SECTION 1

Efficiency tests for UAV taken data

1.1. The necessity of an experiment for data acquisition.

Considering that the capture of UAV aerial snapshots with drones (UAV) is a key element for achieving the project's general aims (among which particularly the capacity to map correctly and as completely as possible the elements of the Roman boundary), we projected an *Experiment of data acquisition* which to facilitate some conclusions about the optimum of activity.

> Basically, the Experiment (as it is named in the journals of the project) is meant to answer the following questions: which is the best season for planning some UAV activities? What are the other conditions that may lead to an optimal result, both from the perspective of the expenses and from the perspective of sheer scientific benefit (*added value* of archeological/historical information)? For a rapid exemplification – peculiarly interesting are variables like the time of the snapshot, the angle of solar light, the presence of clouds or the visibility's quality (the clearness of the atmosphere).
>
> Of course, the aforementioned questions have to do with several „commonplaces" of the archeological research, both from the surface (the so-called *field survey*), and aerial. It is a well-known fact that the most favourable moments for field surveys are towards the end of autumn, (end of October and November, *after* the autumn ploughing) and the beginning of spring (end of March – first half of April, when the agricultural cultures are still in an initial stage). On the other hand, the experience of the British school in aerial archeological research has to do especially with the so-called „crop-marks", which are the differences in growth of the agricultural crops, due to the buried structures; or, most of the recommendations in this matter point towards the ripeness stadium of the gramineas (May, beginning of June; PALMER et. al. 2009, 29, 202; OLTEANU 2007, 12, 14, 20, etc.).

With the purpose of making our work field transferable, with sustainable arguments, to other archeologists who, eventually, will want to try the UAV technology, we have organized an experiment according to all the necessary rules. We have chosen two distinct perimeters, towards the extremity of the working area, so that the conclusions drawn from a perimeter to be backed up (or not!) by the facts resulted from the other perimeter (which would represent the results *repeatability*). The first areal is 5 km south of Piteşti and at 1 km east of the northern extremity of Albota village, near the toponym Poiana Roşie; the second areal is at approx. 4 km South West of the city Roşiorii de Vede, in the area of the toponym Valea Mocanului, respectively at approx. 2.5 km South West of the Pneumoftiziology Hospital (fig. 1.1).

The field positioning of the experimental perimeters was made both according to scientific criteria, and to economic criteria; the latter are the easiest to explain: the areas are close to cities and several national routes, considering that the respective positions were to be accessed at least eight times. From scientific perspective, each of the two choices considered particular aspects; hence, in the point Poiana Roşie it seems that the embankment (which marked the boundary) makes a turn towards south, suggesting a direction heading to Pârvu Roşu and Costeşti, therefore divergently compared to the traditional view, which connected the forts from Albota and Săpata de Jos to the line of the frontier. Our hope is that the 4 missions in the area will clarify the issue (considering that the actual orthophotos doesn't indicate more than that, and the continuation towards south is debatable).

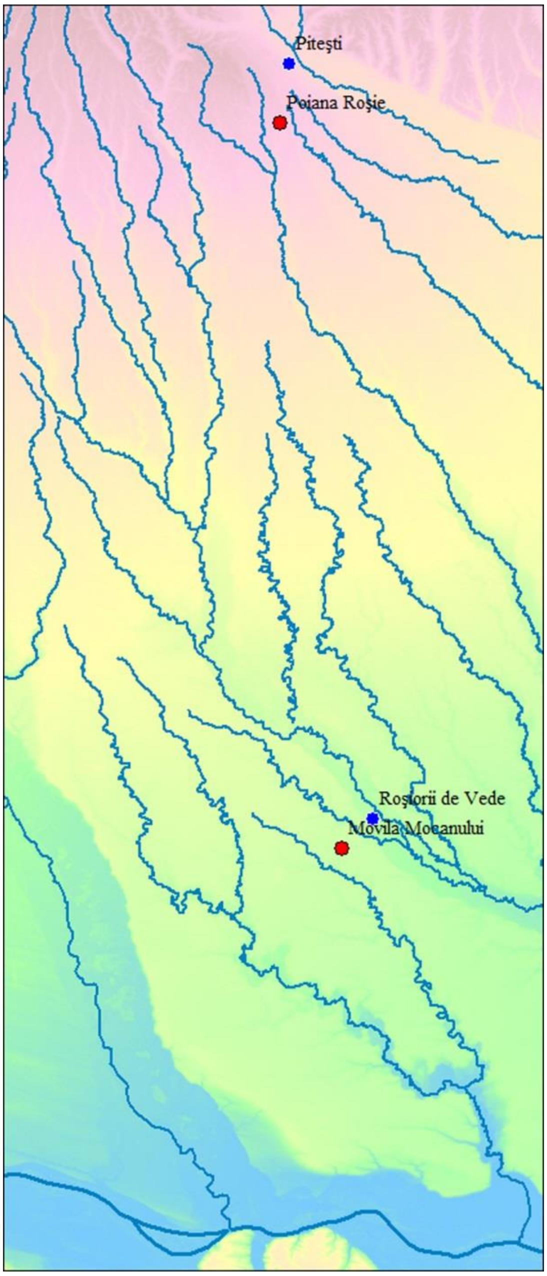

Figure 1.1. General map of the research area, with the demarcation of the two experimental areas.

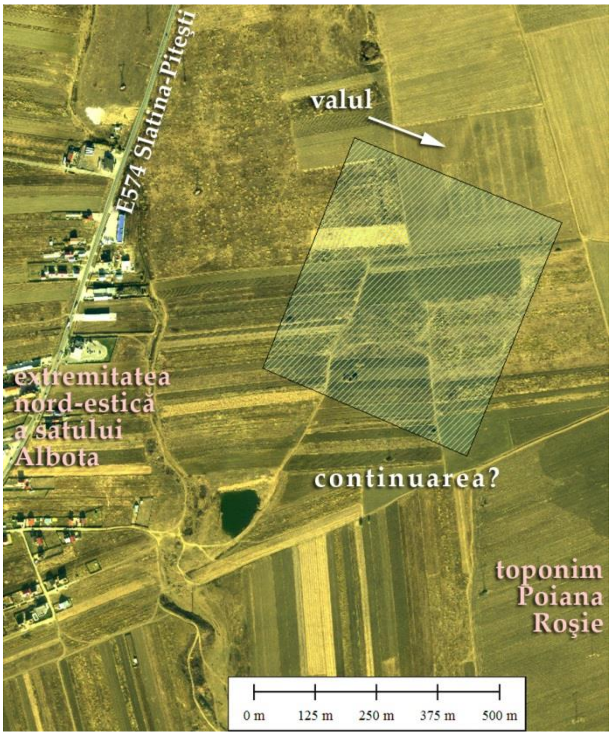

Figure 1.2. Poiana Roşie Perimeter (military orthophoto 2012)

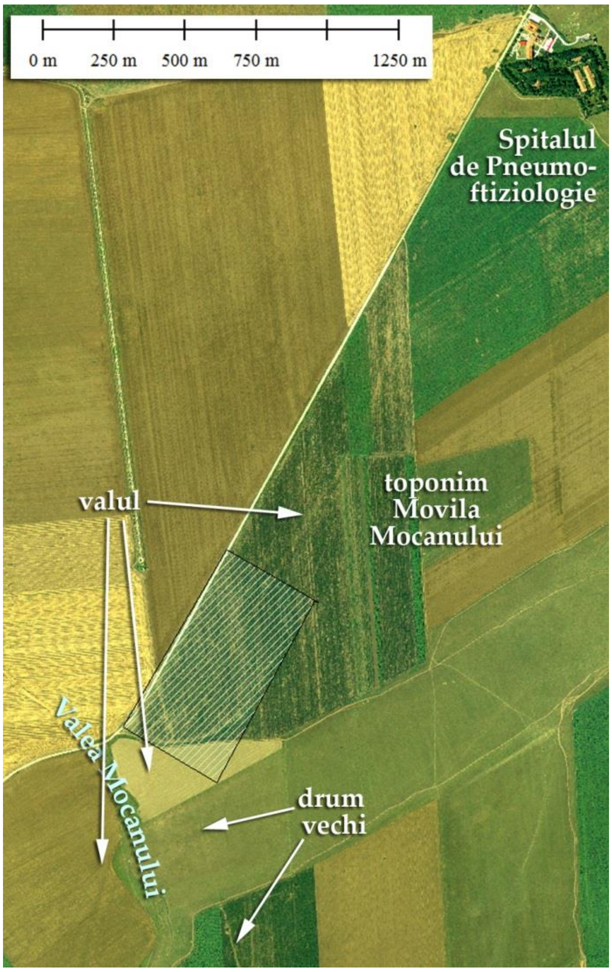

Figure 1.3. Valea Mocanului Perimeter (orthophoto).

The second experimental perimeter, the one from Valea Mocanului, benefits of an unique situation, at least up until now: not only that here we have one of the most visible embankment segments, but also two distinct Roman roads; moreover, in the immediate proximity there are two very probable ways of accomplishing the frontier developments (two distinct phases?). We have to specify that, previously to our research project, not one meter of Roman road was known on *Limes Transalutanus*!

The size of the experimental areas is typical for a „double mission" (two successive drone take offs, starting from the same point, in order to change the accumulators, with launchings in opposite directions), with the final purpose of gathering data from a surface of 1000 m long (or more) and 250 m wide (or more). The work perimeters, as they were delimited by the project (fig. 1.2-1.3) are a little bit wider for particular technical reasons, which are not to be exposed here.

For the clarification of the optimal calendar, 4 distinct missions were planned, in each of the two areas, namely in August, November, March and June. The first two of them were allocated to the first phase of project execution (July – December 2014).

Each mission the purpose to obtain three distinct sets of data:

a) The orthophotoplan (with resolutions of approx. 5-10 cm, dependent on the height of the flight and the resolution of the camera);
b) The digital model of the field (or DEM – Digital Elevation Model, with resolution around 0.2 m);
c) Oblique snapshots (known as the best for observing the field profiling).

1.2. The first two missions at Poiana Roşie

The first mission at Poiana Roşie took place in 11 August 2014, in conditions that were difficult for observation: the northern area of the areal was covered with stubble of crops and straw which were not yet gathered, and the southern area was covered with corn field, blocking any attempt of observing the monument from ground level.

Figure 1.4. Northern areal of Poiana Roşie Perimeter, 11 August 2014. Southern view.

Our initial diagnosis, given the conditions of field coverage, was quite reserved. Indeed, the orthophoto we obtained is of little help, despite de resolution which is 10 times better than the military orthophotography[1]. The salvation came from the model terain, obtained with the same

[1] At the intuition level, because 5 cm (the resolution from din UAV) is 10 times smaller than 50 cm (the resolution of military orthophotoplans, or of the images that are available for public on Google Earth). In fact, a photography is a bidimensional reality, so if a surface of 0.5m^2 is represented, on orthophotoplan, by a single pixel, the same surface will be represented by 10 x 10 (that is 100) pixels on a orthophoto produced from drone captured images.

occasion[2], which proved that, although the former wall that once marked of the empire was completely invisible to the naked eye, it had actually produced, upon its ruin, a slight shriveling of the field surface; this discrete profiling of the field (with the value of approx. 1% and a height which was 100 times smaller than the dispersion) allows the realignment, with high accuracy[3], of the monument on the map.

The second mission from the Experiment series, has developed on 4 November 2014 within the Poiana Roşie perimeter. Despite our expectations, the vegetation conditions weren't better than in August. Most of the fields with harvested crops, were not yet plough; even worse, almost all the corn crop wasn't yet harvested at all. To our great surprise, on one of the few strips that broke the record, south of the bend made by the mound, being tilled recently, we saw the mound in profile, very clearly, accompanied by the usual associated anthropic materials, namely fragments of burnt adobe, especially in the area behind the embankment. Nevertheless, the small observable fragment confirms, fortunately, the layout established in August, based on the field model associated to orthophotography.

Figure 1.5. Tower (?) at Poiana Roşie, 4 November 2014.
North-Eastern view. Notice the vegetation conditions from the sides.

The profiling illustrated at figure 1.5 is unusually bold for the entire area around Piteşti, where we normally cannot detect, at ground level, any king of profiling at all, be it big or small. This is why we kept in mind the position south of the curvature, as a potential place where a watchtower could have been. The distribution of materials, 20-25 meters behind the mound, backs up the same hypothesis.

[2] What we get from the tesselation of the aerial snapshots is, first of all, a DEM (Digital Elevation Model), that is subsequently textured in colours, becoming „orthophoto". The ortho product is bidimensional, but the DEM is tridimensional, therefore a „topographic survey" (of high resolution!). Strictly technically speaking, the resulted models are actually of DSM type – Digital Surface Model, because they also include the vegetation level which cannot be filtered in default of using LiDAR. The distinction is purely technical, because the vegetation is small – in the areas where we use UAV. With this amendment, we will continue to use the acronym DEM, being known better by the public.

[3] The three comparative illustrations – the military orthophoto, the orthophoto from drone and the field's digital model, in fine topographic processing, are exposed in an article published in October in *Journal of Ancient History and Archaeology* (http://www.jaha.org.ro/index.php/JAHA/article/view/68), fig. 2. There is free access to the material.

1.3. The first two missions at Valea Mocanului

The name of the spot is given by the left affluent (un-perennial) of Urlui Brook, which crosses the southern area of the working perimeter.

The first drone lifting was made on 11 August 2014, late at evening, before sunset. Our area of interest seemed, for 90% of its surface, absolutely disarmingly: a thrift of sunflower crop, two meters high and very thick, inside which you couldn't see anything within a stone's throw. We went forth with the flight anyway, because the attempt of getting useful information, even in conditions of grown up vegetation, was one of the purposes of the experiment. The flight made at 300 meters high, got us both vertical and oblique snapshots.

Figure 1.6. The Experiment, Valea Mocanului, phase 1, August 2014, orthophoto.

Superimposing of our orthophoto on the support offered by Google Earth (but at a better resolution).

The results were way beyond the expectations, as the oblique snapshots have demonstrated immediately after their download. One of them was already published in Antiquity[4], at figure 4, being

[4] http://journal.antiquity.ac.uk/projgall/teodor342.

accessible to the public. One more mention should be made: the snapshot taken from the ground, which is displayed in the arrangement from fig. 4, was made in April 2013. Basically the grown crop not only that it doesn't hide the buried objects, but it actually reveals them, and the „crop-mark" theory seems to function also in sunflower fields, this information being without any doubt useful for the future activity.

The orthophoto obtained in that occasion (fig. 1.6) is less explicit than the oblique photo; thus, the road which goes quite parallel with the mound is visible (for certain) only on the southern segment of the researched area; the second road, which cuts both the mound and the aforementioned first road, is also visible, but poorly, and it hasn't been marked on fig. 1.6. In exchange, the orthophoto has the advantage of assigning to each observation a clear localization, with errors below 1 m, a fact that cannot be done on the oblique snapshot.

The second stage of the drone experiment, in the area Valea Mocanului, was accomplished on 7 November 2014, the only day of November when the flight could be done, the rest of the month being practically completely foggy. Even so, the flight conditions were debatable, because of the relative mist. The condition of the field – plowed and sowed probably with grains, in an incipient stage of growth – was excellent, but the luminosity was quite poor (although it was a „sunny day").

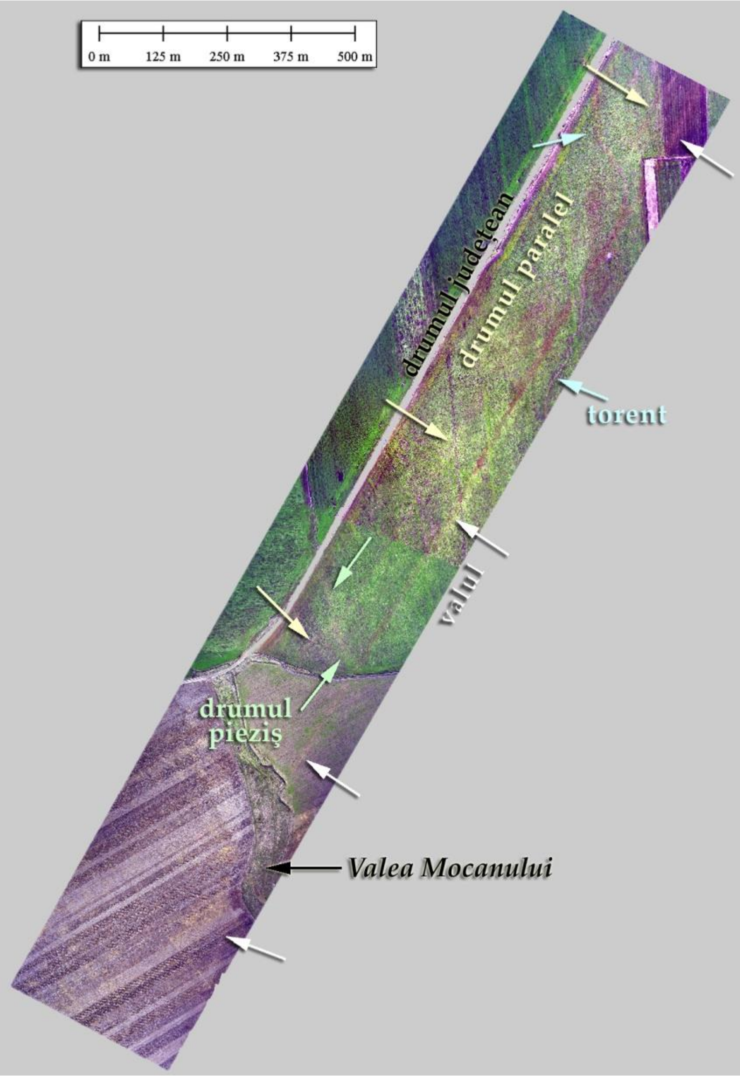

Figure 1.7. The second stage of the drone experiment. Valea Mocanului, 7 November 2014. Orthopho (northern alignment), superimposing of the results of two flights.

The contrasts were intensified, with the purpose of allowing a better visibility of the details.

Despite the difficult light, the orthophoto (1400 x 350 m), produced from two successive flights, is quite descriptive. Still, the diffuse light didn't allow a very clear profiling of the image, which needed an increase of the contrast level, the colours becoming shades that are quite far from the real landscape.

The terrain model (DEM) obtained with the same occasion didn't brought any supplementary elements compared to what we already knew, perhaps except the suggestion that, the more we head towards north, the more the embankment profiling decreases, a very plausible information if we consider the fact that, at the crossing from Valea Bratcov (between hospital and the city), it is almost null (an observation we made during the field trips from 2012).

1.4. Partial conclusions of the experiment

The time of the conclusions will surely come after finishing the experiment, which has two more stages, in April and June. Nevertheless, up until now some things have become obvious.

The drone made snapshot is an extraordinary useful and ductile instrument, being an innovation which will surely change not only the lives of archaeologists, but also and especially the diagnosis procedures. The capacity of exact navigation on a preset track is of high precision, better than what can be accomplished from a plane (first of all because of the very different speed). Moreover, its resolution is way superior. The UAV photo can be useful in any season, although not on the same kind of surfaces. Useful results can be obtained on low vegetation, on ripening crops, but less useful on mature crops, almost dried, and mostly no results at all on surfaces covered with gleanings (unharvested), or old fallow[5].

The disadvantages are represented by the exploitation costs, higher than one might expect (especially for accumulators), and the autonomy is, at least for now, quite limited (approx. 30 minutes and 3 km tops, as maximal distance covered on the equipment we used[6]). Another enemy is the wind (at levels higher than 10 km/h), and, as we have seen … the birds of prey.

The technology of UAV photogrammetry is of the „surgical intervention" type, very accurate, but over small surfaces. It cannot create the „big picture" (for which the images taken from satellite or from the plane are decisive), but it can provide details of a sensible superior level and, more than that, it can be used punctually where and when it's needed.

The UAV made snapshot can serve as reconnaissance for areas which, for one reason or another, are inaccessible. Such an example will be given at the end of Section 2 (field trips).

Finally, we also have to mention other technical issues that condition a useful result. First there is the necessity of some ground points with known coordinates, within the flight perimeter. In order to ensure the horizontality of the terrain model resulted from the superposition of snapshots, minimum three (preferably four or even more) points measured from the total station[7] are needed, so that their spatial relation (on x, y, z) to be known. Therefore the crew that manipulates the drone has to be larger, both to be able to write down all the characteristics of the field above which the team works (the type of culture and the stage of growth, for the main lots), and to take the minimum of measurements with the total station. Finally, at technical conditions we should also mention that very powerful computers are needed, with better video card and minimum 8 GB RAM (preferable 16), and the processing takes quite a long time (one day of work for two drone missions, including the tasks implied by photogrammetry, topography and writing in the mission journals).

[5] It goes without saying – nor above thick forests, for which only the LiDAR technology can bring any contributions.

[6] For a brief technical description of the drone and of the photographic equipment, see Appendix 6.

[7] Visible also in snapshots taken by drone. In practice we used some orange targets (in form of a cone, flexible, on square basis, with a side of 30 cm) used in constructions.