FIELD TRIP TO GROTTA GIGANTE AND TIMAVO SPRINGS
JUNE 8 2016, 15:00-19:30

1. General information

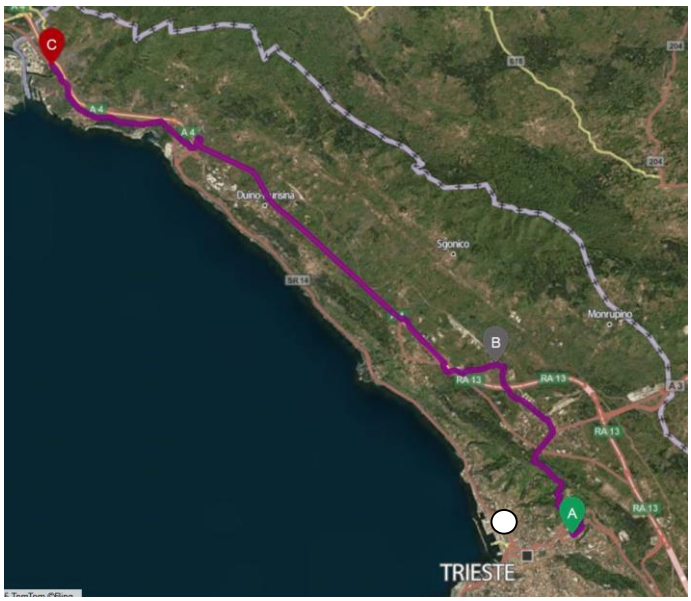

Figure 1 Map of the itinerary from Trieste University (A) to the Grotta Gigante cave, Borgo Grotta Gigante (B) and to the mouths of the underground river Timavo (C). The trip will end downtown in Piazza Oberdan (white dot)

The field trip will start at 15.00 at the Trieste University (venue of meeting) and will end at approximately 19.30 in central Trieste in Piazza Oberdan.

The distance is approximately 30 km one-way; the travel by bus will last less than an hour (one-way), according to the itinerary of figure 1.

The sole difficulties are related to the possibly slippery steps and the permanence for 1 hour at 11 degrees with high humidity in the cave, and to the crossing of a main road nearby the Timavo river mouths.

2. Field Trip Summary

The field trip will cross the Carso/Karst Plateau, from which the geological term “karstic”, related to the dissolution phenomena in carbonatic rock, took its origin. The field trip follows a part of the course of the underground river that flows for about 40 km underground, hidden by the white rocks and the karstic scrub of the Karst: the Timavo River.

Its effective path is still unknown: it disappears underground in the Škocjan Caves, flows at a level of about 8 m above sea level,and it can be seen at the bottom of some of the more than 2000 caves known in the so-called “Classic Karst”. The pendulums of Grotta Gigante and the collocated GPS station sense the high stands of the underground river through characteristic tilt and displacement, respectively. The underground river appears again through four springs atSan Giovanni near Duino, takes an overland course 2 km long, and outflows in the Gulf of Panzano (part of the Gulf of Trieste), 3 kilometres (2 mi) southeast of Monfalcone, into the Adriatic.

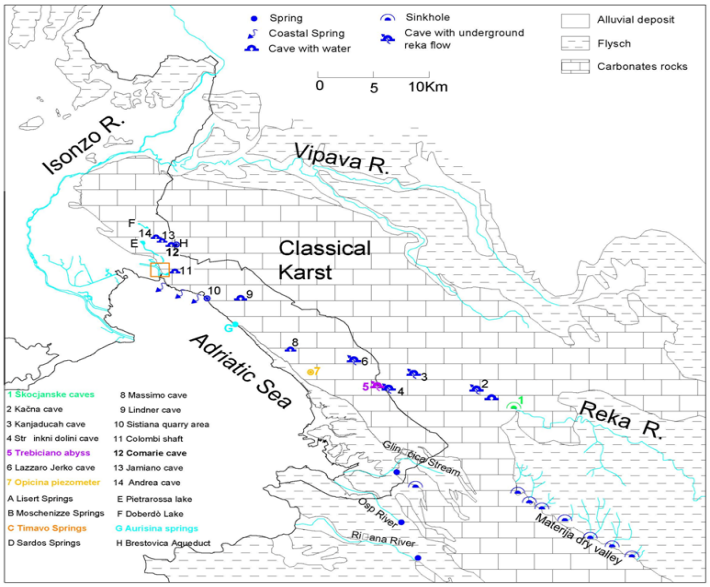

Figure 2 Map of the Karst showing the position of the caves in which the Timavo river is monitored. The increase in water level after strong rainfalls reaches 50 m.

3. The Grotta Gigante cave

The Grotta Gigante cave, situated near Borgo Grotta Gigante, in the municipality of Sgonico (Trieste), is the most reknown among the caves in the italian part of the Classic Karst, the other being in Slovenian territory (Postojna, Škocjan, among the others).

Open to the public since more than 100 years, the exceptionally large size of its main underground chamber enabled it to enter the Guinness Book of Records as the world's largest show cave in 1995.

3.1. Geological aspects of Karst and Grotta Gigante cave

Approximately 10 million years ago, the rivers flowing on calcareous surfaces gradually began to widen and deepen the fractures in the rocks by a process of dissolution. The surface waterways disappeared underground, creating a complex underground water network. The water erosion inside the rocks gave origin to the cave. Approximately 3 million years ago the prehistoric Timavo river abandoned the Grotta Gigante, as it had dug a deeper way throughout the cavity, which looked very different from what we see today.

The Karst has many sinkholes, which are collapsed caves, and which are well seen in digital terrain models.

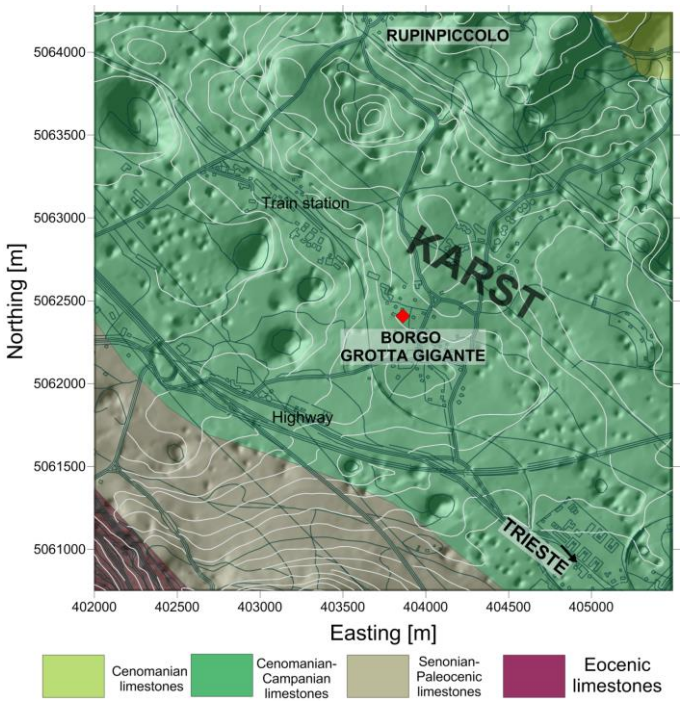

Figure 3 Digital elevation model close to the Grotta Gigante cave. The many sinkholes are well seen, and which are presumably aligned with the flow direction of the underground river.

The phase of concretioning had already started with formation of the cave, and is still going on. The rainwater percolates throughout the limestone and by chemical reaction, melts the calcium carbonate. Drop by drop, during the course of millions of years, it is re-deposited inside the cave, giving origin to stalactites descending from the vault, stalagmites rising from the bottom, columns, created by the fusion of a stalactite with the stalagmite below, and calcium flows, which cover large and small rocks in limestone. Their growth, due to the depositing of calcium carbonate, called calcite, is estimated to be 1 millimeter every 15-20 years.

The special feature of these stalagmites is their shape: a “stack of dishes” and a “palm tree”. These highly original shapes are due to water drops falling from above, which expand as they reach the ground, thus covering a large surface. The variation in the quantity of water, in the course of thousands of years, has led to the differences in the diameter of the dishes.

The different colors you can see on the walls and concretions are due to the presence of mineral salts. White and grey are characteristic of pure calcite, whereas all shades of red, ochre and brown are characteristic of iron oxides and aluminum salts.

Figure 4 A view of the cave pathway.

The cave can be accessed by a downhill tunnel; the flights of steps lead down to the main chamber, which is 98,50 meters high, 76,30 meters wide and 167,60 meters long (total volume 365.000 m^3). The floor and the ceiling are covered with stalactites, stalagmites and other speleothems of all sizes,

among which it is worth mentioning the most impressive one, Colonna Ruggero that is 12 meters in height.

The Grotta Gigante is also an important underground scientific research centre (Pendulums, Seismographic Station, Archaeological excavations, Flora and fauna research centers, Muon radiography, Radon monitoring) and surface scientific research centre (Climatological Observatory of the Karst, Epigean station for the measurement of Karst dissolution). The OGS head quarters and main buildings are located just above the Grotta Gigante cave. The Broad Band seismograph station in the cave links through internet connection directly to the Institute.

3.2 The Geodetic aspects of the cave

The Grotta Gigante cave can be seen as a tangible illustration of geodetic measurements in underground exploration. The first is the fact that underground mass changes alter the Earth gravitational acceleration. The gravity field is reduced by up to 1.5 mGal, which corresponds very well to the expectations given by the laser scan survey of its inside. In Figure 5 the free air and Bouguer anomaly are shown, and the more negative values of the gravity field over the cave are well seen (1.5 mgal). The measurement precision of traditional gravimeters is better than hundred times smaller than the signal of the cave.

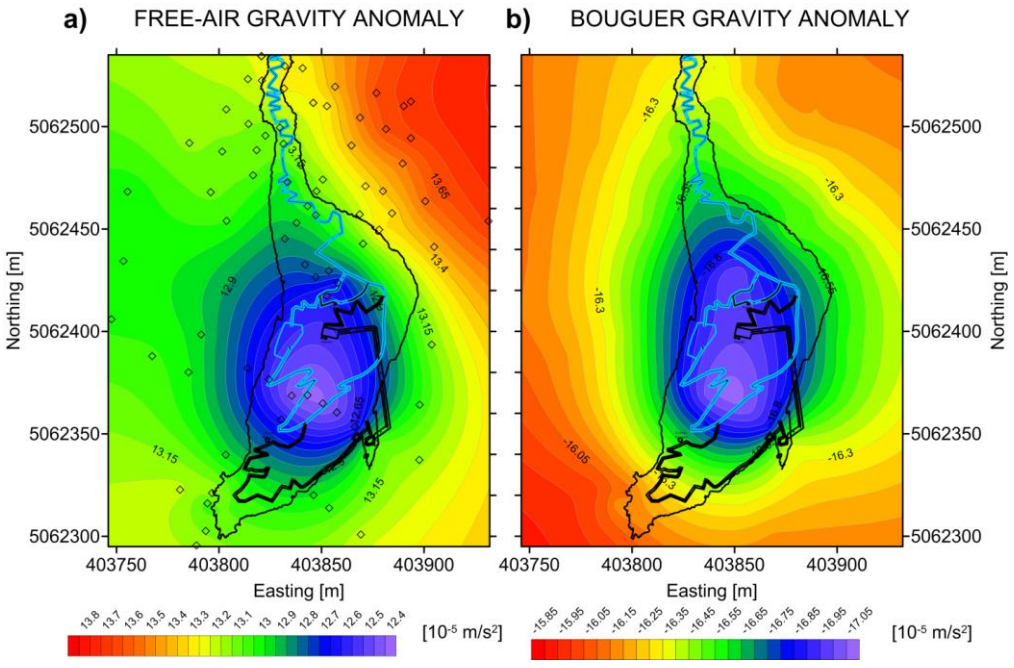

Figure 5 Free Air and Bouguer gravity field anomaly of the Grotta Gigante cave. The Gravity field diminishes due to the missing mass of the cave. Circles: measured gravity points. Black: outline of the cave. Blue line: pathway inside the cave done during the visit.

The second is that underground water flows as those of the Timavo River, shifting great amounts of water at a level 280 m below the cave, deform the overlying rocks in a measurable way, demonstrating that geodetic observations can be used to sense the presence of underground water flows. The cave houses a couple of large scale horizontal pendulums that are mounted on the bottom and top of the cave, as shown in Figure 6. During the visit you will see plastic tubes hanging from the top of the cave, seen also in Figure 4. These are the protection of the upper wire holding the horizontal pendulum. The top mounting is dislocated from the lower mounting by 1 m to give the pendulum the necessary tilting to be able to be sensitive to tilt in the direction orthogonal to the dislocation. This way the pendulum senses either shear between upper and lower mounting or tilting of the entire cave as a whole. The two signals cannot be distinguished.

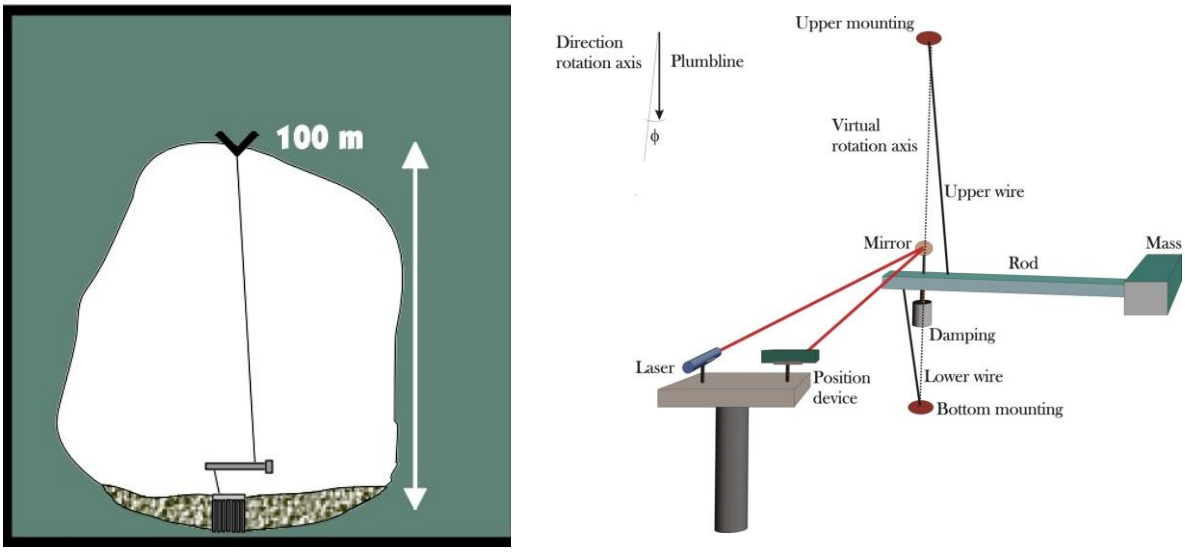

Figure 6 Schematic drawing of the Marussi Horizontal Pendulums and their mounting in the cave.

The floods of the Timavo River can be quantified by the flow rate of the Reka River entering the Karst system at the Skocjan cave in Slovenia and by measuring the flow of water exiting the Karst system at San Giovanni in Tuba near Duino. In San Giovanni the highest flow rate was measured in 1972 and reached 158 m^3/s. The tiltmeters generally tilt towards SW and return back to their original position during the floods in the time frame of about 7 days. A typical movement in response to a flood is shown in the cartoon of Figure 7.

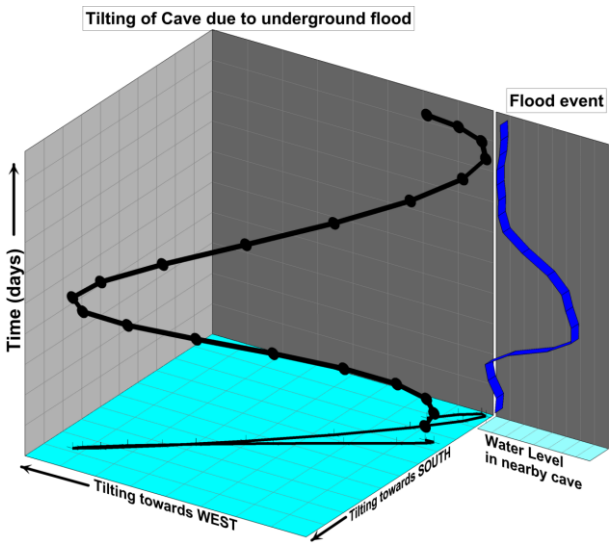

Figure 7 Characteristic movement of the water induced by tilting

4. The Mouths of the Timavo river

The Timavo River flows underground at the base of the Karst for at least 40 km of its 90 km journey to the sea. It comes to the surface near the village of San Giovanni di Duino with four mouths/springs and a few miles later it outflows into the Gulf of Trieste, in the Adriatic Sea. It receives much of its water through subterranean flow from the Reka River (Slovenia), but tracer studies have shown that other sinking rivers, Vipava, Soča, and Raša also contribute. From modelling results, the Timavo is believed to receive one third of its flow from the Reka and two-thirds of its flow from infiltration of precipitation into the Karst Plateau, and to a lesser extent from the other sinking river sources. As it leaves the ground at San Giovanni, it is a fast flowing powerful body of water that seemed to indicate the presence of the gods, and shrines to Diomedes, Hercules, Saturn, Silvanus and Spes Augusta were placed here. The area has been known since pre-historic times, and these springs (the so-called Risorgive), of great naturalistic and historical importance, were once held to be sacred as confirmed by the Roman stone inscription dedicated to the Nume Timavo. Ancient historians and poets such as Livy, Strabo, and Virgil described and mentioned its seven (at those times) mouths. Here stands the church of San Giovanni in Tuba, a rare example of Gothic architecture on the Carso, dating back to the XVth century in its present form, but with much older origins as the Vth century mosaics, which can be seen within, can testify. In the apse, behind the altar, there can be seen the excavations which have brought to light the remains of an early-Christian basilica.

Figure 8 View of the church San Giovanni in Tuba from outside.

Figure 9 The beautiful romanic lateral portal can be admired and the artistic ancient building techniques with local stones.

The church has been built around the smaller more ancient rests, the original pieces of stones dating back to Roman times. The location is characterized by the presence of the underground water, which often penetrates into the church floor from below. The effect is the vegetation that characterizes the older and lower lying church rests, which sometimes are covered with water.

Figure 10 illustrates this more ancient church of which the floor mosaic and some stone walls remained. The interesting half reliefs exposed on the wall are maybe medieval. These are seen in Figure 10.

Figure 10 Rests of the older original stone walls and some artistic sculptures from the time. The sculptures seem to show two persons of different origin.

The first of the Timavo springs (Figure 10) lies near to the church but the thick undergrowth prevents a clear view of the other two branches of the river which are also nearby. These all join together before arriving at the sea, only 2 km away and form a quite big river, as can be seen in the Figure.

Figure 11 The first of the Timavo River mouths. The arrow shows the flow direction of the water. The water level is a few meters above sea level.

Figure 12 The second of the Timavo River mouths.

Figure 13 The Timavo river on its way downwards to the Adriatic sea, output from the base of the Karst at San Giovanni collecting the outpour from the three Timavo mouths.

One hundred metres uphill and towards the left, is the mansio a staging post during the Imperial period along an important road. The archaeological area is located inside the park of the aquaeduct "Randaccio", providing water to the city of Trieste.The excavations, conducted in the '80s and '90s of the last century, brought only partially to light (1300 sqm) the ancient building, lying along the slope of the Karstic hills and accordingly divided into three different level, with 40 rooms.

The life of the complex stretches from the beginning of the 1st centurty BC to the 3rd/4th century AD; during the Augustan epoch (end 1st century BC) many rooms were paved with luxurious mosacis, in the last phases the mansio/villa was converted to productive purposes.

A bit further up of it there are traces of the ancient Roman road which led from Aquileia over the Carso to Trieste.

Figure 14 View of the Mansio, a building active in Roman times with 40 rooms and luxurious mosaics.

5. Practical Information

Personal medication:

If you suffer a medical condition, (e.g. diabetes, hay fever or other allergies) please bring your own medical items with you. If you are on any special medication please make sure you have a spare prescription with you in case of loss or damage. Any relevant medical conditions should also be known to the secretary in advance. Field trip leaders cannot carry personal medical drugs or equipment, so please make sure you are able to bring and carry your own.

Road safety:

When driving and crossing roads, attendees should always be aware of traffic signs and the local traffic regulations. Always wear a seatbelt when in transport.

Cave visit:

The temperature inside the cave is 11°C and the path (safe and comfortable) goes 100 meters deep. We suggest to wear a sweater and gym-shoes. Taking pictures is not allowed down the stairs (it's better to pay attention to the wet steps!), but when you cross the Great Cavern at the bottom and when you climb stairs back it's allowed to take pictures and videos (no tripods please). Small pets are allowed if brought in appropriate bag.

Starting point: University of Trieste, outside Conference venue, (Piazzale Europa 1, Trieste), 8 June 2016, at 15:00

End point: Piazza Oberdan, Trieste, 8 June 2016, approximately 19:30

Dinner: Forst restaurant, Via Galatti 11,Trieste, just off Piazza Oberdan. Starting 20:00

6. Participating Institutions

The tour will be guided by members of the following institutions:

University of Trieste
Institute of Oceanography and Applied Geophysics
Karst Research Institute, Research Centre of the Slovenian Academy of Sciences and Arts
Grotta Gigante Touristic cave, Società Alpina delle Giulie – Sezione di Trieste del C.A.I.
Soprintendenza Archeologica del Friuli Venezia Giulia, Ministero dei beni e delle attività culturali e del turismo

7. Acknowledgements

We thank the Parrocchia San Marco Evangelista for access to the Basilica San Giovanni in Tuba

8. Further information and references from which material was extracted

General information:
http://www.grottagigante.it/
https://en.wikipedia.org/wiki/San_Giovanni_in_Tuba
https://en.wikipedia.org/wiki/Timavo
http://www.marecarso.it/da_vedere_timavo.htm (in Italian)
http://www.marecarso.it/da_vedere_sgiovanni.htm (in Italian)

List of Latin references to the Timavo springs and location:
http://www.liceopetrarcats.it/old_site/sperimentazione/sitocarso/timavo.htm#Miti e culti del Timavo

Recent publications regarding geodetic measurements of the Grotta Gigante:
Pivetta T., Braitenberg C. (2015). Laser-scan and gravity joint investigation for subsurface cavity exploration - The Grotta Gigante benchmark. Geophysics, Vol. 80, No. 4, B83 - B94, doi: 10.1190/GEO2014-0601.1

Braitenberg C., Sampietro D., Pivetta T., Zuliani D., Barbagallo A., Fabris P., Rossi L., Fabbri J., Mansi A. H. (2015). Gravity for detecting caves: Airborne and terrestrial simulations based on a comprehensive karstic cave benchmark. Pure and Applied Geophysics, doi: 10.1007/s00024-015-1182-y, 1-22

Braitenberg C., Nagy I. (2014). Illustrating the superposition of signals recorded by the Grotta Gigante pendulums with musical analogues. Acta Carsologica, 43/1, 139-147