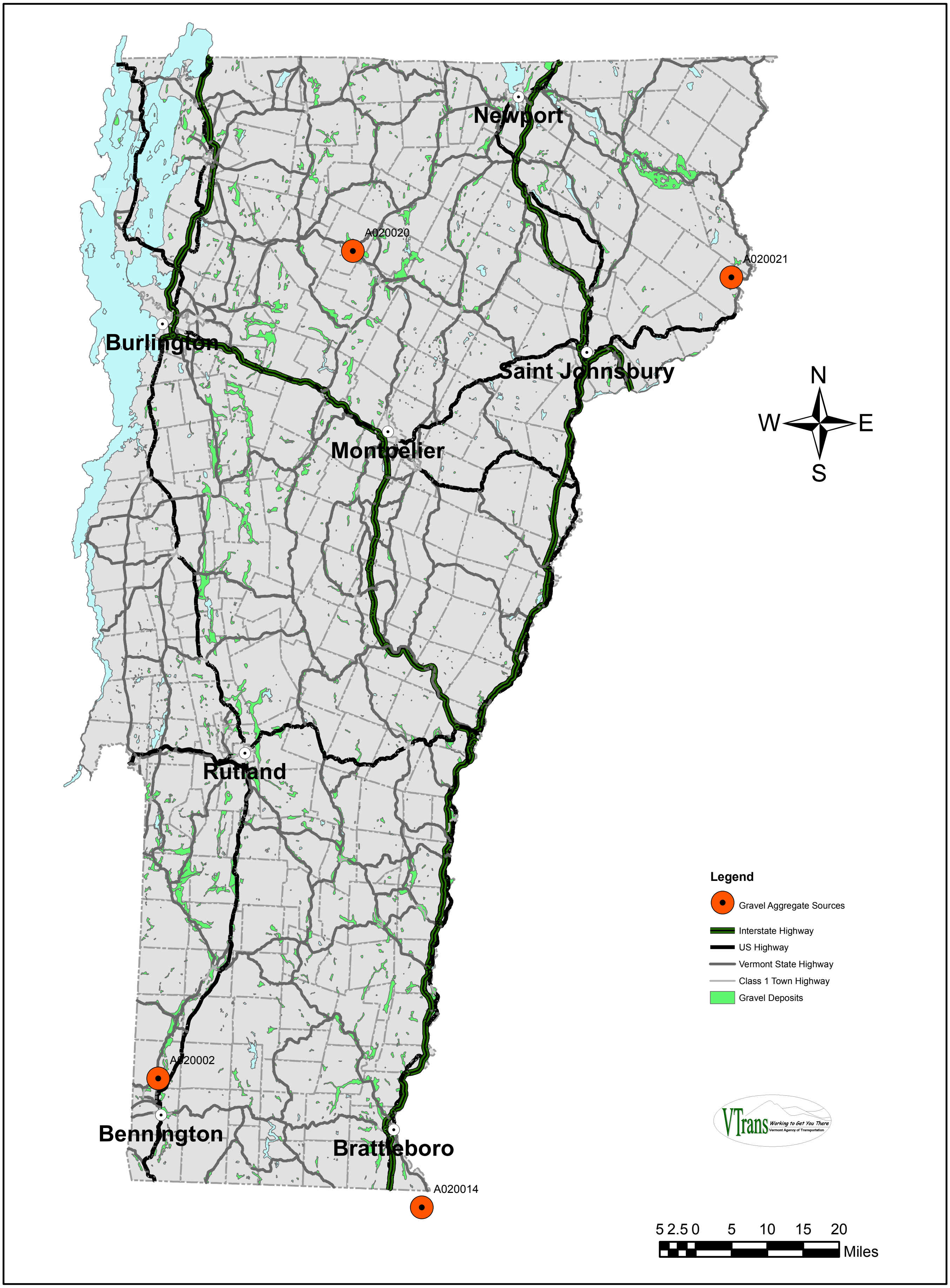
MAP SHOWING AGGREGATE SOURCES
AND BRIDGES INVESTIGATED
DURING THIS STUDY

INVESTIGATION OF ALKALI-SILICA-REACTIVITY IN PORTLAND CEMENT CONCRETE
PHASE II - SELECT VERMONT STRUCTURES



MAP SHOWING BEDROCK GEOLOGY
OF THE STATE AND STONE
AGGREGATE SOURCE LOCATIONS

INVESTIGATION OF ALKALI-SILICA-REACTIVITY IN PORTLAND CEMENT CONCRETE
PHASE II - SELECT VERMONT STRUCTURES



MAP SHOWING GRAVEL DEPOSITS
OF THE STATE AND GRAVEL
AGGREGATE SOURCE LOCATIONS

APPENDIX B

Uranyl Acetate Fluorescence Field Screening Results

URANYL ACETATE FLUORESCENCE FIELD SCREENING RESULTS

Town	Highway	Bridge #	Constructed	Location	Overall Activity	Visible Expansion	Reaction Rims	Gel Filled Cracks/Voids	Map Cracking	Comments
Andover	Weston Rd.	7	1980	NW Corner	None	None	None	None	None	Some rebar corrosion but practically no ASR.
Andover	Weston Rd.	7	1980	SW Corner	Very slight	None	None	None	None	
Andover	Weston Rd.	7	1980	NE Corner	Very slight	None	None	None	None	
Andover	Weston Rd.	7	1980	SE Corner	Slight	None	2	None	None	
Andover	Weston Rd.	7	1980	Overall	Very slight	None	None	None	None	Looks like a brand new bridge.
Arlington	VT 7A	15	1985	NW Corner	Moderate	Joint extruded	None	Numerous	Moderate	Gel filled voids up to 4mm.
Arlington	VT 7A	15	1985	SW Corner	Slight	None	None	2	Slight	Minor settling cracks.
Arlington	VT 7A	15	1985	NE Corner	Moderate-Severe	On face	Numerous	Numerous	Severe	
Arlington	VT 7A	15	1985	SE Corner	Moderate	Joint extruded	None	Numerous	Severe	
Arlington	VT 7A	15	1985	Overall	Moderate	Common	Few	Numerous	Severe	Moderate activity and expansion; not bad for a bridge this age.
Arlington	VT 313	5	1986	NW Corner	Slight	2in displacement	2	1	Slight	
Arlington	VT 313	5	1986	SW Corner	Moderate	Displacement/extrusion	None	Numerous	Moderate	Deck also shows deterioration in this area.
Arlington	VT 313	5	1986	NE Corner	Slight	None	None	None	Moderate	
Arlington	VT 313	5	1986	SE Corner	Slight	2in displacement	3	None	Severe	
Arlington	VT 313	5	1986	Overall	Slight	Common	Few	Few	Moderate	A lot of expansive damage for such low fluorescence. Possible ACR?
Arlington	VT 313	6	1986	NW Corner	None	None	None	None	None	
Arlington	VT 313	6	1986	SW Corner	Slight	None	2	None	Slight	
Arlington	VT 313	6	1986	NE Corner	None	None	None	None	None	Looks brand new.
Arlington	VT 313	6	1986	SE Corner	None	None	None	None	None	
Arlington	VT 313	6	1986	Overall	Very slight	None	Few	None	Very slight	Looks like a new bridge; forms could have come off last week!
Barnet	US 5	121	1978	Pier, mid-span	Slight	None	None	2	Moderate	Patched area due to severe rebar corrosion.
Barnet	US 5	121	1978	SW Corner	Slight	None	None	None	None	Patched area.
Barnet	US 5	121	1978	NE Corner	Severe	Pop outs	Numerous	Numerous	Severe	Older concrete; probably more representative of this structure.
Barnet	US 5	121	1978	SE Corner	Moderate	None	None	Numerous	Moderate	Activity appears to be in fine aggregate
Barnet	US 5	121	1978	Overall	Moderate	Common	Moderate	Moderate	Moderate	Bridge is in trouble. Very bad rebar corrosion along with ASR and freeze-thaw.
Brattleboro	US 5	8	1987	NW Corner	None	None	None	None	Very slight	
Brattleboro	US 5	8	1987	SW Corner	Very slight	None	None	3	None	
Brattleboro	US 5	8	1987	NE Corner	None	None	None	None	None	
Brattleboro	US 5	8	1987	SE Corner	None	None	None	None	None	
Brattleboro	US 5	8	1987	Overall	Very slight	None	None	Few	Very slight	Looks like a new bridge.
Burke	US 5A	1	1986	NW Corner	Very slight	Pop outs	None	None	Very slight	
Burke	US 5A	1	1986	SW Corner	Very slight	None	1	None	None	
Burke	US 5A	1	1986	NE Corner	Very slight	None	1	2	Very slight	
Burke	US 5A	1	1986	SE Corner	None	None	None	None	None	
Burke	US 5A	1	1986	Overall	Very slight	Very low	Very few	Very few	Very slight	Looks like a new bridge.
Burke	VT 114	15	1990	NW Corner	None	None	None	None	None	
Burke	VT 114	15	1990	SW Corner	None	None	None	None	None	
Burke	VT 114	15	1990	NE Corner	Very slight	None	None	10, very small	Very slight	
Burke	VT 114	15	1990	SE Corner	Very slight	None	None	2	None	
Burke	VT 114	15	1990	Overall	Very slight	None	None	Very few	Very slight	Very good condition.
Chester	VT 11	45	1983	NW Corner	None	None	None	None	None	
Chester	VT 11	45	1983	SW Corner	None	None	None	None	Very slight	
Chester	VT 11	45	1983	NE Corner	None	None	None	None	None	
Chester	VT 11	45	1983	SE Corner	Very slight	None	None	1	Very slight	
Chester	VT 11	45	1983	Overall	Very slight	None	None	Very few	Very slight	Looks like the forms were just taken off. Fine aggregate very scarce.
Coventry	US 5	174	1981	NW Corner	None	None	None	None	None	
Coventry	US 5	174	1981	SW Corner	Slight	None	1	Few	Moderate	
Coventry	US 5	174	1981	NE Corner	Slight	Pop outs	1	Numerous	Moderate	
Coventry	US 5	174	1981	SE Corner	Very slight	None	1	None	Slight	
Coventry	US 5	174	1981	Overall	Slight	Low	Few	Few	Moderate	Piers good; deck + walls showing some deterioration.
Shrewsbury	VT 103	50	1992	NW Corner	None	None	None	None	Very slight	
Shrewsbury	VT 103	50	1992	SW Corner	None	None	None	None	Very slight	
Shrewsbury	VT 103	50	1992	NE Corner	None	Impact pop out	None	None	Very slight	
Shrewsbury	VT 103	50	1992	SE Corner	Very slight	None	None	2	Moderate	

URANYL ACETATE FLUORESCENCE FIELD SCREENING RESULTS

Shrewsbury	VT 103	50	1992	Overall	Very slight	None	None	Very few	Very slight	Good condition. Aggregate appears to be marble.
Essex	VT 289	13	1993	NW Corner	Slight	None	2	1	Very slight	
Essex	VT 289	13	1993	SW Corner	Very slight	None	None	2	Very slight	
Essex	VT 289	13	1993	NE Corner	Very slight	None	None	1	Very slight	
Essex	VT 289	13	1993	SE Corner	Slight	None	3	1	Slight	
Essex	VT 289	13	1993	Overall	Very slight	None	Few	Few	Very slight	Generally good condition. Aggregate may be slow reactive.
Essex	VT 289	16	1993	NW Corner	Very slight	None	1	Few	Very slight	
Essex	VT 289	16	1993	SW Corner	None	None	None	None	Very slight	
Essex	VT 289	16	1993	NE Corner	Very slight	None	1	None	Very slight	
Essex	VT 289	16	1993	SE Corner	None	None	None	None	Very slight	
Essex	VT 289	16	1993	Overall	Very slight	None	Very few	Very few	Very slight	Good condition.
Groton	US 302	32	1991	NW Corner	Slight	None	Few	Numerous, small	Slight	
Groton	US 302	32	1991	SW Corner	Slight	None	Few	Numerous, small	Slight	
Groton	US 302	32	1991	NE Corner	Slight	None	1	Few	Slight	
Groton	US 302	32	1991	SE Corner	Slight- Moderate	None	Numerous	Few	Moderate	
Groton	US 302	32	1991	Overall	Slight	None	Few	Common	Slight	Overall good condition.
Groton	US 302	35	1980	NW Corner	Slight	None	2	Few	Slight	
Groton	US 302	35	1980	SW Corner	Slight	None	None	Few	Slight	
Groton	US 302	35	1980	NE Corner	None	None	None	None	Very slight	
Groton	US 302	35	1980	SE Corner	Slight	None	Few	Few	Slight	
Groton	US 302	35	1980	Overall	Slight	None	Few	Few	Slight	Mostly good condition. Good air void system.
Hardwick	VT 15	66	1984	NW Corner	Severe	General swelling	Very numerous	Very numerous	Very severe	
Hardwick	VT 15	66	1984	SW Corner	Severe	Bulging and pop outs	Very numerous	Very numerous	Very severe	
Hardwick	VT 15	66	1984	NE Corner	No access	No access	No access	No access	No access	
Hardwick	VT 15	66	1984	SE Corner	Very severe	Deck displaced	Very numerous	Very numerous	Very severe	
Hardwick	VT 15	66	1984	Overall	Severe	Ubiquitous	Very numerous	Very numerous	Very severe	Bridge is in very bad condition.
Hartford	US 4	71	1986	NW Corner	Very slight	None	1	1	Very slight	
Hartford	US 4	71	1986	SW Corner	Very slight	None	1	None	None	
Hartford	US 4	71	1986	NE Corner	Slight-Moderate	Pop outs	Few	2	Slight	
Hartford	US 4	71	1986	SE Corner	Slight	None	3	1	Slight	
Hartford	US 4	71	1986	Overall	Slight	Low	Few	Few	Slight	Most cracking and pop outs look like freeze-thaw damage. Good condition.
Johnson	VT 15	33	1988	NW Corner	Slight	None	1	Few	Slight	
Johnson	VT 15	33	1988	SW Corner	Slight-Moderate	None	Few	Numerous	Slight-Moderate	
Johnson	VT 15	33	1988	NE Corner	No Access	No Access	No Access	No Access	No Access	
Johnson	VT 15	33	1988	SE Corner	Slight	None	1	None	Moderate	
Johnson	VT 15	33	1988	Overall	Slight	None	Few	Few	Slight-Moderate	Most cracking appears due to freeze-thaw.
Milton	US 2	17	1980	NW Corner	Slight	None	2	1	Slight-Moderate	
Milton	US 2	17	1980	SW Corner	Slight-Moderate	None	2	Numerous, small	Moderate	
Milton	US 2	17	1980	NE Corner	Very slight	None	None	1	Slight	
Milton	US 2	17	1980	SE Corner	Slight	None	None	Few	Slight	
Milton	US 2	17	1980	Overall	Slight	None	Few	Few	Slight	Good condition, minor activity.
Morgan	VT 111	12	Unknown	NW Corner	None	None	None	None	None	
Morgan	VT 111	12	Unknown	SW Corner	Slight	None	1	2	Very slight	
Morgan	VT 111	12	Unknown	NE Corner	None	None	None	None	Very slight	
Morgan	VT 111	12	Unknown	SE Corner	Very slight	None	1	None	Very slight	
Morgan	VT 111	12	Unknown	Overall	Very slight	None	Very few	Very few	Very slight	Good condition, only damage is a settling crack with associated carbonation.
Plymouth	VT 100	106	1975	NW Corner	Very slight	None	None	None	Very slight	
Plymouth	VT 100	106	1975	SW Corner	Slight	None	None	Few	Slight	
Plymouth	VT 100	106	1975	NE Corner	Slight	None	None	3	Slight	
Plymouth	VT 100	106	1975	SE Corner	Very slight	None	None	None	Very slight	Very good condition.
Plymouth	VT 100	106	1975	Overall						
Pomfret	North Pomfret Rd.	15	1983	NW Corner	Moderate	Swelling on wall	Very Numerous	Few	Moderate	
Pomfret	North Pomfret Rd.	15	1983	SW Corner	Slight	None	2	None	Slight	
Pomfret	North Pomfret Rd.	15	1983	NE Corner	Slight	None	1	1	Slight	
Pomfret	North Pomfret Rd.	15	1983	SE Corner	Slight	None	Numerous	None	Slight	
Pomfret	North Pomfret Rd.	15	1983	Overall	Slight	Low	Numerous	Few	Slight	Most activity on one corner - exposure related?
Shrewsbury	VT 103	51	1979	NW Corner	Very slight	2in Displacement	None	None	Slight	

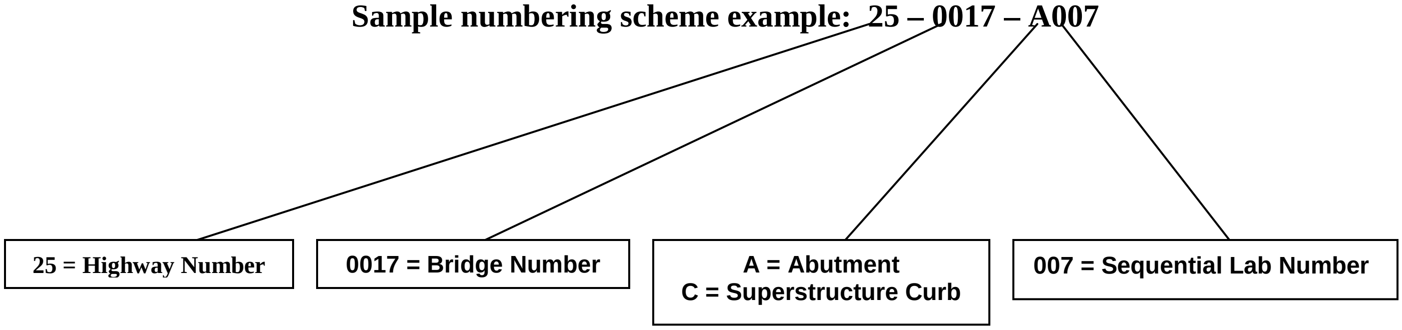
URANYL ACETATE FLUORESCENCE FIELD SCREENING RESULTS

Shrewsbury	VT 103	51	1979	SW Corner	Slight	None	1	None	Slight	
Shrewsbury	VT 103	51	1979	NE Corner	Moderate	None	2	Few	Slight	
Shrewsbury	VT 103	51	1979	SE Corner	Slight-Moderate	None	None	Numerous	Slight	
Shrewsbury	VT 103	51	1979	Overall	Slight-Moderate	None	Few	Few	Slight	Entire bridge deck displaced 2in. Abundant ASR gel in cores, nearly absent at surface.
Topsham	VT 25	17	1985	NW Corner	Moderate	None	Numerous	Numerous	Slight	
Topsham	VT 25	17	1985	SW Corner	Slight-Moderate	None	1	Numerous	Moderate	
Topsham	VT 25	17	1985	NE Corner	Slight	None	None	Numerous	Slight	
Topsham	VT 25	17	1985	SE Corner	Slight	Pop outs	3	1	Moderate	
Topsham	VT 25	17	1985	Overall	Slight	Low	Moderate	Numerous	Slight-Moderate	Seems to be in early stages of ASR expansion. Deck is lightweight aggregate.
Tunbridge	VT 110	2	1987	NW Corner	Moderate	None	Numerous	Few	Moderate	
Tunbridge	VT 110	2	1987	SW Corner	Moderate	Pop outs	Numerous	Few	Slight-Moderate	
Tunbridge	VT 110	2	1987	NE Corner	Moderate	Pop outs	Numerous	Numerous	Moderate	
Tunbridge	VT 110	2	1987	SE Corner	Slight	None	Numerous	None	Slight-Moderate	
Tunbridge	VT 110	2	1987	Overall	Moderate	Common	Numerous	Few	Moderate	Fair to good condition; ASR beginning to accelerate.
Windham	VT 121	11W	1978	NW Corner	Very slight	None	1, faint	None	Very slight	
Windham	VT 121	11W	1978	SW Corner	None	None	None	None	None	
Windham	VT 121	11W	1978	NE Corner	Not Tested	Not Tested	Not Tested	Not Tested	None	
Windham	VT 121	11W	1978	SE Corner	None	None	None	None	None	
Windham	VT 121	11W	1978	Overall	Very slight	None	Very few	None	Very slight	Looks like a new bridge; excellent condition.
Wolcott	VT 15	61	1985	NW Corner	Moderate	None	Numerous	2	Slight-Moderate	
Wolcott	VT 15	61	1985	SW Corner	Severe	Pop outs	Numerous	Numerous	Severe	
Wolcott	VT 15	61	1985	NE Corner	Slight	None	2	Few	Slight	
Wolcott	VT 15	61	1985	SE Corner	Moderate	Pop outs	Numerous	Numerous	Moderate	
Wolcott	VT 15	61	1985	Overall	Moderate	Common	Numerous	Numerous	Moderate	Severe deterioration in spots, other spots look good.

APPENDIX C

Petrographic Analysis Photomicrographs

Sample numbering scheme example: 25 – 0017 – A007



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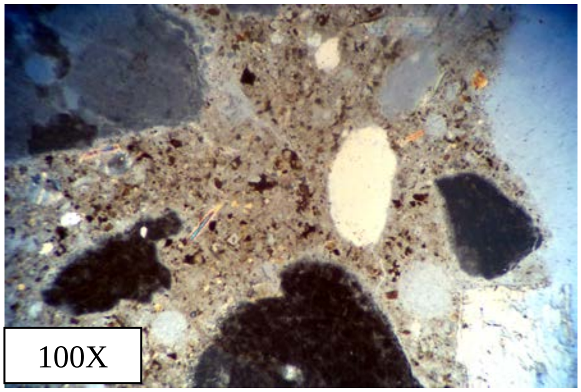
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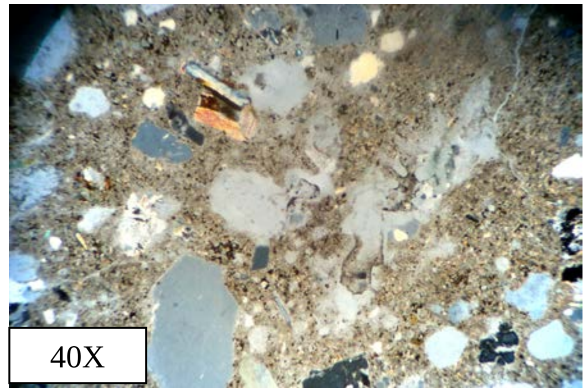
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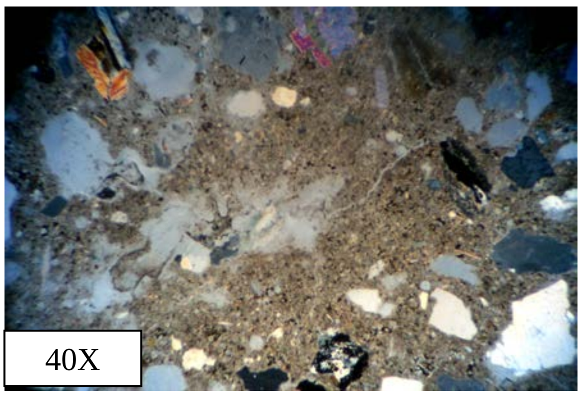
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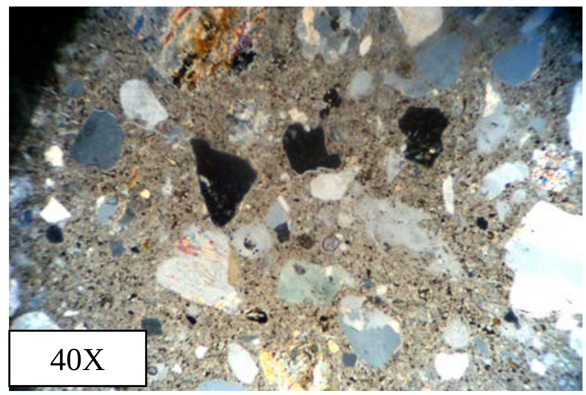
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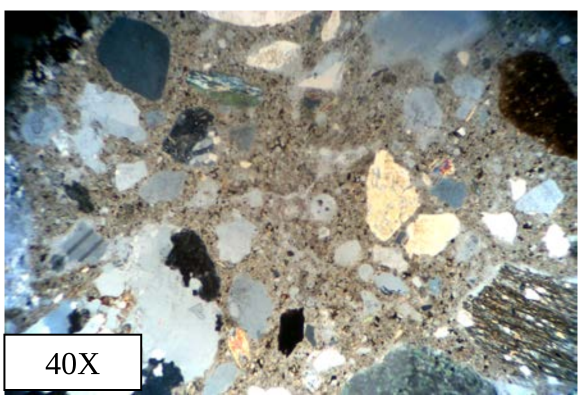
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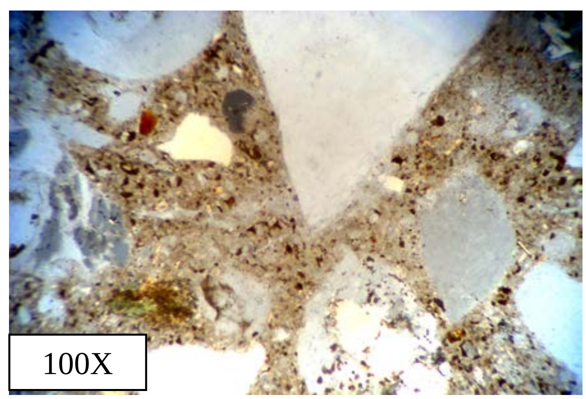
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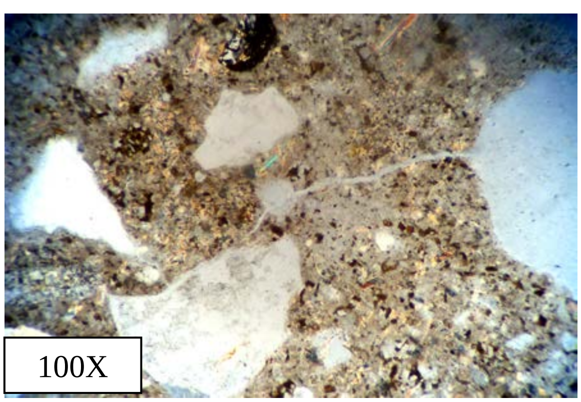
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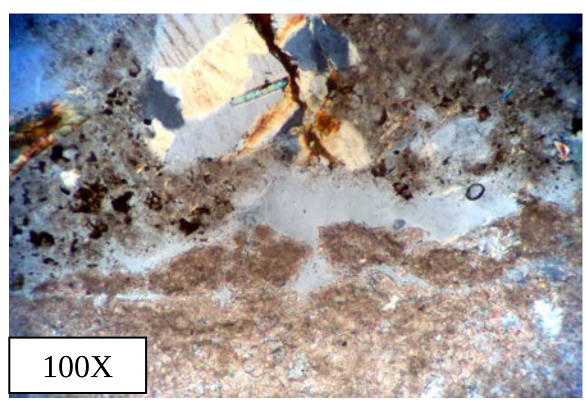
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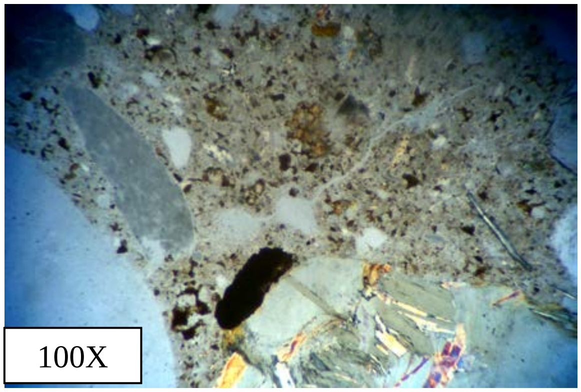
SAMPLE 2-0017-A019 (Cont.)



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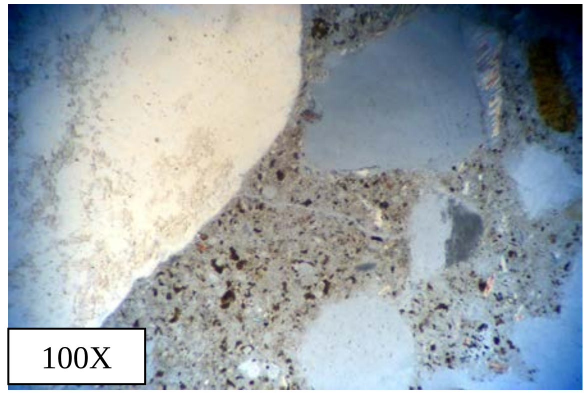

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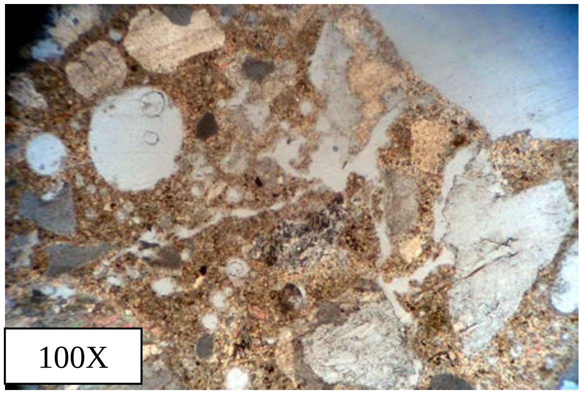
SAMPLE 2-0017-C021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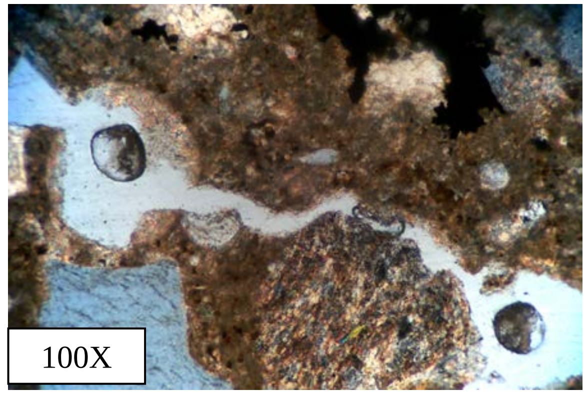
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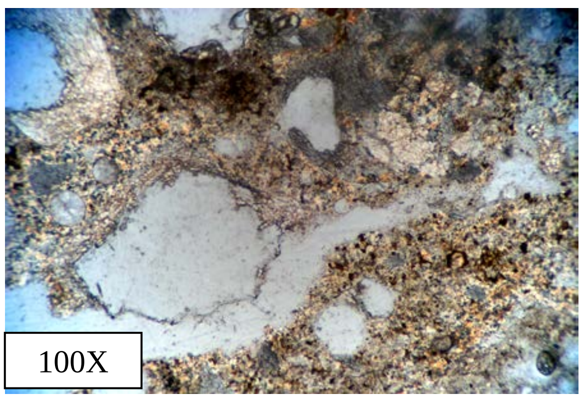
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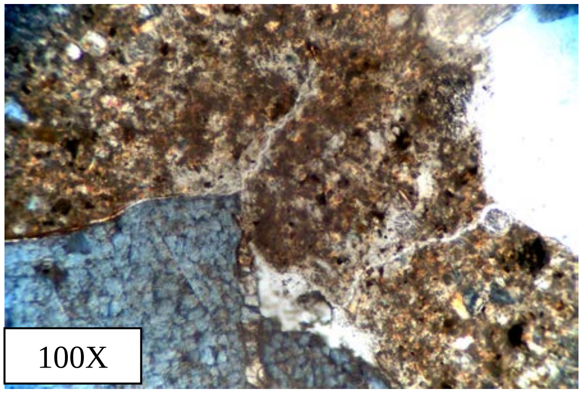
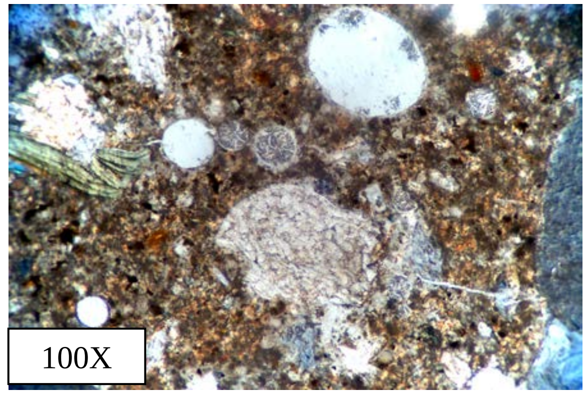
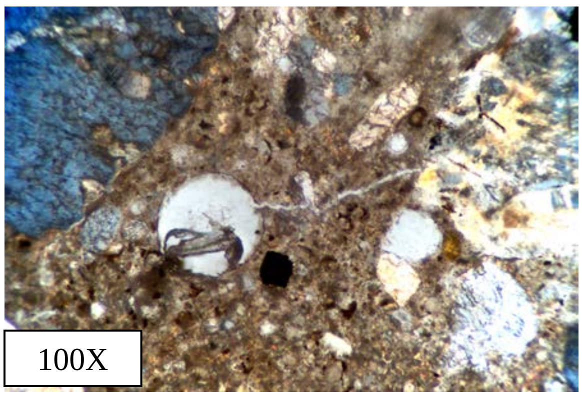
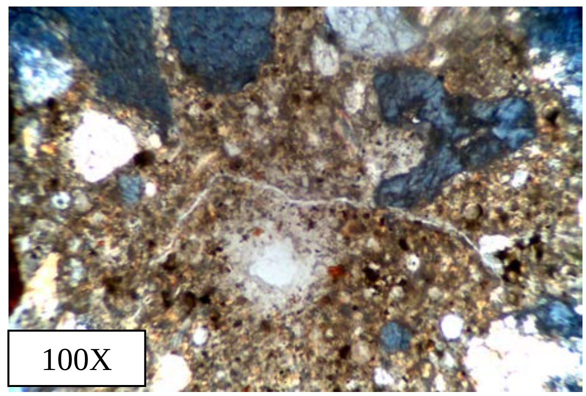
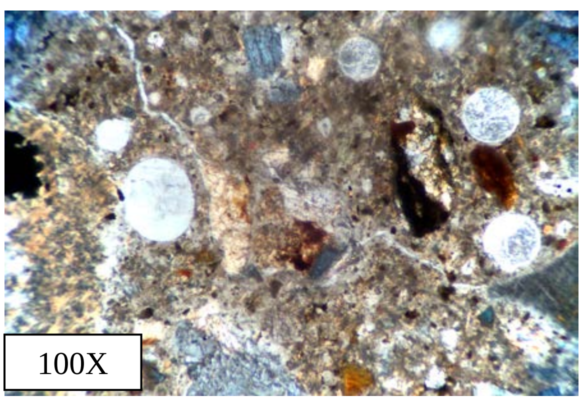
SAMPLE 5-0174-A028

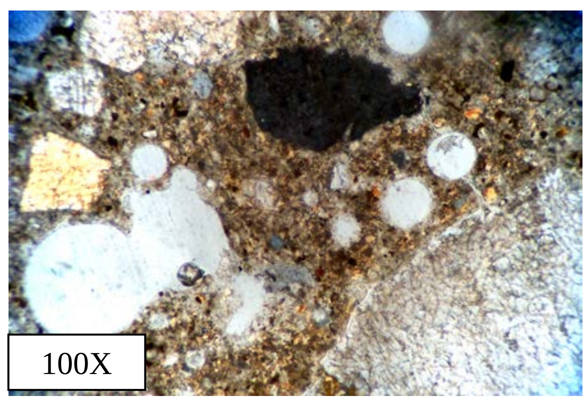


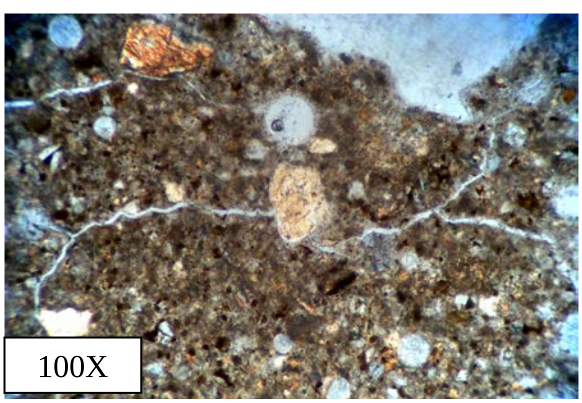


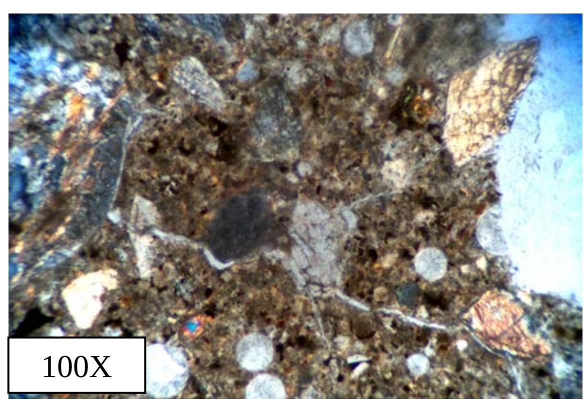




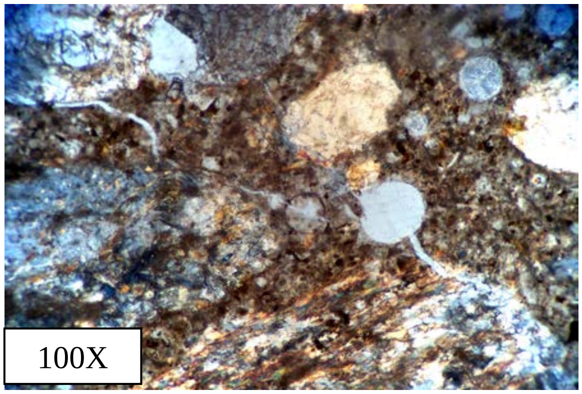


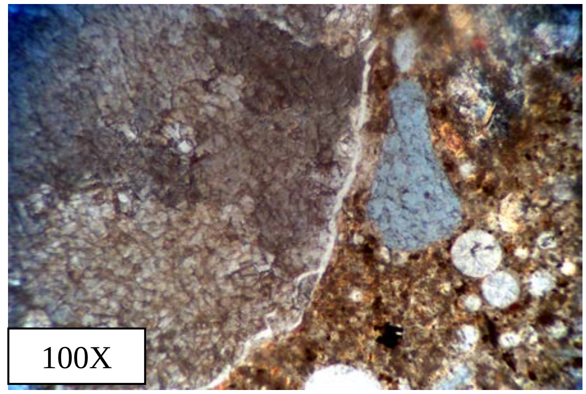


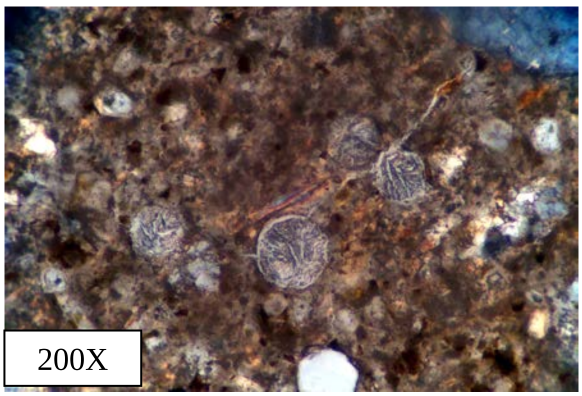




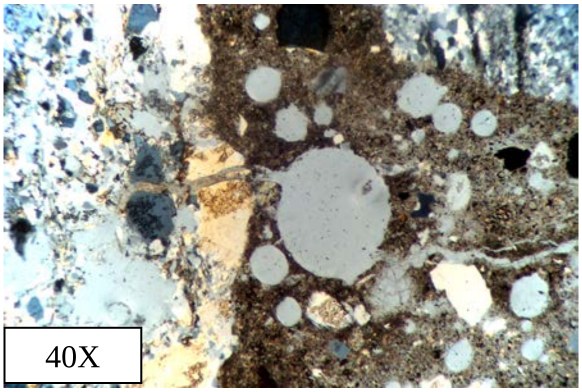
SAMPLE 5-0174-A028 (Cont.)







SAMPLE 5-0174-A029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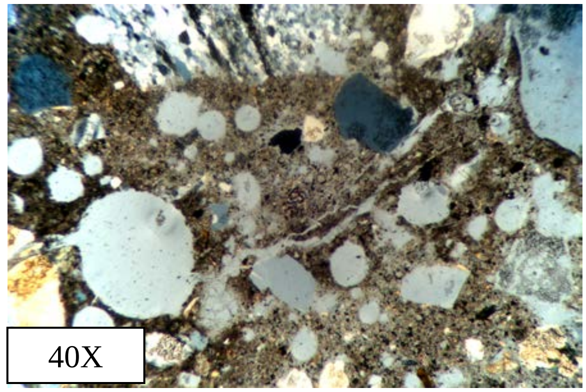
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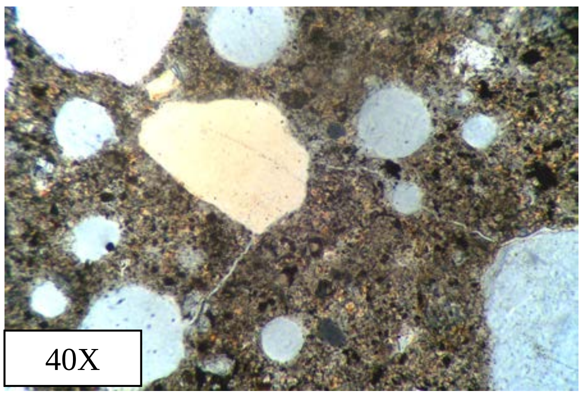
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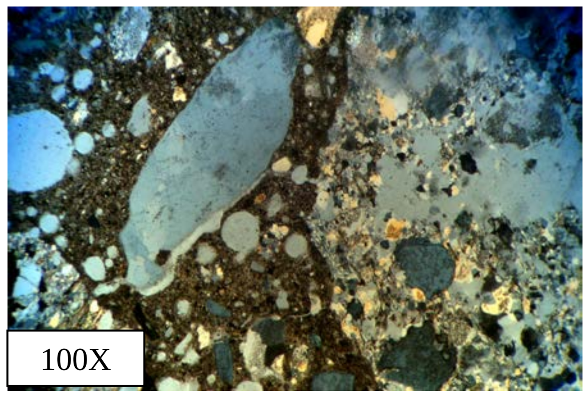
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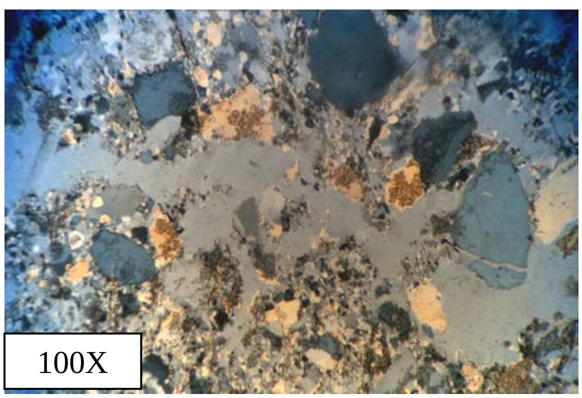
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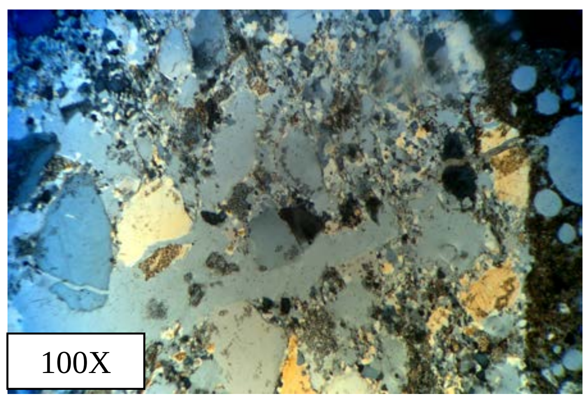
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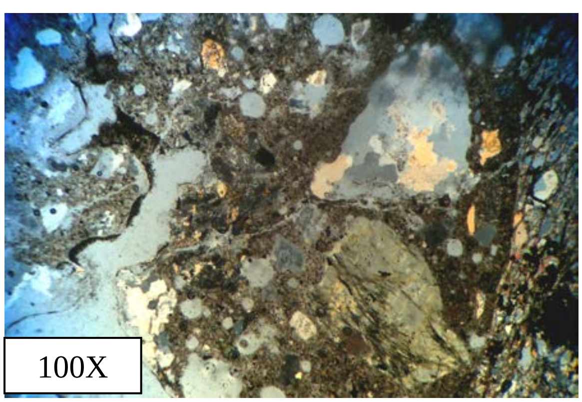
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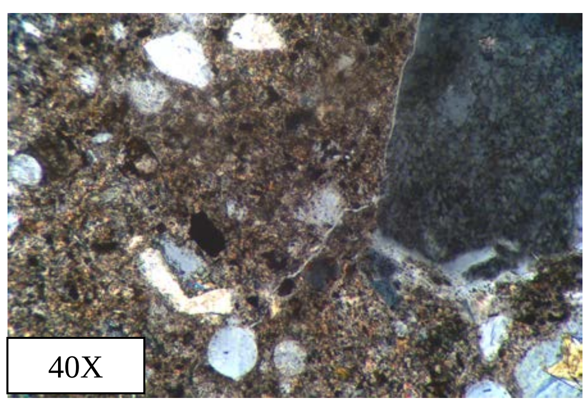
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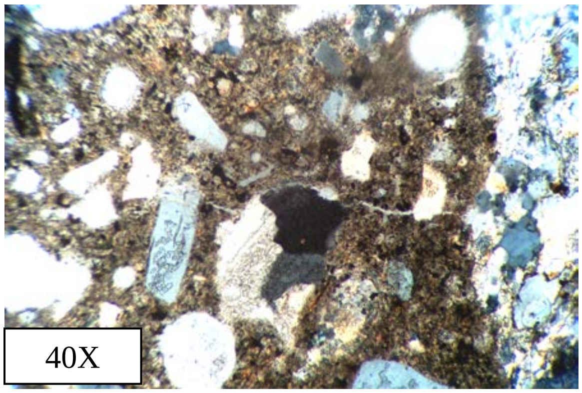
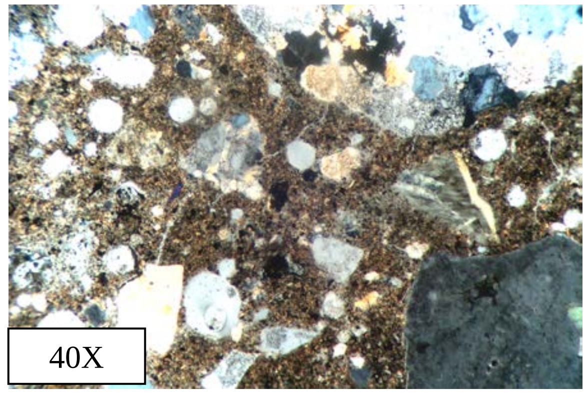
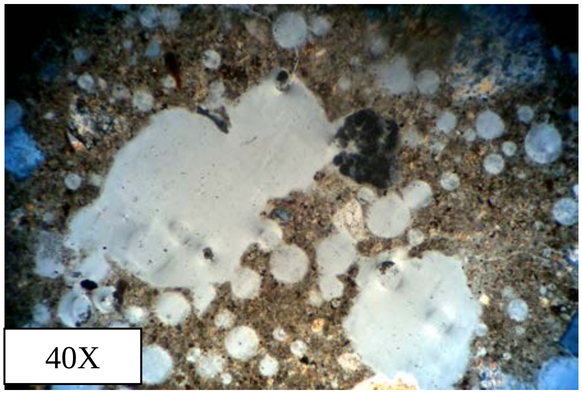
SAMPLE 5-0174-A029 (Cont.)





SAMPLE 5-0174-C030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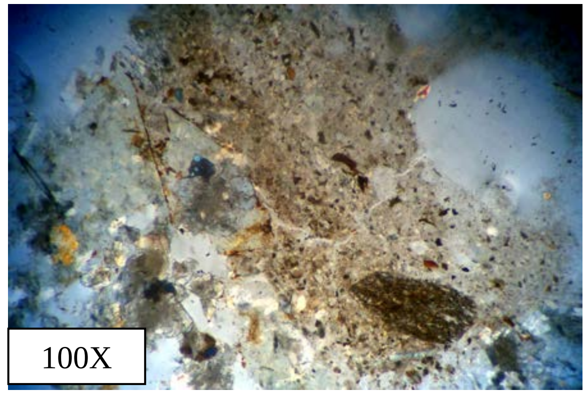
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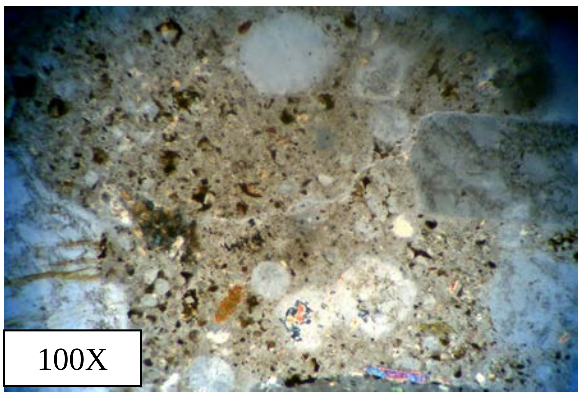
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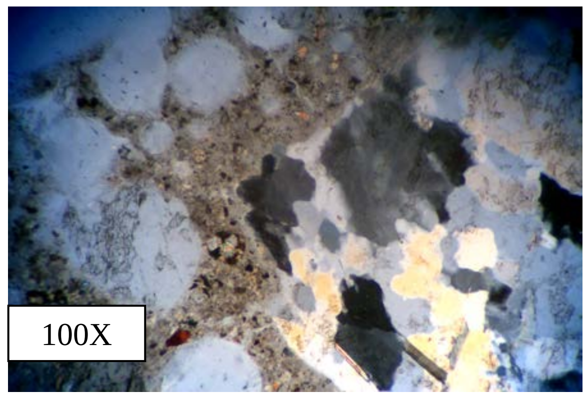
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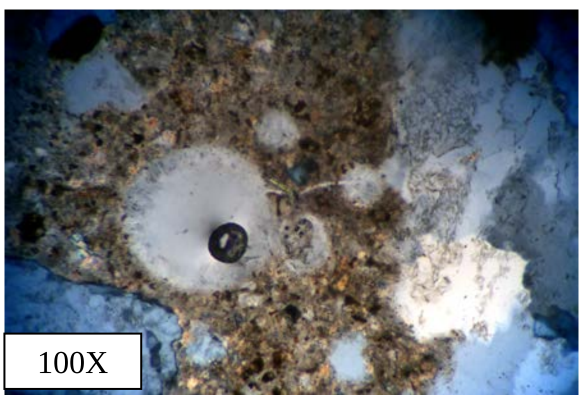
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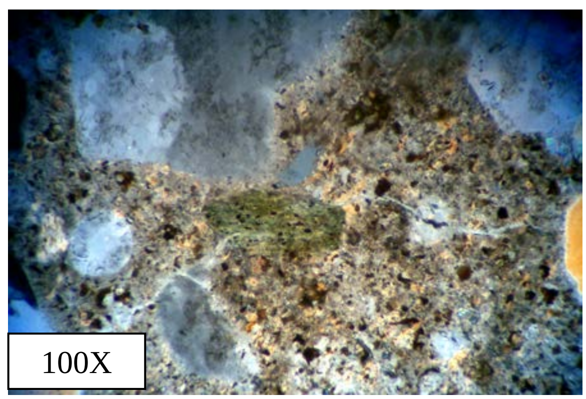
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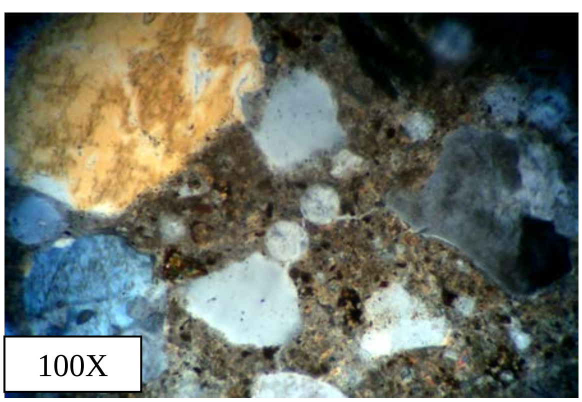
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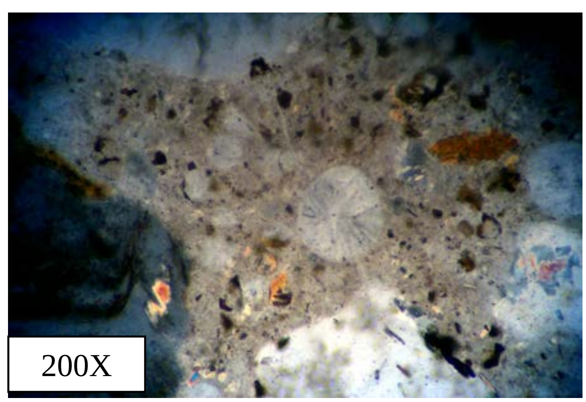
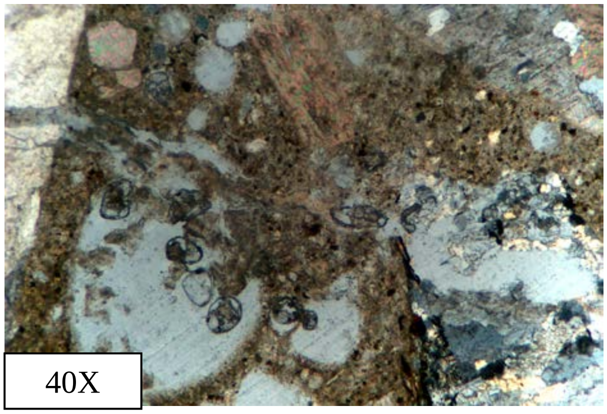
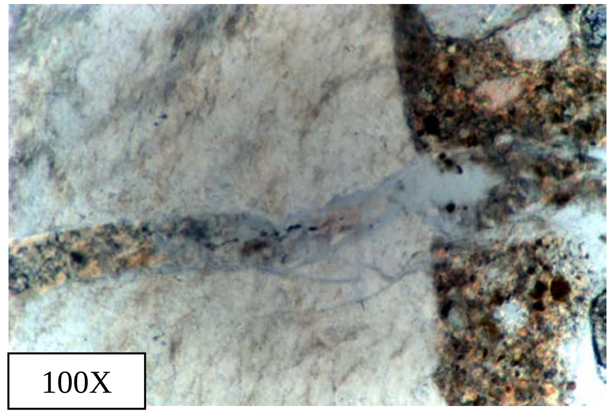
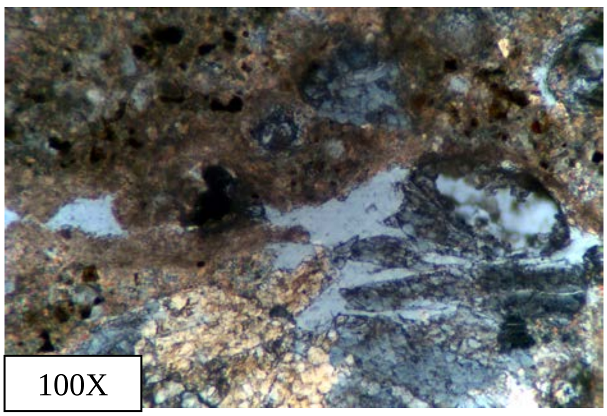

200X

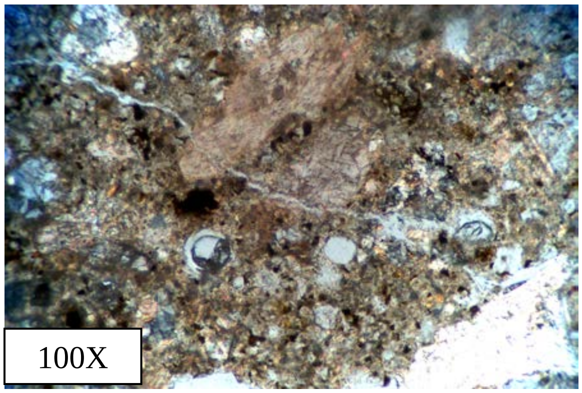
SAMPLE 7A-0015-A071

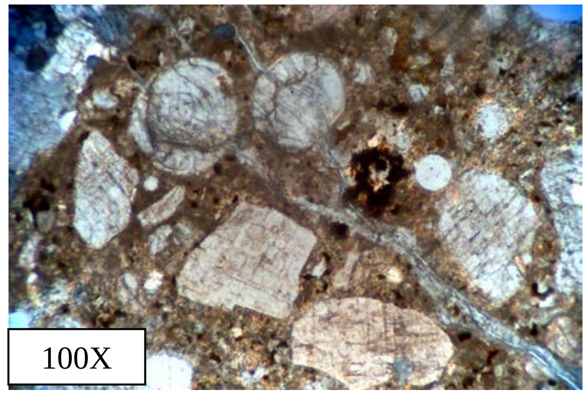


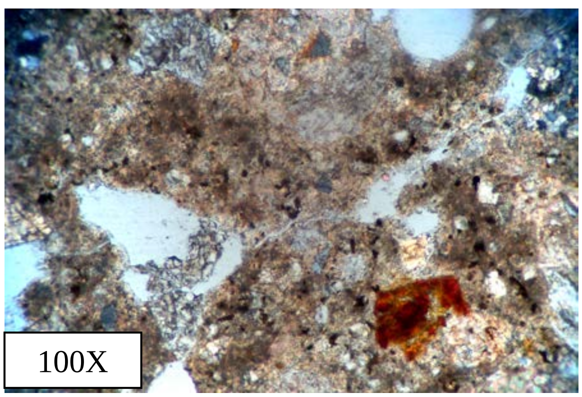


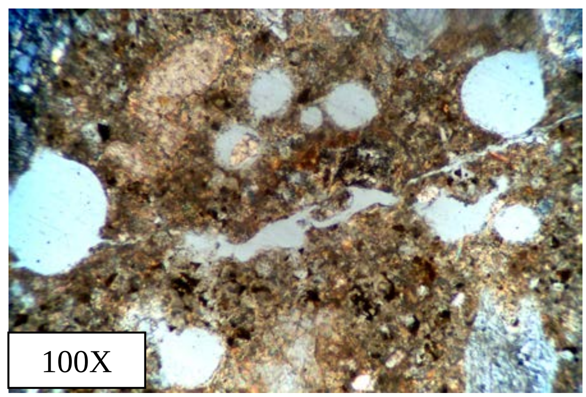


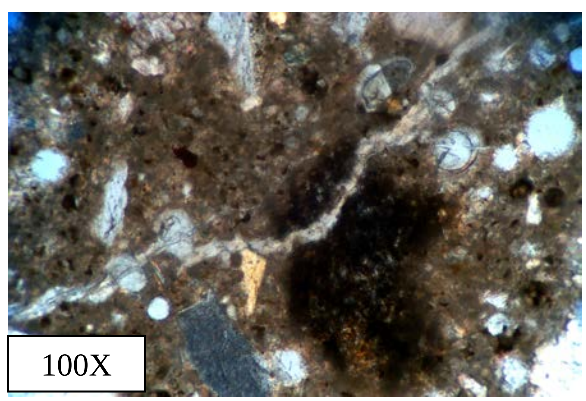
SAMPLE 7A-0015-C072



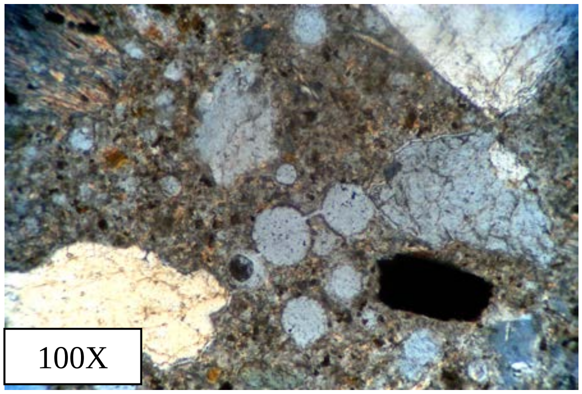


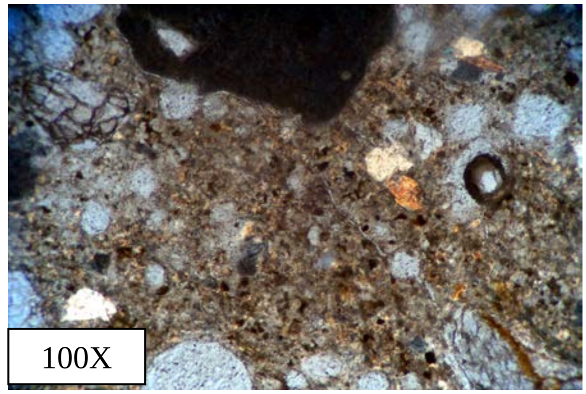


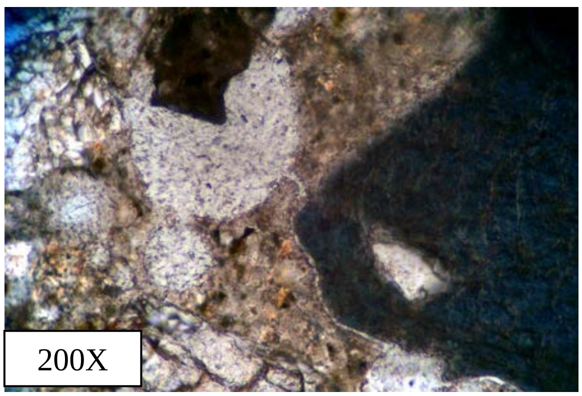


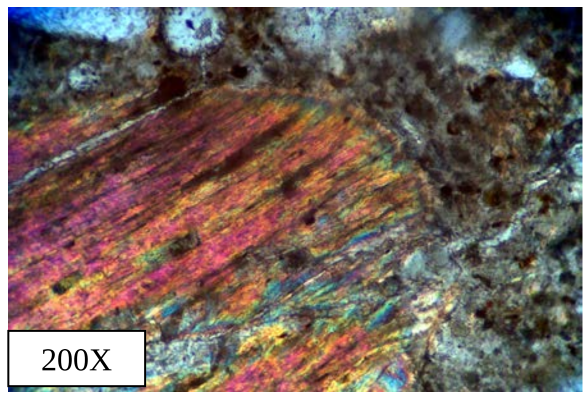


SAMPLE 15-0016-A022

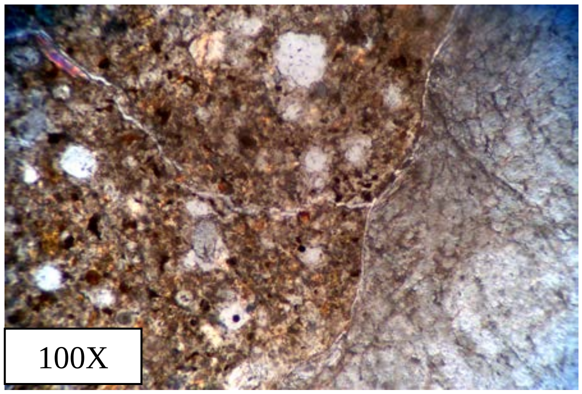


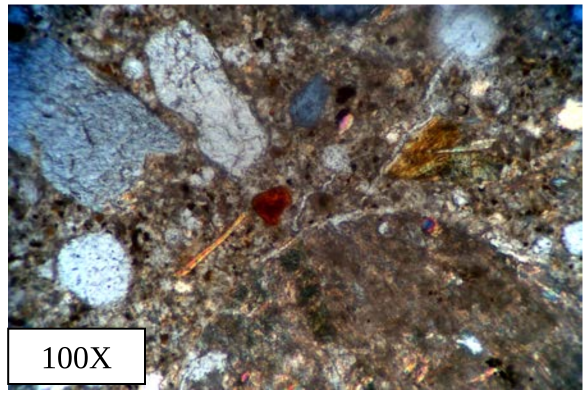


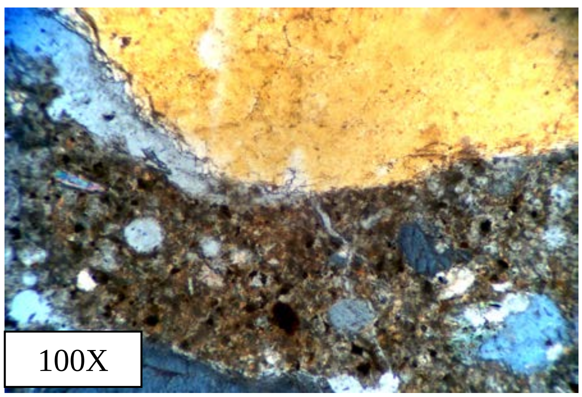


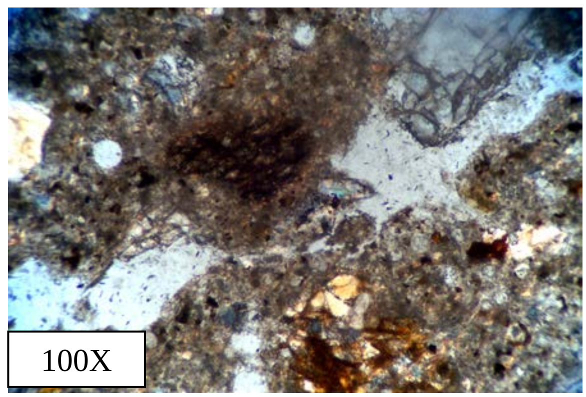


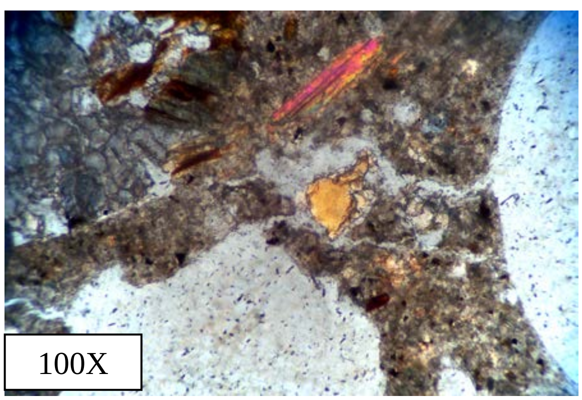
SAMPLE 15-0016-A024

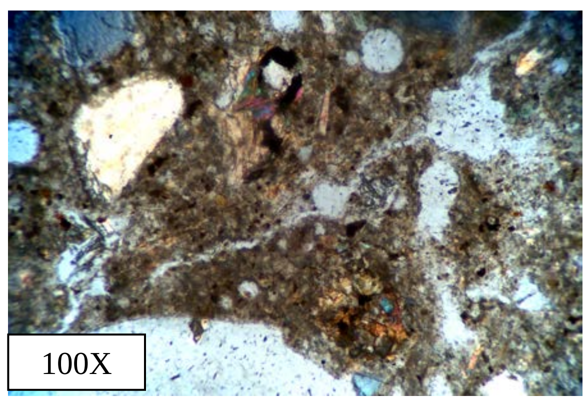


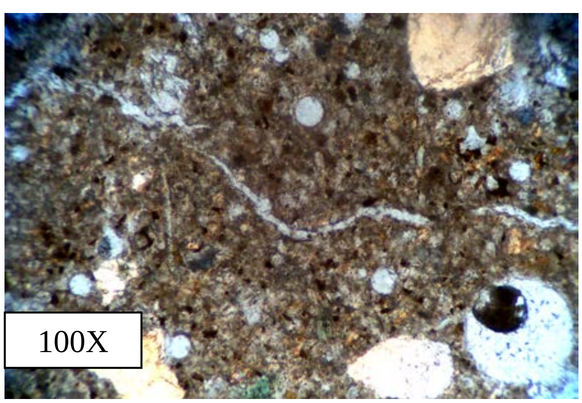


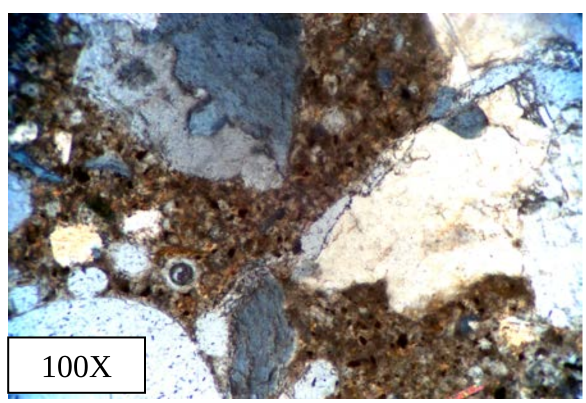




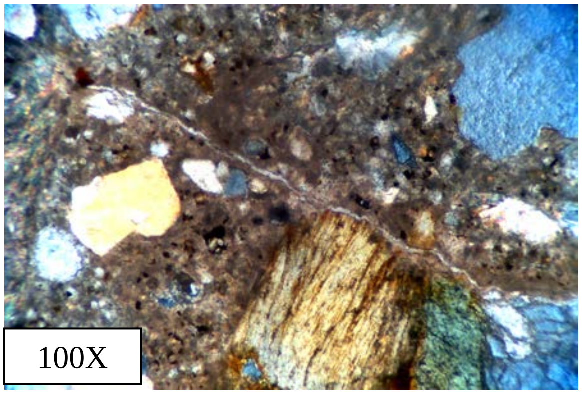


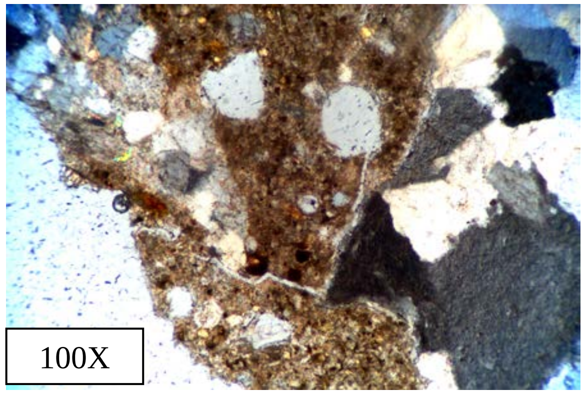


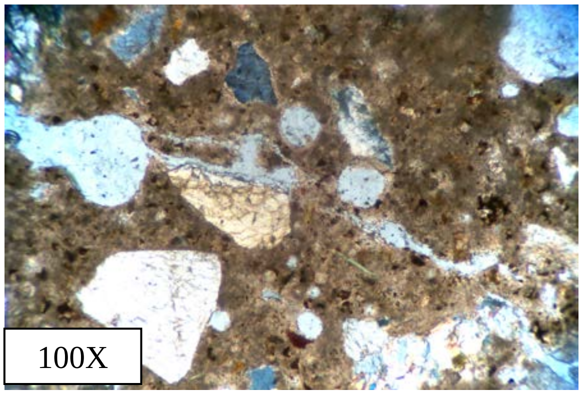


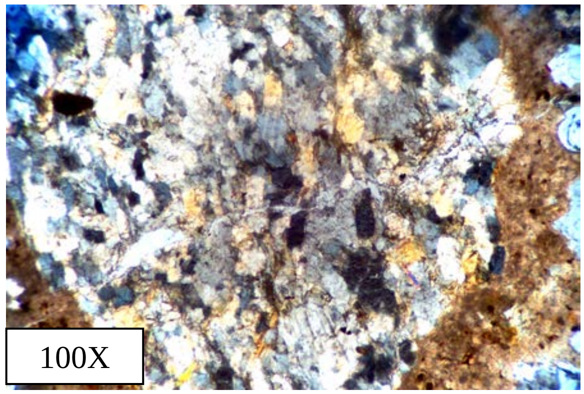


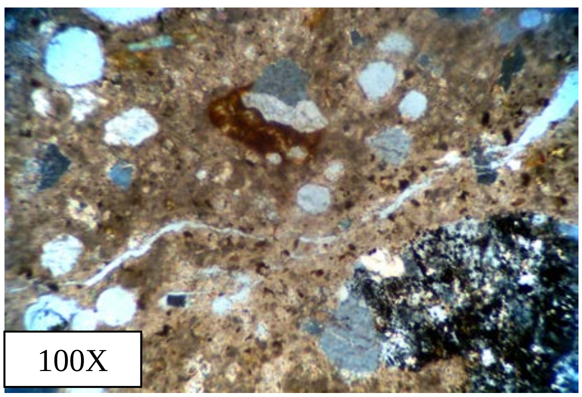
SAMPLE 15-0016-C023

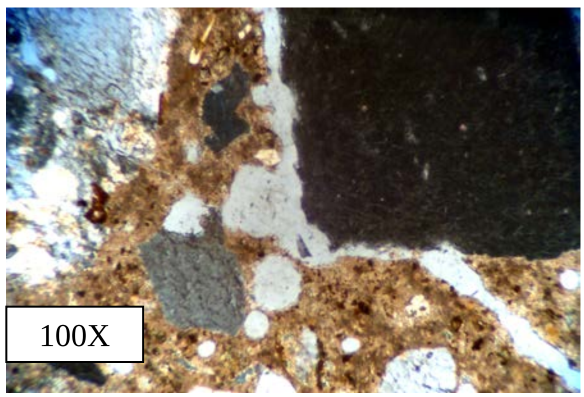


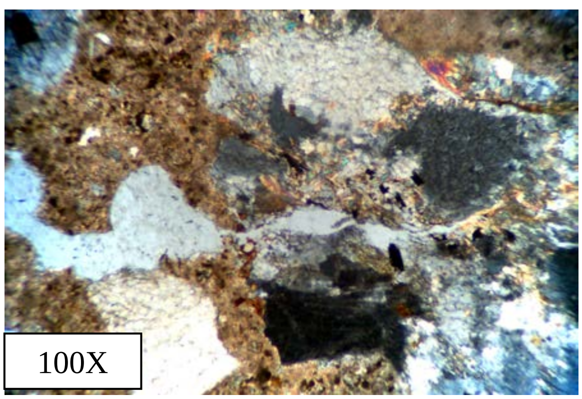




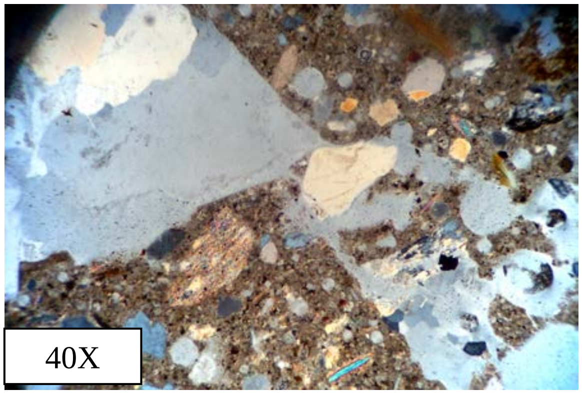








SAMPLE 15-0033-A011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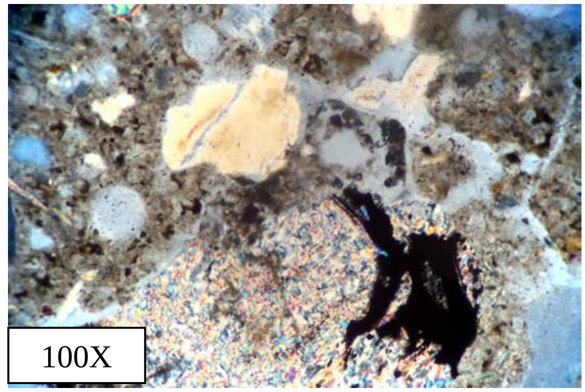
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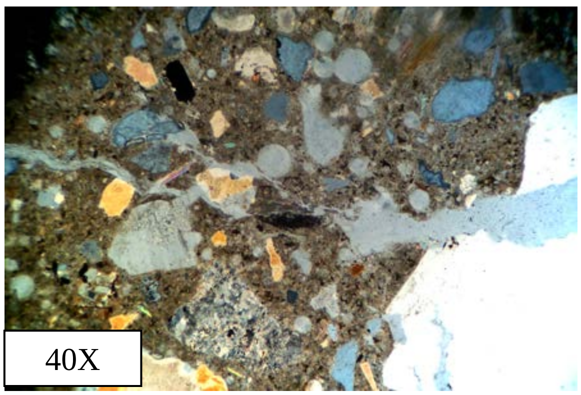
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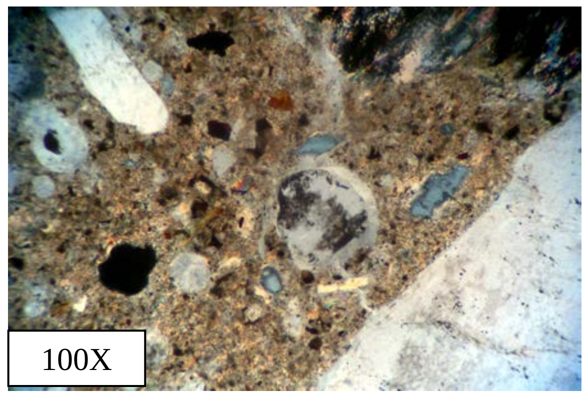
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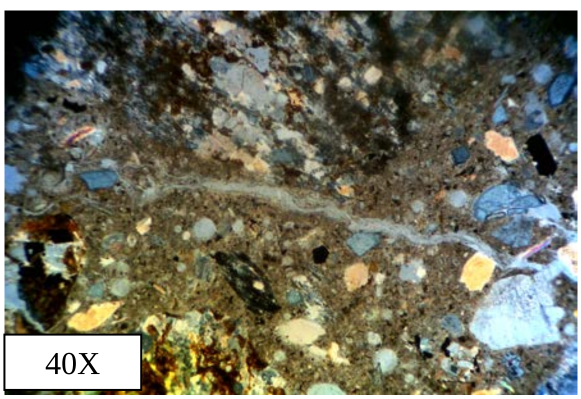
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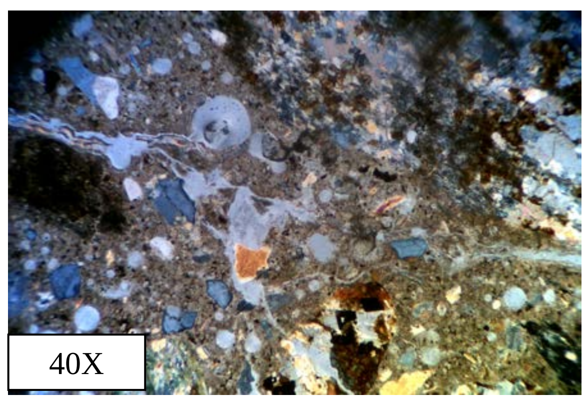
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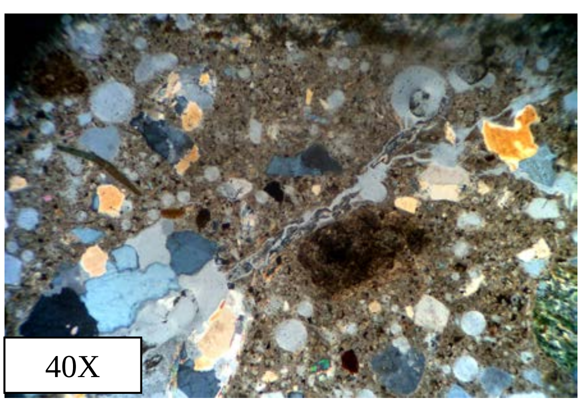
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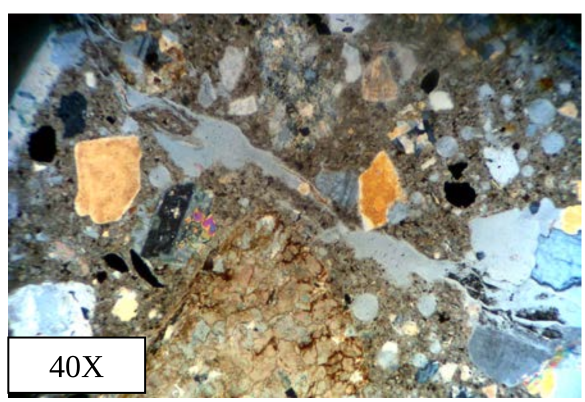
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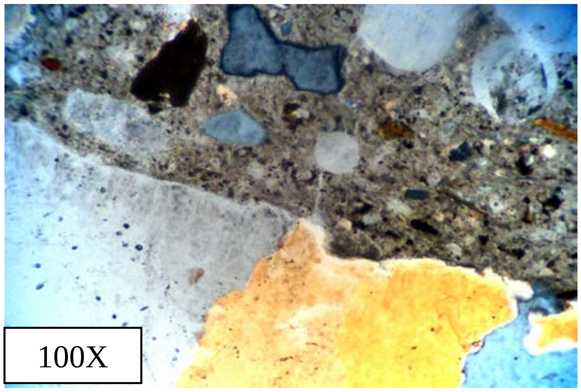
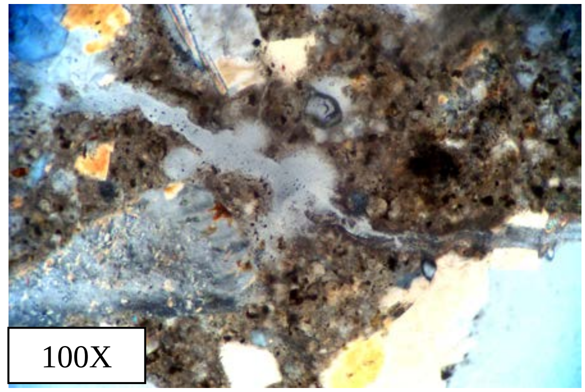
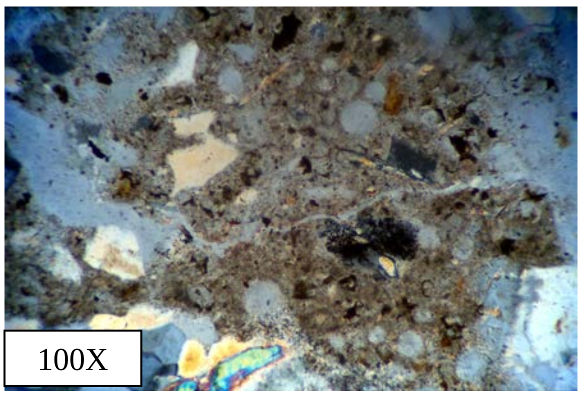
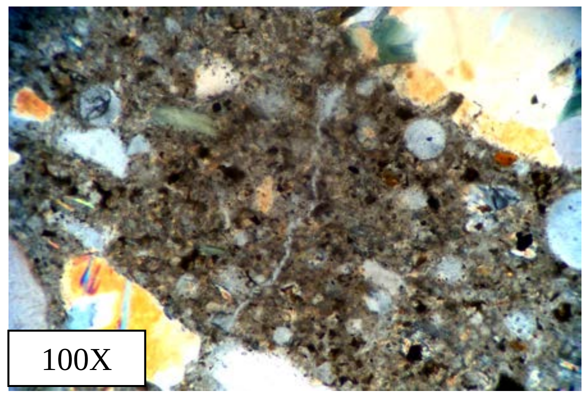
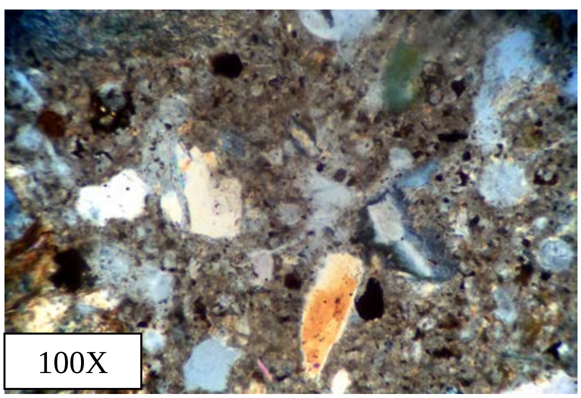
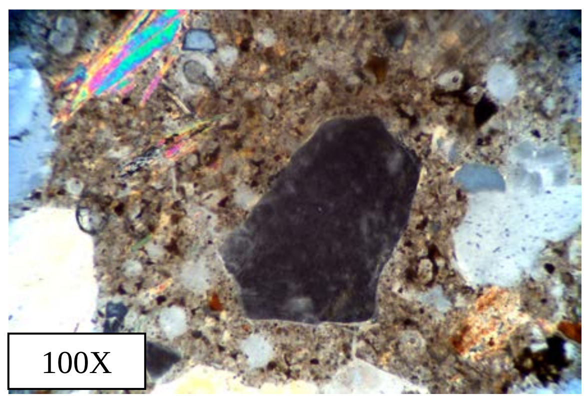


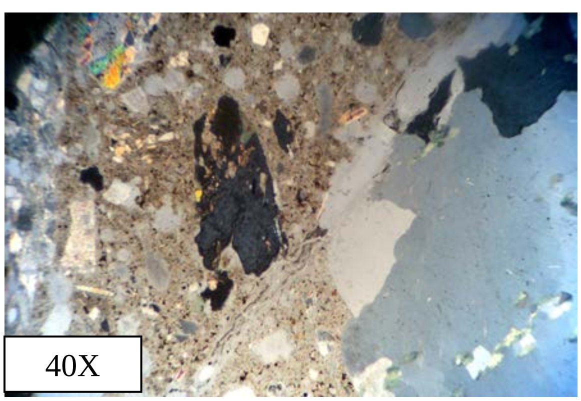


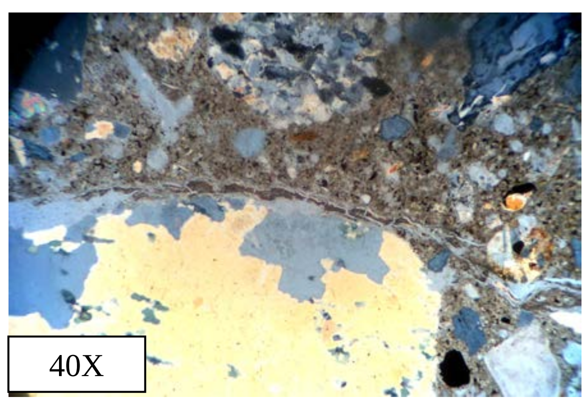




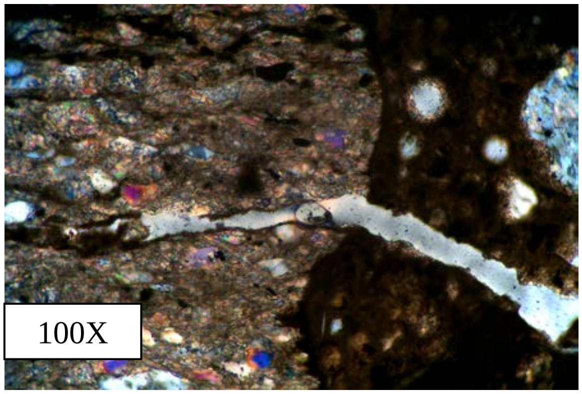








SAMPLE 15-0061-C014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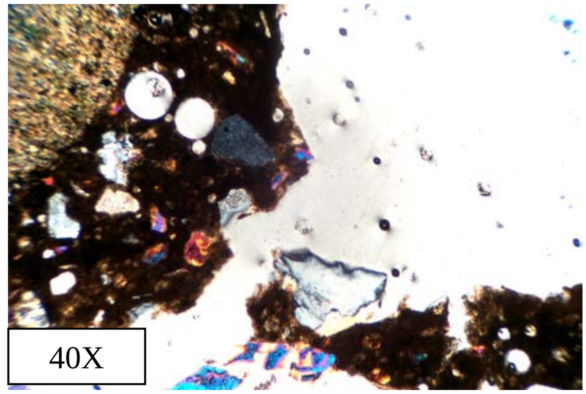
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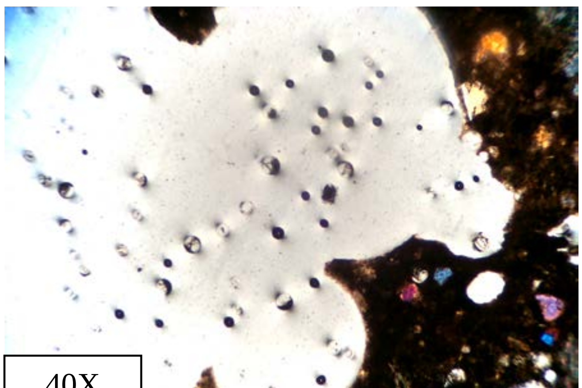
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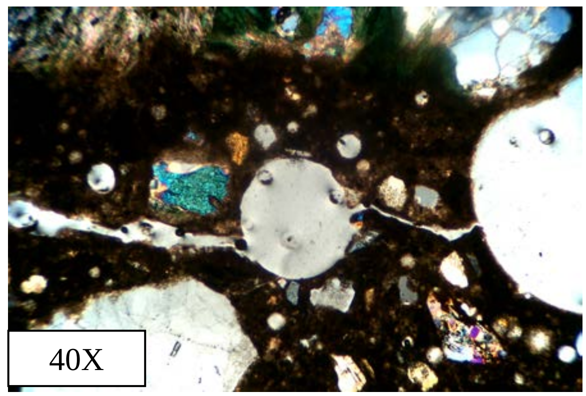
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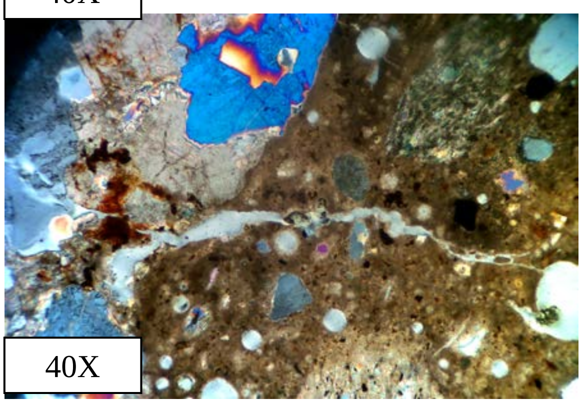
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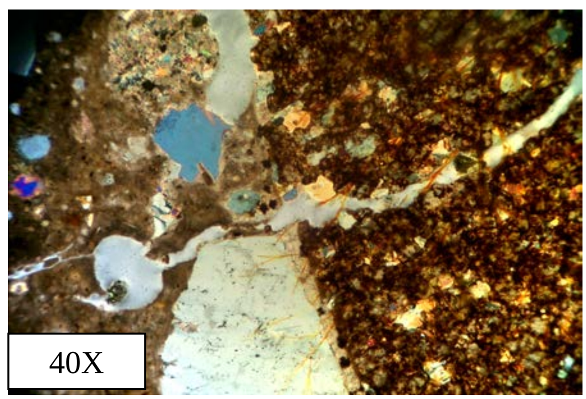
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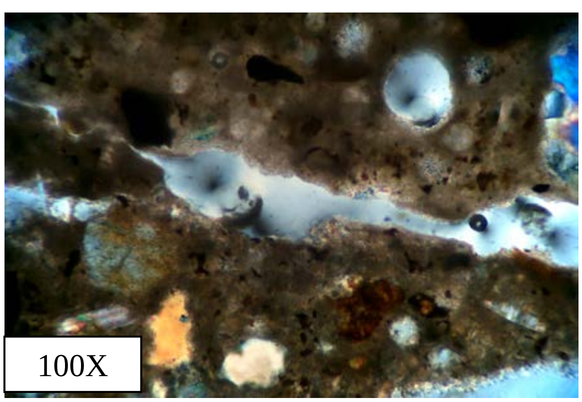
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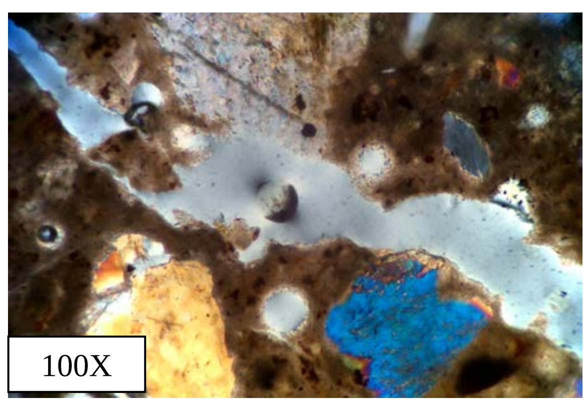
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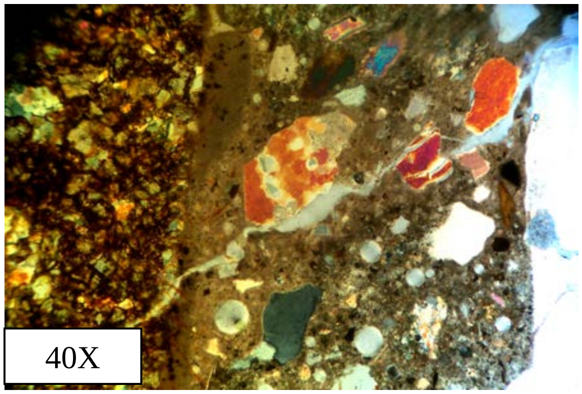
SAMPLE 15-0061-C014 (Cont.)



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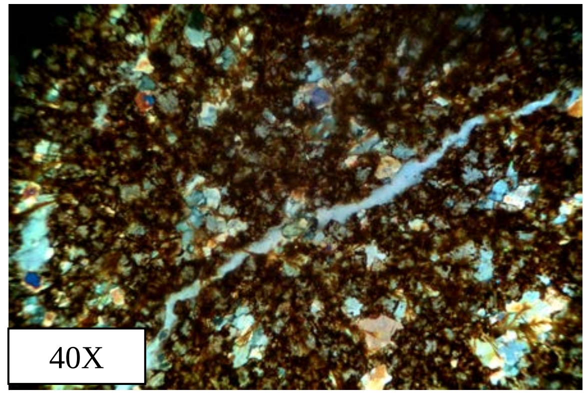

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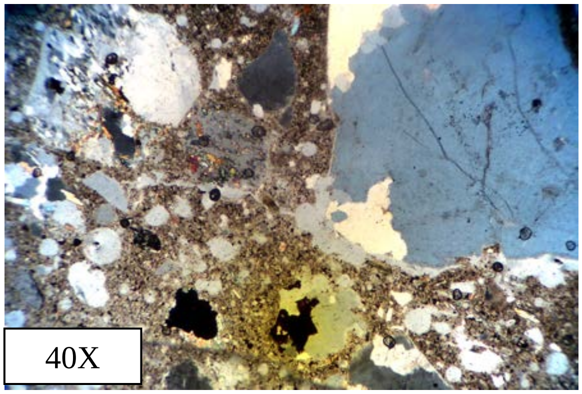
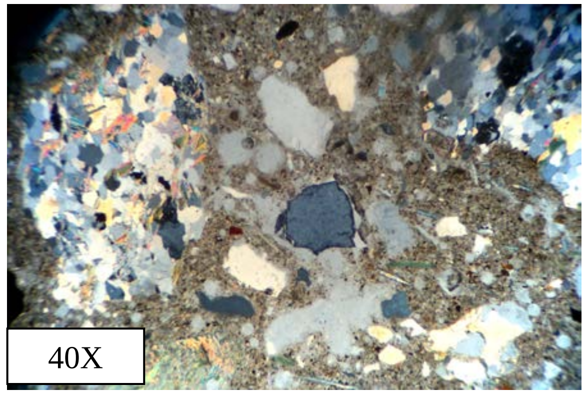
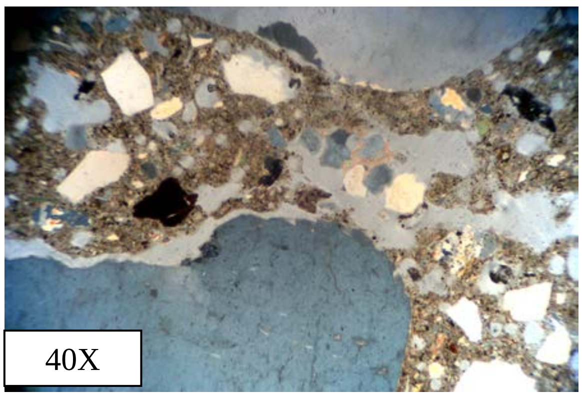
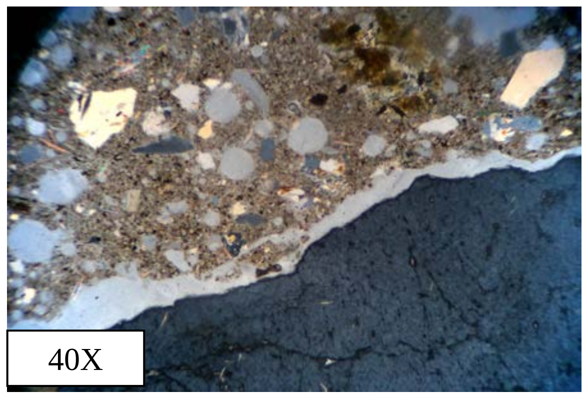
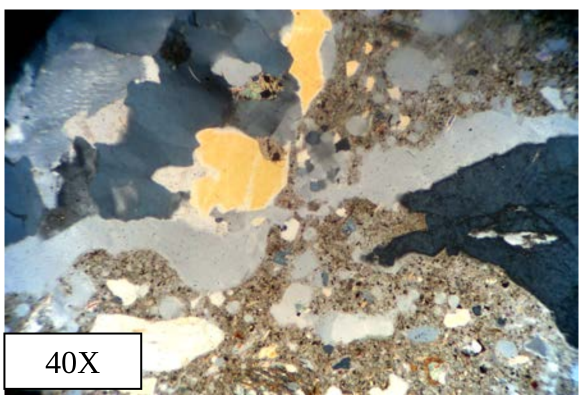
SAMPLE 15-0066-A018

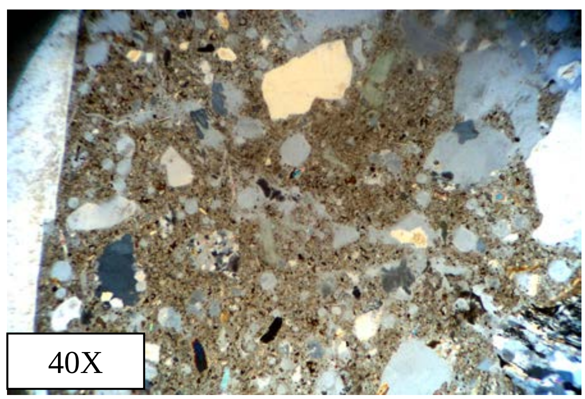


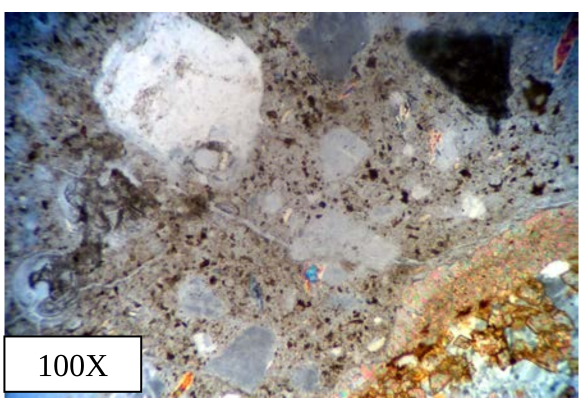


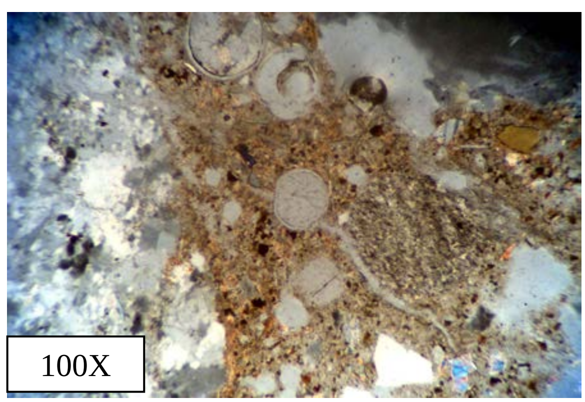




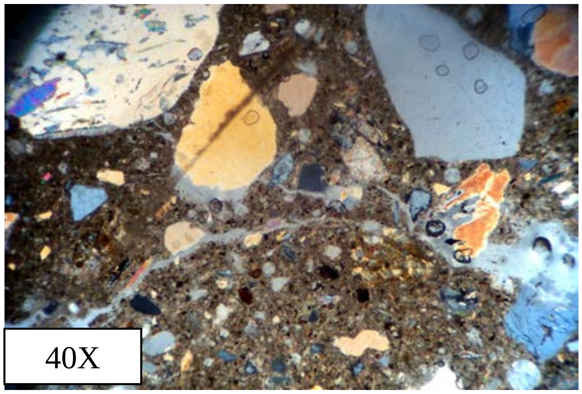


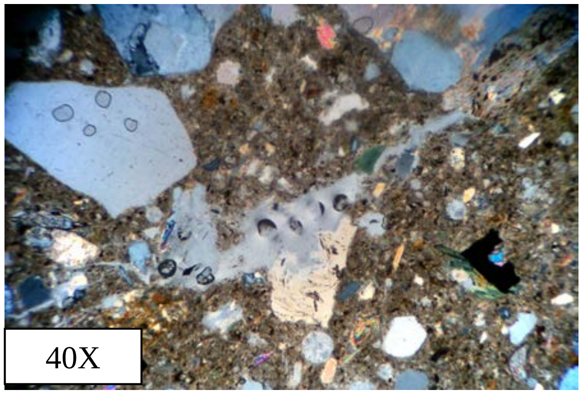


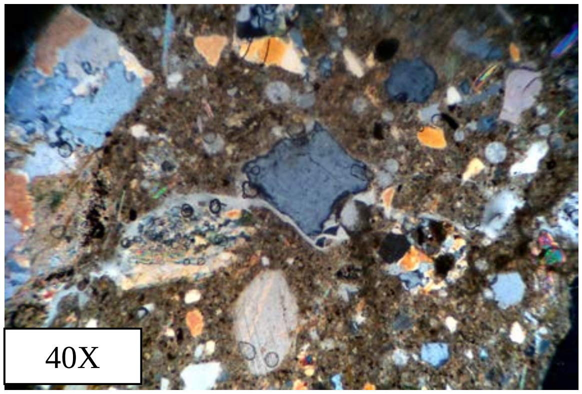


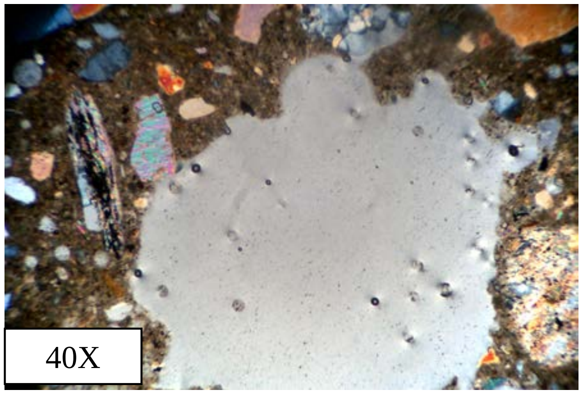


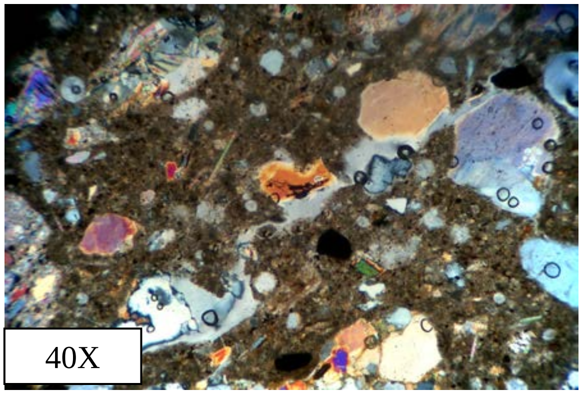
SAMPLE 15-0066-C017

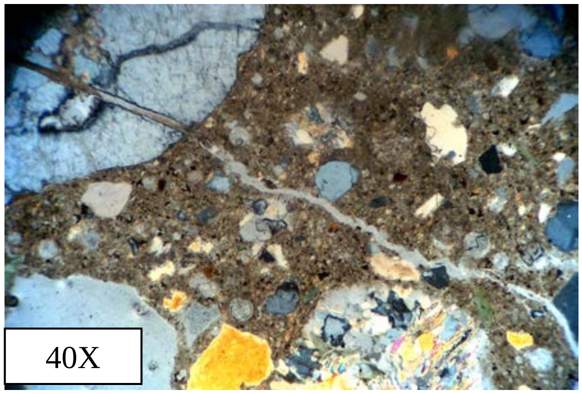


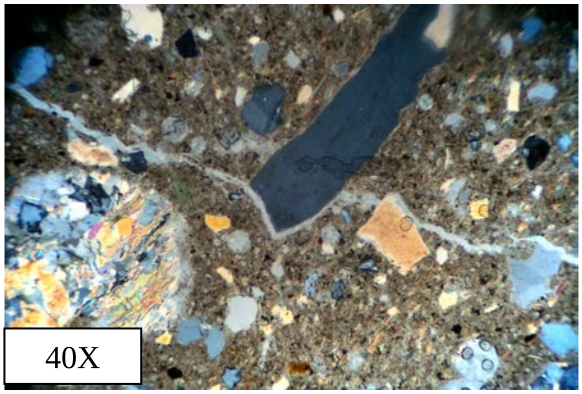


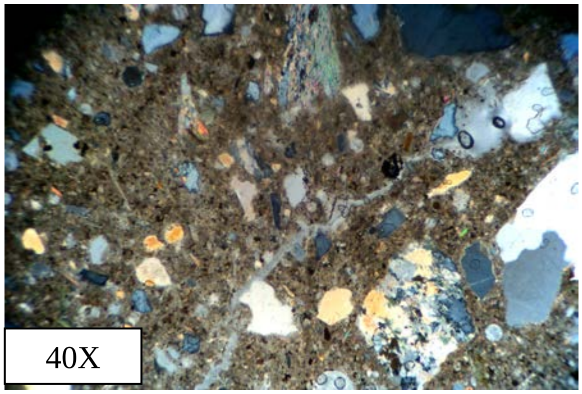




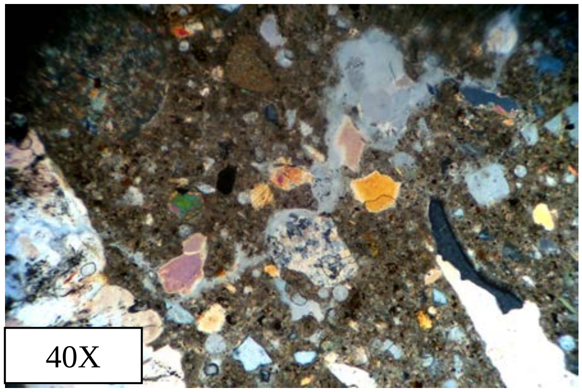


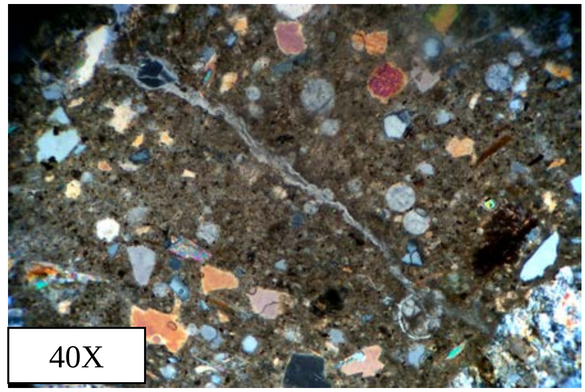


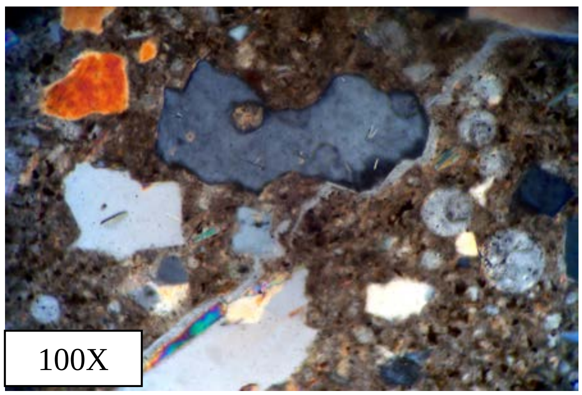


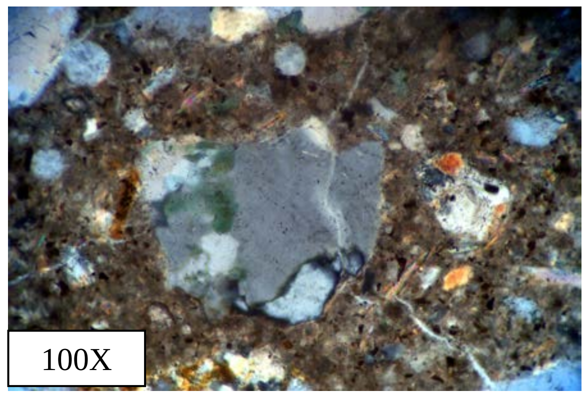


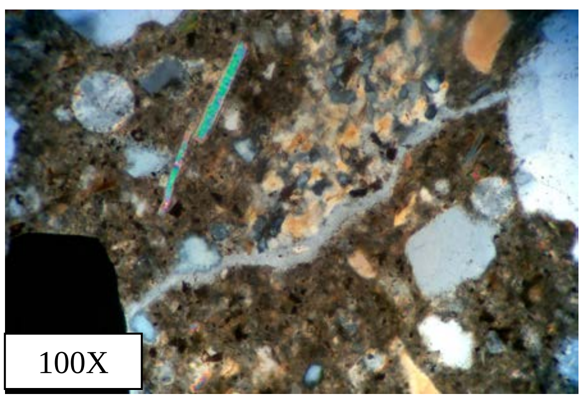
SAMPLE 15-0066-C017 (Cont.)

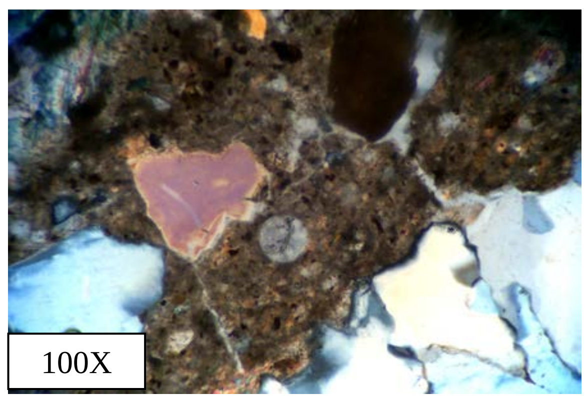


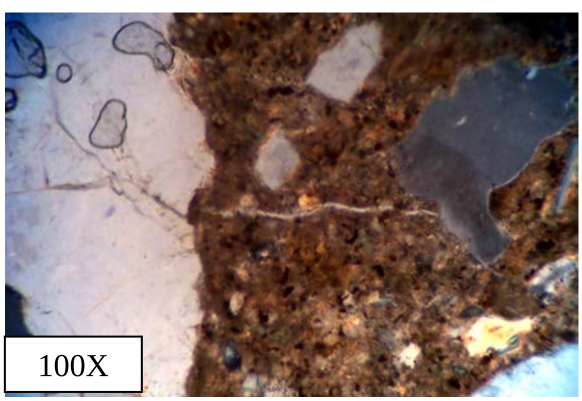


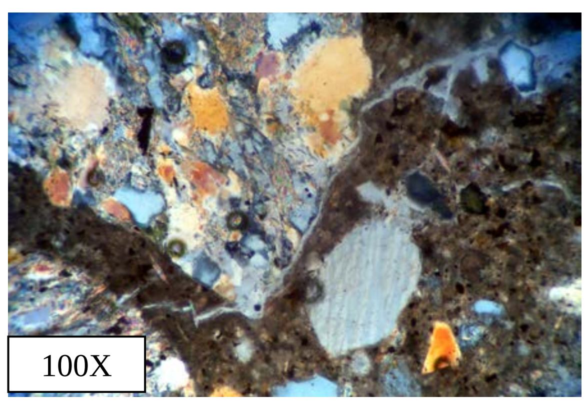




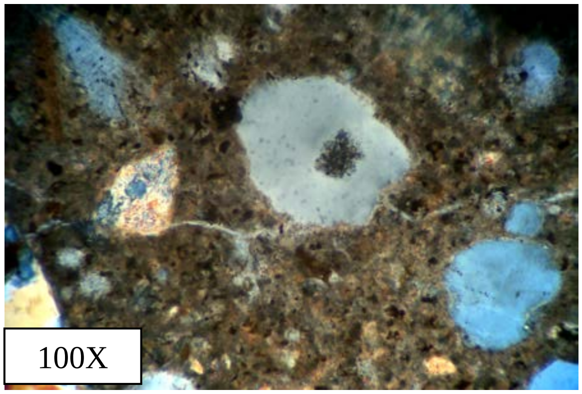








SAMPLE 25-0017-A007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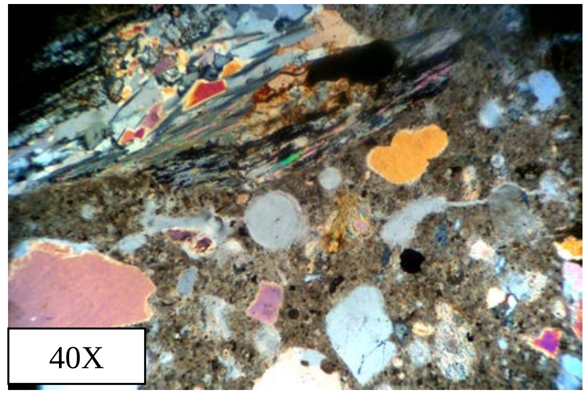
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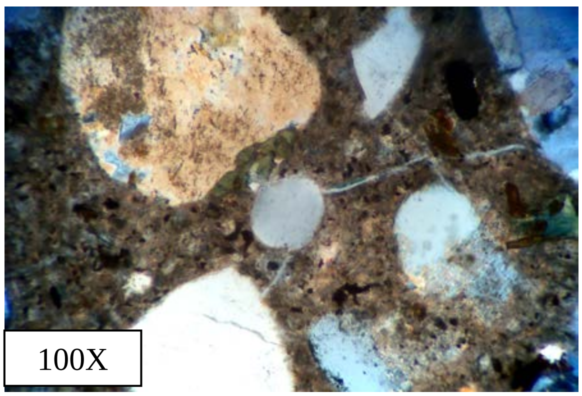
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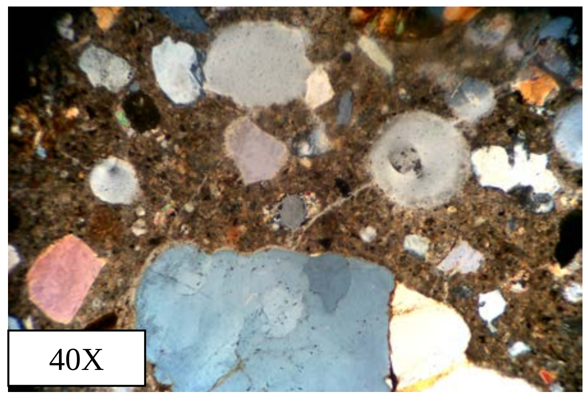
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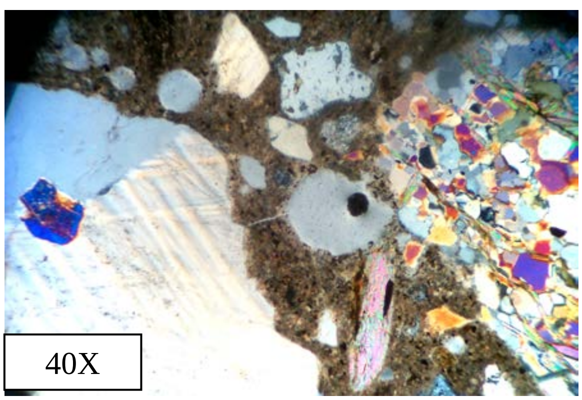
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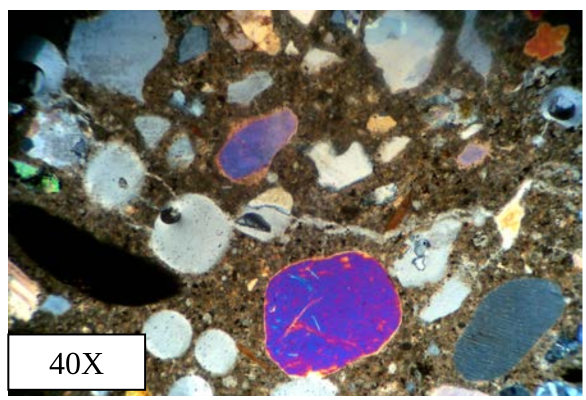
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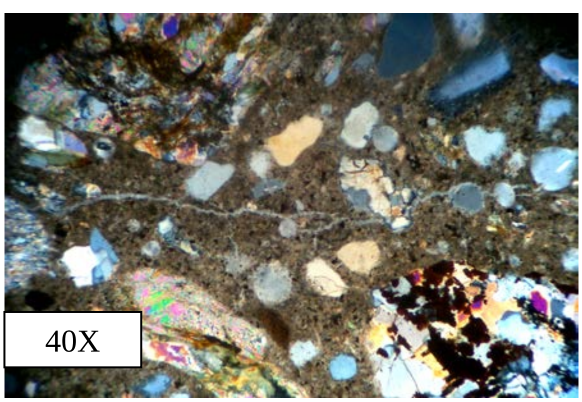
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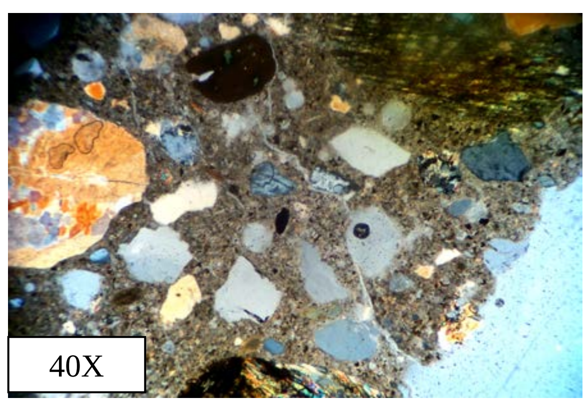
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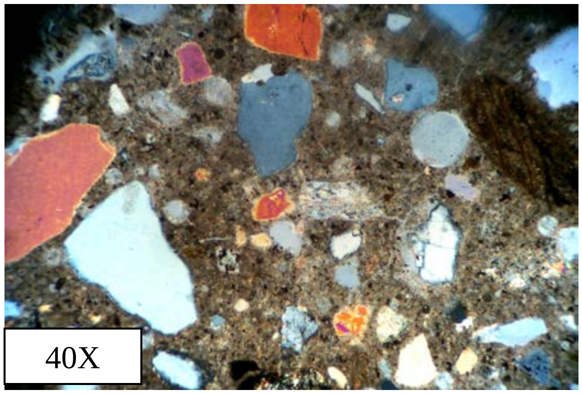
SAMPLE 25-0017-A007 (Cont.)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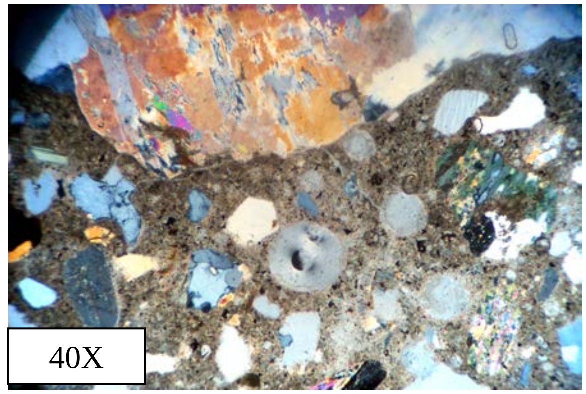
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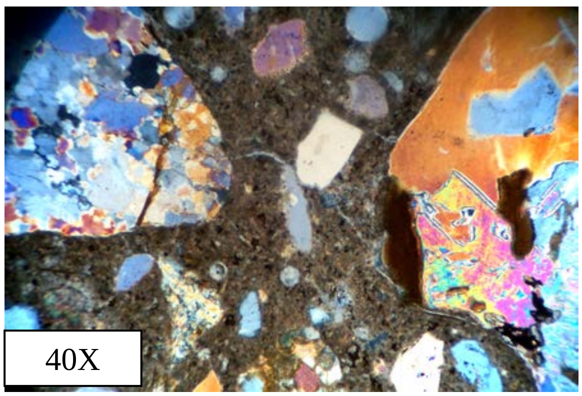
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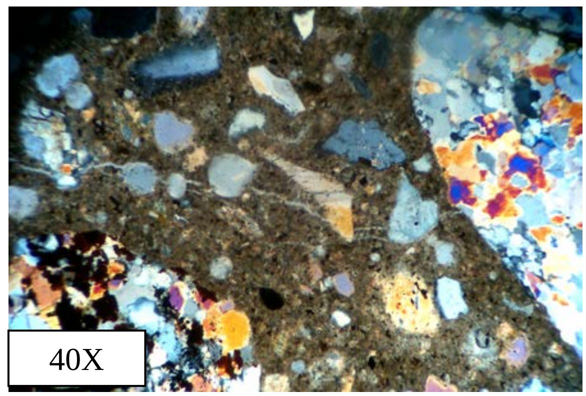
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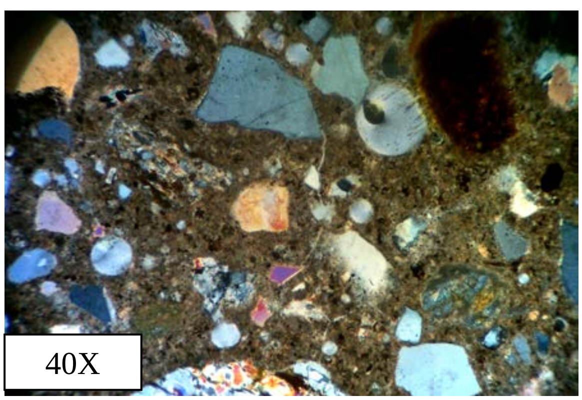
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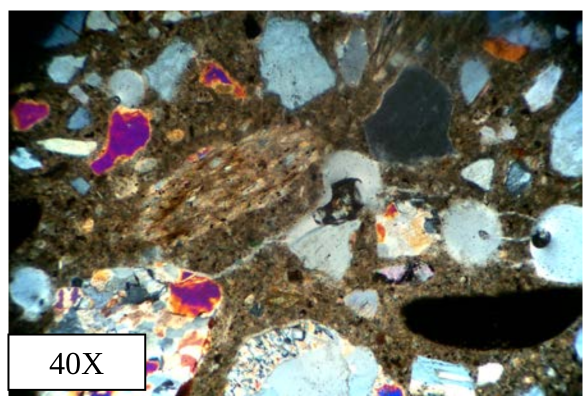
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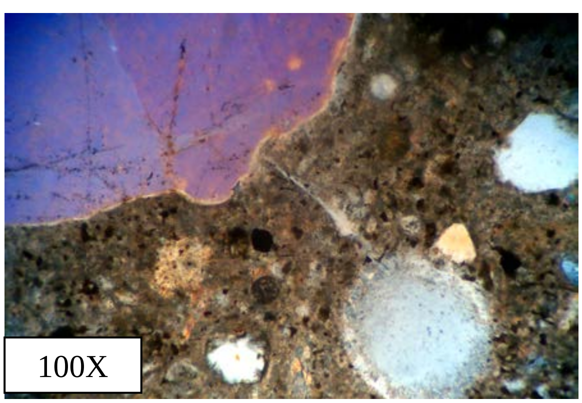
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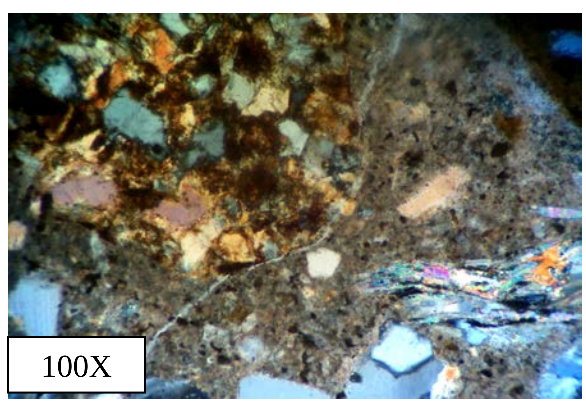
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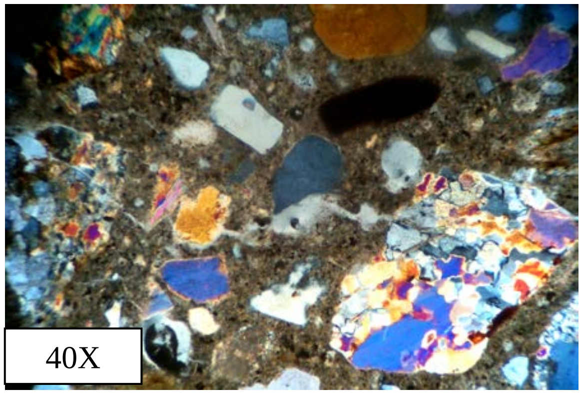
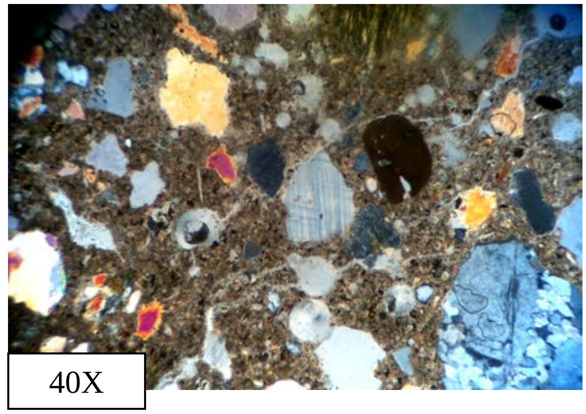
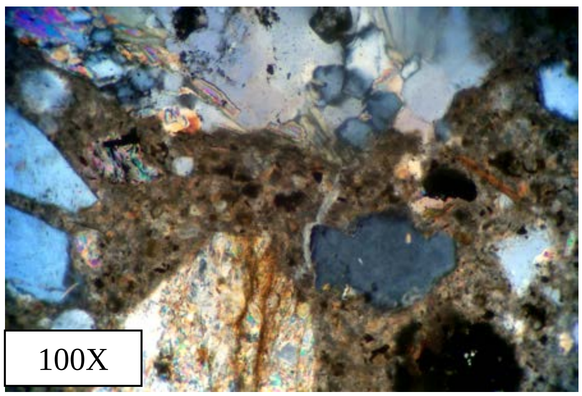
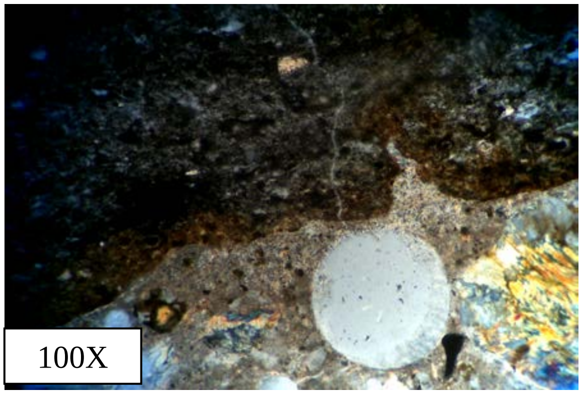
SAMPLE 25-0017-A007 (Cont.)

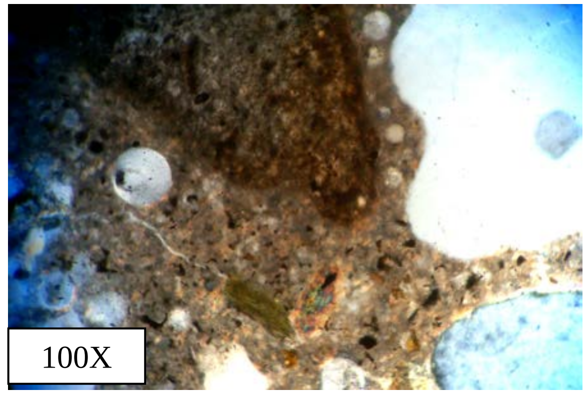


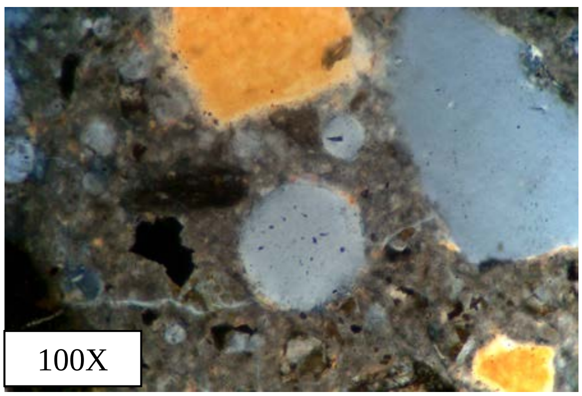


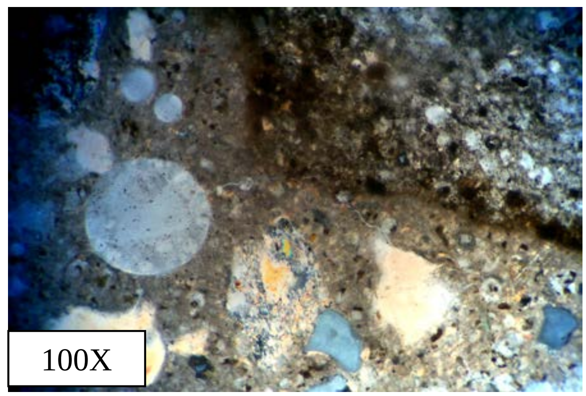


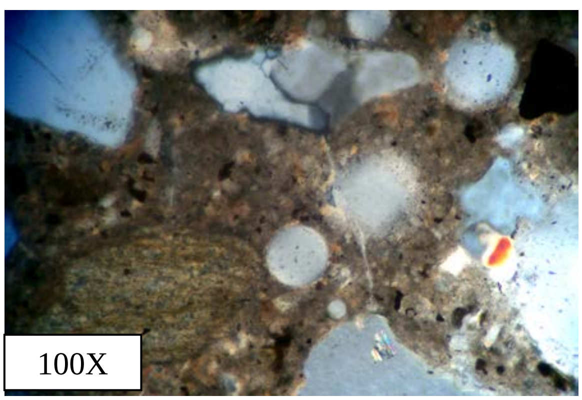
SAMPLE 25-0017-C009

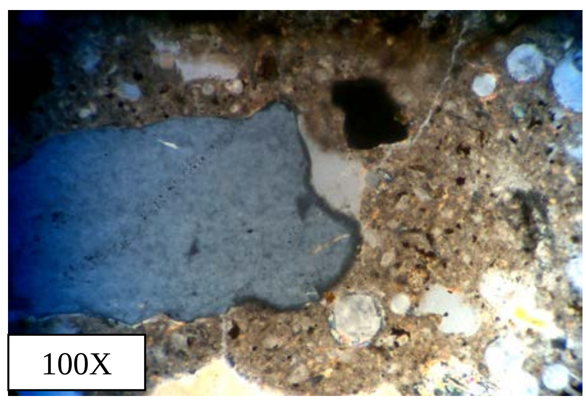




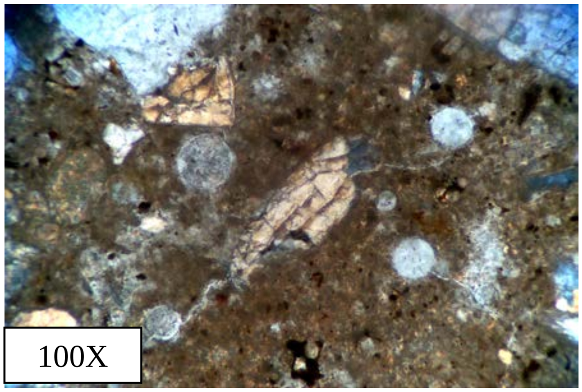


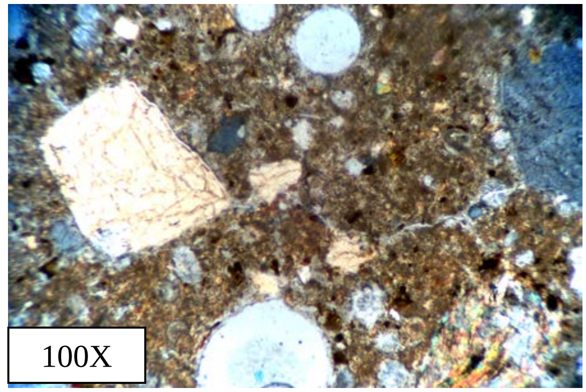


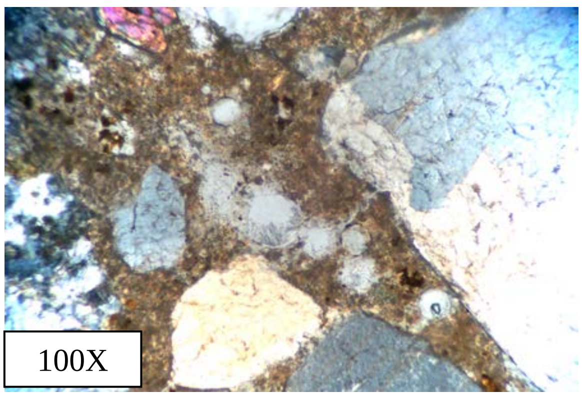


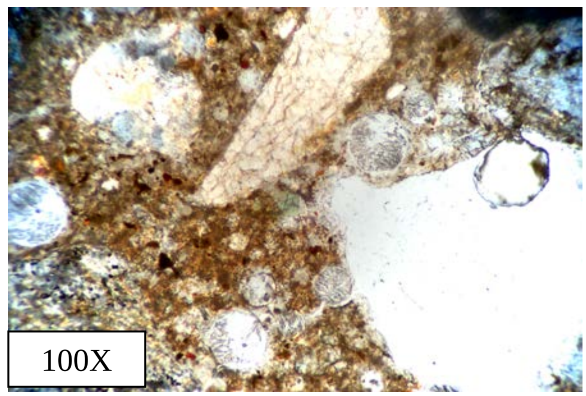


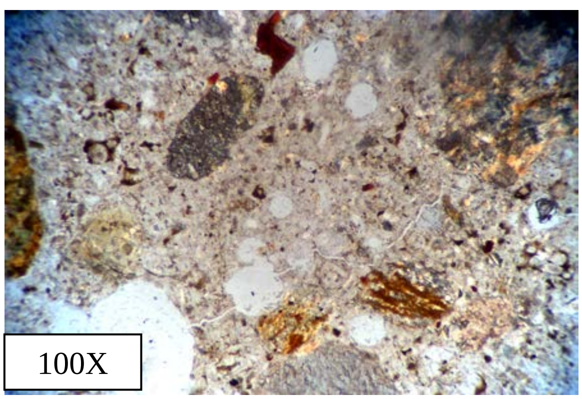
SAMPLE 111-0012-C033

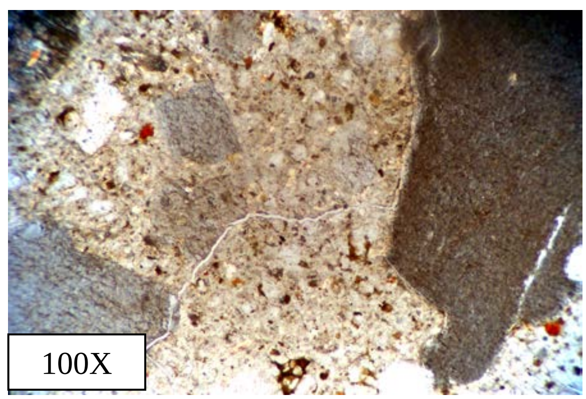


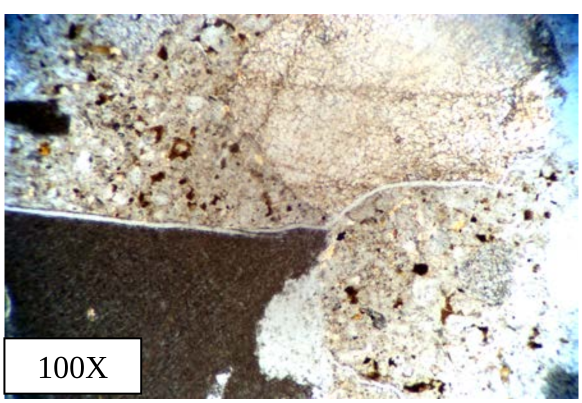


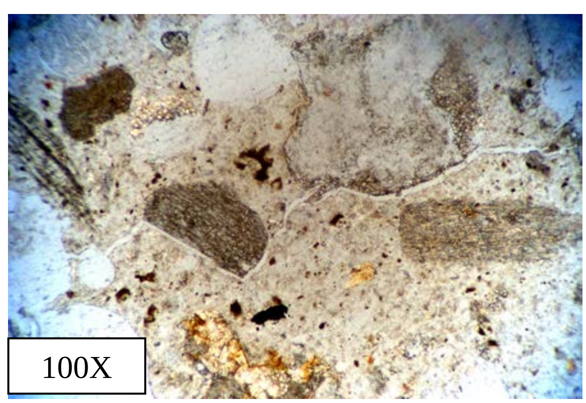




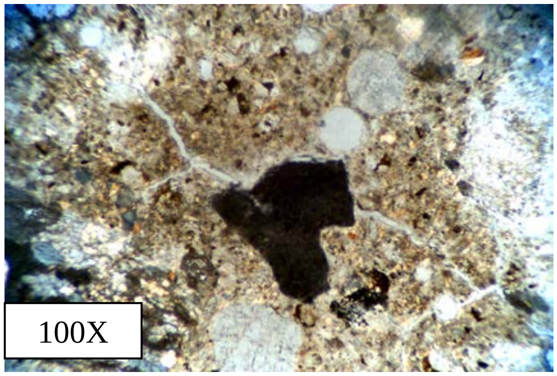








SAMPLE 111-0012-C033 (Cont.)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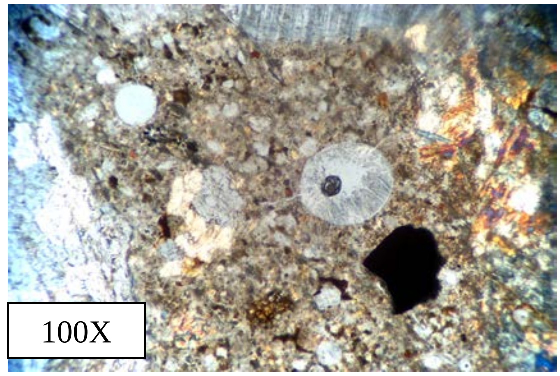
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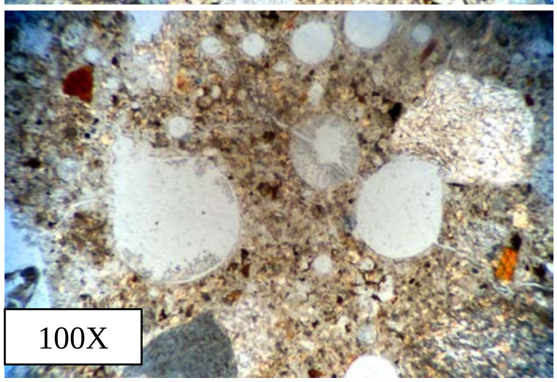
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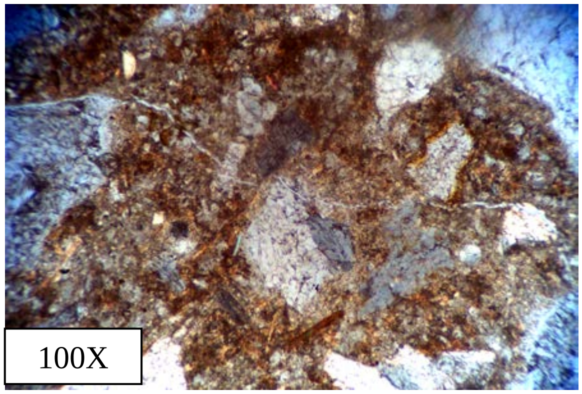
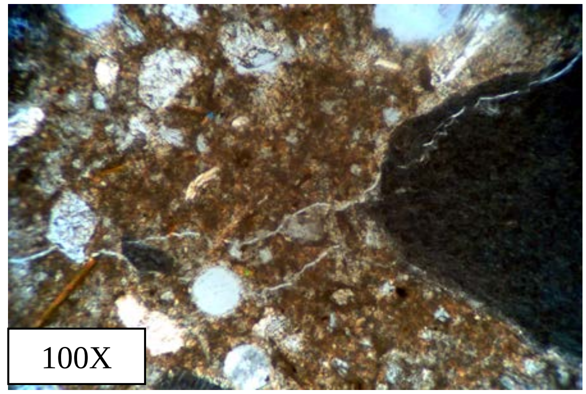
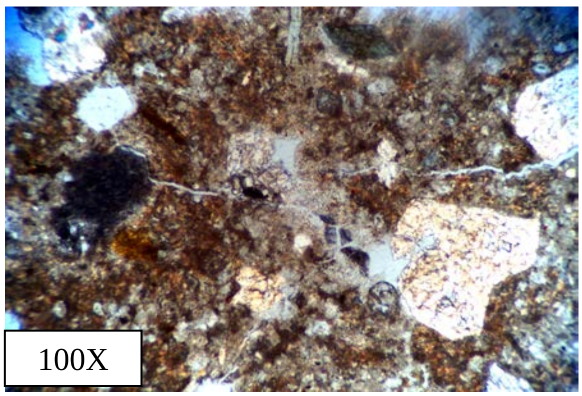
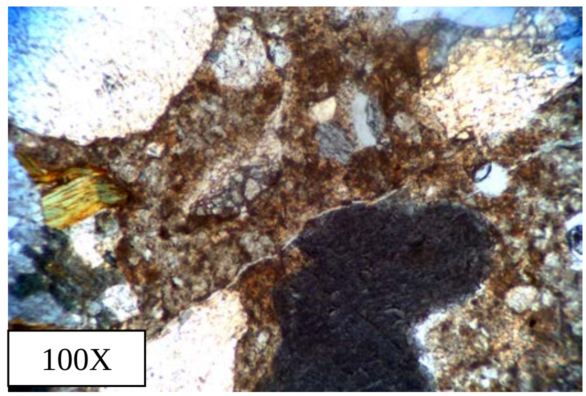
200X

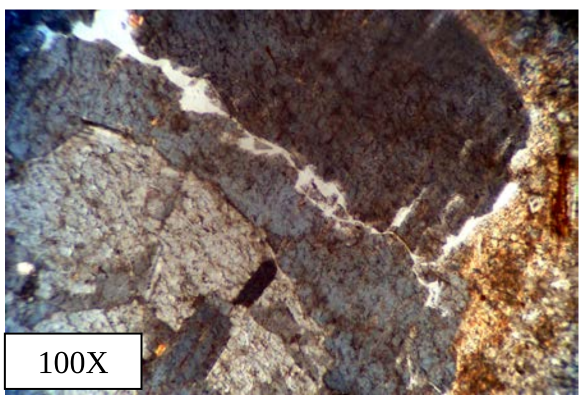
SAMPLE 126-011W-C048

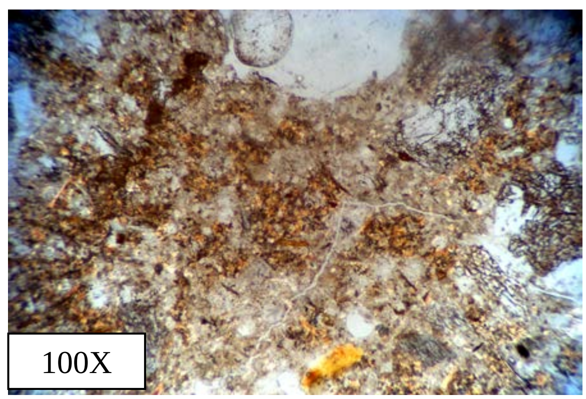


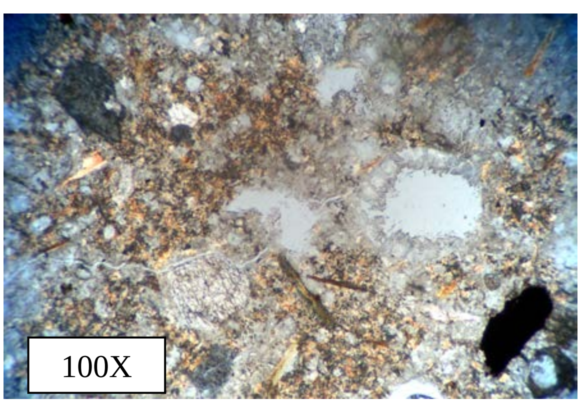


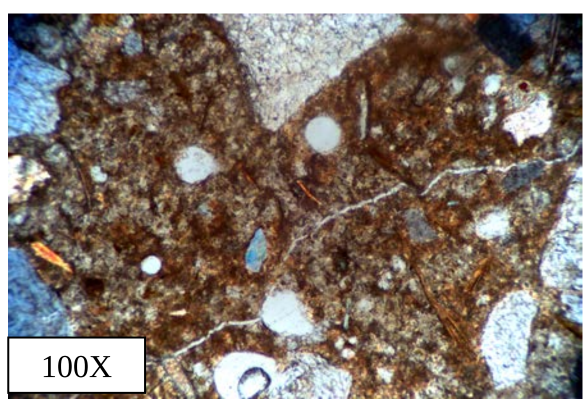




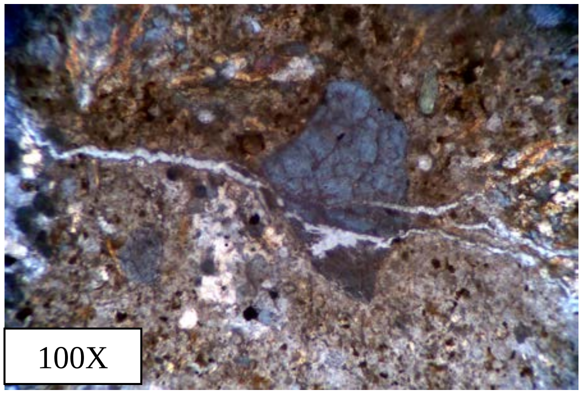


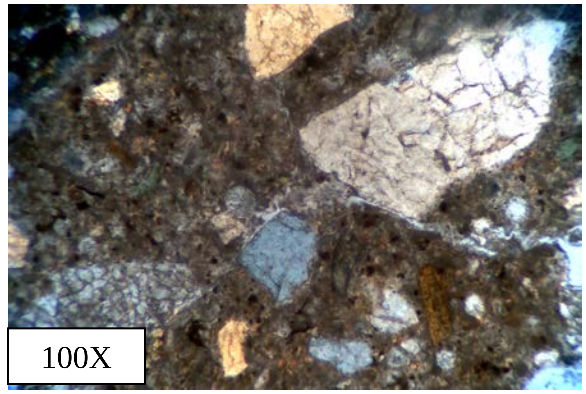


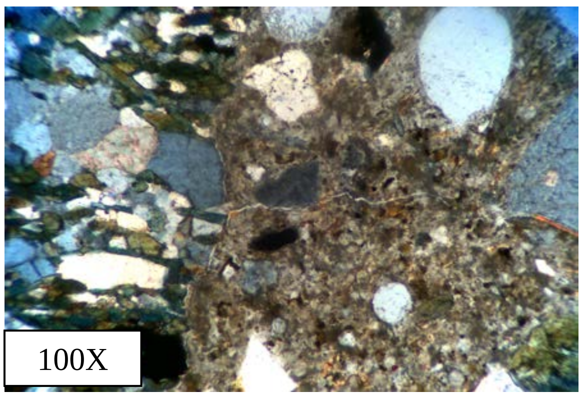


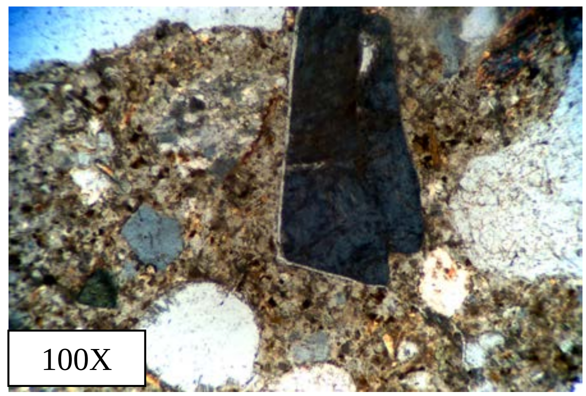


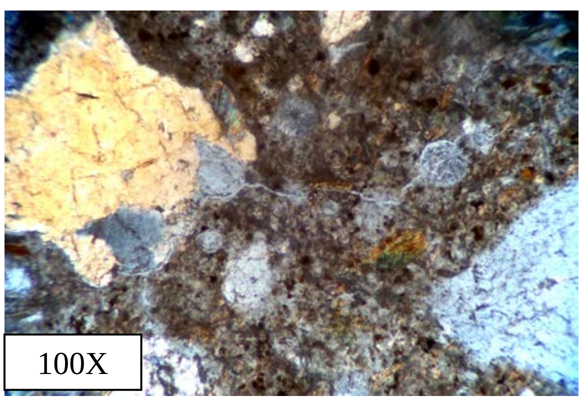
SAMPLE 166-0015-A034

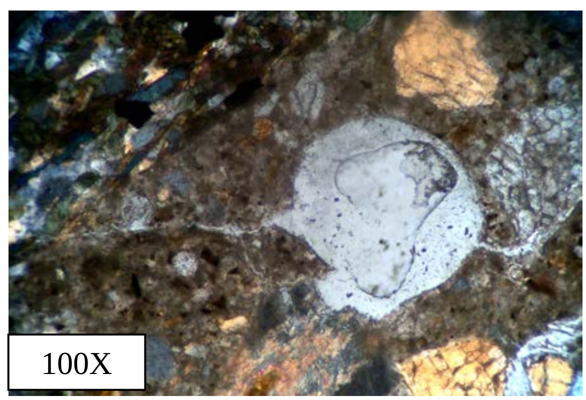




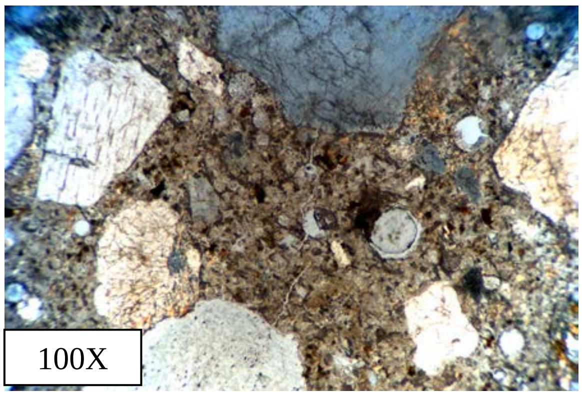


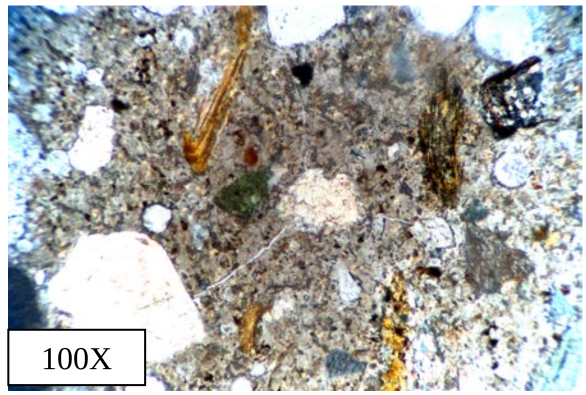


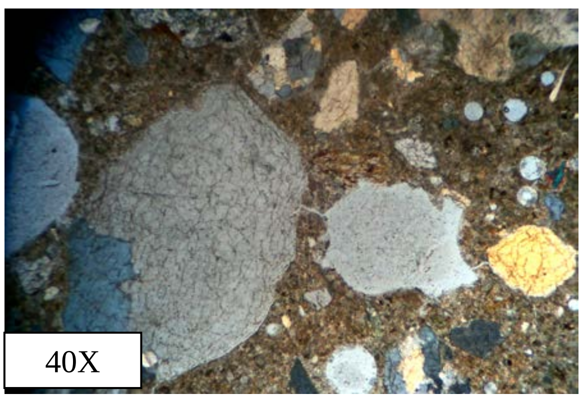


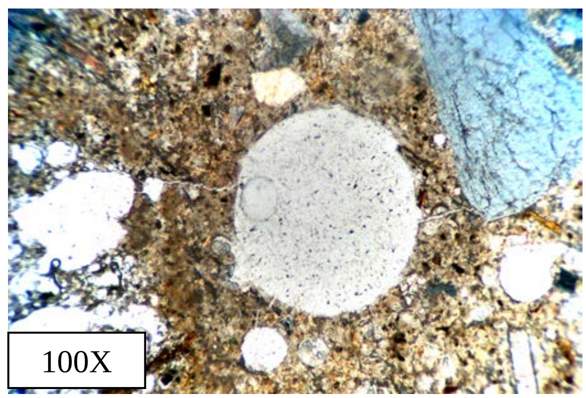


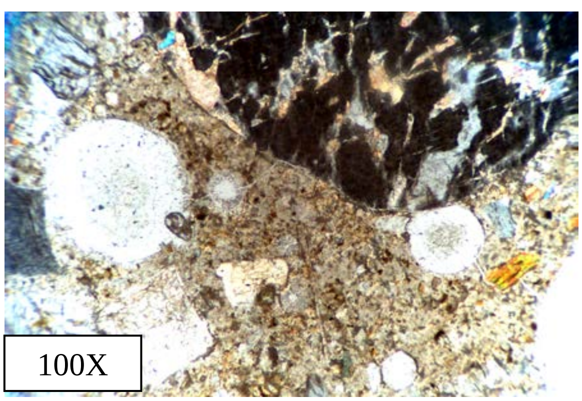
SAMPLE 166-0015-C036

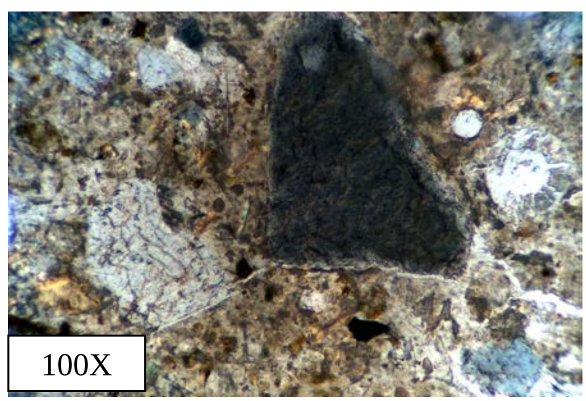




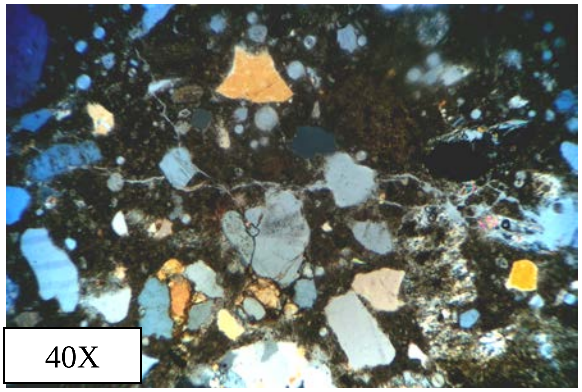


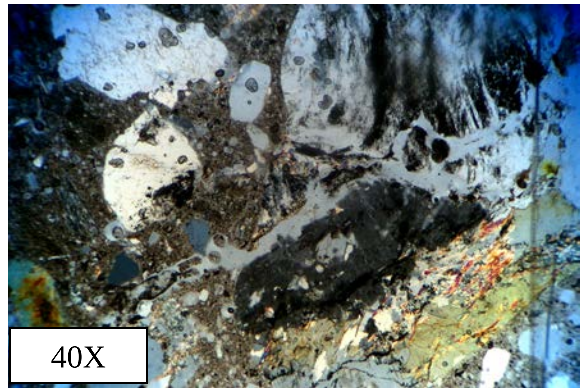


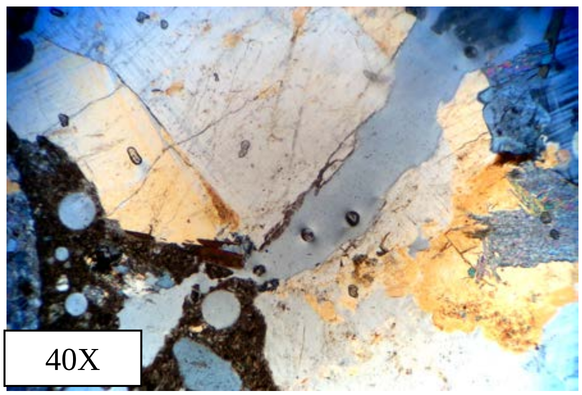


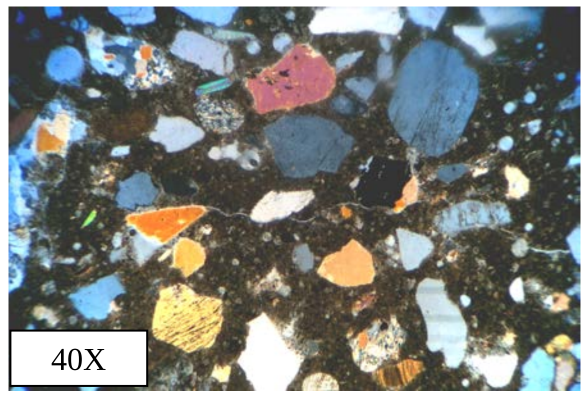


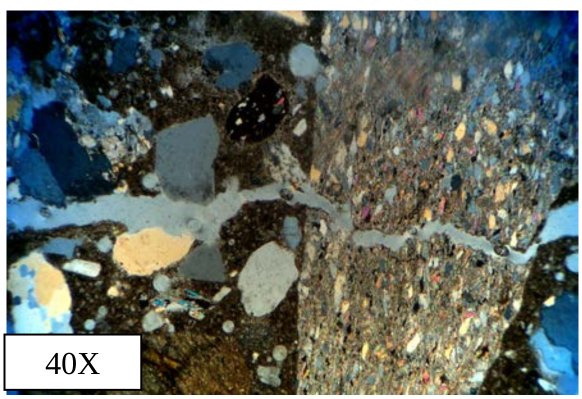
SAMPLE 302-0032-A003

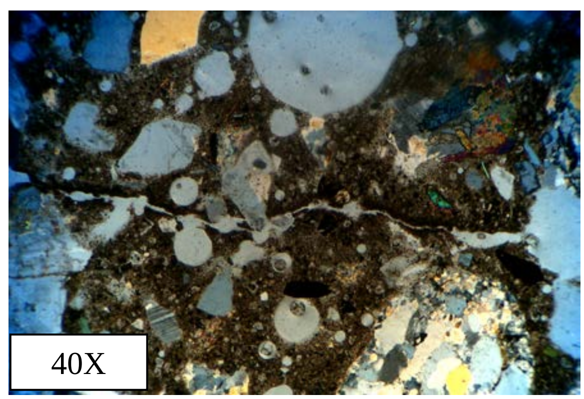


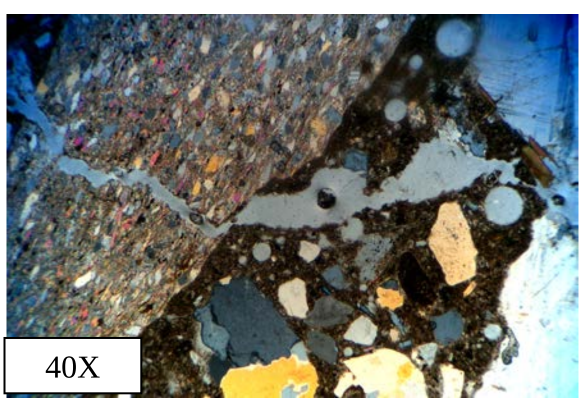


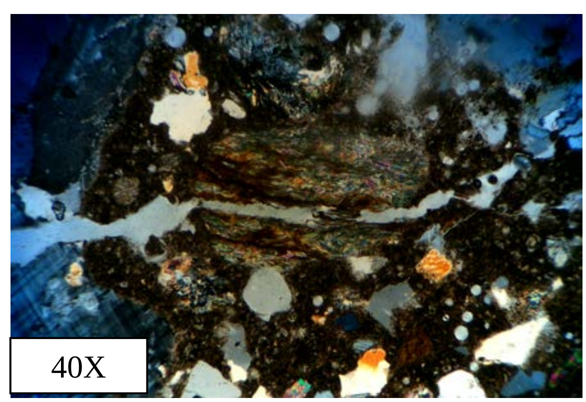




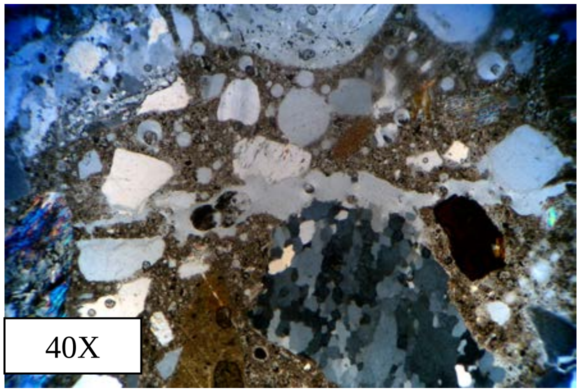


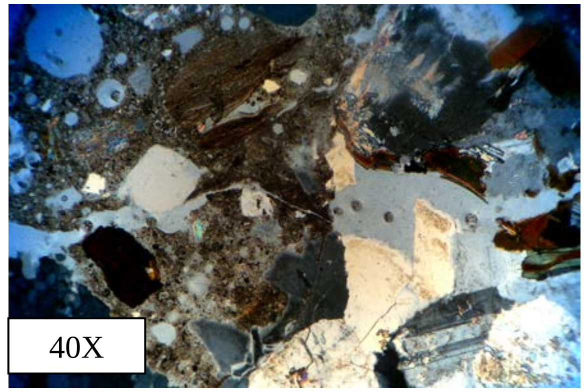


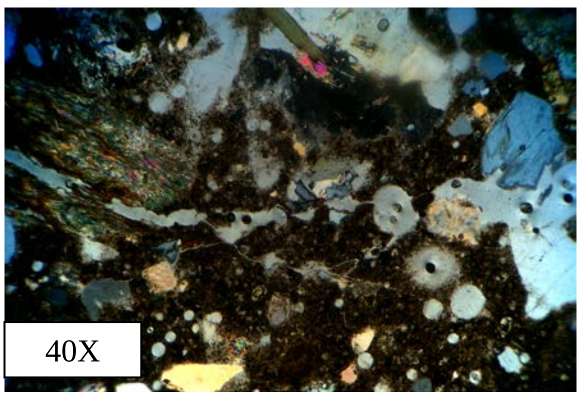


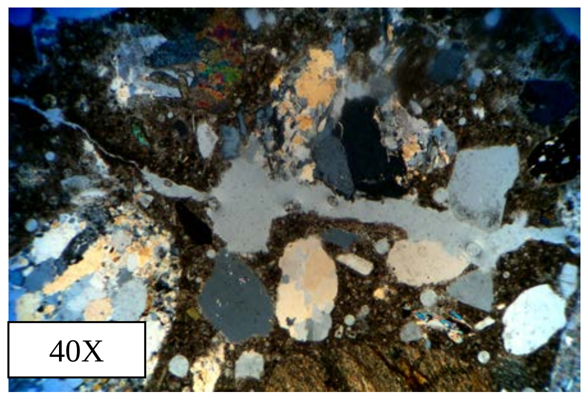


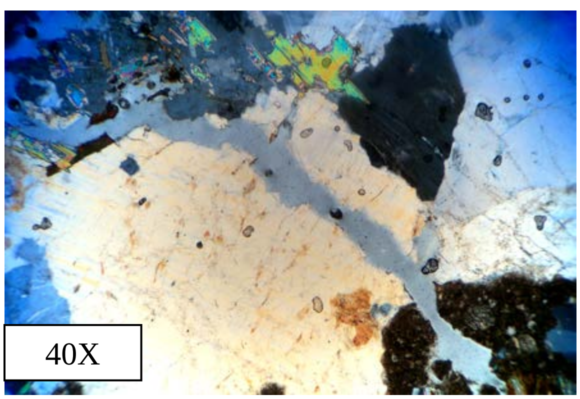
SAMPLE 302-0032-A003 (Cont.)

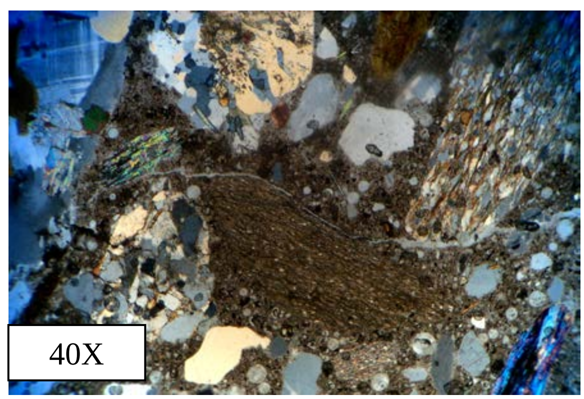


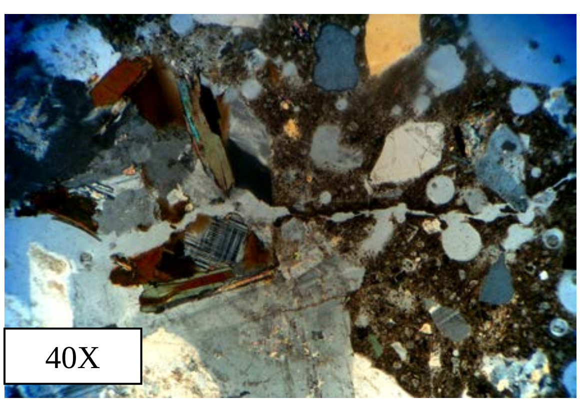


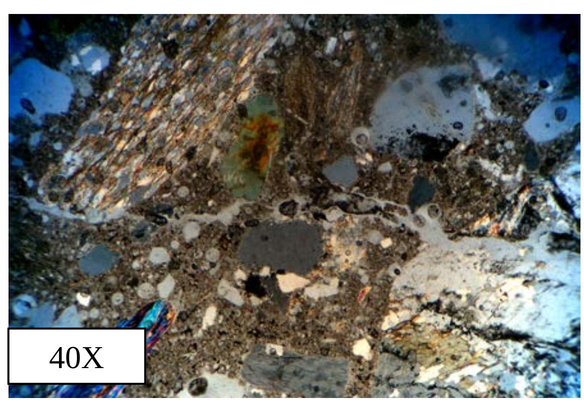




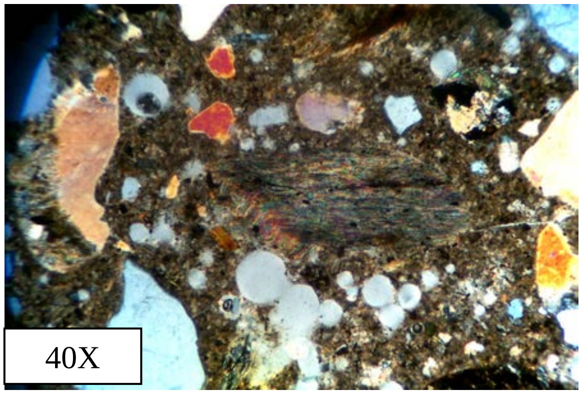


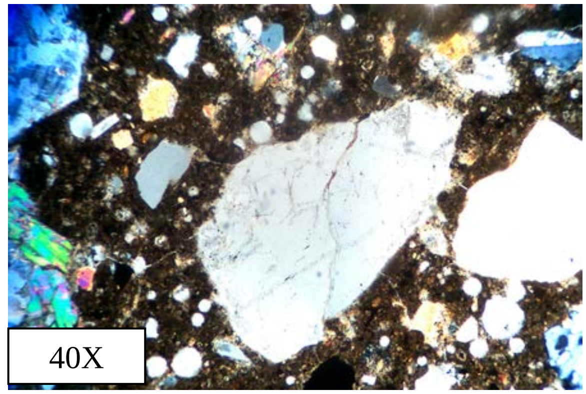


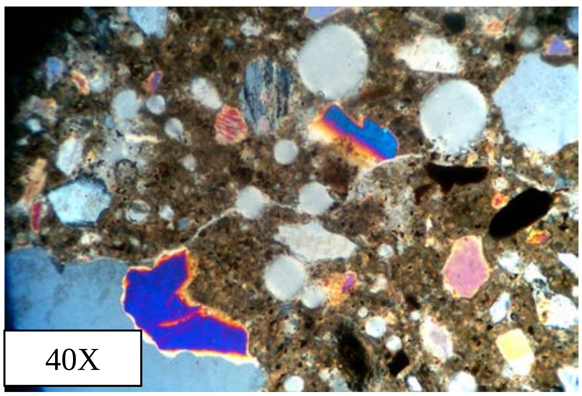


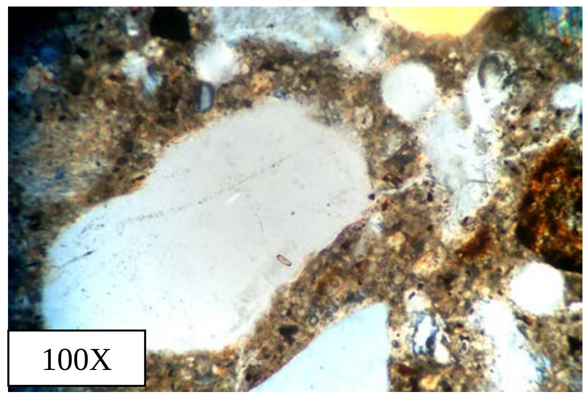


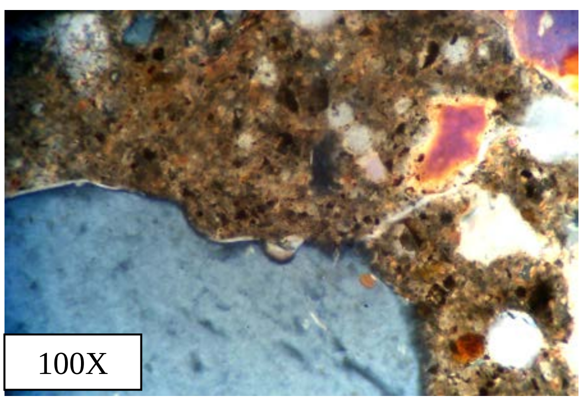
SAMPLE 302-0032-C001

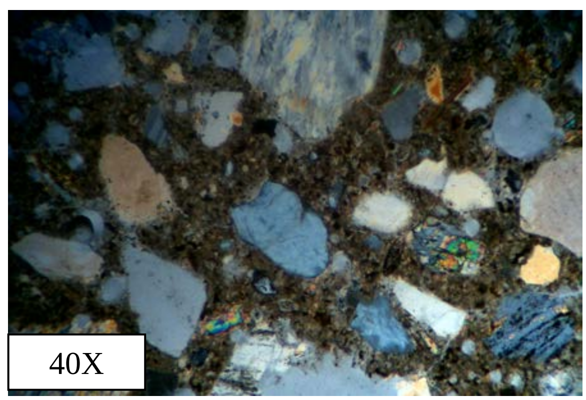




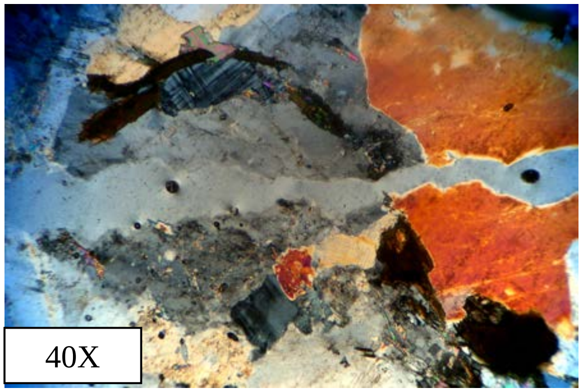


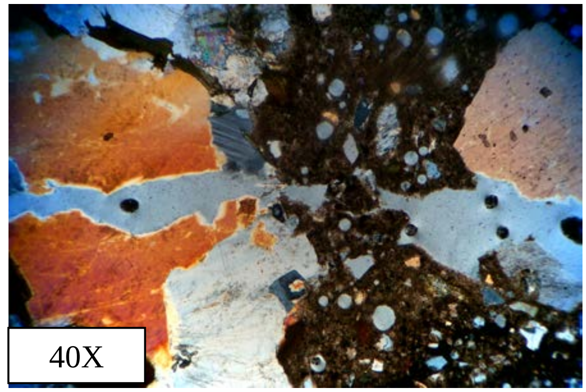


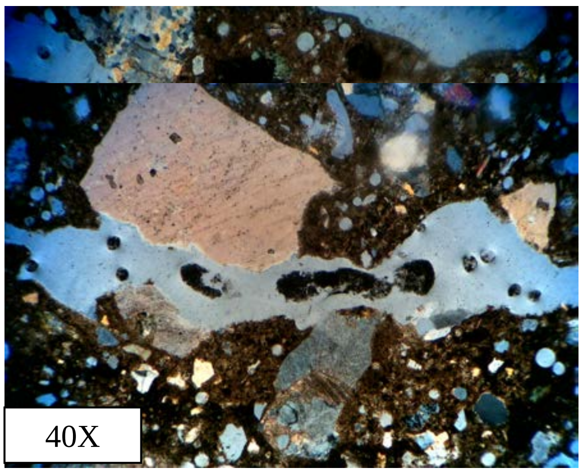


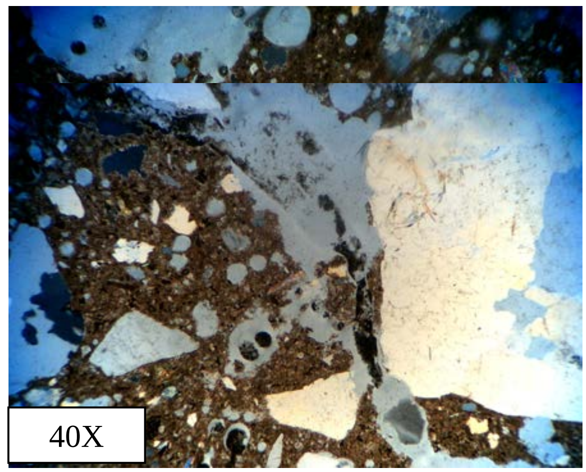


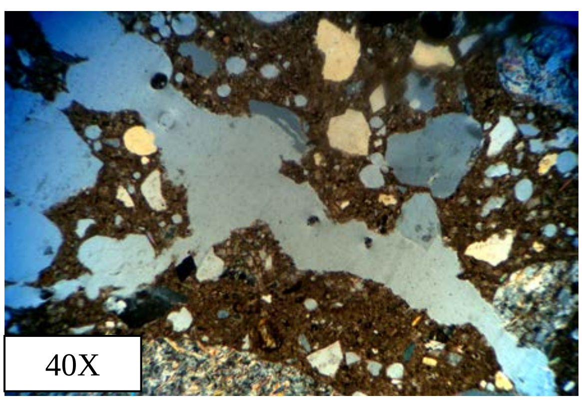
SAMPLE 302-0035-A004

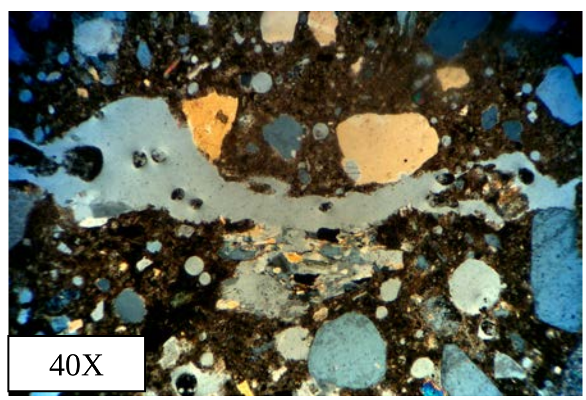


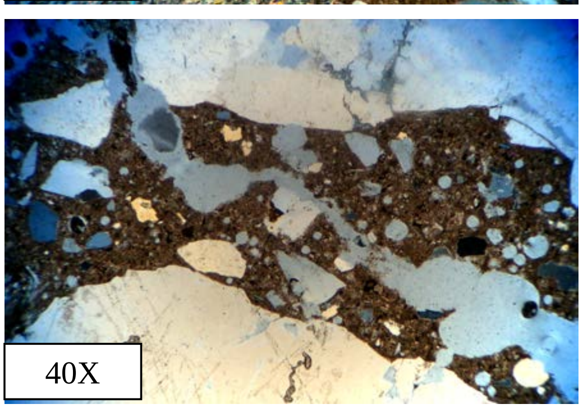


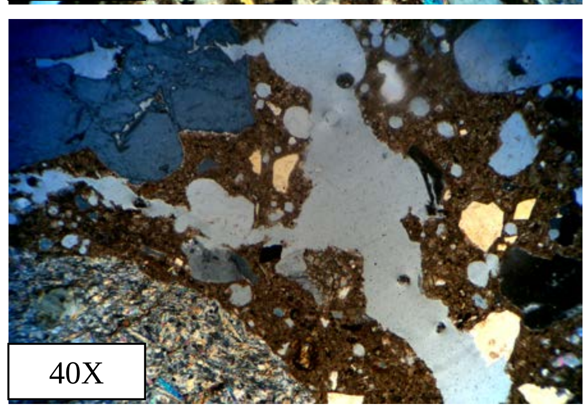




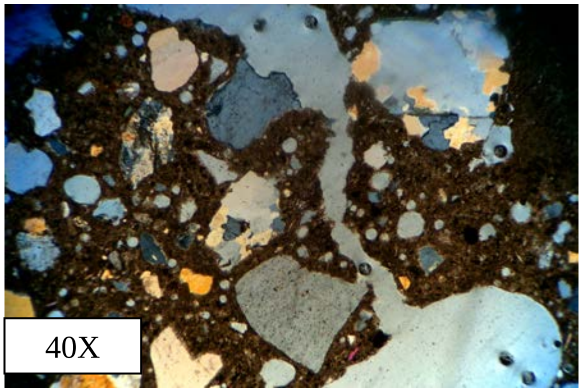


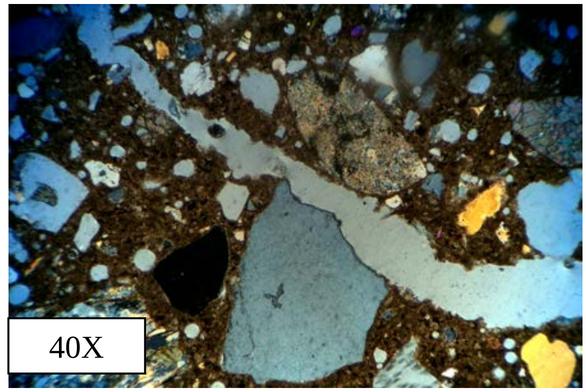


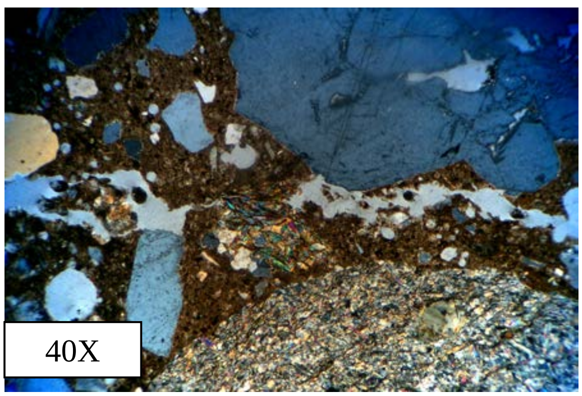


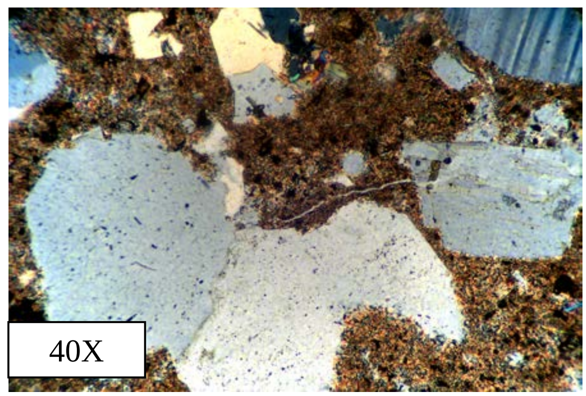


SAMPLE 302-0035-A004 (Cont.)

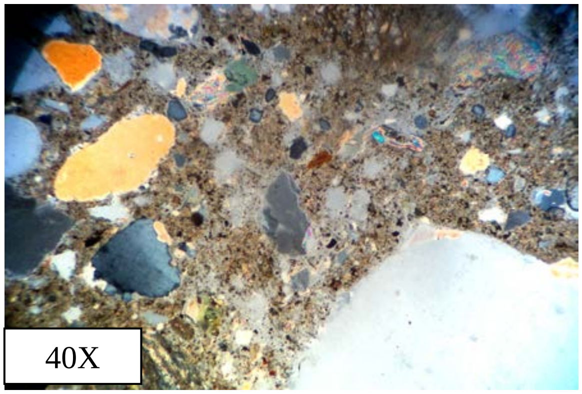


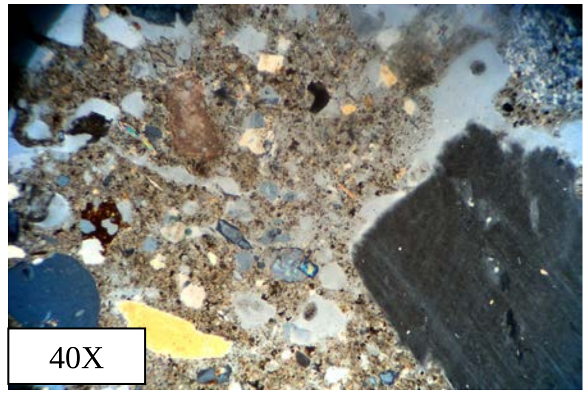


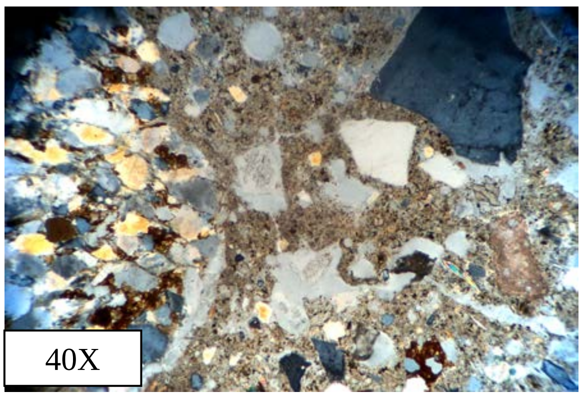


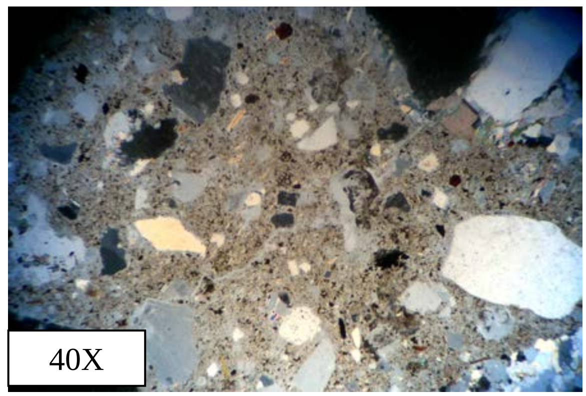


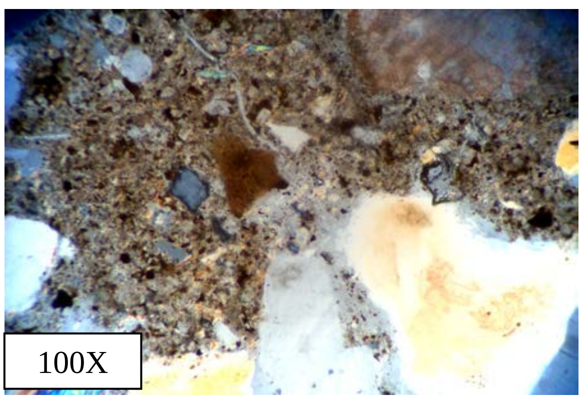
SAMPLE 302-0035-A005



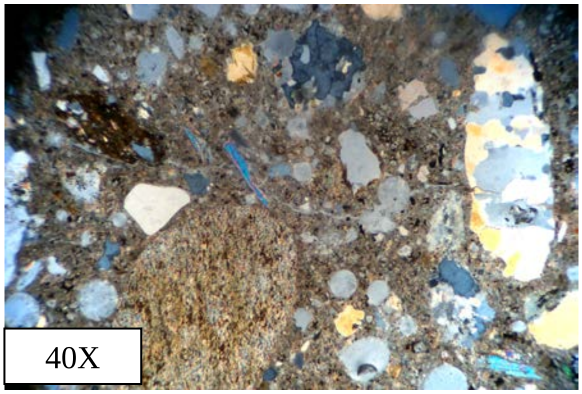








SAMPLE 302-0035-C006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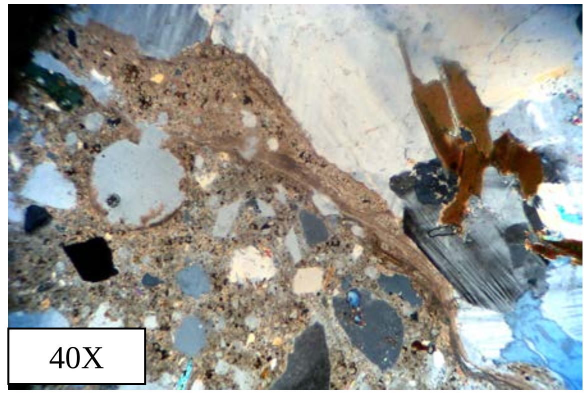
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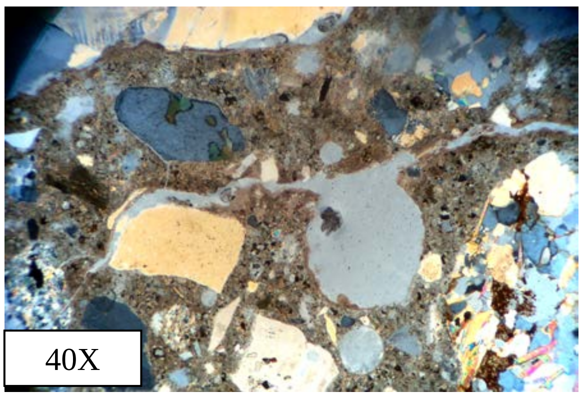
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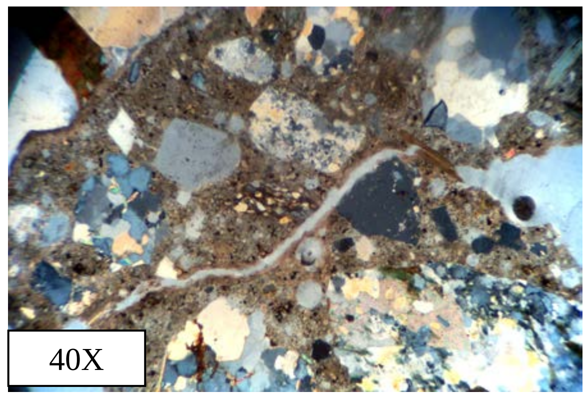
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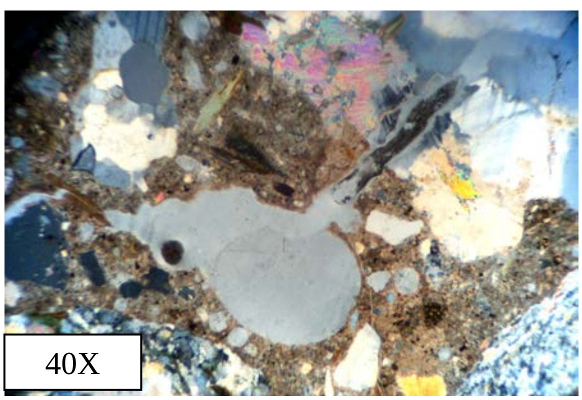
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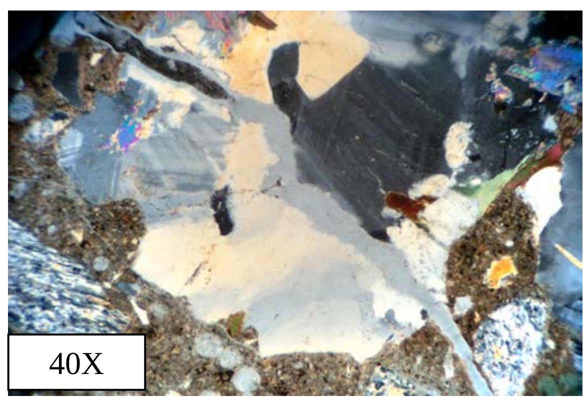
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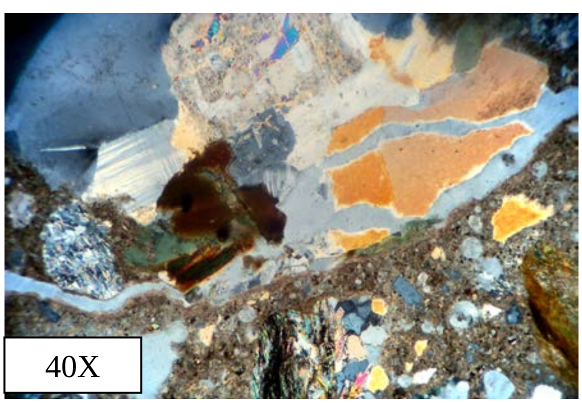
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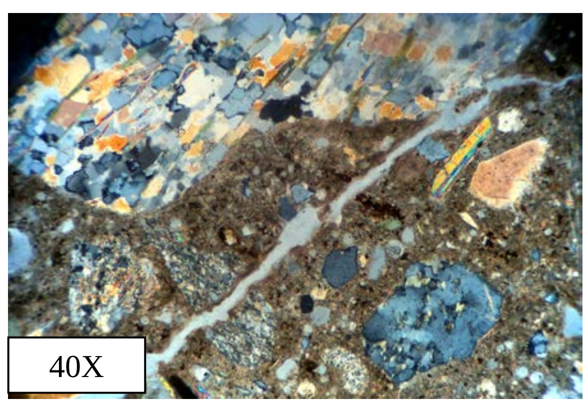
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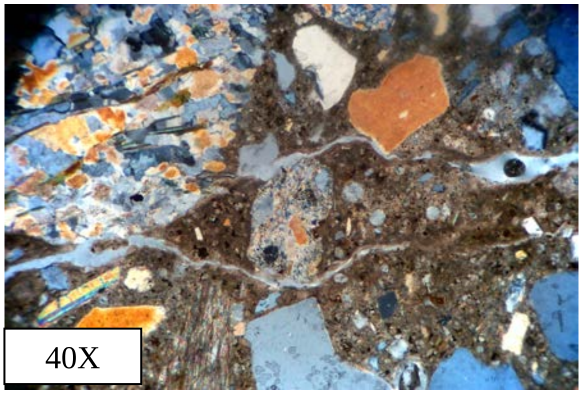
SAMPLE 302-0035-C006 (Cont.)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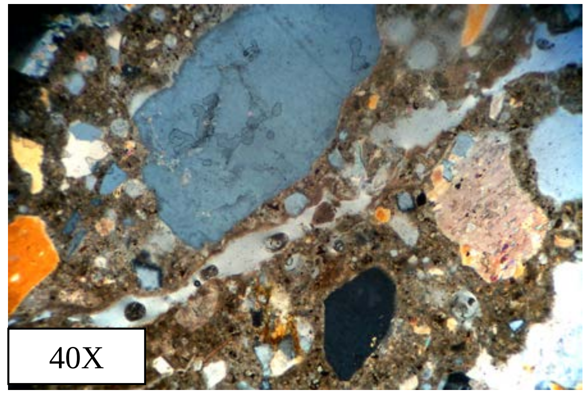
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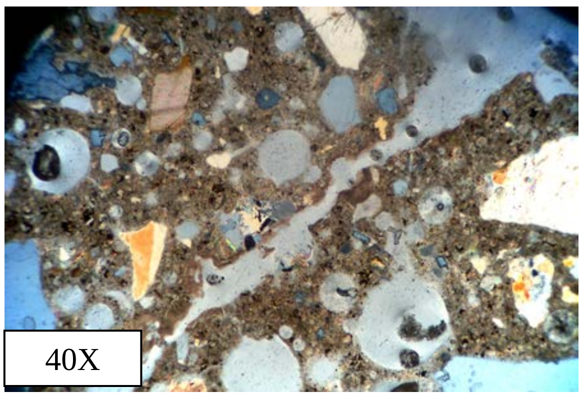
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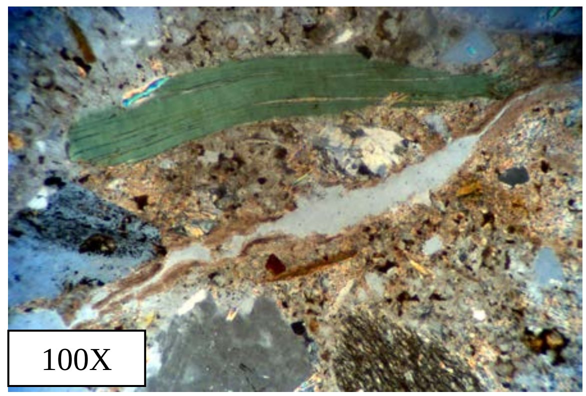
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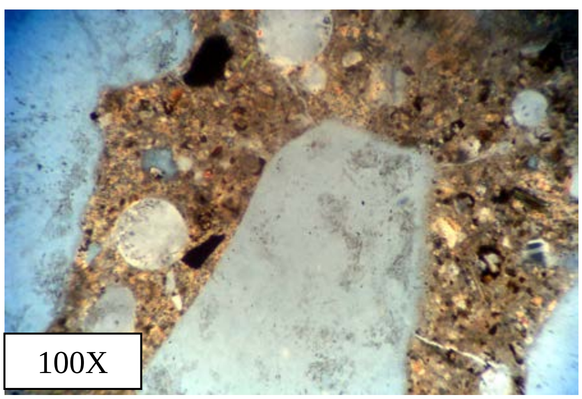
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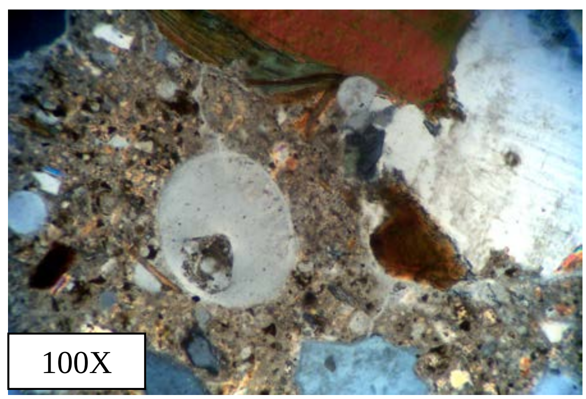
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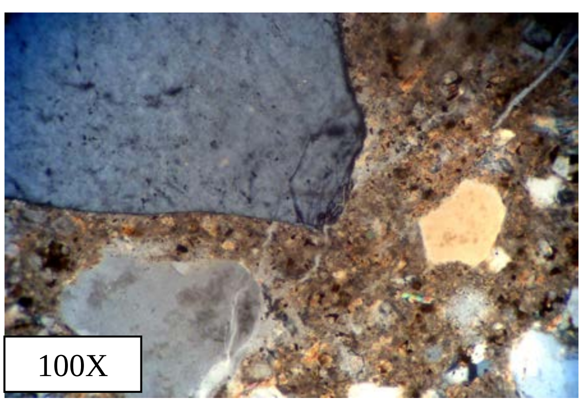
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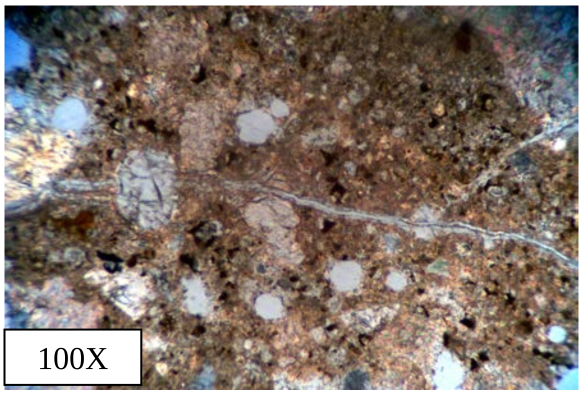
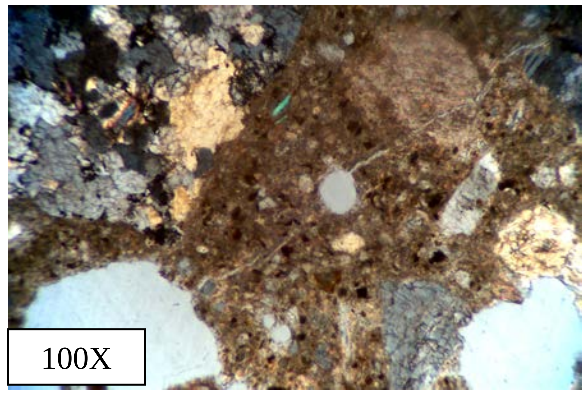
SAMPLE 313-0006-C075



100X



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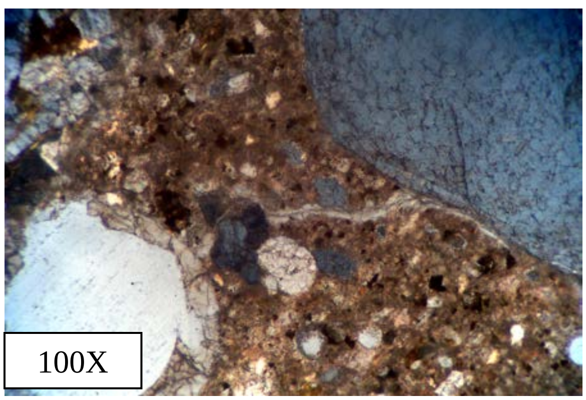

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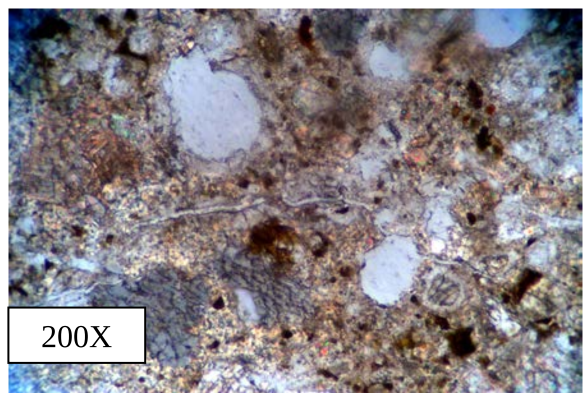

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