Gorgan and Tammishe Walls

IRAN

Qaleh Kharabeh, Forts 15 and 16 and Bansaran Fort

Geophysical Surveys using Magnetometery and Earth Resistance

26 December 2007

For
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1 SUMMARY

Magnetometer and some small earth resistance surveys were carried out on these sites in late July and in August 2007.

Qaleh Kharabeh had a central crossroads with possible buildings along the sides of the roads, with these being more visible near the cross roads and with possible burning and pits in that vicinity. On the eastern side of the site there appeared to be rows of small enclosures. The purpose of these is unknown but they could possibly be gullies dug around tents or similar temporary structures. There were large areas with no detectable remains, only an indication of the pre-fort field system.

Fort 15 had mounds of earth where there could have been buildings and a sample area was surveyed. These mounds showed in the magnetometery results but no mud brick or other walls were detected.

Fort 16 may well have had fired brick side walls and a rear gate. It appeared to have had a central road with buildings on either side although these could not be defined at all well. There were four areas which could have been kilns or similar.

The Bansaran fort had an aisled building and brick walls. There were areas of rubble and possible small mud brick buildings indicating a complex amount of deposits.

INTRODUCTION

The geophysical surveys were part of the work on this wall being carried out by the Gorgan Wall Research Project in 2007. In the previous years brick kilns along the wall had been located and excavated to produce samples for scientific dating and investigations in fort 4 had shown 3 rows of mud brick rooms– See Iran 44, 2006 and 45, 2007.

The 2007 season had geophysical surveys of part of Qaleh Kharabeh,
fort 15 and part of fort 16 on and near the Gorgan wall. It also had further work on the Bansaran Fort on the Tammeshe wall.

All the sites on the Gorgan wall can be identified on the ground as they have earth banks around them which are between approximately 2 and 4 metres high. These appear to have been the upcast from the broad ditches around the forts. The Bansaran fort had almost vertical slopes on two of its sides.

Qaleh Kharabeh had wheat stubble through which the cultivation undulations could be seen. Fort 14 had the remains of a maize crop and fort 16 had wheat stubble. Bansaran fort had a short crop of beans or similar.

The weather was mainly hot and dry and work had to take place early in the mornings before the heat affected the equipment as the alomalies were so small that processing to remove the heat effects could also have lost the archaeologically significant information. The equipment was re-balanced after every 3 grids but, even so, unacceptable levels of drift occurred after 9.30am.

The geology of the Gorgan wall sites is understood to be a thick bed of loess whilst the Bansaran fort had a more stony soil.

3 Survey Design and Equipment

Magnetometery was chosen for most of the work as it is a fairly rapid and thus cost efficient method of locating shallow buried features. It largely depends on the soil having natural iron in it which can be enhanced by human or bacterial action. Unlike resistivity, which was also used over small areas, it does not require the ground to have a sufficient water content to enable anomalies to be detected and would therefore be preferred on dry sites.

A Bartington Grad 601/2 gradiometer was used with the probes 1 metre apart and with a 1 metre spacing between the top and bottom sensors.

The survey was carried out with traverses 1 metre apart and 4 readings being taken per metre along each traverse. Our experience is that traverses at less than 1m separation seldom produce sufficient additional information to justify the extra effort which would be necessary if the traverses were half a metre apart. Whilst we could have taken readings at 8 readings per metre we felt that the more usual 4 readings per metre would be adequate bearing in mind the fact that the grids were at an angle to the main axis of the forts and, as Qaleh Kharabeh was large, a higher reading density could well have given major problems with data processing.

The grids were 30metres by 30 metres and were at an angle to the main axis of the forts in order to maximise the chances of locating features and reduce the possibility of features being lost in the data processing. The person carrying the gradiometer walked along strings with markings every metre to seek to ensure that the data was collected at the correct intervals. As it was anticipated that the anomalies would be weak the sensors were carried approx 10 cms from the ground surface.

Data processing
For magnetometery the following processes were principally used:-

1 Base Layer

2 Zero Mean Traverse – this seeks to correct imbalances between the 2 magnetometers.

3 Clip – this seeks to prevent the plot of the data being unduly influenced by a few very high or low readings.

6 De Stagger – this removes a problem inherent in this equipment.

7 FFT Filter - this seeks to remove modern ploughing effects and to enable the archaeology to be seen.

8 Interpolate: Match X & Y – this seeks to adjust for the raw data having 1 reading per metre on one axis and 4 per metre on the other.

A TR Systems earth resistance meter was used for the resistivity surveys. This was chosen as it is a relatively small and lightweight piece of equipment which is also relatively easy to use. A twin probe layout was adopted with 2 mobile probes half a metre apart and two fixed probes which were positioned some 20 metres from the survey area. Readings were taken at 1 metre spacings.

Data processing

For resistivity data the following processes were usually used :-

1 Clip – this seeks to prevent the plot of the data being unduly influenced by a few very high or low readings.

2 Despike – this seeks to remove isolated erroneous readings caused by the mobile probes hitting stones and similar.

Location

The survey areas were located by a hand held Global Positioning System and the grids were laid out using tape measures. The Gorgan Wall team kindly laid out base lines on Qaleh Kharabeh to enable the later layout using tapes to be as accurate as reasonably possible. It is estimated that the furthest parts of the grid in Qaleh Kharabeh from the base line may have been some 30 cms from their true positions, although this could have been exceeded in the small isolated raised fort area to the south eastern corner of that site.

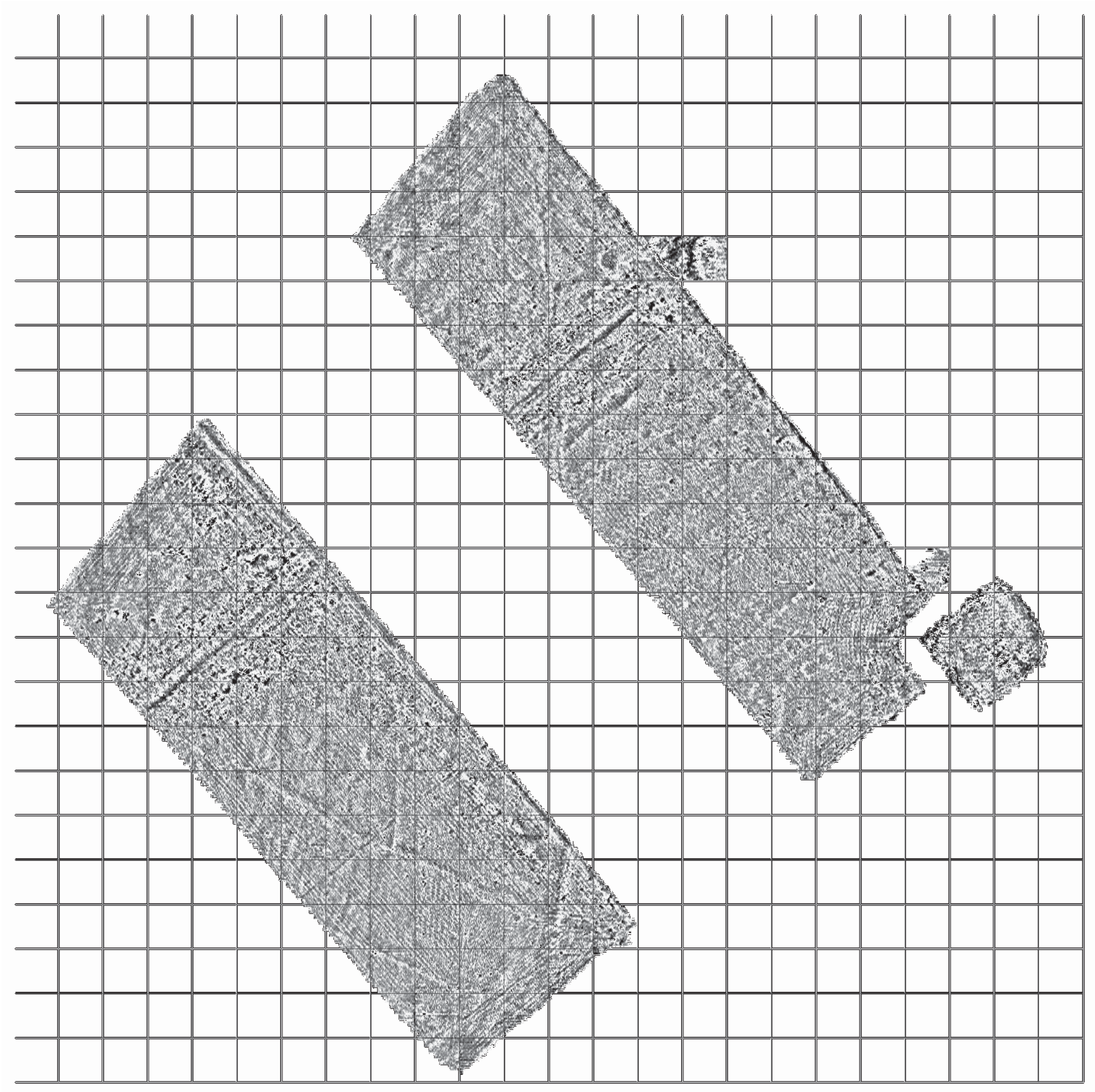
4 Survey results

Qaleh Kharabeh

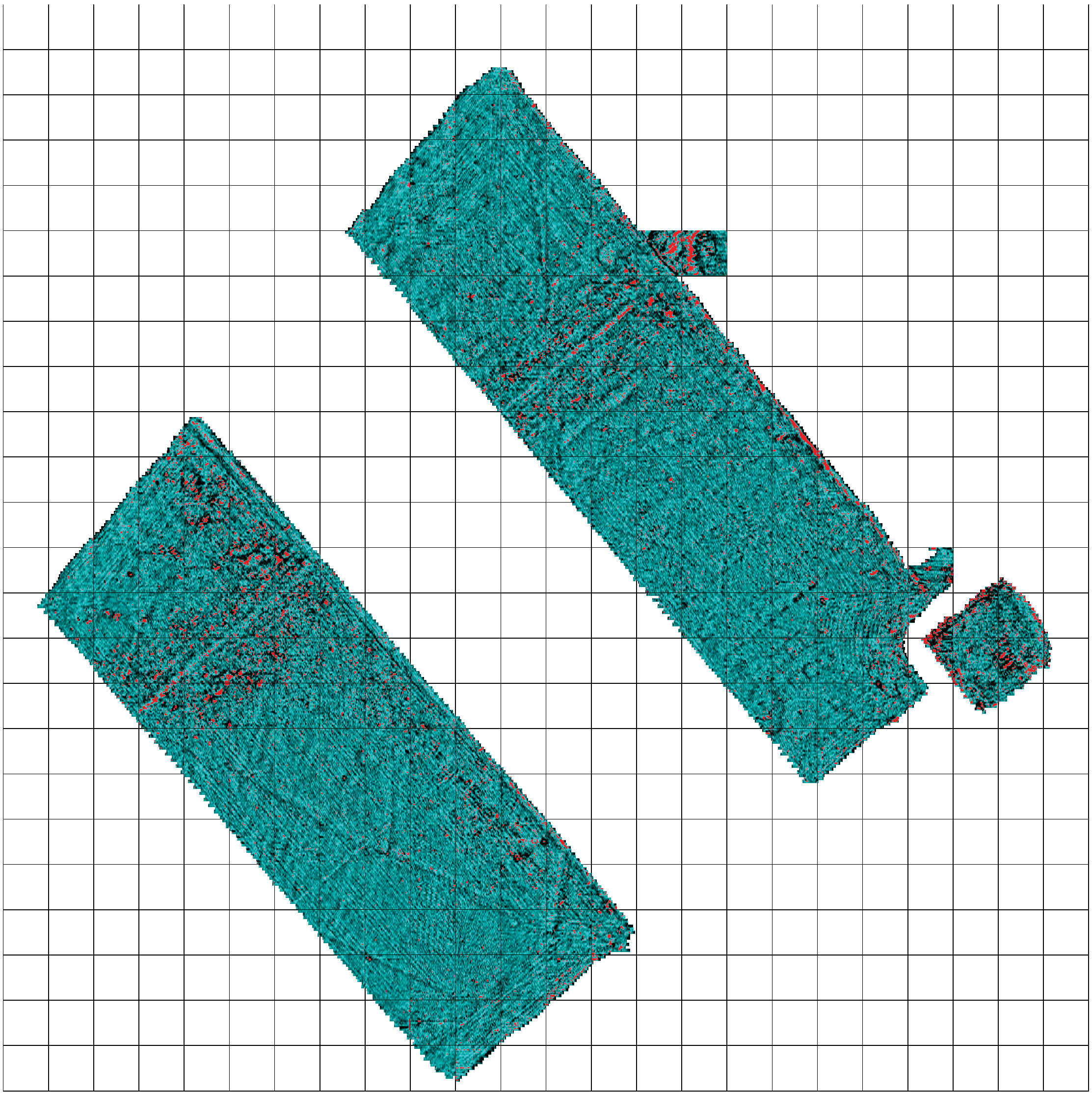
The illustrations below show this site in various ways with and without grid lines. The main results appear to be:-

1. Large areas of the fort appear to have little which could be detected with magnetometery.
2. These blank areas however appear to have remains of field boundaries which could pre-date the fort. As these ditches were detectable it could be that these areas were open spaces.
3. There is a central crossroads which is the focus of activity and there could be buildings along the sides of the roads with these being more visible near the cross roads with possible burning and pits in that vicinity.
4. On the eastern side of the site there appear to be rows of small enclosures. The purpose of these is unknown but they could possibly be gullies dug around tents or similar temporary structures.
5. The roads had a signal strength of 1.5nT, the buildings near the cross roads had 2nT and the gullies had approximately 0.7nT. These are all approaching the point of undetectabilty so there could be other remains there which could not be detected using this equipment.

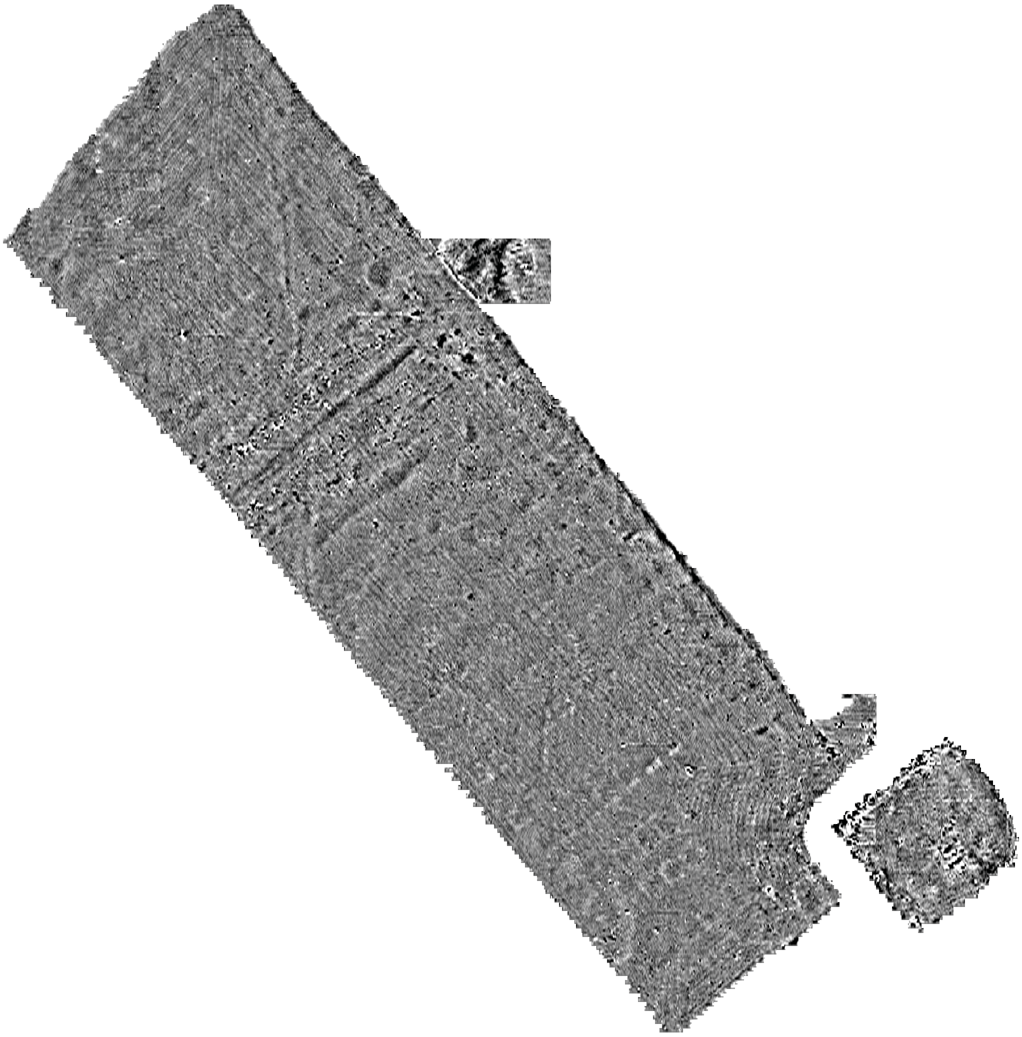
Qaleh Kharabeh – whole site greyscale



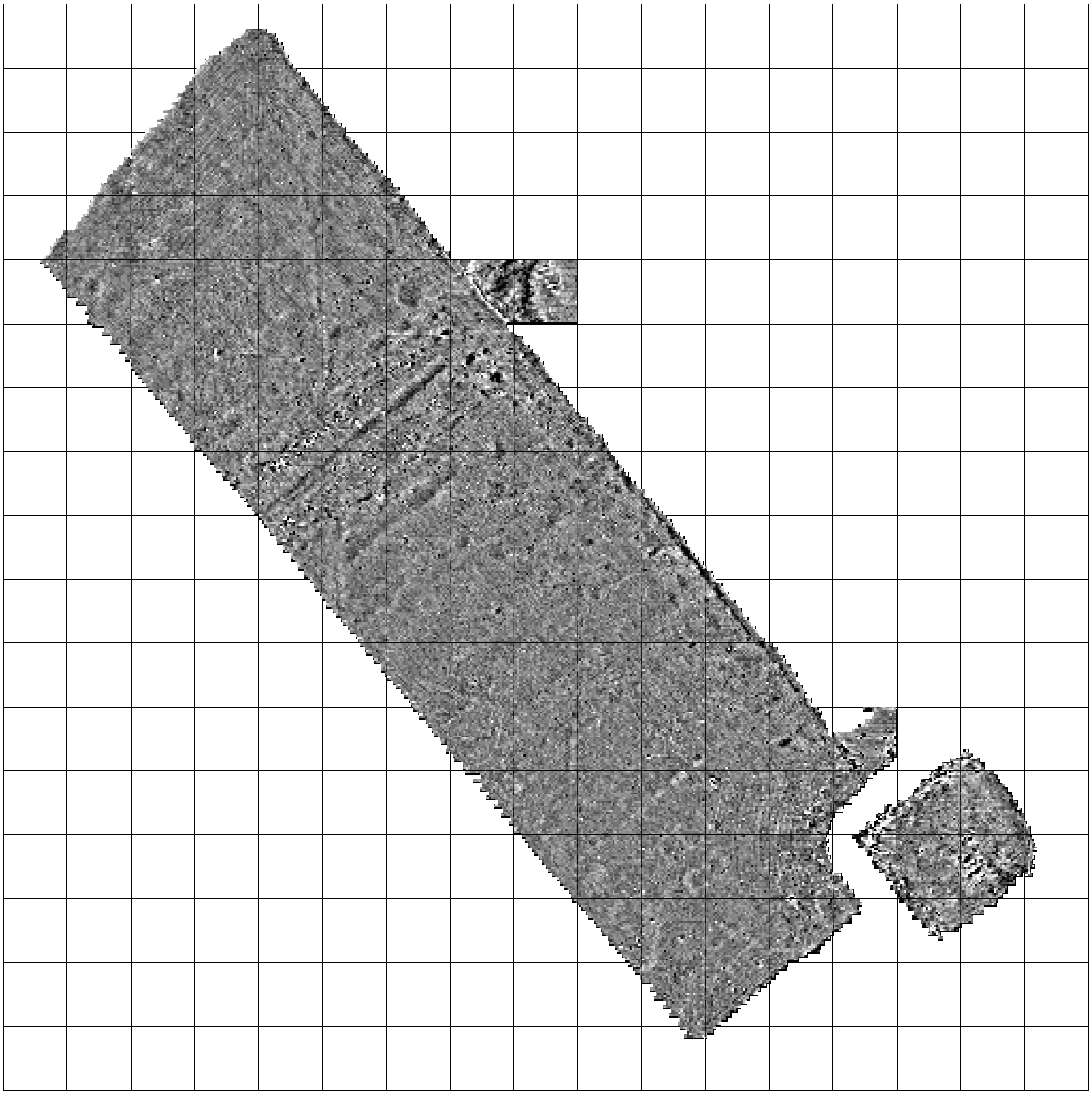
Qaleh Kharabeh –whole site colour



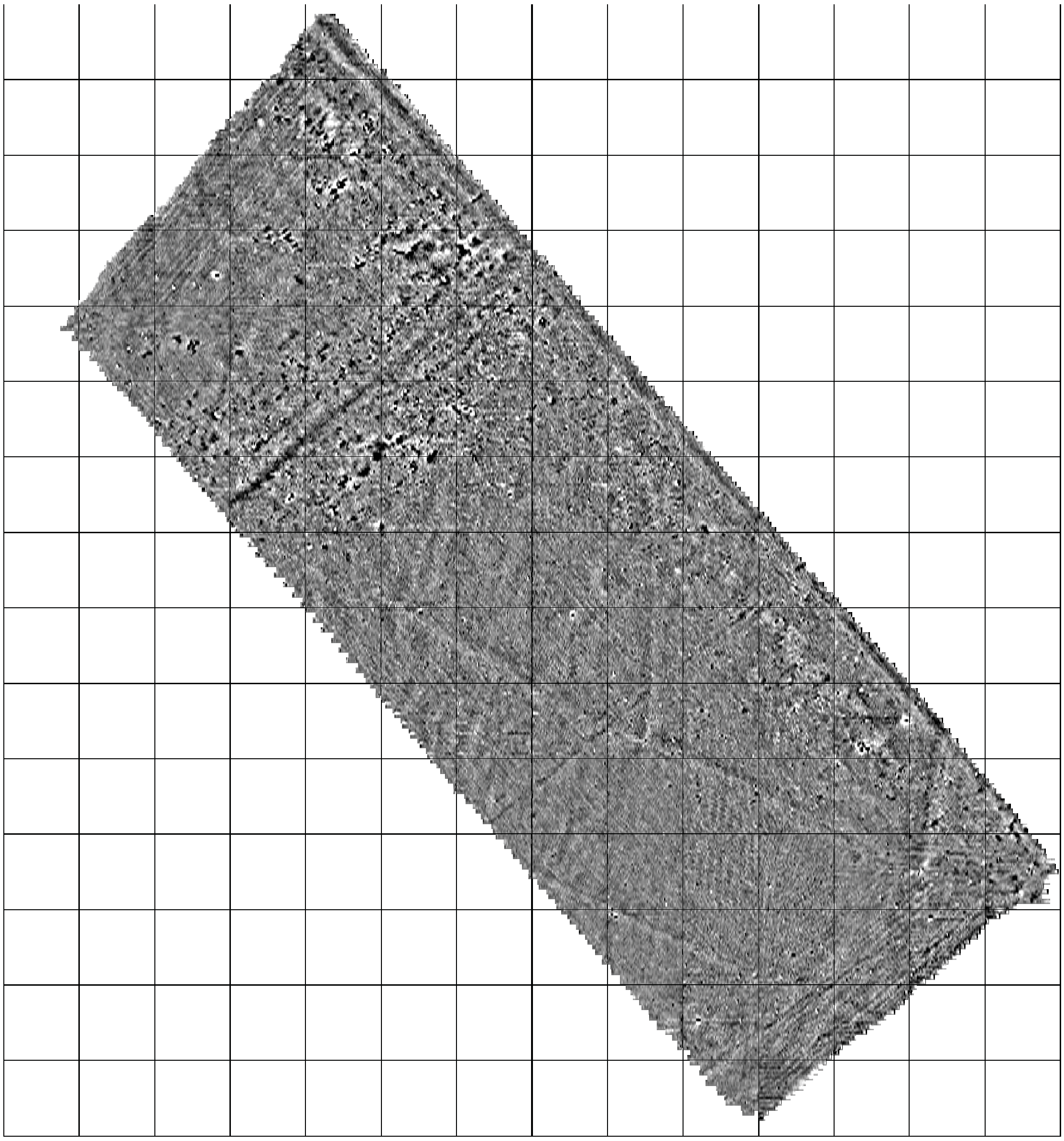
Qaleh Kharabeh –Eastern Part



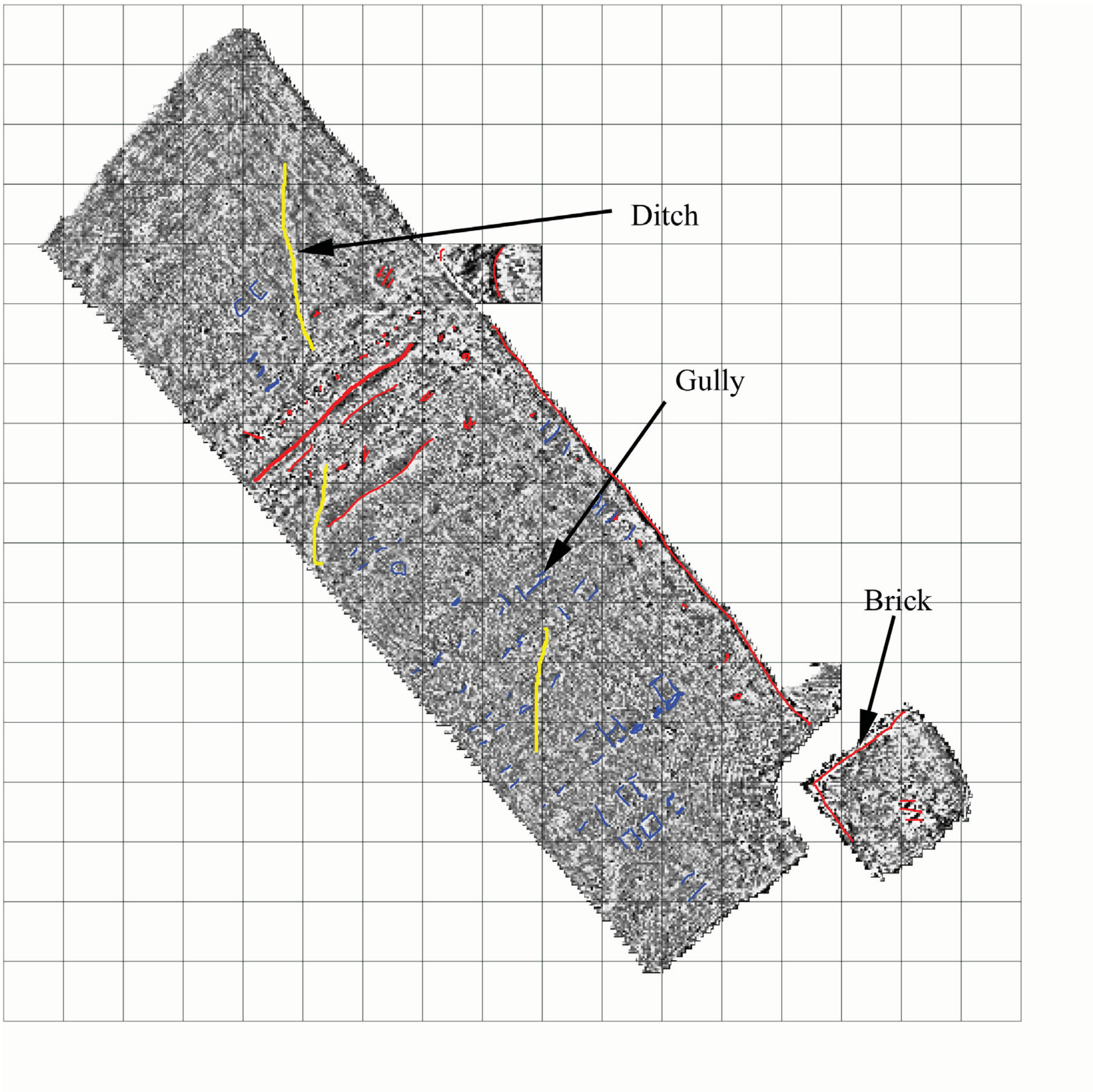
Qaleh Kharabeh – Eastern Part



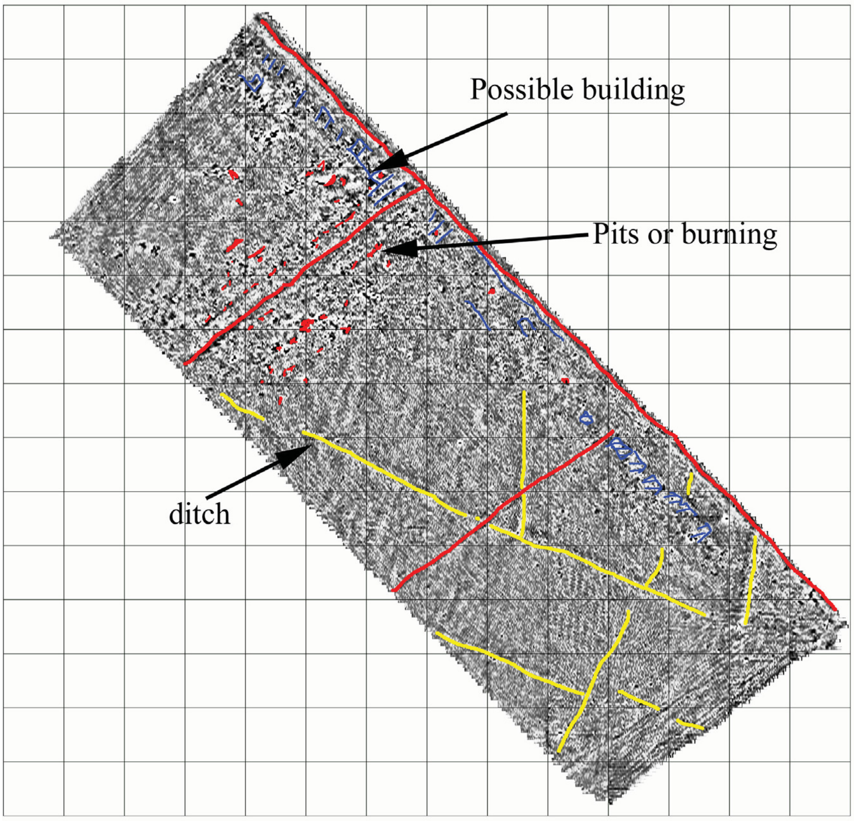
Qaleh Kharabeh - Western Part



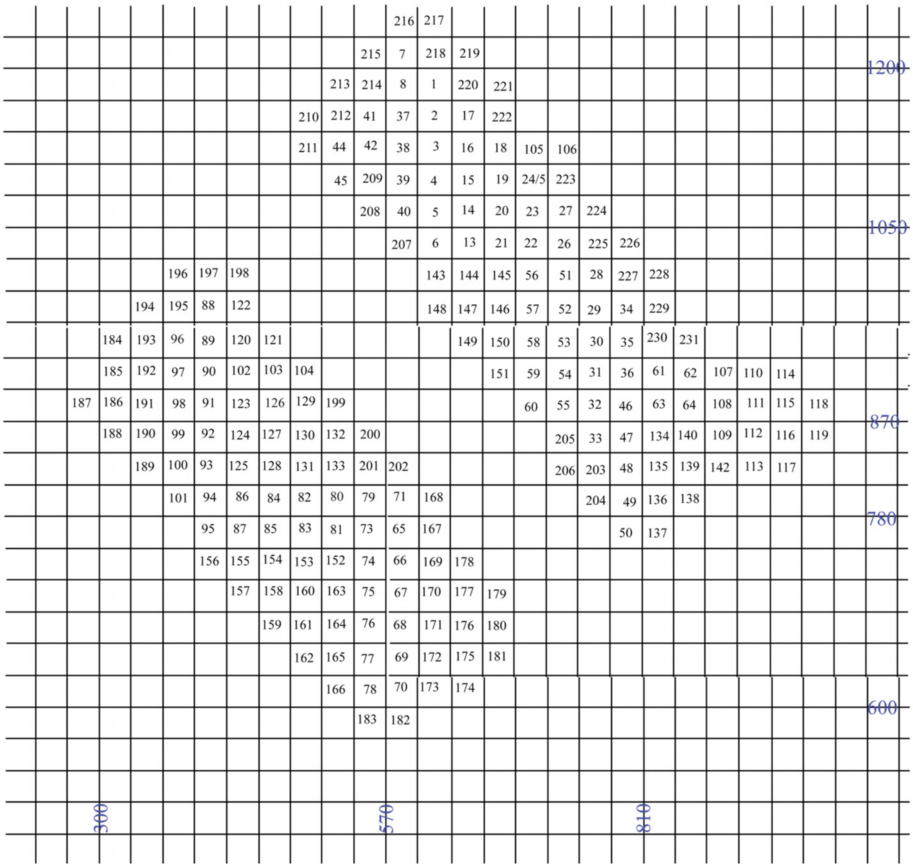
Qaleh Kharabeh - Eastern Part – Interpretation



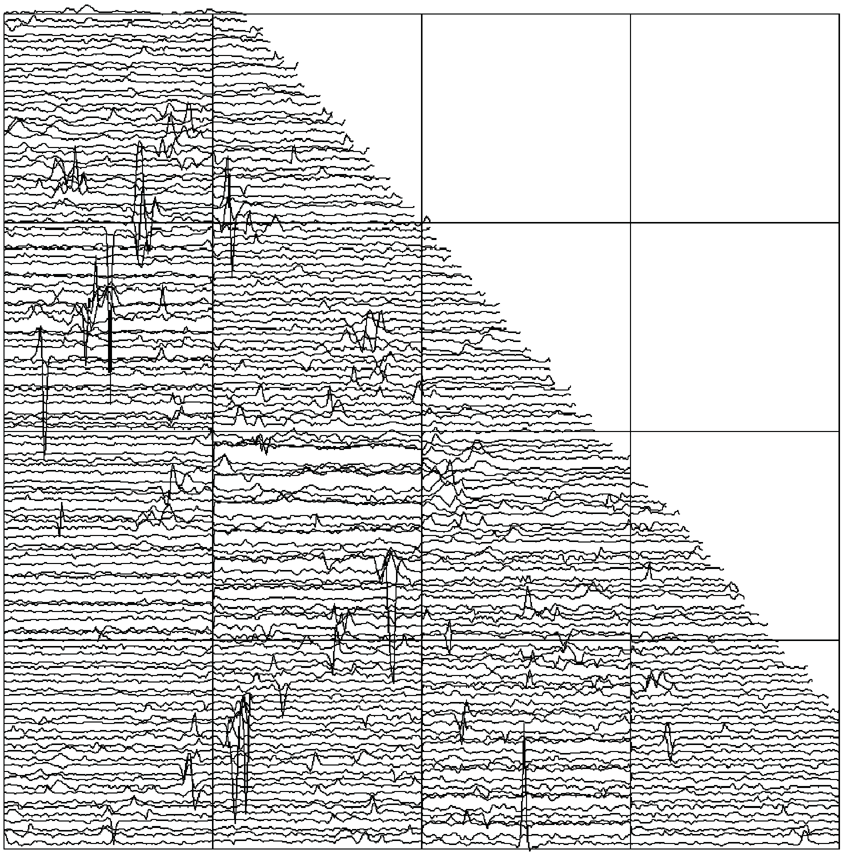
Qaleh Kharabeh - Western Part - interpretation



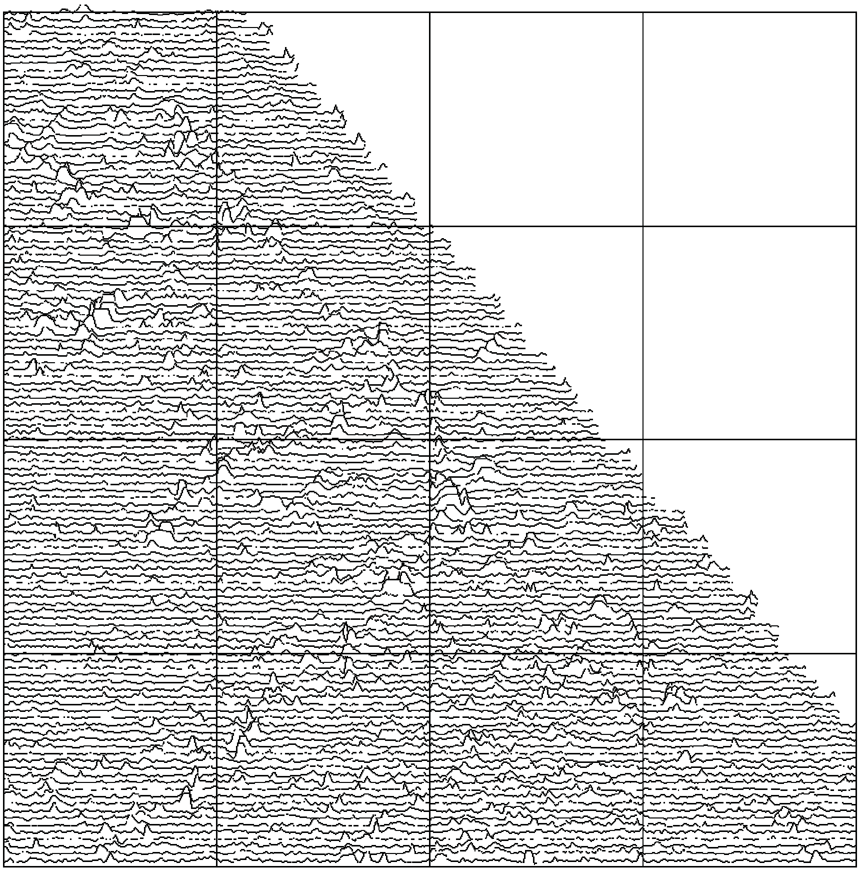
Qaleh Kharabeh - Grid Location



Qaleh Kharabeh - Part of Western Part
Trace plot unprocessed



Qaleh Kharabeh - Part of Western Part
Trace plot processed

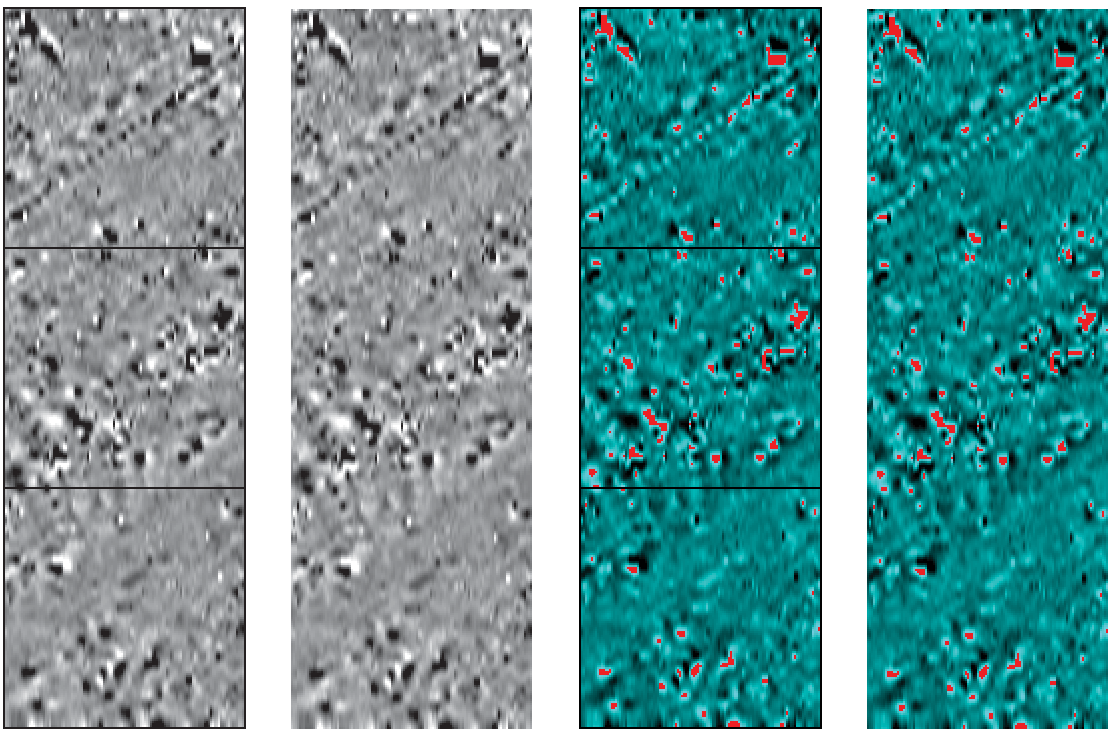


Fort 15

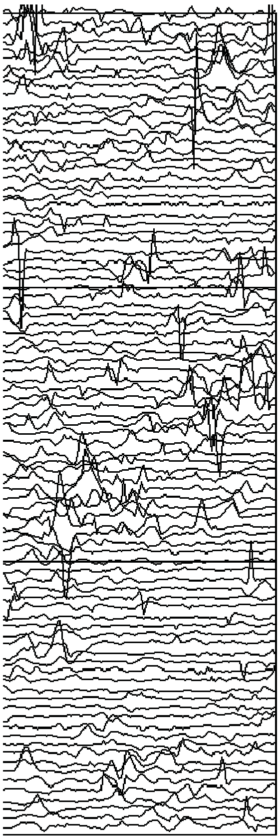
Some grids were surveyed using magnetometery on this fort to see whether the mounds of earth visible on satellite pictures were blocks of buildings as found in fort 4.

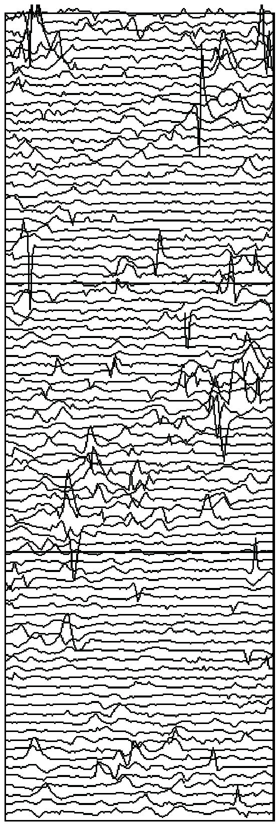
Results
These were:-
1 No structures were located using this method. This is probably because this site had been ploughed and this may have obscured the faint magnetic anomaly which mud brick walls cause. Earth resistance could be tried or even a Caesium vapour type of magnetometer could have more chance of locating mud brick on this site.
2 The earth mounds were however detected as they had more magnetic disturbance than the areas between them.
3 Various possible pits or similar more magnetic anomalies were detected

Greyscale and colour plots

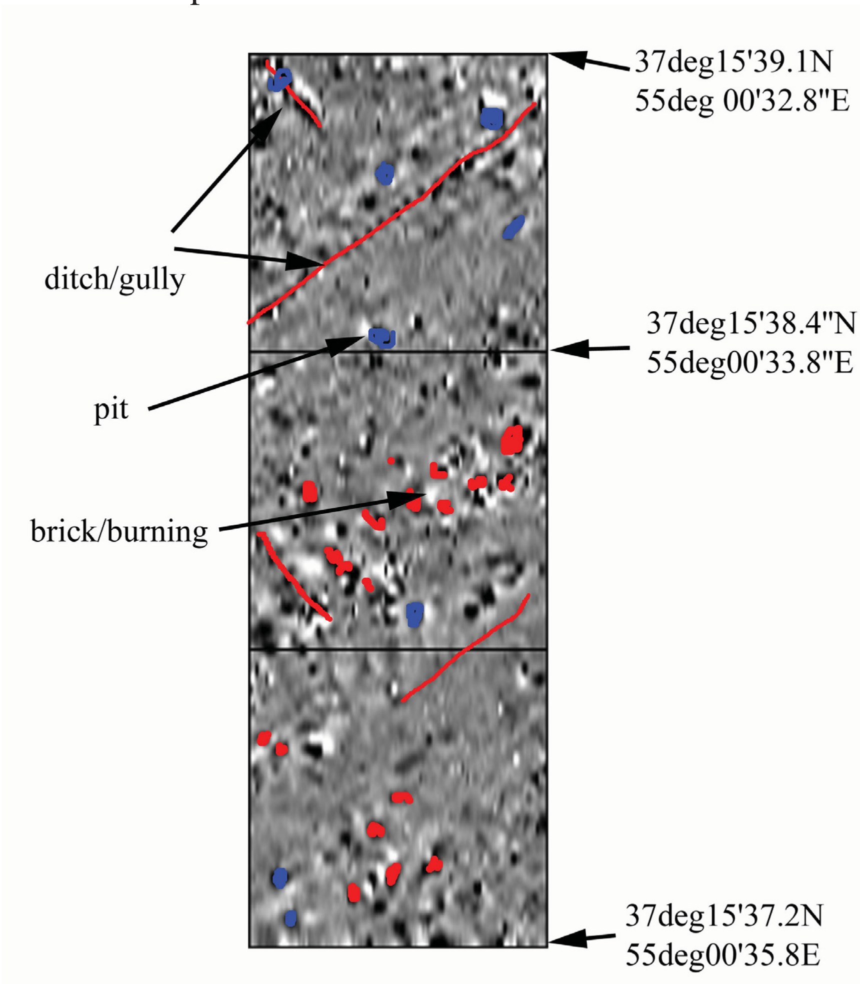


Trace plot unprocessed and processed





Fort 15 Interpretation



Fort 16

This was in a dry area with a small irrigation channel to its north which ran alongside the route of the Gorgan wall. The sides of the fort ,apart from the side in the wall itself survive as earth banks approximately 2 metres high.

Results

These were:-

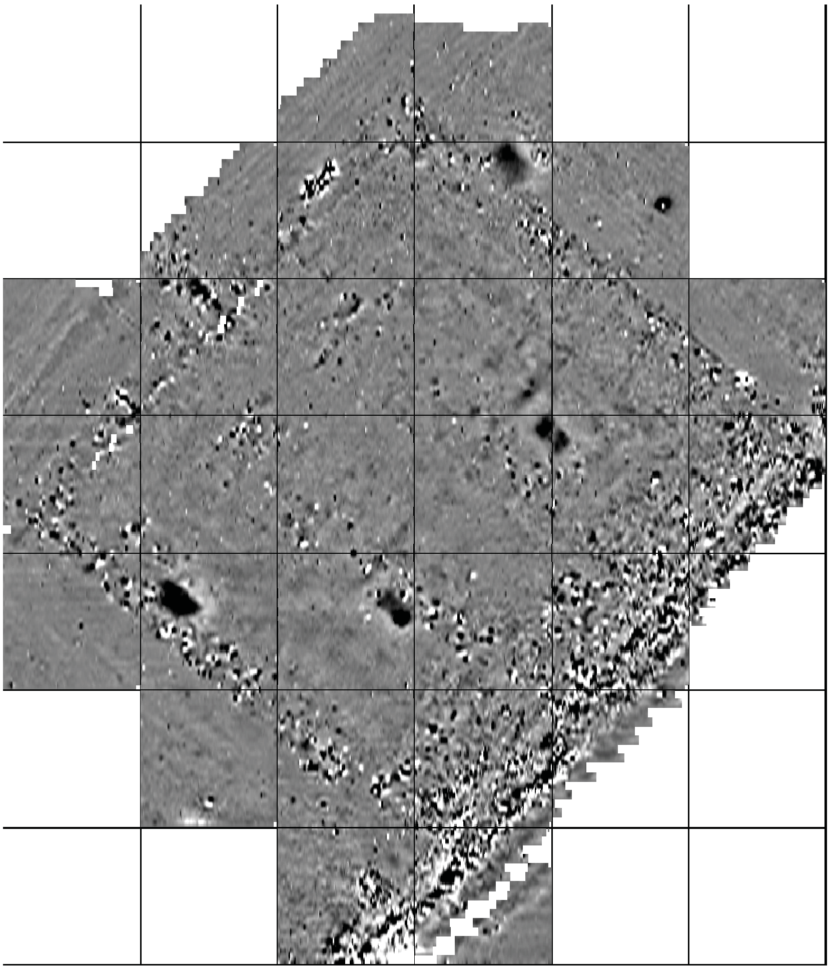
1 The fort may have had fired brick side and rear walls and there could have been a gateway in the rear wall.

2 There appeared to be two areas of higher disturbance which could indicate 2 blocks of buildings, one on each side of a road coming in through the gate in the rear wall and, presumably going through a gate in the Gorgan wall itself.

3 There were four anomalies on the order of 20nT which could be kilns or similar structures.

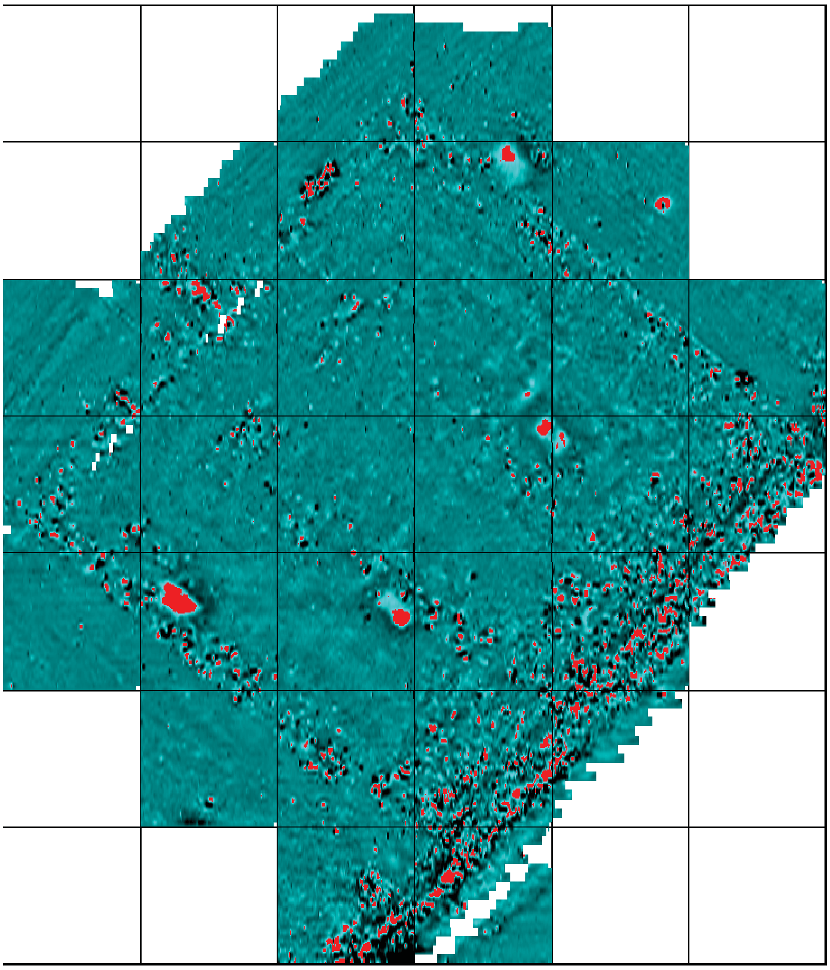
4 The earth resistance survey produced unexpectedly good results. It located the roadway but was less good at locating a possible kiln.Whilst the dryness of the soil was expected to lead to high contact resistance problems, the opposite was the case with it being difficult to obtain readings in excess of 1 ohm. This could well be caused by the mineral salts in the soil conducting the current. If this is the case it could also mean that features on this type of soil and location may be difficult to identify using ground penetrating radar as that technique is rendered less effective by salts in the soil.

Fort 16 Greyscale

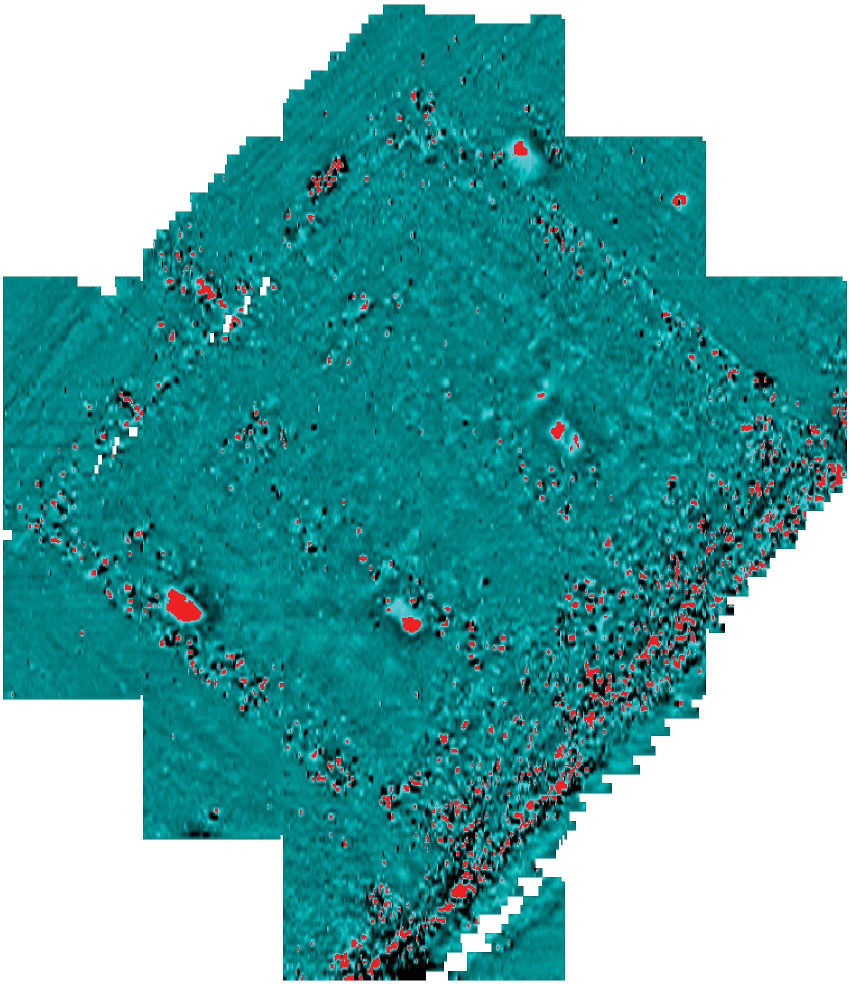


Fort 16 Greyscale

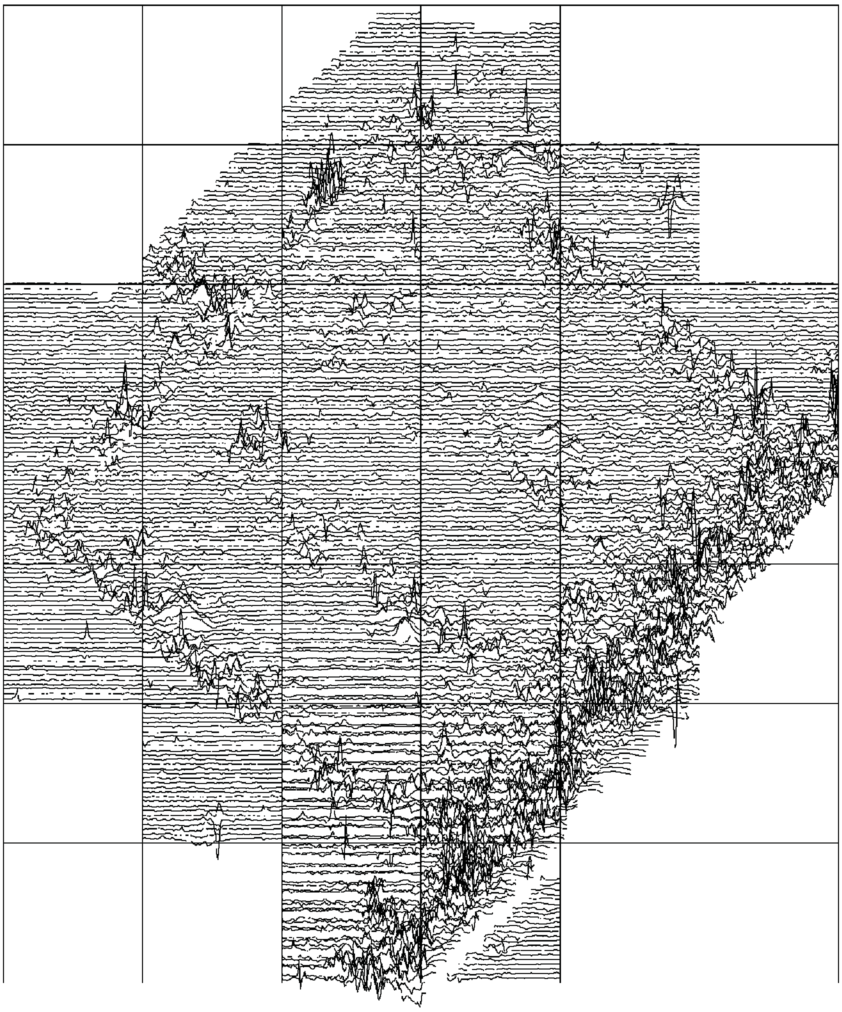
Fort 16 Colour



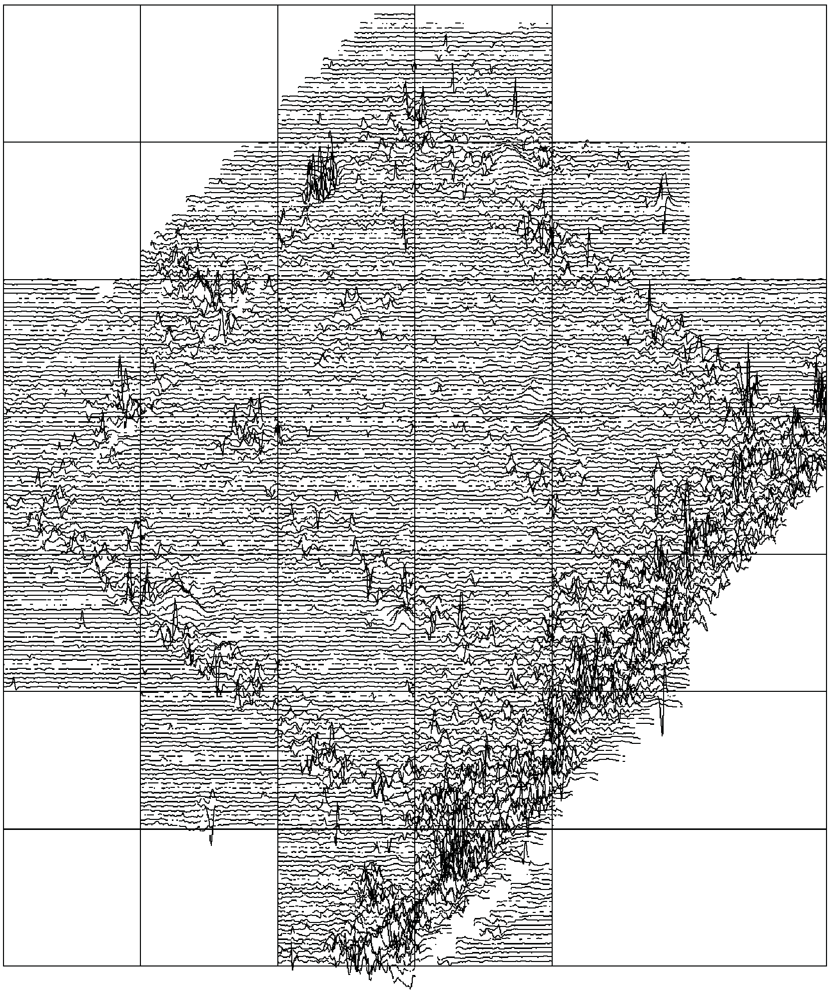
Fort 16 Colour



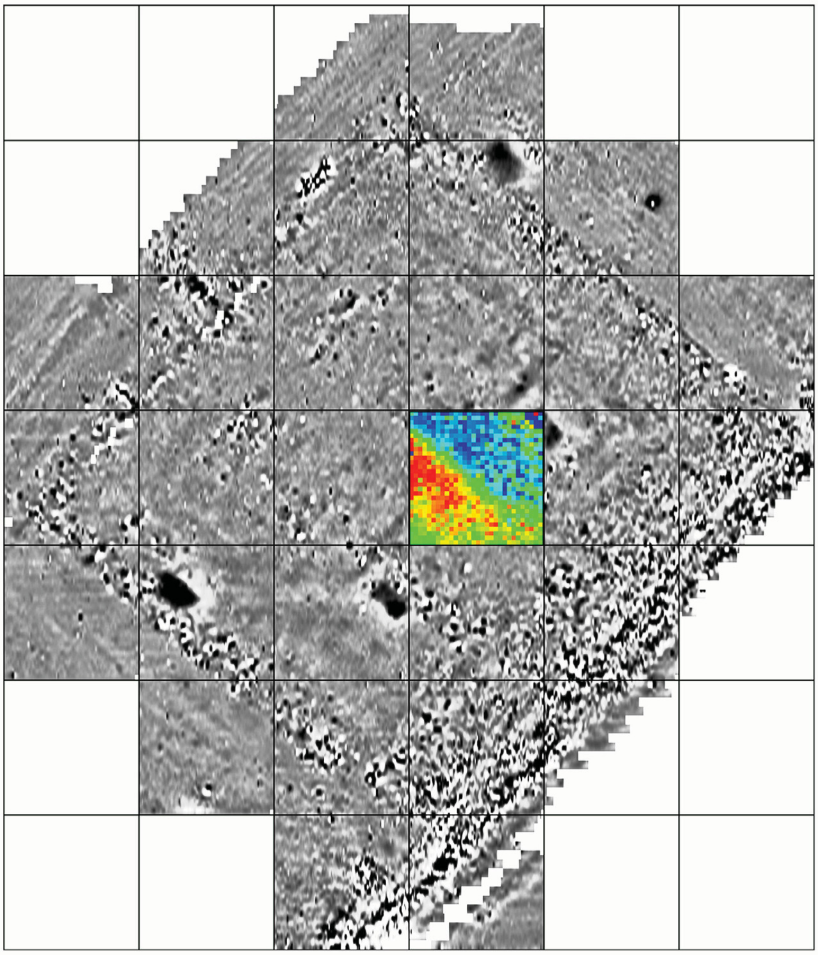
Fort 16 Trace plot unprocessed



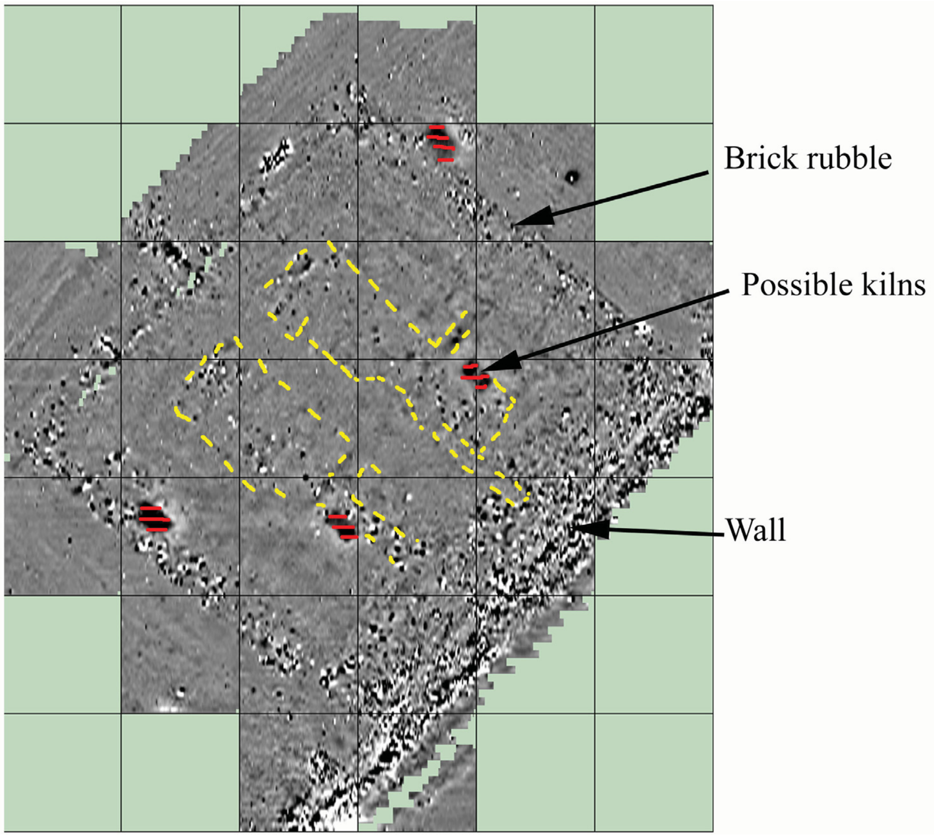
Fort 16 Trace plot processed



Fort 16 Greyscale magnetometery with colour resistivity



Fort 16 Interpretation



Fort 16 Grid order

		15	1		
	22	16	2	8	
27	23	17	3	9	12
28	24	18	4	10	13
30	25	19	5	11	14
	26	20	6	29	
		21	7		

Bansaran Fort

This is on the Tammishe wall and is to the south-west of Gorgan in the where the land increases in elevation. The soil is stonier there as opposed to the almost stoneless loess of the areas near the Gorgan wall.

The main results were:-

1 There was an aisled building in the western part of the site. This was aligned north south with its entrance to the south. This had several pier bases which produced magnetometery readings in the order of 50nT. This had previously been located in the 2006 survey.

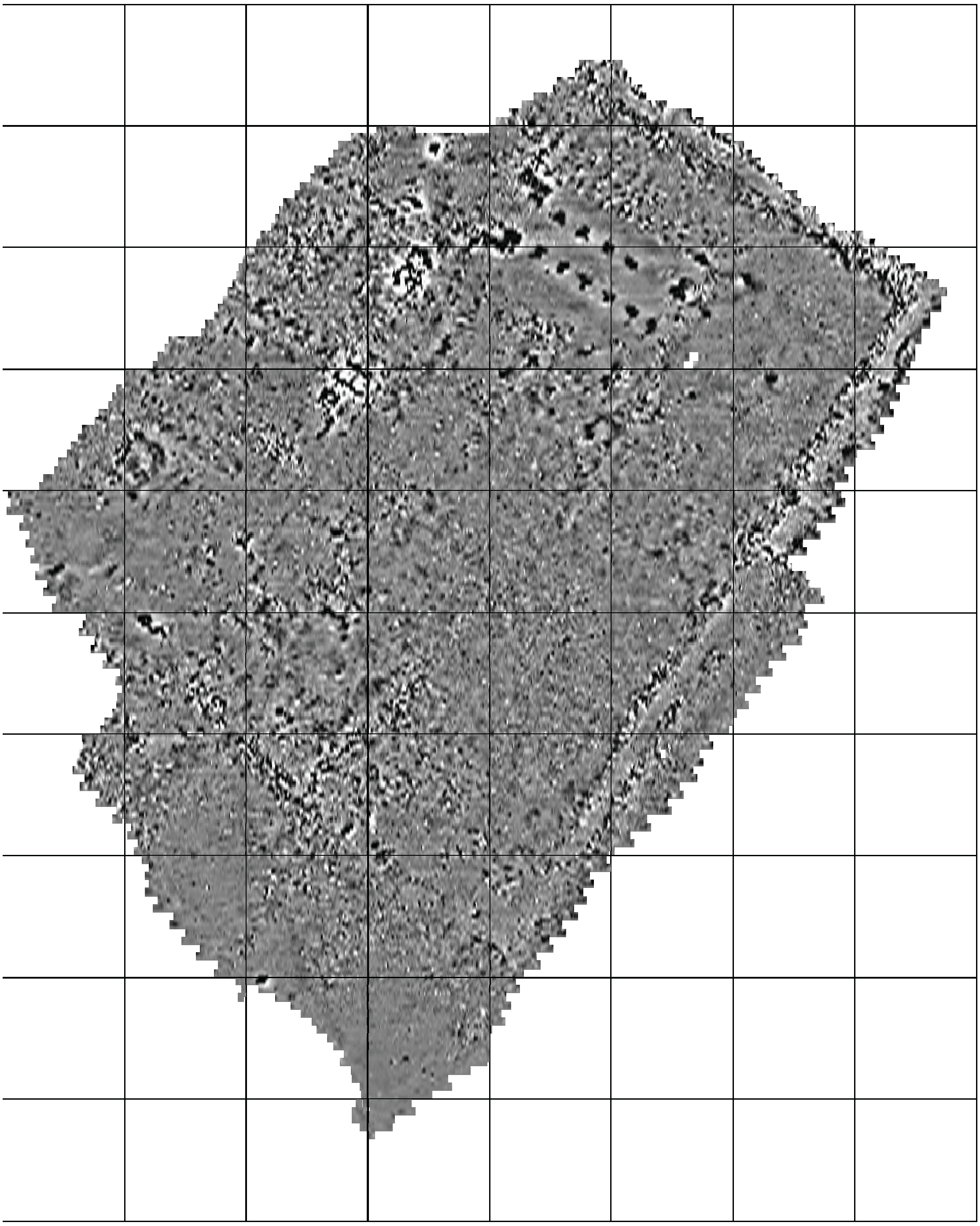
2 The wall around the site was best detected on the northern and western sides. It appeared to be two lines of high but irregular magnetic readings with an area of low readings between them. This could indicate that the fired brick wall had been robbed out and that the robber trench had silted naturally rather than being backfilled with the discarded broken bricks.

3 There were traces of low level anomalies, approx 10nT, which could be surviving mud brick.

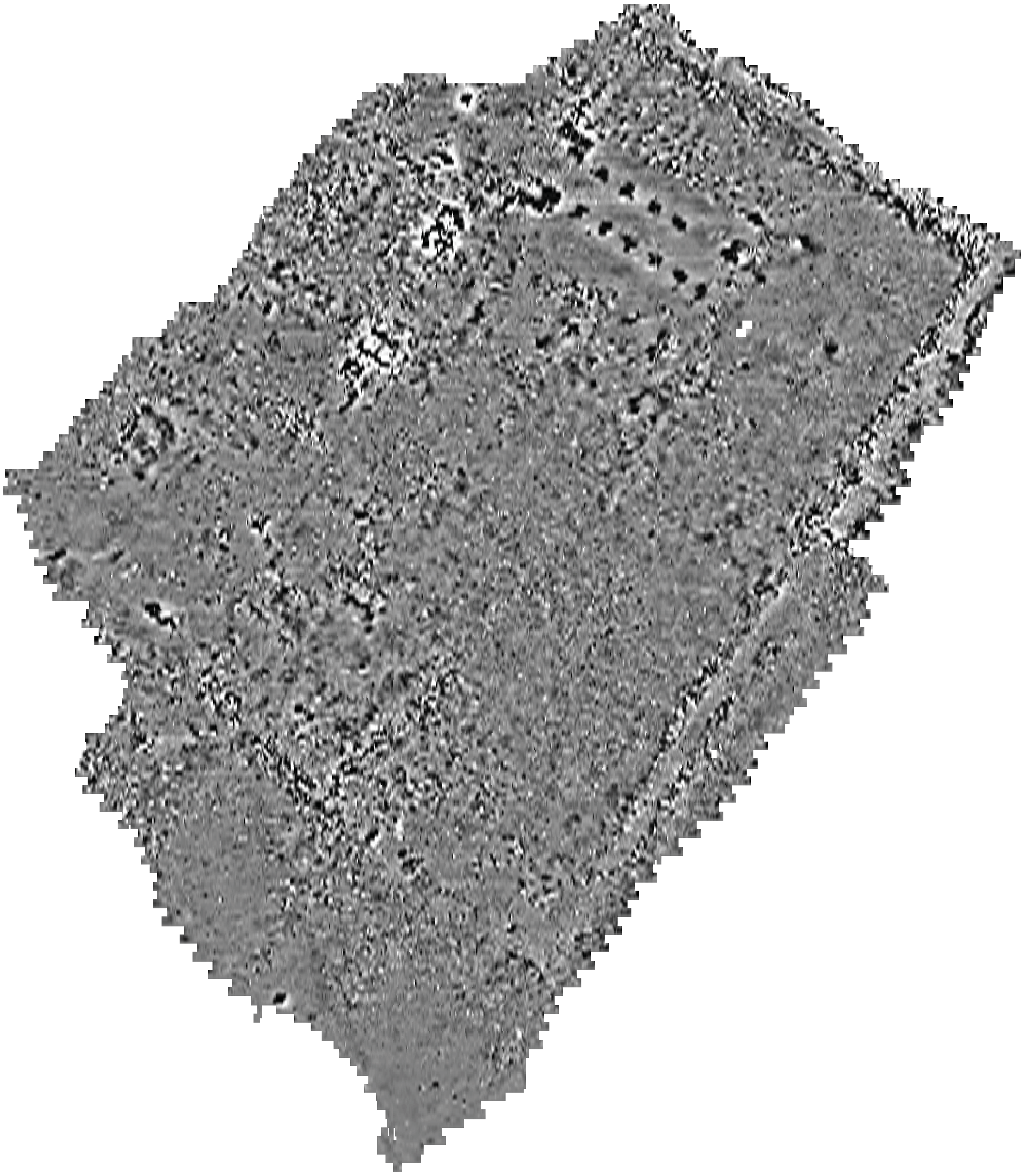
4 Some areas had rubble spreads and others were remarkably clear of rubble. This could indicate that whilst the smaller buildings decayed and were left as piles of rubble, the larger buildings were systematically cleared of rubble. Whether this means they were demolished and then removed or whether they collapsed and had better quality material for re-use is not a question answerable by geophysics.

5 The resistivity survey was able to locate some features although not as well as the magnetometery. Readings were usually approximately 20 Ohms although there were very many defective readings caused by stones in the soil (approx 15%) and these often gave readings of over 1500 Ohms. If the resistivity had been carried out when the soil was damper the results would have been far better.

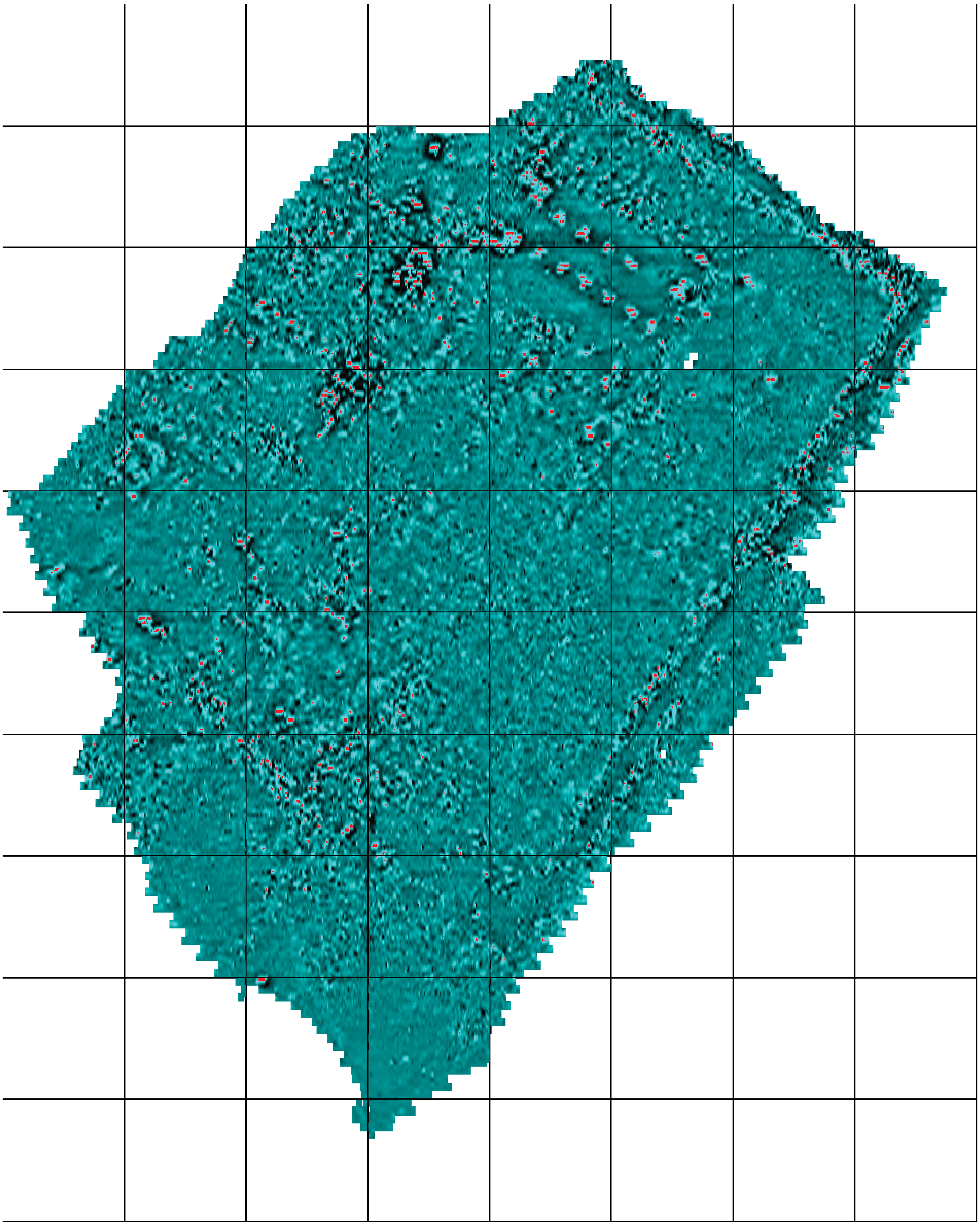
Bansaran Fort   Greyscale



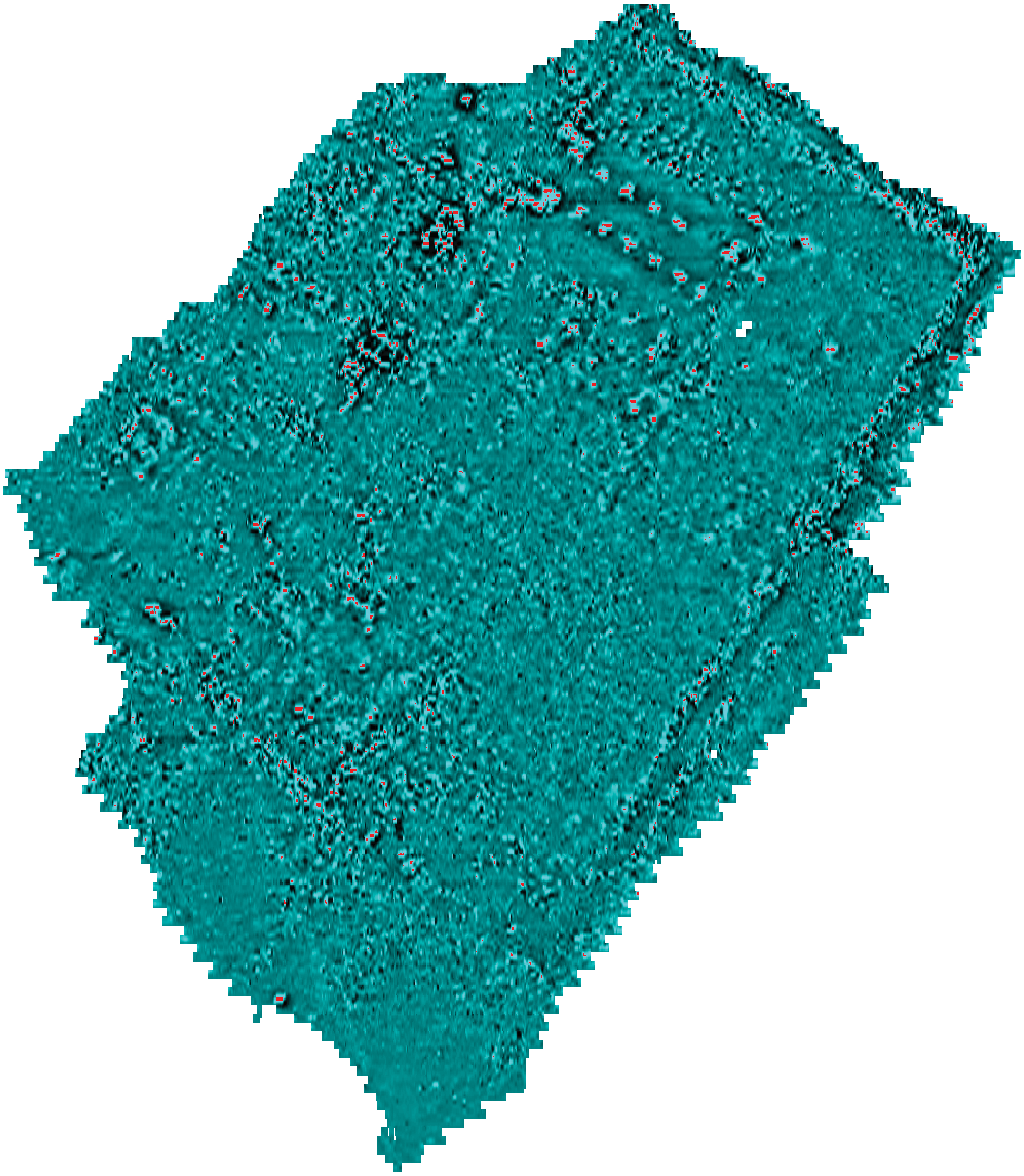
Bansaran Fort   Greyscale



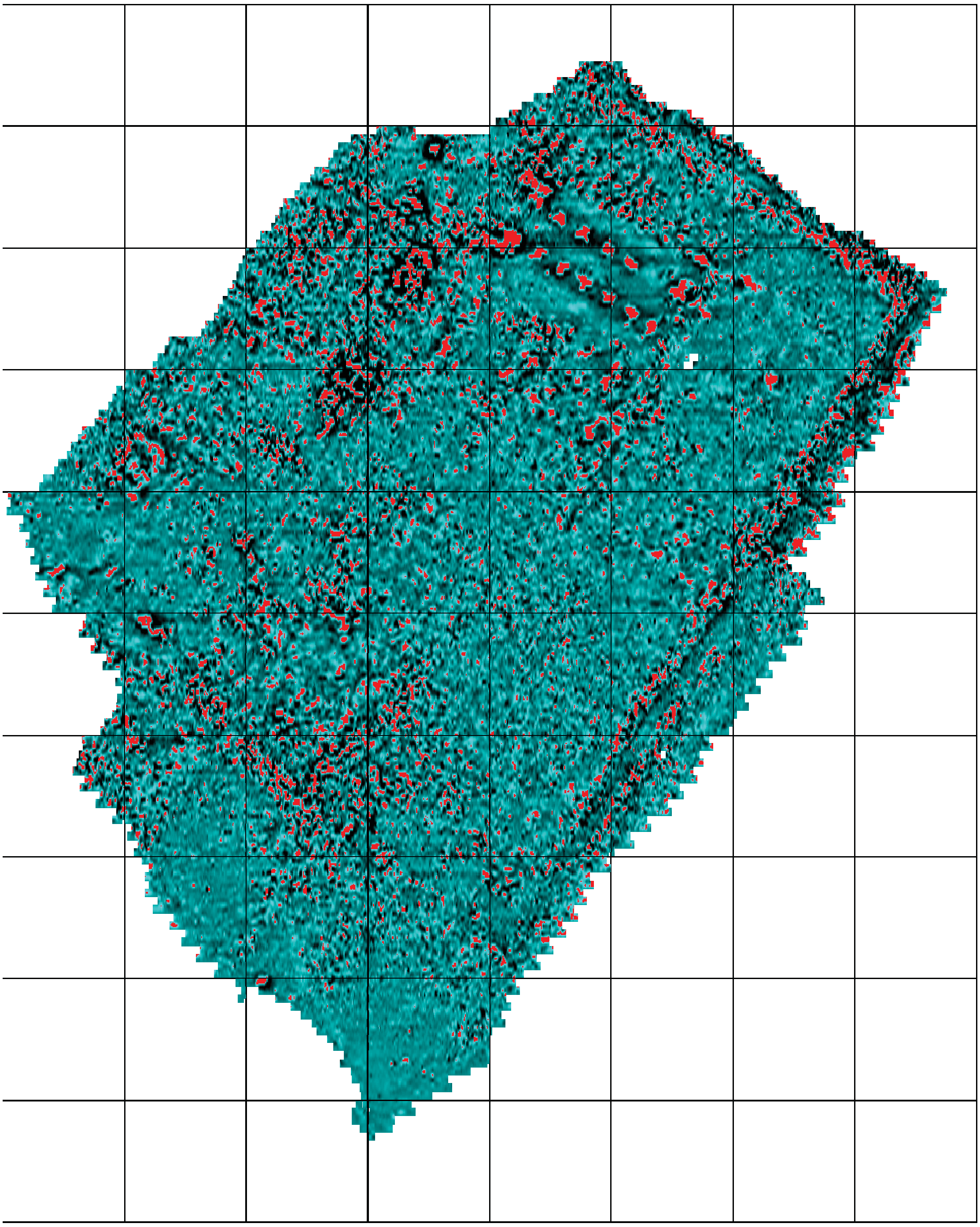
Bansaran Fort   Colour



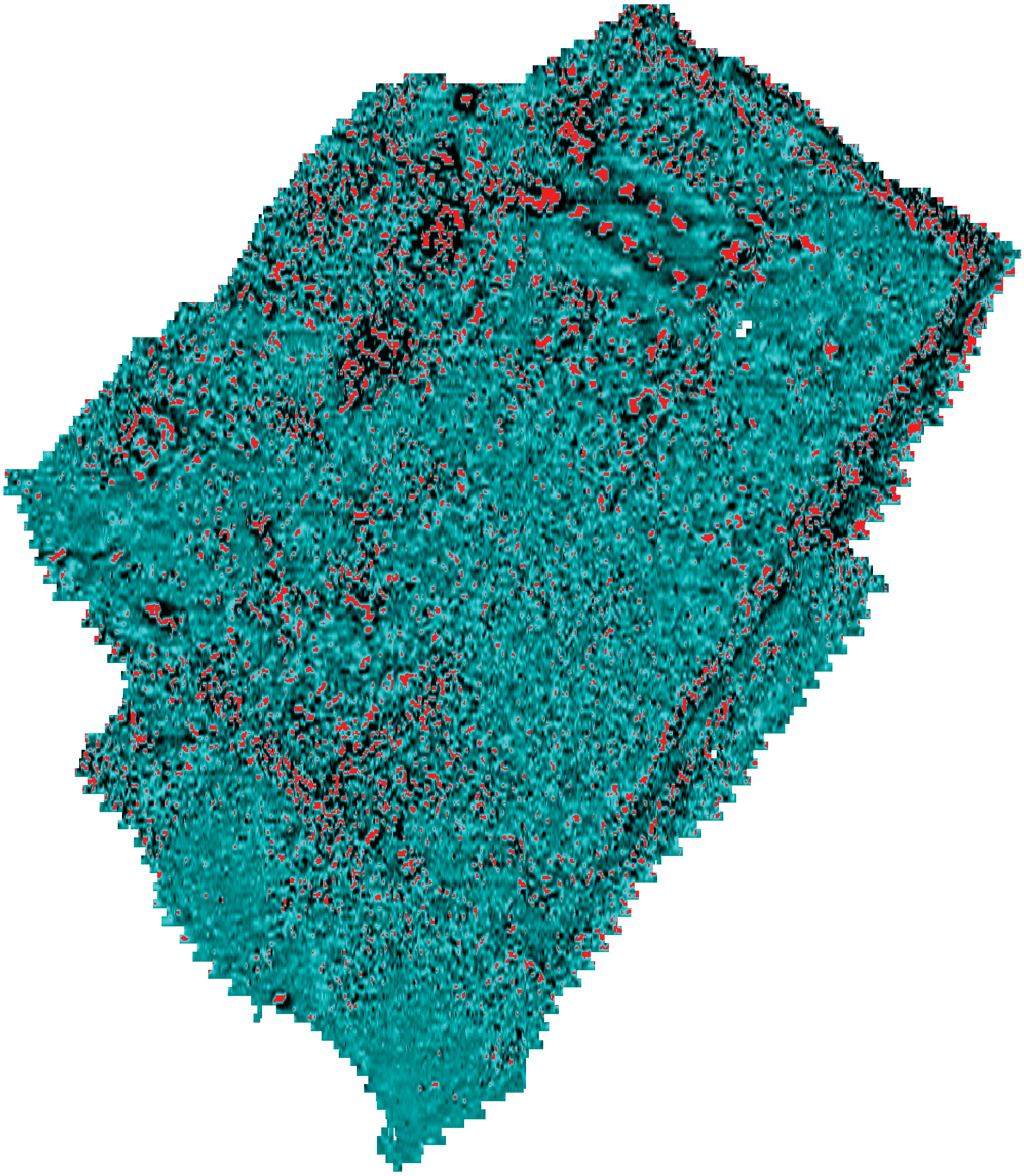
Bansaran Fort   Colour



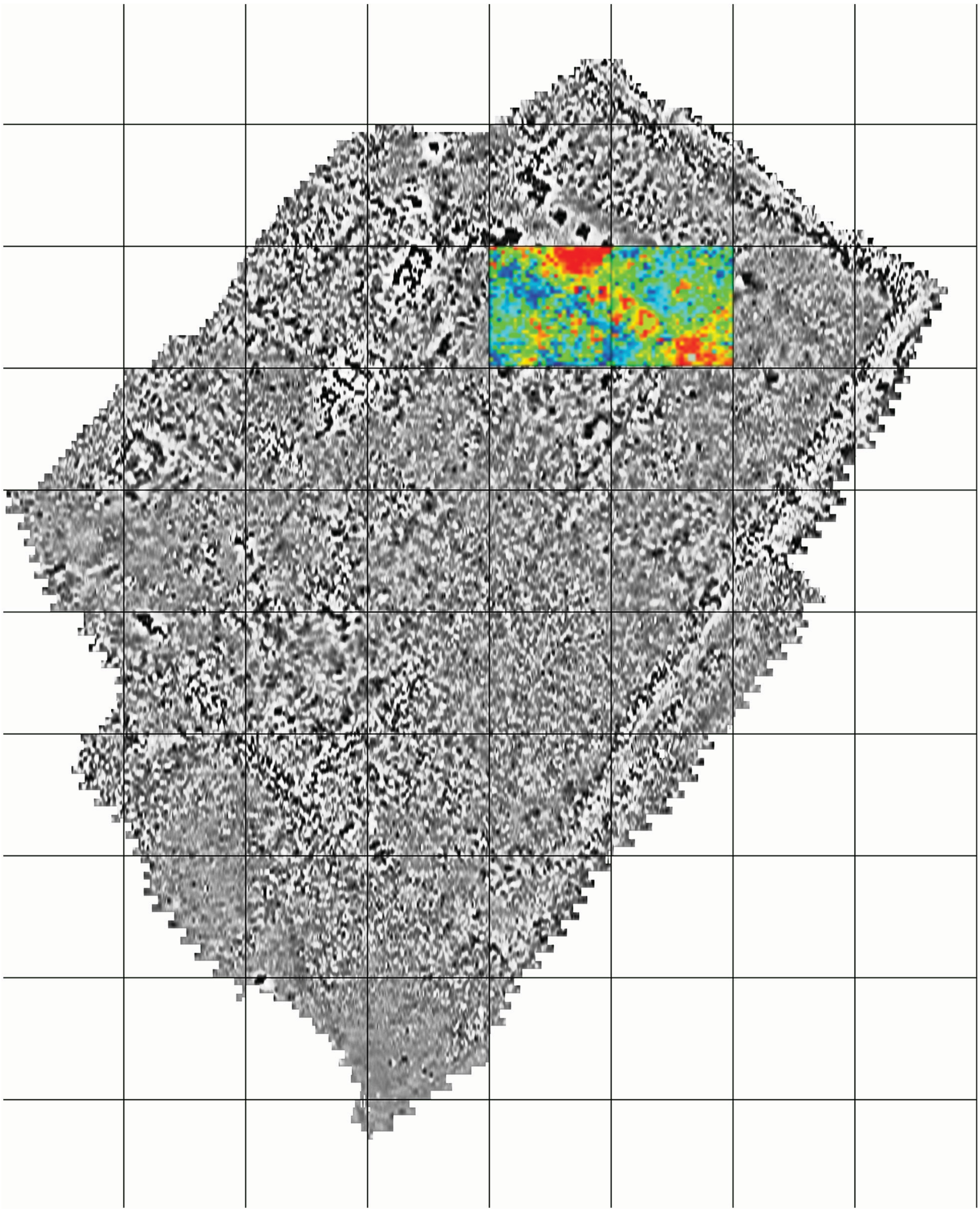
Bansaran Fort Colour – high readings enhanced



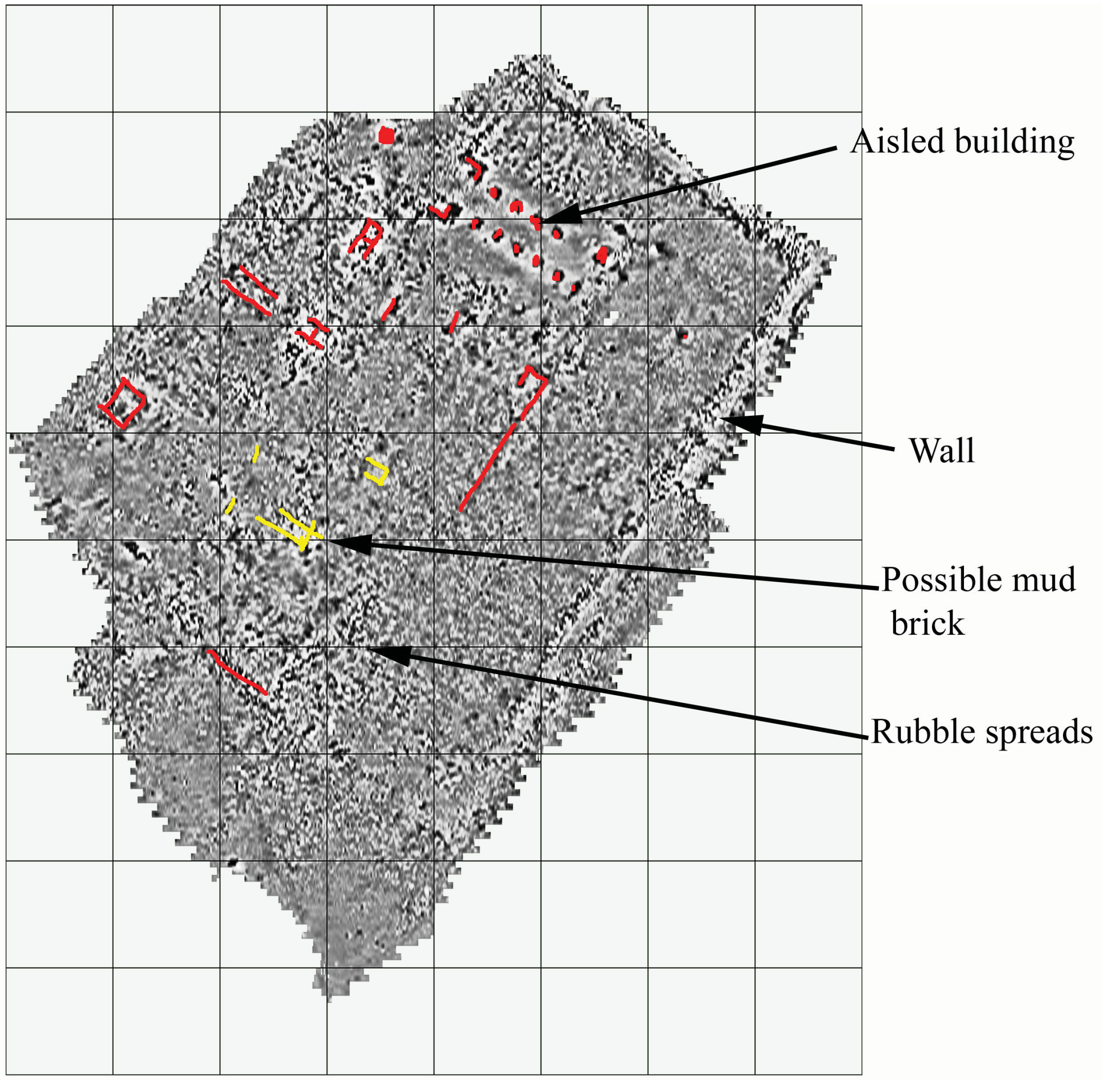
Bansaran Fort   Colour - high readings enhanced



Bansaran Fort   Magnetometery greyscale and resistivity colour



Bansaran Fort   Interpretation



Bansaran Fort   Grid order

				19	20		
		17	16	15	14	13	12
	31	18	7	4	1	10	11
33	32	21	8	5	2	25	26
34	43	22	9	6	3	27	
45	44	23	35	36	29	28	
47	46	25	38	37	30		
	48	49	39	42			
	50	51	40	41			
		53	52				

5 Conclusions

The results this year were not as good as those obtained from fort 4 in the previous season but are more likely to be representative of the results which can normally be expected. Magnetometery has however located areas of interest and has thus provided a guide to enable excavations to be targeted. A caesium type of magnetometer could possibly produce better results on areas where there is little other than mud brick. Otherwise it may end up losing the slight mud brick response amongst the higher readings caused by brick rubble. Resistivity proved to be better than expected although for reasonable results the soil should have been damper. The very low readings obtained in fort 16 indicate that salts in the soil could affect both resistivity and ground penetrating radar results (Conyers 2004 p 50). Ideally it would be best to have high density resistivity surveys of areas of interest before excavation takes place.

Disclaimer

Any magnetometery survey will not be able to detect small features and those, such as graves, which have fills which are magnetically undetectable. Resistivity is affected by the dampness of the soil and this can often be affected by non-archaeological factors such as trees taking moisture from the soil.
In general if geophysics hasn't found anything it does not mean that there is nothing there.
For more detail on this please refer to the English Heritage guidelines by Andrew David.

Dissemination

Please let me know if you wish this to be kept confidential for longer than 6 months from the date of this report as, unless you wish otherwise, I would wish to be able to put it on my website.

6 Geophysical techniques-General notes

Magnetometery

A magnetometer is designed to detect variations in the Earths magnetic field. These variations occur where the field has been changed by factors such as iron pipes and features of archaeological interest. To be detected these features have to have certain properties. They have to contain iron which can be magnetically enhanced by human settlement. The larger the difference the better it can be detected. This enhancement can be by being burnt or it can be caused by microbes which by some process tend to concentrate magnetic material. The two factors necessary are therefore to have iron in the soil and for this to have been changed where human activity (or bacteria) has altered it.

It is therefore very unlikely that features will be detected which are made exclusively of oolitic limestone or chalk as these deposits contain very little iron. Even if there has been a lot of human activity there has just not been the iron there for that activity to enhance. Fortunately the topsoils on chalk soils often have quite strong magnetic characteristics so they can reveal ditches and other features which are cut into the underlying chalk. It is this difference in one area having magnetically enhanced soil and others not having it which is detected. A road surfaced with limestone over an iron rich topsoil would similarly show as that area would have less magnetic enhancement than the surrounding soils.

The theory is all very well but the practicalities are a bit more difficult. The main problem is that the earth has a magnetic field of approximately 47,000 nanoTesla whilst the features which we are seeking to detect have a difference above the background level of 0.5 to 10 nanoTesla. Things are complicated further by the magnetic field then changing during the day by some 30% and by magnetic fields caused by railway trains, electricity pylons and other factors changing as well. In order to seek to overcome these problems the sensors which are used are put in gradiometer mode which means that they are mounted as pairs with one above the other. My equipment has the sensors separated by 1 metre but other manufacturers make equipment where the separation is 0.5 metres. What happens then is that the earths magnetic field is detected by both sensors but only the bottom one also detects most of the reading caused by archaeological features. The readings from the top sensor are automatically deducted from those of the bottom sensor and this gives the reading which should approximate to the reading of the archaeological features.

A magnetometer will detect ditch - like features better than it can detect shallow spreads even of the same volume. The orientation of the survey traverses can be of importance as the processing used to remove striping caused by minor balancing errors in the sensors can also remove some of the data from the archaeological features. It is therefore best to have a grid at an angle to the expected remains rather than being on the same alignment.

Magnetic anomalies are difficult to detect at the best of times and the amount which can be detected declines with the cube of the distance between the anomaly and the sensor. Therefore an anomaly which had a strength of 8 nanoTesla is only read as 2 nanoTesla by a sensor 1 metre away from it. I tend to carry mine with the bottom sensor approx 15cms from the ground surface. The equipment can therefore detect small shallow anomalies or deep ones provided that they are large. Alluvium covering weak archaeological anomalies can therefore make them undetectable. It is possible to obtain equipment which can detect anomalies down to 0.1 nanoTesla but this caesium type equipment is expensive.

Earth Resistance (also known as Resistivity)

This is, in theory, the simplest method as it relies on detecting the electrical resistance of the soil. In practice this is a bit more complex as it has been found that if you just place two probes into the ground then the current between them will change as the ground around the terminals becomes polarised. Then if you then stick the probes into the same area again you get a different reading. This is caused by the contact between the soil and the probes changing each time as different surface areas of grains touch the surface of the probes. To overcome this various arrays of probes have been developed but these rely on the current being sent via one set of probes and read by another set. There are various arrays such as Wenner, Schlumberger, pole- pole and Twin. The most commonly used are twin and pole- pole both of which involve having a pair of remote probes at least 15 metres away from the area being surveyed (assuming 0.5 metres between the probes in the survey area). For twin the remote probes are spaced approx 0.5metres apart and this is increased to over 15metres for pole-pole.

Earth resistance is largely dependent upon the moisture content of the soil as a ditch will often have silts which retain moisture whilst the natural soil around may be more freely draining. Of course the opposite can happen, as rubble filled ditches can be more freely drained than the surrounding soils. Similarly walls tend to be drier and give higher resistance values than the soil around them.

Various pieces of equipment are used which can give between one and four readings at a time. My equipment unfortunately only takes one reading at a time. Usually these have probes which are separated by 0.5 metres which can give a depth of reading of almost 1 metre-depending upon soil conditions and probe array. A 1 metre separation between the probes in the survey area, (the mobile probes), can go even deeper.

This method is good for finding walls but has the drawback of being far slower than magnetometery-about one third of the speed at best. The data often needs less processing than magnetometery data although high pass filtering can be useful to remove the effects of geology on a site, and de-spike used to remove the effect of the occasional poor reading caused by the probes hitting stones on the soil surface. The other main drawback of this method is that as it is greatly influenced by the amount of moisture in the soil. In the summer soil conditions can be too dry to get good results and in the winter the opposite can be the case. Often, however, something shows at most times of the year, it is just that at optimum times the clarity of the features is far better.
Interpreting resistivity results can have its problems which include:-
Walls usually have high resistance but robbed out walls can have low resistance.
Ditches usually have low resistance but if they are filled with rubble or gravel they can have high resistance.

Paved surfaces can resemble broad walls but sometimes the paving ponds groundwater creating a low resistance area.

7 General

The relatively recent availability of automatic data logging, reasonably priced computer memory and processing software has made it possible to survey far larger areas than were previously practicable. Earth resistance survey however still takes a long time to carry out but it is still far quicker than excavation.

8 Further Reading

The best reference book on this is *Seeing Beneath the Soil* by A. J. Clark, 1990. Other books by I Scollar *Archaeological Prospecting and Remote Sensing* Cambridge University Press 1990 and by Gaffney and Gater *Revealing the Buried Past* Tempus, 2003 are also available. . Lawrence Conyers *Ground Penetrating Radar for Archaeology* 2004 gives a good account of that method.
Andrew David's guide *Geophysical survey in archaeological field evaluation* English Heritage Society 1995 gives a good, if now somewhat dated, overview of techniques and what to expect in reports

9 Acknowledgements

We would like to thank the Gorgan Wall research team and Eberhard Sauer of Edinburgh University for asking us to carry out these surveys and for all their support whilst we were in Iran.

10 Compact Disc

This contains this report and the various pictures and data. The data is mainly in Asg. fomat which is used by the ArcheoSurveyor programme. Data has also been saved as XYZ comma separated files in the Export folders as other programmes can use this format. This unprocessed data has been saved both as grids and as composites (i.e. grids joined in the right order) if there is more than one grid.
In the folders you will see sub folders of comps, Export, Graphics, Grids, Comments and Site

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