The geomorphological cave features of Għar il-Friefet

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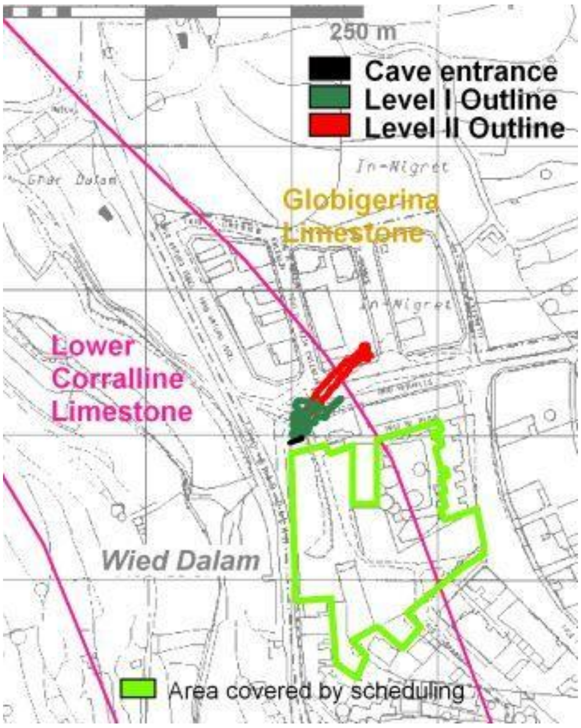
Introduction

Għar il-Friefet is located in the south-eastern part of Malta, on the bank of a dry valley and in close proximity to the well-known cave named Għar Dalam. In July 2003, the Malta Environment and Planning Authority commissioned an ecological and a geological survey of the cave in response to an application for a new residential development in the cave's near vicinity. The main objective of the latter survey involved an assessment of the structural integrity of the cave. Given that there is no public access to the cave, the survey offered the authors a unique opportunity to record the cave's geomorphological features.

Għar il-Friefet is a geomorphological phenomenon as a whole, that evolved through what is known as karstification, i.e. the dissolution of carbonate rock. In this instance, the karstification process resulted in the formation of a cavity with a volume of about 2200 m^3 within the limestones of the Lower Coralline formation. The cave displays specific, interior geomorphological features which contribute to the understanding of how the cave, during its multi-phase evolution, came to develop into its present shape. There is also evidence of past and present fluvial geomorphological processes at work at the land surface especially in the Wied Dalam valley, outside the cave's entrance, which may project a continuation of the Għar il-Friefet cave system across the valley.

***Fig.1:** View of Wied Dalam from cave entrance*



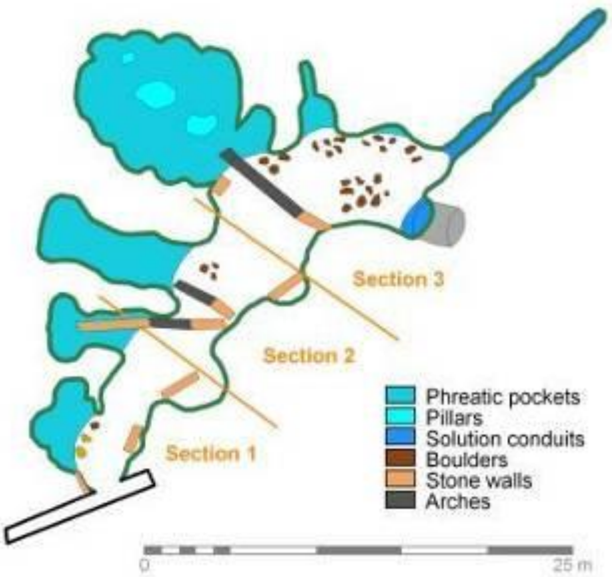
Location and extent of the cave

The cave consists of two levels, an upper and a lower level which are shown as ‘Level I’ ‘Level II’ respectively. Both levels are found within the Lower Coralline Limestone, which outcrops along the bottom of the valley called Wied Dalam. This formation is overlain by the Globigerina Limestone, which outcrops above the latter part of the lower level. The area covered by scheduling, i.e. the area which was deemed to ‘protect’ the cave from development, proved to have been defined outside the actual location of the cave. Instead, the entire cave complex has been covered by residential development and roads.

Map 1: *Map showing location of the cave on survey sheet.*

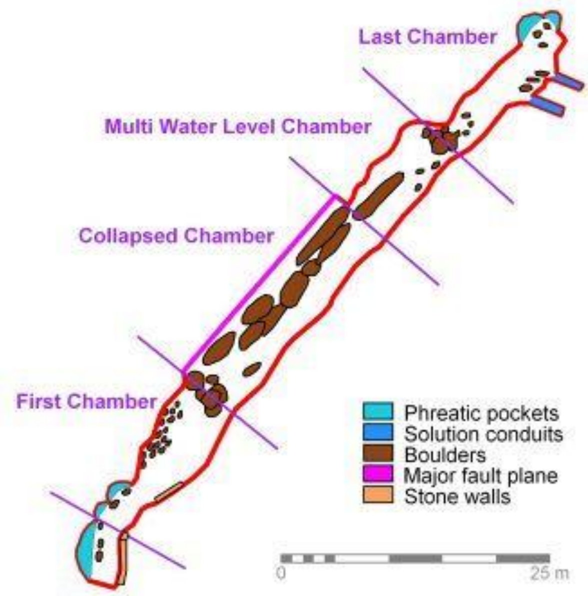
Cave Geometry

Level I, the upper level, consists of one long chamber which has been sub-divided in Sections 1, 2, and 3 for easy reference. The chamber is characterised by several elliptical voids (phreatic pockets), located to the west of the chamber, and ends with an intricate solution conduit made up of several shafts. The latter shafts have a diameter ranging from 35 to 50 cm. A shaft near the entrance of this solution conduit connects to yet another solution conduit which rises practically vertically from the main chamber and ends in the basement of a residence. Stone walls and arches, built to support the residences above show the human intervention inside the cave.



Map 2: *Plan view of Level I, the upper level.*

Level II has a distinct linear shape as it is to a large extent structurally controlled by a fault plane, exposed over a distance of more than 20 metres and with an average height of 8 metres. For easy reference Level II has been divided into different chambers, starting with the ‘First Chamber’. This is followed by the ‘Collapsed Chamber’ which is obvious from the high number of large to very large boulders that cover this part of the cave. This chamber is delineated by the exposed fault face. Then comes the ‘Multi Water Level Chamber’, so called because it has several very clear cut paleo water table notches on one side. Finally, yet also the most difficult part of the cave to access as it is necessary to crawl and squeeze for almost five meters in wet soil, the ‘Last Chamber’ is reached.



Map 3: *Plan view of Level II, the lower level.*

Fig.2: *Vertically rising solution shaft ending in the basement of residence built above the cave. Level I, Section 3.*

Fig.3: *Difficult access to the Last Chamber, Level II.*

Geomorphological features

Phreatic pockets. Għar il-Friefet displays several classic examples of phreatic elliptical pockets, both in Level I and in Level II. At several cross sections, the cave profile has an elliptical shape indicating phreatic (pressure flow) hydrogeological conditions during cave formation. The elliptical shape of these pockets, with an elongated horizontal diameter is attributed to solutional attack at the weakest points of the bedding plane or fracture zone. These elliptical phreatic pockets were formed when the cave was situated below groundwater level and the cavities were filled with water. Under these saturated conditions water flow caused both chemical corrosion of the carbonates and mechanical erosion of the clastic parts of the lithology. Saturated water flow occurred in a direction south-west towards the today's cave entrance. It can be noted that the predominant distribution of elliptical phreatic pockets in the cave are found on the left side of the cave system, both in Level I, Section 1, 2 and 3 and in the Last Chamber of Level II.

Fig.4: *Natural pillar inside phreatic pocket, Level I, Section 3.*

Solution conduits. Also the solution conduits are found in both levels of the cave and were formed during the phreatic phase of the cave proved by their elliptical shape. These steep conduits acted as hydraulic connections between different cave levels. Tectonic occurrences allowed karstification to proceed downwards with the lowering groundwater table by developing deeper cavities. Once the upper part of the system, Level I, fell dry and lost its phreatic regime it changed from saturated lateral water flow into an unsaturated vertical water percolation and/or stream flow respectively. In such vadose conditions solution conduits act as preferential percolation pathways.

An intricate solution conduit with several vertical shafts is found at the far end of Level I, Section 3. Once inside this solution conduit, it was noted that the furthest shaft was blocked by boulders, (either man-filled when the housing development occurred above or boulders collapsed inadvertently into this shaft during excavation). The cave's continuation in this direction has already been removed by surface erosion processes.

Fig.5: *Entrance to solution conduit, Level I, Section 3.*

In the Last Chamber of Level II, a thick layer of wet sediments originates from the two conduits that are found here. Due to the very steep inclination and slippery conditions, it was difficult to explore the conduit system of this Last Chamber in more detail. Whilst most elliptical pockets are on the left of the cave system, the solution conduits are located on the right of the cave. The solution conduits may have been the original source of water brought to the cave.

Pendants. Għar il-Friefet also boasts of two classic examples of pendants found in Level II, respectively in the middle and on the right of the Last Chamber. Pendants are residual pillars of rock between anastomosing channels. There are various ways of how they can develop but in this case these gently rounded, hanging pendants were carved by fast flowing water draining down on both sides of it. The presence of these rounded pendants denotes a phase where groundwater must have been flowing through the subsurface via separate conduits which were later on merged due to progressing karstification by forming the cave cavity. They are thus a demonstration of the evolution of the cave with time.

Fig.6: *Pendant in Last Chamber, Level II.*

Corrosion notches. Corrosion notches are found in Level II on the left of the First Chamber and again on the left side of the Last Chamber. These are commonly formed where in a standing pool water convection carries fresh water to the rock walls at the water surface. A sharp notch is dissolved there, tapering off very steeply below the waterline. These features are indicators for partly vadose conditions in the cave. The distinct notches found in Level II also suggest mixing corrosion at the interface of the karst groundwater and seawater which may have occurred before the uplift of both chambers or seawater level lowering respectively.

Fig.7: *Corrosion notch, First Chamber, Level II.*

Fig.8: *Multi Water Level Chamber, Level II.*

In the Multi Water Level Chamber, there are several corrosional notches that signify paleo-water table levels one above the other very precisely. Also in the Last Chamber there is evidence of such notches on the left side of the chamber. It is of note to remark that during the Quaternary, sea level oscillation occurred in the range of +5 to -80 metres, over comparatively brief time spans.

Speleothems. Speleothems are carbonate dissolution on the one hand and precipitation on the other hand which is still at present an ongoing process. Rainwater infiltrating in the subsurface above the cave percolates through the soil and the fissures of the uppermost part of the limestone. In this way, carbonates are dissolved and transported downwards. When reaching the cave ceiling, the carbonate precipitates by forming speleothems, like small calcite tubes. Particularly the phreatic pockets display an array of speleothems hanging from their ceilings. Calcite ligaments or flowstone, which is a deposit formed by thin films or trickle of water over walls or floors, are found on both sides of the cave in Level I Section 1. Speleothems give clear evidence of vadose conditions during their formation. However, major speleothems, such as stalactites and stalagmites, are not present in the cave. This is due to dry climatic conditions since the vadose cave regime has established with limited percolation water availability.

Fig.9: *Flowstone, Level I, Section I.*

Fluvial deposits. Fluvial deposits are mainly found on the left of Level I Section 1 and on the left of the First Chamber in Level II. During vadose conditions and perhaps after the uplift of the chamber occurred, a stream must have flowed through, bringing with it a bedload of suspended solid matter and pebbles. On the left of these chambers the stream channel has undercut the cave walls and thus encouraged roof collapse so that it is difficult to separate what is the former bedload and what is the result of roof collapse. However, the semi-angular shape of the rocks gives rise to the conclusion that most of them originate from the above ceiling and that they must have been carried only for a short distance and possibly only during intermittent periods of flooding if at all. In the Last Chamber of Level II a thick layer of recent fluvial deposits consisting of clayey material is found. These may originate either from surface material swamped into the cave, or, which is probably the main mechanism, are residuals from clay-rich strata during karstification.

Fig.10: *Recent, thick layer of fluvial deposits, Level II, Last Chamber.*

Breakdown. In practically every part of the cave there is evidence of roof collapse. This is apparent by the jagged surfaces of rupture in the walls and in the roofs of the cave and the angular shape of the piles of rocks found. These shapes are consistent with the cuttings of tectonical joints and ruptures in the carbonate rock. Mechanical failure within or between rock beds and weak joints are normally attributed to breakdown in most caves leading to further cave genesis. However, several processes may explain roof breakdown experienced at Għar il-Friefet.

The uplift and water level decline respectively would have drained the cave system and removed the buoyant force of water giving rise to mechanical failure. Additionally, stream erosion during subsequent vadose conditions, and the ongoing karstification by seepage waters would also have led to the weakening of the roof stability. Forming part of the block faulting, tectonic processes would also have caused the major falls that are found at the very end of the First Chamber, throughout the Collapsed Chamber and at the entrance to the Last Chamber.

It is not difficult to distinguish between boulders resulting from roof collapse through mechanical failure and the fault breccia caused by major tectonic movements. Two typical samples of the rocks of the former type measure 44 cm x 54 cm x 80 cm and 35 cm x 54 cm x 70 cm, resulting in a volume of 0.19 m^3 and 0.13 m^3 respectively. The boulders caused by major tectonic movements are on average much larger. Two typical samples measure 1.50m x 2.00 m x 2.50 m and 1.70 m x 1.40 m x 1.40 m respectively, corresponding to a volume of 7.50 m^3 and 3.33 m^3 respectively. The boulders of the Collapsed Chamber are again of a much higher magnitude, with one particular monoclinal block estimated at 60 m^3.

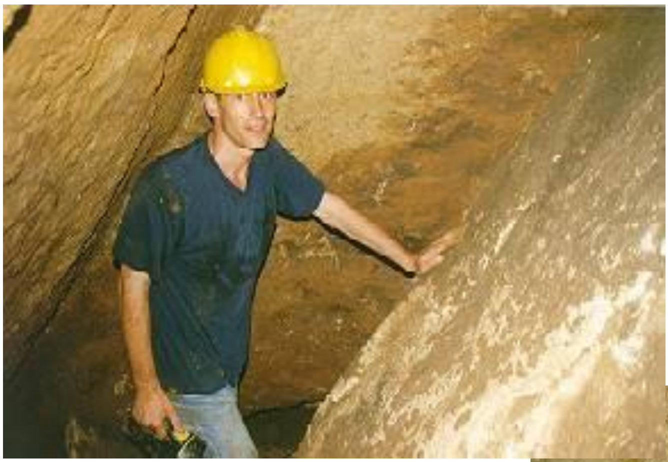


Fig.11: *Fault plane (left) and massive monoclinal block, estimated at 60m^3 (right), Collapsed Chamber, Level II.*

Fig.12: *Fault breccia, First Chamber, Level II.*

Further reading

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