Searching for ancient pits and voids at the Ouels Mine (Castel-Minier, France) by using geophysical methods

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Abstract

A map from the early twentieth century shows the relative positions of several entrances to the Ouels mining area, but it is not fully georeferenced. Some mines have been reported in the south-western part of the map and the archaeological team would like to confirm these locations. To this end, a geophysical prospection campaign was organised, which included electrical resistivity tomography (ERT) and microgravimetric profiling over the area of interest. Several anomalies were identified. Two of them, in the north, are very likely to be related to voids (robbed area), since gravimetric and electrical anomalies are superimposed. Conversely, in the southern part, where microgravimetric anomalies occur, there are no electrical anomalies, but cavities could be electrically shielded by the overburden. An additional deeper ERT shows a new but small resistivity anomaly in the upper slope, outside the area preliminarily surveyed. Although not all of the gravimetric anomalies are confirmed by the ERT, the geophysics ultimately proved very effective in supporting at least some archaeological targets in the northern part of the prospect.

1. Introduction

1.1. Archaeological context

Mining archaeology " a continuouly increasing but still emerging branch of archaeology." It suffers mainly from the difficulty of accessing the underground. Entrances to galleries and shafts are often blocked. It takes a lot of time and effort for the researcher to get to the areas of interest, with the risk of ending up in collapsed and scientifically unusable areas. The development of prospective methods that allow the volume of existing cavities to be assessed before the first shovel is used, as well as the extension of the discovery to be treated, therefore appears to be a major challenge for this discipline. It is a question of making it possible to study the mining systems that provide the raw material for all metallurgy, whatever the period under

consideration. The example we are developing here is no exception to the rule, but is firmly in line with a methodological framework for future archaeological interventions.

The Ouels mining network in Castel-Minier was the subject of several more or less intensive mining operations between the 10th and 20th centuries. It is located near Aulus-les-Bains in the department of Ariège, France (see Fig. 1). The most important works seem to have been carried out between the end of the 13th century and the turn of the 16th century (Téreygeol, 2023). In the Middle Ages, the mine was owned by the Viscount of Couserans. This viscountcy was part of the county of Comminges, an autonomous state with links to both the Crown of Aragon and the Crown of France. (Higounet; 1947). At the beginning of the 14th century, the mine seems to have been one of the most important in the Pyrenees, delivering one tonne of silver a year (Bailly-Maitre, Benoit, 1998). Thanks to the most recent exploitation, which ended after the First World War, we have access not only to modern exploitation areas, but also to much older ones. However, a large part of the network has been gradually filled in. Several mining sectors, although known from old documents, remain inaccessible to us.

Since 2003, several geophysical surveys have been carried out on the right bank of the Garbet (e.g. Bonnamour et al. 2007, Florsch et al. 2011 and Florsch et al. 2012). If the deposit and the mine are well located, an archaeological operation in a mine must be carried out at the access points, which must be geolocated as accurately as possible. Above all, we need to be able to estimate the scale of the required excavation work to study these mining networks. It is therefore essential to gather as much information as possible prior to the archaeological work, in particular to determine whether there are any accessible voids. This work can be carried out using traditional speleological techniques, but in mining areas where access is unknown, geophysics must be used prior to any major archaeological work. This is the case here, based on both surface anomalies observed at the site and a 1913 mining plan.

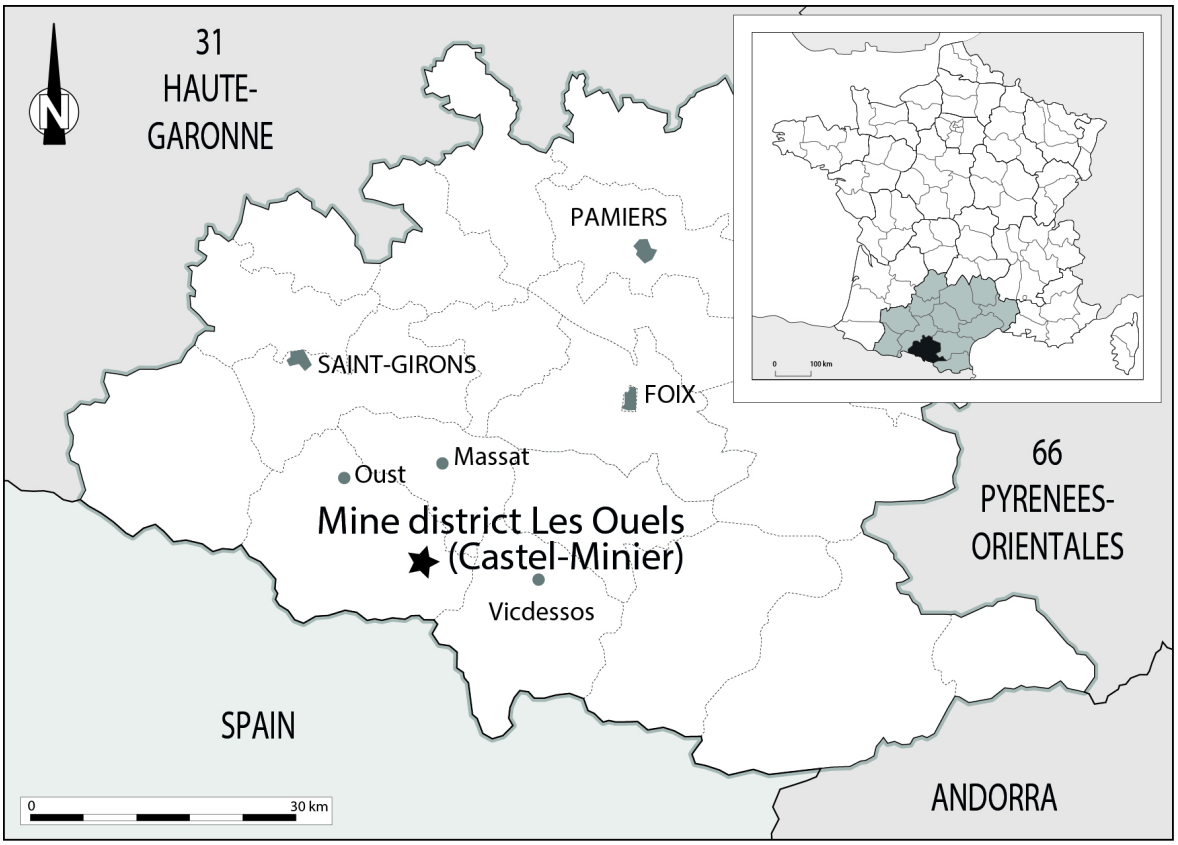


Fig. 1. Mine district " Les Ouels" located in the south of France.

1.2. Geology, mineralogy and documented historical mines

The mining network is located in the central part of the northern slope of the Pyrenees, where the highest peaks of this massif are concentrated. This area is crossed by the North Pyrenean Fault, which in our case is materialised by the Garbet stream. On the right bank, the terrain is of Post-Hercynian age, whereas on the left bank it is mainly Devonian (Laforêt et. al. 1983).

The deposit that supports the mine is of hydrothermal type and was emplaced in Paleozoic sedimentary terrains. It lies between Silurian shales (-443.4 to -419.2 Ma) to the north and Devonian dolomites (-419.2 to -358.9 ±0.4 Ma) to the south. The mineralisation is of vein type. It occurs in two parallel veins at the shale-dolomite contact and directly in the dolomite. They strike N 120°E to N 140°E (Dubatik et. al. 1981).

The mineralisation consists mainly of galena, sphalerite and chalcopyrite in a vein system that varies from calcite to quartz, depending on what is still visible in the workings. The silver, which is at the heart of this exploitation, is present in the galena, sometimes in the sphalerite. It also accompanies the grey copper. This last mineralisation, as well as the bournonite, is only known through the ores found during the archaeological excavations of the surface workshops located on the other bank of the Garbet (Flament et. al. 2019). Thus, this research is of interest to both

archaeology and mineralogy, and contributes to the advancement of knowledge in these two fields.

The above-mentioned vein zone is developed at the contact between dolomites and shales, as shown in Fig. 2. There is no other detailed geological mapping of the area around this zone (existing geological maps are only at 1: 50,000 scale and show no detail).

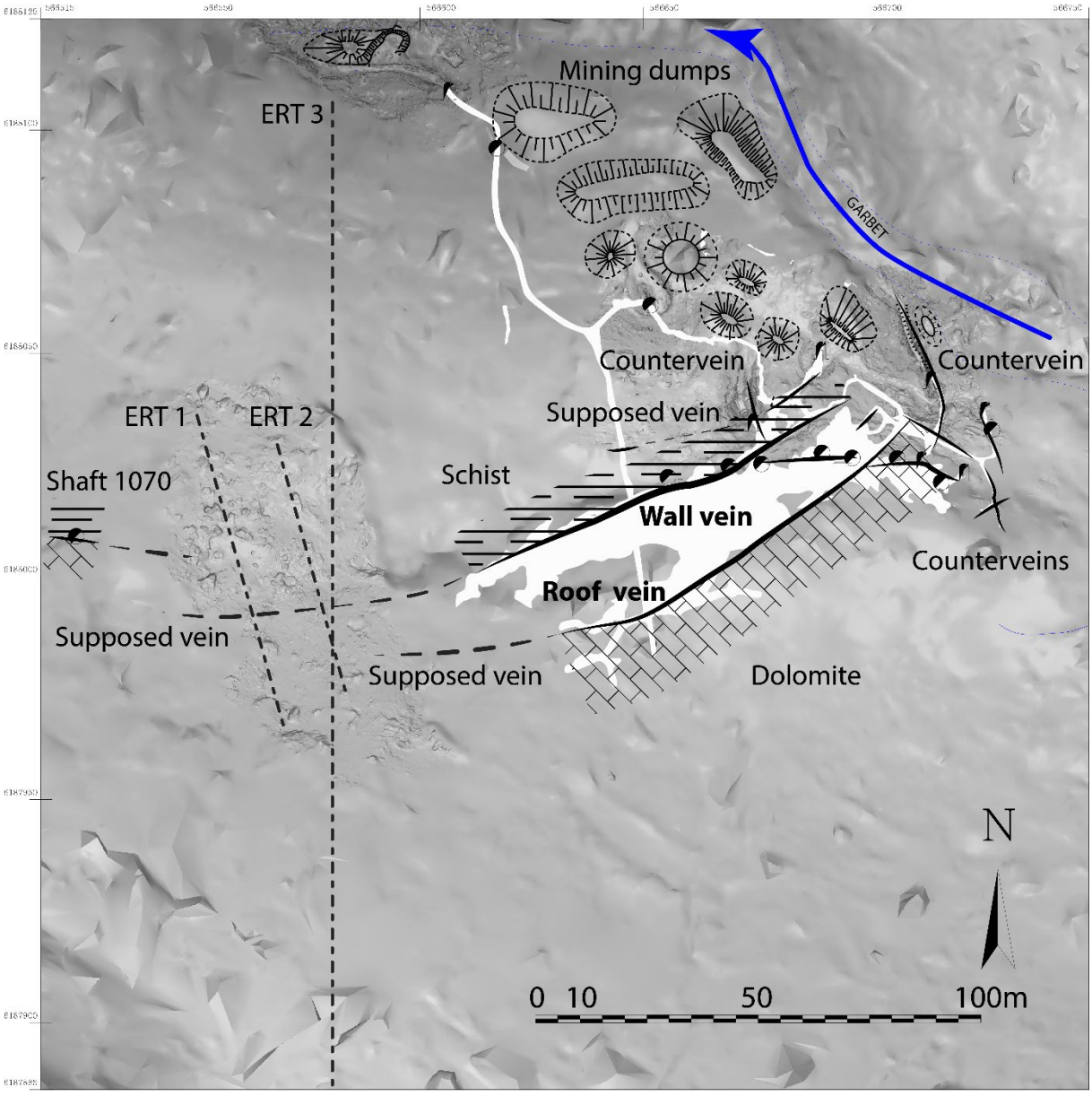


Fig. 2. Mineralized vein and its surroundings, with dolomites to the south and shales to the north. We have also traced the resistivity sections ERT1 to ERT3 (dotted lines).

One of these veins, the hanging wall vein, is easily accessible through several shafts and galleries. Its location is particularly easy to see on the surface. It follows a

dolomitic wall at the foot of which a series of drill holes are still accessible. Conversely, the footwall vein has only been explored in small sections, mainly through rare connections with the hanging wall vein network, and always in the lower eastern half of the mineralised panel. It is this vein that we are focusing on. We have an archive plan from the last mining attempt in the early 20th century. On the 1913 mine plan (Fig. 3), the engineer has two pieces of information that are essential to our study: an extension of the formerly mined lode in its western extension with the mention of "shafts and crumbling deposits, orifice" at 64 shoreline, and the positioning of an "old shaft" at 68.94 shoreline, which is within a radius of 145 m of the "large trench". This shaft is also 14 m north of the hanging wall vein. Underground, our reconnaissance indicates that the veins are blocked at a distance of 50 m from the location of the supposed shaft. In particular, this blockage is observed at the base of the deposit at level 0, whereas the supposed shaft head is at +70 m. This difference in level makes any attempt to re-open illusory and disproportionate, unless we are sure that the overburden forms a plug at the surface and that there are empty spaces to be explored.

In fact, the topographical locations mentioned in ancient documents are not precisely georeferenced and are therefore only a guide for the archaeologist. This is why geophysical surveys are required to pinpoint, if possible, the location of significant voids in this upper part of the claim.

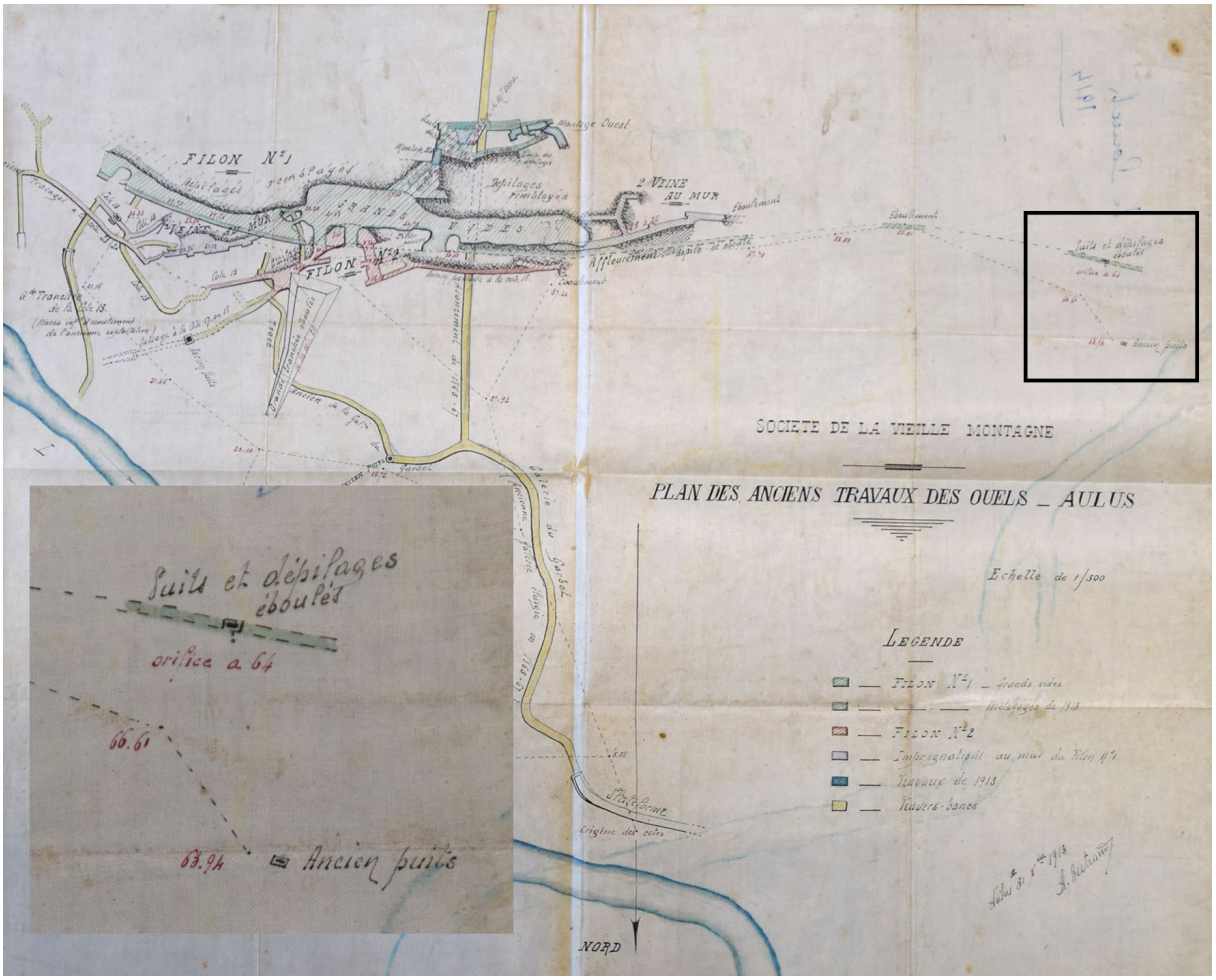


Fig. 3. Mine plan from 1913. It shows the knowledge at the beginning of the 20th century as represented by the engineers. The small enlarged square marks our area of interest, with two pits. Note that the north faces downwards.

2. Materials and methods

2.1. Topography and survey induced constraints

Fig. 4 shows the surrounding topography with an enlarged central coloured area on the right. The latter also shows the gravimetric profile location (in red) and the three electrical resistivity tomographies (ERT) performed (shown in black). The dots are real electrode positions. Two of the ERTs are classified as "shallow" with an electrode spacing of 1.5 m, while the large one, strictly N-S, is classified as "deep" with an electrode spacing of 5 m.

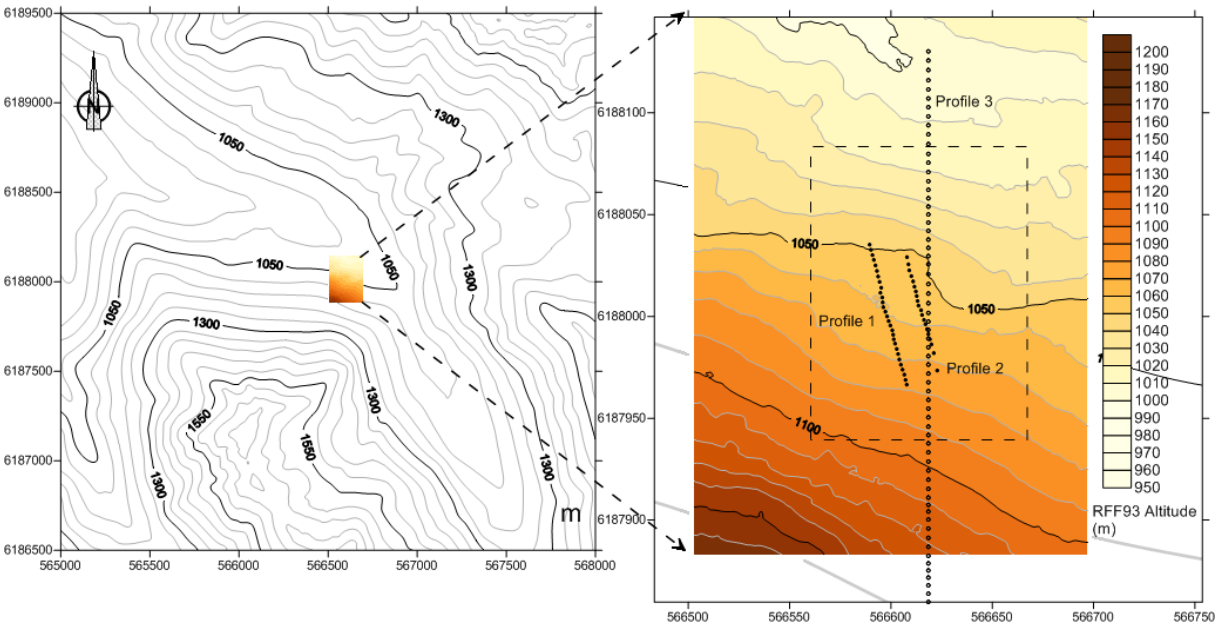


Fig. 4. DEM of the area, 3 km × 3 km with a 5 m × 5 m grid in the periphery and a coloured central area of 1 m × 1 m. The large mesh is derived from data of French IGN (National Geographical Institute), while the small mesh is a mixture of LIDAR overflight and ground photogrammetry. Black points are relative to the ERT with two short profiles (1.5 m spacing) and one large profile exactly NS (5 m spacing). Coordinates are Lambert 93 in RGF 93 metric system.

From the geophysicist's point of view, the conformation of the site leads to several practical difficulties. Slopes often approach 100%. Some boulders are present and the bedrock is regularly outcropping in many places. Tree stumps and snags lie on the ground and the field is actually covered by a deciduous forest. Colluviation is important, and the thickness of the colluvium is irregular: sometimes the bedrock outcrops, and a few metres laterally it can be several metres deep. Fig. 5 illustrates

these field conditions and shows a measurement with the gravimeter in this environment.

2.2. Gravimetrical field procedure

Fig. 5. This picture shows the ground conditions. The gravimeter is leveled using the Gravimeter 3 micrometer screw system, but a special plywood platform has been designed to make the instrument easier to set up. Without this, levelling would have been extremely difficult, if not impossible. This platform is shown in detail in Fig. 6.

A special platform has been built to facilitate the gravimeter stationing, it is shown on Fig. 5 and a drawing plus one photo on Fig. 6 shows the platform design in more detail.

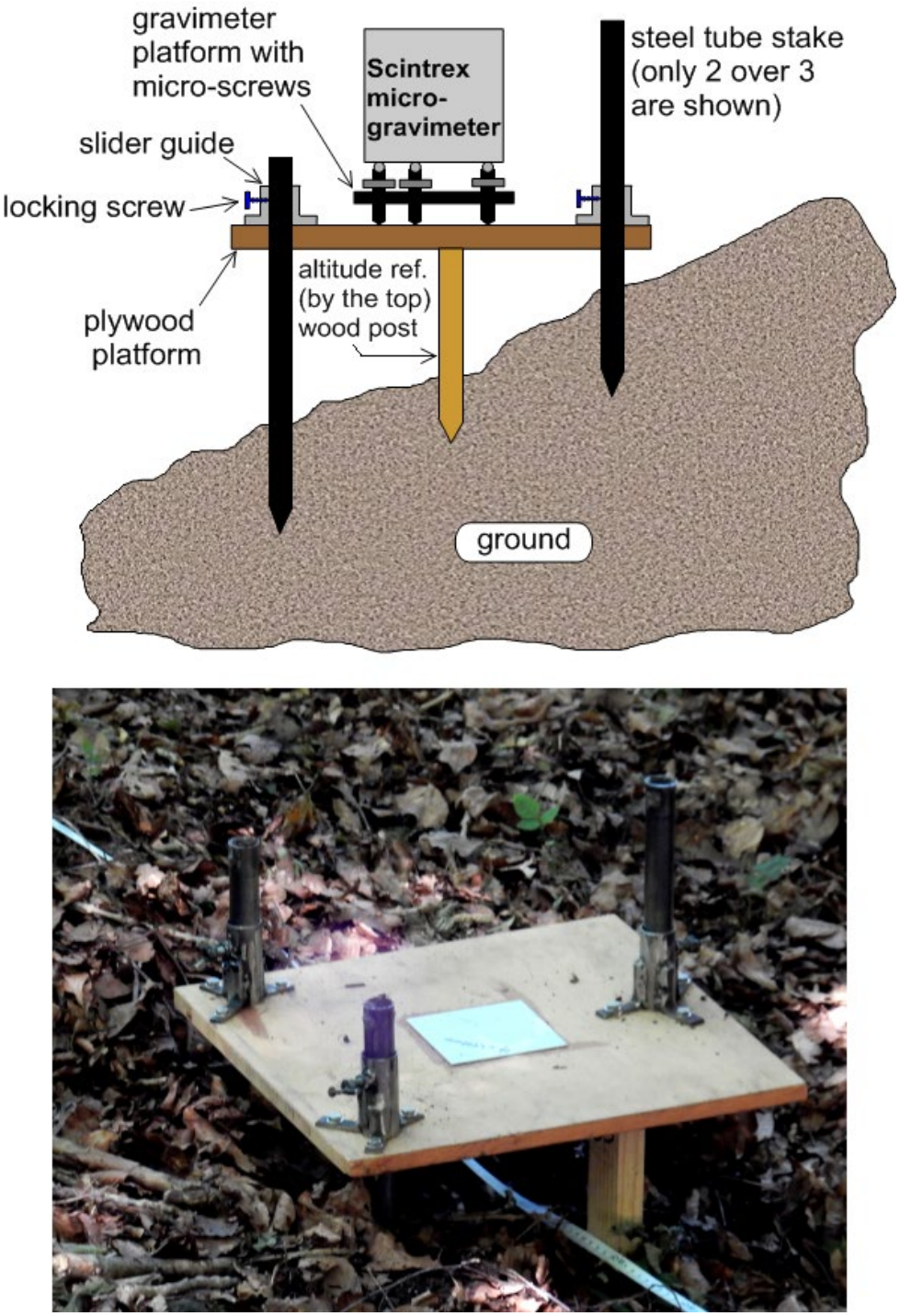


Fig. 6. Design and photo of the first platform installed. It consists of three sliding feet that move vertically thanks to three vertical guides. The sliding tubes are locked with screws once the mobile posts are in place. The wooden platform is levelled thanks to a level indicator, so that the levelling of the gravimeter requires a minimum and residual work. This system can cope with high slopes despite loose ground, while the posts can be driven 10 to 40 cm deep.

All these soil conditions do not facilitate measurement. Special precautions must therefore be taken to ensure the quality of the measurement and post-processing, as described below.

2.3. Construction of the local DEM for gravimetry data processing and ERT.

Creating a suitable DEM (Digital Elevation Model) is not just a matter of data location or environment description. For electrical tomography, the classical 2.5D approach requires at least the relative altitude of the electrodes. This allows us to take into account the main topographic effects affecting electrical measurements, while true 3D effects are generally more or less rightly neglected when using software such as RES2DINV (Loke 2000 and 2011). This means that taking into account the true surface topography will obviously affect the inversion results, but less so than neglecting the 3D reality of the subsurface, which is not investigated in 2.5 surveys anyway. This compromise is accepted because it does not generally ruin the tomography results, although it may lead to a few percent uncertainties in the tomography that remain acceptable.

An accurate DEM is much more critical when used for microgravimetry. There are two levels of topographic issues. On the one hand, the height of the measurement points must be accurately determined in order to make accurate free-air corrections. Since one centimetre of height corresponds to a variation of 3 μGal, and since one wants to be close to μGal accuracy, the levelling of the measurement points must be better than, say, +/- 2 mm (this is for the "free air effect" correction). To obtain this accuracy and to maintain it during the campaign, the measuring point is materialised by a wooden stake of at least 30 cm length (or more) that one buries to leave about 10 cm above the ground. The platform supporting the gravimeter, of constant thickness, is then placed on top of the stake and its horizontality is adjusted using the sliding tripod and a spirit level. On top of this plywood platform, the commercially available microscrew tripod associated with the gravimeter is placed. As a precaution, one of the screws of this platform is blocked during the whole campaign to ensure that the vertical offset of this tripod remains strictly constant over time.

A trade-off must be made between the requirements for altitude accuracy and the time spent in the field. Assuming that the altitude of the stakes is known to be, say, 2 mm (in relative terms), and that the rest of the errors are of the same order or magnitude, we conclude that no better than 2 μGal accuracy (RMS) could be achieved in this levelling operation.

The second point relates to terrain corrections. Traditionally, in addition to correcting for instrumental drift, tidal and latitudinal effects, one has to take into account the attraction of the surrounding topography, traditionally dividing this direct Newtonian effect into two contributions, the so-called "Bouguer effect" and the "terrain effect". The Bouguer effect is the attraction due to an infinite plate between your height and a reference height that you choose at the beginning of the survey. If your terrain is flat, there is no additional effect to consider. But if it is not, you need to take into account the relief, the difference between the actual topography and a horizontal surface. For example, if you are at the foot of a hill, the hill will have a direct upward Newtonian attraction, reducing the gravity field that would exist without it.

Further details on topography are given in the sections devoted to the two methods used in this study. For details of the gravimetric or the electrical resistivity tomography methods themselves, the reader will benefit from reading Loke 2000 and 2011 or the recent book by Binley and Slater, 2020. For gravimetry, one of the best books that contains everything you ever wanted to know about this method is that by Blakely (1995).

The topography we use here includes an "outer part" based on the IGN 5m datum (Institut Geographique National), but in the central area we have combined lidar data (1 m lateral resolution) and photogrammetry, which is more suitable for accurate altitude, especially as far as gravimetry is concerned. The central area corresponds to the coloured rectangle in Fig. 4. The precise heights of the reference gravimetric stakes were measured (with an accuracy of about 3 mm equivalent to 1 μGal) using a Leica total station tachometer in a local altimetric reference system, before referencing these data to the French RGF93 reference system.

2.4. Deployment of gravimetric and ERT methods

The subsurface and degree of geological heterogeneity preclude the use of some of the most powerful geophysical techniques such as GPR (Ground Penetrating Radar), IEM (Induced ElectroMagnetism) or MASW (Multichannel Analysis of Surface Waves). They would have been relevant in a less harsh topographic context, but not here.

Since the aim is to detect robbeb cavities, microgravimetry is the first suitable method that comes to mind. Gravimetry is one of the rare "direct" methods in the sense that it directly detects the lack (or excess) of mass (density directly affects the gravitational field). Moreover, our targets (robbed caves) are scaled in such a way that gravimetry is effectively applied: they are large enough to produce significant and undeniable anomalies. Thanks to the ever-increasing accuracy of gravimeters, microgravimetry is increasingly being used in archaeology, see for example Eppelbaum (2010), and Pašteka et al. (2000).

The second appropriate method, ERT, is chosen because robbing voids are large enough to justify a significant resulting resistivity anomaly. The method is indirect: only a very resistive body will give an anomaly similar to that due to a void. It's not because the current doesn't cross that you have a cavity, it may just be very resistive in appearance. In this case, based on previous resistivity campaigns in the area, it is assumed that the surrounding resistivity extent is capped, and then a very high resistivity underlines with high probability the presence of a cavity, if there is one.

The profile implementation for ERT methods has already been shown in Fig. 4. The gravimetric profiles are shown on Fig. 10 (blue dots) They are oriented to be more or less perpendicular to the expected robbed and to respond to the field practical conformation.
Another archaeological example of combining microgravimetry with electrical tomography can be found, for example, in Pašteka et al. (2019). Other extensive archaeological studies of ancient mines can be cited, such as Hruby et. Al. 2021 and

Trebsche et. al., 2022. Note, however, that they do not look for cavities, but mainly for metallurgical targets, at least as far as geophysics is concerned.

The instrument, a Scintrex CG-5M (relative gravimeter), is shown in operation in Fig. 5. A relative precision of 1 μGal is theoretically achievable, provided a careful procedure is followed. Over a small range altitude interval, the accuracy is equal to the precision. However, in the context of such a campaign in the forest and under rather harsh conditions, the realistic repeatability (then precision) is probably around 5 μGal. This can be trusted by following a procedure of taking 3 measurements (each lasting 2 min) and then taking the median of these three, but a loss of accuracy also results from the topographical conditions. Classical corrections, such as those for time drift (which turns out to be very linear when using this instrument), air-free, Bouguer (or "plateau"), tidal and latitudinal effects are easily obtained. The calculation of the tidal effect itself is a built-in service of the gravimeter, requiring the setting of UCT and geographical coordinates thanks to the instrument's configuration facilities. The only correction that requires further discussion here is the terrain correction.

Terrain corrections are processed to make the effect of relief negligible. In fact, gravimetry is based on Newton's universal law of attraction. Therefore, any surrounding mass will affect the measurement. For a given volume of the subsurface, this gravitational effect depends on density. However, it is impossible to assess in detail the density distribution near (or far!) from the instrument. In addition, one has to rely on a mean density value that is assumed to be known or has to be determined.

This average density is at least needed to calculate the terrain correction. A way to determine an average density for the terrain correction is very simple: just try different values, for example from 2 to 3 in 0.1 steps, and keep the density that gives a minimum correlation between the relief and the fully corrected gravity map: this is the density to use (this is called the Nettleton method, (1939)). Note that it is the same density that must be used for the Bouguer (plateau) correction; both effects (plateau and terrain) are relative to the same environment. In short, it would be ideal to know the entire surrounding density in 3D, but this is not possible in practice or even in theory (without digging everywhere).

Now a question arises: what resolution (lateral and vertical) does a DEM need to be known in order to get a "good" measurement (better than 3 μGal)? There are several ways to answer this question. A simple pragmatic way is to perturb the given grid (e.g. 1m × 1m) and evaluate the effect on the corresponding theoretical gravimetric map. Note that a DEM grid thinner than 1 × 1m would question the very meaning of what constitutes a surface topography: would we be taking into account boulders of 0.5m size, tree stumps, and this question is compounded by the fact that there may be boulders or stumps just below the surface that you will never know about. The geophysicist (and other people) have to accept a compromise. The rule of thumb is: we stop the effort in the correction process by following the idea that we invest work until we reach acceptable errors within the framework of the method and the objective.

Let us imagine a benchmark dedicated to this procedure. In Fig. 7, we show the gravity variations induced by varying the altitude of the points (on a 1m × 1m grid),

following a uniform probability density function (pdf) within a +/- 50 cm interval. This is a relatively blunt assumption, as it could represent the error in modelling the topographic model by interpolation within the 1m × 1m grid. We note that the resulting gravity standard deviation (SD) is less than 4 μGal, and we consider this satisfactory in our context: our "surface knowledge" is better than 50 cm (but remember that we are ignorant of possible subsurface heterogeneities, buried rock blocks, etc.).

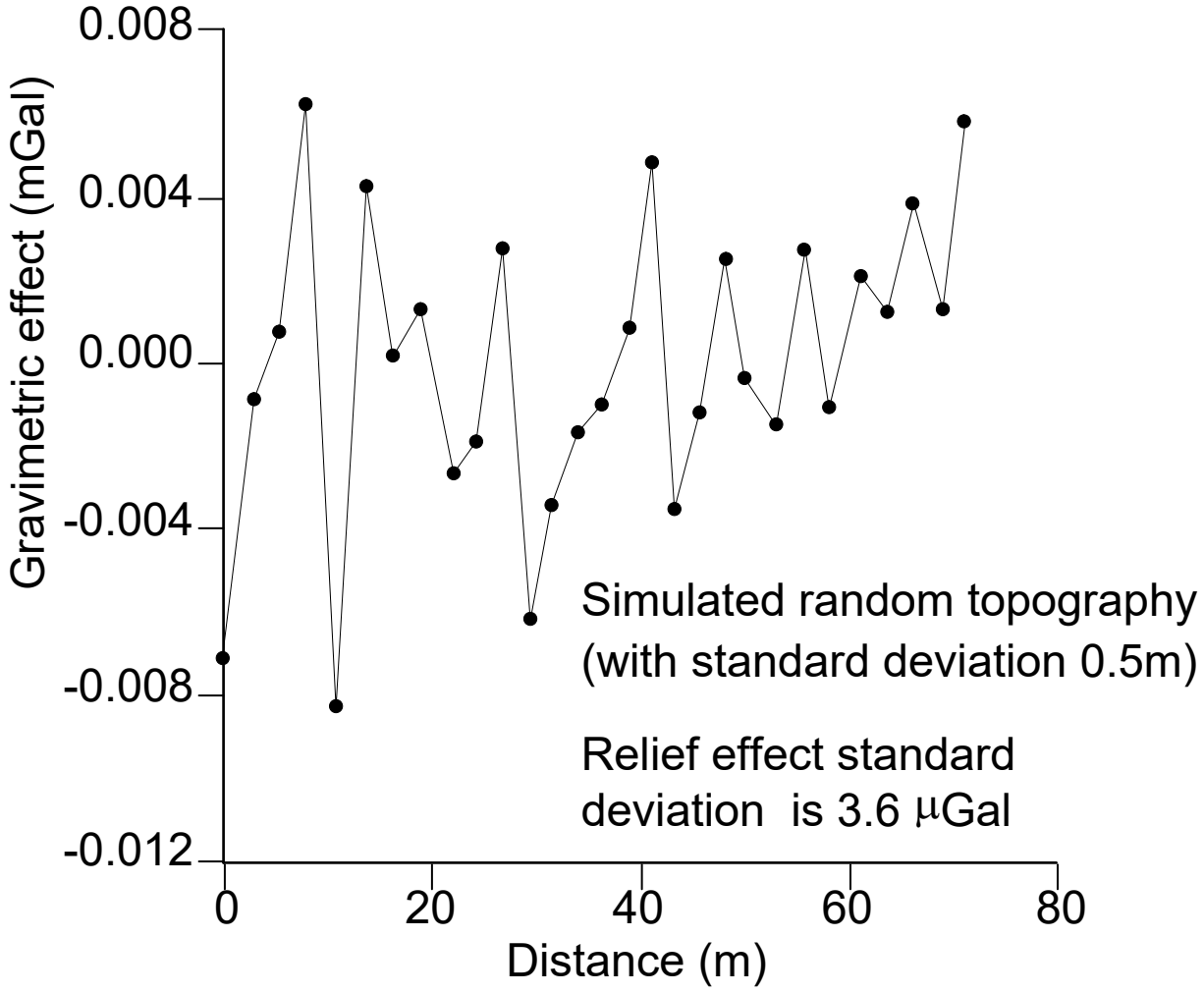


Fig. 7. Simulation of the fluctuation of the gravitational field assuming the uncertainty (real or interpolated) of the topography of our field. From this result we conclude that our corrections are quite realistic within an interval of +/- 5 μGal.

2.5. Gravimetric results and models

Fully corrected data (from drift, tide, free air, Bouguer, topography) are shown in the lower part of Fig. 8 with two superimposed curves: data (red lines) and computed modelled anomalies (blue line) derived using the models shown in the upper part of the figure. The eastern fit appears to be of better quality (or success) than the

western one. Discrepancies can locally reach 20 µGal, which can be considered as random outliers with respect to our standard deviation of 5 µGal.

These interpretations were obtained using a blind approach, i.e. with no prior assumptions other than that the structures are centred on the profile and extend for 200 m in the direction perpendicular to the profile. This is consistent with the likely geological configuration of the mine voids on the site. A manual error and trial approach was preferred to a blind inversion where a priori knowledge would have been difficult to incorporate. In particular, the dip of the void was chosen to match the known dip of the fault.

Of course, one could judge that these interpretations are trustworthy by noting that the fit is satisfactory. In fact, this would be to forget that the gravimetric interpretation model can present an extreme variability. As is often the case in geophysics, and especially when dealing with potential methods, the fit can be satisfactory but the relative interpretation variable (this is an aspect of the non-unicity of the solution in the inverse problem, see for example Tarantola, 2005). This may come back to haunt us.

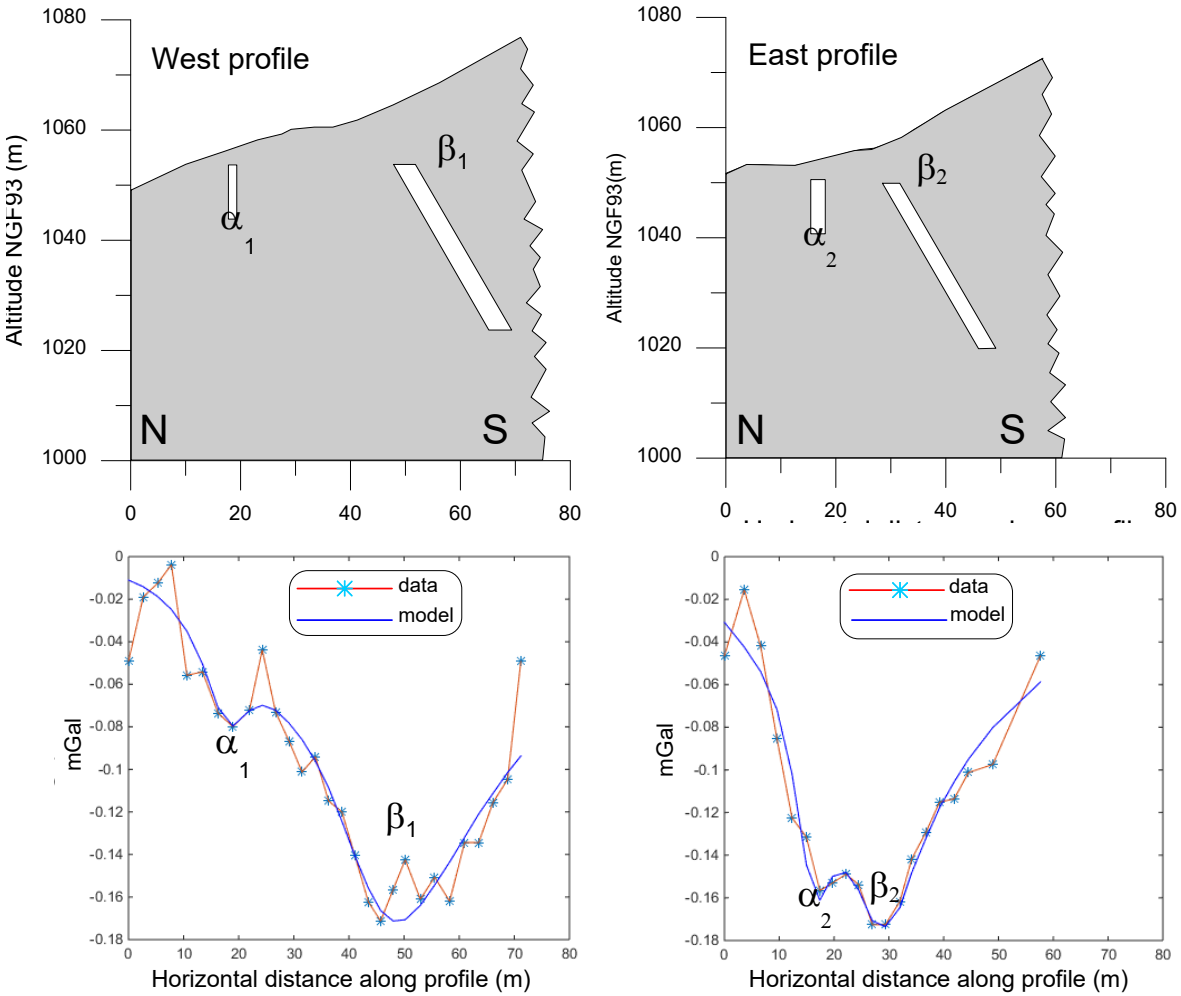


Fig. 8. West and East cavity models (top), data in red line and modelled anomalies in blue line (bottom). The Greek letters are relative to the positions shown in Fig. 10. These

anomalies are computed along the topography where the gravimetric measurements lie (even after relief corrections).

2.6. Electric tomography settlement and results

Electrical methods in geophysics have been used worldwide since Conrad Schlumberger published his book (1920). Modern developments include electrical tomography (Binley and Slater 2020).

All data were acquired using a Terrameter GEOREVA LS23, which provides a progressive pseudo-section display during acquisition (useful mainly for checking that the measurement process is correct).

We first processed two parallel electrical resistivity tomographies (ERT) with 1.5 m electrode spacing, Wenner-Schlumberger arrays with 64 electrodes, displayed along the slope (descending from south to north). These two profiles are shown as black lines in Fig. 4. The corresponding resistivity sections are shown in Fig. 9(a) and 9(b).

Later we processed a single long profile (also a Wenner-Schlumberger array) but with 5 m electrode spacing along the more or less constant slope (Fig. 9 (c)). This section is shown in Fig. 4 as a strictly N-S profile with black points used for real electrode positions.

The results were obtained using RES2DINV (Loke 2000 and 2011).

In parts (a) and (b) a highly resistive body is shown in red (labelled A on the east profile and B on the west profile). This body is likely to be less than 10m below the surface. The same body is also clearly seen on the larger tomography (labelled A,B) with a coherent shallow depth. The lower resistivities (in blue) are associated with wet fractured rocks, while the higher resistivities at the surface are associated with drained, drier colluvium, particularly on the upper part of the slope. In Fig. 9(c), the larger and deeper tomography shows another body of high resistivity (resistivities greater than 1000 Ω.m, labelled C) occurring at 20 - 30 m depth. This body is located around the centre of the section.

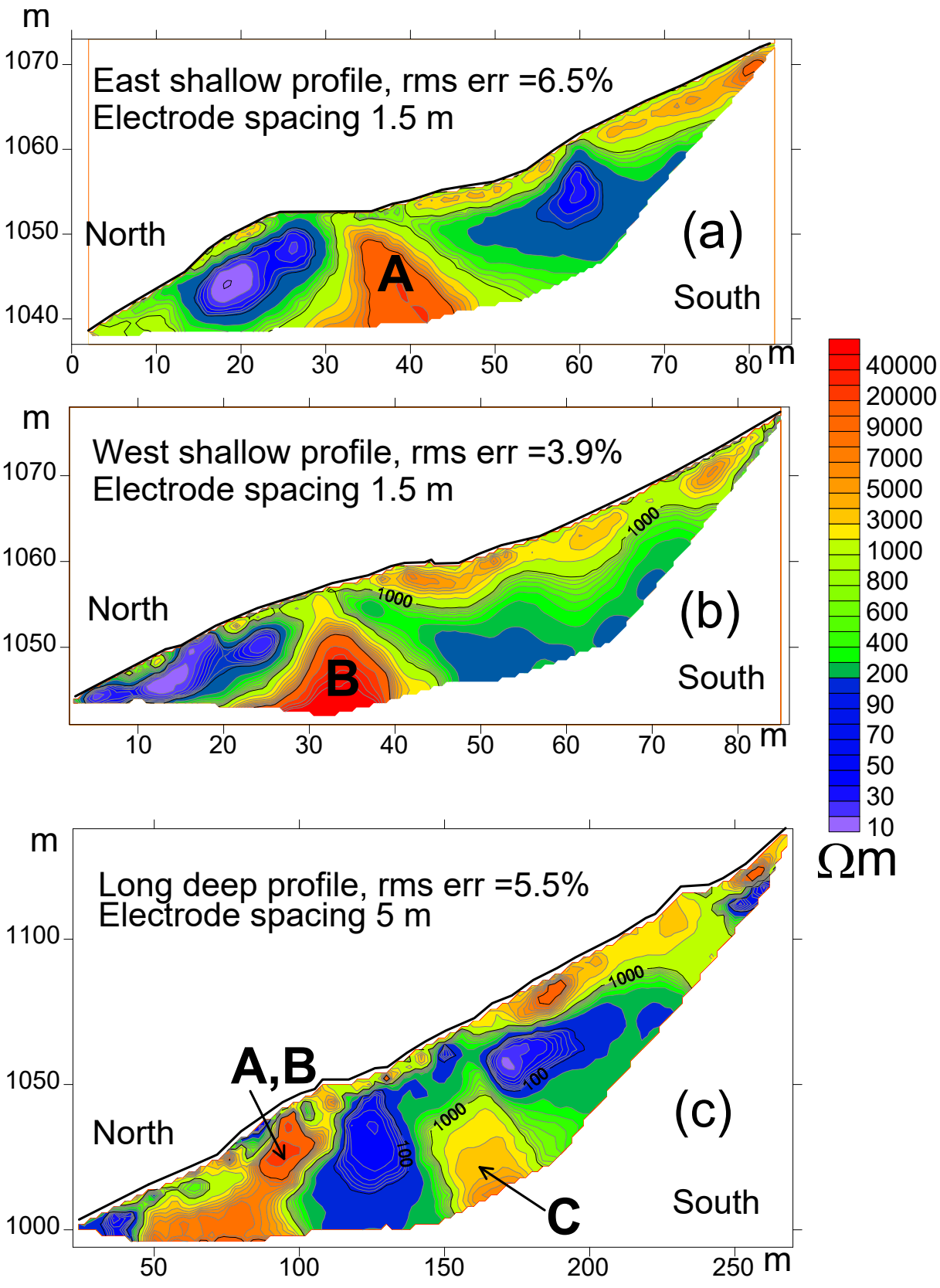


Fig. 9. The two shallow ERTs are shown in (a) and (b) and reach a length of 94.5 m along the surface, while (c) shows the "deep section" with a length of 315 m. Anomalies A and B are most likely due to voids, as the interpreted resistivities can only be explained by such anomalies. In part (c), the deeper section again shows an anomaly associated with voids A and B. An additional resistivity body is now found in C, which could also be due to a cavity.

The interpreted resistivity is slightly lower than for the shallow suspected cavities, but this is consistent with the size/depth ratio in this case. The deeper the body, the lower the resistivity contrast.

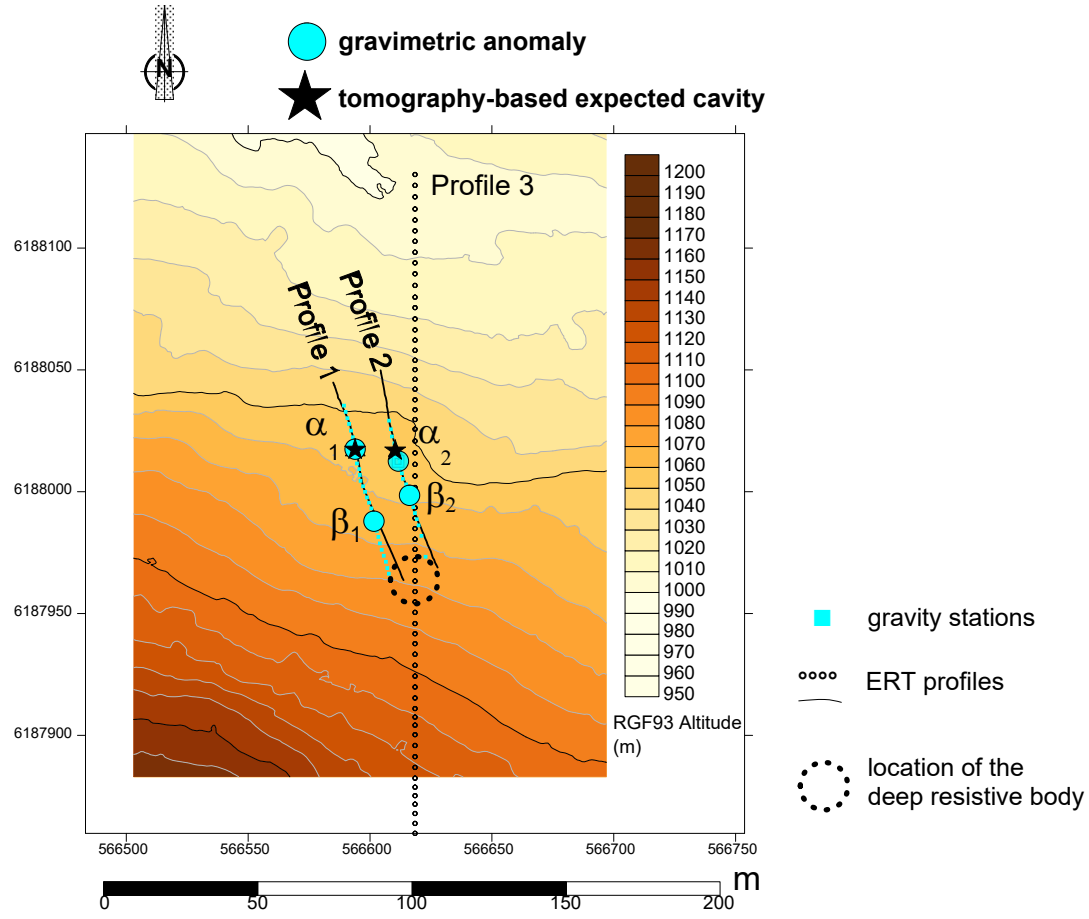
It should be noted that this field survey was carried out over three years, with the two shallow sections in the first year, the two gravimetric profiles in the second year with this indication of a deeper cavity, and then in the third year we did the "deep" ERT which shows this C anomaly indicating a deeper cavity if there is one.

3. Results summary and discussion

As far as inversion is concerned, we are (apparently) doing exactly the opposite of what Tarantola (2006), from whom we quote, suggests: « Using observations to infer the values of some parameters corresponds to solving an 'inverse problem'. Practitioners usually seek the 'best solution' implied by the data, but observations should only be used to falsify possible solutions, not to deduce any particular solution. »

In fact, we fully agree with Albert Tarantola (who was our master in inversion) and we believe that we have not found "the best solution". In a sense, we are doing the opposite of what he suggests by "apparently deducing a particular solution" (particularly for gravimetry). Definitely not. That is the point, we do not pretend to deduce a solution, but only to offer a possible solution, just to provide an example of a solution. We are fully aware of the limitations of geophysics, but we just want to provide tools for dialogue with archaeologists and historians.

Only the α_1 and α_2 pair of cavities, probably revealed by gravimetry, appear to be detected by the shorter electrical tomographies shown in Fig. 9(a) and 9(b). Obviously, the second deeper pair of gravity anomalies, β_1 and β_2, although clearly visible on the gravity profiles, are not detected by these first two profiles of the shallow ERT.



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435 **Fig. 10.** Gravity station locations are shown as small blue squares, and the three ERT
436 profiles are shown as small black dots. We have plotted the gravimetric anomalies as blue
437 discs, and the tomographic expected cavity as a black star. We have a good match between
438 the electrical and gravimetric anomalies α_1 and α_2 in the north, but no match for the
439 gravimetric anomalies β_1 and β_2. The black dotted circle indicates the location of the deep
440 resistive body seen (anomaly C in Fig. 8(c)).

441

442 *It is clear that the northern anomalies, electrical* and gravimetric, are superimposed
443 within 2 or 3 metres (i.e. the resolution of the methods), and this is a real success of
444 our investigation, which has made the existence of the cavity virtually certain.

445 However, the two southern gravimetric anomalies, β_1 and β_2., are isolated, without
446 any correspondence with electrical anomalies.

447 It must be admitted that if there are caves here, they are not detected by the ERT. It
448 is therefore difficult to say that the southern cavity is certain from a gravitational point
449 of view. There could also be an electrical masking effect that prevents any electrical
450 anomaly from being seen, and this is known to occur particularly when trying to
451 detect resistive bodies at depth.

452 The aim of the third major ERT (Fig. 9(c)) was to electrically target this hypothetical
453 deeper cavity seen by gravimetry. It is, so to speak, desired. However, this is not the

case, as shown in Fig. 10. On this profile we detect an unexpected deeper resistivity anomaly, marked C on Fig. 9. It is too far away from the hypothetical void seen by gravimetry to be interpreted as coming from a common source. Ultimately, an additional gravimetric campaign would provide new insights, but this is not on the agenda.

4. Conclusion

The aim of the geophysical survey was to confirm and locate old map indications of currently covered pits and mine accesses. This objective has been achieved for at least one pit, which is likely to be the northern pit (lower pit on the enlarged part of ancient map, remembering that north is down on this historic map). In this case there is excellent agreement between the high resistance electrical anomalies and the gravimetric anomalies. This confirms the presence of cavities with almost certainty. On the other hand, we cannot associate the triple consisting of: i) the southern structure as seen on the old map; ii) the southern gravimetric anomalies; iii) the deep resistive body, as there is no overlap between these three.

The use of geophysics in this archaeological survey has proved to be very efficient and relevant in contributing to the knowledge of the old Ouels mine. This opens up the possibility of a future mining archaeological operation, as the geophysical survey has defined the area of interest, thus limiting the archaeological work, while confirming the existence of a cavity that can be accessed by emptying the access shaft. Despite the success of the geophysical survey, the archaeological operation that was to confirm the data could not be undertaken for safety reasons. However, the area is now defined as an archaeological reserve.

Acknowledgements

We would like to thank Jean-Charles Méaudre for the construction of the platform for the installation of the gravimeter, without which this prospection would not have been possible, and also Jurgen Heckes for the production of maps from several data sets and for directing the photogrammetric and topographic campaign on the mining side of Castel-Minier.

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