INTEGRATED SURVEY FOR QUARRIES MONITORING

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ABSTRACT:
In Puglia region the activities of survey and georeferencing in the monitoring of quarries are regulated with the executive decree D.D. 38/DIR/2012. The topographic operations required concern the territorial framework and the detailed topographic survey for geometrically defining the site and the calculation of the amounts of extracted material. In order to meet the above-mentioned requirements with a continued monitoring activity, the authors have carried out a integrated surveying procedure which, beginning with operations and activities during the initial phase relative to 2012, has permitted, in later phases, work only in the area involved in excavation, and the verification over time of their global variations. This allowed the georeferencing and timereferencing of the 3D models with a resolution consistent with the required scale of representation.

***Key-words**: Quarry monitoring, Integrated survey, DSM, Georeferencing, Timereferencing.*

1. INTRODUCTION

A quarry is defined as any open air area used for the excavation of rocks and minerals. A quarry may appear as an industrial complex organized for economic exploitation that is to "grow" a field by means of work taking place on the terrain surface.

The commodity quarry is therefore divisible into real estate (land ownership) and quarrying (business), the management of which is of substantial interest for the national economy. The excavation of mineral resources is an activity of cultivation (similar to agriculture, forestry, fishing, etc.) by which raw materials are extracted from natural resources. It should be noted that for the above-mentioned activity in Italy in 2014 (and only in the regions where effective monitoring was in place) there were 5592 active sites as compared to 16045 brownfield sites. With particular regard to the Puglia region there were 2994 quarries: 415 active (representing approximately 10% of national-level excavation activity), and 2579 inactive. Although the crisis in the building sector, in recent years has resulted in a reduction of the quantity of extracted stone material the numbers are still huge. For 2012 we are speaking, in fact, of approximately 80 million cubic meters of sand and gravel, approximately 31.6 million cubic meters of calcareous material, and more than 8.6 million cubic meters of ornamental stone. At the national level, the Royal Decree of 29 July, 1927, n. 1443 remains the law that regulates a field of activity having notable impact on both the environment and economic interests. The requirements specified by this 88 year-old decree are no longer consistent with the reality of current excavation activity and its consequent impact on the environment.

2. NATIONAL AND REGIONAL REGULATIONS

The process of mining must take into account the environmental context. Therefore, it is necessary that this activity be governed by relevant authorities using planning and control/monitoring in the phases of operating, disposal and reuse of the site.

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The basic rules and regulations of mining in general and quarrying in particular is contained in the aforementioned R.D. 29 July, 1927, n. 1443 containing: “Legislative rules to govern the search and development of the mines in the Kingdom”.

Specifically, Art. 1 states “... the search and the cultivation of minerals and energy of the subsoil, industrially usable in any form or physical condition, are regulated by this law ...”, while Art. 2 states that “... the processes referred to in Art. 1 are divided into two categories: mines and quarries ...”.

In addition, Art. 45 first specifies that “... the quarries and the peat bogs are left available to the owner of the land ...” and, therefore, regulates their use.

Quarries, and specifically, their property, are also dealt with in the Civil Code, Art. 826 that provides “ … quarries and peat bogs belong to the exclusive heritage of the State […] when their availability is removed from the landowner ...”.

Beginning with the 1970’s the process of administrative decentralization commenced: the D.P.R. n. 2/1972 and D.P.R. n. 617/1977 transferred rules and regulations concerning activities of quarries and peat-bogs to the Regions. The Puglia Region in 1985 issued Law 37 for governing mining activities, establishing a procedure for authorization of the exploitation of the quarries. This law is also expected to produce a PRAE (Regional Plan of Mining Activities) by means of which to program a logical process of these activities, adopted by the Puglia region with the deliberation of Regional Council n. G.R. 1744/2000.

The determination of Executive Service Mining Activities n. 38/3009 was promulgated in consideration of the requirement to take action to acquire more detailed data and information on mining activities, and, at the same time, to satisfy the obligation to be connected to the national-level statistical system. This determination does not involve an accounting obligation, but defines the approval of a statistical form requiring from the companies involved an annual compilation in full, and the simultaneous submission of topographic plans.

3. TERRITORIAL FRAMEWORK OF THE SITE

The measurement procedure adopted by the authors refers to a limestone quarry located in the territory of Statte (TA) along the SP Taranto-Statte, km 5 (**Fig. 1**) called the “Nuova Cava Due Mari”, controlled by the CALME Group.

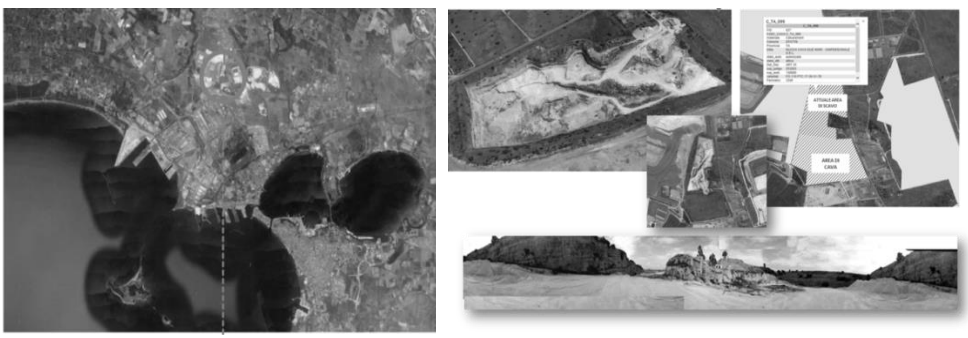

Fig. 1 The case study: “Nuova Cava Due Mari” quarry

The geomorphological features of the area are those of a flat terrain sloping gradually toward the sea. The area under investigation is located in the coastal strip of the Taranto “Murge”, a morphologically flat region geologically characterized by the transgression overlapping of a pleistocene clastic sedimentary series with a mesozoic carbonate substrata, commonly found in the regional hinterland. In particular, the onsite geognostic investigations conducted by coring, and the performed chemical and physical characterizations, revealed the stratigraphic sequence, from bottom to top, consisting of: Altamura limestone, Gravina calcarenite, sub-Appennine clays, Monte Castiglione calcarenite, gravel and marine sands (**Fig. 2**).

The surface survey and the observation of the viewable levels of the existing quarry faces reveal that it consists solely of Altamura limestones characterized by grayish-white or tan fine grains. These limestones compose gently undulating layers dipping generally in a southward direction with an inclination of approximately 5°.

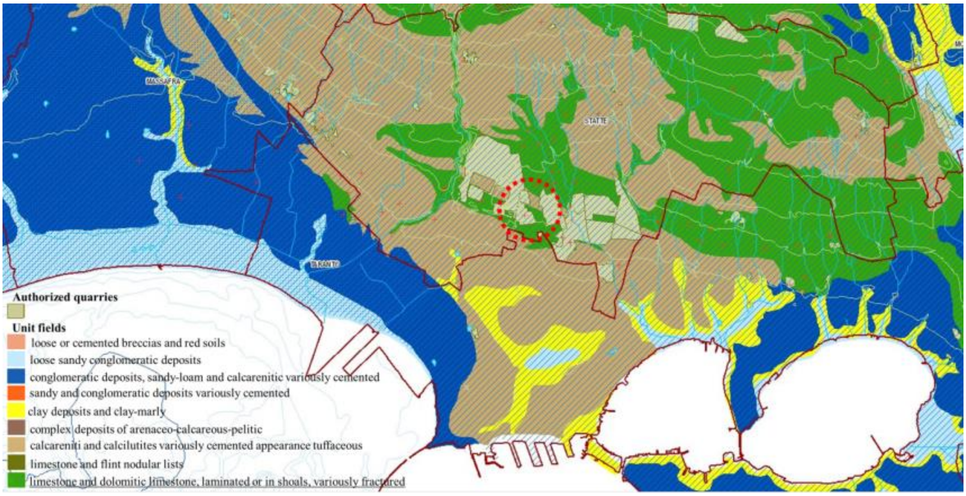

Fig. 2 Geological map of the Puglia region: site location

4. ACTIVITIES PLANNING

In planning the survey the authors took into consideration the objectives to be achieved in order to obtain data appropriate to meet the norms of the previously cited regional law, its amendments, and, more specifically, that are suitable for the drafting of a topographic plan georeferenced in the UTM33-WGS84 reference system. The most appropriate methodology to ensure the uniformity of detectable data was examined, given the vast area under investigation, and the possible timereferencing of acquired data, all in order to guarantee the continuous control and monitoring of mining activity.

With regard to the verified onsite situation, and for the reasons listed above, a survey has been carried out using an integrated methodology which resulting from an appropriate action plan. In the project planning phase, the location of the vertices of a closed traverse (inside of which most of the area of the quarry should be included) was identified.

The choice of the vertices locations has been governed both by the required intervisibility of the points, and by the necessity to have the largest possible field of view of the quarry, useful for subsequent detection of the GCPs (Ground Control Points).

The location of the TLS stations for the point cloud acquisition has been selected keeping in mind the complexity of the site, and in order to eliminate any possible shadow zone; the point cloud, once aligned, allows for the restitution of the entire area. Finally, for the geometric framework of the area in the UTM-WGS84 system, a fast-static mode GNSS survey has been planned using as control points the traverse vertices connected to the permanent station TARA of the ITALPOS network (ca. 6 km as the crow flies).

5. SURVEYING PERFORMANCE AND DATA PROCESSING

A Leica Geosystems TS11 total station, a GNSS Leica Geosystems GS12 system and a Terrestrial Laser Scanner HDS3000 Leica Geosystems have been used to perform the survey activities.

The authors proceeded with the location of the station vertices needed for the realization of the closed traverse and with their monumentation by means of cement pillars and topographic nails. The realization of the monuments was performed by constructing reinforced concrete foundations and pillars having a diameter of 0.30 m and a height of 1.20 m, on top of which a constrained centering plate was anchored (**Fig. 3**).

Fig. 3 Station vertices map (left); monument example (right)

Construction of the topographic nails was carried out by means of constrained centering nails (painted with read lead) whose selection was made according to the soil type of the location.A survey of both the closed traverse and all celerimetric points (internal roads, buildings, fences, etc.) required for the project has been performed.

The GNSS (Global Navigation Satellite System) survey was carried out in fast-static mode taking measures on the vertices of the traverse, by acquisition epochs of 15 s and a standing time equal to ca. 1200 s.

Data processing was carried out using the TARA permanent station as reference, and therefore, determining the coordinates of the remaining vertices in the UTM-WGS84 system. The calculation and the compensation of the traverse, together with all detected points, were made by using a spreadsheet indicating the calculated values of coordinates and relative RMS (**Tables 1, 2**).

Once the location of the laser scanner stations had been defined (Scaioni et al., 2004) the authors proceeded with a survey. A spatial resolution of 0.10 m (grid size 0.1 x 0.1 m) was selected with a maximum range of 100 m, and, the use of four targets positioned in advanced.

Table 1. Traverse vertices: coordinates and r.m.s

ID vertex	UTM - WGS84			r.m.s.		
	N (m)	E (m)	Q m.s.l. (m)	N (m)	E (m)	Q (m)
100	687056,360	4488972,490	58,264	0,002	0,001	0,004
200	687103,615	4489113,907	57,213	0,001	-0,001	-0,004
300	687182,965	4489179,815	56,638	0,003	-0,001	-0,0003
400	687194,590	4489340,871	59,260	-0,001	0,002	-0,006
500	687040,177	4489403,130	24,382	0,005	0,003	-0,007
600	686974,983	4488995,258	43,082	-0,003	0,002	0,006
700	687031,435	4488987,954	59,166	-0,005	-0,003	0,005
800	686968,759	4488954,816	34,141	0,001	0,005	0,003

Table 2. TLS target coordinates

ID vertex	**UTM - WGS84**		
	N (m)	**E (m)**	**Q m.s.l. (m)**
1	687074,265	4489407,867	18,937
2	687121,644	4489361,639	20,601
3	687071,737	4489288,707	8,134
4	687170,186	4489299,305	24,505
5	687055,082	4489262,238	8,650
6	687038,571	4489184,548	14,819
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34	686936,307	4488949,261	34,152
35	686974,974	4488942,705	34,541
36	687251,360	4489256,321	21,702
37	6870121,236	4488222,113	12,562
38	6869852,312	4489251,333	18,564

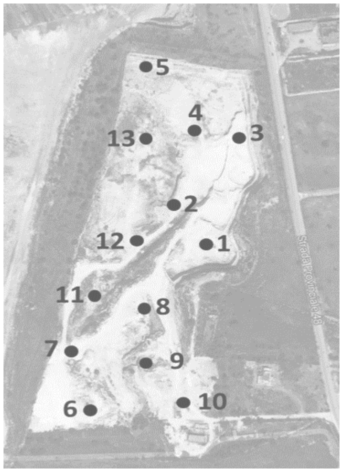

Fig. 4 Map of laser station vertices

The targets placements, required in the following data processing phase, had been topographically measured utilizing the vertices of the traverse. A total of 13 laser stations as shown in **Fig. 4** were carried out covering the entire area.

A clean-up of the TLS data was carried out in order to facilitate its processing (Vettore et al., 2011). It was followed by a semi-automatic alignment of the scans (Fraštia et al., 2014) using the reflective targets and pre-processing the data by use of the Leica Geosystems Cyclone software. The global point cloud was imported into Geomagic software, and, after eliminating the outliers, a surface 3D model (Edelsbrunner, 2001; Costantino & Angelini, 2012) was generated (**Fig. 5**).

Starting from the model a grid of 0.10 m was performed. The export of this grid represented the set of points that have been delivered as a numeric format of the data. The same points were processed for the realization of the contour lines DEM (Costantino & Angelini, 2013), (**Fig. 6**).

The authors implemented this procedure by using a calculation algorithm, created by them and explained in Costantino & Angelini (2011), thus producing an output subsequently managed inside the CAD and GIS environments.

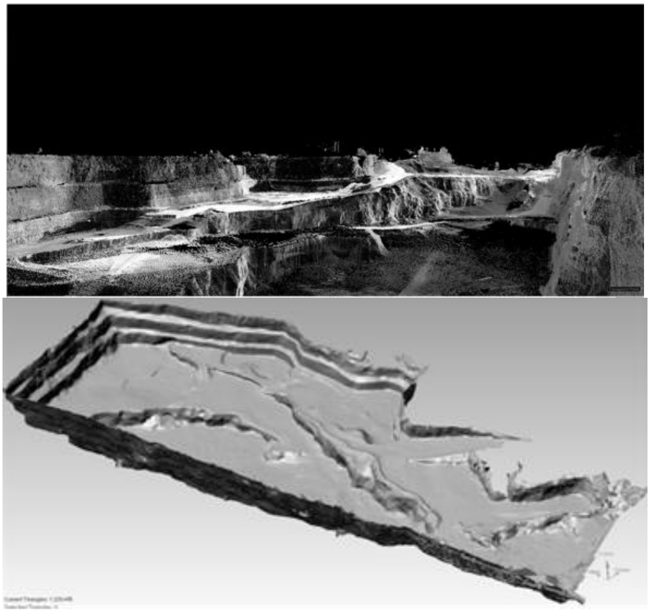

Fig. 5 Visualization of the global point cloud in Cyclone and 3D modelling in Geomagic

Fig.6 Georeferenced numerical model

6. GEOREFERENCING PROCEDURE

The georeferencing process permitted the overlapping of the cadastral maps with several earlier maps of the area. This activity was performed using the ENVI software by means of a polynomial transformation function of the first order, with RMS consistent with the scale of representation. The aforementioned process has also enabled the integration of the collected data with the geo-cartographic information available on the Puglia SIT (Puglia Territorial

Information System) in order to overlap them to the Puglia region CTR (Regional Technical Map), with a scale of 1:5000, and to the deposits map. The entire georeferenced 3D model (**Fig. 7**) was also exported to both numerical and shape formats.

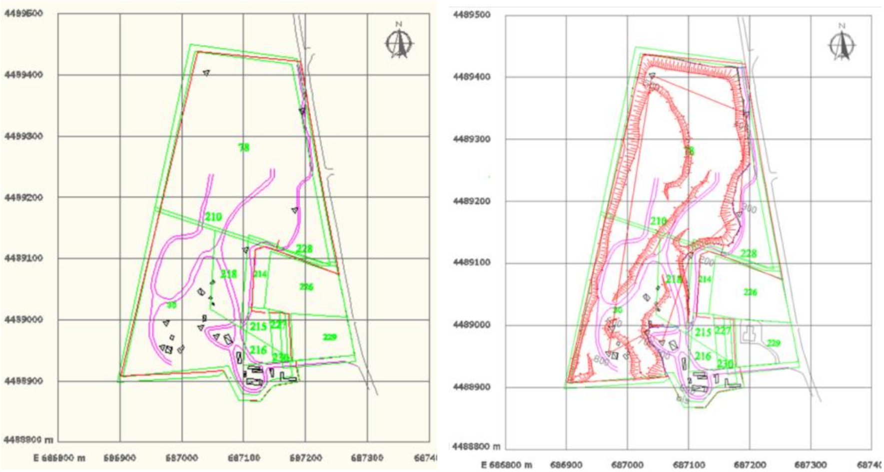

Fig. 7 Cadastral georeferenced map and planimetric view

7. STABILITY CHECKS

The stability analysis was implemented keeping in mind several sections (Kovanič & Blišťan, 2014) that were considered representative of the quarry. The verifications were performed on a spreadsheet utilizing the application of "limit equilibrium methods" with circular failure surfaces. In fact, when the elements present are homogeneous, and no method for detecting the critical sliding surface is available, it becomes necessary to be able to assess a large number of potential surfaces. Beginning with the assumption that the shape of the surfaces was circular, and in order to identify the critical sliding surface, a mesh of m·n points, was taken into consideration. Moreover, all surfaces having a center in the generic node of the mesh and a radius variable within a given range were examined. The method used for the solution was that of Fellenius (**Fig. 8**). It should be noted that the algorithm used complies with the new Technical Regulations on Construction (D.M. 14/01/2008).

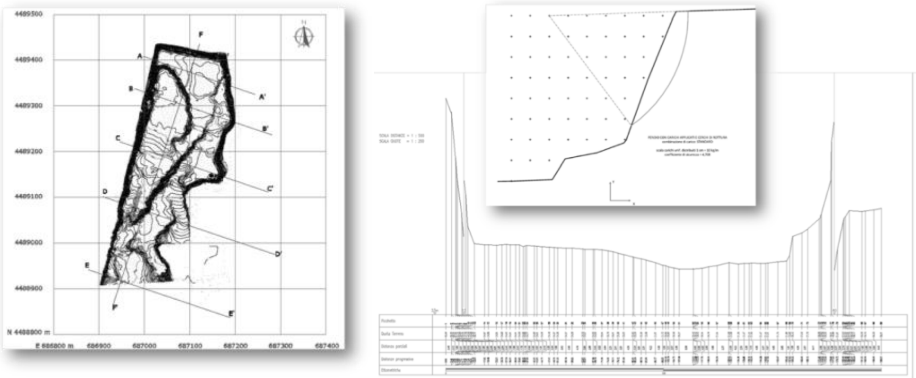

Fig.8 Sections that are considered representative of the quarry and standard verification

8. INTEGRATION OF THE 2012 AND THE 2013 TLS SURVEYS

Starting from the data collected and the its processing carried out in 2012, the authors continued the monitoring of the quarry referring to the mining activities performed in 2013; for these activities they proceeded by surveying only the excavation and storage areas (**Fig. 9**).

To this end, the laser stations and their location were identified. The TLS survey was carried out with a density of 0.10 x 0.10 m and measurements were taken from only three station points for global coverage of the areas. The integration of the TLS 2012 survey with that of 2013 and the subsequent creation of the 3D model revealed that the total volume of excavation was approximately equal to 2800 m3 (**Fig. 10**).

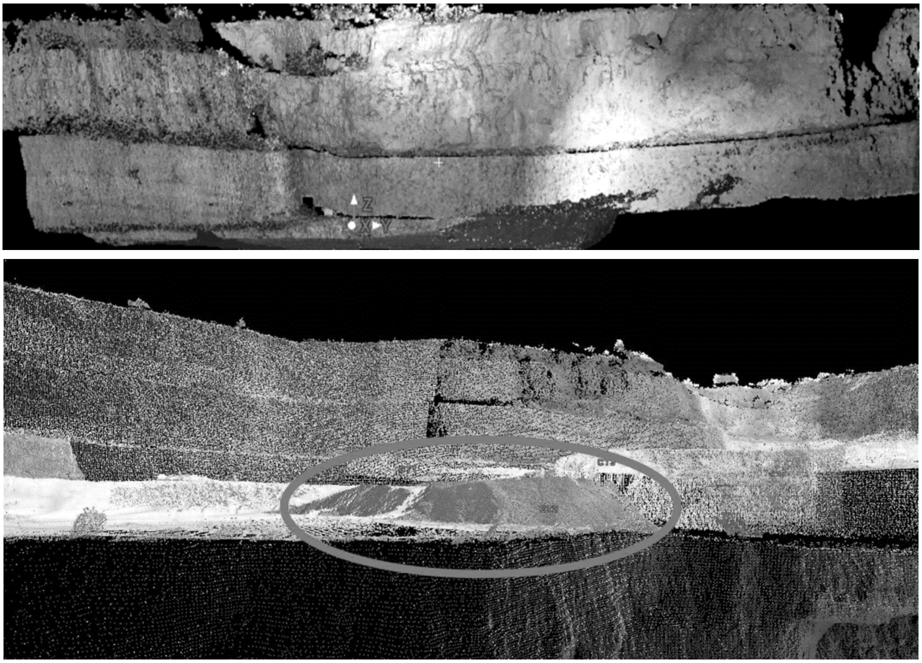

Fig. 9 2013 Point Cloud related to the excavation area (up) and stockpiled (down)

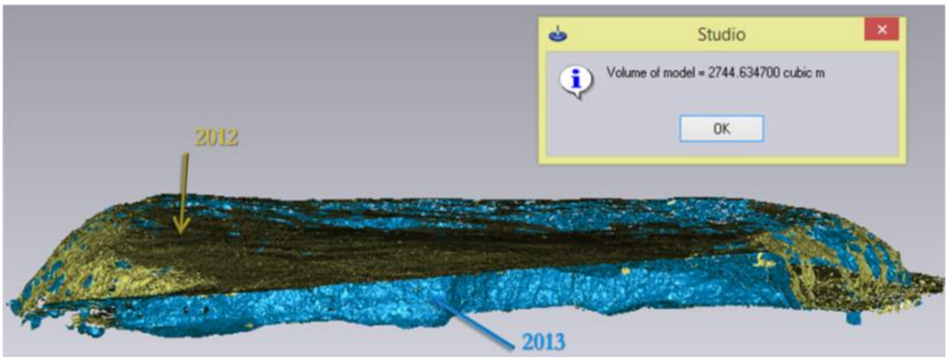

Fig. 10 Excavation area: DTM of 2012 overlapping DTM 2013

9. CONCLUSIONS

The realization of integrated survey activities applied to the monitoring and control of a quarry has enabled the authors to comply with, in a systematic manner involving periodically replicated measurements, the requirements of the regulations in force. Specifically, the use of a traverse with forced centering has enabled the geometric framework and the georeferencing of the area, as well as the temporal analysis of excavation activities (carried out with a reduction in the required time and costs of survey and data processing). The TLS surveys have allowed the authors to obtain a restitution of a highly dense 3D model (DSM) with a sub decimeter resolution (as provided by the requested map at 1:1000 scale), (Sequeira et al., 1999). The restitution has consisted of drawing up contour lines with 1 m contour intervals, and the inclusion of all morphological (slopes, large steps, etc.) and anthropic (roads, fences, etc.) details. It was also possible to quantify the volume of the semi-finished heaps present in the quarry and, consequently, to assess the sales volumes. Moreover, it was possible to perform a number of structural checks of the area using extractions of typical sections. The method adopted was assuredly based on scrupulous planning, followed by careful survey activity and by a processing step utilizing, as in many cases, commercially available software, as well as algorithms previously implemented by the authors. It is worth noting that the use of these algorithms was of considerable importance in ensuring greater reliability of the results and the most immediate representation.

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