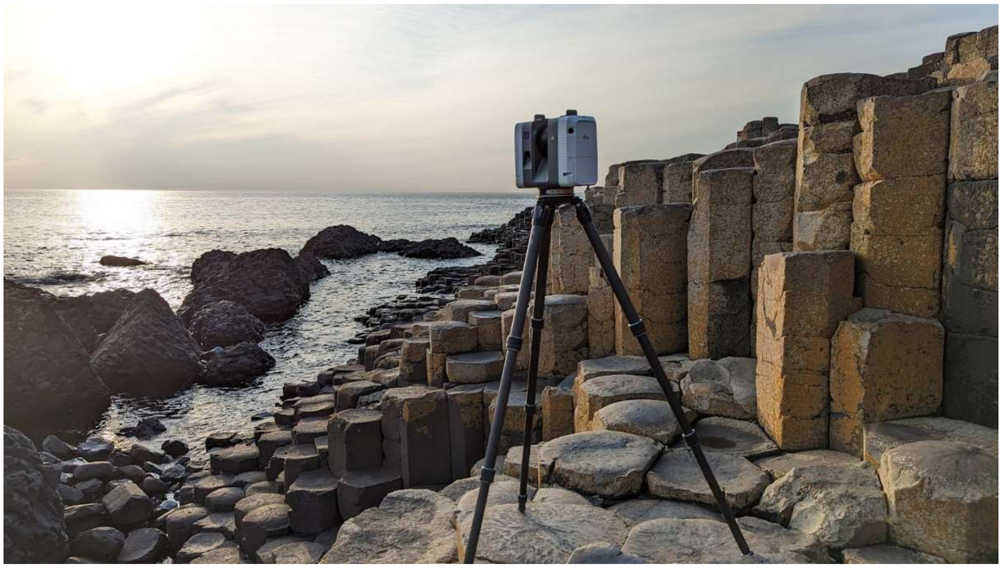
Grand Causeway, The Giant's Causeway Terrestrial Laser Scanning (TLS) Survey 2023

Survey Report v1 03/24



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1.0 Introduction

The *Centre for GIS and Geomatics* were approached by *Giant's Causeway Coast and Glens Heritage Trust* to undertake a digital 3D Terrestrial Laser Scanning (TLS) survey of an area of the Grand Causeway, The Giant's Causeway, Co. Antrim. The survey was undertaken in response to observations of site visitors 'depositing' coins of varying international currencies within the basalt columnar jointing at the Causeway (horizontal & vertical). The survey is an attempt to have a baseline 3D digital geometrical survey of the area of concern and included exploratory/pilot survey/analysis techniques (Fig 1).

Fig 1. Extent of large-scale TLS centered around the Grand Causeway – close range TLS location inset. (OSNI MOU203).

The 'large-scale' Grand Causeway TLS survey was completed in parallel to an experimental localised 'very close range' TLS survey to ascertain if these methods could metrically capture coins in situ within joints. A Tablet based 'photogrammetrical' 3D image analysis was also undertaken to demonstrate current 'lower cost' 3D imaging/surveying available using consumer grade equipment as a possible monitoring/management technique. Finally, a portable handheld X-Ray Fluorescent (XRF) instrument was utilised at a sample coin deposition area to ascertain if coin oxidation elements could be recorded on the surface of basalt columns effected by coin deposition (surface staining areas). Short range TLS, 3D image analysis and XRF survey were observed at the same location (Fig 1.).

2.0 Grand Causeway - TLS Survey

The 'large scale' TLS survey was conducted over a 3-day period (June 20th – 23rd 2023) utilising a *Leica Geosystems RTC360* tripod-based laser scanner. The majority of the survey work was conducted after 5pm to reduce disturbance to the visitor experience and collect data at a time when visitor numbers are greatly decreased, reducing data cleaning at the data postprocessing stage.

Due to the scanner's high speed data collection rate, small size, portability, and small tripod footprint, it is an ideal instrument for accessing the main columns, especially the uneven nature of the Grand Causeway surface. The scanner has a practical range of c130m at low density mode (resolution 12mm@10m) and 65m range on high density mode (resolution 3mm @10m). In practice both range and resolution are affected/limited by surface albedo (e.g. black/grey/wet surfaces). The instrument can collect color (RGB) imagery which is mapped to the pointcloud observations during data processing and are available to view as interactive 'panoramic' images in data outputs. n62 scan setups were collected in high resolution mode and registered (combined) to generate a final 3D 'point cloud' dataset containing c2600 million points (Fig 2).

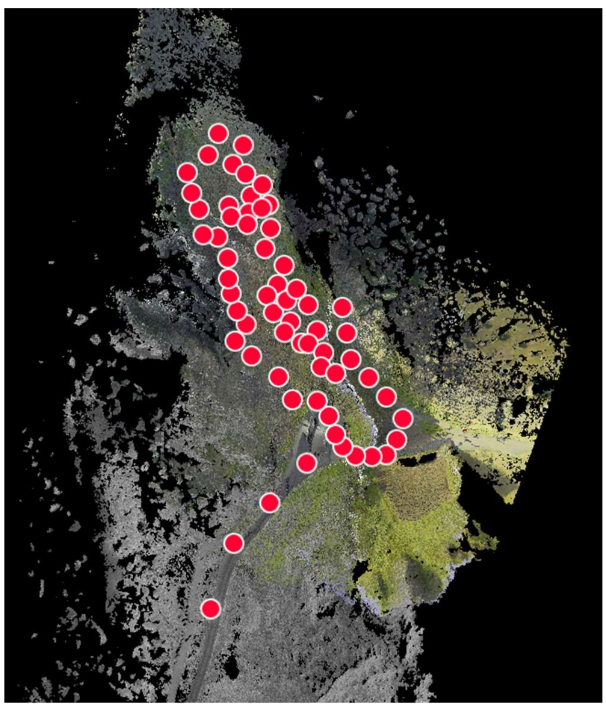


Fig 2. TLS Survey setup locations.

The point cloud was georeferenced using RTK GNSS field measurements on geometries and features visible in the scan data and in scan 'control targets'. The final processed dataset has been supplied as Irish Transverse Mercator (ITM IRENET95) coordinate system, Ordnance Datum Mean Tide Level Belfast Lough (OSGM15). The Data is compatible with OSNI mapping products within GIS and 3D point cloud (Fig 3).

2.1 Survey Limitations

As the instrument is a ‘survey grade’ scanner, abet with a high-resolution scanning function, it has not been able to completely discern individual coin placements/depositions or coins within the columnar joints. Were surveyed, columns, stones and joint locations/geometries have been scanned in detail creating a ‘baseline’ database for any future ‘change’ analysis surveys/analysis (e.g. column loss/collapse, erosion). Coin placements may be visible in the supplied panoramic images, including ‘staining’ resulting in the oxidation of the coin groups. Very high-resolution metric 3D Imaging/scanning of coins in column joint placement would require ‘Object Scanning’ techniques (<1mm) utilising ‘hand held’ instruments or photogrammetrical techniques, but limited to smaller scale survey areas (e.g. monitoring unique joint areas – Section 3.0).

As an unplanned observation output, areas a surface vegetation and/or ‘greening’ of the columns is visible in the pointcloud. This may be of interest if undertaking research in climatic / vegetative / visitor impacts and management outcomes on the Grand Causeway.

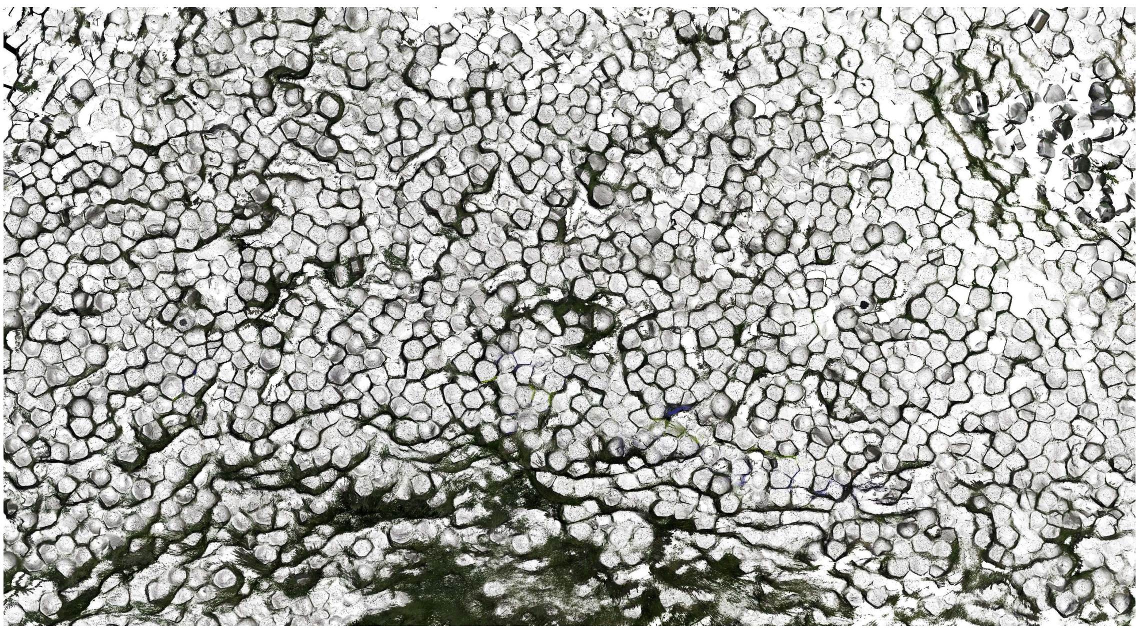


Fig 3. TLS Point cloud data – sample of Grand Causeway area.

3.0 Exploratory Coin Deposition Survey (Small Pilot Area).

As a test to validate the 3D survey/monitoring of coin depositions in column joints, a small survey area was identified with significant coin deposits containing both ‘established’ oxidising coins, staining and newly deposited coins. A vertical column ‘joint/block panel’ was identified at the NE facing elevation of the Grand Causeway c3.5m from the ‘Giant’s Gate’ (ITM e694709.34m n944664.92m h8.92m), (Fig 4). This area to the left of the ‘Giant’s Gate’, north of the main visitor approach to the Grand Causeway, had a notable reduction in NT warden presence, contains on inspection substantial accumulations of coins both seaward (NW) and vertically along column jointing.

Fig 4 Substantial evidence of coin jointing deposition, oxidation of coin deposits and brown surface staining originating from the coin mass (Test survey ‘panel’).

During our test survey setup visitors were observed placing coins within joints around this area and ‘hammer/strike’ marks are present below/above some of the column joints (Fig 5), and on coin edges (coin deformation). No visitors were observed ‘hammering’ coins into the joints, but the strike marks suggest naturally eroded column debris and foreshore materials are being used in some cases to force coins into joints. This is also evident by the difficulty manually removing coins close to these ‘hammer marks’ on site.

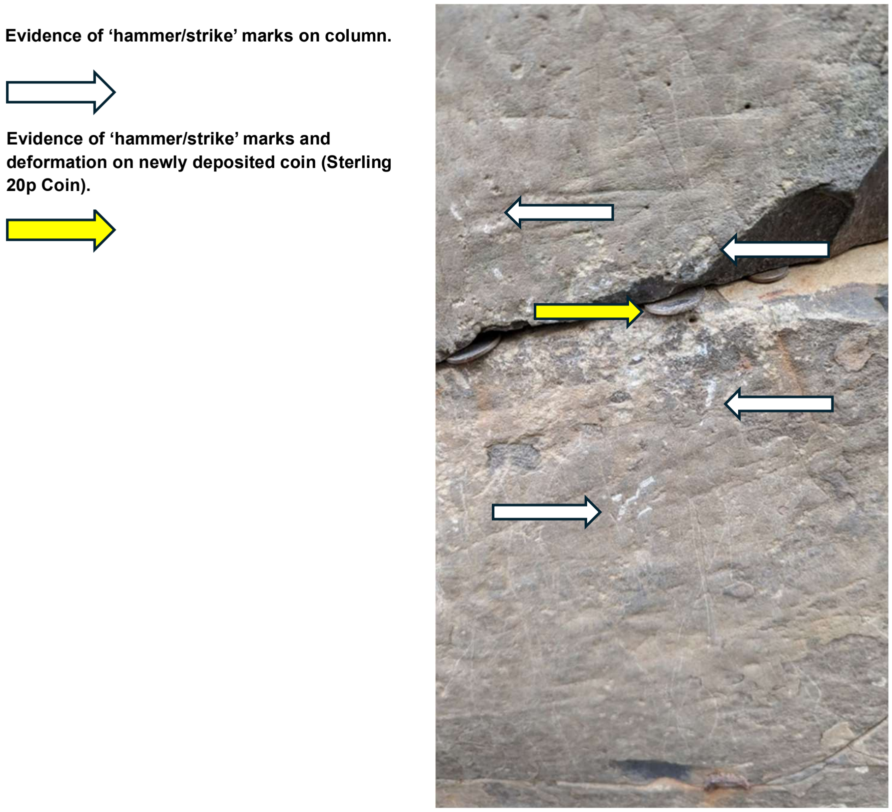
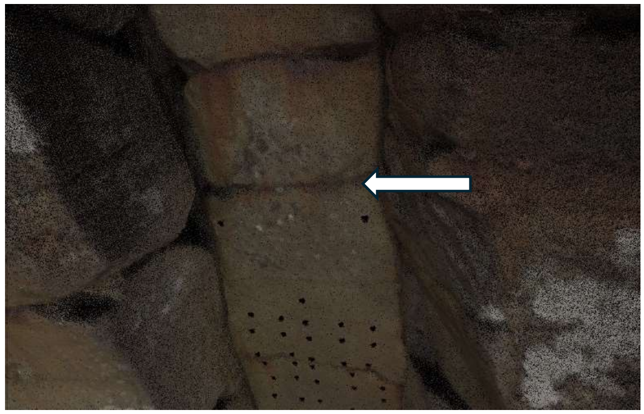
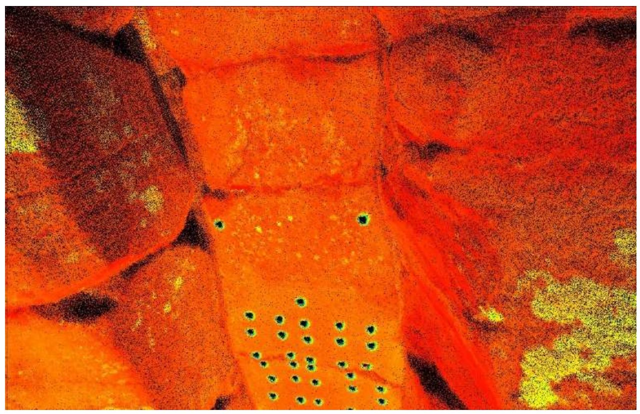


Fig 5. Newly deposited coin and evidence of 'hammer/strike' marks.

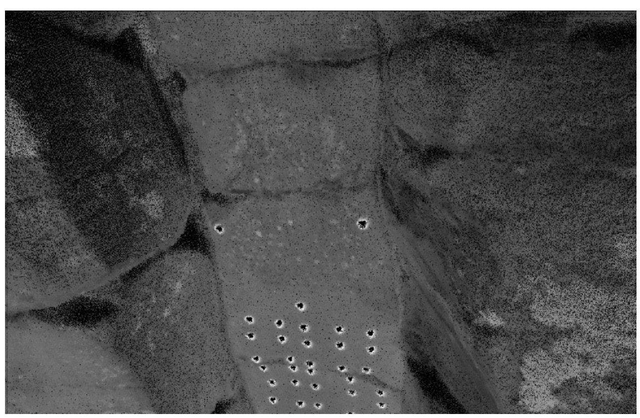
The 'block panel' area was 3D laser scanned at very close range (<1.5m – High Resolution) to collect surface geometry and ascertain if coins can be recorded at very close range using a survey grade TLS instrument. As with the larger Grand Causeway survey both column geometry and jointing were accurately measured in 3D, but coin deposition is difficult to infer in the data. Some evidence of coin depositions and individual coins are visible in the scan data with careful exanimation and experimentation with data visualisation (Fig 6). 3D scanning the Grand Causeway at such close range would be challenging due to the reduction of instrument field of view (FOV), the size of the area to be scanned at very close range and would involve a considerable increase of survey time on site. This type of survey may be more suitable to 'Object Scanning' instruments at predefined 'monitoring' locations. It is also difficult to access the mechanical and chemical 'weathering' effects on coin deposited jointing due to lack of 'control' data for comparisons and/or geometrical surface difference/change monitoring.



a. TLS Point Cloud - Colour (RGB)



b. TLS Point Cloud – Intensity/Reflectance



c. TLS Point Cloud - Intensity/Reflectance Greyscale.

Fig 6. Short-range high-Resolution TLS Point Cloud data of column and deposited coins (Arrow Inset).

3.1 Demonstration of 'Low Cost' 3D imaging for bloc/joint monitoring applications.

As part of our experimental close range TLS survey (3.0) we imaged the block/joint panel using the 'Lidar' function of an *iPad Apple Pro* Tablet. The iPad Pro (2023) can be used as a 'short range' laser scanner to collect 3D surface geometries and images by combining photometrical techniques (Structure from Motion) and a short-range infrared solid state lidar scanner. Popular Apps (e.g. Scaniverse) generate models in real time by passing/sweeping the tablet cameras over the subject. 3D surface models can be inspected and/or shared digitally and/or published publicly as annotated visualisations (e.g. SketchFab.com). Although not a true TLS instrument, tablet-based 3D scanning/surveying is a useful aid for natural/cultural heritage management 'reconnaissance' data collection, quick localised return/monitoring applications and internal training / educational outreach applications. This technique is more suitable to 'visual' change inspections with absolute model dimensional accuracies in the c10mm range (Fig 7).

Example of iPad Pro Lidar based 3D outputs can be viewed online:

https://skfb.ly/oFCo7

https://skfb.ly/oFC7Q

Fig 7. Published and Annotated Tablet Lidar derived 3D Model (Giant's Wall).

4.0 Handheld X-Ray Fluorescent (XRF) Survey (Pilot Study).

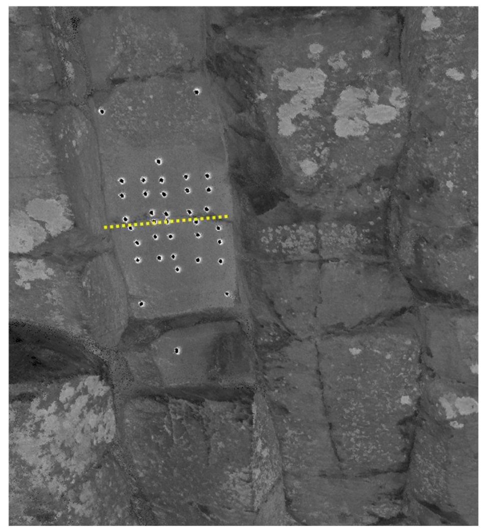
A *Bruker Tracer 5i* handheld X-Ray Fluorescent (XRF) survey grid (n30 points) was conducted on an area of the block/join panel to ascertain if a geochemical signature could be observed on the surface of the basalt columns in and around the areas of coin oxidisation and staining (Fig 8). XRF is a non-invasive process where electrons are displaced from their atomic orbital positions, releasing energy characteristic of a specific element present. This release of energy is then registered by the detector in the XRF instrument, potentially categorising the element. The instrument relies on applying a 'standards library' to field measurements to infer elements present on the surface of the survey object. 10sec average count observations were recorded at each grid point.

Fig 8. Handheld XRF Grid Survey of block/joint panel surrounds

Our field survey applied the Bruker 'Geology' element library. Subsets of the observed gridded observation XRF data were visualised in a GIS using simple 'surface interpolation' functions to aid exploratory analysis of the distribution of elements present (Fig 9, 10, 13). A table (with summary statistics) and plot of element results is shown below (Fig 11, 12).

The most abundant elements found are Iron (Fe) and Calcium (Ca) most likely originating from the iron rich geochemical composition of the basaltic columns and proximity to a coastal environment. Trace elements of metals including Copper (Cu), Nickel (Ni), Zinc (Zn), Titanium (Ti) are also observed (Fig 11). Due to the experimental nature of this survey additional analysis (field & lab) would be required to better identify the origins of these elements, not in the scope of the overall TLS survey.

a) 

b) 

a) Colour Image b) Point Cloud Reflectance Intensity Grayscale.
Fig 9. XRF 'block/joint' coin deposition survey panel (Jointing and sample grid locations shown)

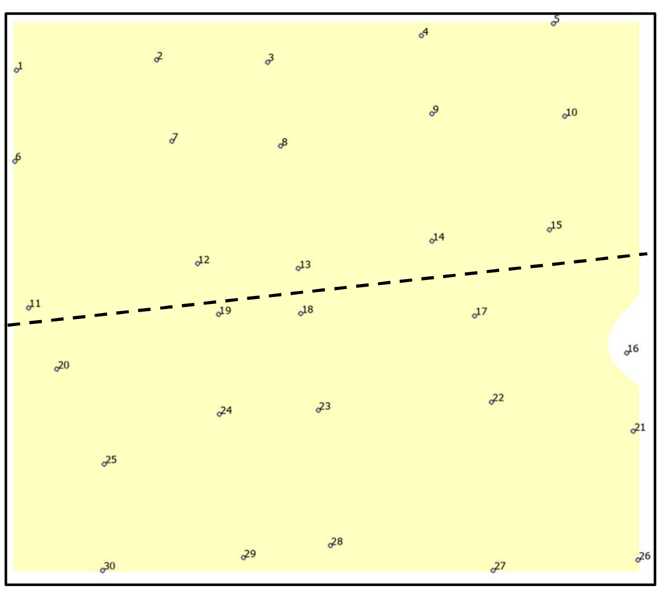


Fig 10. XRF 'block/joint' coin deposition survey panel (Jointing and sample 'grid locations shown)

Grid Sample	K	Ca	Ti	V	Mn	Fe	Co	Ni	Cu	Zn	Ga
1	0.601	3.994	0.626	0.039	0.109	8.198	0.040	0.006	0.016	0.031	0.001
2	0.617	4.847	0.702	0.030	0.131	8.775	0.040	0.008	0.028	0.027	0.001
3	0.617	4.371	0.647	0.033	0.113	8.193	0.045	0.008	0.021	0.019	0.001
4	0.642	4.580	0.668	0.033	0.125	8.467	0.035	0.008	0.024	0.016	0.002
5	0.841	4.645	0.713	0.040	0.144	10.319	0.041	0.006	0.045	0.031	0.002
6	0.704	3.966	0.673	0.032	0.117	10.119	0.045	0.007	0.018	0.027	0.002
7	0.614	4.245	0.650	0.035	0.131	9.027	0.040	0.010	0.097	0.034	0.002
8	0.655	4.067	0.680	0.036	0.134	9.671	0.046	0.008	0.031	0.022	0.002
9	0.668	4.588	0.690	0.038	0.127	9.305	0.049	0.006	0.024	0.015	0.002
10	0.778	3.986	0.705	0.038	0.121	10.072	0.051	0.005	0.038	0.051	0.002
11	0.345	2.621	0.313	0.020	0.066	7.300	0.028	0.005	0.014	0.009	0.002
12	0.369	2.654	0.395	0.021	0.063	5.297	0.025	0.007	0.020	0.020	0.002
13	0.630	4.328	0.660	0.035	0.108	9.287	0.040	0.008	0.026	0.018	0.002
14	0.575	3.351	0.535	0.029	0.082	7.420	0.033	0.006	0.021	0.012	0.002
15	0.562	3.162	0.511	0.024	0.153	7.746	0.034	0.007	0.024	0.030	0.001
16	0.711	4.009	0.564	0.030	0.105	8.772	0.041	0.025	0.082	0.017	0.002
17	0.680	3.621	0.599	0.030	0.107	10.178	0.041	0.014	0.033	0.008	0.001
18	0.589	4.544	0.693	0.038	0.126	9.474	0.047	0.013	0.062	0.026	0.002
19	0.653	3.931	0.755	0.036	0.146	10.988	0.054	0.014	0.101	0.030	0.001
20	0.736	2.531	0.615	0.033	0.095	13.720	0.049	0.005	0.033	0.008	0.001
21	0.654	3.651	0.647	0.029	0.117	9.701	0.042	0.019	0.035	0.028	0.002
22	0.675	3.941	0.678	0.041	0.120	10.598	0.048	0.012	0.029	0.012	0.001
23	0.433	3.007	0.435	0.025	0.091	6.127	0.029	0.008	0.037	0.020	0.001
24	0.580	3.016	0.535	0.029	0.115	12.622	0.041	0.017	0.065	0.024	0.001
25	0.608	3.618	0.600	0.030	0.107	8.300	0.041	0.012	0.023	0.032	0.002
26	0.671	4.484	0.643	0.037	0.117	9.066	0.042	0.008	0.026	0.013	0.002
27	0.614	4.213	0.595	0.032	0.111	8.067	0.041	0.010	0.022	0.012	0.002
28	0.630	4.299	0.651	0.035	0.136	9.690	0.045	0.011	0.033	0.022	0.002
29	0.608	3.856	0.604	0.039	0.119	10.326	0.049	0.016	0.036	0.015	0.001
30	0.610	3.829	0.608	0.039	0.120	10.261	0.046	0.016	0.036	0.016	0.001
Min	0.345	2.531	0.313	0.020	0.063	5.297	0.025	0.005	0.014	0.008	0.001
Max	0.841	4.847	0.755	0.041	0.153	13.720	0.054	0.025	0.101	0.051	0.002
Average	0.622	3.865	0.613	0.033	0.115	9.236	0.042	0.010	0.037	0.022	0.002
Range	0.496	2.317	0.442	0.021	0.090	8.423	0.029	0.020	0.087	0.043	0.001

Fig 11. XRF Elemental Observation data (ppm) - Brooker Geology Library

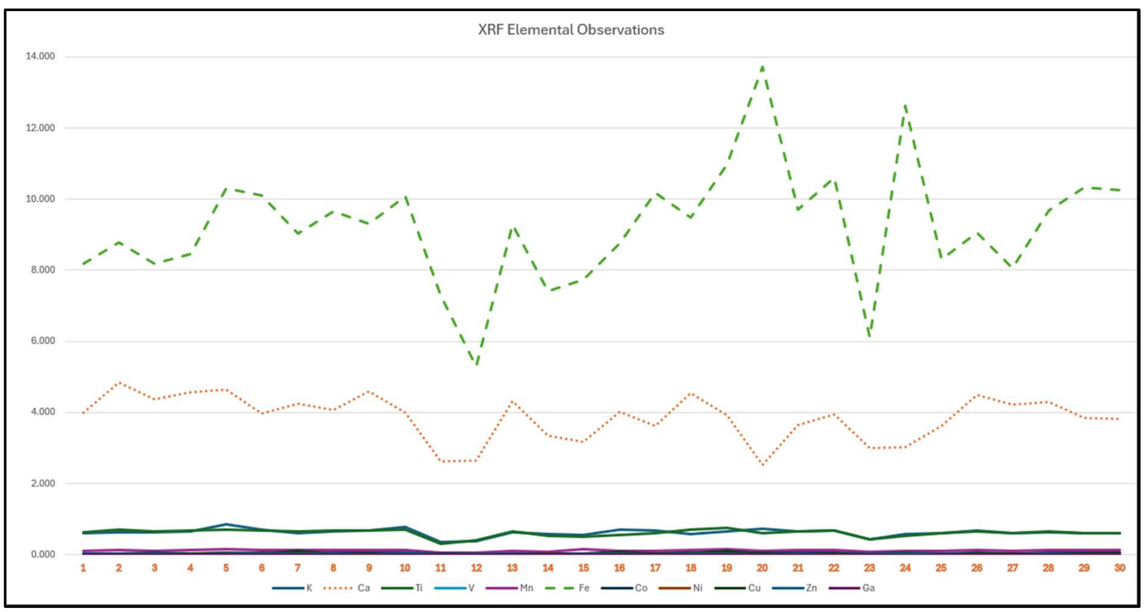
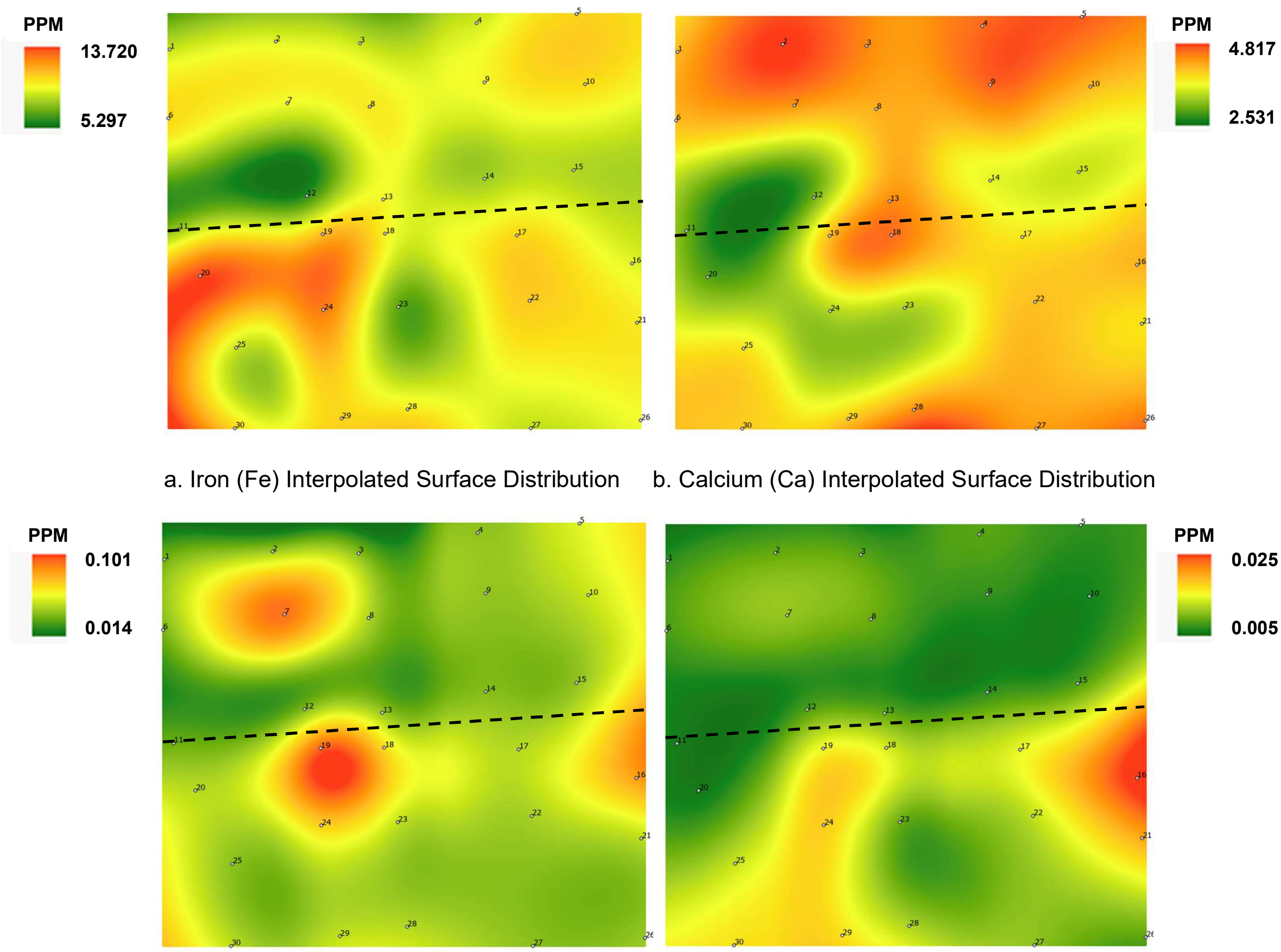


Fig 12. XRF Elemental Observation Plot (ppm) - Brooker Geology Library



a. Iron (Fe) Interpolated Surface Distribution

b. Calcium (Ca) Interpolated Surface Distribution

c. Copper (Cu) Interpolated Surface Distribution

d. Nickel (Ni) Interpolated Surface Distribution

Fig 13. Samples of XRF elemental surface distributions (Jointing and sample grid locations shown).

5.0 Conclusions and Recommendations

A high-resolution base line TLS survey was conducted to record the current geometry and topology of an area of the Grand Causeway, Giants Causeway. Experimental/pilot parallel short-range TLS, tablet-based 3D imagery/modelling and handheld XRF survey observations were undertaken at a vertical column location displaying visitor coin deposition within a horizontal basalt block joint and analysis presented.

The largescale TLS survey is supplied as various point cloud software independent data formats to allow future survey comparisons as part of management policy / applications at the Giant's Causeway.

5.1 Recommendations

Based on data collected and field observations presented in this report the authors recommend the following possible management applications/outcomes.

1. The largescale TLS survey can be the basis for future repeat laser scan surveys to identify and quantify 'gross changes' in block/column/jointing geometry resulting in natural erosional events, rockfalls, bio weathering, block displacements etc. Although it is not possible to ascertain the effects of coin placements on column erosion from a single baseline TLS survey, this may be possible when combined with future TLS campaigns in and around the Grand causeway (surface change/deviation detection).
2. The TLS survey instrument is limited in collecting coin geometry within joints in this campaign using current equipment. This may change with future TLS instruments or different vendors. We recommend 'Object Scanning'(<1mm) instruments and techniques at dedicated 'monitoring' locations to observe 'micro-scale' geometry changes within joints effected by current coin mass oxidation areas. This has potential for future geo-scientific research and would be suitable for a postgraduate research project.
3. Introduction on-site of 'lower cost' tablet-based 3D survey applications to collect 3D data at areas of concern, as detailed in 3.1. Wardens could be empowered to collect data as a new monitoring campaign (published to a dedicated project site), with an added benefit of increasing the 'visibility' of this issue on site as a deterrent.
4. The extent of 'established' oxidising coin mass and surface staining observed during the survey, coupled with observations of visitors continuing to deposit coins in block joints on site requires a management decision to immediately stop visitors from continuing this practice and challenge instances observed on site. This could be done through a dedicated visitor education campaign, new signage, and increased warden presence/rounds in popular areas of coin deposition. As a significant number of visitors arrive as pre-booked managed tour groups, educational materials could be supplied to group leaders to explain the issue and the negative implications of this practice. We also recommend introducing this a 'management' issue within current National Trust personal and audio guide materials. A social and local media campaign could be designed to highlight the issue and the research undertaken to mitigate past coin depositions.
5. A significant amount of international currencies are being deposited by visitors for various reasons including superstition, travel mementos or copying coin depositions

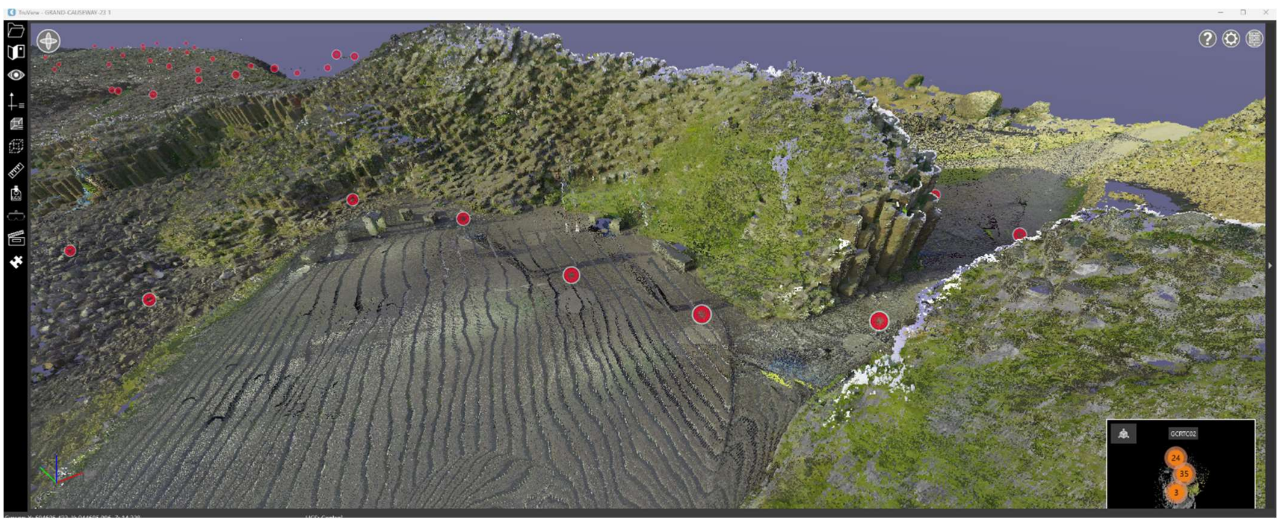
already present. These actions may be driven by social media photo and video posts and are similar to other coin deposition sites from around the UK and Ireland (e.g. Wishing Trees). Visitors could be encouraged to deposit coin mementos at dedicated 'themed' collection locations at the main approach to the Grand Causeway. 'Make a Wish' coin bins modelled on a basalt column could be used as a focal point for visitors wanting to leave a memento. The coins could be collected as donations to managing the site.

6.0 Data Outputs/Downloads

Point Cloud data and supporting datasets are available to download at:

http://go.qub.ac.uk/GC2023

- Leica Geosystems .LGS Point Cloud (including Interactive Viewer Software)
- .Las, .e57 (popular vendor independent Point Cloud formats)
- XRF Observation data (ppm)
- Sample Point Cloud 'Flythrough' Animation.



Interactive TLS Point Cloud and Panoramic image viewing software.