



ARTIFICIAL CAVITIES IN LAVA FLOWS: GRAVEL QUARRIES

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Summary

The Authors describe hereby the main characters of the gravel quarries buried under the modern Catania, as well as under its lava-formed surroundings, based on their observational and research studies of this kind of artificial cavities. Their attention is mainly focused on gravel quarries themselves, though some note does also concern ruins of artefacts existing prior to the covering lava expansions.

Foreword

Men dug wide underground cavities in past times, for quarrying a specific material, with tiny granulometry, generated by the action of lava flows on the pre-existing paleo-soil. These hollows are usually named *quarries of "agghiara"* (gravel), a stuff mixed with lime for production of mortar, in the building trade. Quarrymen named gravel according to its quality and different colours: *terra rossa* (red soil), for its reddish colour and its *pozzuolana* behaviour, and *azzolo*, the greyish variety of this building material.

The essential structure of a lava flow should be borne in mind: the flanks, made by sharp loose material, are named *lateral moraines*; the central part can host a *flow channel*; the cross section of a chilled lava flow has usually a lenticular shape, with central thickening of the roof, and of the bottom as well, when the flow occurred along a depression. The following characters can be observed from top to bottom: the upper scum, named *sciara* by quarrymen; the massive middle body, named *afficilàto*, constituted by the chilled flow; the bottom scum, that quarrymen name *rifùsa* (re-molten), as it is generated by the "track motion" of the flow front, buried and re-molten



Fig. 1 - Quarry front displaying the cross flow section. The sequence of various layers and their different features can be noted: the upper dark-greyish layer is formed by scoriae. The intermediate layer is much more thick and light-greyish coloured and is formed by basaltic rock («*afficilàto*»); it is currently exploited for hew lava stones production. The lower layer, of variable thickness, is made by «*rifùsa*» (re-molten), and down below the reddish «*agghiàra*» (gravel) layer can be detected (pict. by E. Lo Giudice)

by the advancing flow. *Azzolo* results from an adequate riddling of the *rifùsa*; *terra rossa* is the reddish metamorphosed paleo-soil supporting the flow bottom.



Gravel utilisation techniques⁽¹⁾

- The *terra rossa* gravel is mixed with slaked lime for kneading ordinary mortars, for wall manufacturing, at a mixing ratio of two volumes to one, whereas the ratio involves seven red gravel volumes and four ones of lime, for producing hydraulic mortars for exterior plastering.
- The mortars kneaded by mixing seven volumes of *azzolo* gravel with three ones of slaked lime, are employed in thwacked floor production, named *làstrici* (pavements), that harden like solid lava stone, whereas one volume of slaked lime and two volumes of *azzolo* are mixed for kneading ordinary mortars.

The quality of the resulting mortars is largely related to their manipulation: the minimum necessary quantity of water has to be used, and the longer the components are kneaded, the better the mortar results.

Some notes on origins and evolution of the use of (volcanic) gravel-lime mortars

Sumerian people already knew and used slaked lime, named *kalga*, to lock one stone block to another for wall manufacturing. Nevertheless Romans first kneaded slaked lime with Pozzuoli gravel, named *puteolana* (the trachytic tuff, nowadays known as *pozzuolana*), for producing a mixture capable of underwater hardening. Pozzuolana products are characterised by their content of amorphous silica, that is formed when silica reaches temperatures ranging between 500 and 900°C. Amorphous silica interacts with lime by producing calcium silicate, insoluble in water and even aggressive waters resistant. It was surely ascertained during Roman rule that the reddish soil of Etna, kneaded with lime, presented similar hydraulic characters, as those obtained from the *pozzuolana* of Pozzuoli.

The *pozzuolana* gravel of Etna, named *terra rossa* (reddish soil), is produced by thermal metamorphosis: the phenomenon occurs when the mass of the flowing lava is sufficiently thick for a durable preservation of its thermal energy as well as of its high bottom temperature, while flowing on gravelly soils without humus. Our *pozzuolana* gravel is perhaps the sole formation, with hydraulic features, generated by metamorphosis rather than by the chilling of pyroclastic products; furthermore it is “ready-to-use”, no previous crumbling is needed.

In former times gravel and stony materials were hauled together from the same quarries. The exploitation of specific underground gravel quarries spread around, especially from the eighteenth century to the first half of the twentieth one, when the request for *agghiàra* (gravel) largely exceeded the one for lava stone, because its tiny sands were massively utilised (after adequate riddling) for preparing external plasters which characterise, by their reddish colours, many facades in Etna villages. Unfortunately gravel mortars were entirely replaced by cement mortars, after the end of World War second, due to the increasing digging difficulties and high hauling costs. The quarries became rapidly misused and forgotten, many of their adits were destroyed and buried by the tumultuous expansion of urban centres, and entire boroughs, intensely populated, hid today a broad underlying network of artificial galleries.

Location of the main quarries

The main quarries known and reported by last century authors are:

- Ancient *Botte dell'Acqua* (water barrel) quarry⁽¹⁾, lava of the 1669 eruption that produced excellent gravel. Its entrance was probably located near the homonymous street, close to the ancient city walls, today almost entirely destroyed. A street named Via Petriera (Stone Quarry Street), in the nearby area, still shows cliff remnants of the Danieli quarry, formerly exploited for construction stones.



- *Ognina* quarry⁽¹⁾, produced second-rate material, due to the vicinity of the sea and the relevant marine salt contamination.
- *Via di Cave Villarà* quarry, 1669 eruption, is located inside an agricultural estate and its galleries wind around below an intensely populated area, in the outskirts of Catania.
- *Via Masaniello* quarry, lava-field “*Curia*” of the 1669 eruption, is located inside a former stone quarry that is used today as a dump for waste building material; its passages wind below intensely inhabited areas.
- *Via Condorelli* quarry, probably formerly exploited even for hauling pumice stone, used as ceiling-making material for its lightness. The quarry is located inside the Spina estates, includes remarkably ample rooms, and extends up to *Due Obelischi* (Two Obelisks) Street.
- Quarries of “*Prache*” (Gravina), 1669 eruption, providing first quality material; their venue is located in the territory of Gravina di Catania.

Terra rossa and *azzolo* were often hauled from quarries inside the city boundaries, to the extent of reducing problems and costs of transportation. Ancient quarries were exploited in the historic centre of Catania, in the lava expansion of Fratelli Pii (Merciful Brothers) covering the Santa Maria (Holy Mary) hill. They were probably used in the Roman period for building public edifices as the Amphitheatre, the Theatre, the Spas, and further ones. Maybe these quarries are the same underground cavities mentioned by F. Ferrara⁽²⁾, who reports repeated visits to “*immense pozzuolana quarries*” close to the Buglio Mansion and to the St. Julian’s Monastery, *Via Crociferi* (Crucifers Street); in Ferrara’s times they were considered catacombs, rather than quarries. Sometimes the supplying quarry was directly dug inside the relevant building yard: the dungeons of the Capuchins Monastery host the entrance of a small gravel quarry.

The gravel quarrying was certainly widespread, and a large deal of minor quarries is still unknown. Sometimes ruins of loose-laid walls or gallery adits, observed in the trenches dug for new building groundwork, witness the pre-existence of probable hauling galleries. The hauling activity was very rough; no supporting structures were added to loose-laid walls, and very simple tools, mattocks and hoes, were used digging. The hauled stuff was placed into wicker baskets named *cufîni*, back-carried outside the quarry by donkeys or children. A preliminary rough hand selection was performed inside the quarry, prior to arranging the stuff in the baskets, whereas a subsequent

riddling was performed by hand sieves, named *crivi*, with wooden frames and metallic riddling plates. The diameter of the riddling holes varied according to the specific utilisation of the final stuff.



Fig. 2 - Villarà Quarry; typical entrance at the lava flow margin (pict. by A. Marino).

Description of typical quarries

The entrances of quarry adits are usually located at the margins of lava flows (Fig. 2), where the rock texture is not too dense, or inside construction stone quarries (Fig. 3). Frequent lighting shafts, harnessed with wooden ladders, ensure

ventilation and rapid access to the underlying galleries. The adit normally slopes downward until the base of the flow, wherefrom horizontal trenches start, forming the quarry passages; the height of their vertical section continuously varies between one and two meters, as it was probably governed by the thickness of the exploitable deposit. Stony steps connect the steeper differences in height of the quarry passages (Fig. 4) winding here and there through the paleo-soil, according to



the pre-existent orography. The galleries are roofed by the lava flow bottom, which includes various stony materials carried by the flow. Sometimes a glimpse can be caught on fragments of brick-made walls (Fig. 5), and of an ancient – probably Roman – wheat crusher (Fig. 6) (Capuchins Quarry⁽³⁾). The digging activity proceeds towards every direction, often leaving wide hollow spaces (Fig. 7) behind, where supporting



Fig. 3 - Curia Quarry; typical entrance inside a stone quarry (pict. by N. Scalia).



Fig. 4 - Curia Quarry; steps connecting two different levels (pict. by N. Scalia).

pillars (Fig. 8) are left (a hall some 30m wide was found inside a quarry, near Via Nuovalucello). The hollow spaces are subsequently filled by waste digging material – even huge stony blocks – and

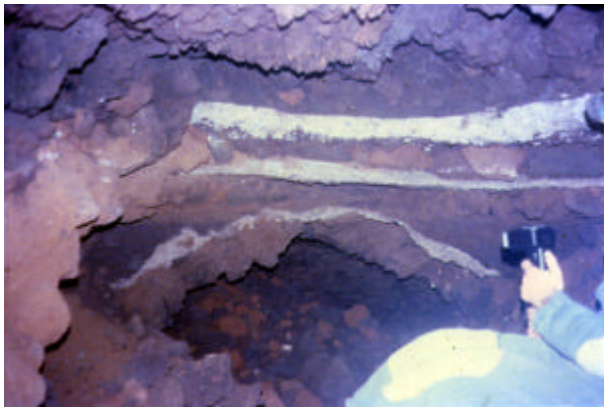


Fig. 5 - Capuchins Quarry; remnants of an edifice engulfed by the molten lava (pict. by F. Politano).

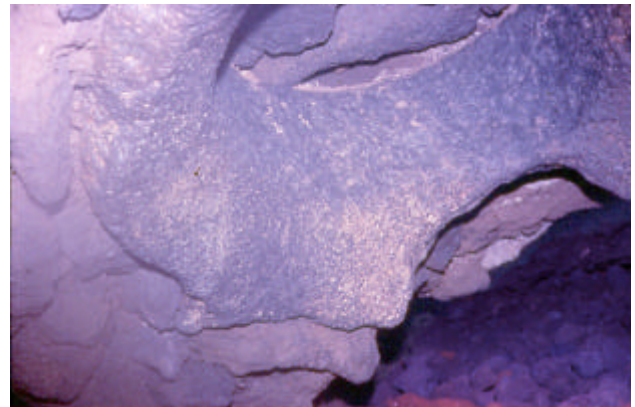


Fig. 6 - Capuchins Quarry; remnants of a lava-stone mill welded in the vault of a narrow passage (pict. by F. Politano).

eventually closed by loose-laid walls (the lateral walls marking many passages) (Fig. 9). Ceilings and walls are very crumbly, when supports are missing; in addition large flooded zones can be found in quarries underlying urbanised areas, due to the intense dripping of rainwaters or to the leaking of sinkhole sewage.



Fig. 7 - Curia Quarry; a large hall can be observed to the right, close to the quarry entrance (pict. by N. Scalia).



Fig. 8 - Botte dell'Acqua (water barrel) Quarry; residual «agghiàra» pillar close to material partially collapsed from walls and vault (pict. by A. Marino).



Fig. 9 - Botte dell'Acqua (water barrel) Quarry; passage flanked by loose-laid walls (pict. by A. Marino).

Archaeological potential of gravel quarries

Ruins of edifices, and traces of the ancient urban frame, can be eventually found in hauling passages, when the parent lava flow invaded and buried inhabited areas in historic times. Furthermore, as previously mentioned, the passage allure follows the pre-existing orography, and runways and staircases can be found, in connection with ancient subsidences and small relieves, whereas the present orography has quite changed.

The study of the late-medieval archaeology could take advantage from the topographic survey of the quarries underlying the 1669 lava flow (that reached the town of Catania). The upper parts of the artefacts were molten or engulfed by the fluid lava mass, whereas their lower parts – eventually survived to the lava destruction – were engulfed (and protected) by the *rifusa*. House walls, with openings introducing into close spaces defined by bricked-up walls and man-made ceilings – with eventual pavements and various debris – can be observed in the narrow galleries branching throughout the ancient buried village, from the cavity engulfing the transept of the ancient Church of the Annunciation, at Mompilieri. Local elders' *tales* report the alleged existence of galleries dug behind the ancient city walls (Botte dell'Acqua, Naumachia or Roman Gymnasium, buried by the 1669 eruption). If their entrance adits could be traced, probable ruins could be observed of skirting boards and ground structures of Roman and medieval artefacts, invaded rather than destroyed by the *rifusa*.



Conclusions

The presence of wide networks of hauling passages, often unknown or forgotten, nowadays involves objective risks for the surface artefacts and activities, mainly in urbanised areas. The partial speleological exploration of some underground quarries revealed very insecure standing conditions both for the rough exploitation techniques, and for the progressive natural degradation of the underground artefacts. Limited collapse phenomena affect some passages (Capuchins Monastery,



Fig. 10 - Botte dell'Acqua (water barrel) Quarry; example of vault collapse: this phenomenon is widespread throughout the quarry and often stops up the passage. A lava-stone slab in contact with the «*agghiàra*» and traces of water dripping through the vault cracks can be observed (pict. by R. Bonaccorso).

Via di Cave Villarà and Curia lava field quarries⁽³⁾), and huge collapsed blocks eventually obstruct the main passage (Fig. 10). These phenomena could result in turn in progressive surface collapses, chasm formation and more or less severe cracks. The sharp surface overlying Villarà quarries, still unfarmed and bare, is affected by several funnel-shaped depressions, of two and even more meters in diameter. House proprietors and masons of Gravina di Catania reported that the Prache quarry underlying Via Gramsci caused several dislodgments to the foundation ground of some edifices built up in the very last decades. The complex phenomena of structural instability, and of the various factors interacting with the urban framework, involve binding investigations and interventions in such cases, with heavy financial disbursements.

Obviously the whole resulting problem demands the Public Authorities' attendance and coordination, due to the remarkable financial commitment and to the involvement of institutional bodies

with their interconnected specific competences. The preliminary localisation of all existent quarries should be therefore carried out, including the ones with buried entrance adits, with relevant exploration and topographic survey of their galleries, and, if and where possible, measurement of the thickness between the gallery roofs and the foundations of the overlying buildings. This operation should make possible a quantitative evaluation of the involved risks, and enable the observers to rationalise the technical and financial commitments for more detailed investigations, more accurate evaluations of risks and intervention demands, and determination of the most appropriate strengthening actions.

The present period is still particularly favourable for an organic and exhaustive research, since the last *agghiàra* quarries were abandoned at the beginning of the Sixties, and many *ghiaiòti* (gravel quarry labourers) are still alive. Their cultural heritage of sentences, tales, engravings, pictures, digging tools, knowledge of hauling and exploitation techniques, etc., represents an actual living memory of the world of quarries, exploited for materials destined to lime kneading, and uninterruptedly lasted from the Romans up to present times. This heritage should be assembled and published, in order to hand down to posterity the hard job reported by the writer Giovanni Verga in his novel «*Rosso Malpelo*» (Red-haired Mischief).



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