Evaluation of Bridge Abutments, Retaining Walls, and Barrier Walls along the Post Road Ext. near Providence, Rhode Island

Petrographic Evaluation

ASR Development and Deployment Program
Field Application and Demonstration Projects

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16. Abstract

This report presents the findings of the petrographic examination of six concrete cores extracted by the Rhode Island DOT in 2011 from bridge abutments, retaining walls, and barrier walls along the Post Road Ext. near Providence, Rhode Island. The evaluation mainly consisted of the Damage Rating Index (DRI), a method that provides a semi-quantitative assessment of the damage in concrete based on a count of petrographic features of deterioration generally associated with alkali-silica reaction (ASR).

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Table of contents

List of Tables

List of Figures

Appendix A

Appendix B

1. Introduction

This report presents the findings of the petrographic examination of six concrete cores extracted by the Rhode Island DOT in 2011 from bridge abutments, retaining walls, and barrier walls along the Post Road Ext. near Providence, Rhode Island. The evaluation mainly consisted of the Damage Rating Index (DRI), a method that provides a semi-quantitative assessment of the damage in concrete based on a count of petrographic features of deterioration generally associated with alkali-silica reaction (ASR).

2. Field Work – Extraction of Cores

Coring was conducted by the Rhode Island DOT. Table 1 presents the basic information about the cores received at Laval University, i.e. cores number, location, and length.

Table 1 : Cores provided for petrographic examination.

Core number	Location	Condition	Lenght (cm)
RI-1	Post Rd. Ext. S.B. - Greenwood Ramp Retaining Wall 8-3-2011	Core in 1 section	31.0
RI-2	Post Rd. Ext. S.B. - Greenwood Ramp Retaining Wall East Face 8-3-2012	Core in 1 section	26.1
RI-3	Post Rd. Ext. S.B. - Barriers 8-4-2011	Core in 1 section	5.2
RI-4	Post Rd. Ext. S.B. - Barriers 8-4-2011	Core in 1 section	12.9
RI-5	Post Rd. Ext. E.B. - Bridge Airport Connector 8-4-2011	Core in 1 section	24.7
RI-6	Post Rd. Ext. S.B. - Barriers 8-4-2011	Core in 1 section	18.2

3. Laboratory Testing of Cores – Damage Rating Index (DRI)

The concrete cores were sent to Dr. Benoit Fournier at Laval University, Quebec, Canada in October 2011. The five cores were first examined macroscopically and photographed. The five cores were then cut in two axially and polished, then examined under the stereomicroscope to determine the Damage Rating Index (DRI).

The portable hand-polishing device (Figure 1) uses a series of diamond-coated rubber disks to ensure progressive polishing from coarser to finer sizes (i.e. from disks no. 50 (coarse), 100, 400, 800, 1500 to 3000 (very fine)). The polished sections are then photographed and a grid is drawn on the section, which includes a minimum of 200 grid squares, 1 cm by 1 cm (0.4 by 0.4 in) in size (Figure 2). Each grid square is then examined under the stereomicroscope to determine the *Damage Rating Index* (DRI) (Figure 3).

Figure 1 : Polishing process of the concrete specimens for the Damage Rating Index.

Figure 2 : One cm by one cm grid drawn at the surface of the polished concrete section for petrographic examination using the DRI method.

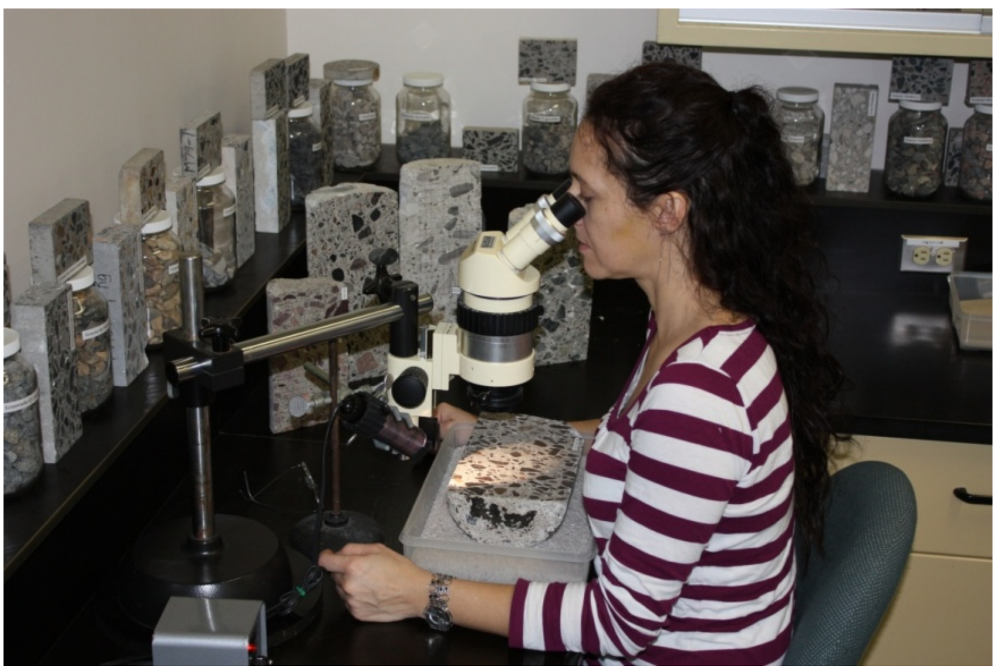


Figure 3 : Examination of the polished concrete section under the stereomicroscope for the determination of the Damage Rating Index.

Grattan-Bellew (1992) and Dunbar and Grattan-Bellew (1995) described a method to evaluate the condition of concrete by counting the number of typical petrographic features of ASR on polished concrete sections (15x magnification) (Table 2). The *Damage Rating Index* represents the normalized value (to 100 cm^2) (16 in^2) of the presence of the above petrographic features after the count of their abundance over the surface examined has been multiplied by weighing factors representing their relative importance in the overall deterioration process. Table 2 also gives the weighing factors originally proposed by Dr. Grattan-Bellew from the National Research Council of Canada and used in this study. Figure 4 gives examples of the petrographic features that are quantified as part of the process.

There is currently no rating system for the DRI values that correspond to concrete affected to a low, moderate or severe degree by ASR. However, our experience is such that values below 200-250 are indicative of a low degree of reaction / deterioration, DRIs of 200-500 correspond to moderate degree of reaction, and DRIs in excess of about 500-600 represent a high to very high (DRI > 1000) degree of ASR. It is important to mention, however, that since the DRI is not a standardized method, values can vary significantly from one petrographer to another.

Table 2 :Petrographic Features and Weighing Factors for the DRI (Grattan-Bellew and Mitchell 2006).

Petrographic feature	**Abbreviation**	**Weighing factor**
Crack in the coarse aggregate particles	CrCA	x 0.75
Open crack in coarse aggregate	OCrCA	x 4.0
Crack with reaction product in the coarse aggregate particles	Cr + RPCA	x 2.0
Coarse aggregate debonded	CAD	x 3.0
Reaction rims around aggregate particles	RR	x 0.5
Crack in the cement paste	CrCP	x 2.0
Crack with reaction product in the cement paste	Cr+RPCP	x 4.0
Air voids lined or filled with reaction products	RPAV	x 0.50

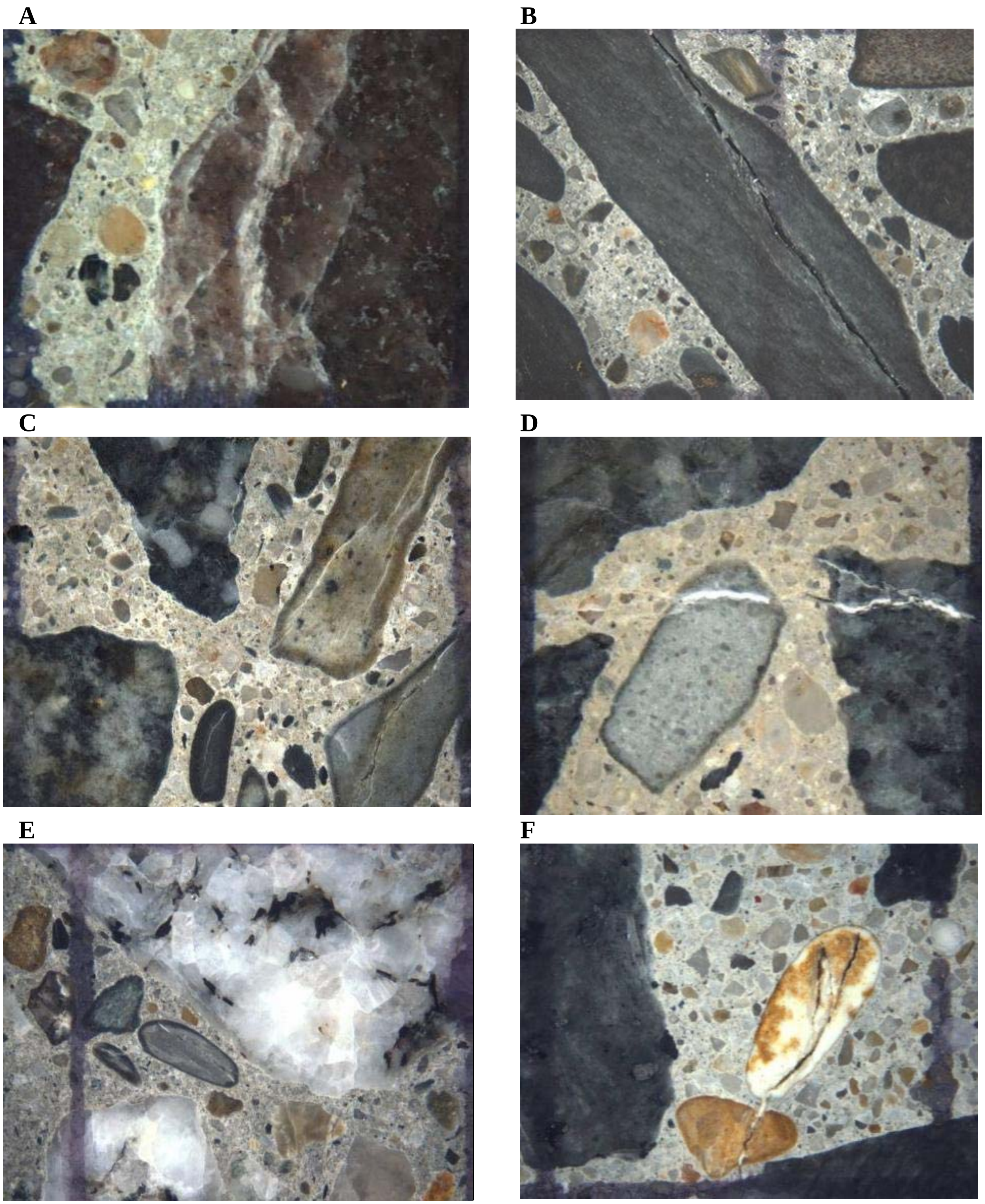


Figure 4 : Examples of typical petrographic features of deterioration due to ASR identified on polished concrete sections as part of the Damage Rating Index (DRI). A&B: Cracks in coarse aggregate particles (A- tight cracks; B- open cracks); C&D: Cracks with reaction products in the coarse aggregate particles; E&F: Cracks with reaction products in fine aggregate particles.

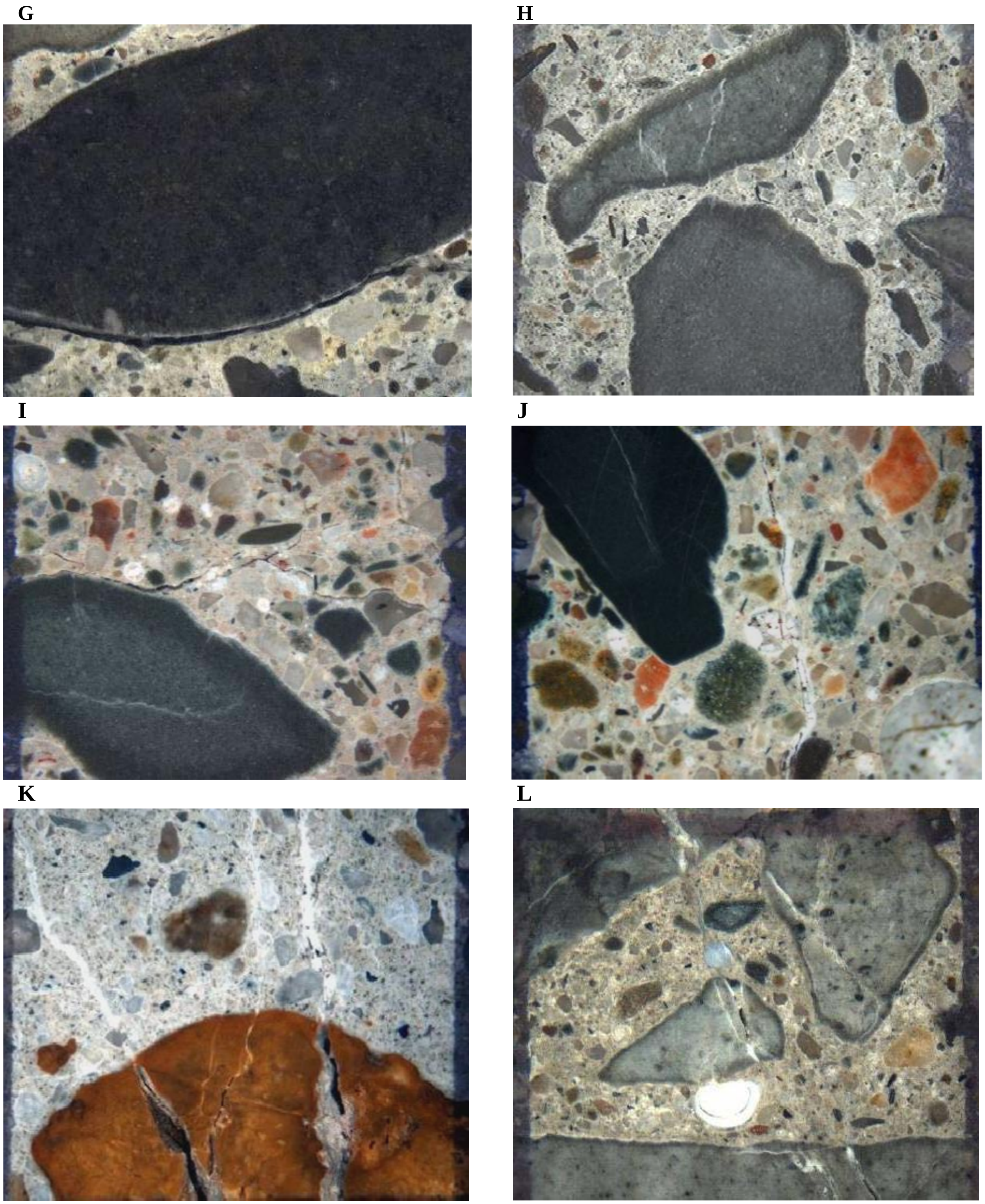


Figure 4 (cont'd): G: Debonded coarse aggregate particle; H: Reaction rims around reactive coarse aggregate particles; I : Cracks in the cement paste; J-L: Cracks with reaction products in the cement paste; L: Whitish and glassy alkali-silica reaction products in air voids of the cement paste.

4. Results of the Petrographic Examination

The Appendix A illustrates the six cores in their "as-received" condition. Pictures of noticeable macroscopic features of deterioration/reaction are also presented, particularly cracking in the concrete specimens, as well as air voids in the cement paste filled with secondary products. Table 3 gives a summary of the petrographic observations and a rating of the extent of ASR in the concrete of the seven polished sections examined as part of this investigation. The sections are illustrated in Figure 5, while the results (numerical) of the DRI are summarized in Table 4 and illustrated in Figure 6. Figure 7 provides micrographs of the typically petrographic features identified in this set of core. The detailed results of DRI, including micrographs of the petrographic features in each of the cores examined, are given in the Appendix B.

Table 3 : Summary of the petrographic observations in the cores from the Rhode Island DOT.

Sample	DRI	**Noticeable features, including extent of cracking and typical cracks width in the cement paste (mm)**	**Degree of ASR**
RI-1	**157**	• Surface cracking penetrates about 3 cm into the concrete. • Significant cracking is observed in the aggregate particles. • Deposits of ettringite are found in air voids of the cement paste.	Low
RI-2	**129**	• Surface cracking penetrates about 1.5 cm into the concrete. • Significant cracking is observed in the aggregate particles. • is observed.	Low
RI-3A	**546**	• Significant cracking is observed in the cement paste and in the aggregate particles, without/with reaction products (ASR gel). • Deposits of ettringite (mainly) and some ASR gel are found in air voids of the cement paste.	Moderate to high
RI-3B	**285**	• Significant cracking is observed in the cement paste, with/without reaction products (ASR gel). • Deposits of ettringite (mainly) and some ASR gel are found in air voids of the cement paste.	Low
RI-4	**325**	• Surface cracking penetrates about 4 cm into the concrete • Significant cracking is observed in the cement paste and in the aggregate particles, with/without reaction products (ASR gel) • Deposits of ASR gel (mainly) and ettringite are found in air voids of the cement paste.	Low to moderate
RI-5	**296**	• Surface cracking penetrates about 1.5 cm into the concrete • Significant is observed cracking in the cement paste and in the aggregate particles, with/without reaction products • Deposits of ettringite (mainly) and some ASR gel are found in air voids of the cement paste.	Low to moderate
RI-6	**230**	• Surface cracking penetrates about 5.5 cm into the concrete • Significant cracking is observed in the cement paste, without reaction products • Deposits of ettringite (mainly) and some ASR gel are found in air voids of the cement paste.	Low

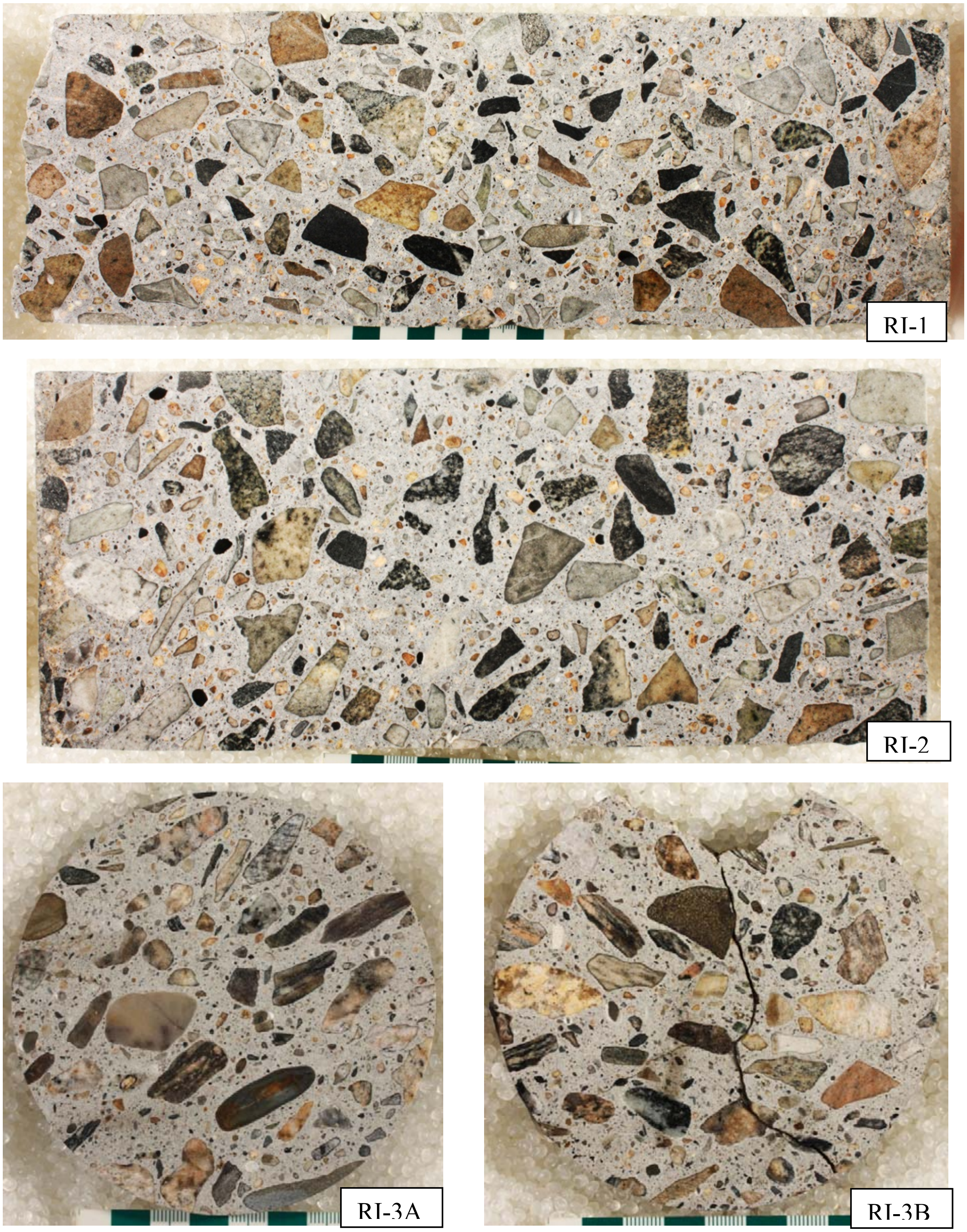


Figure 5 : Polished concrete sections from Rhode Island DOT.

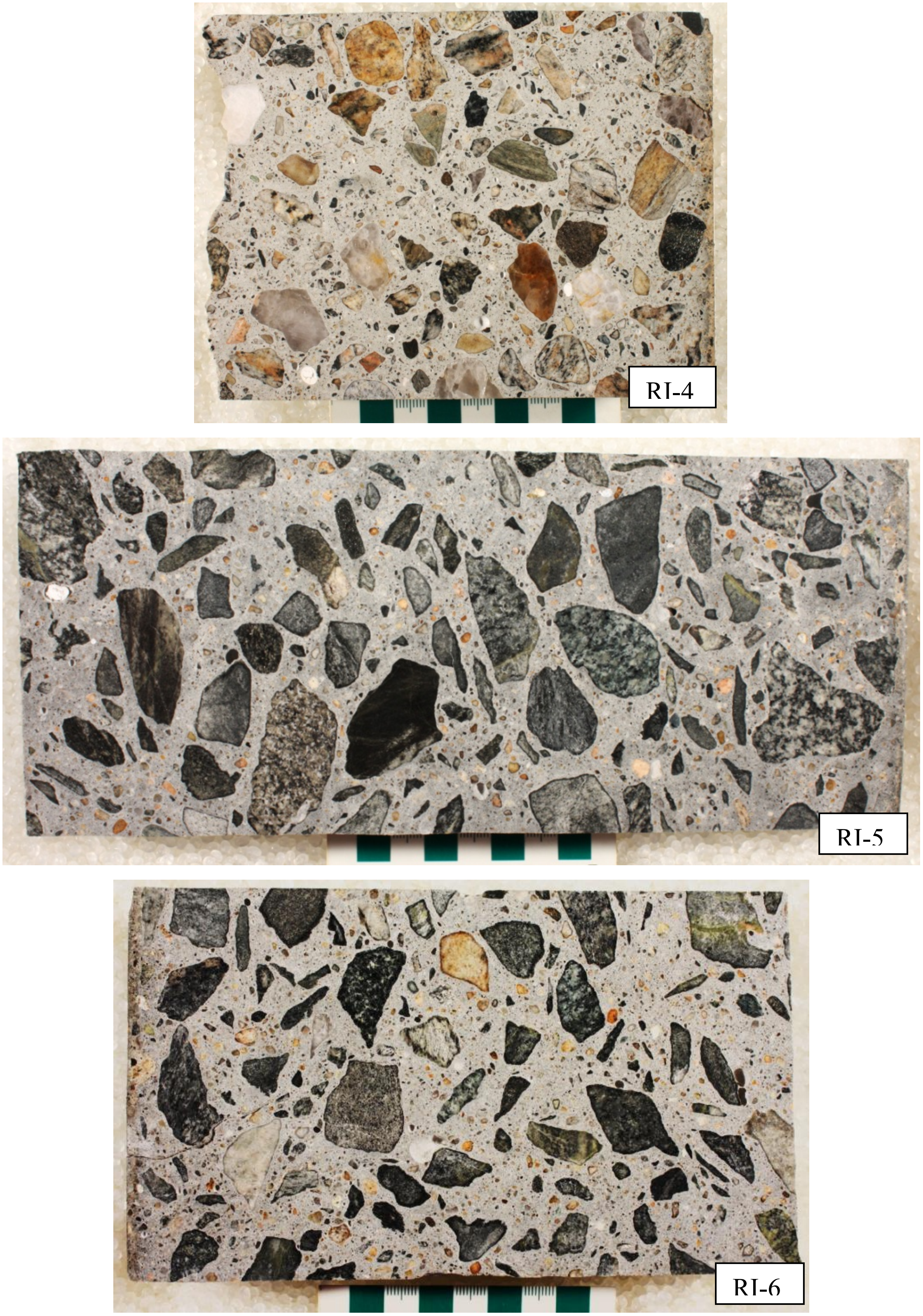


Figure 5 (cont'd): Polished concrete sections from Rhode Island DOT (cont'd).

Table 4 : Results of the Damage Rating Index (DRI) for the Rhode Island DOT cores.

Specimen	Feature	Cracks in the aggregate particles			Crack in the cement paste		Other features			DRI
		CrCA	OCrCA	Cr+RPCA	CrCP	Cr+RPCP	CAD	RR	RPAV	Total
RI-1	DRI	42	0	0	30	0	0	32	53	**157**
	% of the DRI	*26*	*0*	*0*	*19*	*0*	*0*	*20*	*34*	***100***
RI-2	DRI	50	0	0	9	0	0	26	44	**129**
	% of the DRI	*39*	*0*	*0*	*7*	*0*	*0*	*20*	*34*	***100***
RI-3A	DRI	52	0	71	58	241	0	49	75	**546**
	% of the DRI	*10*	*0*	*13*	*11*	*44*	*0*	*9*	*14*	***100***
RI-3B	DRI	39	0	21	57	57	0	32	79	**285**
	% of the DRI	*14*	*0*	*8*	*20*	*20*	*0*	*11*	*28*	***100***
RI-3mix[1]	DRI	47	0	50	57	161	0	41	77	**433**
	% of the DRI	*11*	*0*	*11*	*13*	*37*	*0*	*10*	*18*	***100***
RI-4	DRI	49	0	51	54	84	7	53	27	**325**
	% of the DRI	*15*	*0*	*16*	*17*	*26*	*2*	*16*	*8*	***100***
RI-5	DRI	74	0	42	83	33	5	26	33	**296**
	% of the DRI	*25*	*0*	*14*	*28*	*11*	*2*	*9*	*11*	***100***
RI-6	DRI	62	2	6	106	0	2	35	17	**230**
	% of the DRI	*27*	*1*	*3*	*46*	*0*	*1*	*15*	*8*	***100***

[1] Results obtained by combining the observations made on the polished sections R1-3A and R1-3B.

CrCA: Cracks in coarse aggregate particles
OCrCA: Open crack in coarse aggregate
Cr+RPCA: Crack with reaction product in the coarse aggregate particles
CrCP: Crack in the cement paste
Cr+RPCP: Crack with reaction product in the cement paste
CAD: Coarse aggregate debonded
RR: Reaction rim
RPAV: Reaction products in air voids of the cement paste

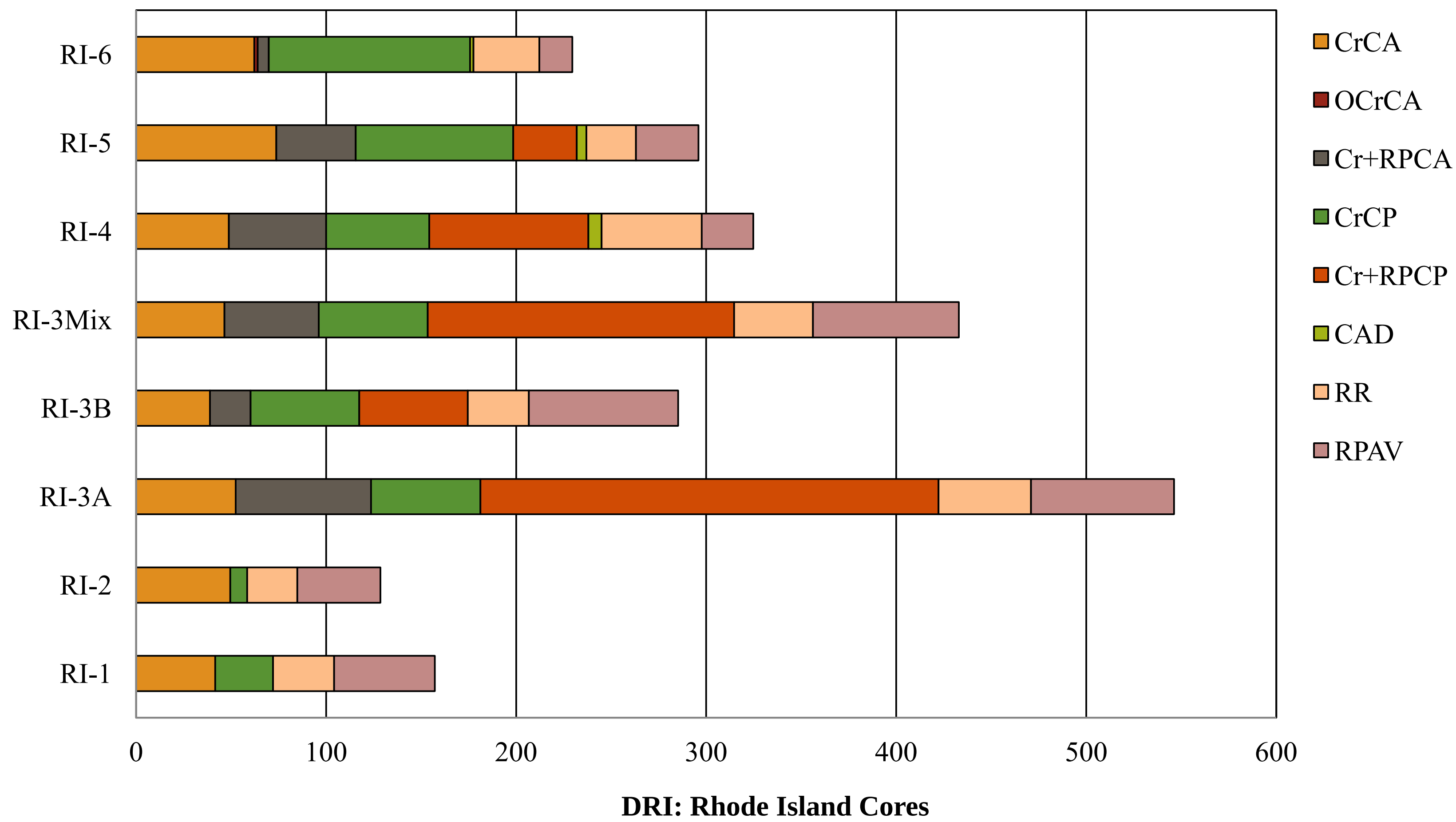


Figure 6 : Results of the Damage Rating Index (DRI) for the Rhode Island DOT cores.

CrCA: Cracks in coarse aggregate particles
OCrCA: Open crack in coarse aggregate
Cr+RPCA: Crack with reaction product in the coarse aggregate particles
CrCP: Crack in the cement paste
Cr+RPCP: Crack with reaction product in the cement paste
CAD: Coarse aggregate debonded
RR: Reaction rim
RPAV: Reaction products in air voids of the cement paste

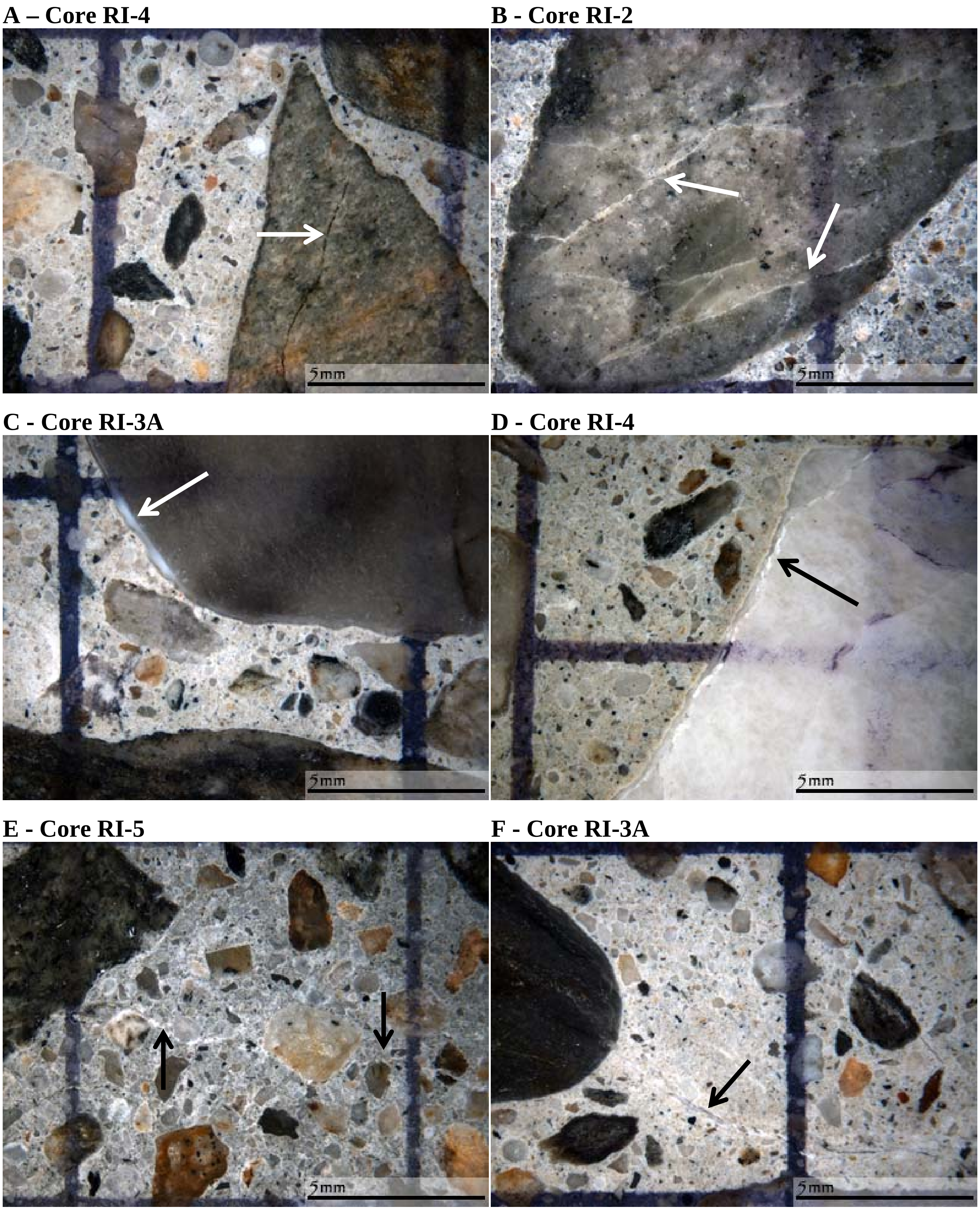
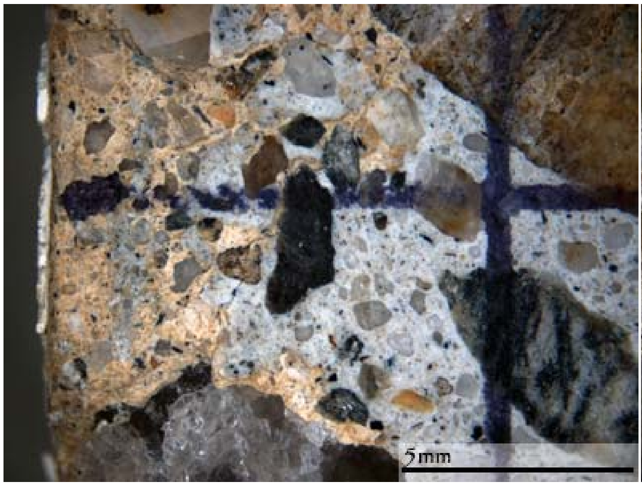
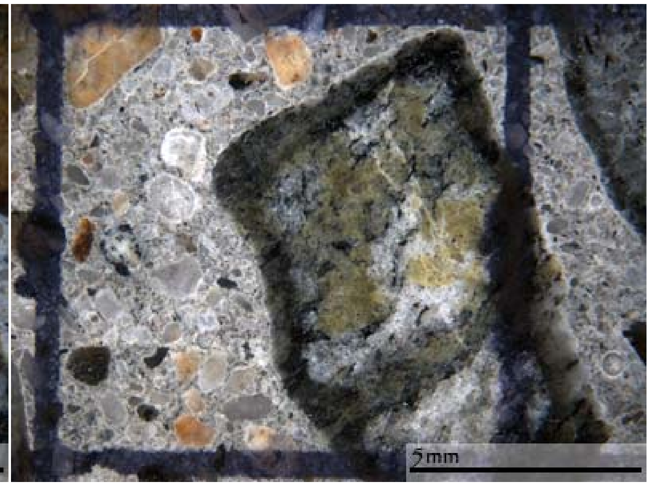


Figure 7 : Example of the petrographic features identified in the Rhode Island concrete cores. A-B: Crack in coarse aggregate particles; C-D: Cracks with reaction product in coarse aggregate particles; E-F: Cracks in the cement paste.

G - Core RI-4



H - Core RI-6



I - Core RI-4

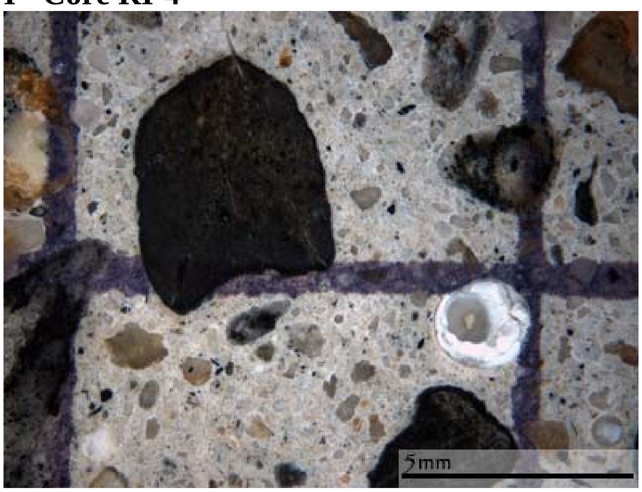


Figure 7 (cont'd): Example of the petrographic features identified in the Rhode Island concrete cores. G: Surficial carbonation; H: Reaction rim; I: Coarse aggregate particle debonded and reaction products in a void of the cement paste.

4.1 Deterioration description

4.1.1 General

As illustrated in Figures 5 and 6, with Damage Rating Indices ranging from 129 to 546, the polished concrete sections of the Rhode Island DOT cores show low to moderate degree of deterioration/damage due to ASR. Details of the DRIs and micrographs of the polished sections can be seen in the Appendix B, Figures B1 to B14.

As indicated in Table 4 and Figure 6, the highest contributor to the DRI for this set of cores is *Cracks in the cement paste, with or without reaction product (CrCP, CrCP+RP)* (7 to 55%). Widths of cracks in the cement paste vary from 0.05 to 0.1 mm. Those cracks are not always filled with ASR products and show some signs of carbonation (i.e. for those cracks penetrating from the surface of the cores).

Globally, *cracks in the aggregate particles, with or without reaction product (CrCA, OCrCA, CrCA+RP),* represent the second most important petrographic sign of damage in the Rhode Island DOT cores (22 to 39%). Air voids in the cement paste are frequently lined or even filled with secondary products (*RPAV*), either ettringite (mainly) or alkali-silica gel. Dark (reaction) rims are observed around a fair number of coarse aggregate particles, and are present in most of the cores examined. The presence of reactions products in voids, as well as reaction rims, are however not indications of "damage" in the concrete.

4.1.2 Cores RI-1 and RI-2

As illustrated in Figures 5 and 6, the polished concrete sections RI-1 and RI-2 show limited signs of damage/deterioration. Damage Rating Indices of 129 and 157 were obtained for those cores, respectively, thus indicating a low degree of damage due to ASR. Details of the DRIs and micrographs of the above polished sections can be seen in the Appendix B, Figures B.1 to B.4.

The aggregate materials in the cores RI-1 and RI-2 show a variety of petrographic types/ compositions (quartzitic sandstone/quartzite, granitic gneiss). As indicated in Table 4 and Figure 6, the highest contributors to the DRI for this set of cores are *Cracks in the aggregate particles (CrCA)* (26-39% of the DRI), *Air voids lined of filled with reaction product (RPAV)* (34% of the DRI), and *Reaction Rims (RR)* (20% of the DRI). This means that more than 50% of the DRI values for those two cores correspond to petrographic features (RPAV and RR) that are not a direct indication of "damage".

Coarse aggregates show a fair amount of cracks (*CrCA),* but essentially tight (closed) cracks. Very limited deposits of alkali-silica gel were observed in the concrete of these two cores (in cracks or voids of the cement paste), ettringite being the main secondary product observed in air voids of the cement paste. The presence of reaction rims around a fair number of coarse aggregate particles indicates that ASR is present in the concrete, but likely at a low stage of development or severity. Carbonation is typically limited to the first 1 to 2 mm from the surface of the cores, except along some surface cracks that penetrate down 3 cm (core RI-1) and 1.5 cm (core RI-2) into the concrete.

4.1.3 Cores RI-5 and RI-6

As illustrated in Figures 5 and 6, the polished concrete sections RI-5 and RI-6, show noticeable but limited signs of deterioration. With Damage Rating Indices of 230 and 296, those two cores indeed show low to mild degrees of deterioration/damage due to ASR. Details of the DRIs and micrographs of the polished sections can be seen in the Appendix B, Figures B11 to B14.

The aggregate material observed in the above two cores is somewhat more homogeneous than in the other cores. Aggregate particles are mostly light to medium grey in color, and the rock types mainly correspond to granitic gneiss, quartzite and schist. As indicated in Table 4 and Figure 6, the two highest contributors to the DRI for this set of cores are *Cracks in the cement paste without reaction product (CrCP)* (28 and 46% of the DRI) and *Cracks in the aggregate particles (CrCA)* (25 and 47% of the DRI). Widths of the cracks observed in the cement paste vary from 0.05 to 0.1 mm, with typical opening of 0.1 mm. Silica gel was observed in some cracks of aggregate particles and of the cement paste in the concrete core RI-5. Secondary reaction products (mainly ettringite with some ASR gel) were found in some voids of the cement paste (8 and 11% of the DRI); also, reaction rims were noticed around a fair number of aggregate particles (9 and 15% of the DRI). Carbonation is typically limited to the first 5 mm from the surface of the cores, except along some surface cracks that penetrate down 1.5 cm (core RI-5) and 5 cm (core RI-6) into the concrete.

Overall, signs of ASR are slightly more developed in the cores RI-5 and RI-6 than in the cores RI-1 and RI-2, but are still of a mild (between low and moderate) degree.

4.1.4 Cores RI-3 and RI-4

With Damage Rating Indices ranging from 285 to 546, the polished concrete sections RI-3 and RI-4 show moderate to high degree of deterioration/damage due to ASR (Figures 5 and 6). Details of the DRIs and micrographs of the polished sections can be seen in the Appendix B, Figures B5 to B10.

The aggregate material observed in the above two cores show a variety of petrographic compositions/types (quartzitic sandstone/quartzite, granitic gneiss, schist), as for the first set of cores (RI-1 and RI-2). As indicated in Table 4 and Figure 6, the highest contributors to the DRI for this set of cores are *Cracks in the cement paste with or without reaction product (CrCP – CrCP+RP)* (40 to 55% of the DRI), *Cracks in the aggregate particles with or without reaction product (CrCA – CrCA+RP)* (22 to 23% of the DRI) *and Air voids lined or filled with reaction product (RPAV)* (8 to 28% of the DRI). Widths of the cracks in the cement paste vary from 0.05 to 0.1 mm, with typical opening of 0.1 mm.

Reaction products (silica gel) were observed in this set of cores (especially in the core RI-4), mostly in cracks of the cement paste, but also in cracks of aggregate particles and lining/filling air voids in the cement paste. Reaction rims (RR) were also noticed around a fair number of aggregate particles (9 to 16% of the DRI) in the cores RI-3 and RI-4. Carbonation is typically limited to the first 3 mm from the surface of the core RI-4, except along some surface cracks that penetrate down 4 cm (core RI-4) into the concrete.

The frequent presence of alkali-silica gel, in cracks of the aggregate particles and of the cement paste, as well as in voids of the paste, would indicate that alkali-silica reaction is at a more advanced state of development (higher severity) in these cores than in the other cores examined (RI-1 and RI-2, RI-5 and RI-6).

5. Conclusion - Summary of Findings

This report summarizes the results of the petrographic examination, using the *Damage Rating Index* method, of a set of six cores provided by the Rhode Island DOT. Overall, cores RI-1, RI-2, RI-5 and RI-6 are showing low to mild degree of deterioration / ASR-related damage, while cores RI-3 and RI-4 show more advanced signs (moderate to high degree) of deterioration / ASR-related damage. Ettringite is often observed in voids of the cement paste in all cores examined.

Petrographic observations demonstrate that noticeable cracking is occurring in the cement paste, as well as in the aggregate particles. Since silica gel has been observed in a fair number of cracks in the cement paste and in the aggregate particles, especially in the case of cores RI-3, RI-4 and RI-5, it is concluded that ASR is involved in the deterioration process of the above concretes.

6. References

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Grattan-Bellew, P.E. and Mitchell, L.D. 2006. Quantitative petrographic analysis of concrete – the damage rating index (DRI) method, a review. Proceedings of *Marc-André Bérubé Symposium on Alkali-Aggregate Reaction (AAR) in Concrete*, Montréal (Canada), May 2006, edited by B. Fournier, CANMET-MTL, 45-70.

Appendix A

Rhode Island Cores

Table A 1 : Cores provided for petrographic examination

Core number	Location	Condition	Lenght (cm)
RI-1	Post Rd. Ext. S.B. - Greenwood Ramp Retaining Wall 8-3-2011	Core in 1 section	31.0
RI-2	Post Rd. Ext. S.B. - Greenwood Ramp Retaining Wall East Face 8-3-2012	Core in 1 section	26.1
RI-3	Post Rd. Ext. S.B. - Barriers 8-4-2011	Core in 1 section	5.2
RI-4	Post Rd. Ext. S.B. - Barriers 8-4-2011	Core in 1 section	12.9
RI-5	Post Rd. Ext. E.B. - Bridge Airport Connector 8-4-2011	Core in 1 section	24.7
RI-6	Post Rd. Ext. S.B. - Barriers 8-4-2011	Core in 1 section	18.2

Core: RI-1

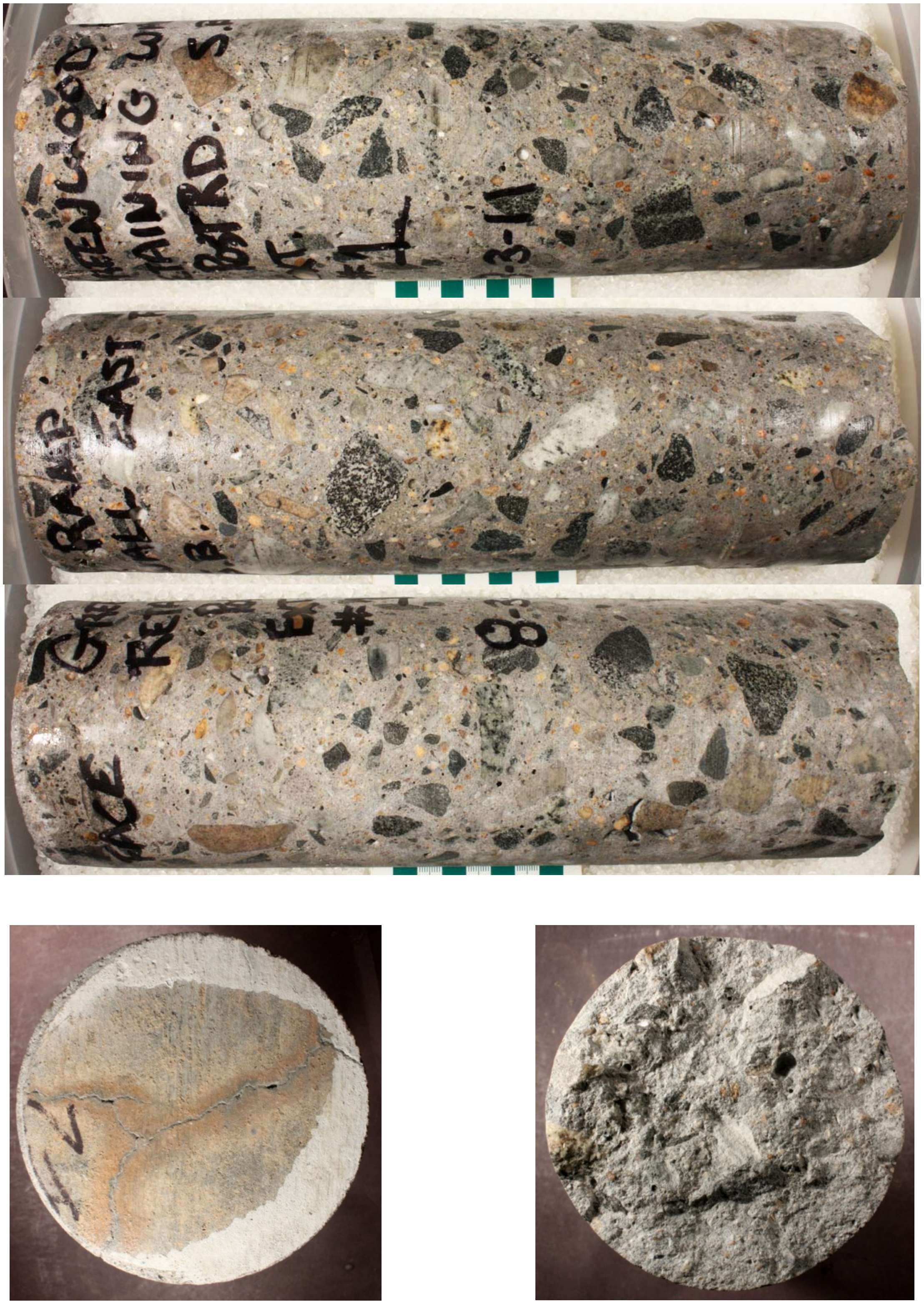


Figure A 1 : Core RI-1

Core: RI-2

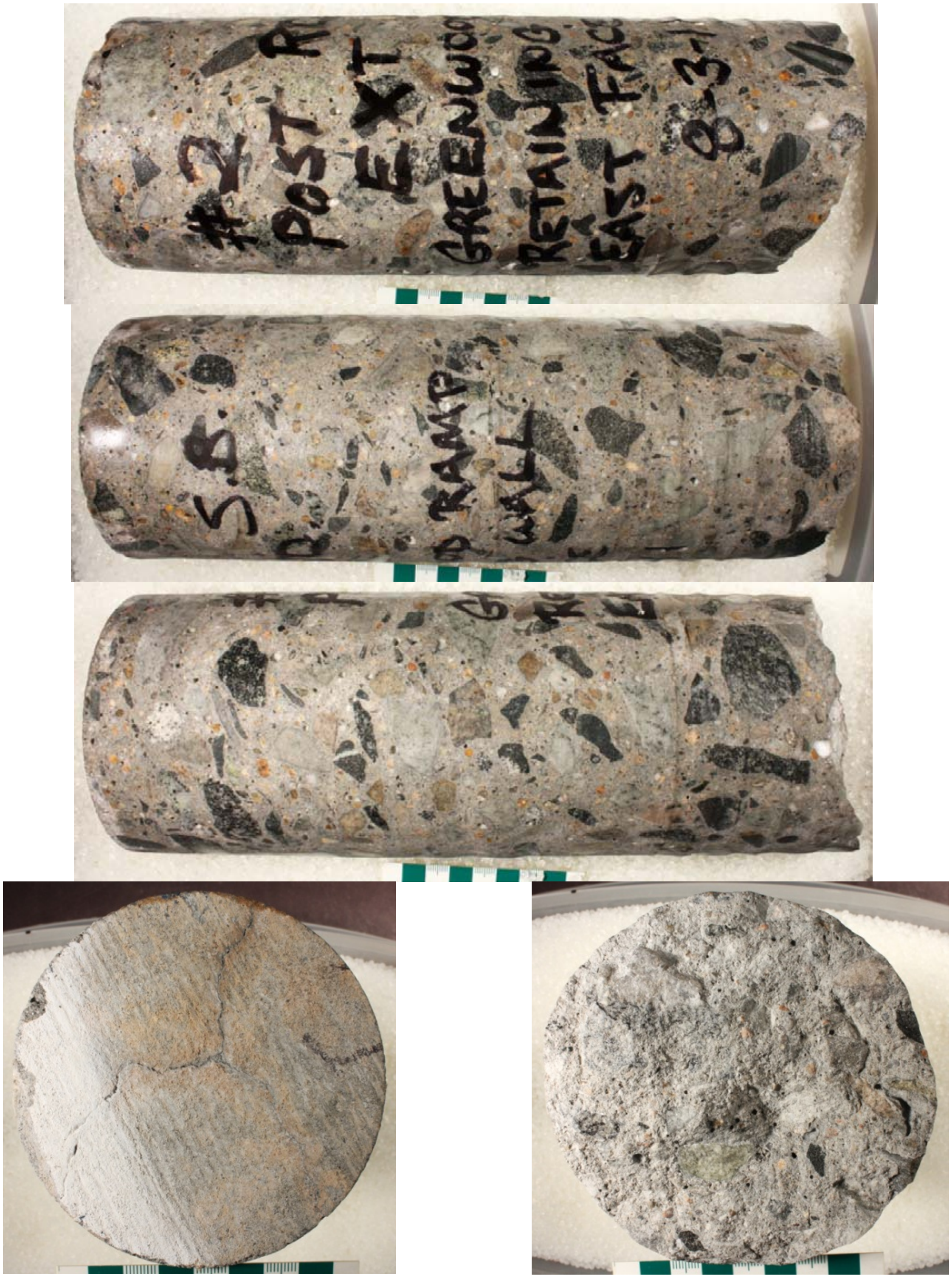


Figure A 2 : Core RI-2

Core: RI-3

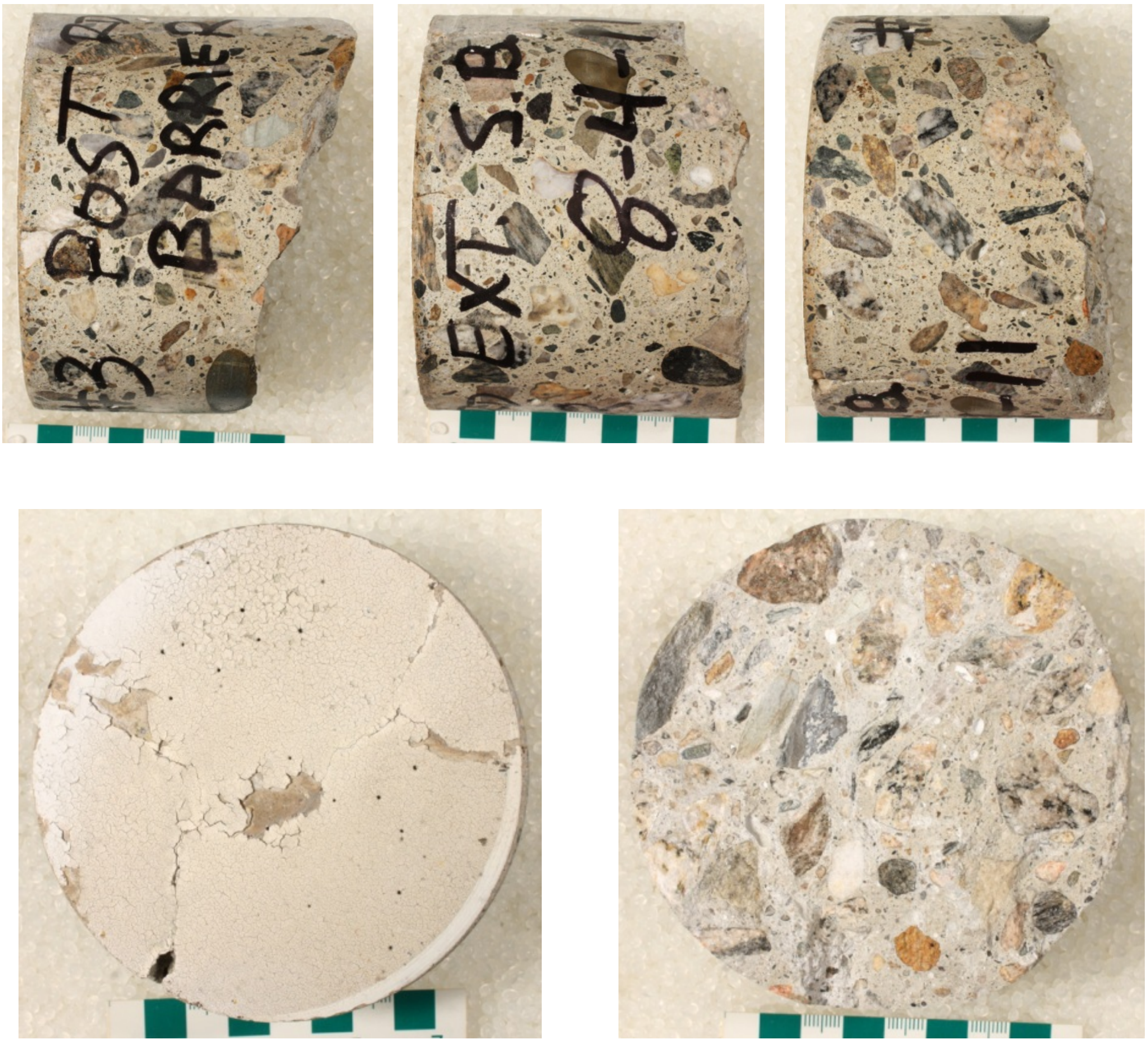


Figure A 3: Core RI-3

Core: RI-4

Figure A 4 : Core RI-4

Core: RI-5

Figure A 5: Core RI-5

Core: RI-6

Figure A 6 : Core RI-6

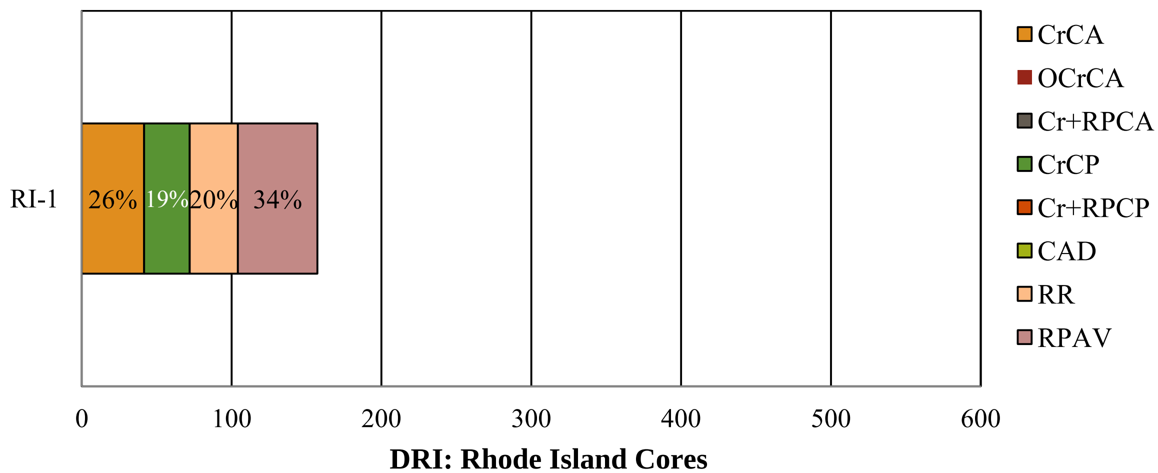
Appendix B

Photographs of the polished concrete core sections,

detailed results of the DRI and

micrographs of the petrographic symptoms of deterioration

Core: RI-1



Sample		**Cracks in the aggregate particles**			**Crack in the cement paste**		**Other features**			**DRI**
RI-1	**Feature**	**CrCA**	**OCrCA**	**Cr+RPCA**	**CrCP**	**Cr+RPCP**	**CAD**	**RR**	**RPAV**	**Total**
	DRI	42	0	0	30	0	0	32	53	157
	% of the DRI	*26*	*0*	*0*	*19*	*0*	*0*	*20*	*34*	*100*

Figure B. 1 : Polished core section RI-1 and DRI results

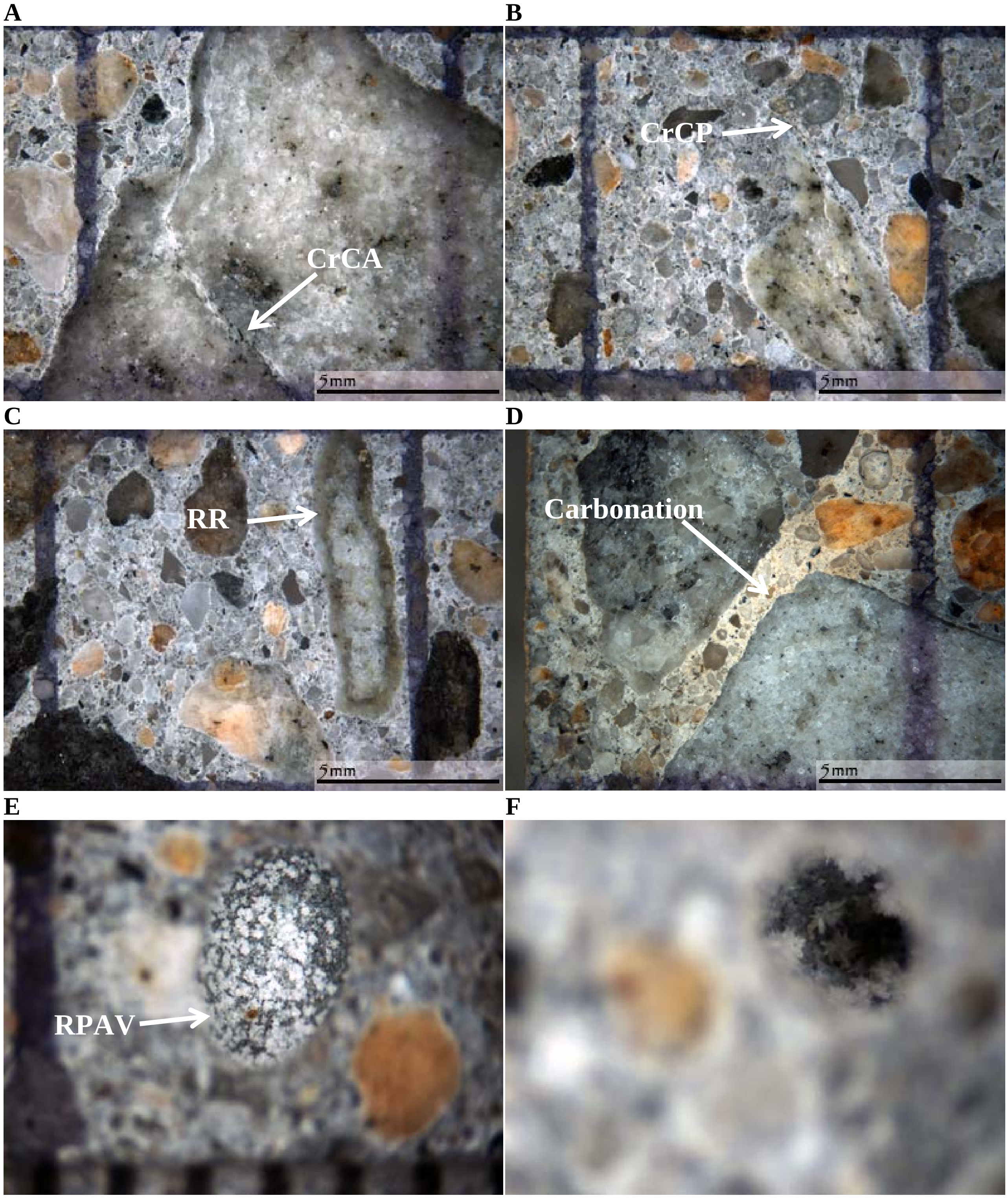
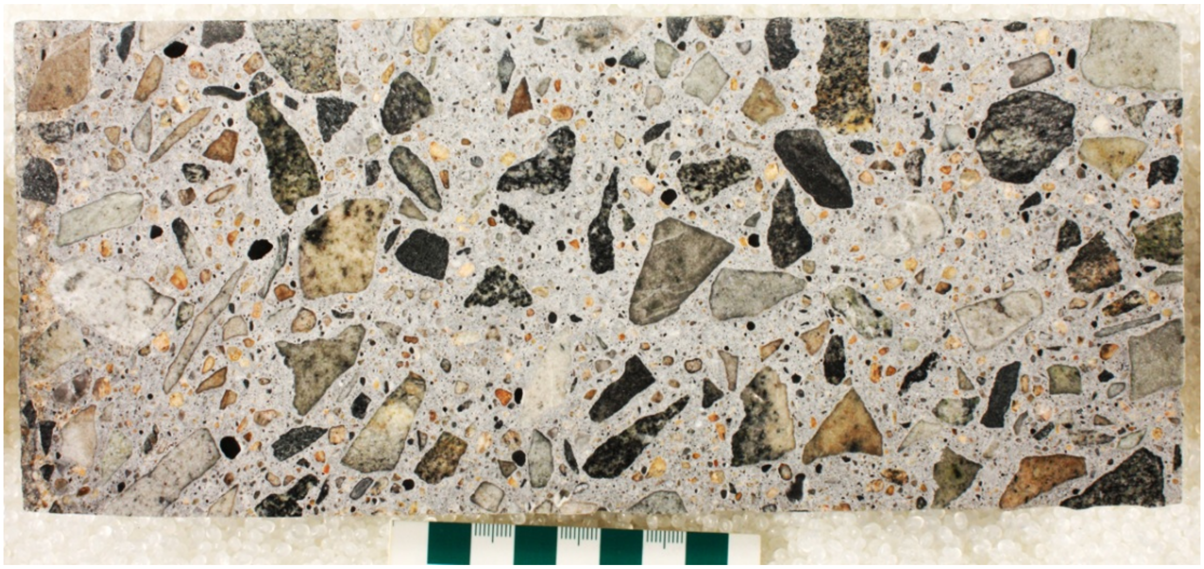
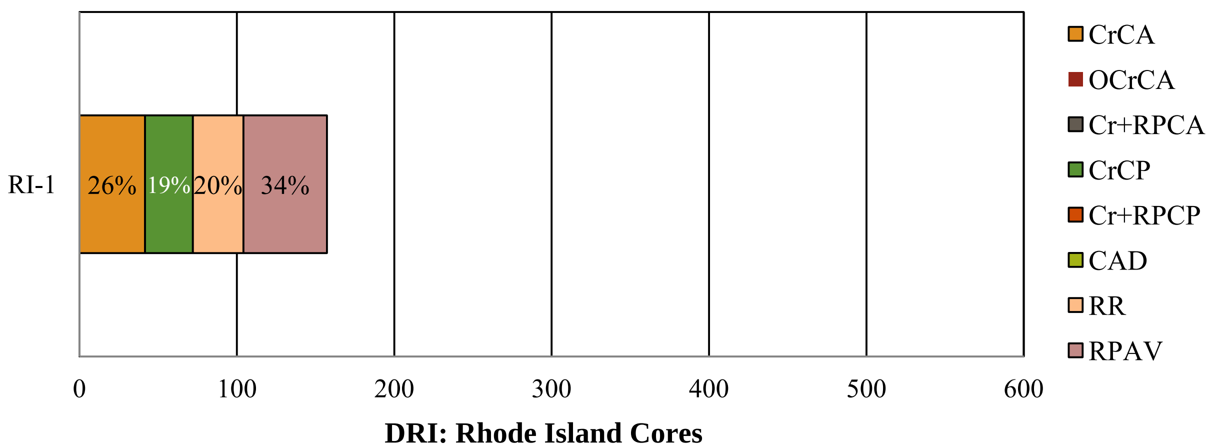


Figure B. 2 : Micrographs showing petrographic features observed on the concrete polished section of core RI-1. A. Cracked aggregate particle; B. Crack in the cement paste; C. Reaction rim; D. Carbonation of the cement paste; E-F. Ettringite in air voids of the cement paste.

Core: RI-2





Sample		Cracks in the aggregate particles			Crack in the cement paste		Other features			DRI
RI-2	Feature	CrCA	OCrCA	Cr+RPCA	CrCP	Cr+RPCP	CAD	RR	RPAV	Total
	DRI	50	0	0	9	0	0	26	44	129
	% of the DRI	*39*	*0*	*0*	*7*	*0*	*0*	*20*	*34*	*100*

Figure B. 3 : Polished core section RI-2 and DRI results

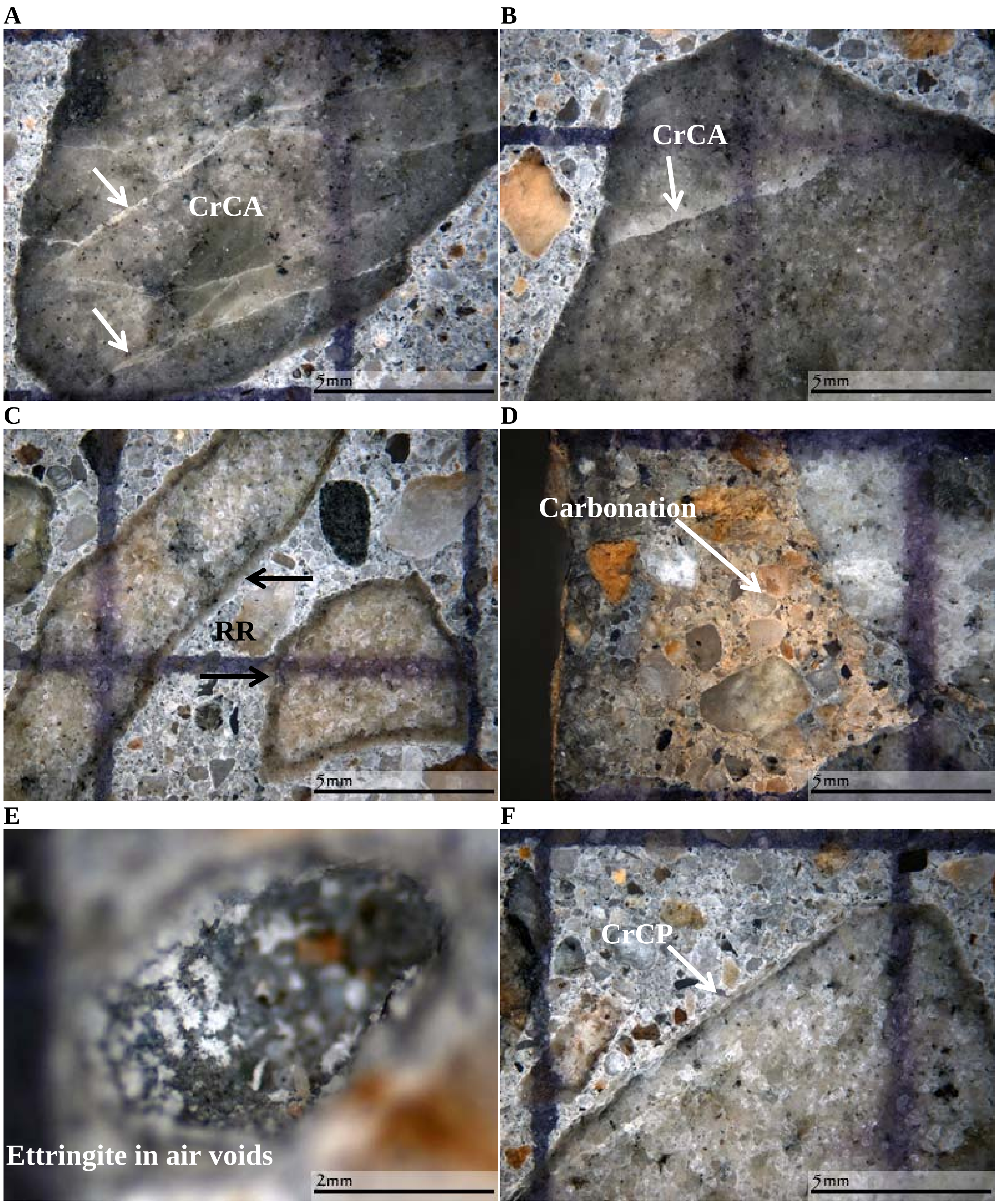
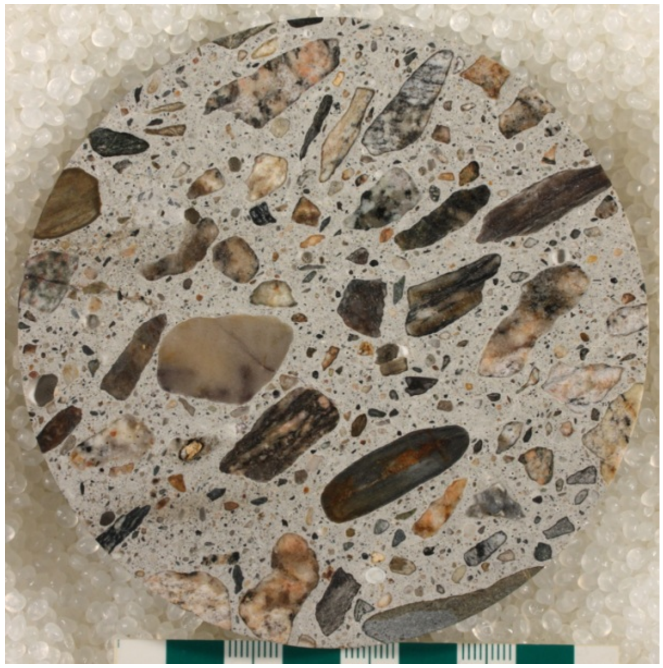
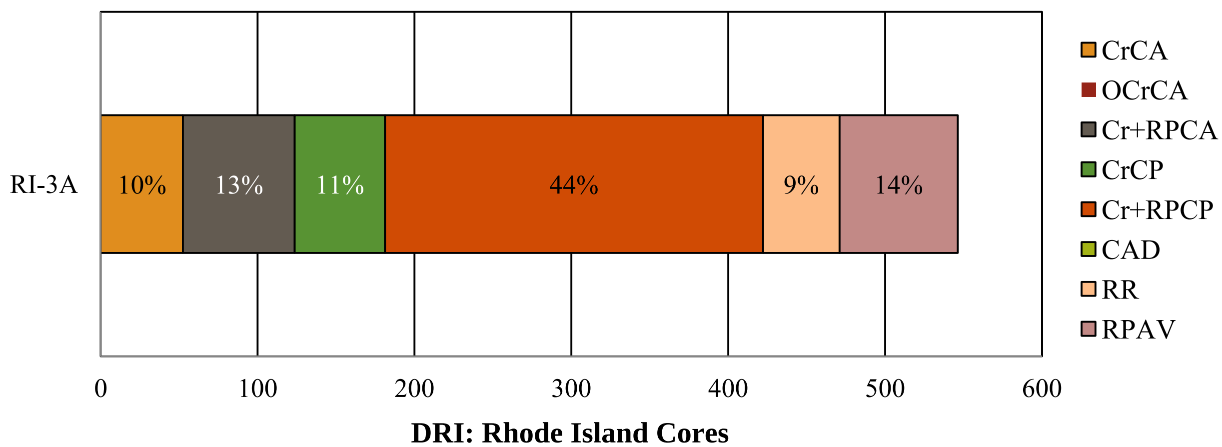


Figure B. 4 : Micrographs showing petrographic features observed on the polished section of core RI-2: A-B. Cracked aggregate particles; C. Reaction rim; D. Carbonation; E. Ettringite in an air void of the cement paste; F. Cracks in the cement paste.

Core: RI-3A





Sample		Cracks in the aggregate particles			Crack in the cement paste		Other features			DRI
RI-3A	**Feature**	**CrCA**	**OCrCA**	**Cr+RPCA**	**CrCP**	**Cr+RPCP**	**CAD**	**RR**	**RPAV**	**Total**
	DRI	52	0	71	58	241	0	49	75	546
	% of the DRI	*10*	*0*	*13*	*11*	*44*	*0*	*9*	*14*	*100*

Figure B. 5 : Polished core section RI-3A and DRI results

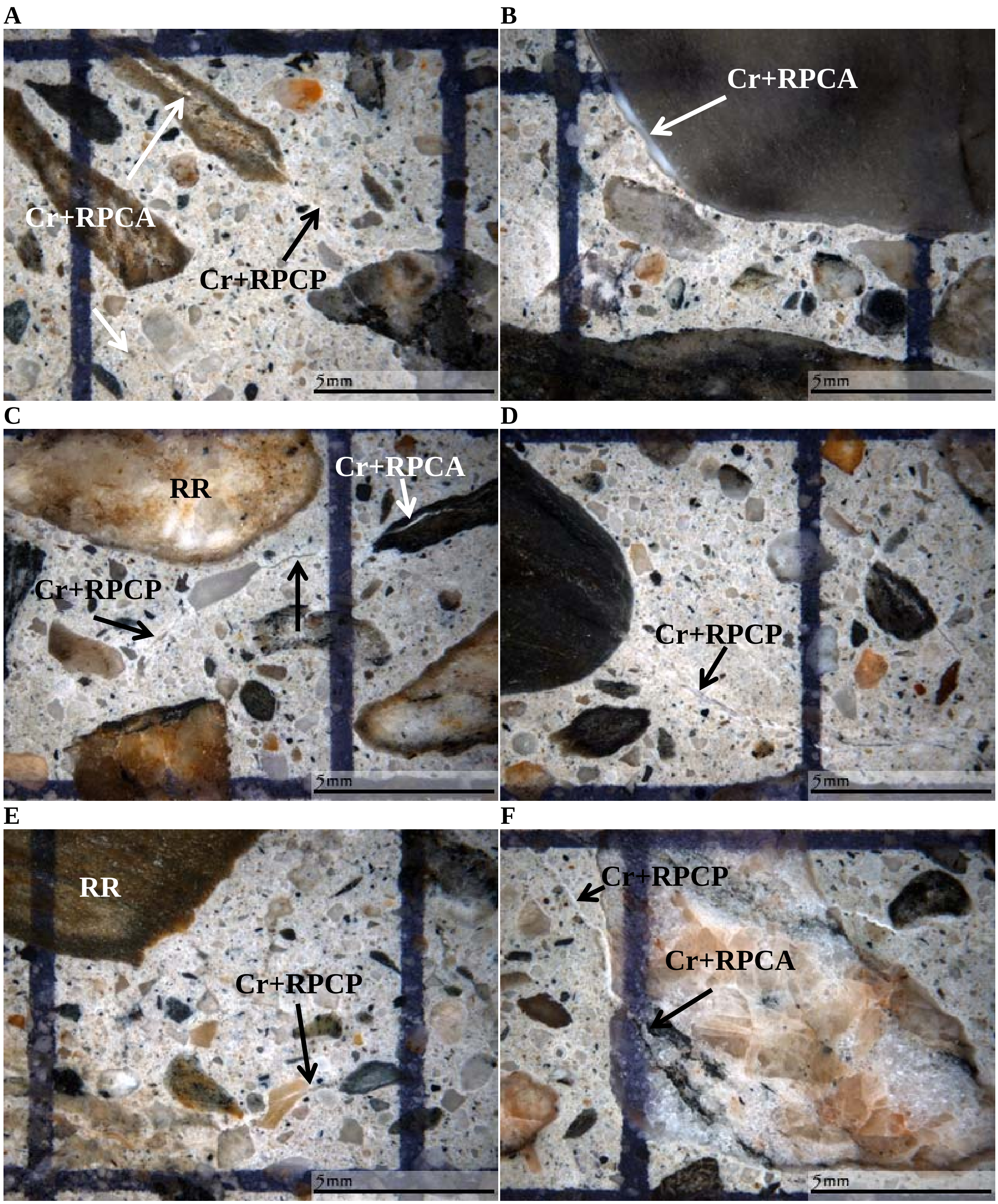
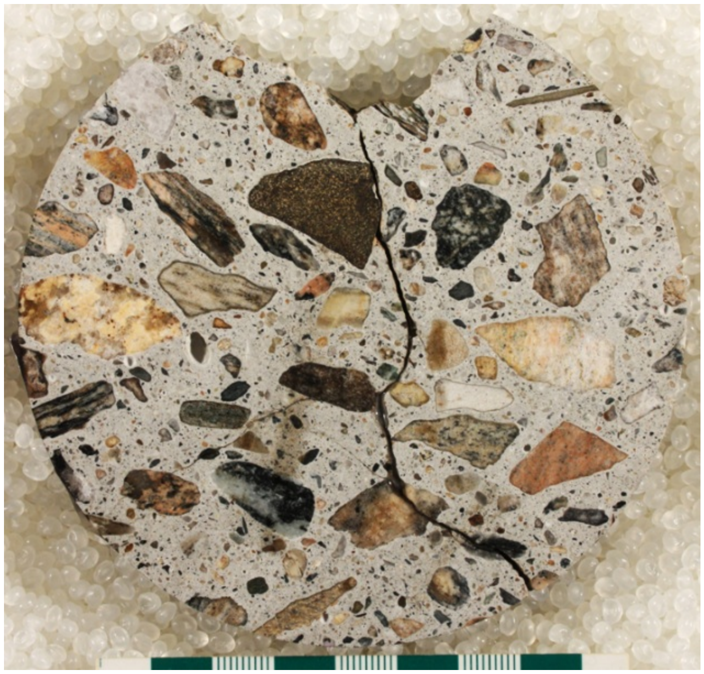
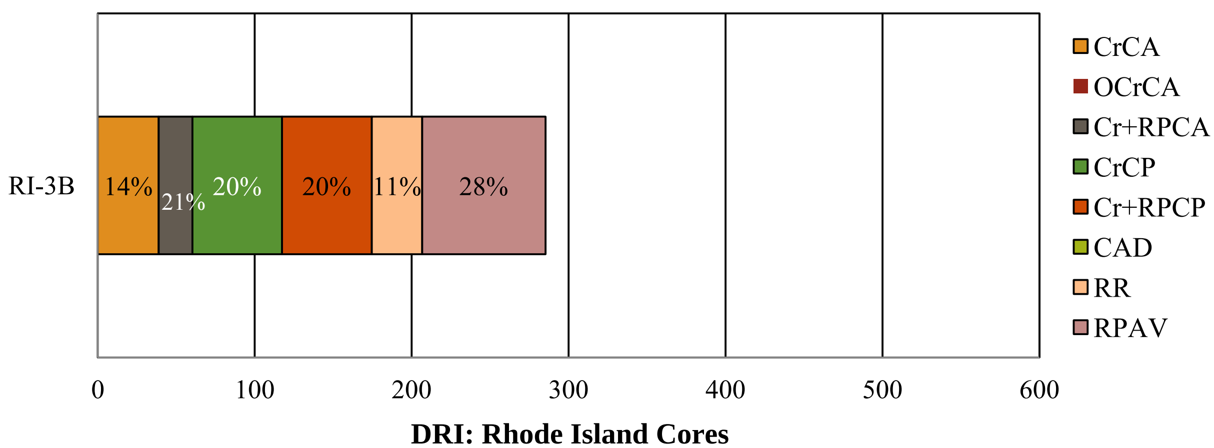


Figure B. 6 : Micrographs showing petrographic features observed on the polished section of core RI-3A. A-F. Cracks with reaction products (gel) in the coarse aggregate particles (Cr+RPCA) or in the cement paste (Cr+RPCP); also, reaction rims (RR).

Core: RI-3B





Sample		Cracks in the aggregate particles			Crack in the cement paste		Other features			DRI
RI-3B	**Feature**	**CrCA**	**OCrCA**	**Cr+RPCA**	**CrCP**	**Cr+RPCP**	**CAD**	**RR**	**RPAV**	**Total**
	DRI	39	0	21	57	57	0	32	79	285
	% of the DRI	*14*	*0*	*8*	*20*	*20*	*0*	*11*	*28*	*100*

Figure B. 7 : Polished core section RI-3B and DRI results

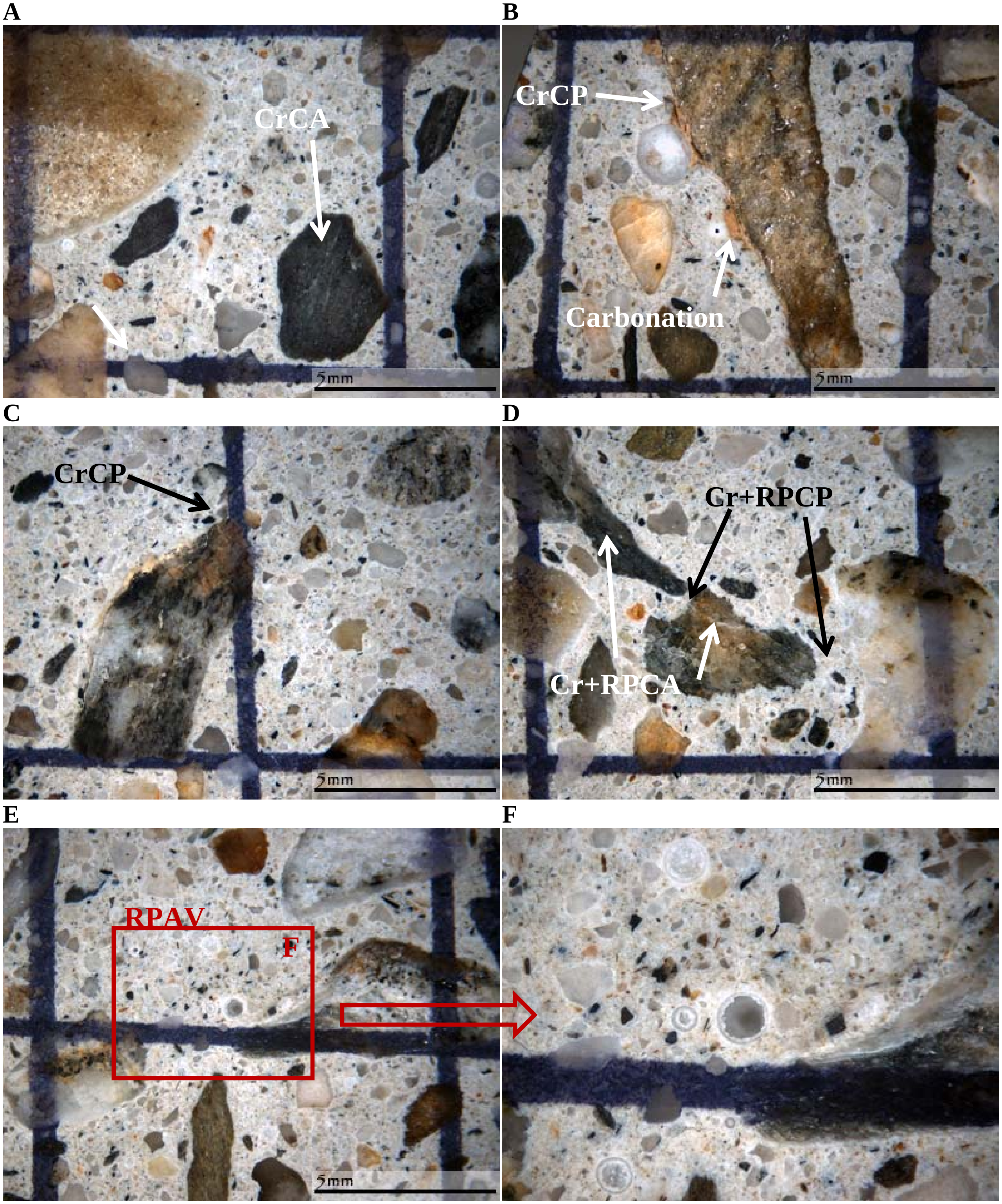
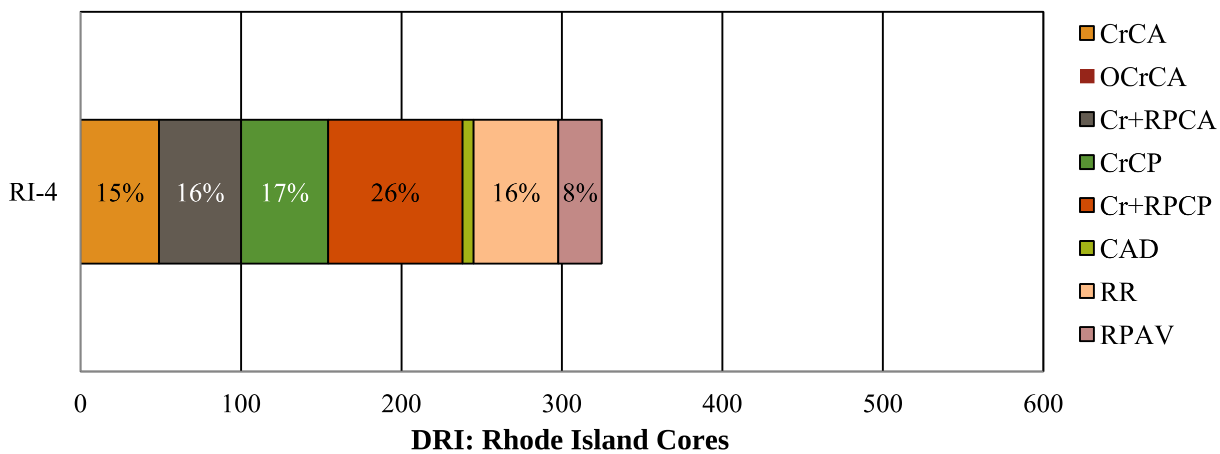


Figure B. 8 : Micrographs showing petrographic features observed on the polished section of core RI-3B. A. Cracks in a coarse aggregate particle (CrCA); B-C. Cracks and carbonation in the cement paste; D-E. Cracks with reaction products (gel) in coarse aggregate particles (Cr+RPCA) and in the cement paste (Cr+RPCP); E-F. Air voids lined or filled with reaction product (ettringite).

Core: RI-4



Sample		Cracks in the aggregate particles			Crack in the cement paste		Other features			DRI
RI-4	Feature	CrCA	OCrCA	Cr+RPCA	CrCP	Cr+RPCP	CAD	RR	RPAV	Total
	DRI	49	0	51	54	84	7	53	27	325
	% of the DRI	*15*	*0*	*16*	*17*	*26*	*2*	*16*	*8*	*100*

Figure B. 9 : Polished core section RI-4 and DRI results

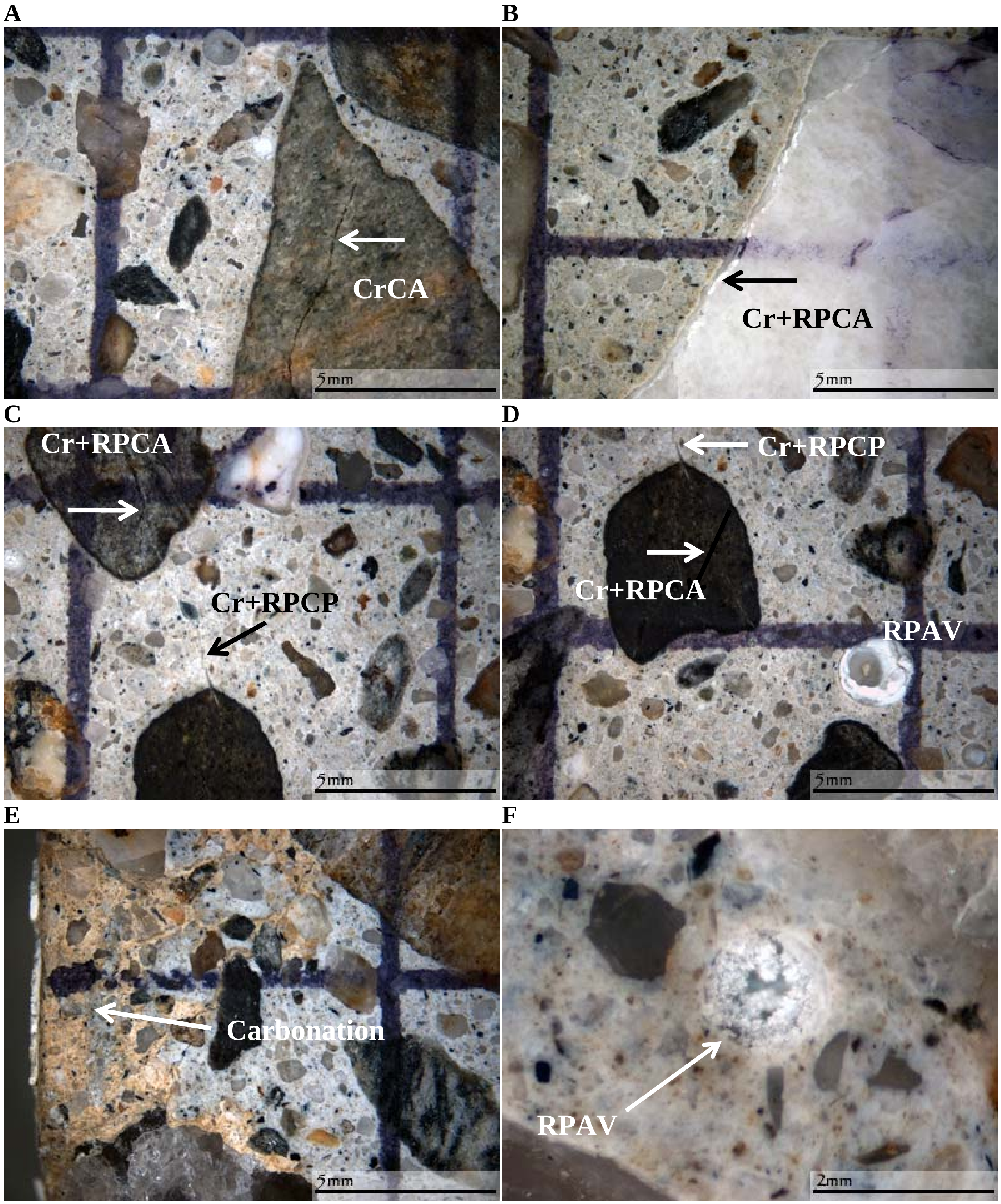
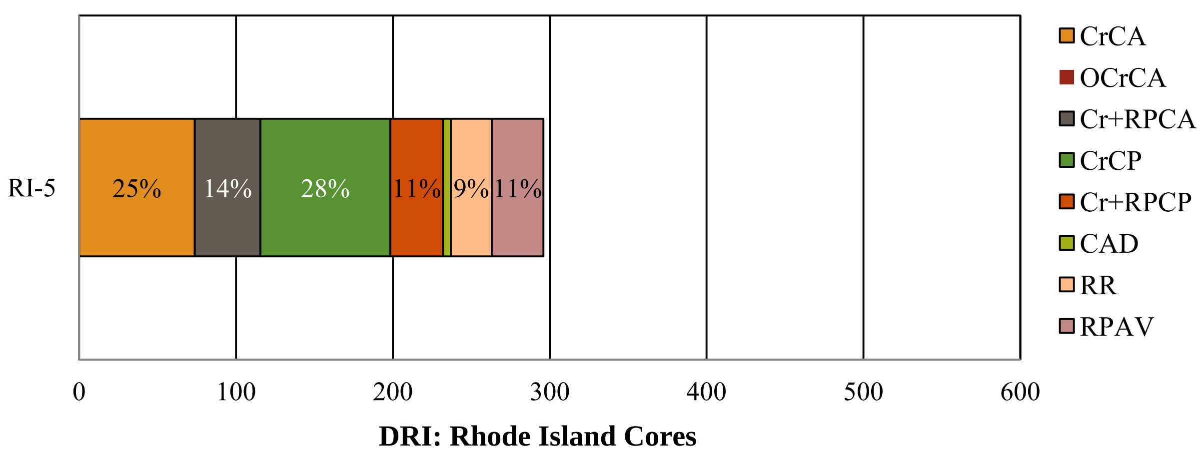


Figure B. 10 : Micrographs showing petrographic features observed on the concrete polished section of core RI-4. A-D. Cracks in coarse aggregate particles, without (CrCA) or with reaction products (Cr+RPCA), and in the cement paste (Cr+CPRP); E. Carbonation of the cement paste at the surface of the core; F. Air void lined with reaction product (RPAV) (ettringite).

Core: RI-5



Sample		Cracks in the aggregate particles			Crack in the cement paste		Other features			DRI
RI-5	Feature	CrCA	OCrCA	Cr+RPCA	CrCP	Cr+RPCP	CAD	RR	RPAV	Total
	DRI	74	0	42	83	33	5	26	33	296
	% of the DRI	*25*	*0*	*14*	*28*	*11*	*2*	*9*	*11*	*100*

Figure B. 11 : Polished core section RI-5 and DRI results

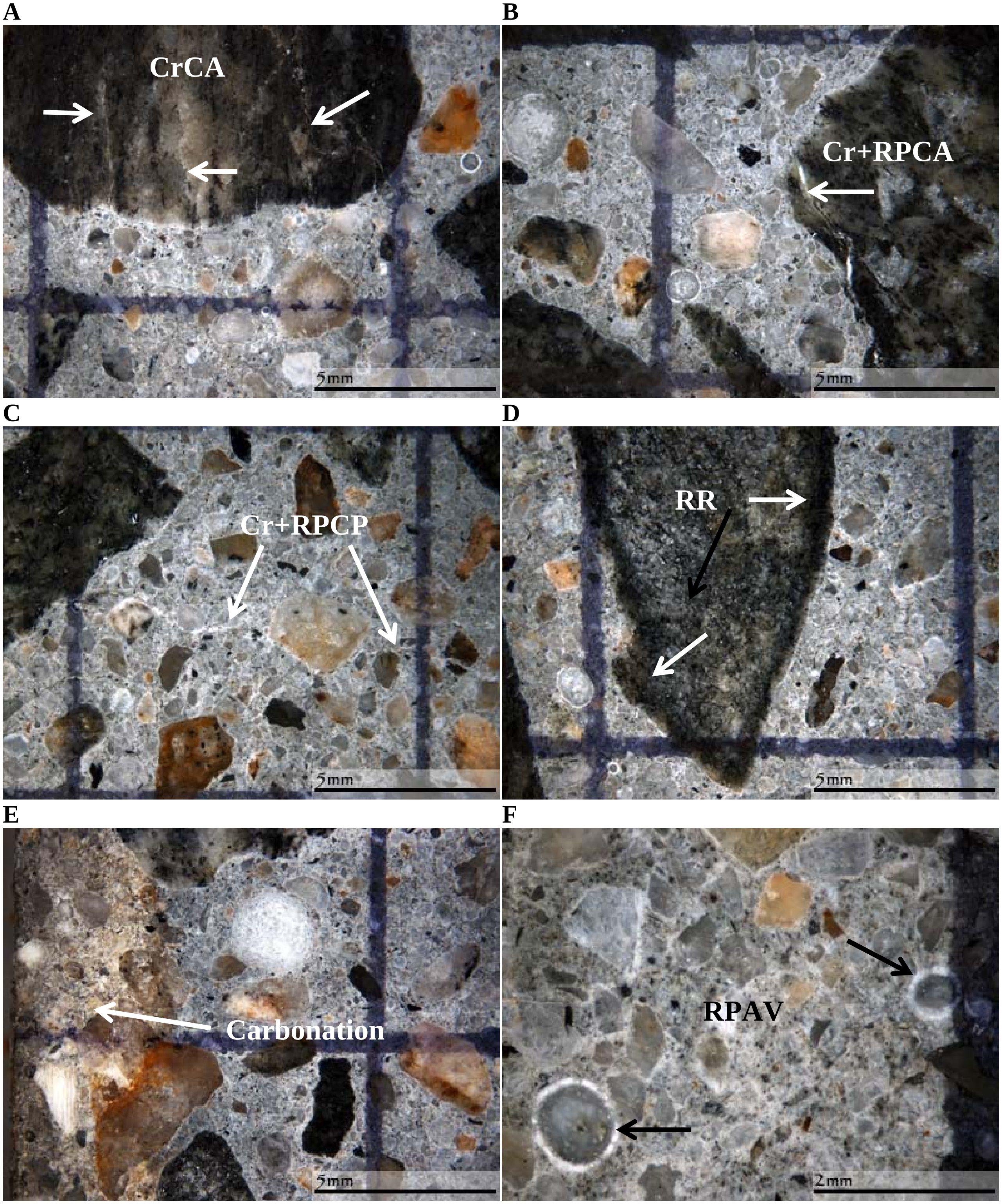
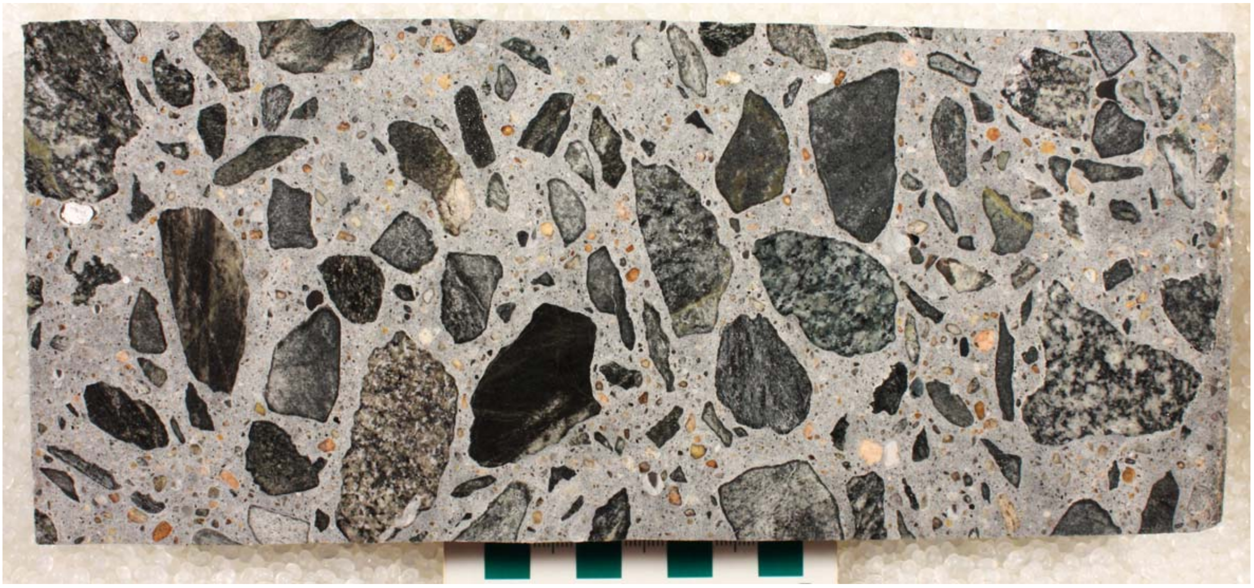
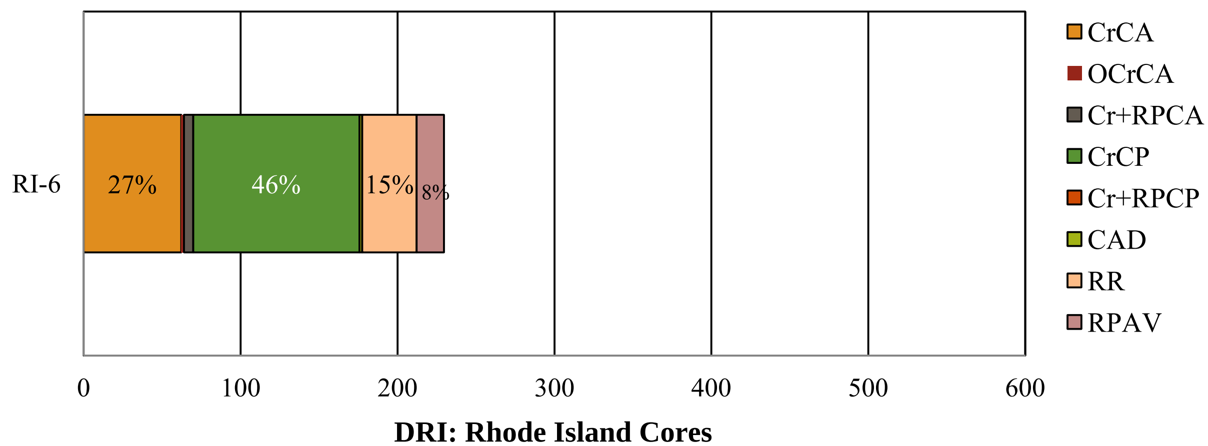


Figure B. 12 : Micrographs showing petrographic features observed on the concrete polished section of core RI-5. A-B. Cracks with (Cr+RPCA) or without (CrCA) reaction products (gel) in coarse aggregate particles; C. Cracks with reaction products (gel) (Cr+RPCP) in the cement paste; D. Reaction rim; E. Carbonation of the cement paste at the surface of the core; F. Air voids lined with reaction product (RPAV) (ettringite).

Core: RI-6





Sample		Cracks in the aggregate particles			Crack in the cement paste		Other features			DRI
RI-6	**Feature**	**CrCA**	**OCrCA**	**Cr+RPCA**	**CrCP**	**Cr+RPCP**	**CAD**	**RR**	**RPAV**	**Total**
	DRI	62	2	6	106	0	2	35	17	230
	% of the DRI	*27*	*1*	*3*	*46*	*0*	*1*	*15*	*8*	*100*

Figure B. 13 : Polished core section RI-6 and DRI results

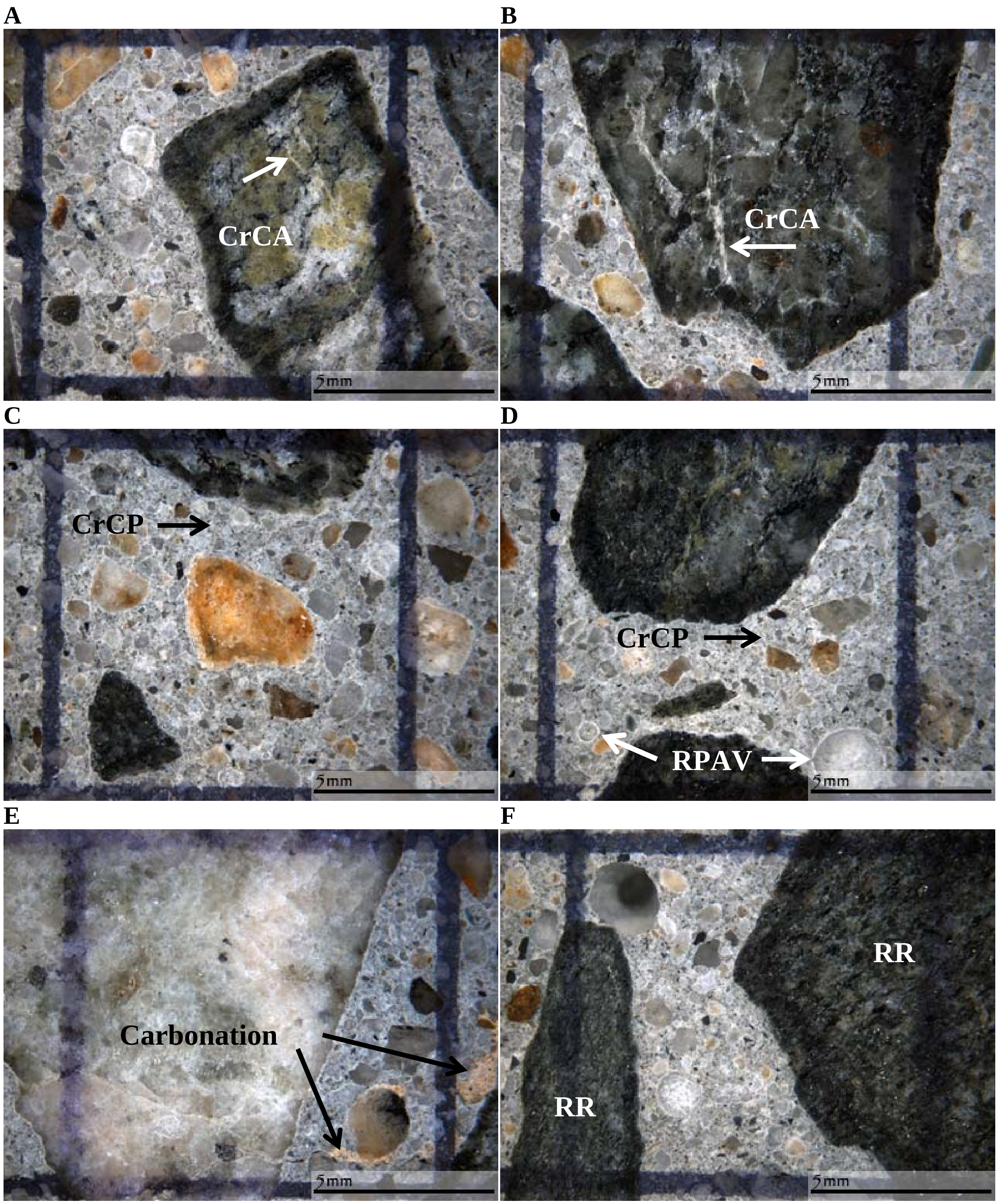


Figure B. 14 : Micrographs showing petrographic features observed on the concrete polished section of core RI-6. A-B. Cracks in coarse aggregate particles (CrCA); C-D. Cracks in the cement paste (CrCP); air voids lined with reaction product (RPAV) (ettringite). E. Carbonation along cracks in the cement paste. F. Coarse aggregate particles with reaction rims (RR).