Water and Cosmology in the Prehistoric Maltese World: Fault Control on the Hydrogeology of Ġgantija, Gozo (Maltese Islands)

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ABSTRACT
The dry limestone geology of the Maltese islands presented a challenging environment to prehistoric communities, who required reliable water sources to support agricultural subsistence. Ġgantija, one of the iconic Maltese Late Neolithic Temples on Gozo, and now a World Heritage Site, was surveyed using Ground Penetrating Radar to reveal a significant line of geological faulting running beneath the megalithic structure. The seepage of water from this fault had major implications for the siting of the monument. This seems to reflect a pattern of situating many of these key sites adjacent to ancient sources of water, as is shown by the close association of two thirds of these sites with toponym evidence for the presence of springs in the medieval period. It is possible that the prehistoric Maltese embraced this natural resource as part of the cosmology of their ritual sites.

Keywords: Temple Culture, Neolithic, Maltese Islands, hydrogeology, remote sensing, ground penetrating radar

1. Introduction: Water Sources and Prehistoric Temples in the Maltese Islands

The so-called Temples of the Maltese Islands (~3600 BC to ~2500 BC) have been objects of antiquarian and more latterly archaeological curiosity for more than two centuries (reviewed in Bonello 1996; Grima 2004b; Malone et al. 2009; Vella 2013). The Temples are remarkable for the size and weight of the blocks (some weigh up to 50 tonnes and are over 6 m in height), the complexity of the structures and the technical skill that would have been needed to transport, design and erect these features (Clark 2004). The makers of the temples were knowledgeable about stone quality, in that they used the harder Coralline Limestone for the outer structure and the softer, easily-carved Globigerina Limestone for the interior, more decorative features, (geological terminology follows Pedley et al. 1976, 2002) and produced a plaster-like substance derived from pounded stone, mixed with water, and used to render the floors and walls of the temples (Evans 1971).

These massive megalithic structures are some of the oldest human-made upstanding structures known, with only tumuli and passage graves of France (e.g. Barnenez and Bougon at 4700 BC) known to be older, and are generally still claimed to be the oldest free-standing monuments in Europe (e.g. Malone et al. 2009; Vella, 2013). They were produced by what, by many accounts (Evans 1971; Malone et al. 2009), were relatively isolated Late Neolithic communities on a group of small, semi-arid, resource-poor islands. Although some recent scholars have emphasized the connectivity of the islands with the outside world (e.g. Robb 2001), there was always a level of risk in reaching the islands. Several hypotheses have been put forward to account for the construction of the Temples (Evans 1959; Stoddart et al. 1993). This paper describes evidence that appears to link a significant proportion of the Late Neolithic Maltese Temples - and particularly the important complex on the Xagħra Plateau on Gozo - to water resources, suggesting that control of access to scarce resources, including water, may have been one of the drivers that led to the foundation of the temples.
The present research was informed by earlier GIS-based work on the different factors in the landscape that may be influencing the location of the 'temples' (Grima 2004a; 2005). One of the factors considered was the presence of fresh-water springs. Medieval and early modern toponyms referring to an 'Għajn' (Maltese for fresh-water spring) were taken as a proxy indicator of the presence and distribution of springs in the prehistoric landscape. When the horizontal distance and the cost-distance from the location of such toponyms and the location of 'temples' were subjected to a Kolmogorov-Smirnov test, 'temples'

were found to be distinctly concentrated in areas nearer to fresh-water springs. This pattern was even more marked for cost-distance than for horizontal distance (Grima 2005).

2. The Geology of the Maltese Islands

2.1 Tectonics and Structural Geology

The Maltese Islands are a group of small, low-lying islands in the central Mediterranean. The combined area of the archipelago is 316 km^2, with a highest point of 253 m at Ta' Dmejrek, on the main island of Malta. The second island of Gozo (Figure 1) has an area of 67 km^2 and a highest point 187 m at Ta' Dbieġi. The archipelago is oriented SE – NW. The islands lie on a submarine shelf that extends from Libya to the southwest to Sicily to the north-east (the Malta-Ragusa Rise: Schembri 1997; Schembri and Lanfranco 1993; Pedley et al 1976; 2002). This shelf is intersected by two main types of fault systems, where the dominant is normal, arranged often as NW – SE graben, and strike-slip structures in a variety of orientations. Gardiner et al. (1995), show the Malta-Ragusa Rise as intersected to the south-west of the islands by the NW – SE oriented Malta Graben (see Gardiner et al., 1995). This graben is separate from, but in the same orientation and possibly associated with the Pantelleria Graben to the north-west. North-west of Gozo, the Malta Shelf (the north-eastern portion of the Malta-Ragusa Rise) is split by the NE – SW oriented North Gozo Graben, forming the south-eastern margin of the Gela Basin, south of Sicily. Malta itself is dominated by northeast – southwest oriented normal faults, arranged as horst and graben structures (the classic example being the Great Fault, or Victoria Lines, along the Binġemma Valley, Malta), dominant in the north of the island. Gozo by contrast has no evidence of such strong structural control, albeit that a strike-slip fault (the Scicli, Ragusa, Irmino Line) is conjectured by Gardiner et al. (1995) and Yellin-Dror (1997) to run south-west to north-east to the north of Gozo. Thus our work (below), that invokes a structural geological influence on water sources on Gozo, is somewhat surprising.

2.2 Stratigraphy

The stratigraphic geology of the Maltese Islands is relatively simple, comprising the following succession (oldest at the base).

Table 1: Stratigraphy of the solid geology of the Maltese Islands (after Pedley et al., 1976).

Age	Name	Thickness (m)	Description	Permeability
Miocene	Upper Coralline Limestone	70-100m	Shallow marine limestone with abundant coral-algal mounds and reefs, commonly altered to micrite and sparite.	Moderate to very high (especially where karstified).
	Greensand	5-15m	friable, glauconitic argillaceous sandstone,	Moderate.
	Blue Clay	20-50 m	Massive to bedded grey/blue shallow marine/offshore calcareous claystones with occasional to abundant marine fossils.	Impermeable, an aquiclude.
	Globigerina Limestone	20-60m	Shallow marine, calcareous mudrocks with abundant fossils, phosphatised hardgrounds, rare chert nodules.	Poor.
Oligocene	Lower Coralline Limestone	100-140m	Shallow marine limestones with spheroidal algal structures, abundant echinoid fossils. Well-cemented.	High, usually a coastal zone aquifer with observed/assumed coastal springs.

Unlike Malta, where the stratigraphy is juxtaposed by normal faults, arranged as graben and half-graben, Gozo is structurally less complex, preserving a more or less layer-cake stratigraphy (House et al., 1961). The centre of Gozo is dominated by the Upper Coralline Limestone, resting on Blue Clay, with the Globigerina Limestone and Lower Coralline Limestone cropping out in coastal locations, where erosion has proceeded low enough in the succession to expose these formations. Our study site is focused on the megalithic structures at Ġgantija, dominated by the Upper Coralline Limestone and Blue Clay.

3. The Hydrogeology of the Maltese Islands

Rainfall in the Maltese Islands is typical for a southern Mediterranean location, with ranges of 80-110 mm per month from October through to January, but limited to 1-5 mm per month from May to August (Chetcuti et al. 1992). Thus aquifer recharge is highly episodic, and with May to September maximum temperatures of 24-32^{0} C, during these months direct evaporation from the ground or rapid transpiration occurs (Newberry, 1968).

Two main aquifers occur. The Lower Coralline Limestone and to a lesser extent the Globigerina Limestone at sea level form a significant aquifer as it is deep and thus holds the winter recharge of freshwater. The second is the Upper Coralline Limestone, which forms a perched aquifer on the Blue Clay. While smaller in volume, the perched aquifer has been of historic importance due to its inland location and proximity to dwellings and farmland (Chetcuti et al., 1992). Springs and slower flowing water seeps occur along the base of the Upper Coralline Limestone where it is in contact with the Blue Clay: this commonly forms a break in slope from steep limestone cliffs to sloping clay soils (commonly in valley floors), which retain their moisture content and are thus ideal for crop-based agriculture (Chetcuti et al, 1992). Such a break of slope is seen running east – west from Santa Verna to Ġgantija on Figure 1). At the base of Upper Coralline Limestone plateaux with a significant area (and thus catchment), such springs flow all year round, with reduced discharge in the late summer and early autumn. Most are now plumbed by farmers, either by direct piping, shallow pumps, storage tanks, or a combination of these, obliterating the original springs: the location of such pumps and tanks can sometimes be a clue as to the original location of springs and seeps. This causes water supply issues for lower ground, as the springs originally fed the *widien* or ephemeral stream-fed valleys found throughout Gozo and Malta: these *widien* also act as storm-water courses. With the tapping of springs, one of the water sources for such *widien* is precluded, while dams have now been built as a secondary water storage mechanism downslope (Haslam, 1989).

4. Location and Methods

The megalithic structures at Ġgantija, Gozo (Figure 1) comprise two hemicircular buildings commonly interpreted as temples, along with upstanding blocks outside and plinths, alcoves and other features within. The so-called "temple" structure is designated as a UNESCO World Heritage Site for its archaeological significance. The two adjacent megalithic buildings that form the core of the temple site at Ġgantija, appear to have been built between 3600 BC and 300 BC (Grima 2004b; Vella 2013). The megalithic platform to the south of the temples has the form of a forecourt and may have taken shape during the first half of the third millennium BC, after which the structures are presumed to have fallen into disuse (*op cit.*) . The temples appear to have remained visible features of the landscape in the centuries that followed, until largely revealed by excavations in the 19th and 20 centuries (Grima 2004b; Vella 2013).

During archaeological surveys for the FRAGSUS (ERC funded project: Fragility and Sustainability in restricted island environments: Adaptation, Culture Change and Collapse in Prehistory) project and the preceding Cambridge Gozo project, the area around the megalithic structures of Ġgantija was surveyed by field walking and topographical measurements. Water sources such as springs were noted both from Ordnance Survey maps (ground-truthed by direct observation), as well as first-hand observation.

Ground penetrating radar (GPR) data was gathered adjacent to the spring locations identified from surface mapping. The GPR data was gathered at different times, using a variety of antennas, showing the consistency of the subsurface features at four locations (see Figure 2). A Mala RAMAC GPR system was used, deploying a 100MHz rough terrain antenna, a 200MHz unshielded antenna and a 250MHz shielded antenna: examples of the results from each antenna are described below.

5. Ground-Based Evidence For Subsurface Water Flow near Ġgantija

Whilst springs were noted in their predicted location, at the break of slope at the base of the Upper Coralline Limestone, an unusual pattern of water seeps, karstic features and farm pumps/storage locations were recorded (Table 2). The importance of springs for the location of the Temples has been noted for the Maltese islands in general (Grima 2004a) from place names and physical springs and more specifically for the Xagħra plateau (Grima et al. 2009), where water is closely associated with monuments and life (Ġgantija and Santa Verna) and death (Brochtorff Xagħra Circle). The toponym 'Tal Għejjun, Maltese for 'the place of springs', further suggests that the area around Ġgantija has long been characterized by springs. North of the study area, but of note is the field directly north of the megalithic stone circle surrounding the Brochtorff Xagħra burial site (Stoddart, 2002) which contains a filled cavity, partly overgrown with a large carob tree, that appears to coincide with a former sink hole. This may be a parallel feature (below, interpreted as a fault) to Ġgantija. The seeps and sinkhole associated with the site are described in Table 2, with Ġgantija providing the natural and archaeological focus for the study. The listing of sites in Table 2 emanate from north to south with the Ġgantija temple site as the focus (Location b. on Figure 2 and in Table 2).

Table 2: Evidence for water-related features near Ġgantija

Notation on Fig.1	Feature	Grid reference	Description
a.	Road and Pavement Collapses, north of Ġgantija		On Triq John Otto Bayer (an E-W oriented road north of Ġgantija) there occurs a N-S line of road and pavement collapses: water emanates from these seeps most of the year, except in late summer and early autumn (Figure 2, location a and Figure 3). The road authorities have repaired the road with numerous tarmac patches and installed some drains, with inspection manholes.
b.	Sinkhole northeast of Ġgantija and Ġgantija Platform		Within the archaeological compound of Ġgantija, ~40 m NE of the Temple is a 20 m diameter sinkhole, filled with broken cobble-sized clasts of Upper Coralline Limestone and with abundant vegetation (asparagus, chicory, geraniums). The infill makes investigation of the feature hazardous, and the lack of flowing water makes this a minor, if significant (due to its position next to the site) feature. The toponym 'TalGħejjun, Maltese for 'the place of springs', further suggests that the area around Ġgantija has long been characterized by springs.
c.	Water Pumps and Storage Tanks, Southeast of Ġgantija		Three pumping houses and associated concrete water tanks (Figure 2, Location c; Figure 4) and adjacent to the southernmost pumphouse, a piped spring (Fig. 5), with abundant vegetation around it. These occur at the break of slope from the Upper Corraline Limestone Plateau to agricultural fields to the southeast of the site, in a north-northwest to south-southeast orientation, south of the tourist platform at Ġgantija, and orientated across the valley towards In-Nuffara.
d.	Line of lush vegetation between Ġgantija and In-Nuffara		South of Ġgantija there occurs an equivalent Upper Coralline Limestone Plateau, In-Nuffara: looking north from here toward Ġgantija and the town of Xagħra, the line of lush vegetation can be observed running south southeast to north northwest, from the Eucalyptus grove on Daħla tal-Għejjun (Location e), to Ġgantija (Locations d and a) and onward to the north (Location b): Figure 7.
e.	Road Subsidence on Triq-il-Tafla (Road 103)		The main road to the south of the site has numerous deformed areas of tarmac that occur in line with the water pumps to the north and the water seeps (described below) to the south. At the time of writing, this roadbed damage had recently been repaired.
f.	Water Seeps and Road Collapses (Farm Track,		A southwest – northeast oriented concrete track named Daħla tal-Għajjun occurs to the south of Ġgantija (Figure 2, Location e). Here, the concrete road is broken by numerous cracks, from which water seeps most of the year (Figure 6): adjacent to the

	South of Ġgantija)		seeps is a farmstead with abundant vegetation, including the only stand of mature Eucalyptus trees in the area.

6. Subsurface Evidence (Ground Penetrating Radar)

At locations (a, b, e, f on Figure 2 and in Table 2) all antennas showed comparable reflections, with bedded stratigraphy to the west of each water seep, sometimes with what is interpreted to be fault drag (where bedding is forced down as a fault moves) of each fault trace (see below for descriptions). We interpret the bedded successions on the western side of the postulated fault to be Globigerina Limestone, from observations of nearby outcrops. The opaque GPR texture to the east of the supposed fault shows few features, so is hard to interpret, but such a pattern is often indicative of clay or similar opaque material. If we had surveyed only one location with the GPR responses shown on Figure 8, or with only one antenna, the results could be put down to chance or an isolated feature. The very similar GPR responses from various locations, separated by tens to hundreds of metres, makes the argument for some disruption in the subsurface geology being highly likely. We interpret this as a normal fault, given the geometry of the reflections.

7. Temples and water in the Maltese Prehistoric landscape

The cost-distance analysis between temples and spring toponyms (and thus springs still active before modern-period water-extraction) suggests that the majority of known temples are located close to water sources (Grima, 2005; Schembri et al. 1993; Schembri, 1997). It must be pointed out that the toponyms postdate the temples by several thousand years, and that there may have been changes in the hydrogeology (for instance of karstic conduits) since the Temple Period. It should be remembered that springs are not the only source of freshwater on Malta: the Tarxien temple (Evans 1971, 116-135) is located some distance from the nearest spring. However, near the Tarxien temple there is dry phreatic conduit (within the bounds of the archaeological enclosure) and two shallow wells, both still containing water and formerly containing prehistoric deposits. Access to water for drinking and agriculture would have been a major limiting factor in prehistoric Malta, as it was in the recent past (Jones & Hunt 1994). Since the best current estimates of past climate (Carroll et al. 2012; Hunt 2015; Gambin et al. 2015) suggest that the Temple Period climate did not have appreciably higher precipitation than the present day, control of permanent water sources, however exercised, would have conferred great prestige and power on those who exercised this. As the Temple Culture developed, this power and prestige, legitimized perhaps through cosmology, may well have provided the impetus that started construction of the temples.

8. Implications for the location of Ġgantija

The likely presence of the fault near Ġgantija has tremendous implications for the choice of location, given both the geological controls on water flow, and the topographic location of the site (Figure 2). A ~N – S fault adjacent to the main Ġgantija site would have ensured the greater reliability of a water supply than that of other alternative water sources available to the prehistoric Maltese. Faults (and their associated fracture systems) are known to be permeable at shallow (tens of metres) depth in bedrock geology (Bense & Person, 2006). Such fault-controlled permeability may differ in various stratigraphic (sub)horizontal aquifer-aquiclude systems, faults being vertical or steeply-inclined geological features. In the fault systems of the Maltese Islands, it is hard to predict how deep water may flow: the abundance of calcium carbonate in the soils and rocks of the area may have caused cementation of faults and fractures from any depth. As such, faults may advance the deep percolation of groundwater, with resultant long transport paths and longevity of water supply (Bense & Person, 2006).

Ġgantija shares its situation on the southern edge of the Xagħra plateau with two nearby important contemporary sites: the highly degraded temple at Santa Verna (Figure 2), and the burial hypogeum known as the Brochtorff Xagħra Circle (Grima et al. 2009). Some of the subsurface cavities of the Brochtorff Xagħra Circle have phreatic features, suggesting that part of the site was originally a karstic conduit. The probable collapsed cave to the north of the Brochtorff Xagħra Circle suggests the possibility of a second N-S trending geological disturbance (sub)-parallel to the fault associated with Ġgantija, though whether this second disturbance (if present) was associated with water is at this point uncertain.

9. Temples in the wider landscape

Study of the landscape context of prehistoric Maltese monuments by Grima (2004a; 2005) has demonstrably shown the systematic importance of a number of factors that were important for their location: access to the sea, access to drinking water and access to workable soils. Due to the highly fragmented and variable landscape, the local topography and surface geology of individual temple sites may vary considerably. In spite of this variety, however, a characteristic that practically all these sites have in common is their proximity to workable soils, drinking water, and embarkation points. It is less clear whether at sites other than Ġgantija there is any evidence for the fault detected in this work. Tarxien Temples and at the nearby Hal Saflieni Hypogeum have yielded evidence of a cultural, possibly even cultic, interest in fault systems and bedding planes that served as natural ground water conduits (Grima 2016a). Further research and re-evaluation of the hydrogeology of all known sites now appears desirable, in light of the results from Ġgantija being presented here, primarily because Grima (2016a) made his assessment of Prehistoric water sources on topographic and soil maps: we now have a further possible control on Maltese hydrogeology that can be critically evaluated. The simple geometry of Globigerina Limestone above Lower Coralline Limestone and of Upper Coralline Limestone/Greensand above Blue Clay certainly controls the location of many springs on the Maltese Islands, but in locations where this hydrogeological stratigraphy cannot explain water sources (such as Ġgantija), then a fault control (or indeed other geological structures such as fractures) may be sought as an explanation. As regards other sites in the Maltese Islands, Haġar Qim appears to have remained unaffected by changes in the landscape, with the exception of sea-level changes (Grima, 2016a). Borġ-in-Nadur is likewise a stable landscape location, but in a more fragile environment affected by variable rainfall and possibly subject to periodic failure (Grima, 2016a): its location is currently being re-assessed, as Grima based his analysis on modern topography/soil maps, as opposed to reconstructions.

Recent work on soils by the FRAGSUS team headed by Charly French and Sean Taylor has shown that key fertile humic soils were very close, at least in the case of Ġgantija and Santa Verna to the temples themselves, reinforcing Grima's argument with new knowledge that has only emerged through the FRAGSUS project (French *et al.,* in prep). Furthermore, the close availability of water would have been crucial for the maintenance of these soils, together with manuring and control of vegetation cover and food crops. The reliable source of water near Ġgantija may have been crucial in the apparent shift of activity during the Tarxien phase (i.e. 2900 to 2350 BC) away from Santa Verna, where there is less evidence for easily accessible subsurface water, despite its similar topographical and geological context.

The combination of these three variables – fertile, workable soils, water and access to peoples beyond the Maltese Islands – most probably fed into the identity and cosmology that framed the Maltese temples. Periodically displayed and consumed agricultural products from the island and exotic items from outside the island were intrinsic to the temple-based activities and the enduring success of their purpose. A deeper understanding of the provision and reliability of water is one key step forward (Stoddart 2002; Stoddart and Malone 2010; 2013). Subsurface cold blooded and water loving creatures – fish, turtles, snails and other invertebrates, lizards, and snakes (Malone 2008) – were also important components of the symbolic landscape that constituted the prehistoric Maltese world.

Evidence from a number of monumental sites suggest that water may have acquired symbolic associations that went beyond its obvious utilitarian value (Stoddart and Malone 2013). In the megalithic complex of Tarxien as well as the underground funerary complex of the Hal Saflieni Hypogeum (Malta), there is evidence for curation of water in a ritual context (Grima 2016a). In both these instances, water percolating along natural bedding planes and fissures in the rock appears to have received considerable attention, as witnessed by small basins that were carefully cut into the rock for the water to collect in, reminiscent of the evidence of ritual activity surrounding water percolating into underground cave environments in southern Italy during the Neolithic (Whitehouse 1992).

At Xagħra (Stoddart 2002; Stoddart and Malone 2010; 2013) another point of interest is the symmetry in how the temples at Santa Verna and Ġgantija are positioned relative to the watershed that exists between them – the respective basins drain at opposite sides of the plateau on the northern coast of Gozo – and the hypogeum's central position, between the temples and sited on the watershed itself (upland areas to the north of Santa Verna and Ġgantija on Figure 2). The apparent concern and interest in 'special' forms of water emanating from the rock at specific points in the ritual landscape may therefore be a component of a wider worldview in which topography, faults, bedding planes and fissures in the rock had cosmological significance, and as argued elsewhere may have been interpreted and deployed to mediate boundaries between different cosmological planes, such as that between the world of the living and the underworld of the dead (Grima 2016b).

The social and economic functions of the prehistoric temples, of which Ġgantija is one of several in the Maltese and Gozitan landscape, still remain to be fully understood. However, some new evidence points strongly to feasting and food consumption activities. It has been proposed (Stoddart et al. 1993, 8; Malone in press) that competitive feasting took place alongside major social gatherings. Evidence includes abundant pottery, including vessels of immense size, as well as hundreds of standard-shaped drinking cups and offering bowls, combined with records of butchered animal bones and burning strengthen this hypothesis. The concentration of this material, and the remarkable scale of the sites, imply large groups of people were involved. Indeed, vessels measuring a metre cubed certainly could provide food or liquid sufficient for hundreds of participants (some vessels may have held up to 3000 litres). The availability of water for such crowds would have been important, as would the year-round irrigation of the food crops in the immediate vicinity that doubtless provided some of the food and watered the stock animals. Thus the siting of Ġgantija – and probably most of these enigmatic monuments in Malta, appears to be associated closely with springs linked to the geological faults in the landscape.

10. Conclusions

In light of the above observations, the fault detected in the vicinity of Ġgantija during the course of the FRAGSUS project through a combination of surface observations and remote sensing, as reported above, is doubly significant.
First, its interruption of the perched aquifer appears to have contributed to a concentration of fresh-water springs in the immediate vicinity, as confirmed by first-hand observation as well as the toponomastic evidence. This circumstance presents obvious advantages for any agricultural community in a semi-arid environment, and would have made this area an immediately more attractive node for activities ranging from settlement to agriculture.
Second, the proximity of the Ġgantija megalithic complex to the source of permanent water raises the possibility of some awareness among the Neolithic builders that this location was somehow distinct and different. In light of the ritual interest in and association with natural sources of water witnessed on other monumental sites, it may be suggested that at Ġgantija too, the presence of water yielded up from the underworld was marked, monumentalised and celebrated, as an intrinsic and indispensable ingredient of a cosmological system on which the islanders' survival ultimately depended.

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Figure Captions

Fig. 1a. View of the megalithic structures at Ġgantija, from north-east to south-west (location of view on Fig. 4), with the entrance projecting from the main structures to the left of the image.

Fig.1b. View from inside the structure at Ġgantija, from north-west to south-east (location and direction of view shown on Fig. 4).

Fig. 2. Location of the sites investigated, included the location of the Maltese Islands in the Mediterranean, Malta and Gozo, and the locations studied (a to f – see text for descriptions).

Fig. 3. Road subsidence and drains (manhole cover in centre) on Triq (road) John Otto Bayer (Location a in Figure 2) where freshwater seeps are common in November to March.

Fig. 4. Aerial image courtesy of Google Earth (permission granted) of Ġgantija, together with the area to the south, where three pumphouses (Location c on Figure 2) and water storage tanks can be observed. The location and direction of the views shown in Fig. 1 are shown.

Fig. 5. Spring associated with area of lush vegetation south of Ġgantija, Location d on Figure 2.

Fig. 6a. Water seepage into the concrete track, Daħla tal-Għajjun, Location e on Figure 2. The Eucalyptus trees can be observed to the right of the photograph.

Fig. 6b. Active water seepage into the concrete track at Location e (Daħla tal-Għajjun) on Figure 2. The Eucalyptus grove is to the left of the image.

Fig. 6c. Water seepage on the concrete track Daħla tal-Għajjun, with road subsidence. The Eucalyptus grove is to the right of the image.

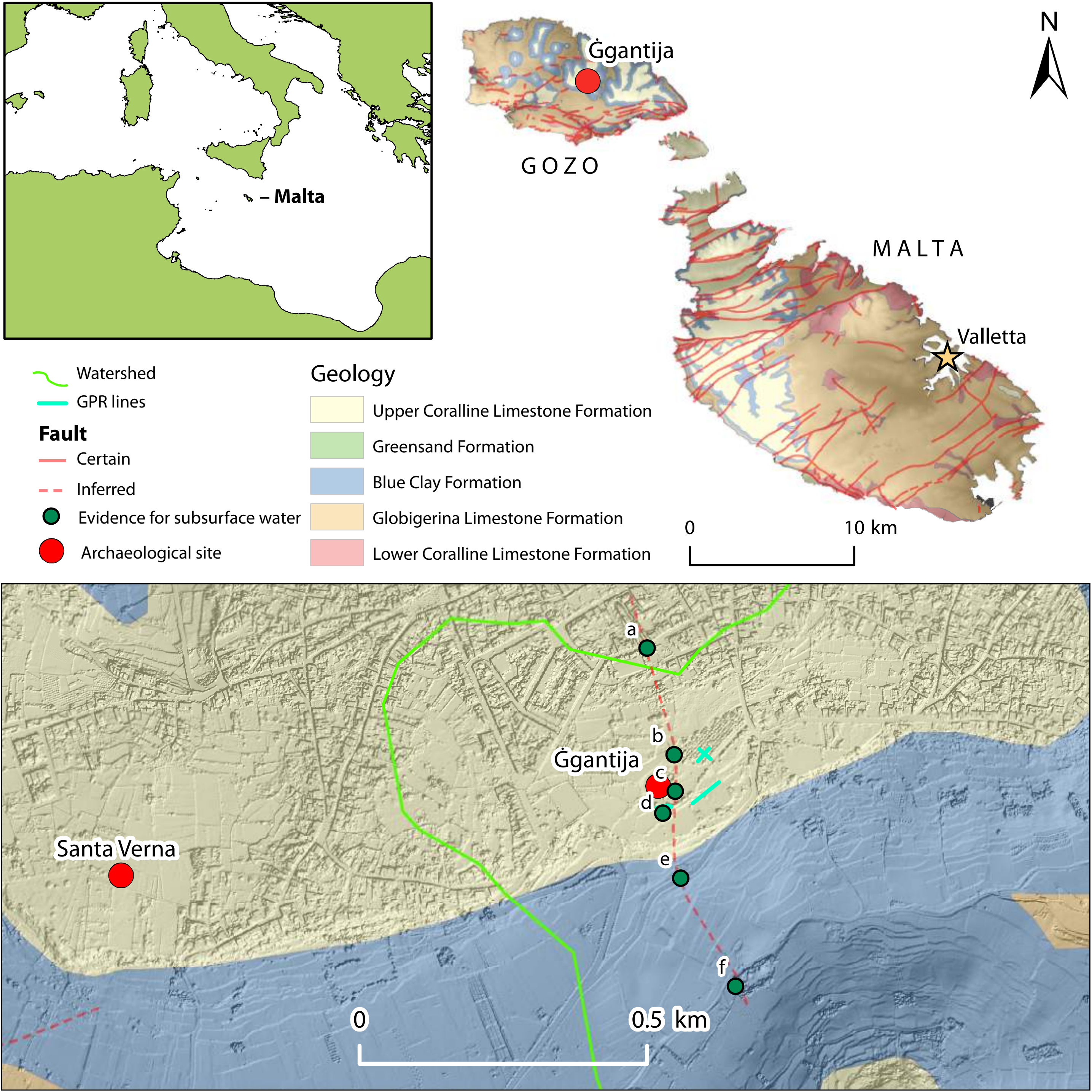
Fig. 7. View from the Bronze Age hilltop settlement of In Nuffara (Location f on Figure 2), facing to the north, with the Eucalyptus trees to the left (west) of the suggested fault line, the areas of lush vegetation south of Ġgantija and the location of Ġgantija on the scarp slope south of Xgahra, all depicted. The view south, to this location, is indicated on Fig. 1b.

Fig. 8a. Raw (uninterpreted) ground penetrating radar profiles across the suggested N-S fault from Xaghra to In Nuffara, east of Ġgantija, Gozo. B, D, E were gathered using 250MHz shielded antennas. C was gathered using a 100MHz unshielded rough terrain antenna, TM Mala Geoscience, Sweden.

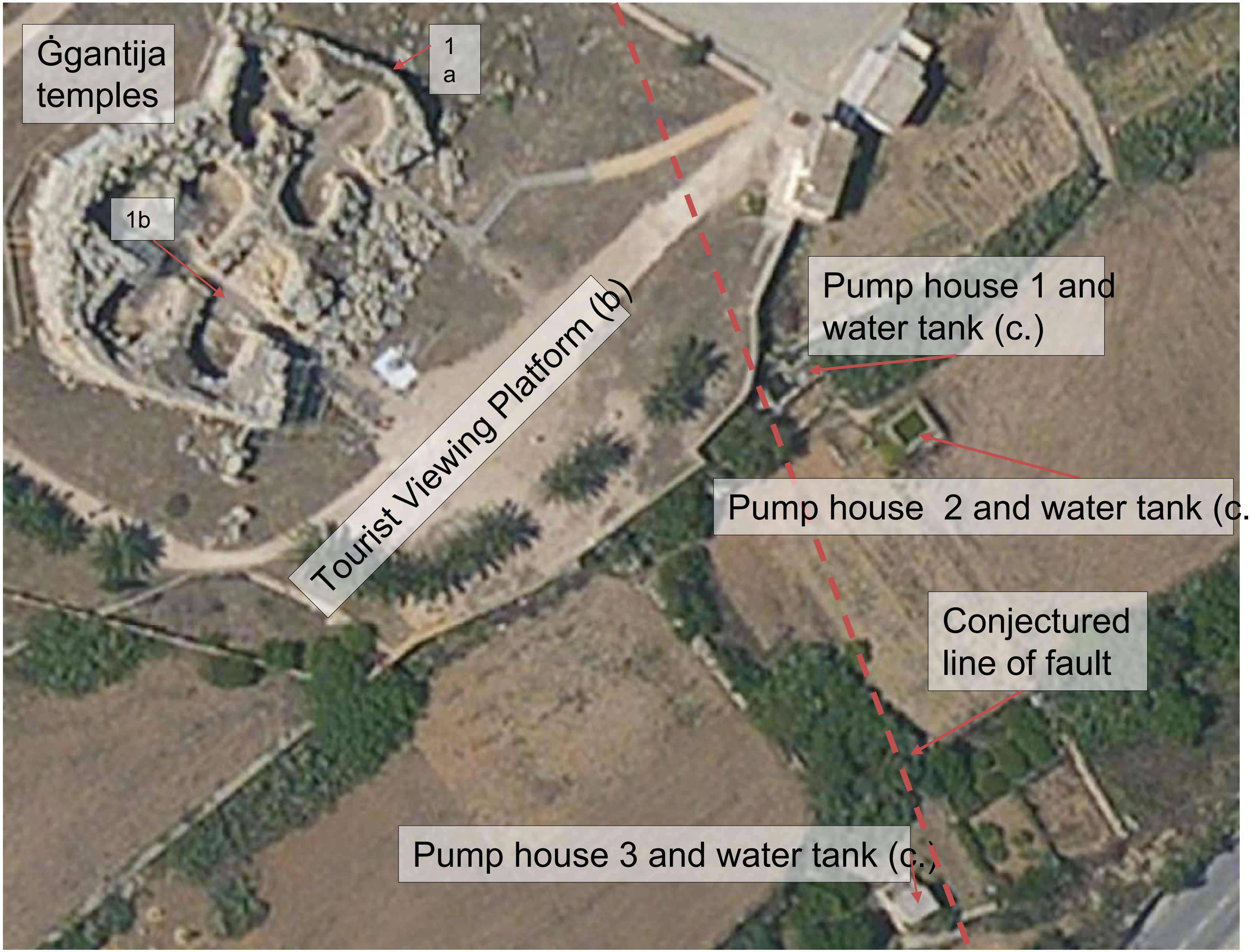
Fig. 8b. Interpretations of the projected fault on the data shown in Fig. 8a.


a

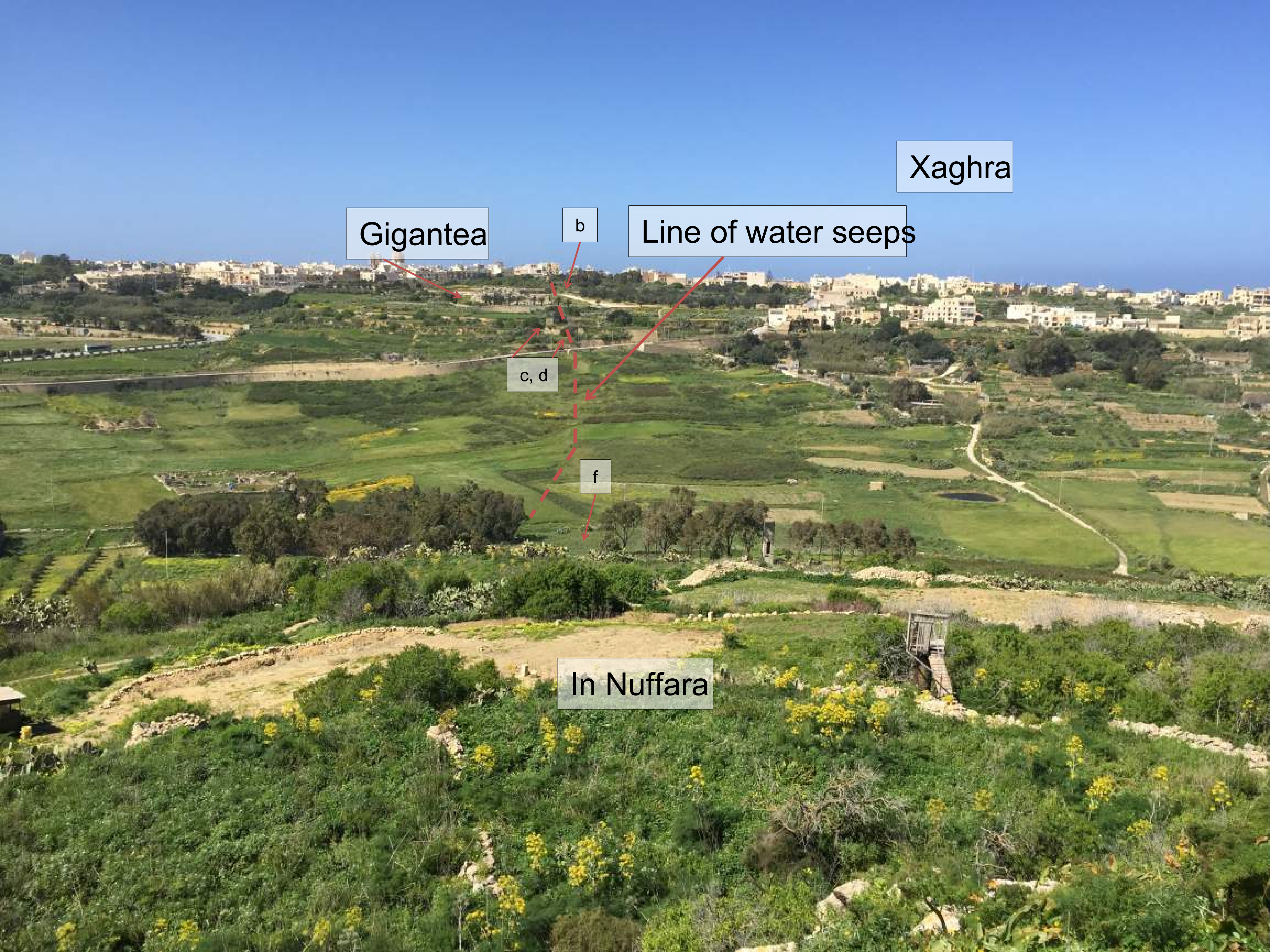

b
In Nuffara
Fig. 7

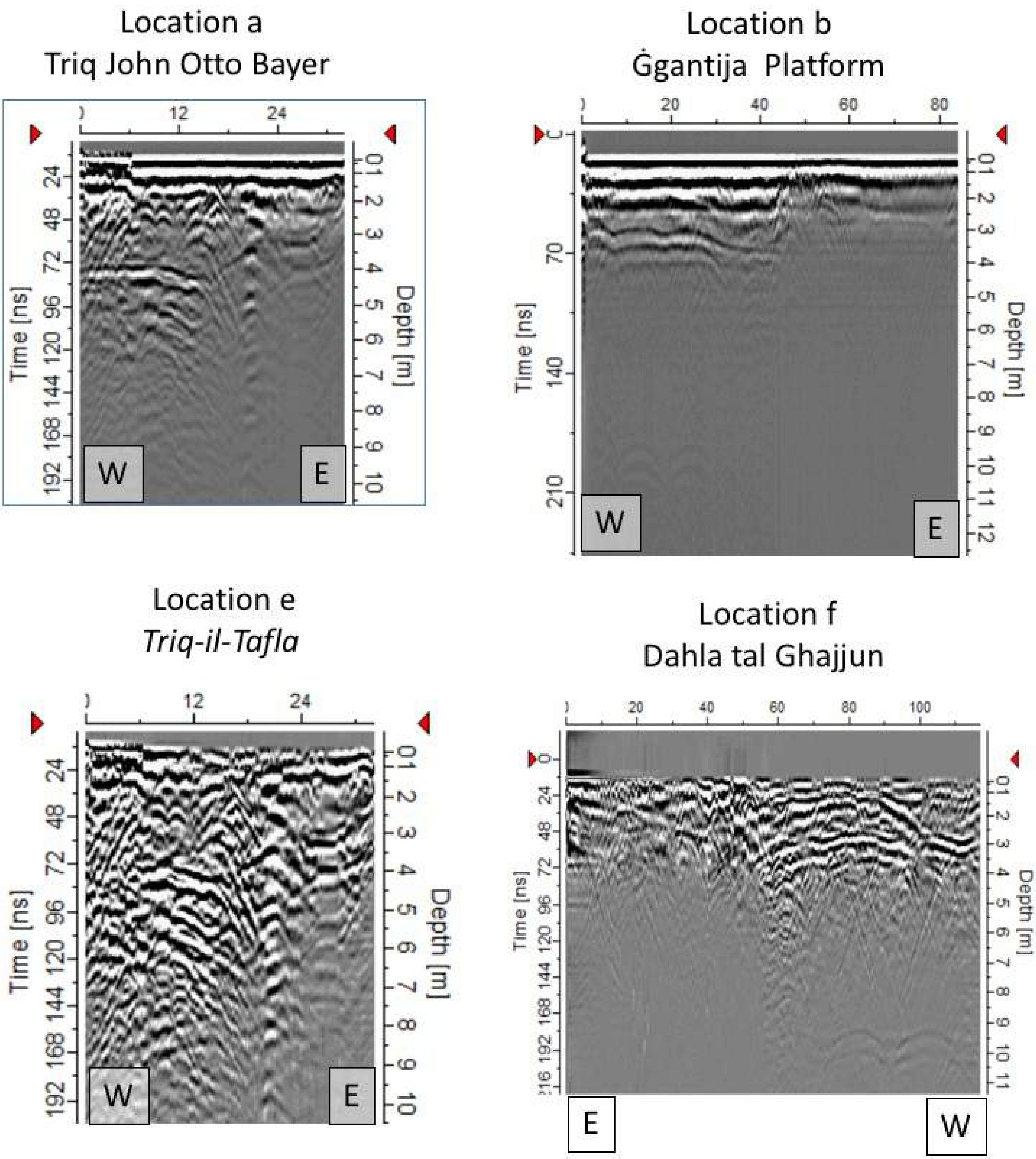


Malta
Ġgantija
GOZO
MALTA
Valletta
N
0
10 km
Watershed
GPR lines
Fault
Certain
Inferred
Evidence for subsurface water
Archaeological site
Geology
Upper Coralline Limestone Formation
Greensand Formation
Blue Clay Formation
Globigerina Limestone Formation
Lower Coralline Limestone Formation
a
b
c
d
e
f
Ġgantija
Santa Verna
0
0.5 km



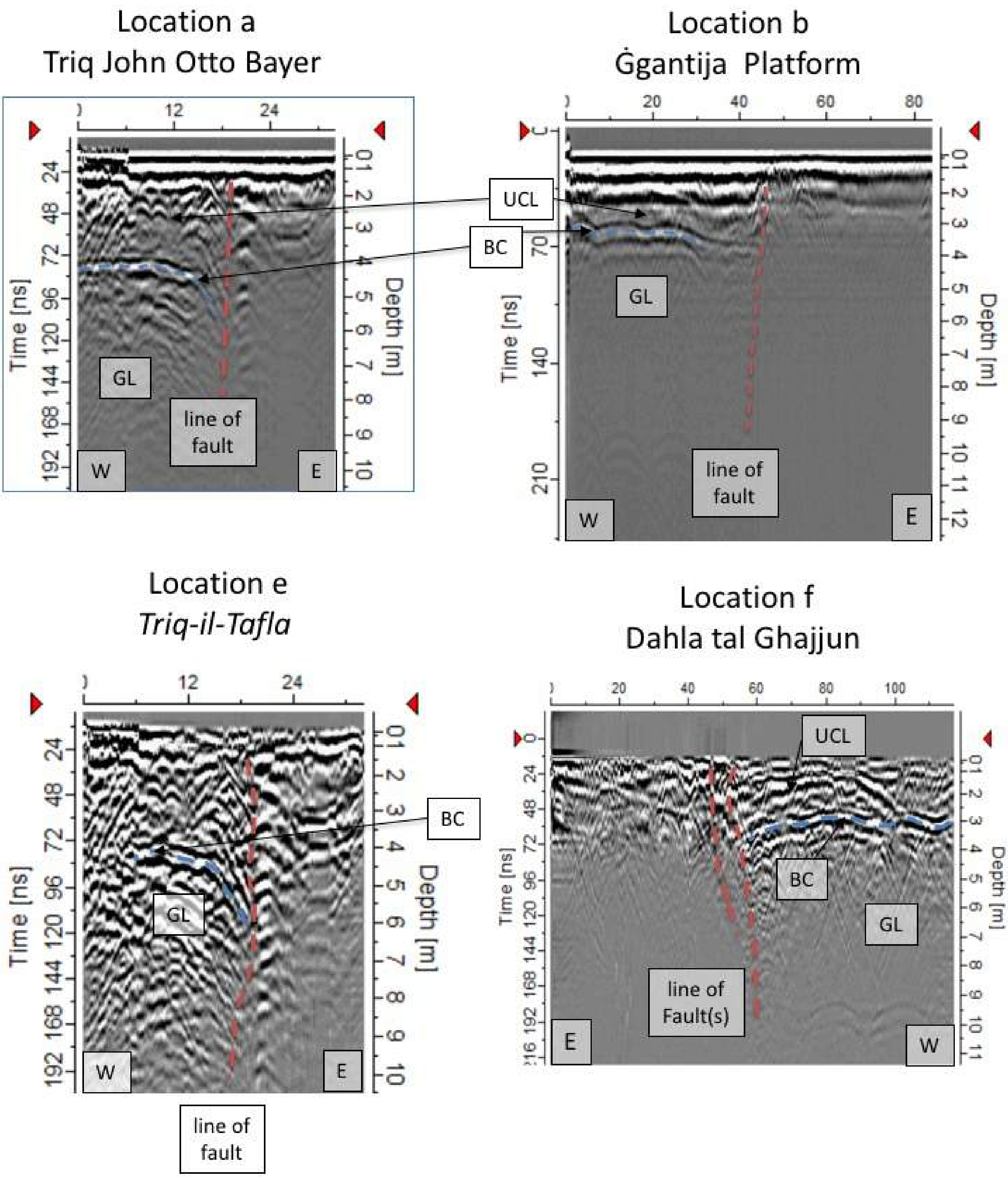
Ġgantija temples
1 a
1b
Tourist Viewing Platform (b)
Pump house 1 and water tank (c.)
Pump house 2 and water tank (c.)
Conjectured line of fault
Pump house 3 and water tank (c.)


Xaghra
Gigantea
b
Line of water seeps
c, d
f
In Nuffara



Location a
Triq John Otto Bayer
Location b
Ġgantija Platform
Location e
Triq-il-Tafla
Location f
Dahla tal Ghajjun
Time [ns]
Depth [m]
W
E

a.



Location a
Triq John Otto Bayer
UCL
BC
GL
line of fault
W
E
Time [ns]
Depth [m]
Location b
Ġgantija Platform
GL
line of fault
W
E
Time [ns]
Depth [m]
Location e
Triq-il-Tafla
BC
GL
W
E
line of fault
Time [ns]
Depth [m]
Location f
Dahla tal Ghajjun
UCL
BC
GL
line of Fault(s)
E
W
Time [ns]
Depth [m]

b.