City&Guilds of London Art School

CONSERVATION DEPARTMENT

REPORT: MAPPING AND MONITORING CRACKS IN THE STANDING IGUANODON IN CRYSTAL PALACE PARK

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Post Graduate Diploma in Conservation
Conservation Department 2017

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1. INTRODUCTION

The Crystal Palace Dinosaurs are a collection of thirty-two concrete sculptures, depicting extinct and prehistoric creatures, including the world's first full scale, three dimensional constructions of dinosaurs. Built between 1850-1854 by the artist Benjamin Waterhouse Hawkins and designed with the scientific guidance of palaeontologist Sir Richard Owen, the dinosaurs were commissioned to accompany the Crystal Palace after it moved from The Great Exhibition in Hyde Park, to its assumed permanent location in the landscaped park of South East London (MacDermot, 1854, McCarthy and Gilbert, 1994). Unveiled by Queen Victoria, five years before the publication of Darwin's The Origin of Species, the antediluvian beasts were enormously popular, capitalising on the scientific and public enthusiasm for palaeontology and what would later be termed the 'dino-mania' of the time. They attracted a vast number of visitors, becoming, at the time, the most viewed scientific work of any kind (Secord, 2004).

This report focuses on recording the structural condition, specifically the development of cracks in the Standing Iguanodon, arguably the most iconic of the Crystal Palace Dinosaurs. Over the past 160 years, the sculpture has been the subject of numerous conservation and restoration campaigns, the most recent being undertaken in 2015 (Cliveden, 2015). In the course of this treatment, the cracks were filled and repainted, however, within 6 months many of the cracks had reopened along the sites of the recent repairs.

By mapping and monitoring the cracks formed since 2015 over a period of three months, this report identifies the patterns and comparative rates of cracking in the Standing Iguanodon. This information is used to better understand the sculpture's underlying structural condition and can be used to assess the necessary action needed to prevent further damages.

2. METHODOLOGY

Crack Recording, Measuring and Monitoring

The cracks were initially identified and measured over the course of two consecutive days – 14.12.2016 and 15.12.2016, recording the number, location, length, width and depth of the cracks that had developed since the 2015 restoration. The cracks were then re-recorded over two days, three months later - 10.03.2017 and 15.03.2017. These measurements were used to compare changes in crack dimensions over the three-month period.

The cracks in the Standing Iguanodon were recorded and measured with the following method:

Equipment

Tape Measure

Digital Callipers

Linestorm Crack Width Gauge

Silverline Crack Depth Gauge

Method

- Each crack was identified and allocated a number and the letter A. These were identified as *primary* cracks. Any 'offshoots' from these primary cracks were given the same number proceeded by the next letter in the alphabet, i.e. 1A, 1B, 1C etc. 2A, 2B, 2C etc. These were identified as *secondary* cracks.
- The identified cracks were annotated onto diagrams of the Iguanodon.
- An 'origin' point was identified for each crack. In the majority of cases, this was a point at the ground. This point was photographed and marked with the number 0 onto the surface of the dinosaur. This would mark the starting point for measuring.
- Working along the crack, at 10cm increments, the length, width and depth of the crack was measured and recorded, using the equipment listed above. Measurement points were marked onto the dinosaur.
- Points of interest, such as spalling, paint loss etc. were recorded photographically.
- This process was repeated after three months.

Limitations

- Depths <0.5mm and >100mm were capped at those figures due to the limitations of the depth gauge. The gauge was not sensitive enough to be able to accurately record measurements <0.5mm and neither was it long enough to record depths >100mm.
- Loose, but non-disassociated fragments were recorded as having a depth of 100mm as these points were too fragile to take accurate readings.

3. RESULTS

3.1. TAIL –

The cracks were identified, measured and recorded on 14.12.2016. They were re-measured and recorded on 10.03.2017.

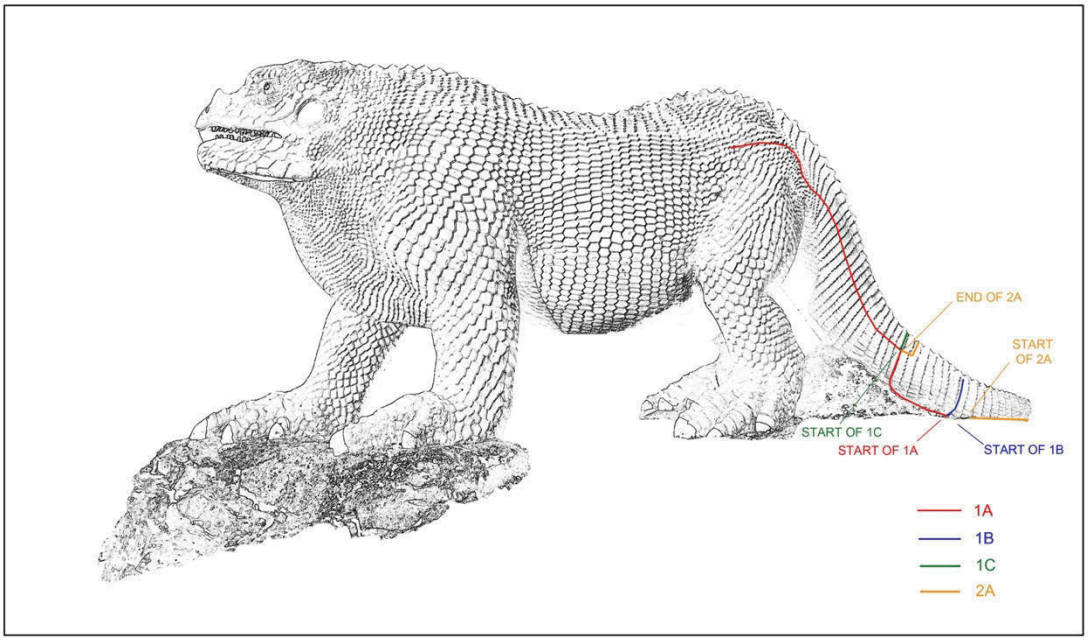


Plate 1. Diagram depicting the location of the cracks 1a,1b,1c and 2a.

PHOTOGRAPHS

Crack 1A. Detail images depicting the progressive deterioration related to cracking. Numbers refer to the measurement points along the length of the crack in millimetres.

Plate 2. Photographed **14.12.16** – 0 identifies the origin and the first measurement point.

Plate 3. Photographed **14.12.16**.

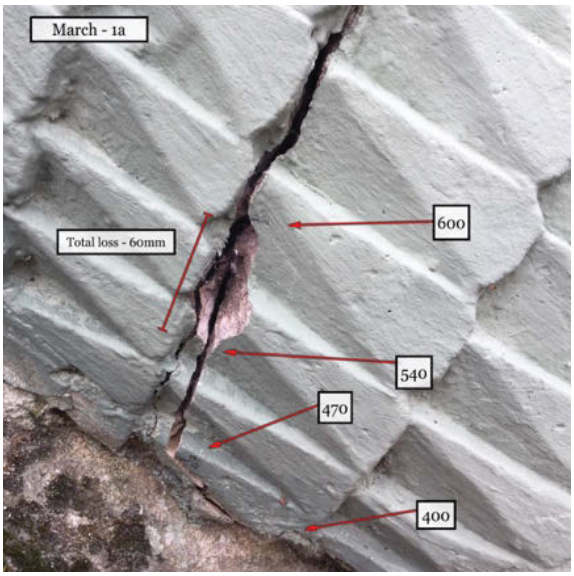


Plate 4. Photographed **10.03.17** – Indicating total loss to crack 1A.

Plate 5. Photographed **10.03.17** - Disassociated fragment from point 540mm along crack 1A

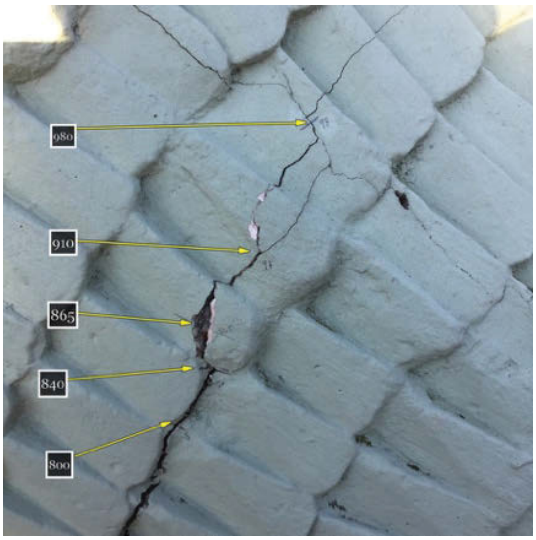


Plate 6. – Photographed **14.12.16 –** Crack 1A.

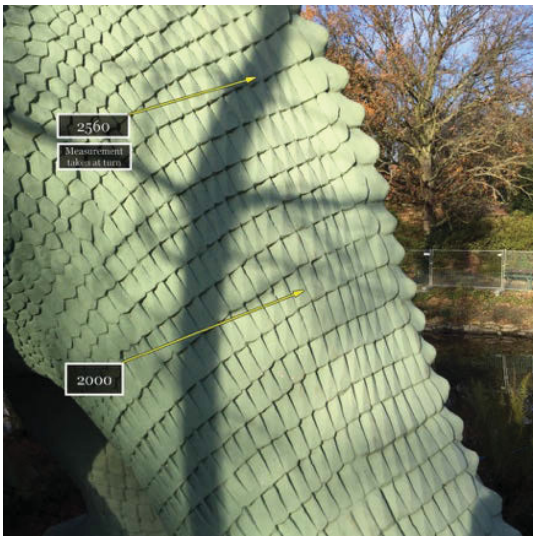


Plate 7. Photographed **14.12.16 –** Crack 1A

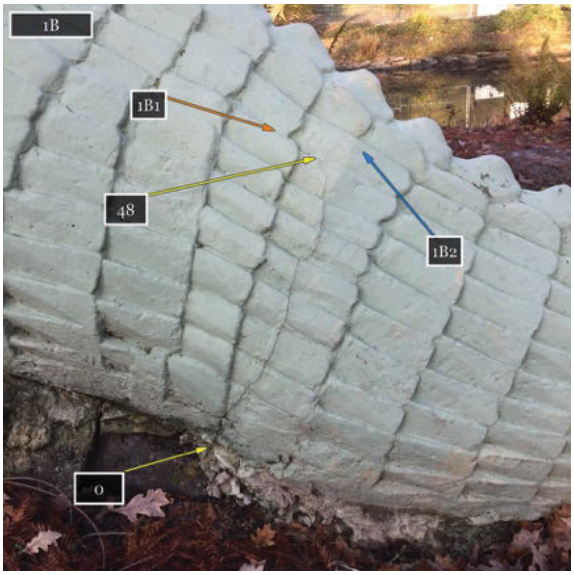


Plate 8. Photographed **14.12.16 –** Crack 1B.

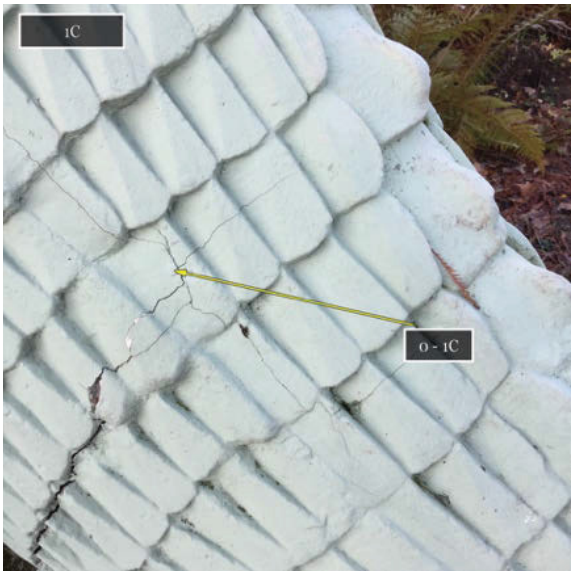


Plate 9. Photographed **14.12.16** – Crack 1C.

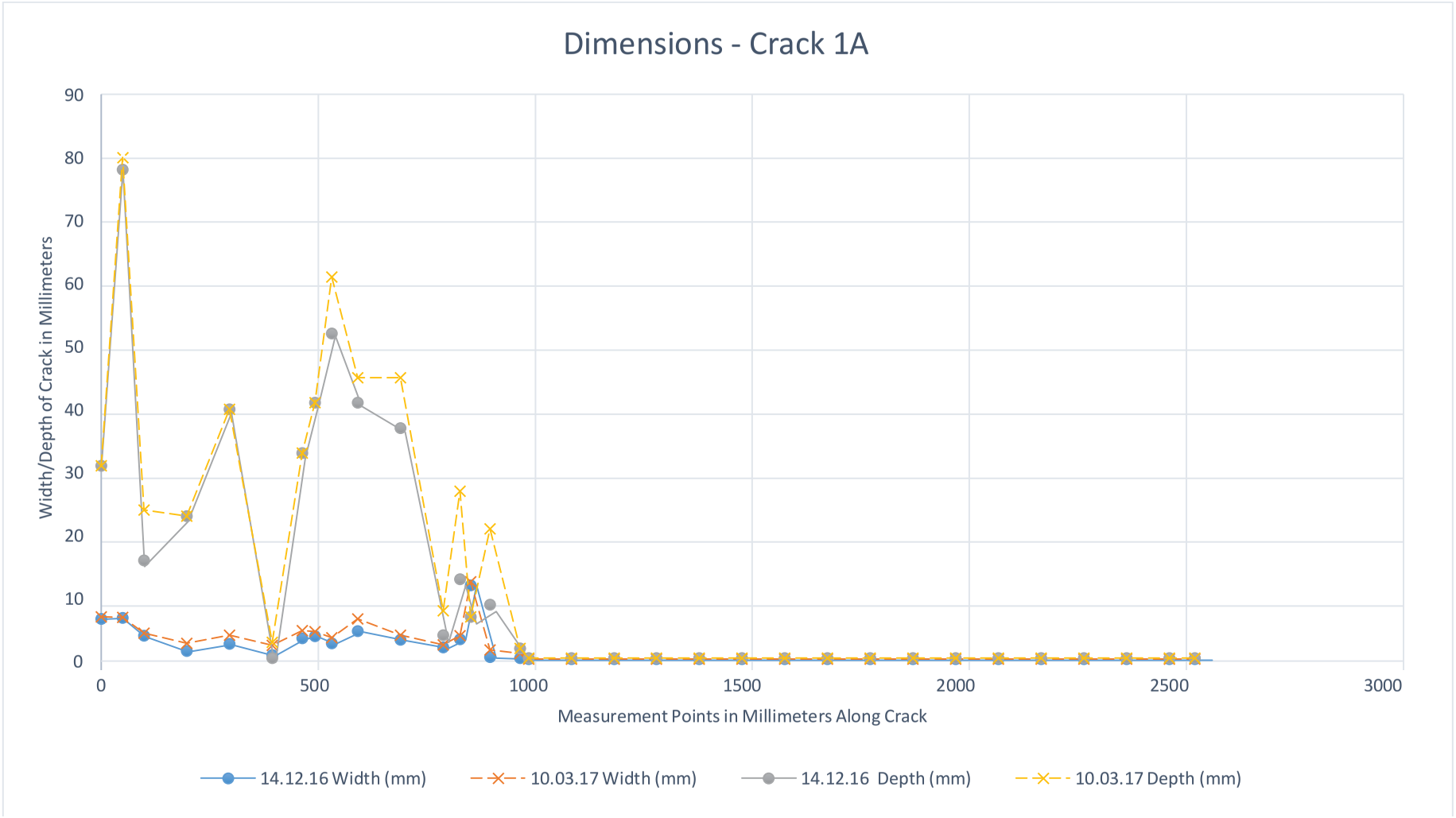
DATA

The graphs display the length, width and depth measurements for each individual crack. Starting at 0mm (the crack's origin point), the measurements were recorded every 100mm along the length of the crack and at points of noticeable deterioration.

Due to the accuracy limitations of the depth gauge, depth values of 100mm indicate values 100> and depth values of 0.5 indicate values of <0.5.

Loose, but non-disassociated fragments were recorded as having a depth of 100mm as these points were too fragile to take accurate readings.

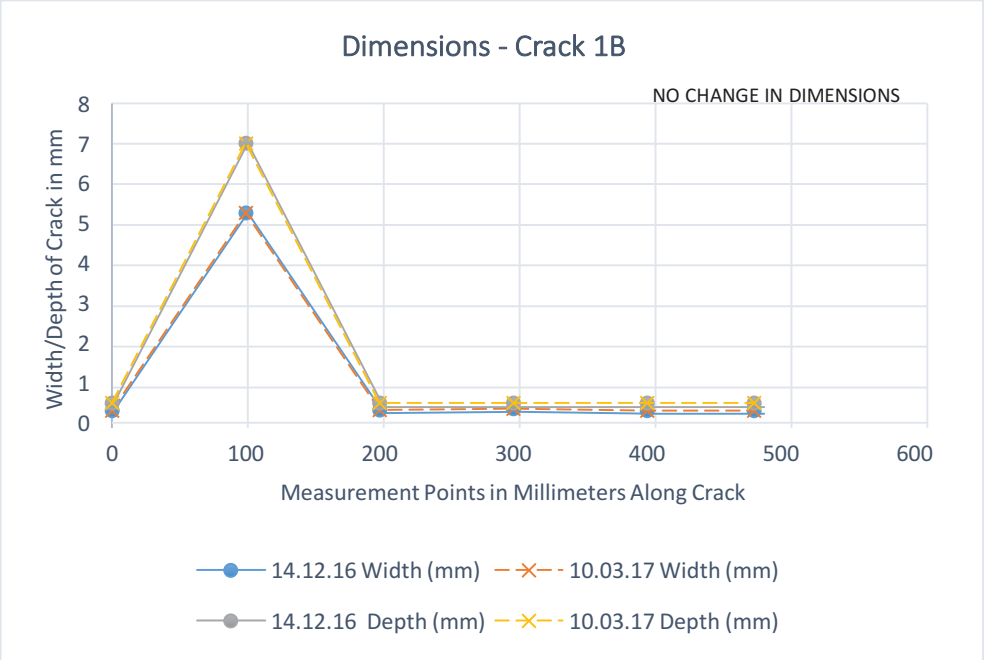
Measurements were recorded on 14.12.2016 and again on the 10.03.2017.


Dimensions - Crack 1A
Width/Depth of Crack in Millimeters
90
80
70
60
50
40
30
20
10
0
0
500
1000
1500
2000
2500
3000
Measurement Points in Millimeters Along Crack
14.12.16 Width (mm)
10.03.17 Width (mm)
14.12.16 Depth (mm)
10.03.17 Depth (mm)

Graph 1.0

Table 1 – Crack 1A

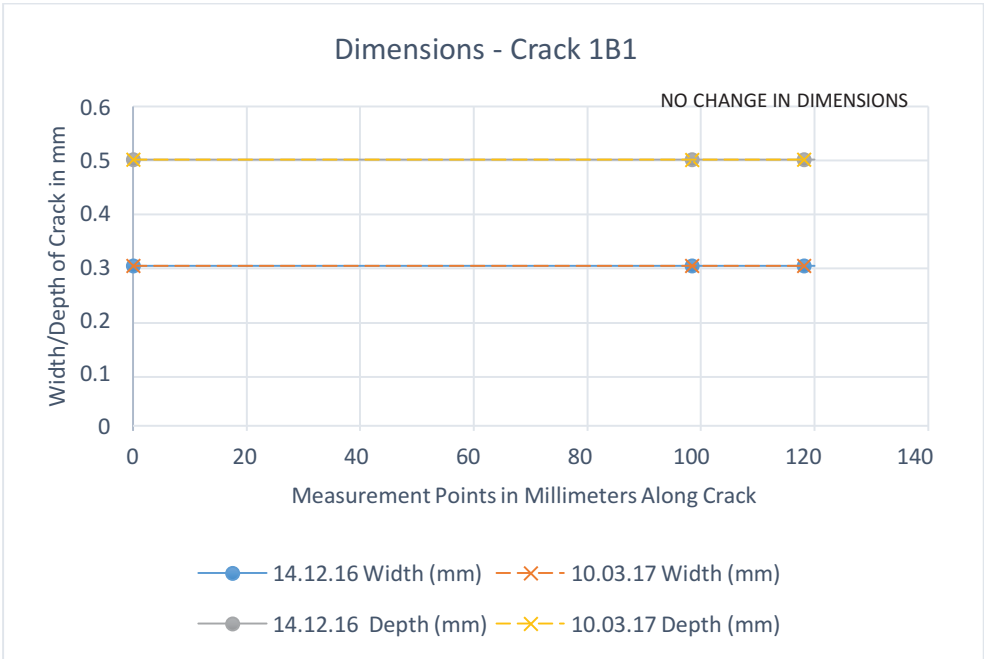
Measurement Points Along Crack (mm)	14.12.16 Width (mm)	10.03.17 Width (mm)	△ Width (mm)	14.12.16 Depth (mm)	10.03.17 Depth (mm)	△ Depth (mm)
0	6.67	7.05	0.38	31	31	0
50	6.9	6.91	0.01	78	80	2
100	4	4.4	0.4	16	24	8
200	1.6	2.79	1.19	23	23	0
300	2.7	4.15	1.45	40	40	0
400	1	2.5	1.5	0.5	3	2.5
470	3.6	4.86	1.26	33	33	0
500	3.94	4.68	0.74	41	41	0
540	2.83	3.69	0.86	52	61	9
600	4.79	6.68	1.89	41	45	4
700	3.36	4.12	0.76	37	45	8
800	2.17	2.6	0.43	4.1	8	3.9
840	3.44	4.05	0.61	13	27	14
865	12	12.56	0.56	7	7	0
910	0.64	1.8	1.16	9	21	12
980	0.45	1.2	0.75	2	2	0
1000	0.3	0.3	0	0.5	0.5	0
1100	0.3	0.3	0	0.5	0.5	0
1200	0.3	0.3	0	0.5	0.5	0
1300	0.3	0.3	0	0.5	0.5	0
1400	0.3	0.3	0	0.5	0.5	0
1500	0.3	0.3	0	0.5	0.5	0
1600	0.3	0.3	0	0.5	0.5	0
1700	0.3	0.3	0	0.5	0.5	0
1800	0.3	0.3	0	0.5	0.5	0
1900	0.3	0.3	0	0.5	0.5	0
2000	0.3	0.3	0	0.5	0.5	0
2100	0.3	0.3	0	0.5	0.5	0
2200	0.3	0.3	0	0.5	0.5	0
2300	0.3	0.3	0	0.5	0.5	0
2400	0.3	0.3	0	0.5	0.5	0
2500	0.3	0.3	0	0.5	0.5	0
2560	0.3	0.3	0	0.5	0.5	0



Graph 1.1

Table 1.1– Crack 1B

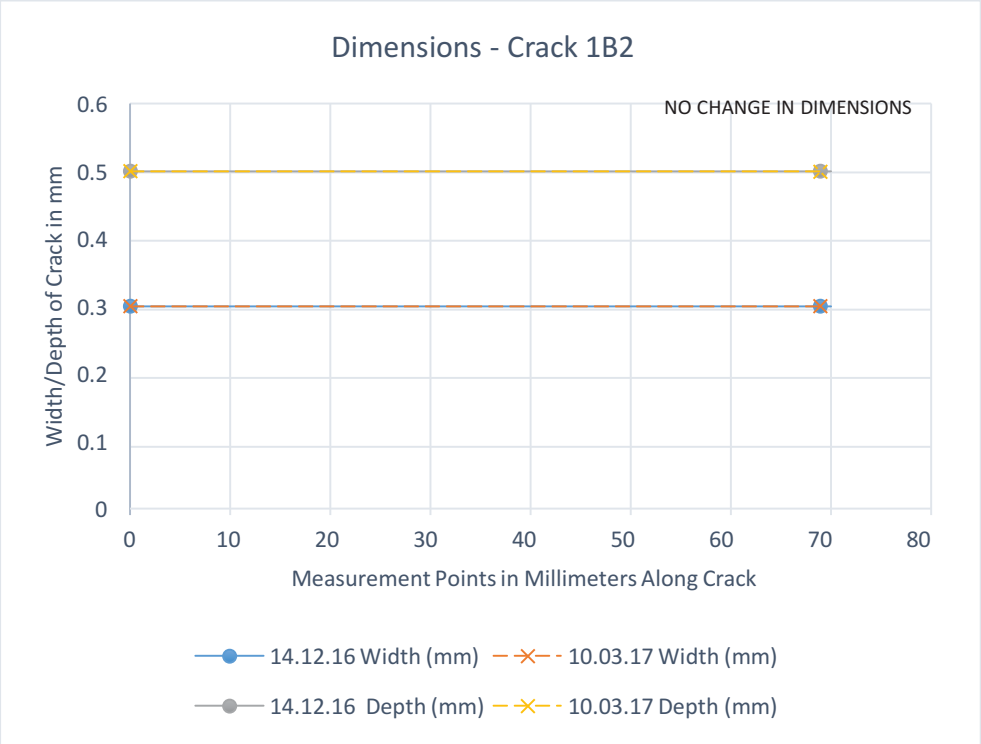
Measurement Points Along Crack (mm)	14.12.16 Width (mm)	10.03.17 Width (mm)	△ Width (mm)	14.12.16 Depth (mm)	10.03.17 Depth (mm)	△ Depth (mm)
0	0.3	0.3	0	0.5	0.5	0
100	5.26	5.26	0	7	7	0
200	0.32	0.32	0	0.5	0.5	0
300	0.35	0.35	0	0.5	0.5	0
400	0.3	0.3	0	0.5	0.5	0
480	0.3	0.3	0	0.5	0.5	0



Graph 1.2

Table 1.2 – Crack 1B1

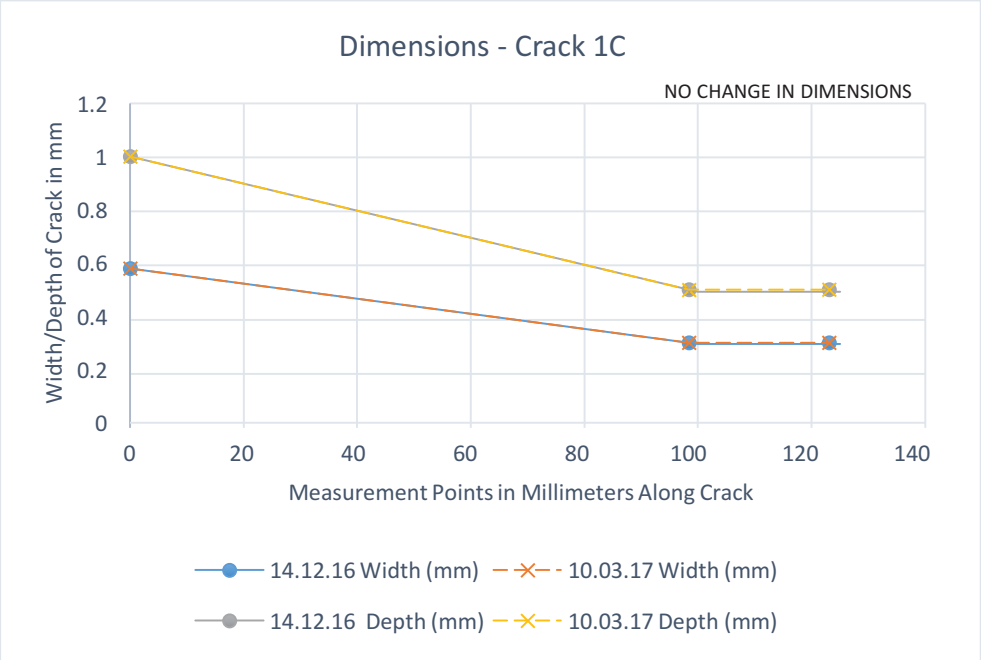
Measurement Points Along Crack (mm)	14.12.16 Width (mm)	10.03.17 Width (mm)	△ Width (mm)	14.12.16 Depth (mm)	10.03.17 Depth (mm)	△ Depth (mm)
0	0.3	0.3	0	0.5	0.5	0
100	0.3	0.3	0	0.5	0.5	0
120	0.3	0.3	0	0.5	0.5	0



Graph 1.3

Table 1.3 – Crack 1B2

Measurement Points Along Crack (mm)	14.12.16 Width (mm)	10.03.17 Width (mm)	△ Width (mm)	14.12.16 Depth (mm)	10.03.17 Depth (mm)	△ Depth (mm)
0	0.3	0.3	0	0.5	0.5	0
70	0.3	0.3	0	0.5	0.5	0



Graphs 1.4

Table 1.4 – Crack 1C

Measurement Points Along Crack (mm)	14.12.16 Width (mm)	10.03.17 Width (mm)	△ Width (mm)	14.12.16 Depth (mm)	10.03.17 Depth (mm)	△ Depth (mm)
0	0.58	0.58	0	1	1	0
100	0.3	0.3	0	0.5	0.5	0
125	0.3	0.3	0	0.5	0.5	0

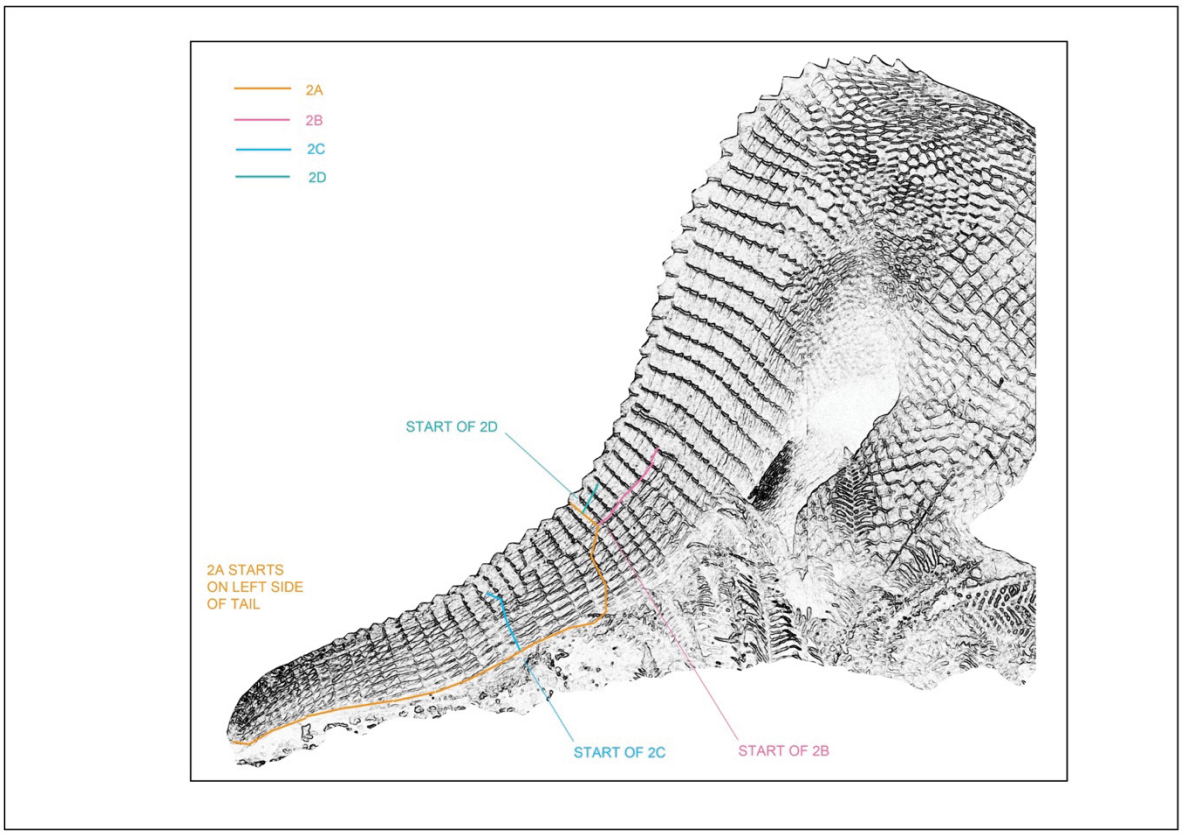


Plate 10. Diagram depicting the location of the cracks 2A, 2B,2C,2D.

Crack 2A. Detail images depicting the progressive deterioration related to cracking. Numbers refer to the measurement points along the length of the crack in millimetres.

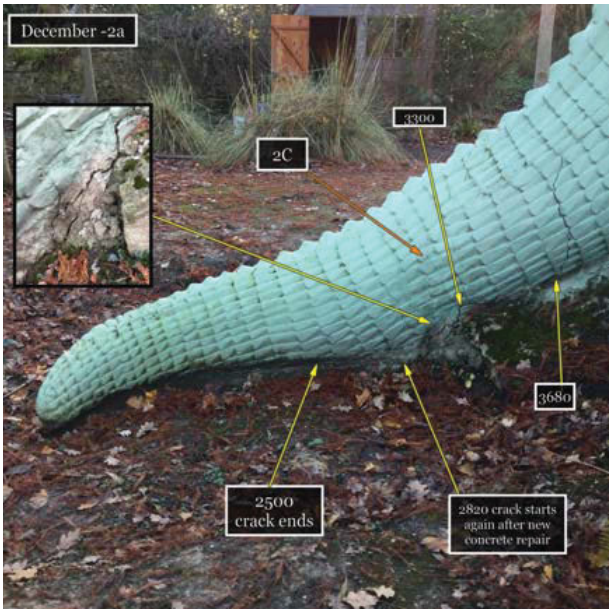


Plate 11. Photographed 14.12.16.

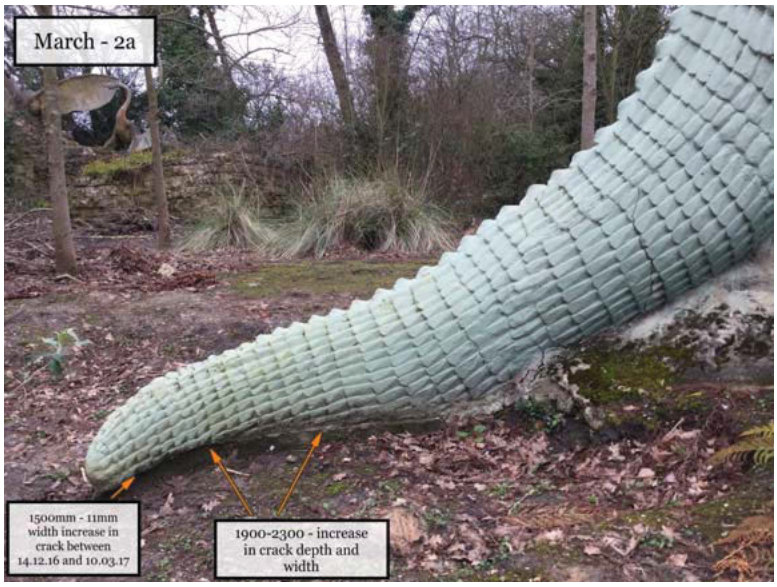
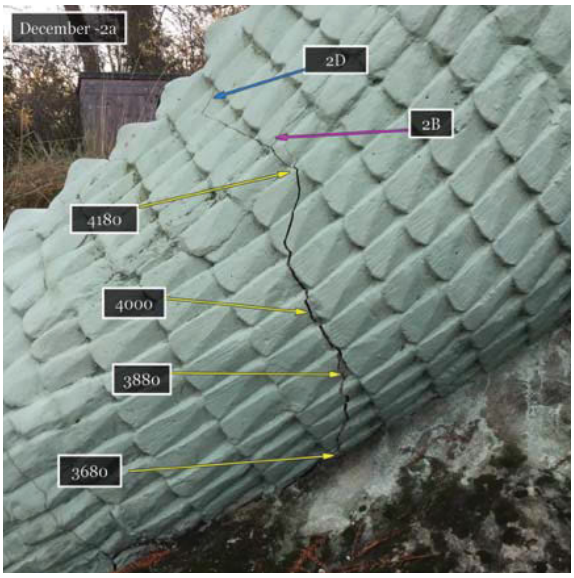


Plate 12. Photographed **10.03.17** - Locating the points of greatest crack depth and width increase.

Plate 13. Photographed **14.12.16 –** Crack 2A origin point and end of tail.



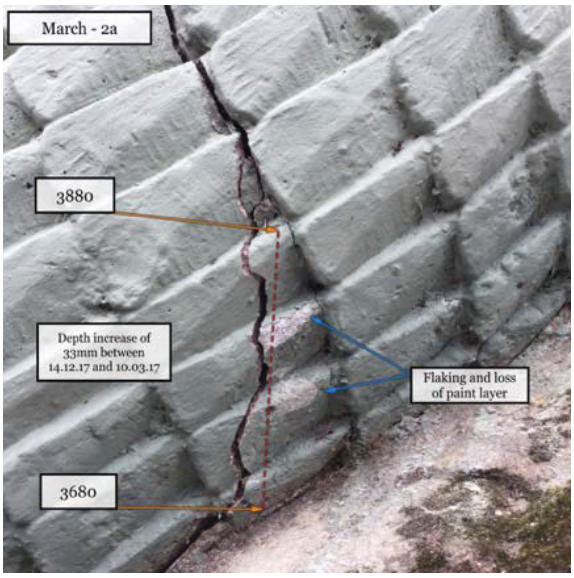
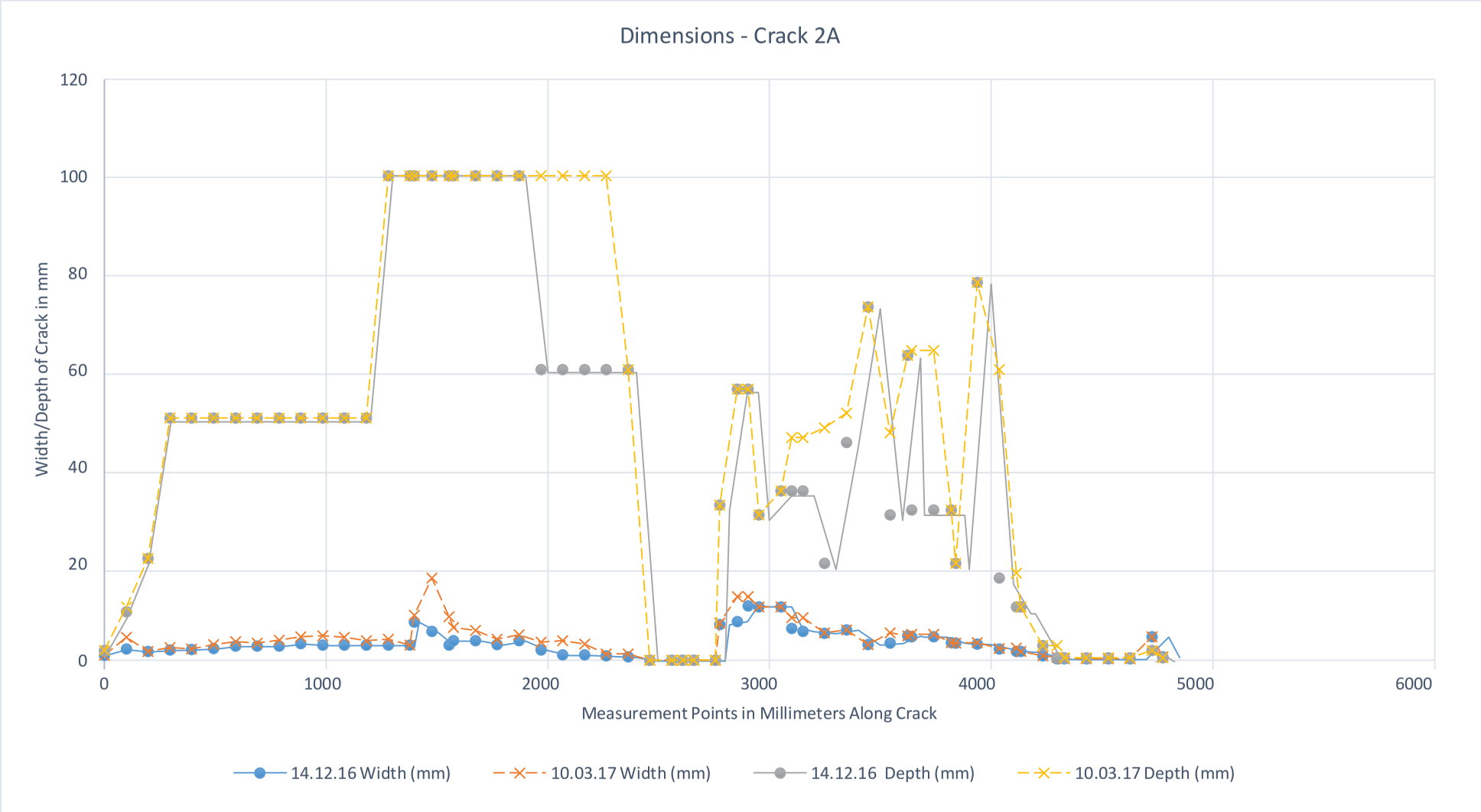


Plate 14. Photographed **14.12.16** **Plate 15**. Photographed **10.03.17**
Crack continues from base and over to the left side of the tail where it meets crack 1a. Crack 2a has formed in the original concrete, not in a historical repair.

Plate 16. Photographed **14.12.16 –** End measurement point of Crack

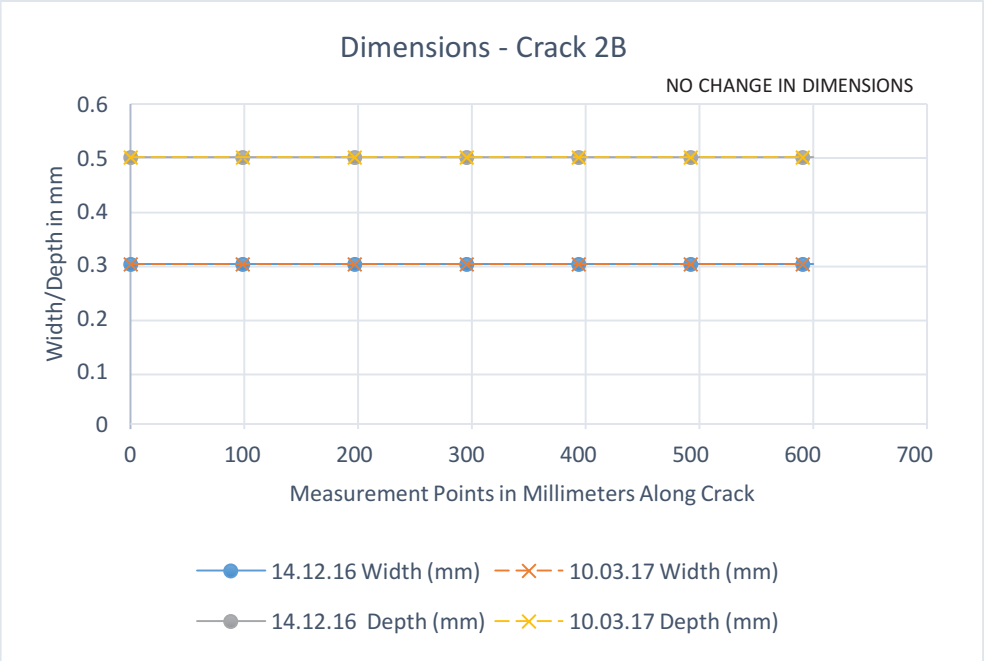

Dimensions - Crack 2A
Width/Depth of Crack in mm
120
100
80
60
40
20
0
0
1000
2000
3000
4000
5000
6000
Measurement Points in Millimeters Along Crack
14.12.16 Width (mm)
10.03.17 Width (mm)
14.12.16 Depth (mm)
10.03.17 Depth (mm)

Graph 2.0

Table 2 – Crack 2A

Measurement Points Along Crack (mm)	14.12.16 Width (mm)	10.03.17 Width (mm)	△ Width (mm)	14.12.16 Depth (mm)	10.03.17 Depth (mm)	△ Depth (mm)
0	1	1	0	2	2	0
100	2.3	4.7	2.4	10	11	1
200	1.8	1.8	0	21	21	0
300	2.1	2.64	0.54	50	50	0
400	2.2	2.3	0.1	50	50	0
500	2.4	3.2	0.8	50	50	0
600	2.9	3.8	0.9	50	50	0
700	2.9	3.5	0.6	50	50	0
800	2.9	4.1	1.2	50	50	0
900	3.4	4.85	1.45	50	50	0
1000	3.1	5.09	1.99	50	50	0
1100	3.1	4.8	1.7	50	50	0
1200	3.1	4.03	0.93	50	50	0
1300	3.1	4.35	1.25	100	100	0
1400	3.1	3.1	0	100	100	0
1420	7.9	9.3	1.4	100	100	0
1500	6	17	11	100	100	0
1580	3.1	9	5.9	100	100	0
1600	4	6.78	2.78	100	100	0
1700	4	6.2	2.2	100	100	0
1800	3.2	4.39	1.19	100	100	0
1900	4	5.3	1.3	100	100	0
2000	2.1	3.7	1.6	60	100	40
2100	1.09	4.03	2.94	60	100	40
2200	1.09	3.33	2.24	60	100	40
2300	0.89	1.36	0.47	60	100	40
2400	0.7	1.36	0.66	60	60	0
2500	0	0	0	0	0	0
2600	0	0	0	0	0	0
2650	0	0	0	0	0	0
2700	0	0	0	0	0	0
2800	0	0	0	0	0	0
2820	7.37	7.7	0.33	32	32	0
2900	8	13.1	5.1	56	56	0
2950	11.19	13.1	1.91	56	56	0
3000	11	11	0	30	30	0
3100	11	11	0	35	35	0
3150	6.58	8.84	2.26	35	46	11
3200	6	8.84	2.84	35	46	11
3300	5.57	5.66	0.09	20	48	28
3400	6.3	6.3	0	45	51	6

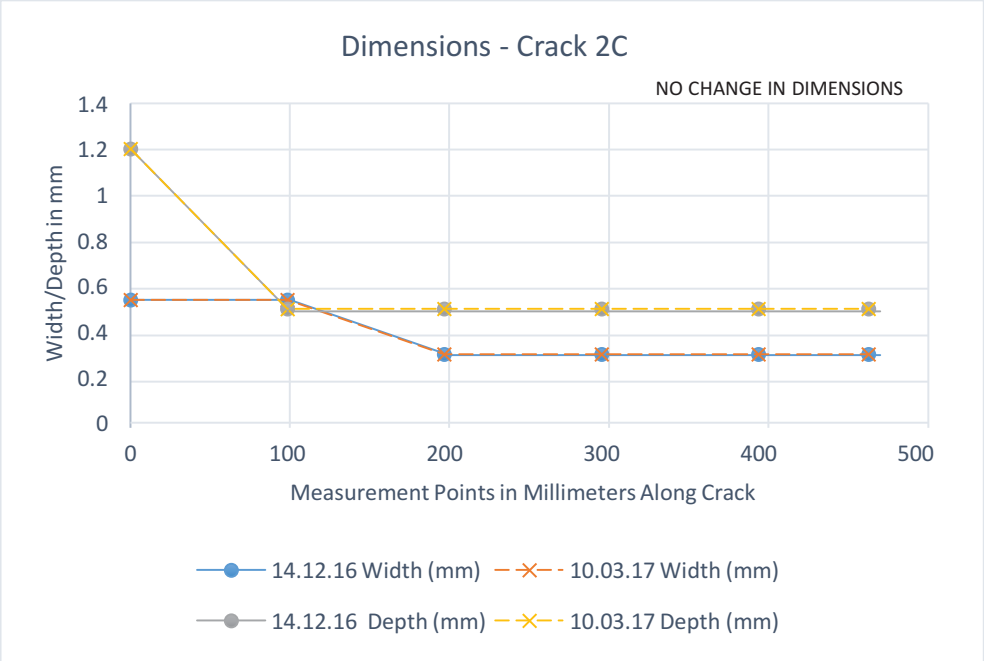
3500	3.2	3.2	0	73	73	0
3600	3.49	5.66	2.17	30	47	17
3680	5.1	5.1	0	63	63	0
3700	4.9	5.35	0.45	31	64	33
3800	4.9	5.35	0.45	31	64	33
3880	3.65	3.65	0	31	31	0
3900	3.56	3.56	0	20	20	0
4000	3.29	3.59	0.3	78	78	0
4100	2.3	2.45	0.15	17	60	43
4180	1.8	2.54	0.74	11	18	7
4200	1.8	1.8	0	11	11	0
4300	0.93	0.93	0	3	3	0
4365	0.3	0.65	0.35	0.5	3	2.5
4400	0.3	0.3	0	0.5	0.5	0
4500	0.3	0.3	0	0.5	0.5	0
4600	0.3	0.3	0	0.5	0.5	0
4700	0.3	0.3	0	0.5	0.5	0
4800	4.9	4.9	0	2	2	0
4850	0.7	0.7	0	0.5	0.5	0



Graph 2.1

Table 2.1 – 2B

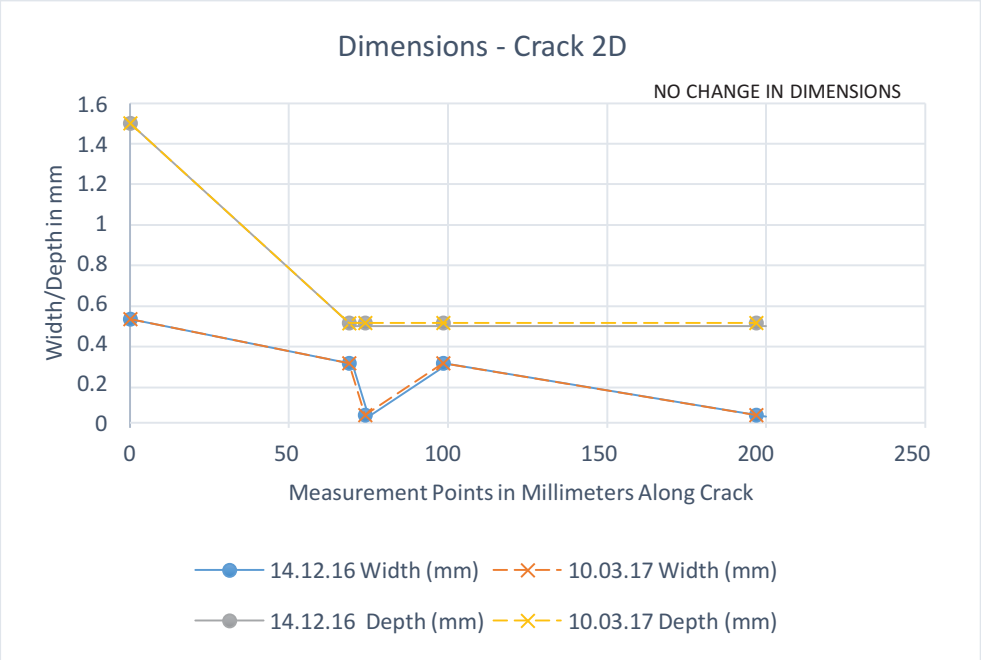
Measurement Points Along Crack (mm)	14.12.16 Width (mm)	10.03.17 Width (mm)	△ Width (mm)	14.12.16 Depth (mm)	10.03.17 Depth (mm)	△ Depth (mm)
0	0.3	0.3	0	0.5	0.5	0
100	0.3	0.3	0	0.5	0.5	0
200	0.3	0.3	0	0.5	0.5	0
300	0.3	0.3	0	0.5	0.5	0
400	0.3	0.3	0	0.5	0.5	0
500	0.3	0.3	0	0.5	0.5	0
600	0.3	0.3	0	0.5	0.5	0



Graph 2.2

Table 2.2 – 2C

Measurement Points Along Crack (mm)	14.12.16 Width (mm)	10.03.17 Width (mm)	△ Width (mm)	14.12.16 Depth (mm)	10.03.17 Depth (mm)	△ Depth (mm)
0	0.54	0.54	0	1.2	1.2	0
100	0.54	0.54	0	0.5	0.5	0
200	0.3	0.3	0	0.5	0.5	0
300	0.3	0.3	0	0.5	0.5	0
400	0.3	0.3	0	0.5	0.5	0
470	0.3	0.3	0	0.5	0.5	0



Graph 2.3

Table 2.3 – Crack 2D

Measurement Points Along Crack (mm)	14.12.16 Width (mm)	10.03.17 Width (mm)	△ Width (mm)	14.12.16 Depth (mm)	10.03.17 Depth (mm)	△ Depth (mm)
0	0.52	0.52	0	1.5	1.5	0
70	0.3	0.3	0	0.5	0.5	0
75	0.04	0.04	0	0.5	0.5	0
100	0.3	0.3	0	0.5	0.5	0
200	0.04	0.04	0	0.5	0.5	0

3.1.1.

Summary of the Tail Cracks

- The tail has 2 primary cracks, identified as 1a and 2a. Emanating from these are numerous secondary cracks, identified as 1b,1b1,1b2,1c, 2b,2c,2d.
- Between 14.12.2016 and 10.03.2017, both primary cracks increased *at points* in both width and depth – see graphs/tables 1.0 and 2.0.
- Crack 1a between points 470mm-1000mm and Crack 2a between points 3680-4850mm, indicate a crack created due to shear force, see plate 17. This crack has increased in width and depth between 14.12.2016 and 10.03.2017.
- Between 14.12.2016 and 10.03.2017, Crack 1a has developed a loss at 540mm, with a disassociated fragment measuring 60x25x18mm. See plates 2,3,4.

- Crack 2a, between points 1300mm and 2300mm displays a complete detachment between the tail and the concrete raft on which it sits. See graph 2.0 and plate 17.
- There was no change in the dimensions of the secondary cracks; 1b,1b1,1b2,1c,2b,2c,2d.

Results from the monitoring of the tail cracks between 14.12.2016 and 10.03.2017 indicate a series of cracks formed due to shear stress as the ground beneath the lower section of the tail subsides. This is causing progressive cracking. The crack across the width of the tail has formed in the original concrete, not in the 2015 repair. The 2015 repair treatment included the insertion of a steel dowel (Cliveden 2015). It is likely that the rigidity of the steel dowels is preventing a crack forming at this point and the stress is transferring further up into the tail where the new crack has developed in the original concrete.

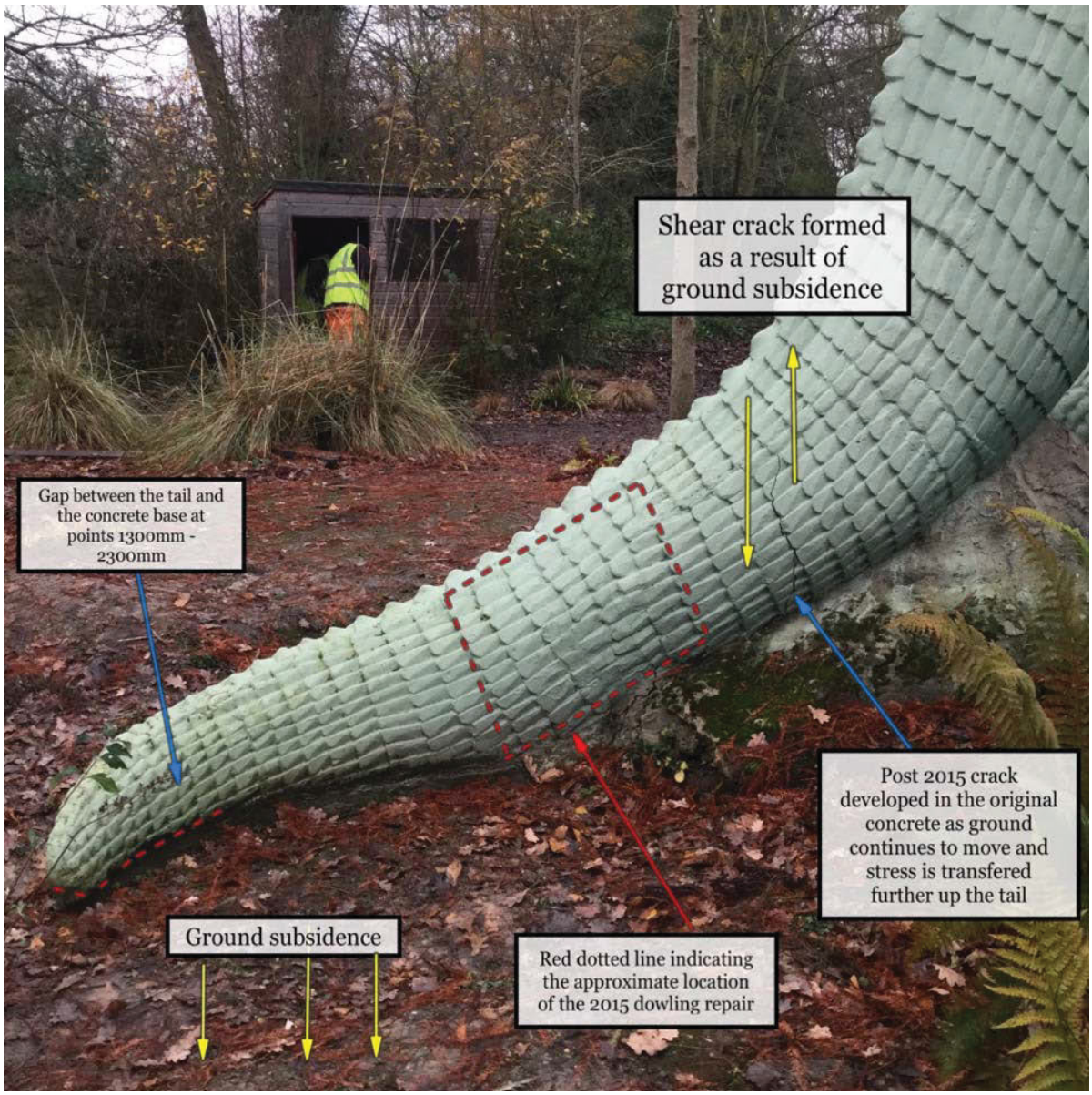
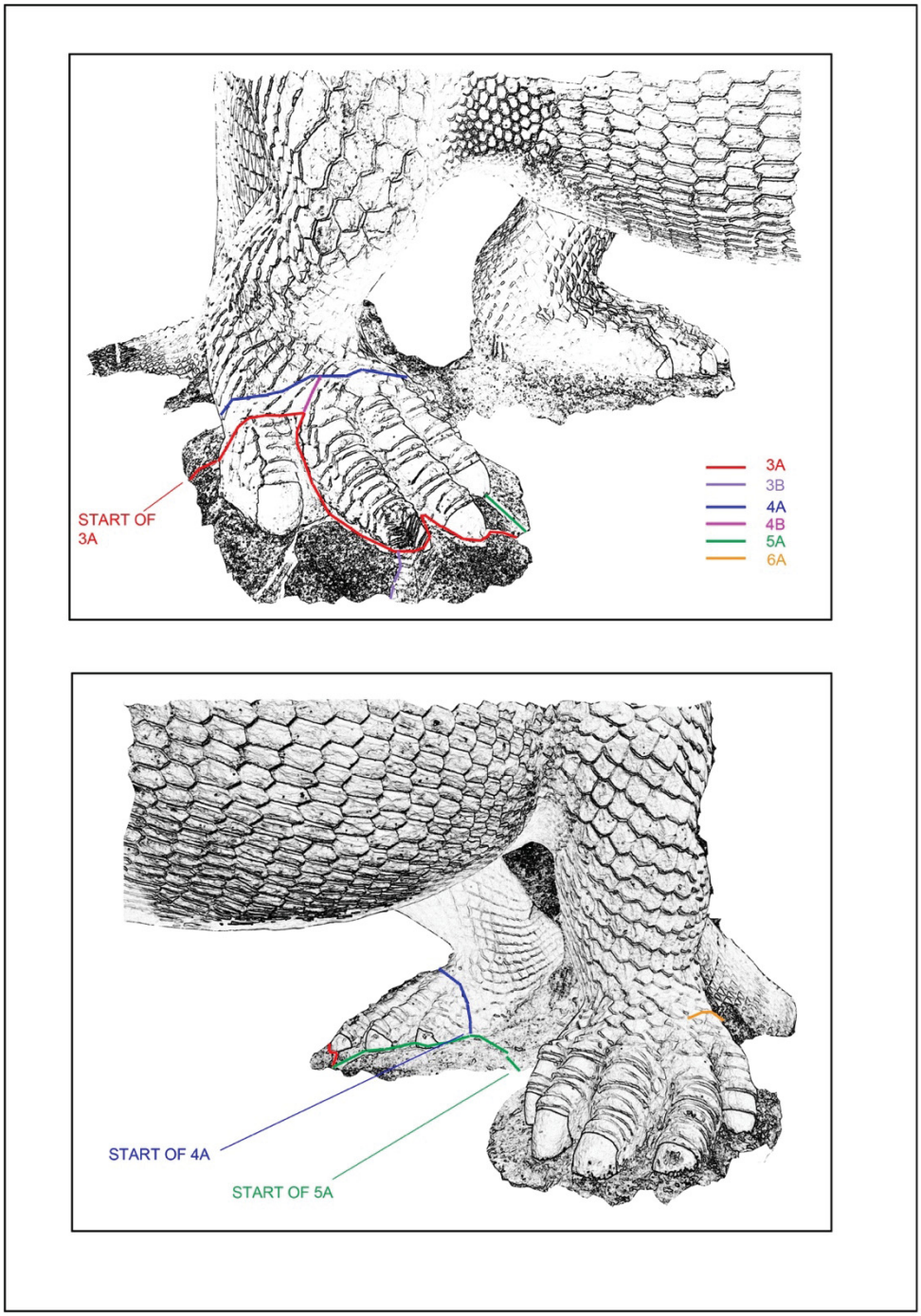


Plate 17.

3.2

BACK FEET

The cracks were identified, measured and recorded on 15.12.2016. They were re-measured and recorded on 15.03.2017.



Plates 18 and 19. Diagrams depicting the location of the cracks.

Crack 3A – see plates 18 and 19 for location. Below- Detail images depicting progressive deterioration related to cracking. Numbers refer to the measurement points along the length of the crack in millimetres.

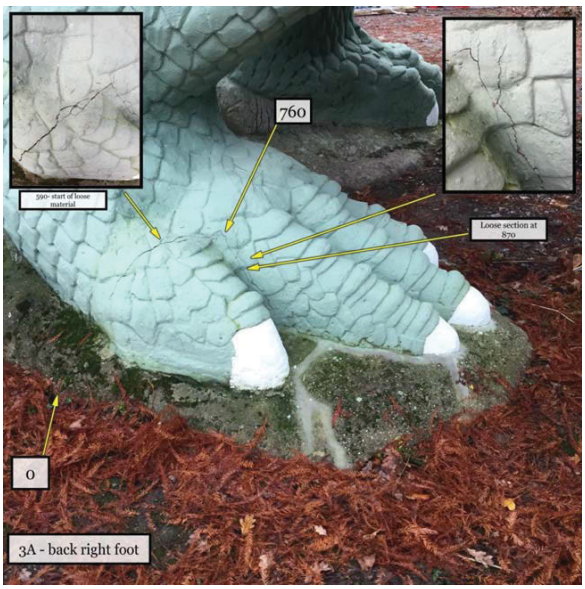


Plate 20. Crack 3A - Photographed 15.12.16.

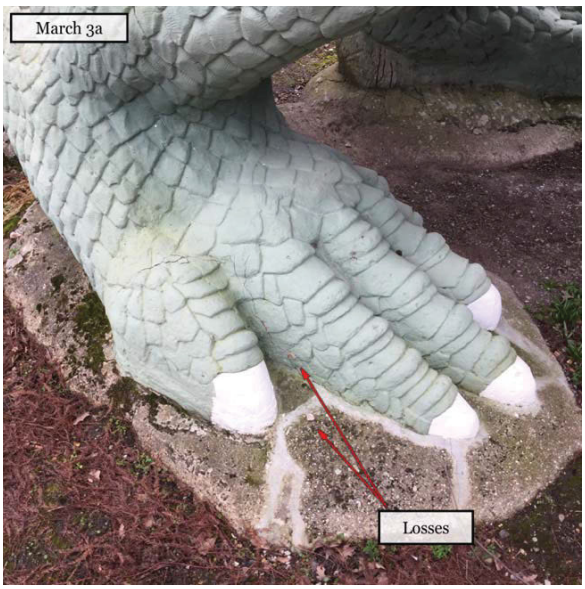


Plate 21. Photographed 15.03.17 – visible losses.

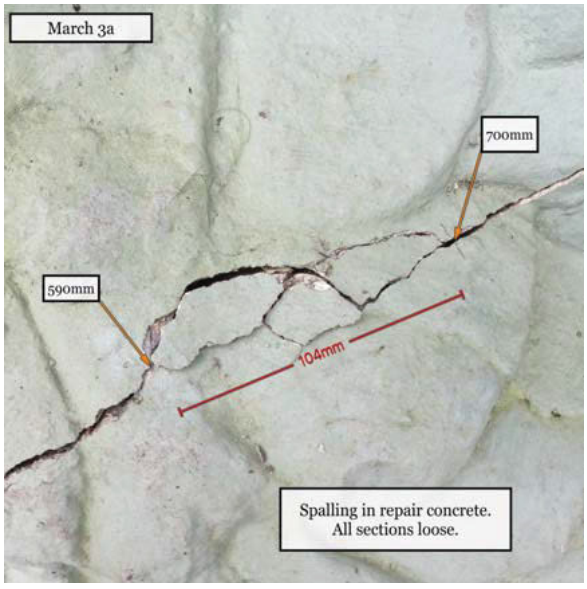


Plate 22.

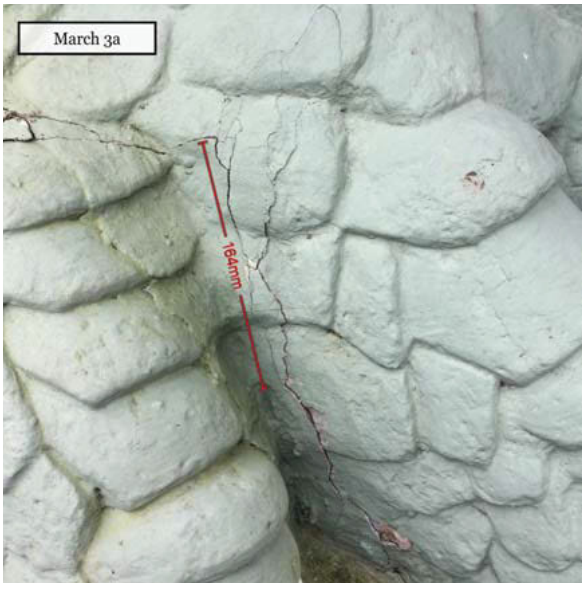


Plate 23.

Plates 22-25- photographed 15.03.17. Details of cracking and spalling in the concrete, including visible losses and detached fragments since 15.12.16.

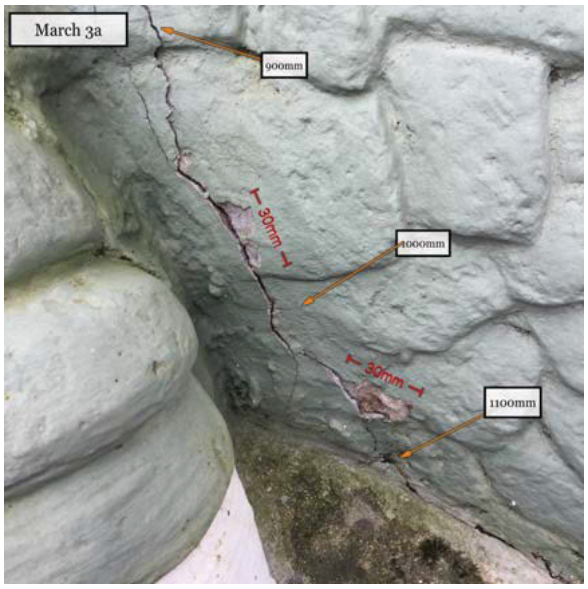


Plate 24.

Plate 25.

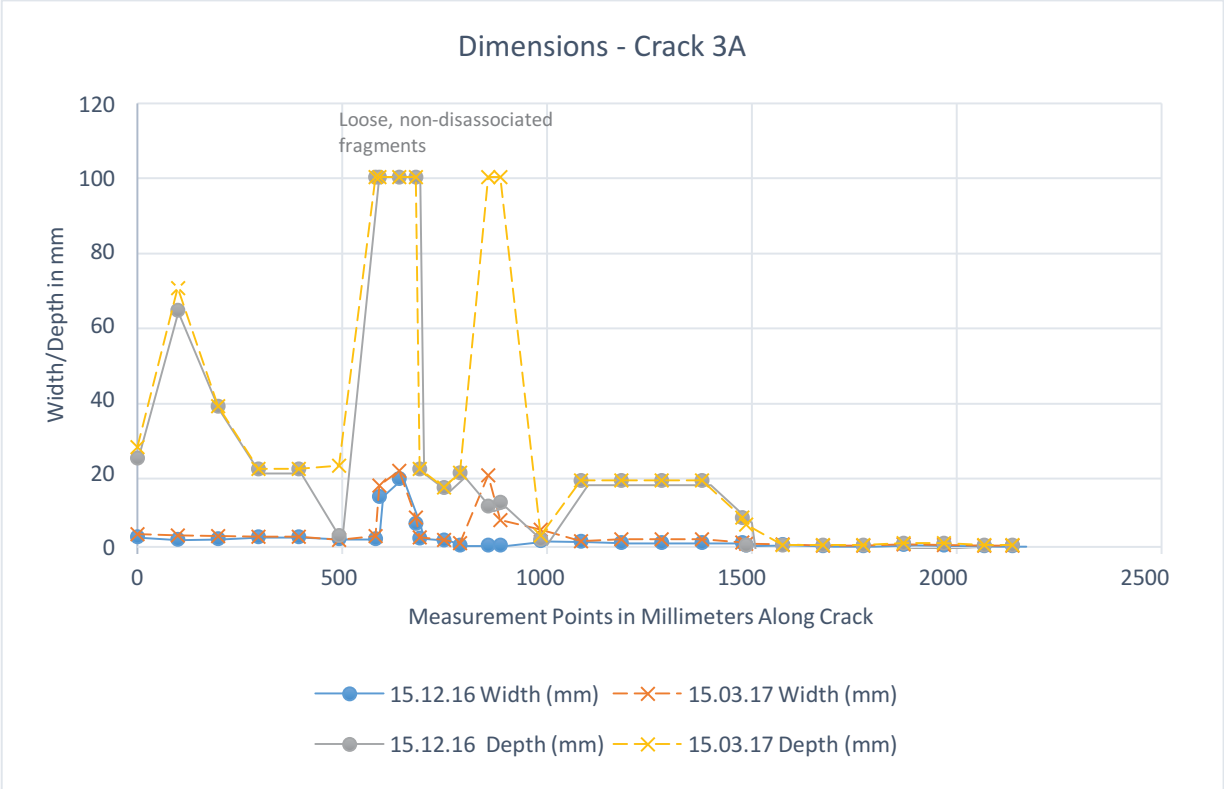
DATA

The graphs display the length, width and depth measurements for each individual crack. Starting at 0mm (the crack's origin point), the measurements were recorded every 100mm along the length of the crack and at points of noticeable deterioration.

Due to the accuracy limitations of the depth gauge, depth values of 100mm indicate values 100> and depth values of 0.5 indicate values of <0.5.

Loose, but non-disassociated fragments were recorded as having a depth of 100mm as these points were too fragile to take accurate readings.

Measurements were recorded on 15.12.2016 and again on the 15.03.2017.

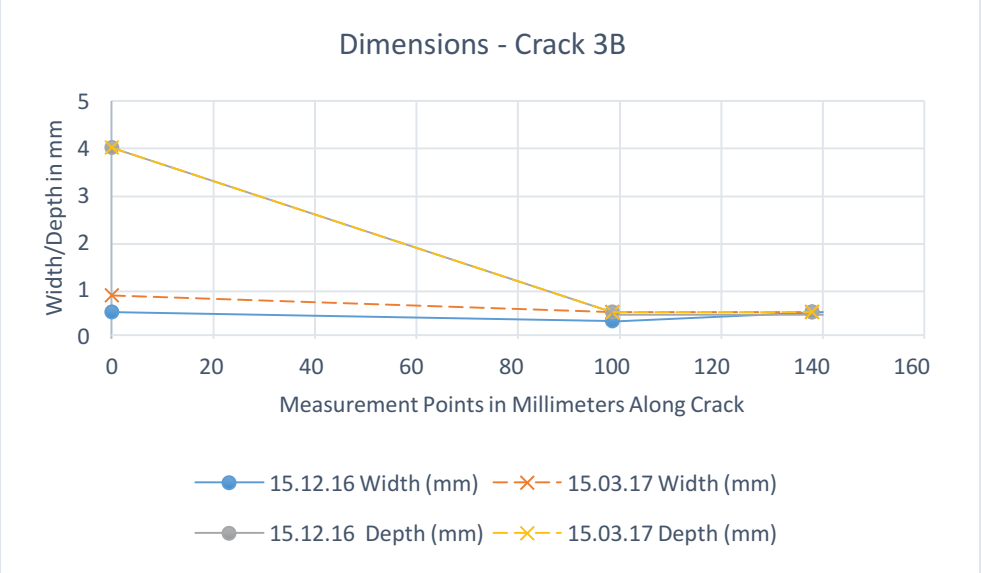


Graph 3.0

Table 3.0 – Crack 3A

Measurement Points Along Crack (mm)	15.12.16 Width (mm)	15.03.17 Width (mm)	△ Width (mm)	15.12.16 Depth (mm)	15.03.17 Depth (mm)	△ Depth (mm)
0	2.68	3.39	0.71	24	27	3
100	2	3.05	1.05	64	70	6
200	2.24	2.86	0.62	38	38	0
300	2.75	2.79	0.04	21	21	0
400	2.65	2.78	0.13	21	21	0
500	2.25	1.81	-0.44	3	22	19
590	2.25	2.83	0.58	100	100	0
600	13.7	16.5	2.8	100	100	0
650	18.4	20.57	2.17	100	100	0
690	6.35	7.85	1.5	100	100	0
700	2.4	2.47	0.07	21	21	0
760	1.81	1.81	0	16	16	0
800	0.45	0.92	0.47	20	20	0
870	0.45	19.27	18.82	11	100	89
900	0.45	7.29	6.84	12	100	88
1000	1.67	4.6	2.93	2	3	1
1100	1.5	1.5	0	18	18	0
1200	1.1	2	0.9	18	18	0
1300	1.1	2	0.9	18	18	0
1400	1.1	2	0.9	18	18	0
1500	1.1	1.1	0	8	8	0

1510	0.5	0.9	0.4	0.5	6	5.5
1600	0.65	0.65	0	0.5	0.5	0
1700	0.3	0.3	0	0.5	0.5	0
1800	0.3	0.3	0	0.5	0.5	0
1900	0.65	0.65	0	1	1	0
2000	0.45	0.45	0	1	1	0
2100	0.3	0.3	0	0.5	0.5	0
2170	0.3	0.3	0	0.5	0.5	0



Graph 3.1

Table 3.1 – Crack 3B

Measurement Points Along Crack (mm)	15.12.16 Width (mm)	15.03.17 Width (mm)	△ Width (mm)	15.12.16 Depth (mm)	15.03.17 Depth (mm)	△ Depth (mm)
0	0.5	0.85	0.35	4	4	0
100	0.3	0.5	0.2	0.5	0.5	0
140	0.5	0.5	0	0.5	0.5	0

Crack 4a and 5a – see plate 19 for location. Detail images depicting progressive deterioration related to cracking. Numbers refer to measurement points along the length of the crack in millimetres.

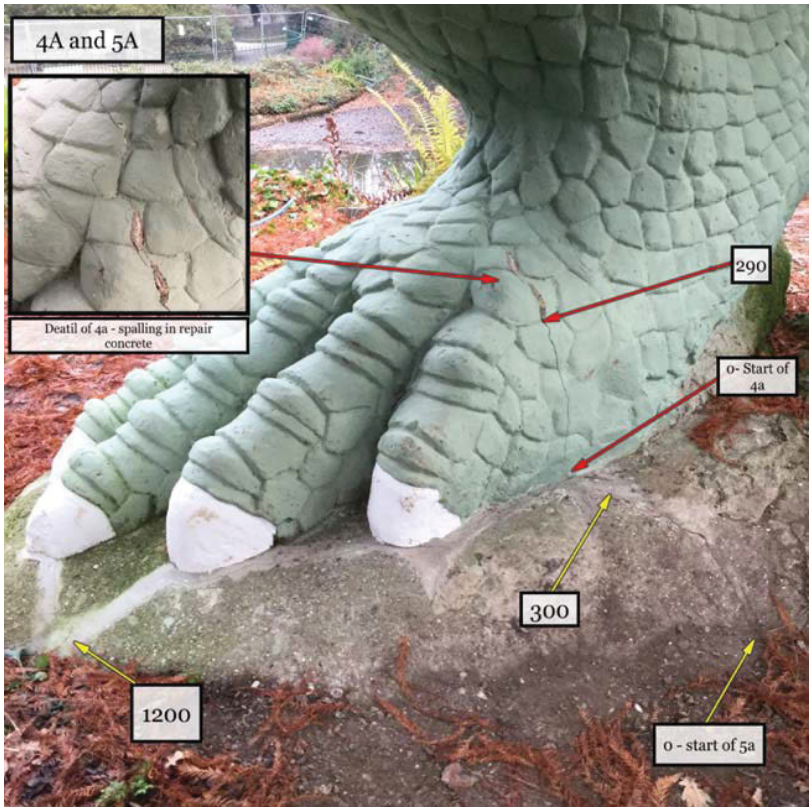
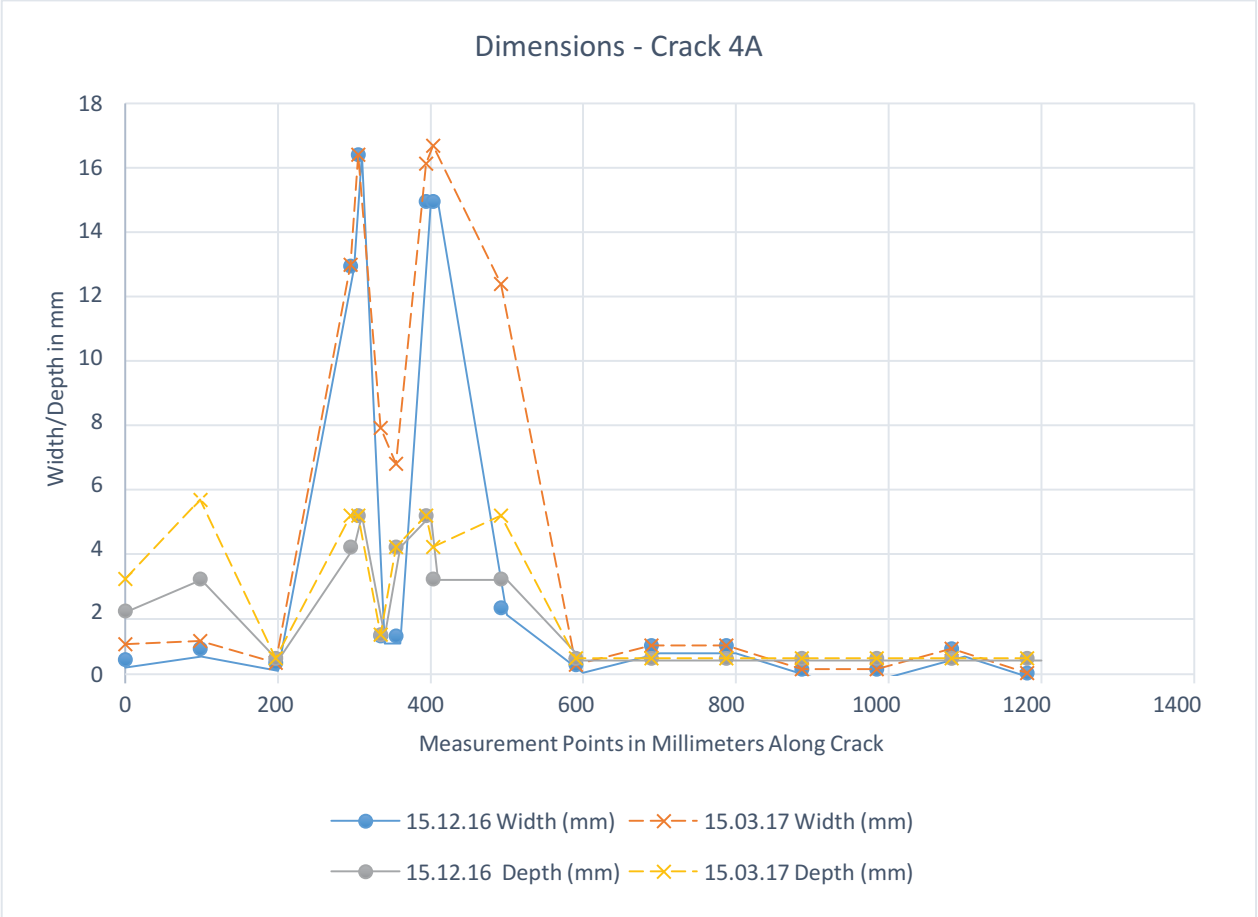


Plate 26. Crack 4A and 5A – Photographed 15.12.16.

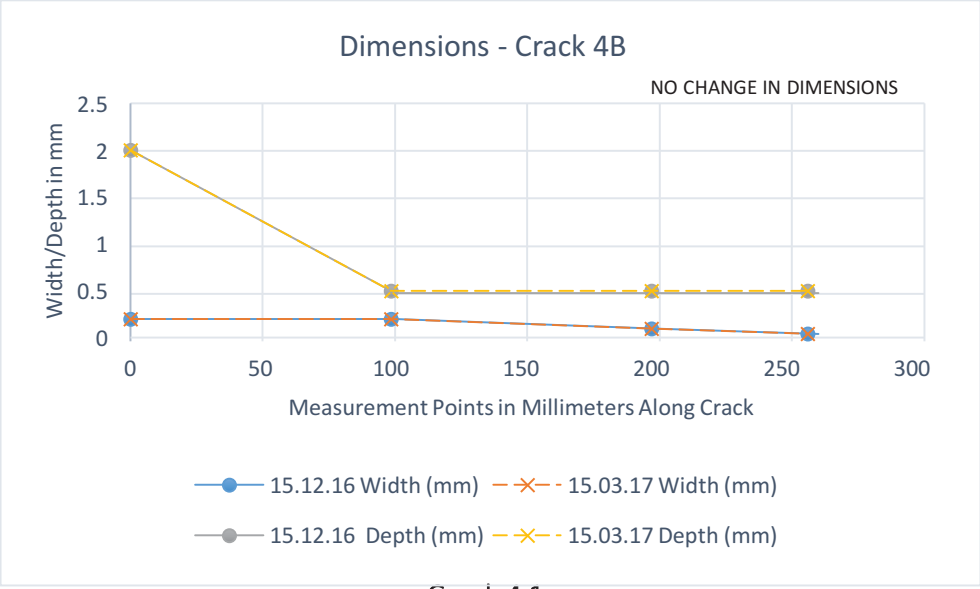
Plates 27 and 28. Crack 4A – Photographed 15.03.17 – disassociated losses incurred since 2016.



Graph 4.0

Table 4.0 – Crack 4A

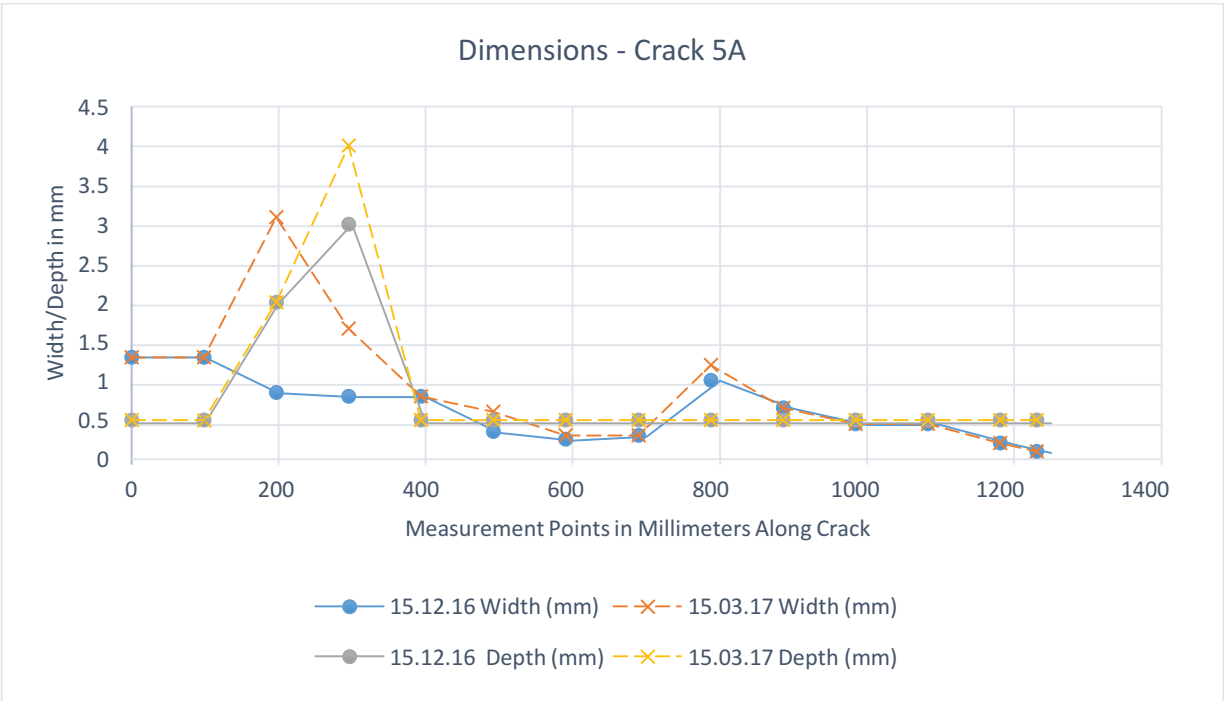
Measurement Points Along Crack (mm)	15.12.16 Width (mm)	15.03.17 Width (mm)	△ Width (mm)	15.12.16 Depth (mm)	15.03.17 Depth (mm)	△ Depth (mm)
0	0.45	0.95	0.5	2	3	1
100	0.8	1.05	0.25	3	5.5	2.5
200	0.35	0.35	0	0.5	0.5	0
300	12.87	12.9	0.03	4	5	1
310	16.37	16.37	0	5	5	0
340	1.2	7.76	6.56	1.24	1.24	0
360	1.2	6.64	5.44	4	4	0
400	14.91	16.09	1.18	5	5	0
410	14.91	16.66	1.75	3	4	1
500	2.1	12.3	10.2	3	5	2
600	0.3	0.3	0	0.5	0.5	0
700	0.9	0.9	0	0.5	0.5	0
800	0.9	0.9	0	0.5	0.5	0
900	0.15	0.15	0	0.5	0.5	0
1000	0.15	0.15	0	0.5	0.5	0
1100	0.8	0.8	0	0.5	0.5	0
1200	0.04	0.04	0	0.5	0.5	0



Graph 4.1

Table 4.1 – Crack 4B

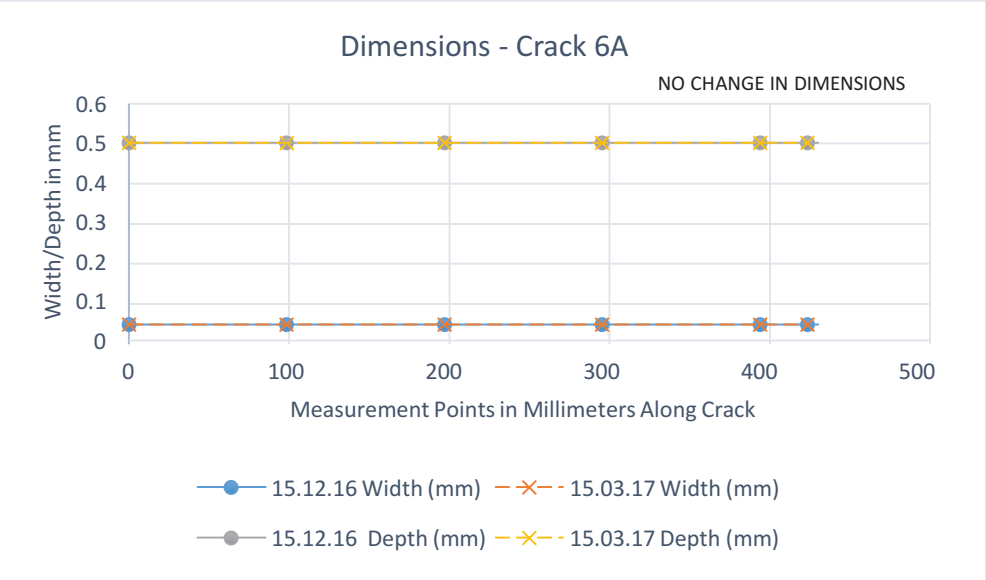
Measurement Points Along Crack (mm)	15.12.16 Width (mm)	15.03.17 Width (mm)	△ Width (mm)	15.12.16 Depth (mm)	15.03.17 Depth (mm)	△ Depth (mm)
0	0.2	0.2	0	2	2	0
100	0.2	0.2	0	0.5	0.5	0
200	0.1	0.1	0	0.5	0.5	0
260	0.04	0.04	0	0.5	0.5	0



Graph 5.0

Table 5.0 – Crack 5A

Measurement Points Along Crack (mm)	15.12.16 Width (mm)	15.03.17 Width (mm)	△ Width (mm)	15.12.16 Depth (mm)	15.03.17 Depth (mm)	△ Depth (mm)
0	1.3	1.3	0	0.5	0.5	0
100	1.3	1.3	0	0.5	0.5	0
200	0.85	3.09	2.24	2	2	0
300	0.8	1.67	0.87	3	4	1
400	0.8	0.8	0	0.5	0.5	0
500	0.35	0.6	0.25	0.5	0.5	0
600	0.25	0.3	0.05	0.5	0.5	0
700	0.3	0.3	0	0.5	0.5	0
800	1	1.2	0.2	0.5	0.5	0
900	0.65	0.65	0	0.5	0.5	0
1000	0.45	0.45	0	0.5	0.5	0
1100	0.45	0.45	0	0.5	0.5	0
1200	0.2	0.2	0	0.5	0.5	0
1250	0.1	0.1	0	0.5	0.5	0



Graph 6.0

Table 6.0 – Crack 6A

Measurement Points Along Crack (mm)	15.12.16 Width (mm)	15.03.17 Width (mm)	△ Width (mm)	15.12.16 Depth (mm)	15.03.17 Depth (mm)	△ Depth (mm)
0	0.04	0.04	0	0.5	0.5	0
100	0.04	0.04	0	0.5	0.5	0
200	0.04	0.04	0	0.5	0.5	0
300	0.04	0.04	0	0.5	0.5	0
400	0.04	0.04	0	0.5	0.5	0
430	0.04	0.04	0	0.5	0.5	0

3.2.1

Summary of the Back Left and Right Feet

- The back right foot has three primary cracks, identified as 3a,4a and 5a. Cracks 3a and 4a both start in the concrete base and extend over the foot, both cracks have secondary cracks, identified as 3b and 4b.
- Crack 5a does not extend into the foot and is limited to the concrete base, following the site of a repair made in 2015.
- Between 15.12.2016 and 15.03.2017, primary cracks 3a,4a,5a have increased *at points* in both width and depth – see graphs/tables 3.0, 4.0 and 5.0.
- Crack 3a, between points 590-1100mm, displays an almost continuous length of spalling concrete, with numerous losses and disassociated fragments. Losses at points 950mm and 1050mm have occurred between 15.12.16 and 15.03.17. See plates 20-25.
- Crack 4a follows the site of a 2015 repair. Point 290-510mm along the crack displays delaminating repair concrete, with total disassociation of fragments occurring between 15.12.16 and 15.03.17. See plates 26,27,28.
- The back left foot has one hairline crack, identified as 6a. This showed no change in dimension between the two dates.
- There was only a very slight change in the width of the secondary crack 3b and no change in 4b.

Results from the monitoring of the back left and right feet between 15.12.16 and 15.03.17 indicate a series of cracks, forming and increasing in width and depth at points, along the top of the back right foot and in the concrete base of the foot. These cracks are occurring at the sites of the previous 2015 repairs, indicating that these are progressive cracks caused by ground subsidence. The back right leg, formed around a 9ft (274cm) cast iron pipe which extends down into the ground, shows no evidence of cracking. Cracking appears at the point of stress where the apparently hollow foot meets the ridged leg. The back left leg displays only one short hairline crack, which has not increased dimensions between the two dates, suggesting that the ground is more stable on the left hand side of the dinosaur and subsiding on the right hand side. The numerous losses along crack 4a are the result of delaminating concrete applied during the 2015 restoration. The concrete has not adhered sufficiently to the concrete substrate and further delamination is developing.

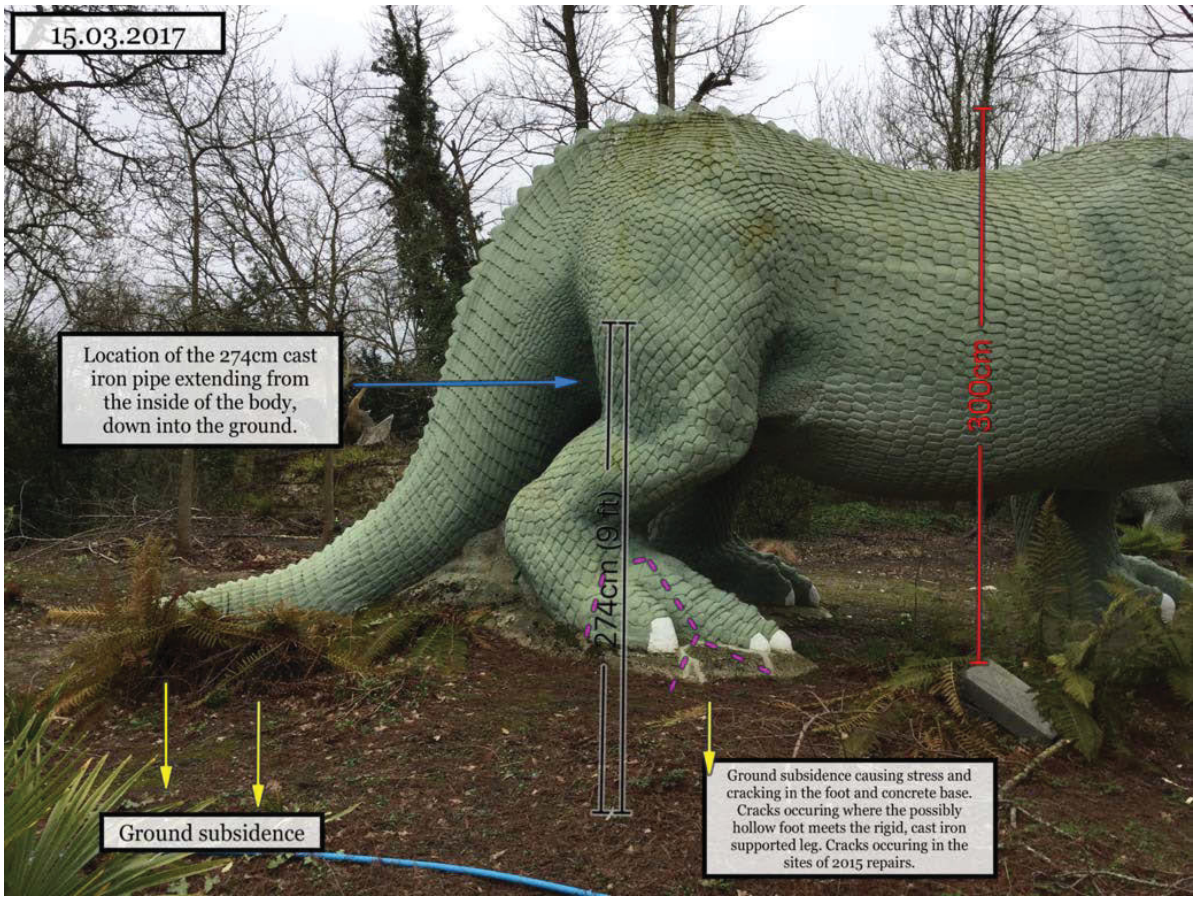
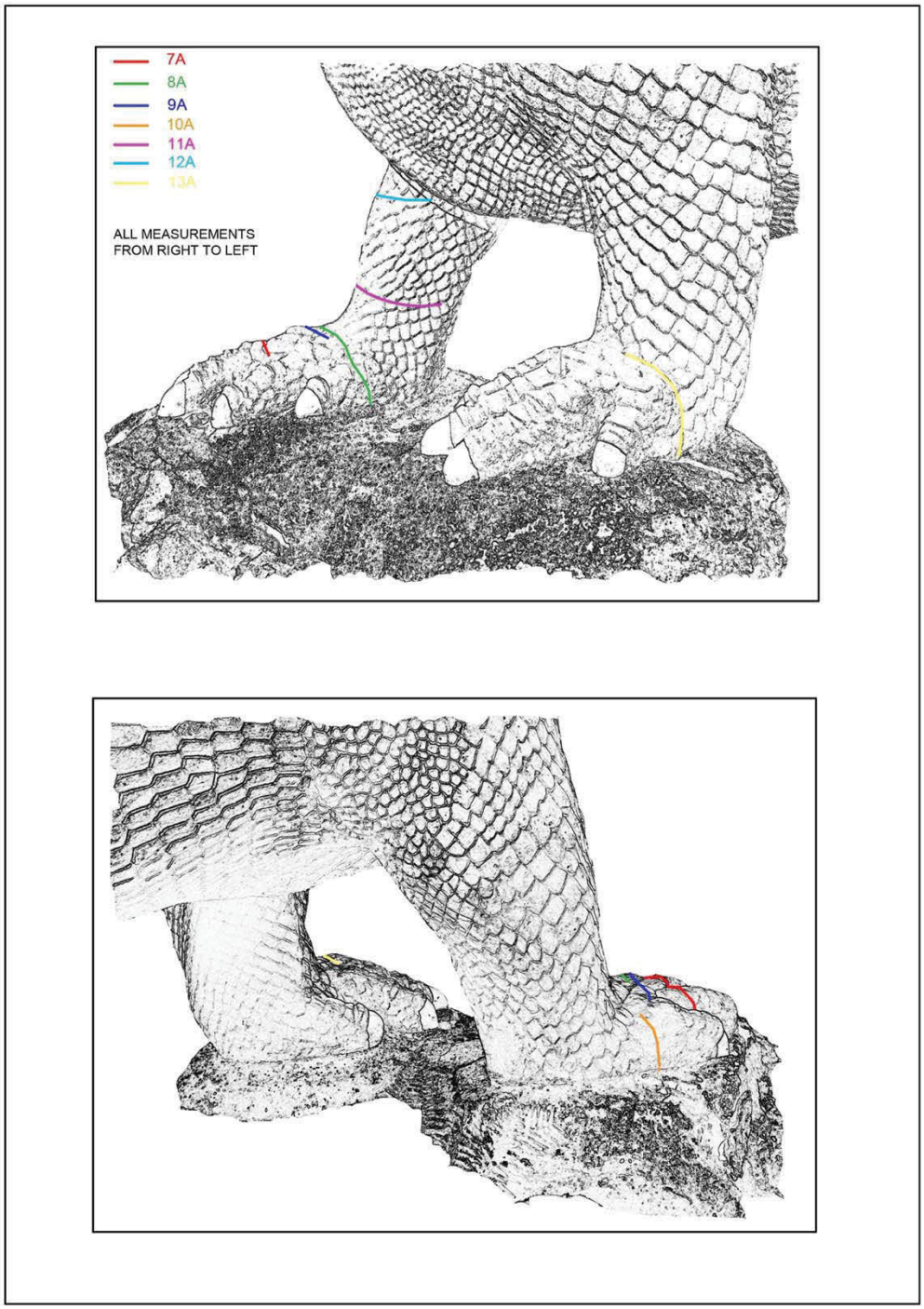

15.03.2017
Location of the 274cm cast iron pipe extending from the inside of the body, down into the ground.
274cm (9 ft)
300cm
Ground subsidence
Ground subsidence causing stress and cracking in the foot and concrete base. Cracks occuring where the possibly hollow foot meets the rigid, cast iron supported leg. Cracks occuring in the sites of 2015 repairs.

Plate 29.

3.3

FRONT FEET AND LEGS

The cracks were identified, measured and recorded on 15.12.2016. They were re-measured and recorded on 15.03.2017.



Plates 30 and 31. Diagrams depicting the location of the cracks.

Cracks 7a - 13a – see plate 30 and 31 for locations. Numbers refer to measurement points along the length of the crack in millimetres.

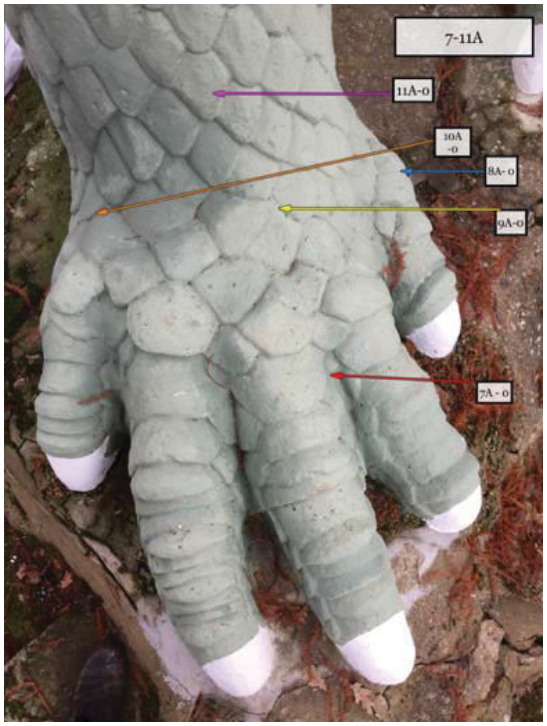


Plate 32. Photographed 15.12.16

Plate 33. Photographed 15.12.16

Plate 34. Photographed 15.12.16

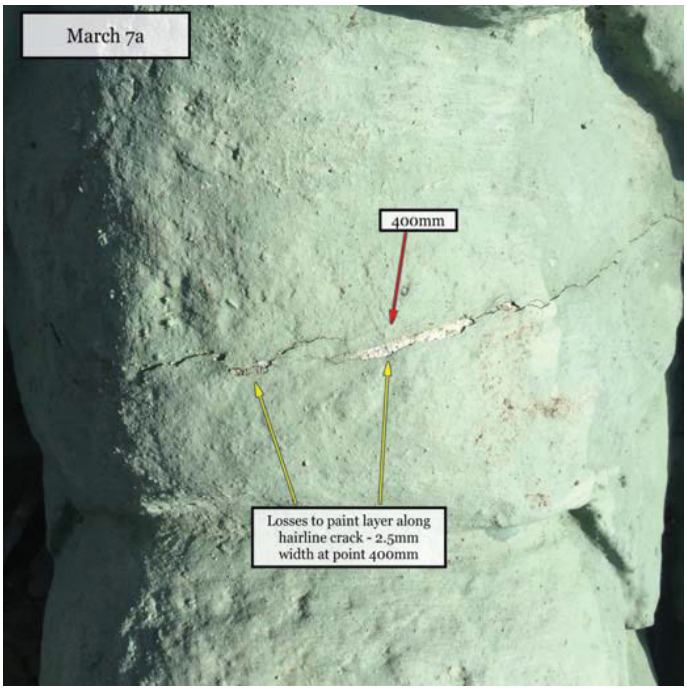


Plate 35 – Photographed 15.03.17 - Crack 7a – delamination and loss of paint along the crack.

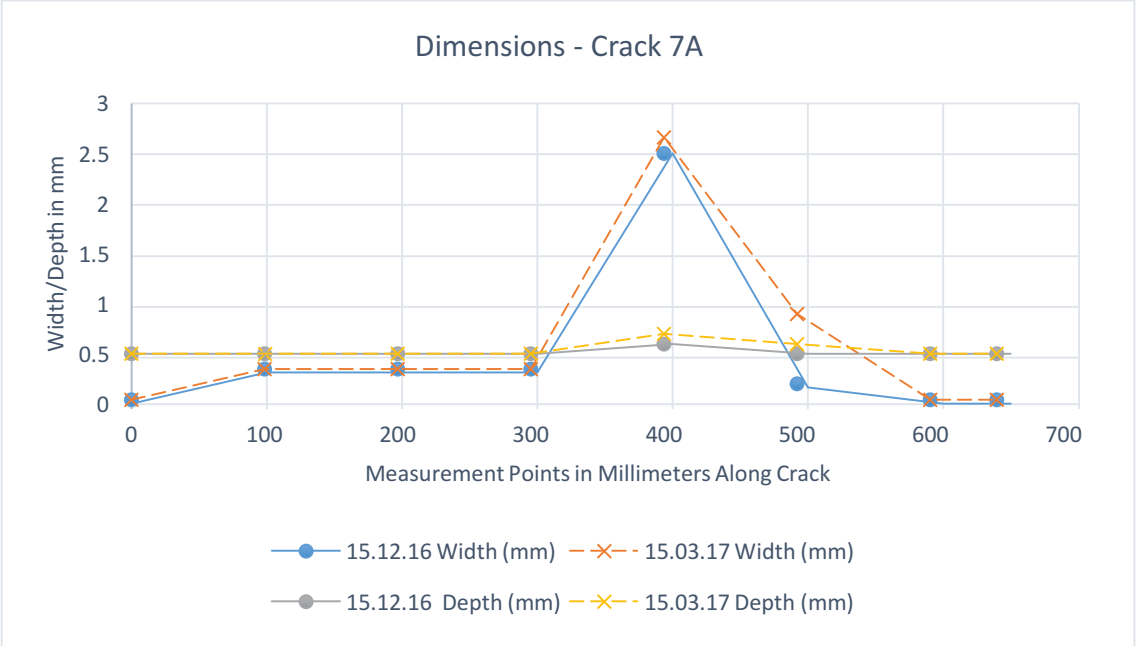
DATA

The graphs display the length, width and depth measurements for each individual crack. Starting at 0mm (the crack's origin point), the measurements were recorded every 100mm along the length of the crack and at points of noticeable deterioration.

Due to the accuracy limitations of the depth gauge, depth values of 100mm indicate values 100> and depth values of 0.5 indicate values of <0.5.

Loose, but non-disassociated fragments were recorded as having a depth of 100mm as these points were too fragile to take accurate readings.

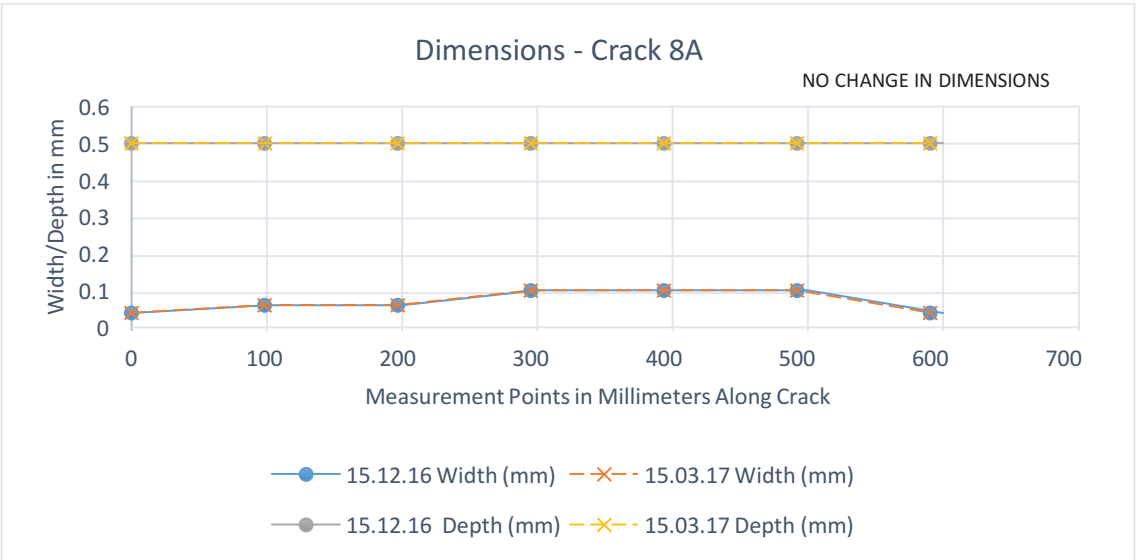
Measurements were recorded on 15.12.2016 and again on the 15.03.2017.



Graph 7.0

Table 7.0 – Crack 7A

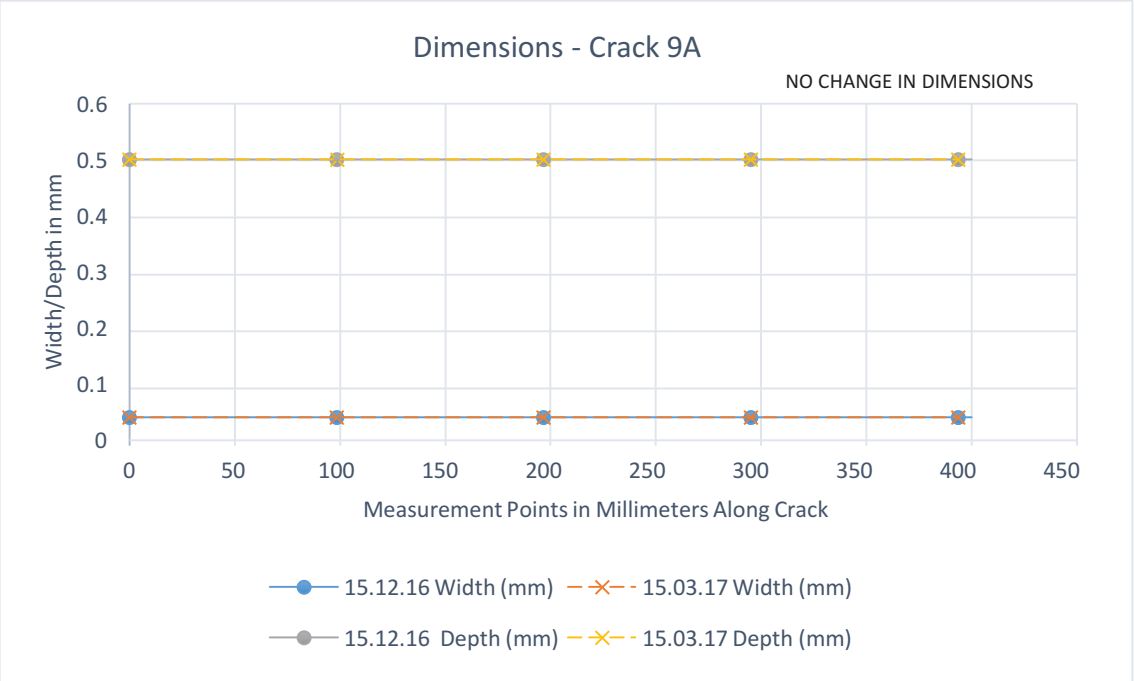
Measurement Points Along Crack (mm)	15.12.16 Width (mm)	15.03.17 Width (mm)	△ Width (mm)	15.12.16 Depth (mm)	15.03.17 Depth (mm)	△ Depth (mm)
0	0.04	0.04	0	0.5	0.5	0
100	0.35	0.35	0	0.5	0.5	0
200	0.35	0.35	0	0.5	0.5	0
300	0.35	0.35	0	0.5	0.5	0
400	2.5	2.66	0.16	0.6	0.7	0.1
500	0.2	0.9	0.7	0.5	0.6	0.1
600	0.04	0.04	0	0.5	0.5	0
650	0.04	0.04	0	0.5	0.5	0



Graph 8.0

Table 8.0 – Crack 8A

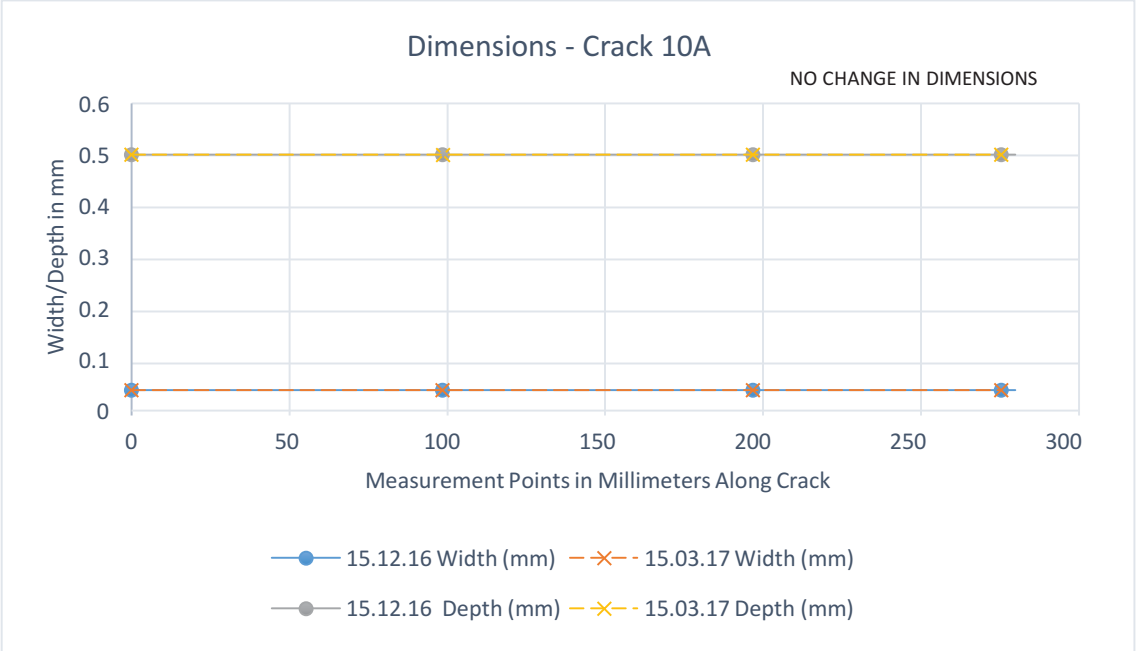
Measurement Points Along Crack (mm)	15.12.16 Width (mm)	15.03.17 Width (mm)	△ Width (mm)	15.12.16 Depth (mm)	15.03.17 Depth (mm)	△ Depth (mm)
0	0.04	0.04	0	0.5	0.5	0
100	0.06	0.06	0	0.5	0.5	0
200	0.06	0.06	0	0.5	0.5	0
300	0.1	0.1	0	0.5	0.5	0
400	0.1	0.1	0	0.5	0.5	0
500	0.1	0.1	0	0.5	0.5	0
600	0.04	0.04	0	0.5	0.5	0



Graph 9.0

Table 9.0 – Crack 9A

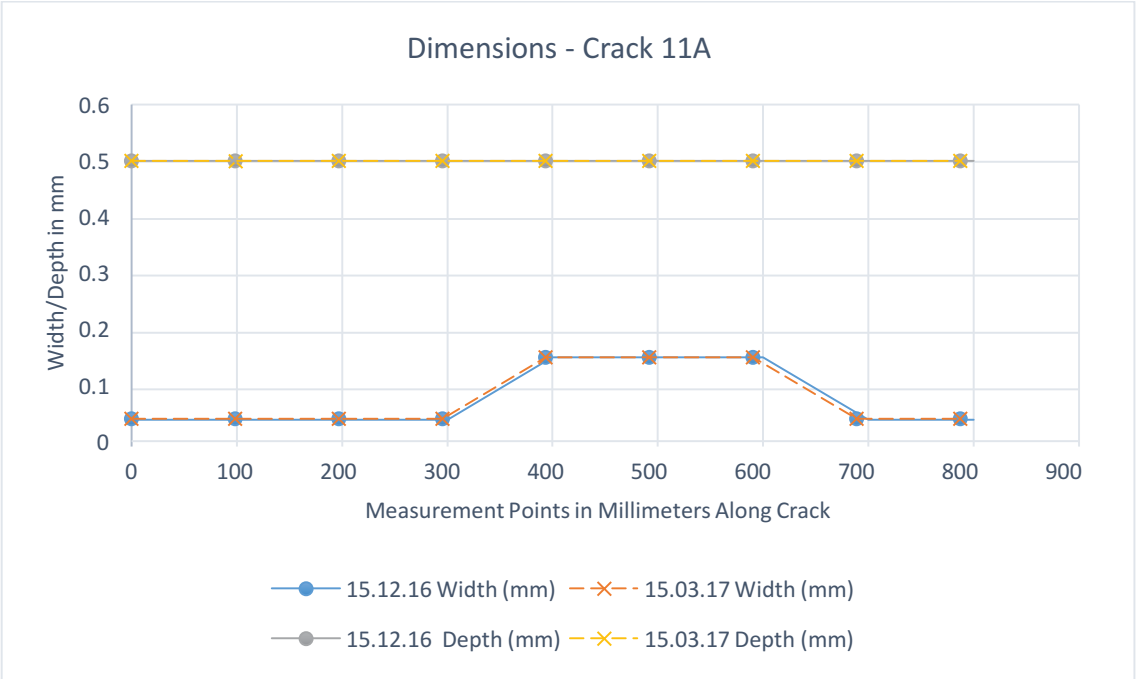
Measurement Points Along Crack (mm)	15.12.16 Width (mm)	15.03.17 Width (mm)	△ Width (mm)	15.12.16 Depth (mm)	15.03.17 Depth (mm)	△ Depth (mm)
0	0.04	0.04	0	0.5	0.5	0
100	0.04	0.04	0	0.5	0.5	0
200	0.04	0.04	0	0.5	0.5	0
300	0.04	0.04	0	0.5	0.5	0
400	0.04	0.04	0	0.5	0.5	0



Graph 10.0

Table 10.0 – Crack 10A

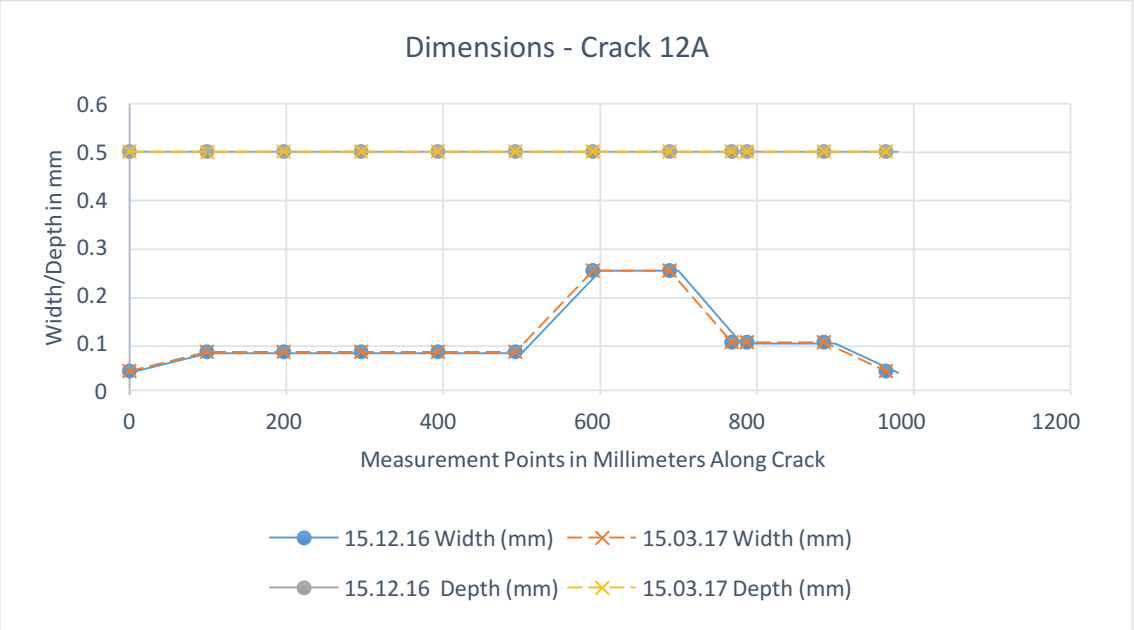
Measurement Points Along Crack (mm)	15.12.16 Width (mm)	15.03.17 Width (mm)	△ Width (mm)	15.12.16 Depth (mm)	15.03.17 Depth (mm)	△ Depth (mm)
0	0.04	0.04	0	0.5	0.5	0
100	0.04	0.04	0	0.5	0.5	0
200	0.04	0.04	0	0.5	0.5	0
280	0.04	0.04	0	0.5	0.5	0



Graph 11.0

Table 11.0 – Crack 11A

Measurement Points Along Crack (mm)	15.12.16 Width (mm)	15.03.17 Width (mm)	△ Width (mm)	15.12.16 Depth (mm)	15.03.17 Depth (mm)	△ Depth (mm)
0	0.04	0.04	0	0.5	0.5	0
100	0.04	0.04	0	0.5	0.5	0
200	0.04	0.04	0	0.5	0.5	0
300	0.04	0.04	0	0.5	0.5	0
400	0.15	0.15	0	0.5	0.5	0
500	0.15	0.15	0	0.5	0.5	0
600	0.15	0.15	0	0.5	0.5	0
700	0.04	0.04	0	0.5	0.5	0
800	0.04	0.04	0	0.5	0.5	0

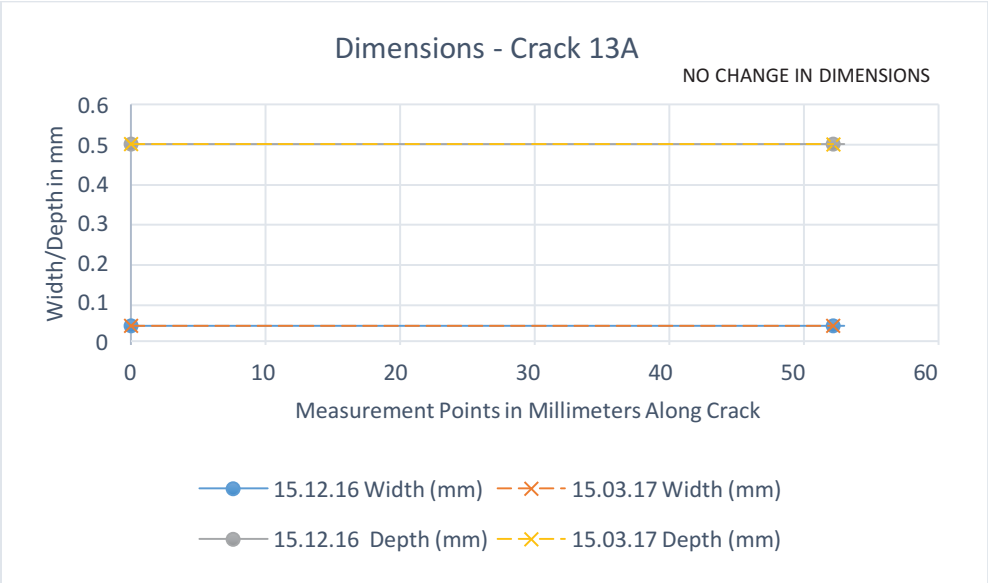


Graph 12.0

Table 12.0 – Crack 12A

Measurement Points Along Crack (mm)	15.12.16 Width (mm)	15.03.17 Width (mm)	△ Width (mm)	15.12.16 Depth (mm)	15.03.17 Depth (mm)	△ Depth (mm)
0	0.04	0.04	0	0.5	0.5	0
100	0.08	0.08	0	0.5	0.5	0
200	0.08	0.08	0	0.5	0.5	0
300	0.08	0.08	0	0.5	0.5	0
400	0.08	0.08	0	0.5	0.5	0
500	0.08	0.08	0	0.5	0.5	0
600	0.25	0.25	0	0.5	0.5	0
700	0.25	0.25	0	0.5	0.5	0
780	0.1	0.1	0	0.5	0.5	0

800	0.1	0.1	0	0.5	0.5	0
900	0.1	0.1	0	0.5	0.5	0
980	0.04	0.04	0	0.5	0.5	0



Graph 13.0

Table 13.0 – Crack 13A

Measurement Points Along Crack (mm)	15.12.16 Width (mm)	15.03.17 Width (mm)	△ Width (mm)	15.12.16 Depth (mm)	15.03.17 Depth (mm)	△ Depth (mm)
0	0.04	0.04	0	0.5	0.5	0
53	0.04	0.04	0	0.5	0.5	0

3.3.1.

Summary of the Front Right and Left Feet

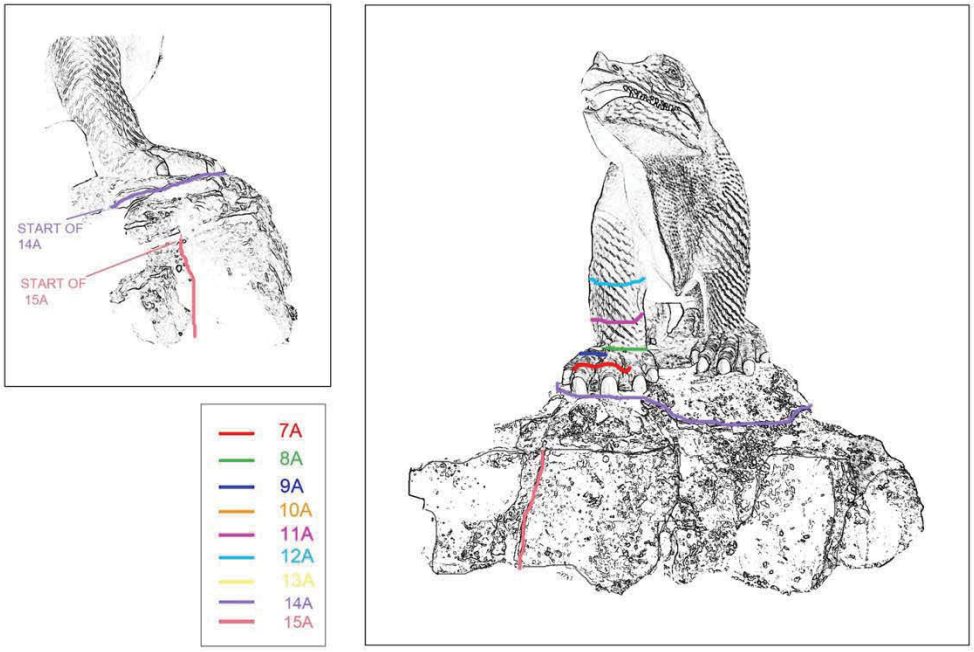
- The front right foot has six hairline cracks, identified as 7a,8a,9a,10a,11a and 12a. There are no secondary cracks.
- The front left foot has one hairline crack, identified as 13a and no secondary cracks.
- Between 15.12.2016 and 15.03.2017 crack 7a increased in width and depth between points 400mm-600mm. This increase is due to a loss in the paint layers, along the site of a 2015 crack restoration. See plate 35 and graph 7.0.
- Cracks 8a-13a have seen no increase in dimensions between 15.12.2016 and 15.03.2017.

Results from the monitoring of the front right and left feet between 15.12.16 and 15.03.17 indicate a series of hairline cracks. These cracks have formed since the 2015 restoration (Cliveden, 2015.) Crack 7a is the only crack to have increased in dimensions between 15.12.16 and 15.03.17. This increase is due to a loss in the paint layer, not due to increased cracking in the concrete. The delamination of the paint is possibly due to water ingress, facilitated by the hairline crack. All the cracks appear to be on the sites of previous restorations.

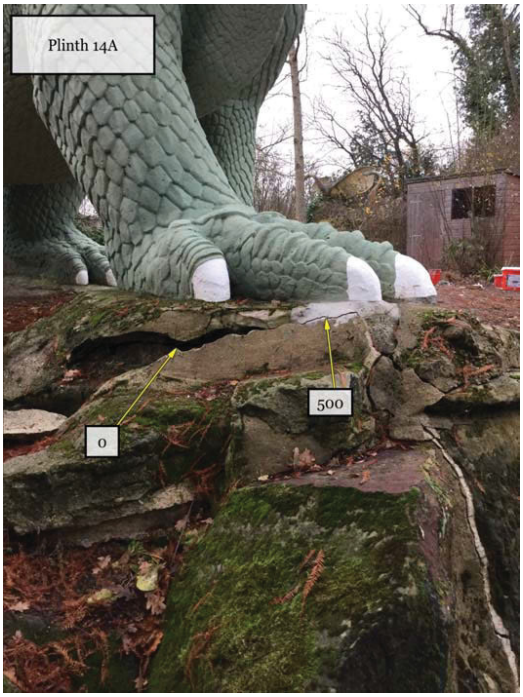
3.4

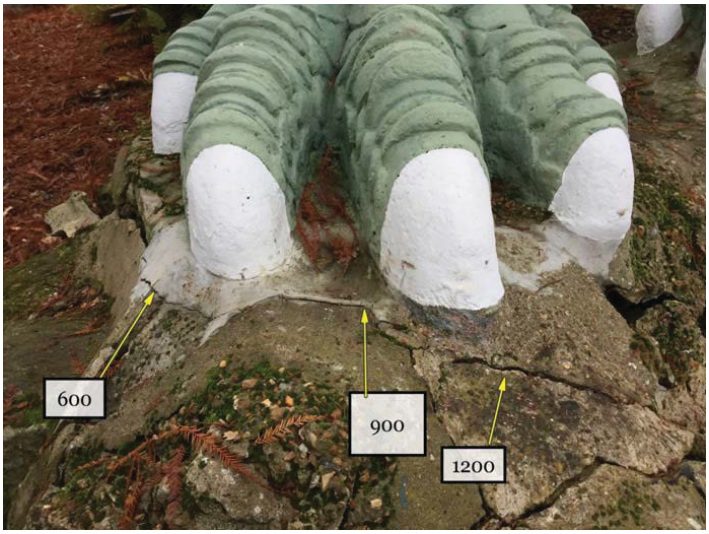
PLINTH

The cracks were identified, measured and recorded on 15.12.2016. They were re-measured and recorded on 15.03.2017.



Plates 36 and 37. Diagrams depicting the location of the cracks 14a and 15a.





Plates 38 and 39 – Photographed **15.12.16** - Crack 14a

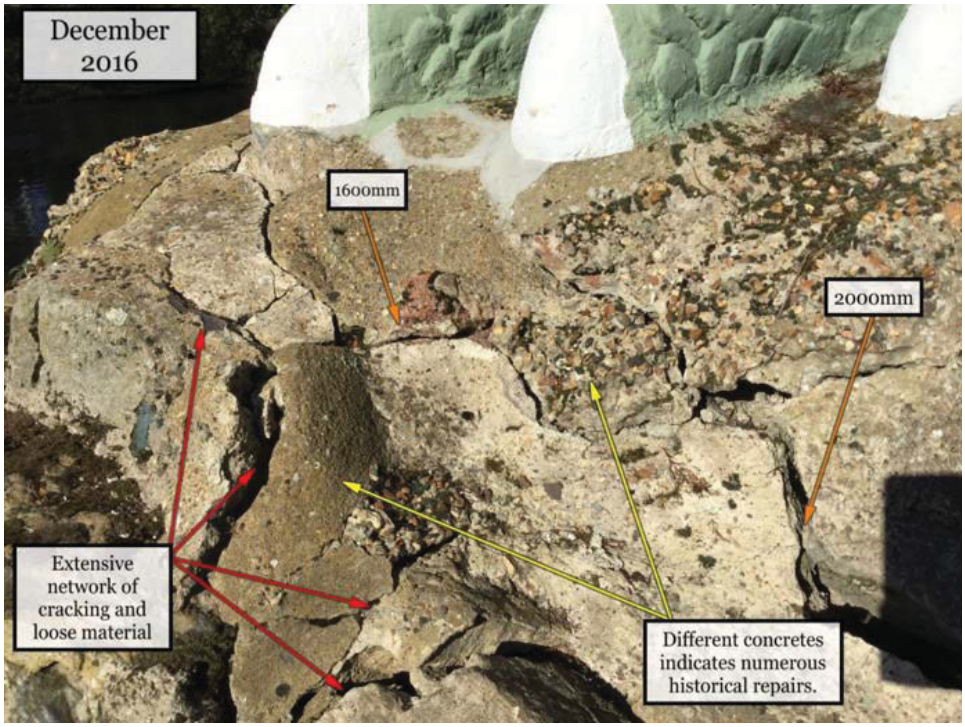


Plate 40. Photographed 15.12.16 – Complexity of crack network.

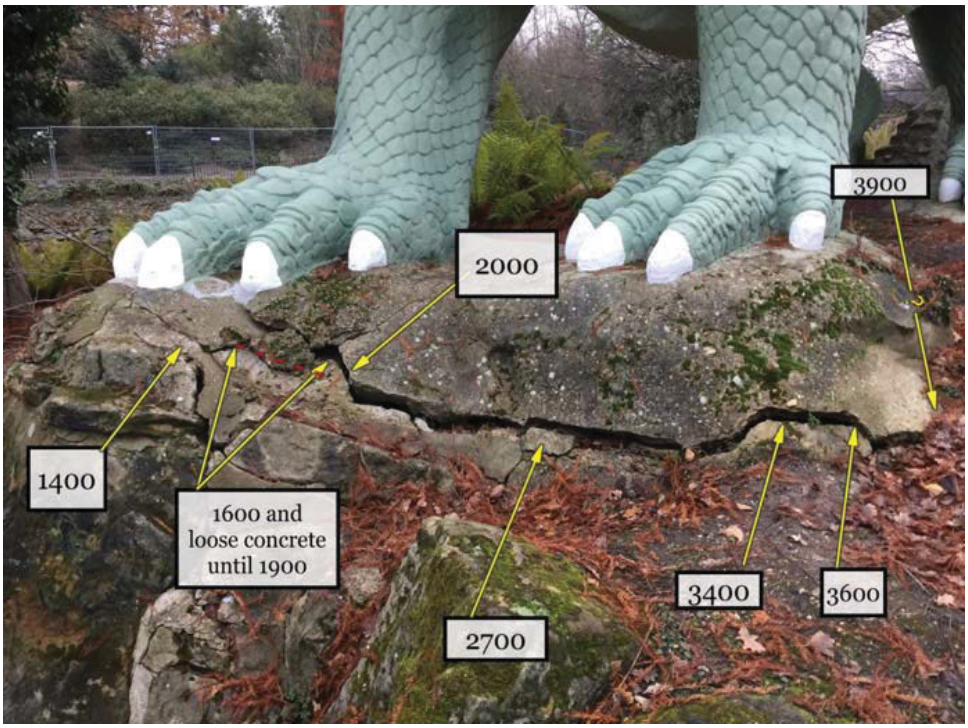


Plate 41. Photographed 15.12.16 – Crack 14A

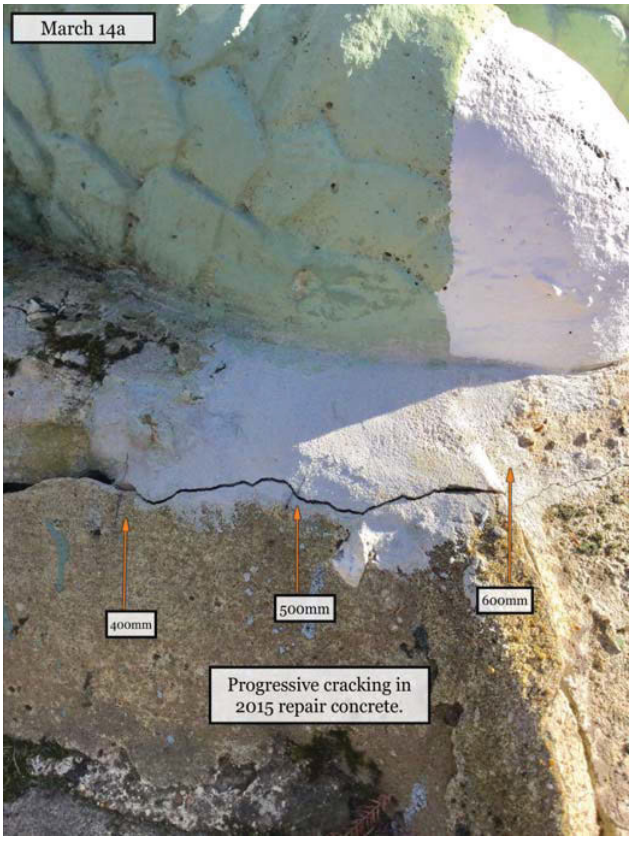


Plate 42 – Photographed 15.03.17 – Crack 14A. Increase in width and depth between points 400-600mm between 15.12.16-15.03.17. Crack occurring in 2015 restoration concrete.

Plate 43. Photographed 15.12.16 – Crack 15A.

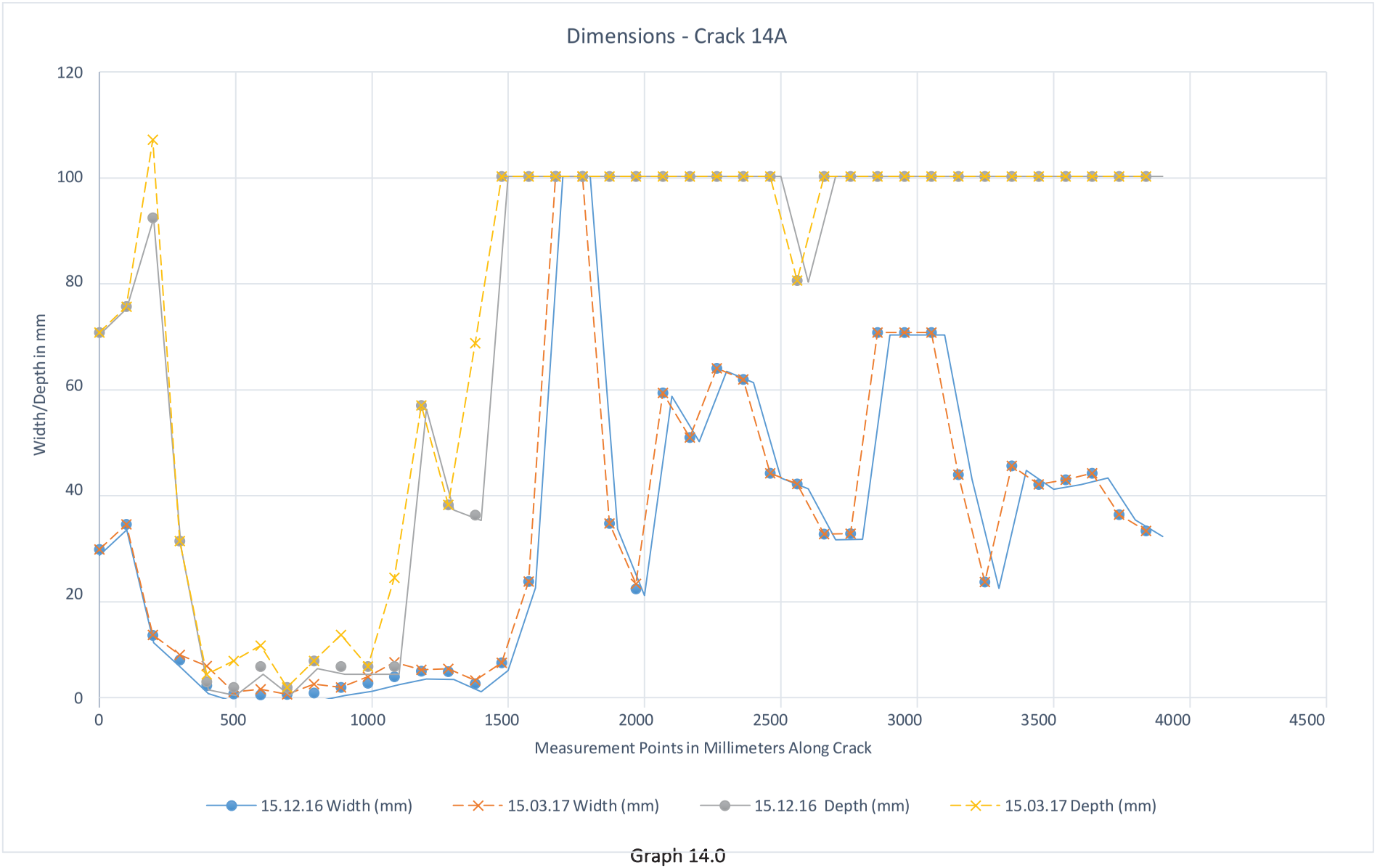
DATA

The graphs display the length, width and depth measurements for each individual crack. Starting at 0mm (the crack's origin point), the measurements were recorded every 100mm along the length of the crack and at points of noticeable deterioration.

Due to the accuracy limitations of the depth gauge, depth values of 100mm indicate values 100> and depth values of 0.5 indicate values of <0.5.

Loose, but non-disassociated fragments were recorded as having a depth of 100mm as these points were too fragile to take accurate readings.

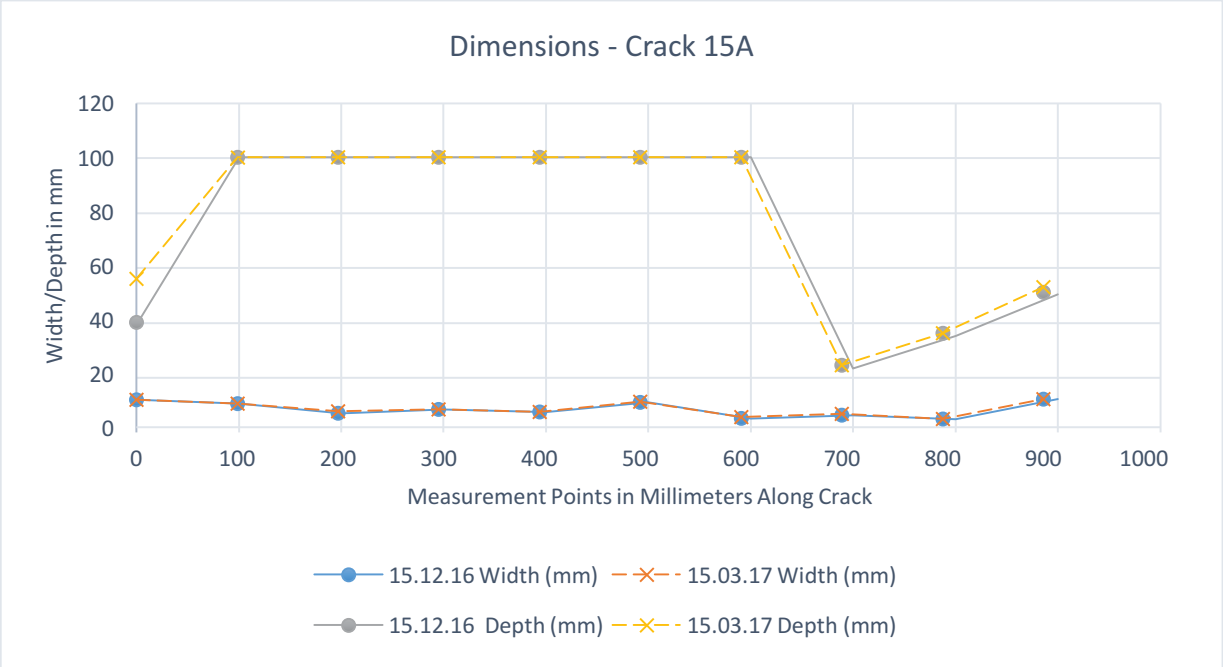
Measurements were recorded on 15.12.2016 and again on the 15.03.2017.


Dimensions - Crack 14A
120
100
80
60
40
20
0
Width/Depth in mm
0
500
1000
1500
2000
2500
3000
3500
4000
4500
Measurement Points in Millimeters Along Crack
15.12.16 Width (mm)
15.03.17 Width (mm)
15.12.16 Depth (mm)
15.03.17 Depth (mm)

Graph 14.0

Table 14.0 – Crack 14A

Measurement Points Along Crack (mm)	15.12.16 Width (mm)	15.03.17 Width (mm)	△ Width (mm)	15.12.16 Depth (mm)	15.03.17 Depth (mm)	△ Depth (mm)
0	28.38	28.38	0	70	70	0
100	33.19	33.19	0	75	75	0
200	11.93	12.05	0.12	92	107	15
300	7.23	8.18	0.95	30	30	0
400	2.3	6.02	3.72	3	4.5	1.5
500	0.7	1.1	0.4	2	7	5
600	0.5	1.6	1.1	6	10	4
700	0.65	0.65	0	2	2	0
800	0.9	2.58	1.68	7	7	0
900	1.95	1.96	0.01	6	12	6
1000	2.72	3.99	1.27	6	6	0
1100	4.04	6.8	2.76	6	23	17
1200	5.12	5.33	0.21	56	56	0
1300	5	5.52	0.52	37	37	0
1400	2.63	3.33	0.7	35	68	33
1500	6.66	6.66	0	100	100	0
1600	22.29	22.29	0	100	100	0
1700	100	100	0	100	100	0
1800	100	100	0	100	100	0
1900	33.45	33.45	0	100	100	0
2000	20.87	21.87	1	100	100	0
2100	58.49	58.49	0	100	100	0
2200	49.91	49.91	0	100	100	0
2300	63.14	63.14	0	100	100	0
2400	61.01	61.01	0	100	100	0
2500	43	43	0	100	100	0
2600	41	41	0	80	80	0
2700	31.37	31.37	0	100	100	0
2800	31.49	31.49	0	100	100	0
2900	70	70	0	100	100	0
3000	70	70	0	100	100	0
3100	70	70	0	100	100	0
3200	42.8	42.8	0	100	100	0
3300	22.16	22.16	0	100	100	0
3400	44.5	44.5	0	100	100	0
3500	40.91	40.91	0	100	100	0
3600	41.8	41.8	0	100	100	0
3700	43.01	43.01	0	100	100	0
3800	35.07	35.07	0	100	100	0
3900	32	32	0	100	100	0



Graph 15.0.

Table 15.0 – Crack 15A

Measurement Points Along Crack (mm)	15.12.16 Width (mm)	15.03.17 Width (mm)	△ Width (mm)	15.12.16 Depth (mm)	15.03.17 Depth (mm)	△ Depth (mm)
0	10.23	10.23	0	39	55	16
100	8.9	8.9	0	100	100	0
200	5.4	6.07	0.67	100	100	0
300	6.65	6.65	0	100	100	0
400	5.9	5.9	0	100	100	0
500	9.4	9.66	0.26	100	100	0
600	3.5	3.99	0.49	100	100	0
700	4.5	5.07	0.57	23	23	0
800	3.19	3.19	0	35	35	0
900	10.6	10.6	0	50	52	2

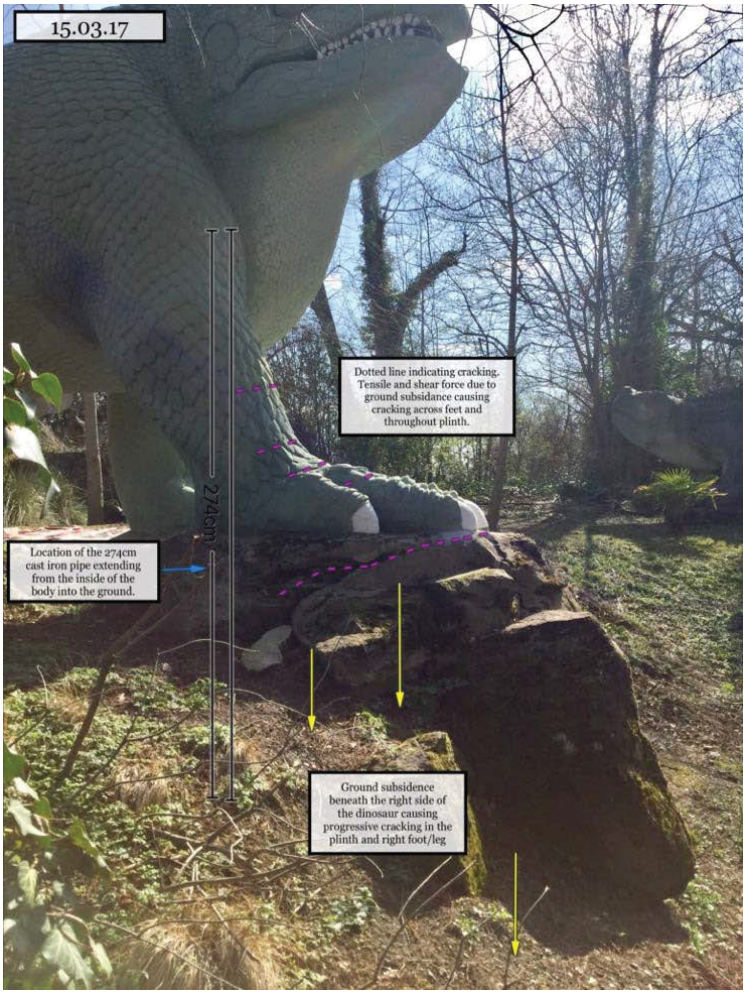
3.4.1.

Summary of the Weald Sandstone Plinth

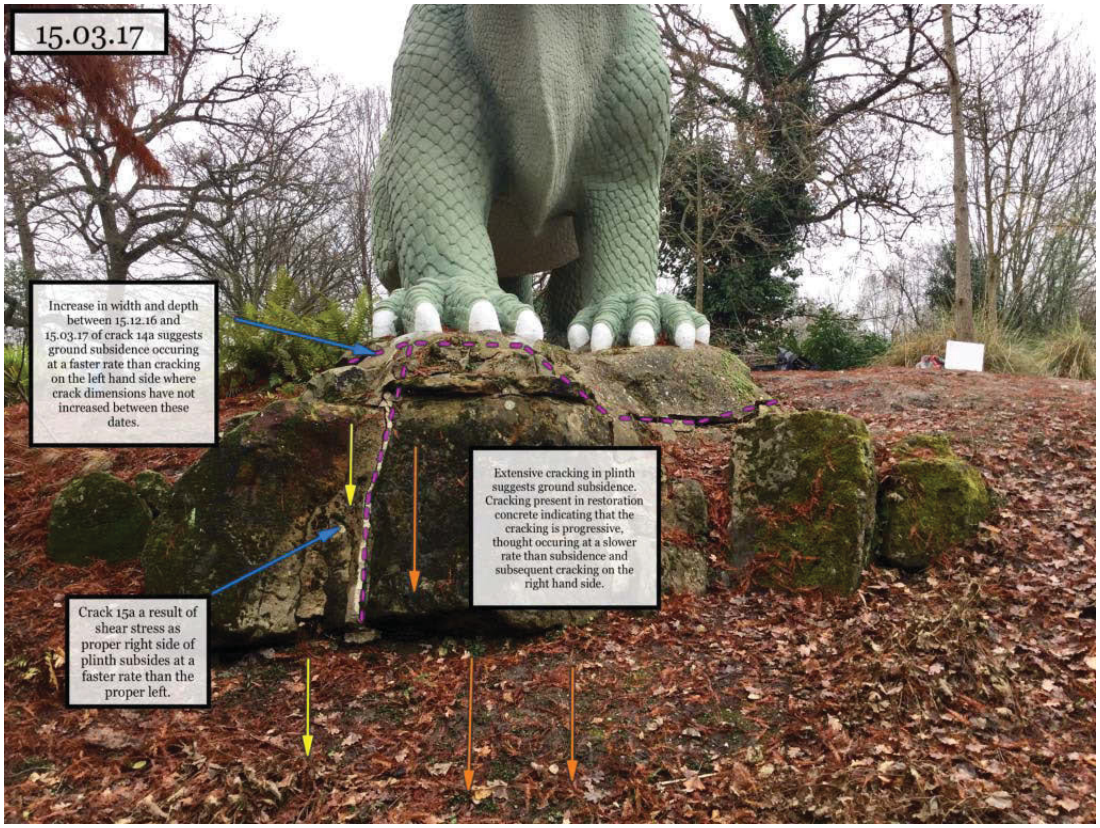
- The front plinth displays an extensive network of cracks. The two most prominent cracks were identified for monitoring, one horizontal 14a and one vertical 15a. See plates 36 and 37 for location.
- Crack 14a runs horizontally, through the site of previous concrete repairs, many of which are undocumented restorations.

- Points 400mm to 800mm of crack 14a run through concrete applied to fill a crack during the 2015 restoration (Cliveden 2015). This crack has increased in both width and depth between 15.12.16 and 15.03.17. See plate 42 and graph/table 14.0.
- Points 1400 to 3900mm is an areas comprising of numerous restorations, with many loose and disassociated fragments and large sections of concrete. See plates 40 and 41 - particularly points 1800mm and 2700mm.
- Points 1400 to 3900mm have seen no change in dimensions between 15.12.16 and 15.03.17, however the deterioration of previous historical repairs indicate progressive cracking.
- Crack 15a runs vertically through historical repair concrete between two boulders as a result of shear stress due to ground subsidence.
- Apart from an increase in depth at point 0mm, crack 15a has not increased in width or depth between 15.12.16 and 15.03.17.

The plinth beneath the front right and left feet consists of large boulders of Weald sandstone and concrete. The extensive cracking in the historical concrete repairs indicate the cracking is progressive and due to ground subsidence. The increase in the width and depth of crack 14a on its proper right hand side and the apparent stability of dimensions of the crack on the left hand side suggest that the ground is subsiding at a faster rate beneath the right side of the dinosaur. See plates 44 and 45.



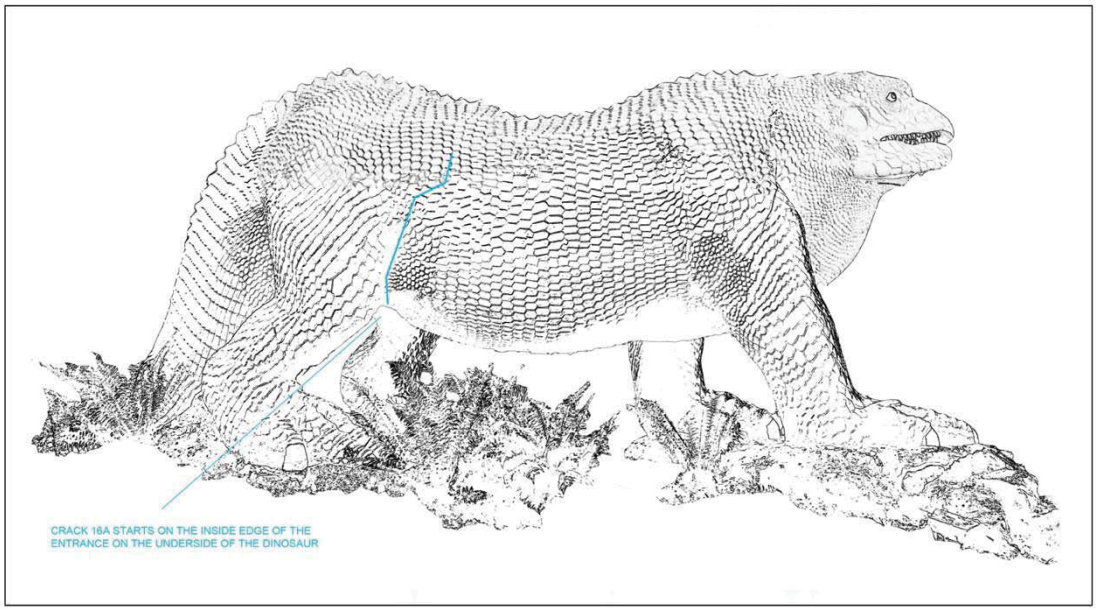
Plates 44 and 45 – Photographed 15.03.17

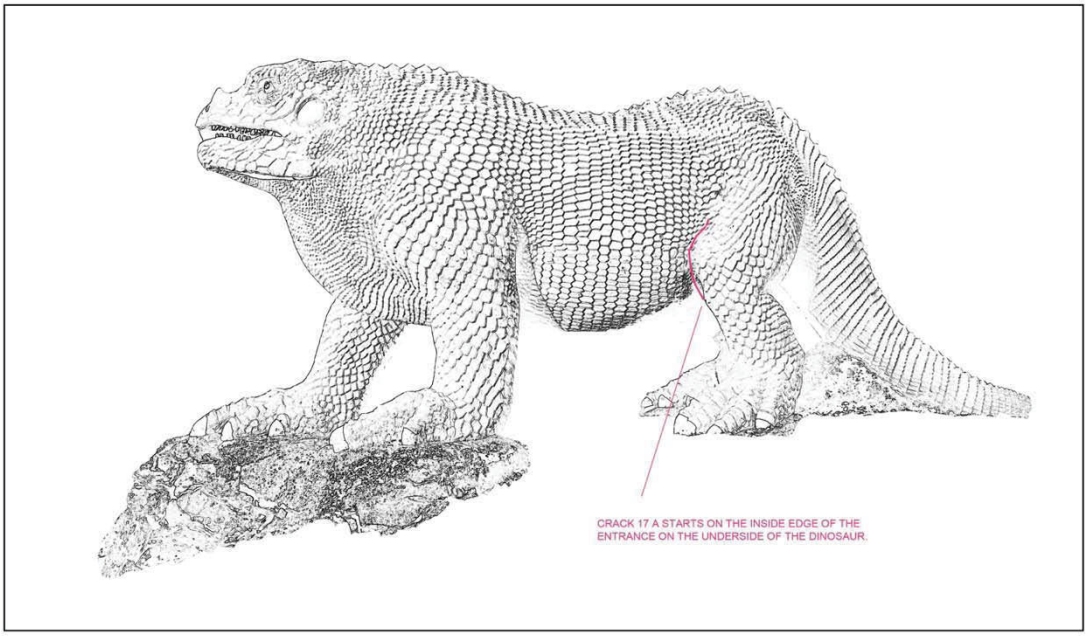


3.5

BODY

The cracks were identified, measured and recorded on 15.12.2016. They were re-measured and recorded on 15.03.2017.





Plates 46 and 47. Diagrams depicting the location of the cracks 16a and 17a

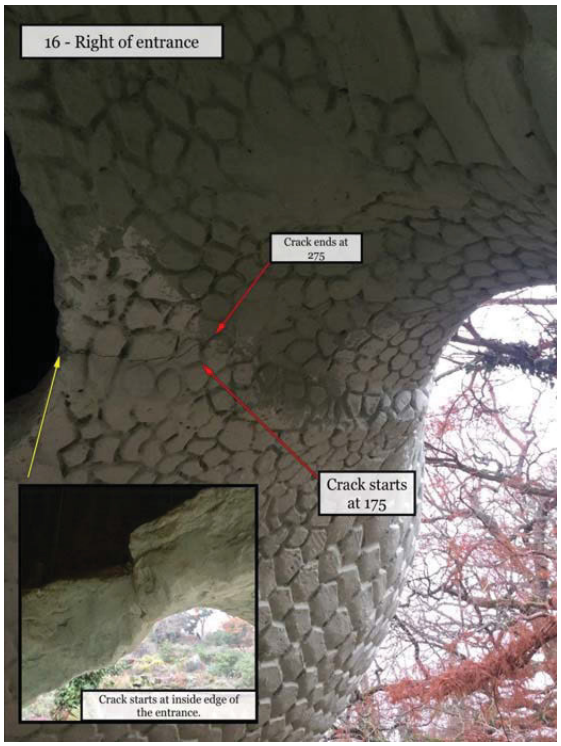


Plate 48 - Crack 16a – Photographed **15.12.16.**

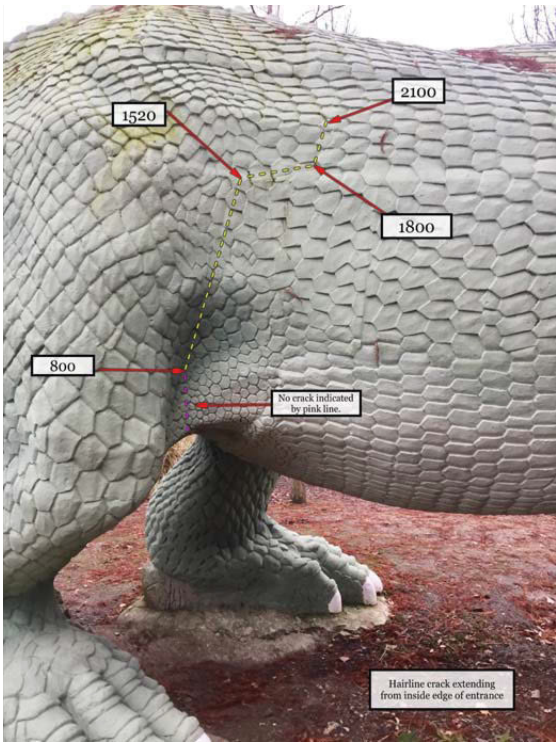


Plate 49 - - Crack 16a – Photographed **15.12.16.**

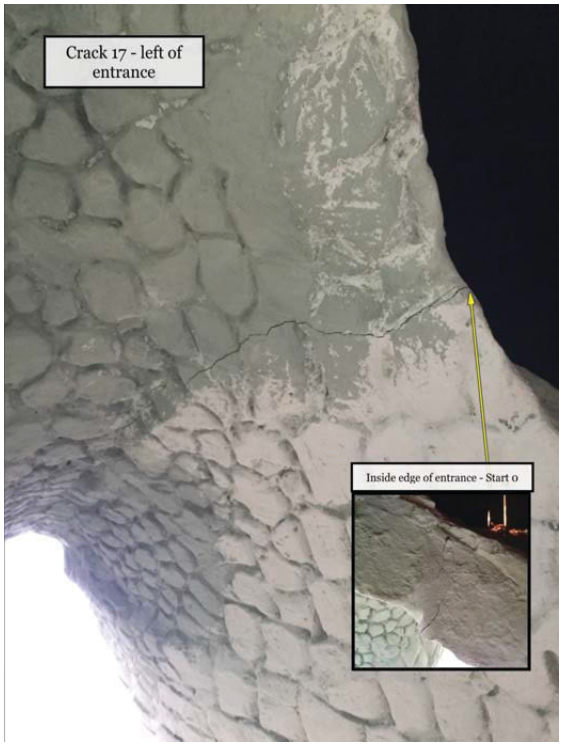


Plate 50– Crack 17a – Photographed **15.12.16.**

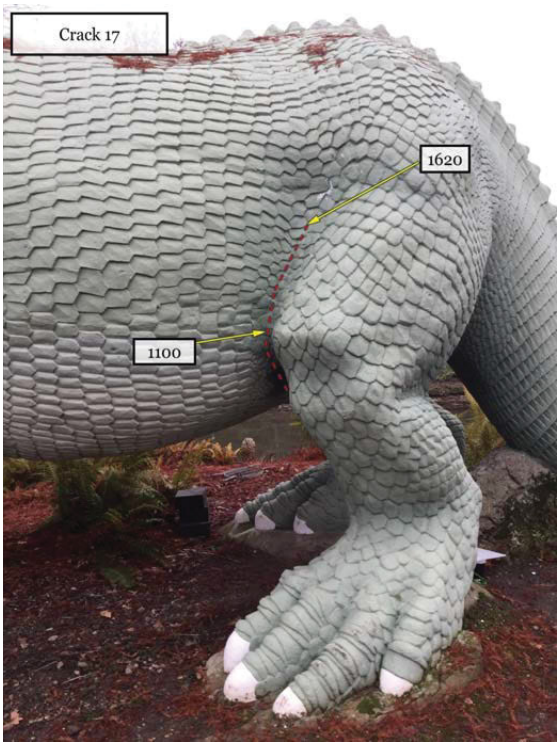


Plate 51– Crack 17a – Photographed **15.12.16.**

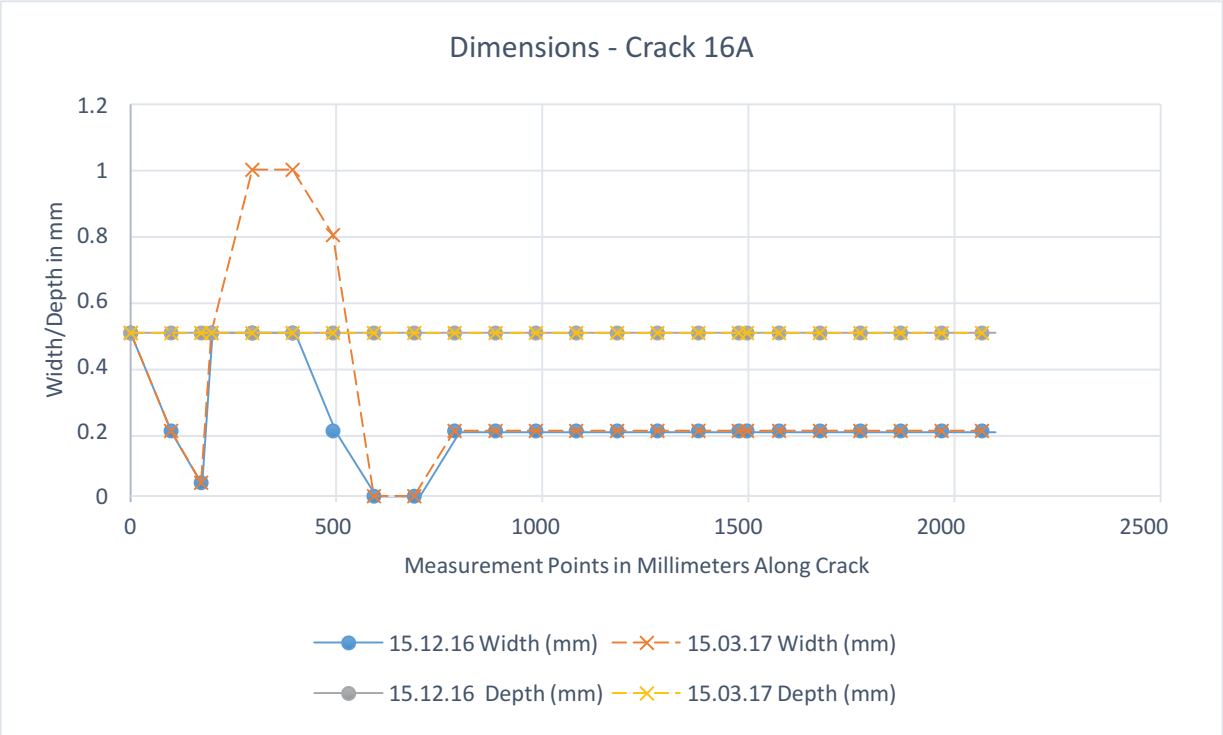
DATA

The graphs display the length, width and depth measurements for each individual crack. Starting at 0mm (the crack's origin point), the measurements were recorded every 100mm along the length of the crack and at points of noticeable deterioration.

Due to the accuracy limitations of the depth gauge, depth values of 100mm indicate values 100> and depth values of 0.5 indicate values of <0.5.

Loose, but non-disassociated fragments were recorded as having a depth of 100mm as these points were too fragile to take accurate readings.

Measurements were recorded on **15.12.2016** and again on the **15.03.2017**.

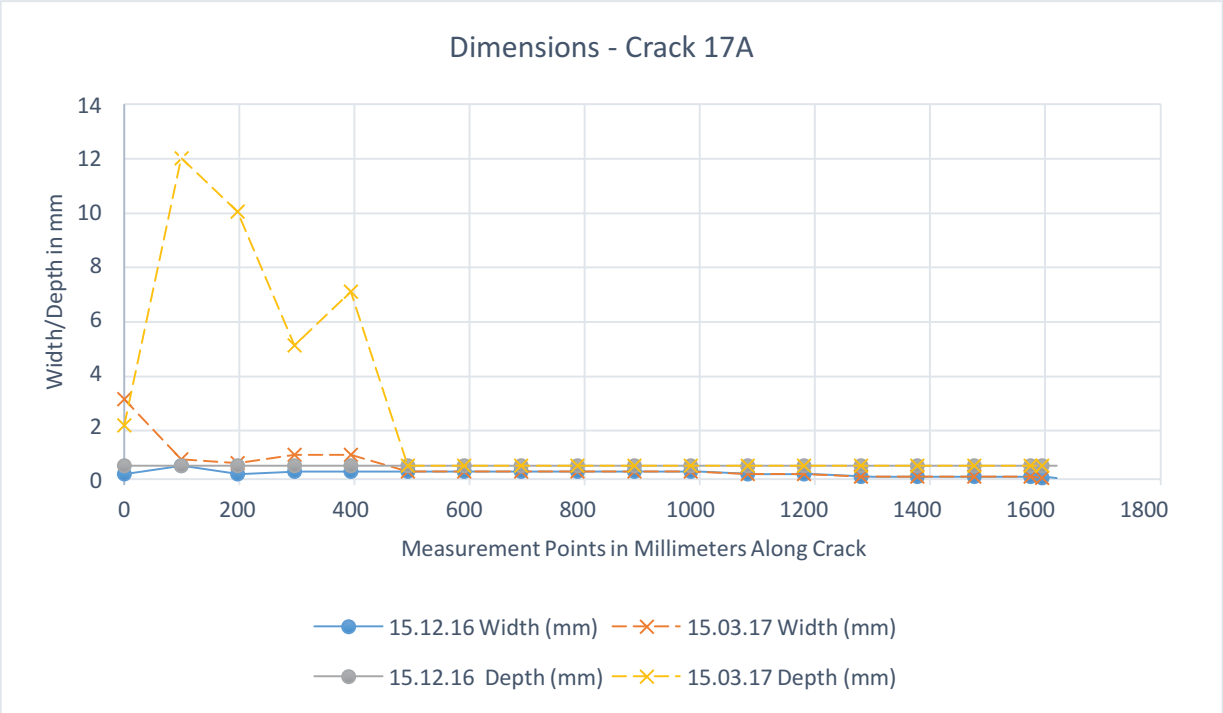


Graph 16.0

Table 16.0 – Crack 16A

Measurement Points Along Crack (mm)	15.12.16 Width (mm)	15.03.17 Width (mm)	△ Width (mm)	15.12.16 Depth (mm)	15.03.17 Depth (mm)	△ Depth (mm)
0	0.5	0.5	0	0.5	0.5	0
100	0.2	0.2	0	0.5	0.5	0
175	0.04	0.04	0	0.5	0.5	0
200	0.5	0.5	0	0.5	0.5	0
300	0.5	1	0.5	0.5	0.5	0
400	0.5	1	0.5	0.5	0.5	0
500	0.2	0.8	0.6	0.5	0.5	0
600	0	0	0	0.5	0.5	0
700	0	0	0	0.5	0.5	0

800	0.2	0.2	0	0.5	0.5	0
900	0.2	0.2	0	0.5	0.5	0
1000	0.2	0.2	0	0.5	0.5	0
1100	0.2	0.2	0	0.5	0.5	0
1200	0.2	0.2	0	0.5	0.5	0
1300	0.2	0.2	0	0.5	0.5	0
1400	0.2	0.2	0	0.5	0.5	0
1500	0.2	0.2	0	0.5	0.5	0
1520	0.2	0.2	0	0.5	0.5	0
1600	0.2	0.2	0	0.5	0.5	0
1700	0.2	0.2	0	0.5	0.5	0
1800	0.2	0.2	0	0.5	0.5	0
1900	0.2	0.2	0	0.5	0.5	0
2000	0.2	0.2	0	0.5	0.5	0
2100	0.2	0.2	0	0.5	0.5	0



Graph 17.0

Table 17.0 – Crack 17A

Measurement Points Along Crack (mm)	15.12.16 Width (mm)	15.03.17 Width (mm)	△ Width (mm)	15.12.16 Depth (mm)	15.03.17 Depth (mm)	△ Depth (mm)
0	0.2	3	2.8	0.5	2	1.5
100	0.5	0.75	0.25	0.5	12	11.5
200	0.2	0.6	0.4	0.5	10	9.5

300	0.3	0.9	0.6	0.5	5	4.5
400	0.3	0.9	0.6	0.5	7	6.5
500	0.3	0.3	0	0.5	0.5	0
600	0.3	0.3	0	0.5	0.5	0
700	0.3	0.3	0	0.5	0.5	0
800	0.3	0.3	0	0.5	0.5	0
900	0.3	0.3	0	0.5	0.5	0
1000	0.3	0.3	0	0.5	0.5	0
1100	0.2	0.2	0	0.5	0.5	0
1200	0.2	0.2	0	0.5	0.5	0
1300	0.1	0.1	0	0.5	0.5	0
1400	0.1	0.1	0	0.5	0.5	0
1500	0.1	0.1	0	0.5	0.5	0
1600	0.1	0.1	0	0.5	0.5	0
1620	0.04	0.04	0	0.5	0.5	0

3.5.1.

Summary of the Body

- The body has two primary cracks, identified as 16a and 17a. See plates 46 and 47.
- Both cracks start on the inside edge of the entrance to the dinosaur (on its underside), 16a on the right and 17a opposite on the left. The location of the cracks is fairly symmetrical. See plates 48 and 50.
- Both crack's widest and deepest points are on the underside of the dinosaur, emanating from the entrance. Both cracks then taper to a hairline from point 500/600mm onwards.
- Crack 16a increased in both width and depth between points 200mm-600mm between the dates 15.12.16 and 15.03.17. See graph 16.0.
- Crack 17a increased in both width and depth between points 100mm-500mm between the dates 15.12.16 and 15.03.17. See graph 17.0.
- Neither crack increased in length between 15.12.16 and 15.03.17.

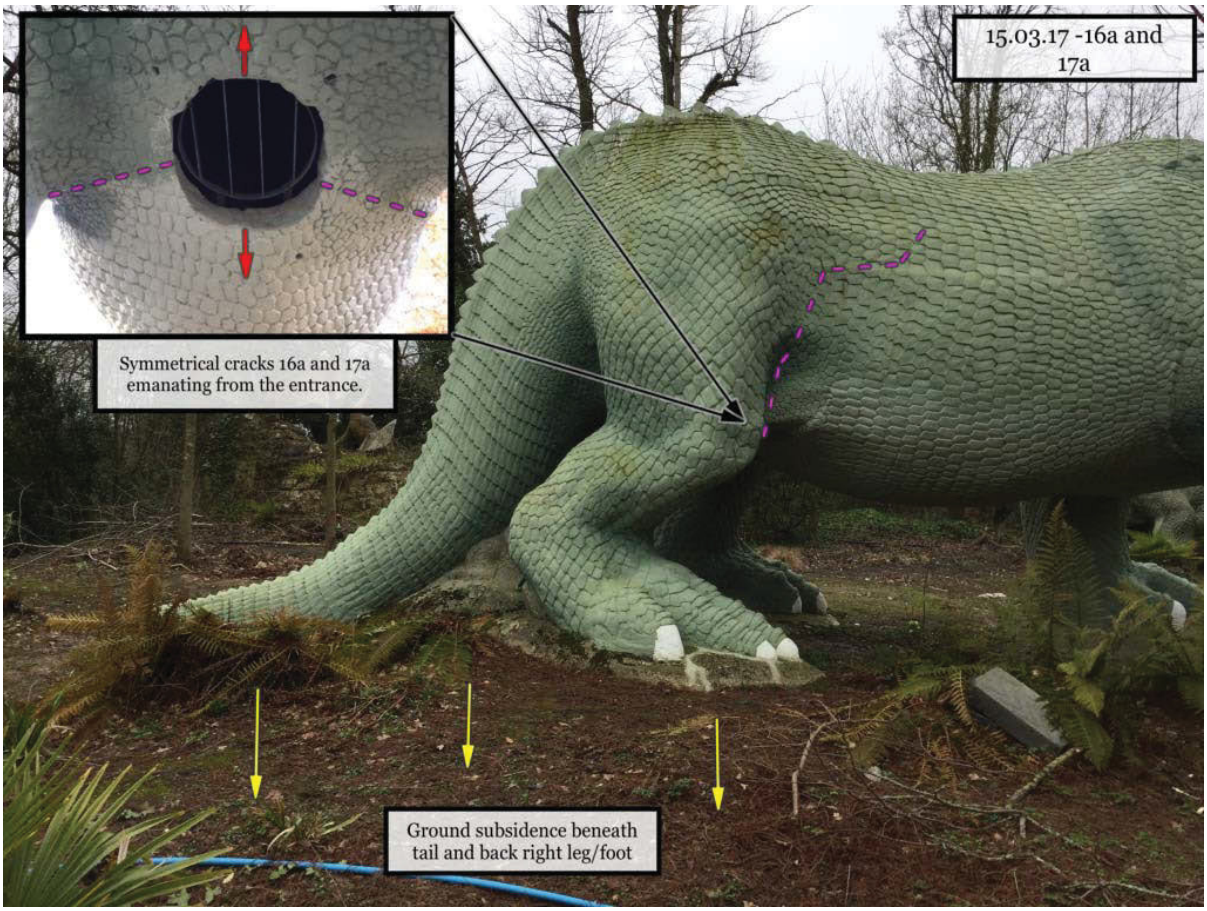

15.03.17 -16a and 17a
Symmetrical cracks 16a and 17a emanating from the entrance.
Ground subsidence beneath tail and back right leg/foot

Plate 52

4.0

CONCLUSION

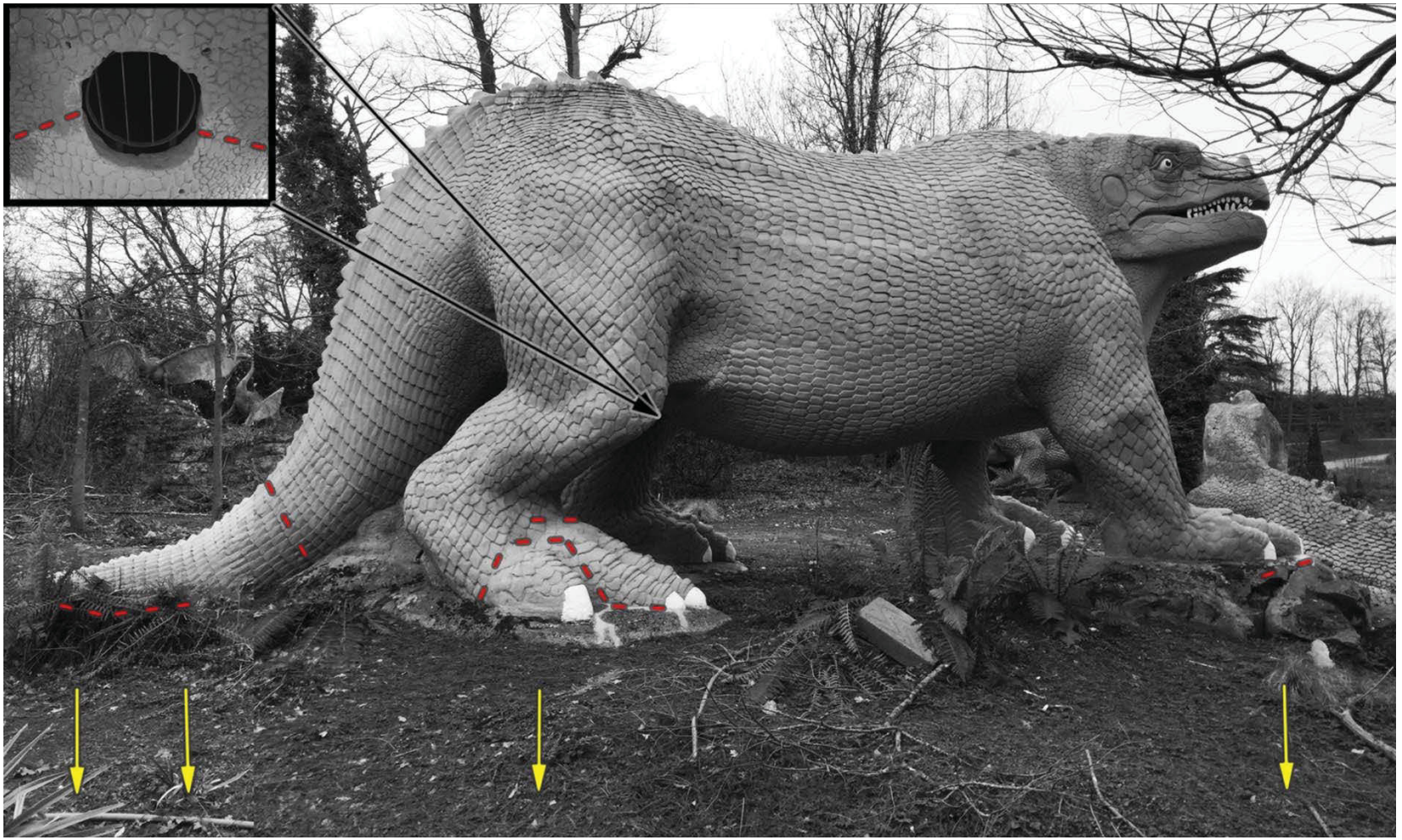


Plate 53.

Red dotted lines - Cracks that have developed since the 2015 restoration and have *further increased* in width and depth between 15.12.16 and 15.03.17.

Yellow Arrows - Indicating ground subsidence beneath the proper right side of the dinosaur.

Conclusion

The recording and measuring of cracks in the Standing Iguanodon between the 14.12.2016 and 15.03.2017 identified four significant points -

- Of the 27 cracks identified for monitoring, 26 had formed *after* the 2015 restoration.
- 41% of the cracks have increased, at points, in both width and depth between 10.12.2016 and 15.03.2017.
- 81% of the cracks start from a point at the ground before progressing across the Iguanodon.
- 89% of the cracks formed after the 2015 restoration occur to the proper right of the Iguanodon.

The identification of cracks formed after the 2015 restoration reveals that the Iguanodon is subject to progressive cracking. Over the three-month monitoring period, many of the cracks saw an increase in dimensions and have subsequently incurred losses, both to original concrete, restoration concrete and restoration paint layers. Such deterioration *may* have been exacerbated by water ingress over the Winter period. The position and location of the cracks, the vast majority starting from a point at the ground, to the proper right and at the site of pervious restorations, clearly indicate that the cracks are a result of the ground subsiding to the right and tail end of the Iguanodon (see plate 53).

The rapidity and progression of the deterioration indicate that previous treatments have not satisfactorily addressed the structural issues effecting the deterioration of the Iguanodon. Furthermore, the 2015 restoration of the tail, particularly the inclusion of a rigid steel dowel and new restoration concrete are most certainly responsible for the transfer of stress up the tail and the development of new cracking in the original concrete.

Results show that without stabilisation of the ground to the right, tail end and front plinth, further ground subsidence and further structural deterioration of the Standing Iguanodon is most certainty inevitable.

5.0

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